First published in 2018

ISBN: 978-0-9956886-3-6 (print)
ISBN: 978-0-9956886-4-3 (online)

ISCI Publishing LTD.
Kemp House
160 City Road
London EC1V 2NX, UK
www.iscipublishing.org

Acknowledgements

The research is funded by the major program of National Natural Science Foundation of China (L.Z., grant number 91224005), the major program of National Natural Science Foundation of China (L.Z., grant number 71233008), the general program of National Natural Science Foundation of China (L.Z., grant number 71774167), the major program of “12th Five-Year Plan” of People’s Liberation Army (L.Z., grant number AWS12J002), the joint research program of major diseases of Shanghai Health System (L.Z., grant number 2013ZYJB0006), 2017 Military Medical Innovation Project (L.Z., grant number 17CXZ001), and the special innovation project of National Defense Science and Technology (L.Z., grant number 003004).

Table of Contents

Abbreviations

ABI	Acid-Base Imbalance
AF	Ardent Fever
AIS	Abbreviated Injury Scale
ARDS	Acute Respiratory Distress Syndrome
ARF	Acute Renal Failure
BI	Bacterial Infection
CA	Cardiac Arrest
CH	Cerebral Hernia
CNSI	Central Nervous system injuries
DC	Disturbance of Consciousness
DT	Destruction
ED	Emergency Department
EDA	Emergency Department Admission
FJI	Fracture and Joint Injuries
GCS	Glasgow Coma Scale
HS	Hemorrhagic Shock
ICD-10	10th International Statistical Classification of Diseases
ICU	Intensive Care Unit
ISS	Injury Severity Score
LOS	Length of Stay
MCIs	Mass Casualty Incidents
MODS	Multiple Organ Dysfunction Syndrome
MOF	Multiple Organ Failure
NTDB	National Trauma Data Bank
PC	Pulmonary Contusion
PLA	People’s Liberation Army
RHOC	Referral from Hospitals in Other Cities
RHS	Referral from Hospitals in Shanghai
SSTI	Skin and Soft Tissue Injuries
TH	Traumatic Hemopneumothorax
TOI	Traumatic Organ Injuries
WED	Water and Electrolyte Disturbance
WHO	World Health Organization

Chapter 1 Introduction

Lulu Zhang[1]*, Wenya Yu*[1] *and Changyong Xie*[2]

[1] *Department of Military Health Service Management, College of Military Health Service Management, Second Military Medical University, Shanghai 200433, China*

[2] *Teaching Affairs Division, Second Military Medical University, Shanghai 200433, China*

1.1 Research background

1.1.1 Significance of trauma research

According to the definition of the World Health Organization (WHO), trauma is injury or damage caused by physical harm from an external source, e.g., traffic accident, submersion, poisoning, accidental fall or burn, violent attack, self-inflicted violence, or war. Trauma is a huge burden for all countries worldwide and is a primary factor for death and disability, especially for low- and middle-income developing countries (Huo *et al.*, 2008; WHO, 2014). As reported by the WHO in 2014, one person dies from trauma every 6 seconds worldwide. However, predictions and precautions regarding trauma have been ignored for many years. Statistics show that there are more than 5,000,000 people who die from trauma annually worldwide, accounting for 9% of all deaths (WHO, 2014), and even more people become disabled due to injury (Yeung and Graham, 2010). As estimated by the Global Burden of Disease and Risk Factors Study, more than 15% of people living with illness worldwide in 1990 were victims of trauma, and this number will increase to 20% in 2020 (Kong *et al.*, 2015). This appalling trend has also been confirmed by the latest statistics (Lopez, 2006; WHO, 2015b).

The WHO has conducted continuous in-depth researches analyzing the status of prevention and control measures for trauma, in particular, the trauma categories and groups of people with high incidence and damage rates. This research aims at encouraging all countries to improve the prevention and treatment of trauma and reduce trauma-related mortality and disability (WHO, 2015b), by focusing on the prevention and control of traffic-related trauma (WHO, 2015a), fall injury prevention guidelines (WHO, 2008), and prevention of injuries to children (WHO, 2005 and 2006). Comprehensive analysis of the risk factors affecting the mortality of trauma patients has critical significance for trauma prevention and treatment, first aid efficiency and quality, and treatment capacity and effective operation of the emergency medical care system. At present, research of the risk factors for trauma involves multiple aspects such as social demography, trauma occurrence, pre-hospital care, in-hospital diagnosis and treatment, and the trauma treatment capacity of medical institutions (Nelson-Williams *et al.*, 2015; Schoenfeld *et al.*, 2013; Gannon *et al.*, 2002; Himanen *et al.*, 2011; Ahmed *et al.*, 2012; Ottochian *et al.*, 2009).

China is a country that is prone to natural disasters, and trauma caused by various types of disasters has always been considered the "primary public hazard" (Huo *et al.*, 2008). According to the China Health Statistical Yearbooks, the fifth leading cause of death in China's urban population is injury and poisoning, which includes 14 causes of injury, such as traffic accidents, accidental falls, accidents attributed to mechanical factors, and accidental poisoning. The number of deaths caused by injury and poisoning accounted for 6.89% of the total number of deaths attributed to various reasons in 1990 and increased to 8.25% in the year of 2005. Furthermore, trauma is the primary reason for death and disability in China's urban-dwelling young adults aged 20–45 years, posing a great threat to national and social development. In 2011, the mortality of adults aged 20–45 years from external causes of injuries and poisoning even exceeded that of cancer, making injury and poisoning the number one reason for deaths of young adults in this age range.

The incidence of injury is particularly high in China's megalopolises (e.g., Shanghai and Beijing). The number of large-scale traumatic events has been increasing, particularly the suddenness, complexity, and degree of hazards that are a potential threat to urban public safety and sustainable development (Wang *et al.*, 2007b; Ma *et al.*, 2007b; Tang and Wen, 1999b).

Trauma poses a significant threat to the health and quality of life for people worldwide. However, trauma-induced death and disability can be reduced by implementing multiple measures, such as reinforcing the medical services system from pre-hospital medical care to in-hospital treatment and finally to recovery (Peden, 2008). Therefore, since 2004, the WHO has paid greater attention to injury-related issues and published a large number of reports on injury prevention and research. For example, guidelines for essential trauma care (Varghese *et al.*, 2005; Mock, 2004) and for programs to improve the quality of trauma care (Yeung and Graham, 2010) appealed to all nations to establish trauma systems and encouraged implementation of trauma-associated studies aiming to decrease the incidence of injury, improve the efficiency and quality of emergency medical care after trauma, and consequently reduce the harm caused by trauma. Many high-income countries have successfully reduced the trauma mortality and disability by improving various aspects of trauma systems such as the pre-hospital environment, initial in-hospital resuscitation, and long-term definitive care (Yeung and Graham, 2010). Organization for Economic Co-operation and Development member countries have obtained remarkable achievements in trauma prevention and control, such that the trauma-related mortality rate of children younger than 15 years was reduced by half during 1970–1995 (UNICEF, 2001). According to statistics from 2008, the standardized mortality ratio attributed to trauma was universally low in high-income countries, at only 0.25‰ in the United Kingdom, Germany, and Italy; 0.3‰ in Australia; 0.36‰ in Japan; 0.35‰ in France; and 0.53‰ in the United States. However, the presence of injury and damage still has a substantial influence in middle- or low-income countries. Standardized mortality ratio caused by trauma was 3.47‰ in Burma, 1.59‰ in Russia, 1.51‰ in Central Africa, 1.49‰ in Afghanistan, and 0.7‰ in China, significantly higher than the average level of standardized mortality ratio in developed countries (China, 2013). In addition to the higher mortality rates, trauma patients in middle- and low-income countries experience difficulties in obtaining high-quality trauma management, particularly reflected by the lack of effective trauma prevention, unsound trauma treatment and recovery systems, and insufficient attention to trauma issues at the state level (Peden, 2008).

The incidence of massive casualty incidents has been consistently increasing worldwide. In addition to massive natural disasters that occur frequently globally, such as earthquakes, tsunamis, and hurricanes, there is a growing number of massive casualty incidents resulting from unnatural factors including industrial development and social environmental change. Existing epidemiological research indicates that the number of large-scale traumatic events has already exceeded predictions (Delgado *et al.*, 2016), demonstrating a continuously increasing trend in the past 8 years (Doughty *et al.*, 2016). The mortality rate resulting solely from terrorist attacks has more than doubled since 2007 (Doughty *et al.*, 2016; Guha-Sapir *et al.*, 2015). Statistical data from the United States website, Gun Violence Archive, show that approximately 30,000 people die from gun violence in the United States every year, with a gradual increase in the probability of a mass shooting occurring (gunviolencearchive.org). Massive casualty incidents occurred more frequently in China, such as the Shanghai subway crash (2011), stampede at the Bund in Shanghai (2014), factory explosion in Kunshan (2014), Tianjin warehouse explosions (2015), Taiwan explosion caused by an overheated spotlight (2015) (Chen *et al.*, 2016), and large-scale collision on the Shanghai-Chengdu Expressway (2016); these lead to huge burdens for the state, society, and individuals.

In addition, due to the great complexity, large scale, and high degree of related damage of the influencing factors for massive casualty incidents, the hazard caused by these events is substantially greater than that caused by other accidents. Therefore, studying trauma and massive casualty incidents has great significance in exploring the general mechanisms of trauma, optimizing the first aid procedures and measures, normalizing the trauma treatment, and effectively reducing the mortality of trauma victims.

Several milestones in the research of trauma and massive casualty events have been achieved globally, especially in high-income countries. For instance, to react to massive casualty events, Spain developed a novel pre-hospital injury classification method, aimed at enhancing the efficiency of wounded patient evacuation (González *et al.*, 2016). Japan, which has a high frequency of earthquakes, has been consistently exploring first aid modes for massive casualty events. They established the doctor-helicopter system in 2007, which served as the key rescue force in disasters such as the Great East Japan Earthquake and effectively shortened the time of arriving on sites (Matsumoto *et al.*, 2013; Omori *et al.*, 2014; Ishikawa *et al.*, 2016). High-income countries that have advanced conceptual and institutional infrastructure for trauma management have been constructing and managing a trauma data bank since half a century ago, which has provided a profound and reliable database for the construction of first aid systems and allocation of health resources. This has not only reduced the mortality and disability rates of trauma patients but also effectively enhanced trauma management quality.

The United States built the first modern electronic trauma data bank in 1969 (Racy *et al.*, 2014) and established the National Trauma Data Bank (NTDB) in 1982, which, as the largest trauma registry system currently available worldwide, has contributed a great deal of consecutive data for trauma studies. By the end of 2014, the NTDB had gathered over 6,000,000 trauma case records from 746 American medical institutions (NTDB, 2015). These trauma data are widely used in diverse aspects of scientific research, providing numerous high-quality data resources for research of trauma epidemiology, trauma mechanisms, influencing factors, and first aid modes and techniques (American College of Surgeons). European countries mostly choose to build their trauma data banks using a trauma registry (Yang and Shi, 1997). The United Kingdom possesses the largest trauma data bank in Europe, the United Kingdom Trauma Audit and Research Network. Since 1991, more than 50% of British trauma institutions have joined this network, contributing 2,000,000 trauma cases to the data bank (Yates *et al.*, 1992) (The Trauma Audit and Research Network). The German Trauma Register DGU, established in 1993, collects almost 2,000 trauma cases from 50 hospitals every year (Trauma Register DGU, 2014). France built the French intensive care recorded in severe trauma in 2003, which consists of the 14 most active trauma centers and conducts management and control of the whole trauma care process from on-site treatment to patient discharge (Tissier *et al.*, 2013). The Japan Trauma Data Bank, founded by the Japanese Association for the Surgery of Trauma and the Japanese Association of Acute Medicine, has recorded trauma data from 196 hospitals, including demographic information, injury mechanisms, in-hospital treatment, trauma severity, and mortality rate, aimed at enhancing the quality of trauma treatment (Japan Trauma Data Bank, 2012). Australia established the Victorian State Trauma System in 2000, which has significantly improved the pre-hospital care and in-hospital management of trauma. The mortality rate of trauma patients in New South Wales has been reduced by 9% since the establishment of the New South Wales Institute of Trauma System (Nathens *et al.*, 2000). In addition, the collaborative Australian and New Zealand National Trauma Registry Consortium constructed a bi-national minimum dataset that is being used in the Australian trauma registry, representing the commencement of a trauma data bank based on the cooperation of the two countries (Palmer *et al.*, 2013).

Therefore, considering the enormous pressure imposed by trauma on the state, society, and individuals, extensive and urgent necessity of trauma prevention and treatment, and low mortality rate in developed countries thanks to successful trauma management, it is paramount to implement comprehensive trauma research in China. Scientific and reasonable trauma management can help us better understand the mechanisms of trauma occurrence and evolution and more effectively manage massive casualty incidents. By lowering the trauma mortality rate and minimizing the loss caused by trauma, the public safety of the nation and health of the people can be better protected. This is of great practical significance for the social and economic development of China.

1.1.2 Overview of trauma research in China

The Chinese government has shown growing concern for public emergency events since the onset of the 21st century. Since 2004, the State Council organized annual assessment analyses of various public emergencies involving natural disasters, accidental disasters, public health events, and social safety-related public events and conducted typical case analyses of the conditions, characteristics, causes, and patterns of very serious and serious public emergencies (Office of the State Council, 2005). On this basis, the formulation and revision of a framework for an emergency response plan for public events (Office of the State Council, 2004) was proposed, showing a continuous effort for the prevention and control of public events. The planned national annual work tasks have definitely highlighted that a medical assistance system for public health events needs to be established as soon as possible to actively prevent and handle group incidents. A three-level planning system including overall public emergency response plans, specific plans, and departmental plans has been published and implemented.

The government also urges the establishment and improvement of emergency response mechanisms, institutions, and legislation. By practically improving the capacity of public safety protection and emergent event management and emphasizing prevention, the target is to minimize the losses caused by natural disasters, accidental disasters, public health events, and public emergencies (Office of the State Council, 2005). The State Council recently introduced a series of policies to enhance emergency management and assistance capabilities for public events, including improving emergency management planning and system development (Office of the State Council, 2006), strengthening primary-level emergency management, improving primary-level capacities for preventing and handling public emergencies (Office of the State Council, 2007), introducing and revising national emergency response plans for public events, establishing uniform prevention and control systems for public events (Office of the State Council, 2011a), and constructing robust assistance systems and operation mechanisms in response to serious emergent natural disasters (Office of the State Council, 2011b).

Meanwhile, with the development of evidence-based medicine, the importance of digital evidence has become recognized. A strategic plan, “Healthy China 2020”, was jointly proposed by the National Health and Family Planning Commission (the former Ministry of Health) and the Ministry of Science and Technology of the People’s Republic of China in 2009. It clearly delineates the plans for improving research of trauma and disaster medicine as well as the associated information platform, emphasizing national trauma, investigating risk factors for various injuries, and introducing comprehensive prevention measures to reduce the mortality rates related with traffic accidents and mine disasters. Although China has paid increasing attention to trauma issues, given the history of trauma and massive casualty event research, five problems still exist within the current research.

(1) Despite the rapid development of research of urban trauma occurrence and evolution and the first aid techniques in China, data analysis remains at the general descriptive level, without comprehensive data mining, data-accuracy analysis, or the capability of deep data mining from the perspective of investigating complexity. Therefore, it is difficult to fulfill the requirement of studying trauma occurrence and evolution in megalopolises (Xin, 2006b,c; Li *et al.*, 2011 and 2012; Chen, 2004; Wen *et al.*, 2005; Xu, 2014;

Shen *et al.*, 2006; Zhang, 2004; Gao, 2004; Chen and Li, 2008).

(2) Existing studies are mostly related to factors influencing trauma outcomes. These studies share several characteristics. Various aspects such as trauma-causing factors, emergency response measures, and trauma categories are qualitatively described using single-factor analysis. Analyses of the different influencing factors from the perspectives of multiple factors, comprehensive in-depth investigations, and complexity research are inadequate (Wen and Wang, 2004; Chen *et al.*, 2004; Cai, 1998; Shen *et al.*, 2008; Zhou *et al.*, 2006; Fu and Jiang, 1987; Zhuang and Qiu, 2012; Liu *et al.*, 2005; Chen, 2005; Chen and Li, 2011; Tang *et al.*, 2008; Zhang, 2011b; Huo *et al.*, 2008; Chen and Yang, 2000).

(3) Existing studies of the urban trauma emergency medical care systems in China mainly concentrated on qualitative investigations of organization construction, plan development, policy and regulation introduction, and cross-sectional status quo and practice analyses. However, these studies cannot be used to explore the overall trauma emergency medical system using quantitative analysis methods from the perspective of evidence-based decision making (Du, 2006 and 2012; Xu, 2011; Qu, 2010; Lu and Luo, 2000; Li, 2008b; Bai and Li, 2010; Zhou and Wang, 2009; Tang *et al.*, 2012a; Sun *et al.*, 2010; Zhang, 2015; Tang *et al.*, 2012b).

(4) Existing studies mostly focus on clinical technologies and preclinical medicine. There are few researchers studying trauma emergency medical services in the range of public health. A literature showed that there is little research regarding the effects of transportation tools on the mortality rate and almost no research on the aspects of time, space, disease occurrence and evolution, correlation between treatment and regression, trauma prevention and reduction, reasonable health resource allocation, and improvement of the capacity and efficiency of the trauma emergency system. Large distinctions still exist between the trauma emergency system and capacity in China and the corresponding international criteria.

(5) Trauma research in China severely lacks investigations of the current massive casualty emergency health services, which is evident from literature search results. There is only one report of an emergency rescue during the massive explosions that happened at Nanjing in 2011 (Lu *et al.*, 2011); this report mainly described the emergency situation of the event without any quantitative research results. This demonstrates a considerable conflict between the research status quo and the increasing incidence and hazard of massive casualty events.

1.1.3 Research design

Shanghai, as a megalopolis, is the economic center of China, with more than 23,000,000 permanent residents; therefore, achieving an understanding of trauma occurrence and the evolution and construction of emergency rescue organizations are considerably more challenging (Zhang *et al.*, 1993; Zhang, 1992). Currently, Shanghai has a severe lack of trauma research and large-scale trauma emergency medical services, which is particularly reflected in the insufficient information for the trauma context, research of trauma occurrence and evolution, experience in massive casualty emergency health care, planning for massive casualty emergency medical care, and construction of a massive casualty emergency medical system. Based on China's attention to public emergency events, considering the absence of urgent requirement for trauma research in Shanghai, the economic center of China, investigations and management of Shanghai's trauma and massive casualty have great practical significance. Therefore, Shanghai is the target city in the present work.

This study essentially focused on trauma occurrence and evolution, and the massive casualty emergency medical system. Based on Shanghai's sociodemographic and economic characteristics as well as the strong practical requirement for massive casualty emergency services, the general pattern of trauma occurrence and evolution is explored by conducting profound traumatic data mining, which will provide a database and rationale for the research of massive casualty emergency systems. Further, a model for massive casualty emergency medical system is established by using the method of system dynamics modeling. The objectives of this research are to determine the universal pattern of trauma occurrence and evolution in Shanghai, enhance medical rescue capability for massive casualty patients, promote the improvement of urban public security, maintain the stability of social and economic development, and provide a model for urban trauma emergency medical care for the entire nation (Alexander, 1985; Walker and Blood, 1998a,b; Chazard and Beuscart, 2007; Chaussalet *et al.*, 2006).

1.2 Overview of the investigation

1.2.1 Objectives and significance of the investigation

This work addresses two major issues: (1) obtaining traceable background data regarding trauma and massive casualty in megalopolises of China, revealing the complicated influencing factors of trauma, and accurately describing the causes of massive casualty; and (2) constructing a model of a massive trauma emergency medical system, obtaining an in-depth understanding of the pattern of trauma occurrence and evolution, and optimizing the operational procedures and efficiency of the massive casualty emergency medical system using the data and results from trauma and massive casualty studies. For these two study objectives, this research primarily utilizes data collection and analysis of trauma and massive casualty. These data are significant to determine the background characteristics of trauma and massive casualty in Shanghai, the foundation for exploring the critical influencing factors of trauma and the basic data and rationale for system dynamics modeling. Therefore, analyses of trauma data have both great theoretical and practical significance for implementation of comprehensive future trauma research.

Global trauma data management indicates that many high-income countries have already implemented comprehensive management from trauma occurrence to pre-hospital care to in-hospital treatment and finally to post-hospital recovery care by establishing trauma management institutes, projects, and systems. The mortality rates of trauma patients in these countries have been successfully reduced. Mainland China has not yet constructed a massive trauma data bank that meets the national standards. Therefore, collecting trauma and massive casualty data and establishing a data bank in Shanghai are of great importance for trauma management, decrease of mortality, and emergency medical system optimization.

1.2.2 Design and scheme of the investigation

To ensure the reliability and validity of the research, 1,314 participants are required, based on confidence level, power, and allowable error of 95%, 90%, and 3%, respectively. Screening for participation was conducted with trauma patients using the definition of trauma as "tissue or organic damage caused by mechanical factors exerted on the human body" and based on trauma classification. Selected patients included patients of traffic injuries, high-level fall injuries, machinery-related injuries, sharp-instrument injuries, ground-level fall injuries and firearm injuries. Data were collected from electronic medical records according to the 10th International Statistical Classification of Diseases (ICD-10) and Related Health Problems, involving 400 types of diseases affiliated with 136 blocks including the code range from S00.001 to T35.701.

In this investigation, demographic characteristics, injury information, treatment, comorbidity information, and outcome were collected. A formal investigation was implemented during the period from June 2014 to January 2015. Data were gathered by selecting eligible medical records according to the ICD-10 and the rules of medical record systems in Chinese hospitals, exporting relevant information, and entering the data to establish the trauma database. Currently, there are seven trauma centers in Shanghai that provide trauma treatment for the whole city. Based on institute scale, admission rate, emergency workload, and major types of trauma treatment, four trauma centers with the largest scale, highest admission rates, and largest trauma emergency workloads were selected for the investigation. These four centers manage and treat almost all types of trauma, and guarantee the representativeness of the samples. In this investigation, qualified trauma records during 2011–2014 were collected from the four trauma centers. To ensure the accuracy and reliability of the gathered data, each center appointed one senior manager and one clinician for communication and instruction on screening records. Meanwhile, retrospective research was conducted with massive casualty incidents that occurred in Shanghai during 2011–2014 for case analysis of the collected data, extraction and screening of the influencing factors of massive casualty, and determination of critical influencing factors of massive casualty.

1.3 Overview of system dynamics modeling

1.3.1 Design and scheme of system dynamics modeling

A trauma emergency system is a structural and functional unit with a large number of individuals. Owing to its inherently open nature, a trauma emergency system is significantly impacted by the external environment. Inside the system, subtle changes caused by the interactions between different individuals can always generate clustering and resultant collision force, which are likely to lead to essentially distinct results. Attempting to change the system resource input level simply by adopting the old linear thinking mode or improve the system efficiency simply by using a certain measure (or several measures) is infeasible for sophisticated systems. Therefore, from an overall perspective, implementing research of trauma emergency systems is reasonable to realize system optimization.

Considering the lack of massive casualty research data in Shanghai and the fact that the insufficient existing data are unable to support comprehensive research on this topic, this research group explored the general pattern and characteristics of trauma occurrence and evolution by deep data mining and constructed a model of a massive casualty emergency system based on the data and their logical relationships as well as the existing emergency organization and resource structure of Shanghai. The validity of the constructed model of the practical system was tested using the existing massive casualty data. By adjusting the parameter settings, a model of a massive casualty emergency medical system with good validity was established. Using this system model, critical factors that affect the efficiency of Shanghai's massive casualty emergency medical system can be identified. By regulating the parameters associated with critical factors, policy intervention experiments of massive casualty emergency medical care can be conducted to quantitatively predict the effects of different intervention measures on emergency system efficiency and optimize the measures, procedures, and schemes of massive casualty emergency medical services. At the same time, the reaction capacity of the emergency system under different scales and different types of massive casualty incidents can be simulated by regulating the initial input parameter. The effects of different emergency care schemes on trauma patients can be simulated by adjusting parameters and changing system behaviors. In this way, optimal emergency measures, procedures, and schemes for massive casualty events of different scales and types can be obtained.

1.3.2 Objectives and significance of system dynamics modeling

The objectives of constructing a massive casualty emergency medical system are (1) integrating the experimental platform of massive casualty emergency health care in megalopolises for the implementation of dynamic simulations on a trauma emergency network system structure; and (2) conducting policy intervention experiments with respect to massive casualty emergency health care to provide experimental tools of quantitative calculation for introducing a scheme of megalopolis massive casualty emergency services and eventually realize efficiency analysis and evidence-based decision-making in a massive casualty emergency medical system.

Establishing a model of a massive casualty emergency medical system is significant for the following reasons: (1) through simulations of the system structure and interaction between individuals in the trauma emergency care system, weak links influencing system efficiency can be detected for system structure modification and optimization; (2) based on the constructed model of a massive casualty emergency system, evidence-based decision-making of the massive casualty emergency mode can be achieved by conducting a series of measures, from setting policy groups and test groups to implementing intervention experiments involving influencing factors and key indicators of the massive casualty emergency mode, and then obtaining the critical intervention targets that impact the systematic structure of the emergency mode (this evidence-based decision-making can contribute to the construction of a Shanghai massive casualty emergency mode and schemes as the test platform and decision-making tools); (3) through system modeling, simulations can be based on previous data to describe the basic patterns and characteristics of people's injuries in different types of emergencies, exploring the total number of trauma patients, structure, distribution, and variation trend, and revealing the pattern of massive casualty occurrence and evolution in megalopolises; (4) a system modeling approach is first introduced into the research on trauma emergency systems, expanding the systematic study of the trauma field and fulfilling the visual simulation of the system's behavioral characteristics; and (5) evidence-based decision-making was followed in the entire research process, where based on the analysis of the status quo, the model platform is used to simulate the system's behavioral characteristics and thereby discover the mechanisms of problem formation; combined with practical situations in China, we propose policy-intervention groups to conduct intervention experiments on the platform and verify the accuracy of actual political measures, which is a significant trial of evidence-based decision-making in the field of trauma studies.

1.3.3 Methodology of system dynamics modeling

Currently, approaches to studying trauma mainly involve a literature review and statistical analysis. Regarding statistical analysis, trauma research is essentially initiated with the screening of trauma regression influencing factors. These two study approaches share the characteristics that influencing factors and results of trauma can only be analyzed in a static manner and a trauma emergency system can only be explored on a local level. That is, collective behaviors and the interaction between individuals in the trauma emergency system cannot be analyzed and simulated in a dynamic and systematic way. Therefore, considering that a trauma emergency system can be regarded as a complex social system, sophisticated system modeling is adopted in this work to conduct dynamic, quantitative, and systematic research on the system. At present, dominant system modeling approaches mainly include agent-based modeling, neural networks, metamodeling, cellular automata, genetic algorithm-based modeling, system dynamics modeling, macro-simulations, artificial life modeling, and fuzzy modeling (Liu *et al.*, 2007; Wang, 2003; Li, 2012). Based on previous study experience in this research group, a complex system study is implemented by establishing a massive casualty emergency medical system model using a system dynamics modeling method from the perspective of high feasibility.

A system dynamics model was first proposed by Jay W. Forrester from the Massachusetts Institute of Technology in 1956. This model was initially used in industrial fields for the research of dynamic characteristic variations in system behaviors against time

(Wang, 1992b and 1994). Construction of a system dynamics model mainly involves four steps: conceptual model construction, cause-and-effect relationship establishment, dynamic stock-flow diagram establishment, and overall model construction. Today, system dynamics are extensively applied in sophisticated systems in the scientific fields of engineering, ecology, environment and health, and social development (Qi and Chang, 2011; Rauner and Schaffhauser-Linzatti, 2002a; Lich *et al.*, 2010; Kollikkathara *et al.*, 2010) to solve problems associated with a complex system.

Since system dynamics modeling was first introduced in the healthcare field, this approach has been widely used for system studies of disease prevention and control, health policy and evaluation, health services supply and demand, and health resources and behaviors (Homer and Hirsch, 2006; Chalmers and Ritter, 2012; Taylor *et al.*, 2005b; Ishikawa *et al.*, 2013). In China, the director of this research group, L. Zhang, applied system dynamics to the macro-health policy investigation in 2006, where the "health care delivery system–system model framework" and "health delivery system–problem model framework" were used (Zhang and Ma, 2006). The introduction of system dynamics has promoted the analysis of system behaviors and problems in the healthcare field from the perspectives of system integrity and dynamics, providing theoretical support to health policy introduction from a more macro-system perspective and offering great potential for system behavior simulations, policy experiment implementation, and dynamic prediction of intervention effects. Therefore, compared with conventional statistical methods, a system's behavioral and structural variations and reaction to the environment can be simulated based on the establishment of a massive casualty emergency system model using system dynamics modeling approaches. According to the simulation results of dynamic intervention experiments including multiple variations in trauma occurrence, emergency mode, and disease occurrence and evolution, practically feasible emergency plans can be introduced to effectively prevent and reduce the incidence of trauma and significantly improve the treatment efficiency of the trauma emergency system.

This research group has focused on the construction of system dynamics models for the health delivery system for the past decade. By taking the macro-system of healthcare delivery in China as the study target, a model framework of (1 + *n*) dual-dimension macro-health delivery system based on the system structure and considering the existing systematic problems faced by this macro-system was constructed, containing over 300 models in up to 37 orders, more than 2,000 functional equations involving over 20 functional relationships, over 30 decision-making targets, more than 3,000 variables, and almost 10,000 feedback loops. In the early stage of comprehensive research of system modeling, a methodological framework of health delivery system complexity investigation was constructed, providing robust methodological support and feasible verification of the establishment of a massive casualty emergency system model.

References

Ahmed, A.; Hoffman, B.; Harland, K.; *et al.* Not just an urban phenomenon: uninsured trauma patients in rural setting at risk for increased mortality. *Annals of Emergency Medicine* **2012**, *60*, S93.

Alexander, D. Death and injury in earthquakes. *Disasters* **1985**, *9*, 57–60.

American College of Surgeons. National trauma data bank. Available online: https://www.facs.org/quality-programs/trauma/ntdb (accessed on 1 December 2016).

Bai, X.J.; Li, Z.F. Necessity of improvement of trauma emergency system. *Chinese Journal of Emergency Medicine* **2010**, *19*, 456–458.

Cai, R.B. Thinking about the trauma emergency system reform in China. *Chinese Journal of Trauma* **1998**, *14*, 129–131.

Chalmers, J.; Ritter, A. Subsidising patient dispensing fees: the cost of injecting equity into the opioid pharmacotherapy maintenance system. *Drug and Alcohol Review* **2012**, *31*, 911–917.

Chaussalet, T.J.; Xie, H.; Millard, P. A closed queueing network approach to the analysis of patient flow in health care systems. *Methods of Information in Medicine* **2006**, *45*, 492–497.

Chazard, E.; Beuscart, R. Graphical representation of the comprehensive patient flow through the hospital. In AMIA Annual Symposium Proceedings, Chicago, IL, USA, 2007.

Chen, C.M.; Li, A.J. Analysis of the current situation of trauma emergency system. *Chinese Journal of Emergency Medicine* **2008**, *17*, 1007–1008.

Chen, C.M.; Yang, R.H. Practice and explorations in regional trauma medical emergency in large cities. *Emergency Medicine Journal* **2000**, *9*, 75–78.

Chen, L.; Li, T.C. Discussion on establishment and improvement of trauma emergency system in China. *Journal of Clinical Emergency Medicine* **2011**, *12*, 376–378.

Chen, R.Z. Fasten the establishment of trauma emergency network and improve the capability of trauma emergency in China. *Chinese Journal of Critical Care Medicine* **2005**, *25*, 50–51.

Chen, S.F.; Yang, X.J.; Qian, H.S.; *et al.* Application of trauma severity score in trauma emergency. *Journal of Traumatic Surgery* **2004**, *6*, 11–12.

Chen, S.W. Management and classification of trauma emergency organization. *Chinese Journal of Clinical Medicine* **2004**, *5*, 101.

Chen, S.Y.; Chaou, C.H.; Ng, C.J.; *et al.* Factors associated with ED length of stay during a mass casualty incident. *The American Journal of Emergency Medicine* **2016**, *34*, 1462–1466.

Delgado, R.C.; Gmez, C.N.; Álvarez, T.C.; *et al.* An epidemiological approach to mass casualty incidents in the Principality of Asturias (Spain). *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine* **2016**, *24*, 1.

Doughty, H.; Glasgow, S.; Kristoffersen, E. Mass casualty events: blood transfusion emergency preparedness across the continuum of care. *Transfusion* **2016**, *56*, S208–S216.

Du, D.Y. Advancement of prehospital trauma emergency: opportunities and challenges of new researches. *Journal of Traumatic Surgery* **2012**, 292–296.

Du, D.Y. Introduction of American traumatic first aid system. *Chinese Journal of Trauma* **2006**, *22*, 718–720.

Fu, X.B.; Jiang, Y.G. Formation and development of trauma emergency system in other countries. *Journal of Traumatology* **1987**, *4*, 33.

Gannon, C.J.; Napolitano, L.M.; Pasquale, M.; *et al*. A statewide population-based study of gender differences in trauma: validation of a prior single-institution study. *Journal of the American College of Surgeons* **2002**, *195*, 11–18.

Gao, J.M. Discussion on trauma emergency and treatment patterns. *Chinese Journal of Trauma* **2004**, *20*, 707–708.

González, P.A.; Delgado, R.C.; Alvarez, T.C.; *et al.* The development and features of the Spanish prehospital advanced triage method (META) for mass casualty incidents. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine* **2016**, *24*, 63.

Guha-Sapir, D.; Hoyois, P.; Below, R. Annual disaster statistical review 2014: the numbers and trends. Centre for REsearch on the Epidemiology of Disasters (CRED), Institute of Health and Society (1RSS) and Université catholoque de Louvain: Louvain-la-neuve, Belgium, 2015.

Himanen, L.; Portin, R.; Hämäläinen, P.; *et al.* Risk factors for reduced survival after traumatic brain injury: a 30-year follow-up study. *Brain Injury* **2011**, *25*, 443–452.

Homer, J.B.; Hirsch, G.B. System dynamics modeling for public health: background and opportunities. *American Journal of Public Health* **2006**, *96*, 452–458.

Huo, Z.L.; Shen, M.H.; Zhou, B.; *et al.* Improvement of regional trauma emergency network and the treatment capability of trauma casualties in large cities. *Chinese Journal of Critical Care Medicine* **2008**, *28*, 1040–1042.

Ishikawa, K.; Jitsuiki, K.; Ohsaka, H.; *et al.* Management of a mass casualty event caused by electrocution using doctor helicopters. *Air Medical Journal* **2016**, *35*, 180–182.

Ishikawa, T.; Ohba, H.; Yokooka, Y.; *et al.* Forecasting the absolute and relative shortage of physicians in Japan using a system dynamics model approach. *Human Resources for Health* **2013**, *11*, 1–10.

Japan Trauma Data Bank. Japan trauma data bank report 2012. Available oniline: http://www.jtcr-jatec.org/traumabank/link/link.htm (accessed on 1 December 2016).

Kollikkathara, N.; Feng, H.; Yu, D. A system dynamic modeling approach for evaluating municipal solid waste generation, landfill capacity and related cost management issues. *Waste Management* **2010**, *30*, 2194–2203.

Kong, G.; Yin, X.; Wang, T.; *et al.* Current state of trauma care in China, tools to predict death and ICU admission after arrival to hospital. *Injury* **2015**, *46*, 1784–1789.

Li, L.H. Improvement of trauma emergency system and trauma treatment capability. *Hainan Medical Journal* **2008**, *19*, 101–102.

Li, T.L.; Li, H.; Shen, W.F.; *et al.* Influence of related factors of trauma emergency system on the stay length of ICU. *Chinese Journal of Trauma* **2012**, 432–436.

Li, W.; Sun, Y.; Song, G.M. Research development of trauma emergency. *Tianjin Journal of Nursing* **2011**, *19*, 246–247.

Li, Y.Y. Methods on complicated system modeling. *Science and Technology Information*

2012, 20.

Lich, K.H.; Osgood, N.D.; Mahamoud, A. Using system dynamics tools to gain insight into intervention options related to the interaction between tobacco and tuberculosis. *Global Health Promotion* **2010**, *17*, 7–20.

Liu, B.C.; Liu, H.Y.; Kang, X.Q. Emergency medical system and trauma emergency. *International Journal of Emergency and Critical Care Medicine* **2005**, *2*, 538.

Liu, X.T.; Liu, L.; Song, K.; *et al.* Thinking of complex system modeling and simulation. *Journal of System Simulation* **2007**, *19*, 3073–3075.

Lopez, A.D. *Global Burden of Disease and Risk Factors*; World Bank Publications: Washington, DC, USA, 2006.

Lu, D.S.; Chen, C.R.; Shao, X.; *et al.* Strategies and methods of responding to sudden massive casualty incidents in tertiary hospitals: a report on first aid of propane explosion in Nanjing. *Journal of Traumatic Surgery* **2011**, *13*, 303–305.

Lu, L.; Luo, Z.F. Role of social consortium in trauma emergency. *Journal of Emergency Medicine* **2000**, *9*, 203–204.

Ma, X.L.; Jiang, Y.G.; Huang, X.K.; *et al.* Practices and expenience of establishing regional trauma emergency network in Chongqing, China. *Journal of Traumatic Surgery* **2007**, *9*, 185–186.

Matsumoto, H.; Motomura, T.; Hara, Y.; *et al.* Lessons learned from the aeromedical disaster relief activities following the great East Japan earthquake. *Prehospital and Disaster Medicine* **2013**, *28*, 166–169.

Mock, C. *Guidelines for Essential Trauma Care*; WHO: Geneva, Switzerland, 2004.

Nathens, A.B.; Jurkovich, G.J.; Rivara, F.P. Effectiveness of state trauma systems in reducing injury-related mortality: a national evaluation. *Journal of Trauma and Acute Care Surger* **2000**, *48*, 25.

Nelson-Williams, H.; Kodadek, L.; Canner, J.; *et al.* Do trauma center levels matter in older isolated hip fracture patients? *Journal of Surgical Research* **2015**, *198*, 468–474.

NHFPC. *Statistic Yearbook of National Health And Family Planning of the People's Republic of China*; Pecking Union Medical College Press: Beijing, China, 2013.

NTDB. *National Trauma Data Bank Annual Report 2015*; American College of Surgeons: Chicago, IL, USA, 2015.

Office of The State Council. *Formulation and Revision Framework of Emergency Plans for Public Events*; Office of The State Council: Beijing, China, 2004.

Office of The State Council. *Notice of the Assessment of Various Public Emergencies*; Officce of The State Council: Beijing, China, 2005.

Office of The State Council. *Regulations on Public Health Emergency*; Office of The State Council: Beijing, China, 2011.

Office of The State Council. *Rescue and Emergency Plans for National Natural Disasters*; Office of The State Council: Beijing, China, 2011.

Office of The State Council. *Suggestions on Overall Strengthening Emergency Management*; Office of The State Council: Beijing, China, 2006.

Office of The State Council. *Suggestions on Strengthening Emergency Management at Grass-*

Roots Level; Officce of The State Council: Beijing, China, 2007.
Office of The State Council. *The Main Points of Working Plan of The State Council*; Office of The State Council: Beijing, China, 2005.
Omori, K.; Ohsaka, H.; Ishikawa, K.; *et al.* Introduction of a physician-staffed helicopter emergency medical service in eastern Shizuoka prefecture in Japan. *Air Medical Journal* **2014**, *33*, 292–295.
Ottochian, M.; Salim, A.; Dubose, J.; *et al.* Does age matter? The relationship between age and mortality in penetrating trauma. *Injury* **2009**, *40*, 354–357.
Palmer, C.S.; Davey, T.M.; Mok, M.T.; *et al.* Standardising trauma monitoring: the development of a minimum dataset for trauma registries in Australia and New Zealand. *Injury* **2013**, *44*, 834–841.
Peden, M. *World Report on Child Injury Prevention*; WHO: Geneva, Switzerland, 2008.
Qi, C.; Chang, N.B. System dynamics modeling for municipal water demand estimation in an urban region under uncertain economic impacts. *Journal of Environmental Management* **2011**, *92*, 1628–1641.
Qu, C.W. Analysis on the development of severe trauma emergency and emergency surgery. *China Practical Medicine* **2010**, 265.
Racy, M.; Al-Nammari, S.; Hing, C. A survey of trauma database utilisation in England. *Injury* **2014**, *45*, 624–628.
Rauner, M.S.; Schaffhauser-Linzatti, M.M. Impact of the new Austrian inpatient payment strategy on hospital behavior: a system-dynamics model. *Socio-Economic Planning Sciences* **2002**, *36*, 161–182.
Schoenfeld, A.J.; Belmont, P.J.; See, A.A.; *et al.* Patient demographics, insurance status, race, and ethnicity as predictors of morbidity and mortality after spine trauma: a study using the National Trauma Data Bank. *The Spine Journal* **2013**, *13*, 1766–1773.
Shen, M.H.; Huo, Z.L.; Chen, C.M. Retrospect and prospect of trauma emergency network in metropolis. *Chinese Hospital Management* **2008**, 15–17.
Shen, W.F.; Jiang, G.Y.; Gan, J.X. Practices and exploration of integrated trauma emergency. *Chinese Journal of Hospital Administration* **2006**, *22*, 114–117.
Sun, J.; Qu, J.F.; Wen, L.; *et al.* Exploration on integrated trauma emergency nursing patterns. *Journal of Modern Nursing* **2010**, 444–445.
Tang, A.P.; Wen, A.H. Concept of natural disasters and grade. *Journal of Natural Disaster* **1999**, *8*, 61–65.
Tang, H.M.; Zhang, J.F.; Zen, G.; *et al.* Specialized thinking on severe trauma emergency patterns. *Modern Medicine Journal of China* **2012**, *14*, 129–130.
Tang, H.M.; Zhang, J.F.; Zhao, H.M.; *et al.* Discussion on prehospital trauma emergency (a report on 48 cases). *Journal of Snake* **2012**, *24*, 73–74.
Tang, Q.Y.; Liu, X.L.; Le, S. Application of chain process management in severe trauma emergency. *Chinese Nursing Research* **2008**, *22*, 2036–2037.
Taylor, K.; Dangerfield, B.; Le Grand, J. Simulation analysis of the consequences of shifting the balance of health care: a system dynamics approach. *Journal of Health Services Research & Policy* **2005**, *10*, 196–202.

The Trauma Audit & Research Network: Trauma Care. Available online: https://www.tarn.ac.uk/Content.aspx?ca=2 (accessed on 2 December 2016).

Tissier, C.; Bonithon-Kopp, C.; Freysz, M.; *et al.* Statement of severe trauma management in France; teachings of the FIRST study. *Annales Francaises D'anesthesie et de Reanimation* **2013**, *32*, 465–471.

Trauma Register DGU. 20 years of trauma documentation in Germany—actual trends and developments. *Injury* **2014**, *45*, S14–S19.

UNICEF. *A League Table of Child Deaths by Injury in Rich Countries*; UNICEF: New York, NY, USA, 2001.

Varghese, M.; Sasser, S.; Kellermann, A.; *et al. Prehospital Trauma Care Systems*; WHO: Geneva, Switzerland, 2005.

Victorian State Trauma System. About the victorian state trauma system. Available online: https://www2.health.vic.gov.au/hospitals-and-health-services/patient-care/acute-care/state-trauma-system/about-vsts (accessed on 2 D 2016).

Walker, G.J.; Blood, C.G. The patient flow of marine disease and non-battle injury conditions within a multi-echelon system of care. *Military Medicine* **1999**, *164*, 731–736.

Walker, G.J.; Blood, C.G. The patient flow of wounded marines within a multi-echelon system of care. *Military Medicine* **1999**, *164*, 423–427.

Wang, F.Q. *System Dynamics*; Tsinghua University Press: Beijing, China, 1994.

Wang, G.S.; Xie, G.A.; Ye, N. Discussion on trauma emergency patterns in Anhui provincial hospitals. *Zhejiang Journal of Traumatic Surgery* **2007**, *12*, 92–93.

Wang, Q.F. *Dynamic Analysis of Complex Social and Economic System*; Fudan University Press: Shanghai, China, 1992.

Wang, Z.Z. Complex system modeling and simulation research based on evolution. *Journal of System Simulation* **2003**, *15*, 905–909.

Wen, L.; Liu, M.H.; Xiong, J.Q.; *et al.* Exploration on trauma emergency patterns. *Chinese Journal of Critical Care Medicine* **2005**, 25, 41–43.

Wen, L.; Wang, Z.G. Several controversial issues on trauma emergency. *Chinese Journal of Emergency Medicine* **2004**, *13*, 223–224.

WHO. *Child and Adolescent Injury Prevention: A Global Call to Action*; WHO: Geneva, Switherland, 2005.

WHO. *Child and Adolescent Injury Prevention: A WHO Plan of Action 2006–2015*; WHO: Geneva, Switherland, 2006.

WHO. *Global Status Report on Road Safety 2015*; WHO: Geneva, Switherland, 2015.

WHO. *Injuries and Violence: The Facts*; WHO: Geneva, Switherland, 2014.

WHO. *WHO Global Report on Falls Prevention in Older Age*; WHO: Geneva, Switherland, 2008.

WHO. *World Report on Road Traffic Injury*; WHO: Geneva, Switherland, 2015. Available online: http://www.who.int/mediacentre/factsheets/fs358/zh/ (accessed on 3 May 2016).

Xin, D.Y. Discussion on trauma emergency patterns. *Chinese Medicine of Factory and Mine* **2006**, *19*, 153–154.

Xin, D.Y. Research on trauma emergency. *Medical Recapitulate* **2006**, *12*, 1177–1179.

Xu, F. Trauma emergency system. In *Traumatic Academic Conference of the Yangtze River Delta and Zhejiang Traumatic Academic Annual Meeting*, Zhejiang, China, 2014

Xu, W.F. Epidemiological analysis of 150 trauma emergency patients in a certain region. *Nei Mongol Journal of Traditional Chinese Medicine* **2011**, *30*, 3.

Yang, J.; Shi, Y.K. Investigation on severe Chinese patients: an analysis of causes, body regions, extent, treatment and outcomes of trauma. *Chinese Journal of Trauma* **1997**, *13*, 329–332.

Yates, D.; Woodford, M.; Hollis, S. Preliminary analysis of the care of injured patients in 33 British hospitals: first report of the United Kingdom major trauma outcome study. *British Medical Journal* **1992**, *305*, 737–740.

Yeung, J.H.; Graham, C.A. Guidelines for trauma quality improvement programmes. *European Journal of Emergency Medicine* **2010**, *17*, 101.

Zhang, G.J. Application of integrated trauma emergency pattern in severe surgical trauma emergency. *Chinese Journal of Trauma and Disability Medicine* **2015**, *23*, 89–90.

Zhang, H.Q.; Zhou, G.T.; Zhang, Y. *Disaster Medicine*; Peking Union Medical College Press: Beijing, China, 1993.

Zhang, J.P. *Disaster Medicine*; Military Science Publising House: Beijing, China, 1992.

Zhang, L.L.; Ma, Y.Q. *Research on Health Delivery System Modeling*; Second Military Medicine University Press: Shanghai, China, 2006

Zhang, L.Y. Discussion on multidisciplinary team pattern in severe trauma emergency. *Chinese Journal of Trauma* **2011**, *27*, 385–387.

Zhang, Y.Z. Problems and development directions of trauma emergency. *Chinese Journal of Trauma* **2004**, *20*, 705–706.

Zhou, J.H.; Wang, Z.G. Discussion on trauma emergency treatment in China. *Chinese Journal of Trauma* **2009**, *25*, 100–102.

Zhou, W.L.; Su, L.; Qin, W.Y.; *et al.* Epidemiological analysis on 10654 trauma emergency patients in Guangzhou, China. *Chinese Journal of Emergency Medicine* **2006**, *15*, 784–786.

Zhuang, H.L.; Qiu, X.M. Clinical characteristics and epidemiological analysis on 130 trauma emergency patients in Haikou, Hainan, China. *Nursing Practice and Research* **2012**, *9*, 139–140.

Chapter 2 Overview of trauma research in China

Chaoqun Hu[1], *Guoshi Yang*[2] *and Lulu Zhang*[1]

[1] *Department of Military Health Service Management, College of Military Health Service Management, Second Military Medical University, Shanghai 200433, China*

[2] *Teaching Support Department, Second Military Medical University, Shanghai 200433, China*

2.1 Review of trauma research development

Trauma is both the traditional and heated topic in medicine. As a traditional issue, trauma has existed in the world since the beginning of human history and trauma treatment can be traced back to the prehistoric ages. As early as the Xia Dynasty of China (21st to 17th century BC), people began to practice wound pressing, bloodletting, and pus expelling using silica and bone needles for pain relief and promotion of wound healing. Trauma is also a fairly recent topic of concern because it is considered a “disease of modern civilized society”, which appears in an increasing trend along with the development of society. In China, trauma and poisoning ranked ninth in 1957, seventh in 1975, and fifth after 1995. At least 100,000 people die from trauma and millions of people are injured every year in China (Chen, 1999). Throughout the world, more than 1,000,000 people die from trauma and tens of millions of people are injured every year. Currently, research on trauma has been expanded from focusing on clinical surgery to encompassing preventive as well as basic medicine, moving from a body/organic/cellular scale to a molecular/genetic scale.

China built the first dedicated research institute studying trauma in the 1950s. After the 1980s, a number of major hospitals in large- and medium-sized cities began to set up traumatology departments and intensive care units, and more research institutes emerged. Subsequently, the Trauma Branch of the Chinese Medical Association (1990) was founded and the Chinese Journal of Traumatology (1990) was launched. A series of national and international academic conferences were held. As a result, basic research on trauma saw satisfying progress at that time. In 1990, the Ministry of Science and Technology approved fundamental research on trauma with a grant of 4 million dollars, showing a serious interest in trauma research from the government.

China started trauma epidemiology research (in particular, traffic accident injuries) in the early 1990s and obtained certain achievements. Medical emergency networks and 120 ambulance telephone lines have been set up in all the large- and medium-sized cities in China, which has shortened the reaction time (from receiving the call to the onset of treatment) and improved the quality of emergency care. The application of modern diagnostic devices and advanced treatment technologies has effectively enhanced the emergency medical care capabilities for injuries of different body parts and enabled profound studies on the mechanisms associated with biomechanics, secondary injuries, and complications (shock, infection, and multiple organic dysfunction syndrome) of primary trauma.

In recent years, China has made substantial progresses in studies and applications of the datasets regarding trauma, trauma surgery, and investigations of traffic-induced trauma. More and more hospitals have participated in collecting trauma data and clinical trauma care studies by using unified trauma database software. The Research Institute of Traffic Medicine in the Third Military Medical University has developed a series of biological impact models in order to simulate the biological impact on different body parts (whole-body or localized) at various speeds at impact. A large rail-based biological impact laboratory was also established, where real cars can be used to simulate injuries of drivers, passengers, and pedestrians (dummies, corpses, or live animals) in collisions. Moreover, the biomechanical mechanisms of stress being transmitted to impacted bodies, the effects of micro-stress on cell damage, and traffic psychology were comprehensively explored, providing corresponding theoretical foundations for impact trauma prevention and treatment. So far, the National Trauma Data Center of China has already collected more than 2,000,000 trauma records from hospitals, preliminarily accumulating a great amount of trauma data. Professor Zhou discovered from the preliminary analysis of trauma records that were gathered from 237 hospitals between 2001 and 2008 that the highest incidence rate of trauma results from traffic injuries, accounting for 30.11% of all the trauma cases (Zhou *et al.*, 1998). Preliminary analysis shows that a huge amount of information has been obtained that is valuable and needs to be further probed in future studies. However, some drawbacks have also been observed. For instance, some content and conventions of the current data are outdated for ongoing development; records of trauma outcomes and recovery assessment are weak; and the ever-growing specialist demands are not being properly satisfied. Research and construction of datasets need to be unceasingly standardized and improved with the cooperation of workers in the field of trauma throughout the whole country (Zhu, 1998).

In the treatment of serious trauma, an increasing number of experts have paid a great deal of attention to the applications of damage-control techniques and have conducted much research, such as damage-control applications on the treatment of multiple trauma resulting from severe traffic injuries and discussions on fracture fixation and damage control of multiple-trauma patients with pulmonary and cerebral damage. In particular, Yu *et al.* conducted preliminary perspective studies on the staging treatment of early definitive surgery and damage control for multiple-trauma patients using quantitative trauma scoring methods, laying a good foundation for the research of quantitative damage control.

2.2 Evolution of trauma research methodology

2.2.1 Methodology of trauma research

(1) Trauma scoring approaches. Trauma scoring is an important part of traumatology. It is a set of diverse schemes that measure the severity of a trauma patient's injury using weight-based quantified parameters, including the patient's physiological indexes, anatomical injury, functional injury, and diagnosis. The severity of injury began to be

quantitatively expressed internationally in the 1950s, and this approach has been gradually promoted since the late 1970s, providing quantitative criteria for measuring injury and treatment of trauma patients and a reference for comprehensively evaluating injury severity and probability of survival.

Trauma severity scoring can be divided into pre-hospital scoring and in-hospital scoring. Pre-hospital scoring makes use of the trauma score, trauma index, revised trauma score (Champion *et al.*, 1989), circulation, respiration, abdomen, motor and speech scale, and pre-hospital index (Adams and Carrubba, 1998), among which pre-hospital index, circulation, respiration, abdomen, motor and speech, and TS are the most frequently adopted, with various advantages and disadvantages. Based on these pre-hospital scoring methods, trauma patients with a high injury severity can be preferentially treated and transferred in a timely manner for their subsequent specialized therapy.

For in-hospital scoring, trauma severity coding is primarily based on scoring the anatomical injury, such as with the Abbreviated Injury Scale (AIS) and some derived methods such as Injury Severity Score (ISS), trauma and injury severity score, a severity characterization of trauma, and anatomic profile. AIS is a method to describe and classify the severity of injuries using quantified data, which has been accepted by all countries. This scale mainly scores trauma according to the quantification of anatomic injury, rather than grading the injuries based on physiological parameters. Because AIS is only able to assess trauma per se without a prognosis, *i.e.*, not able to predict the trauma outcome, AIS needs to be modified for further development. ISS is the most widely used method for trauma scoring at present. Since this method is derived from the AIS scoring system, appropriate AIS scoring is the prerequisite of accurate evaluation of a patient’s trauma.

For the ISS, the human body is theoretically divided into six ISS body regions: (1) head or neck (including skull and cervical spine); (2) face (including mouth, nose, ears, eyes, and facial skeleton); (3) chest (including thoracic viscera, thoracic spine, diaphragm, and ribs); (4) abdomen and pelvic contents (including lumbar spine); (5) extremities and pelvic girdle (including scapulae but excluding spine); and (6) external (including surface tearing on any region of the body, contusions, and burns). The highest AIS value for each of the three most severely injured regions of the six body regions is then squared, and the severity of trauma is represented by the sum of the three squares. If there are only one or two regions, then the severity should be equal to the square of the maximum AIS. The ISS scores range from 1 to 75 (Tan, 1996). A score of 75 will occur in only two particular situations: (1) when the AIS values of three different regions all reach 5 or higher; and (2) when the AIS value of the most seriously injured body regions reaches 6. In the ISS scoring process, all the injuries of a victim are required to be coded one by one without omissions. The survey should not omit cases involving sophisticated calculations or slight injuries. Generally, ISS > 15 and ISS > 20 are adopted as the threshold of severe injury determination. The majority of researchers agree that if ISS > 20, the mortality rate would jump significantly.

For trauma scoring in China, according to the characteristics of trauma, the Fourth Military Medical University proposed the concept of trauma scoring with six-digit coding based on the trauma classifications in ICD-9 and constructed a correspondence table between the six-digit codes of ICD-9 and AIS scores. It can be seen from an investigation of this table conducted using ISS that the AIS scores obtained from the transformation of ICD-9 codes can well demonstrate the anatomic severity of an individual injury and, therefore, can serve as anatomic parameters for trauma scoring. On this basis, Fourth Military Medical University further discussed the influencing factors of the trauma patient's outcome to select other model variables for trauma scoring based on numerical coding, and investigated the influence of various factors on the trauma patient's outcome from the perspective of statistics (Zhou *et al.*, 1999).

(2) Establishment of a trauma database. Based on structured query language, the Trauma Database of the Chinese People (Shi *et al.*, 2001), collaboratively constructed by the Third Military Medical University, Chongqing Emergency Medical Center, and Research Institute for Traffic Medicine of the People's Liberation Army (PLA), includes 10 aspects of trauma: trauma patients' personal information, injury profiles, pre-hospital situations, in-hospital situations, in-hospital treatment, diagnosis and scoring, complications and comorbidities, treatment quality, and hospital discharge. This database includes the functions of data entry, index and inquiry, statistical analysis, compatibility with hospital record systems, and information integration of patients' pre-hospital and in-hospital data. From the perspective of practical medicine applications, this database integrates trauma scoring software, which can be used for studying the basic injuries in medical records, comprehensively constructing the basic trauma database, analyzing medical records with certain identical characteristics, and establishing the pre-hospital treatment models of various traumatic events. The trauma database system network version 3.0, developed by (Zhou *et al.*, 2010) can be used for exchanging and analyzing summarized trauma information through interconnections between the network and other medical organizations. By constructing information streams of therapy for trauma, functions of relational selection of ICD and AIS codes, trauma scoring and treatment quality evaluation, inquiry for any field of the database, and statement establishment, can be realized. This database has the advantages of efficiently standardizing the trauma-related information and comprehensively gathering trauma information, showing a certain value in summarizing and enhancing trauma prevention, improving clinical treatment and management, and promoting trauma informatization. Studies of the injury spectra in China are concentrated on the spectra of wartime injuries and natural disasters (especially spectra of earthquake-related injuries). Earthquake induced injuries demonstrate a high incidence rate and mortality rate in China. Therefore, simple rapid coding and classification of earthquakes have great significance for the subsequent rescue work. Common spectra of earthquake-related injuries are composed of three to four levels of coding and include the injury categories of surgery, medicine, and infectious disease epidemiology, which can be further divided into multiple subcategories, *viz*., injury situations, circulatory system injuries, and diverse infections (Shen *et al.*, 2009).

(3) Intersection of trauma with multiple disciplines. A set of comprehensive multidisciplinary, performance-improving programs has been constructed in some

countries, which can be used to systematically evaluate the trauma treatment level through trauma outcome investigations and efficiently promote the enhancement of trauma treatment quality (Huang, 2011). In trauma research, trauma outcome is generally taken as the dependent variable for studying the critical factors that influence the patient's recovery or death by using statistical approaches such as the χ^2 test, rank-sum test, and regression analysis. Common influencing factors of trauma outcome can be divided into three categories: demographic factors, trauma situations, and medical factors. Demographic factors include sex, age, occupation, marital status, education, and monthly income. Trauma conditions include the cause of the patient's injury, type of trauma, injury severity, complications, and comorbidities. Medical factors mainly involve pre-hospital and in-hospital care (Zhang, 2011a). Moreover, a large number of studies indicate that psychological trauma likewise has a significant impact on trauma prognosis. In China, multi-agent modeling is mainly used for simulating problems such as urban evolution processes and infectious disease transmission, but not as much for studies of non-communicable trauma. Based on the demand for urgent emergency health care in China, investigating in-hospital trauma emergency systems using a multi-modeling approach has great significance for enhancing reasonable rescue and emergency efficiency.

2.2.2 Evaluation

Today, trauma research is drawing more attention in China. Chinese researchers are still exploring this field based on the experience and achievements gained from developed countries. A trauma scoring system has been established based on the features of trauma frequently occurring in China, which is being continuously improved and updated. Trauma datasets are also being constructed and improved, and noticeable progress has been observed toward standardization and informatization. However, we should still be aware that trauma datasets in China are mostly regionally based or based on a single factor, and a general data bank with uniform data management has not yet been built.

2.3 Overview of massive casualty research

Research on massive trauma in China has been conducted on a relatively small scale compared with that in developed countries, with the following characteristics: (1) late onset; (2) theories and methods of massive trauma emergency system management are still in the study and development stage; (3) investigations of specific problems in massive trauma emergency systems are only at a superficial level; and (4) a uniform and complete theoretical framework of a massive trauma emergency system has not been formed. Existing studies of massive trauma are mostly concentrated on injuries due to earthquakes.

Research on earthquake-related issues in China has achieved improvement in the following aspects:

(1) Relatively complete earthquake emergency commanding organizations based on "peace-earthquake combination" have been constructed for implementing unified

coordination and direction of emergency rescues in diverse locations. Up to now, earthquake emergency management institutes for monitoring and defending against earthquakes in 21 key regions and 13 key cities have been established in the nation, initially ensuring the organization, personnel, and measures for earthquake emergency work (Zhang, *et al.*, 2012).

(2) Technical platforms of earthquake emergency command have been preliminarily erected, providing necessary support to the commanding institutes for earthquakes with fundamental functions that meet the post-launch technical requirements of headquarters.

(3) Establishment and implementation of earthquake emergency response plans have been promoted. Emergency response plans are the foundation of earthquake emergency rescue and the reference for determining various response measures. Responsible departments in the State Council and all of the provinces, autonomous regions, and directly controlled municipalities have made and implemented their own emergency response plans in order to deal with destructive earthquakes. In the meantime, two-tiered (*i.e.*, city and county level) emergency response plans have been formulated in all the key regions for monitoring and responding to earthquakes. Apart from governmental departments, some industry organizations, institutes, and key enterprises and institutes have also formulated corresponding earthquake emergency response plans based on their own characteristics, showing adequate mental preparation for rescue work in case of an earthquake. A national emergency rescue team for earthquake disasters, the China International Search and Rescue Team, has been organized and associated training bases constructed (Zhang, 2012).

(4) The China International Search and Rescue Team, collaboratively established by the China Earthquake Administration and the General Political Department, has been officially founded. The rescue team was initially composed of 222 people, divided into three detachments and one general reserve team. Each detachment contains a search unit, rescue units, medical unit, technical unit, support unit, and various specialized rescue devices. Since its foundation, China International Search and Rescue Team has conducted remarkably rigorous training and participated in multiple international and national relief missions, achieving great results. China International Search and Rescue Team membership has expanded from 222 to 480 subsequent to the Wenchuan Earthquake (Li, 2008a). At the time of the Tenth Five-Year Plan, in order to satisfy the training requirement of specified personnel for earthquake emergency rescue, China's first national earthquake emergency rescue training base was established, which can simultaneously accommodate 150 people. The foundation of this training base has provided a good basis for the training of earthquake emergency rescue personnel in China.

2.4 Development of a trauma emergency medical system

2.4.1 Status of the trauma emergency medical system

The trauma emergency medical system represents all the emergency medical service systems in a certain region in a broad sense, which is essentially composed of an external and an internal framework. Trauma centers are generally distributed based on their levels. Level I trauma centers usually have the best trauma rescue quality with the resources and capacity to serve all types of trauma patients as well as the functions of teaching and training to a certain extent. Patient referral can be conducted between emergency medical service departments in trauma centers or trauma systems based on specified practical situations. According to the criteria for pre-hospital trauma triage, patients with severe or critical trauma have the right to receive treatment in corresponding trauma institutes. Today, 69.2% of American patients can go to a Level I trauma center within 45 minutes and 84% can arrive at a Level II trauma center within 60 minutes.

Emergency medical services can be divided into two stages, pre-hospital care and in-hospital care. Pre-hospital care is conducted by specialized multi-level emergency medical care systems, according to the need of the associated administrative areas or communities. Pre-hospital care involves different groups of personnel (e.g., emergency medical care personnel and medical assistants). According to the type of transportation, it can also be categorized as ground or air ambulance service. The director of the emergency care department is responsible for making treatment plans according to the trauma emergency medical care guidelines (Tan, 1996). At the in-hospital care stage, the trauma surgery center should make preparations based on the information provided by the emergency coordination center. A dedicated trauma team and standardized emergency medical care regulations should be in place. This team should be led by surgeons, who make major decisions and assign tasks to team members. Trauma centers receiving injured patients must follow the requirements of emergency medical care service resource optimization to perform basic life support and advanced life support.

(1) There are three major steps involved in pre-hospital care:

a. Triage and first aid. Pre-hospital emergency personnel who arrive at the scene first should immediately execute triage and first aid. While treating severely and critically injured patients, they should gather general information about the scene and report to the hospital in order for them to prepare for further large-scale emergency medical care. The report should include time, location, trauma cause, trauma situation, and number of patients.

b. On-site medical care. Some basic principles of on-site medical care include saving life first, local bandaging, shock treatment, and use of osmotic diuretics for symptoms of increased intracranial pressure.

c. Carrying patients to the ambulance. Emergency personnel should make full use of the onboard equipment to provide the injured patients with life support and monitoring. Nurses should help doctors perform first aid treatment by following orders from the doctors. Regular ambulance medical care includes placing the patient in a comfortable body position, establishing venous access, and observing/maintaining steady vital signs.

Owing to limitations imposed by the environment and equipment, complicated medical treatment measures are usually not expected at the pre-hospital stage. Therefore, the primary target of pre-hospital care is to save patients' lives and minimize the harm caused by trauma. This stage should create favorable conditions for subsequent treatment and help improve survival rates and prognoses.

At present, pre-hospital trauma care is basically conducted according to the pre-hospital trauma life support plan. It has been shown that the application of PHLTS, including the previously mentioned basic life support and advanced life support, can significantly improve the outcome of trauma patients. The former includes basic cardiopulmonary resuscitation, wound hemostasis, fracture fixation, and oxygen feeding, whereas the latter includes tracheal intubation, establishing venous access, intravenous cannulation, intraosseous infusion, and use of medical anti-shock pants. The employment of advanced life support in pre-hospital care in most cases can effectively stabilize trauma patients' conditions and improve trauma prognoses; however, under certain circumstances, this may also prolong the transfer time, adversely affecting prognosis (Xin, 2006a).

(2) In-hospital care. Currently, as the trauma treatment mode in China is restrained by the traditional emergency medical care mode, in most hospitals, trauma patients are sent to specialized departments for treatment, whereas the common practice for treating patients with severe multiple injuries or complications is to implement multidisciplinary consultation. However, trauma usually involves multiple body parts, and it is hard to triage the patient through such consultation owing to the lack of an overall concept of treatment. Furthermore, emergency triage also may delay treatment time and affect treatment outcome. As a response to this issue, a novel trauma treatment mode, *viz*., integrated trauma care, has been piloted in a small number of hospitals in China, with the aim of tackling the disadvantages existing in our traditional trauma medical care system. This mode transforms the old system centering on "emergency medicine" to a new one featuring the joint development of "emergency medicine and trauma and surgical care." In addition, the previous "green channels" are now changed to "definitive trauma treatment centers" and the originally adopted "rapid evacuation" is now replaced by "on-site first aid." Through these changes, the success rate of multiple-injury treatment, especially severe multiple-injury treatment, has been remarkably improved (Zhi *et al.*, 2005).

2.4.2 Response capacity of the trauma emergency medical system

The United States was the first country to evaluate its government emergency response capacity, and their evaluation tools have been widely adopted by other countries. Since 2000, multiple studies have been conducted on the evaluation system for urban disaster emergency rescue capabilities in China. The outbreak of severe acute respiratory syndrome in 2003 prompted Chinese researchers to complete a series of studies on the emergency response capacities of hospitals. Currently, emergency rescue capabilities are primarily evaluated using index systems, with the help of mathematical model construction and evaluation index range determination (Jing, 2008). The Academy of Military Science of the Chinese PLA assessed hospitals that had participated in disaster relief work three times using an emergency rescue capability index evaluation system, where the emergency rescue capacity was divided into five aspects, *i.e.*, organization management, response rapidity, rescue techniques, rescue logistics, and survival, with 15 second-level indexes

(Wang, 2010).

(1) Organization management capacity, which can be evaluated from the aspects of training and drilling, emergency plan institution, commanding and decision-making, and department coordination. In a case study, the actually evaluated value of this capacity was on average 21.12% lower than the theoretically optimal value. Moreover, the actually evaluated values of emergency plan institution, commanding and decision-making, and organizational construction were on average 19.87%, 14.47%, and 12.16%, respectively, lower than their corresponding theoretically optimal values.

(2) Rapid response. The actually evaluated values of response rapidity, transport and transfer, in-hospital treatment, personnel quality, knowledge and skills, and professional rescue were on average 15.39%, 23.77%, 18.89%, 21.82%, 22.22%, and 21.54%, respectively, lower than their corresponding theoretically optimal values (Jin *et al.*, 2012).

(3) Rescue techniques. The actually evaluated values of personnel quality, knowledge and skills, and professional rescue were on average 21.82%, 22.22%, and 21.54%, respectively, lower than their corresponding theoretically optimal values.

(4) Rescue logistics. The actually evaluated values of personnel quality, knowledge and skills, and professional rescue were on average 21.82%, 22.22%, and 21.54%, respectively, lower than their corresponding theoretically optimal values.

(5) The actually evaluated values of independent logistics, anti-epidemic protection, and safety camouflage were on average 18.06%, 23.81%, and 24.61%, respectively, lower than their corresponding theoretically optimal values.

Table 2.1. Comparison of the severe acute respiratory syndrome rescue case between actually evaluated values and theoretically optimal values obtained in an evaluation of the PLA No. 309 Hospital.

Index	**Theoretically optimal value**	**Actually evaluated value**	**Difference**	**Difference in percentage (%)**
1 Personnel quality	1.23	1.11	0.12	9.76
2 Response rapidity	1.06	1.01	0.05	4.72
3 Knowledge and skills	0.45	0.4	0.05	11.11
4 Training and drill	0.44	0.39	0.05	11.36
5 Commanding and decision-making	0.33	0.3	0.03	9.09
6 In-hospital treatment	0.24	0.24	0.00	0.00
7 Emergency plan institution	0.22	0.19	0.03	13.64
8 Information and communication	0.18	0.16	0.02	11.11
9 Organizational construction	0.11	0.1	0.01	9.09
10 Professional rescue	0.11	0.09	0.02	18.18
11Anti-epidemic protection	0.04	0.04	0.00	0.00
12 Funding and investment	0.04	0.01	0.00	0.00
13 Medicine reserve	0.01	0.01	0.00	0.00
14 Transport and transfer	0.00	0.00	0.00	0.00
15 Independent logistics	0.00	0.00	0.00	0.00
16 Safety protection	0.00	0.00	0.00	0.00

Table 2.2. Comparison of a forest fire rescue case between actually evaluated values and theoretically optimal values obtained in an evaluation of the PLA No. 304 Hospital.

Index	Theoretically optimal value	Actually evaluated value	Difference	Difference in percentage (%)
1 Personnel quality	2.45	2.45	0.00	0.00
2 Response rapidity	1.64	1.48	0.16	9.76
3 Knowledge and skills	1.55	1.40	0.15	9.68
4 Training and drill	1.09	1.09	0.00	0.00
5 Commanding and decision-making	0.72	0.63	0.09	12.50
6 In-hospital treatment	0.54	0.48	0.06	11.11
7 Emergency plan institution	0.52	0.49	0.03	5.77
8 Information and communication	0.3	0.29	0.01	3.33
9 Organizational construction	0.24	0.22	0.02	8.33
10 Professional rescue	0.21	0.19	0.02	9.52
11 Anti-epidemic protection	0.2	0.04	0.00	10.00
12 Funding and investment	0.18	0.16	0.02	11.11
13 Medicine reserve	0.12	0.11	0.01	8.33
14 Transport and transfer	0.11	0.10	0.01	9.09
15 Independent logistics	0.07	0.06	0.01	14.29
16 Safety protection	0.06	0.05	0.01	16.67

Table 2.3. Comparison of a tsunami relief case between actually evaluated values and theoretically optimal values obtained in an evaluation of the General Hospital of Armed Police.

Index	Theoretically optimal value	Actually evaluated value	Difference	Difference in percentage (%)
1 Response rapidity	1.91	1.91	0.00	0.00
2 Personnel quality	1.42	1.42	0.00	0.00
3 Training and drill	0.90	0.90	0.00	0.00
4 Commanding and decision-making	0.72	0.63	0.09	12.50
5 Information and communication	0.63	0.57	0.06	9.52
6 Knowledge and skills	0.42	0.40	0.02	4.76
7 Emergency plan institution	0.30	0.30	0.00	0.00
8 Organizational construction	0.20	0.18	0.02	4.76
9 In-hospital treatment	0.18	0.17	0.01	5.56
10 Medicine reserve	0.12	0.11	0.01	8.33
11 Professional rescue	0.08	0.07	0.01	12.50
12 Transport and transfer	0.08	0.07	0.01	12.50
13 Funding and investment	0.07	0.06	0.01	14.29
14 Anti-epidemic protection	0.07	0.06	0.01	14.29
15 Safety protection	0.06	0.05	0.01	16.67
16 Independent logistics	0.00	0.00	0.00	16.67

2.5 Discussion

2.5.1 Achievements

(1) A wide variety of emergency plans have been established. In recent years, in order to better adapt to the ever-changing international and domestic situations, multiple functional departments including the Ministry of Health of the People's Republic of China (*i.e.*, the current National Health and Family Planning Commission), the Health Department of the General Logistics Department of the PLA, and the Ministry of Civil Affairs have established or are implementing research on emergency plans for various kinds of disasters or the associated rescue force and policies. After the promulgation of the Management Measures for Disaster Medical Rescue by the Ministry of Health in 1995 and the National Emergency General Public Emergency Contingency Plans by the State Council in 2006, another four specified contingency plans for public health emergencies have been successively issued, *viz*., the National Public Health Emergency Contingency Plan, the National Public Emergency Medical and Health Relief Emergency Plan, the National Contingency Plan for Major Animal Epidemic Emergencies, and the National Emergency Plan for Major Food Safety Accidents.

(2) The national disaster medical system has been implemented. The objective of establishing this system was to promptly mobilize medical rescue resources from various sectors during disasters and emergencies, rapidly replenish the medical rescue reserve force, and promote rapid formation of local medical service systems in the disaster areas, with the ultimate goal of minimizing death and further injuries. Constructing a national disaster medical system involving military, civil, health, and other sectors under the concept of "big rescue" should be considered a strategic task of the government. By referring to the experience of disaster medicine development overseas and the associated framework and mode of disaster medical systems, the overall development of our system should be boosted based on the unique characteristics of the domestic medical system.

(3) More emphasis has been put on fostering the disaster rescue force. Emergency personnel are the pioneers of the disaster rescue team. In developed countries, emergency doctors are usually required to undergo special training and practice with certificates. However, this system has not yet been universally employed in China. Emergency medical personnel are expected to be rigorous, acute, responsible, and unselfish; they should have robust clinical experience, high-level diagnostic and triage skills, familiarity with different kinds of emergency diseases, and expertise in diagnosis and treatment of severe emergencies; they should also master all kinds of emergency treatment techniques such as basic cardiopulmonary resuscitation, tracheotomy, tracheal intubation, and use of respirators as well as regular on-site treatments such as hemostasis, bandaging, fixation, transport, anti-shock treatment, and pain relief. Moreover, the professional emergency personnel involved in the disaster medical service work should possess the knowledge of the basic concepts of disaster medicine, the basic organization of the disaster medical system, and the various treatment principles corresponding to different types of disasters

(nuclear and biochemical disasters in particular). Additionally, other capabilities including administrative management, psychological consultation, and interpersonal coordination are also required. Only with these knowledge and skills sets can the emergency personnel effectively focus on the on-site organizing, command, and rescue in disasters and emergencies, thereby minimizing mortality and disability rates (Chen, 2007).

2.5.2 Limitations

(1) Lack of sound administrative/managerial organizations. Currently, The Ministry of Health and local health bureaus have established systematic coordination mechanisms of health emergency management as well as the emergency commanding and decision-making system. However, when it comes to hospitals that perform specific emergency medical tasks, we recognize the lack of sound, complete, systematic managerial systems and emergency medical teams with high comprehensive qualifications. When a disaster occurs, what normally happens is that under the supervision of the local health bureau, the hospital would temporarily form an emergency lead group that is responsible for giving orders for medical rescue work. Moreover, there is a lack of standardization for establishing emergency forces among hospitals, without unified standards that every hospital can follow. As a result, staff assignments and grouping could also be problematic, which is frequently indicated by indefinite roles within a group, inappropriate allocation of personnel among groups, non-unified doctor-to-nurse ratios, and lack of rules specifying the source departments of appointed personnel. These problems could lead to highly random grouping and an unstable personnel structure, thereby affecting team functions (Gu, 2005).

(2) Lack of sound emergency plans. When hospitals perform emergency relief tasks, close and coordinated cooperation among the medical, nursing, logistical, and administrative departments is required, which should be backed by a set of sound emergency relief plans. In recent years, although a large amount of effort has been made by all levels of hospitals in building and improving public emergency response plans, there is still a long way to go before these plans can be smoothly utilized in practical emergency relief work; their feasibility, operability, and scientificity need to be tested and improved in practice. Different hospitals have made a wide variety of emergency plans without unified naming and classification conventions. They are usually written based on various writing specifications, resulting in non-unified preparedness elements and plan categories. Some of the emergency plans are written by the upper-level health bureaus, featuring inflexibility and poor operability; they fail to take into account the regional characteristics and specific medical tasks. There are also no unified standards on making and revising procedures of emergency plans. Some of them are amended at the beginning of each year or before performing tasks; some are amended annually; some are amended according to the requirements of the higher-level organizations; some are amended every 6 months. In terms of specific revision procedures, some are advocated by the lead group, drafted by assistants, and decided through expert discussion, whereas some are directly revised by assistants.

(3) Lack of well-trained professional teams. Many members of the emergency medical

service teams lack practical experience, showing inadequate comprehensive performance on physical stamina, tactics, and expertise. When participating in disaster medical rescue, many hospitals temporarily appoint medical and nursing staff among physicians, surgeons, and specialists to form an emergency medical relief group according to the type of disaster. As a consequence, there is uncertainty and randomness in the personnel structure of such a group. The group members normally have inadequate systematic and professional disaster relief knowledge and training. The content, time, and approach of their training are not standardized, resulting in unsatisfactory personnel quality. Hence, there is an urgent need for hospitals to build stationary, well-trained, comprehensive teams with professional disaster relief members.

(4) Lack of necessary emergency supply reserves and rescue equipment. Although China does maintain some medicine and equipment reserves, health departments are still not inadequately capable of stocking and rapidly transferring supplies of emergency rescue medicine and equipment. This is especially true for basic-level hospitals, where both emergency supplies per se and their stocking venues are insufficient. Additionally, the associated updating and transfer mechanisms are also not sound. As a result, during major public emergency outbreaks, especially at the beginning of the event, situations with insufficient preparation and hasty response are likely to occur. From the perspective of rescue equipment, some may be excessively heavy, inappropriate for practical needs, or outdated. For instance, many ultrasound devices are not portable and hard to load/unload. Furthermore, some devices do not have dedicated packages, leading to potential damage during transport. In terms of warehouse construction, some hospital warehouses are old and cramped, without dedicated management personnel. There is also a lack of warehouse amenity rules and standards for storing items (Zhang, 2006).

(5) Lack of transportation equipment and communication facilities for batch delivery. When a disaster happens, communication facilities can be severely damaged, causing communication outages. Without effective connections among rescue personnel, medical care quality will be greatly degraded. After the 2008 Wenchuan earthquake, after sending large numbers of communications specialists and devices, the first call reaching outside was successfully made only after 114 hours, undoubtedly affecting the implementation of medical rescue. Hence, governmental departments should make efforts in building emergency communication systems and eliminating communication blind spots during disasters. Informatization is a critical element in the development of modern emergency medicine. In order to improve efficiency of on-site disaster medical treatment, rapid implementation of various emergency medical plans, early medical care, and flexible maneuvering, a set of high-tech digital equipment and intelligent commanding and decision-making platforms should be in place. Their roles in rapid maneuvering, patient classification for evacuation, commanding of emergency medical organization, and remote medical consultation will help realize our goals of miniaturization, intellectualization, and automation, satisfying the needs of establishing hospital emergency medical care in the new era. In China, a country with frequent natural disasters and limited transportation and communication networks, equipment miniaturization and informatization are rigorously

critical; this also means that some heavy equipment is not appropriate for emergency relief tasks in disaster-affected areas.

(6) Development of air rescue is limited. Many developed countries have long established air ambulance services. For example, Switzerland, France, the former Soviet Union, and Germany built their air rescue organizations in 1952, 1963, 1982, and 1982, respectively. The first air rescue team near the U.S. western coast was formed at the Legacy Emanuel Medical Center of Portland, Oregon, in 1978. Owing to the mountain and forest topology in Oregon, air rescue has proved to be greatly superior. If an accident occurs at any spot in northern Oregon, a rescue aircraft can reach the scene within 30 minutes. Helicopters are normally used in air rescue, owing to their convenience with respect to taking off/landing and flexible maneuvering. With a flight radius of 250 km, a rescue helicopter can transport injured patients to a hospital within 2 hours. Owing to the limitations of economic development, air rescue cannot yet be popularized in China. In the past, civil or military aircrafts would participate in rescue only under special conditions, such as the 1976 Tangshan earthquake and 1984 self-defensive counterattack against Vietnam. Currently, major Chinese cities have reached the point of further development in air rescue. However, considering weather, time of day or night, and landing restrictions, as well as the high use and maintenance costs, universal large-scale deployment of air rescue in China is not expected in the near future.

(7) Currently, profound research on the evaluation and creation of emergency medical rescue capabilities is inadequate in China. Most of the existing studies have focused on the system/mechanism management of earthquake disasters and public health emergencies, without detailed classification of subfields. Moreover, these studies were primarily conducted at the governmental level, whereas research on emergency response capabilities of hospitals and the corresponding evaluation systems are not seen much in the literature; the few existing publications examining hospital emergency capacity are basically specific reports lacking generality that are based on personal or institutional experience. There is also no index system for evaluating a hospital’s comprehensive emergency response capacity that is built based on scientific research and the current situations of China in the literature, let alone the objective assessment tools and the associated plans serving this purpose.

References

Adams, V.I.; Carrubba, C. The abbreviated injury scale: application to autopsy data. *American Journal of Forensic Medicine & Pathology* **1998**, *19*, 246–251.

Baker, S.P.; O’neill, B.; Haddon, W.; *et al.* The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *Journal of Trauma* **1974**, *14*, 187–196.

Champion, H.R.; Sacco, W.J.; Copes, W.S.; *et al.* A revision of the Trauma Score. *Journal of Trauma* **1989**, *29*, 623.

Chen, H. *Study on the Construction of Emergency Medical Rescue Ability in Hospital*; The Army Military Medical Science Academy of the PLA: Beijing, China, 2007.

Chen, T. Thoughts on strengthening the research of trauma medicine. *Chinese Journal of Traumatology* **1999**, *15*, 1–2.

Gu, L. Earthquake disaster prevention and emergency management in Japan. *Knowledge Is Power* **2005**, 14–17.

Hu, W.; Li, Y. Conception of establishing the regional emergency medical system of disaster medicine. *Western Medicine* **2010**, *22*, 393–395.

Huang, Z. Damage control: new advances in surgery. *Chinese Journal of Emergency Medicine* **2011**, *20*, 677–679.

Jin, Q.; Xu, J.; Xu, B.; *et al.* Present situation and analysis of the construction of chinese health emergency system. *China Medical Guide* **2012**, 357–359.

Jing, S. *Study on Evaluation Index System of Urban Public Health Emergency Response Capacity*; Suzhou University: Suzhou, China, 2008.

Li, J. Practice and enlightenment of medical rescue in earthquake relief in Wenchuan. *PLA Hospital Management Journal* **2008**, 15.

Shen, J.; Su, L.; Li, B.; *et al.* Effectiveness analysis of health emergency rescue in Wenchuan earthquake in sichuan province. *Chinese Journal of Evidence-based Medicine* **2009**, *9*, 301–306.

Shi, Y.; Zhou, Z.; Chen, W.; *et al.* Assumption and implementation of the establishment of "the trauma database of the Chinese people". The Eighth National Conference on Wound Academic Exchange, 2001.

Tan, Z. Hospital trauma score system and its application in China. *Chinese Journal of Practical Surger* **1996**, 760–762.

Wang, H. *Evaluation of Disaster Medical Rescue Ability of Field Medical Station in Military Hospital*; Third Military Medical University: Chongqing, China, 2010.

Xin, D. Discussion on emergency treatment of trauma. *Clinical Research in China* **2006**, *19*,153–154.

Zhang, H. *Evaluation of Public Health Emergency Response Ability in Hospitals in Beijing City*; Peking Union Medical College: Beijing, China, 2006.

Zhang, L. Multidisciplinary team model in the first aid of severe trauma. *Chinese Journal of Traumatology* **2011**, *27*, 385–387.

Zhang, L.; Liu, X.; Li, Y.; *et al.* Emergency medical rescue efforts after a major earthquake: lessons from the 2008 Wenchuan earthquake. *Lancet* **2012**, *379*, 853–861.

Zhang, Y. Organization and implementation of medical rescue for mass casualty in earthquake disaster. *Medical Journal of the People's Liberation Army* **2012**, *37*, 1–5.

Zhi, S.; Zhangmin, L.; Lunxian, T.; *et al.* Superiority of integrated trauma emergency mode in emergency treatment of sudden disaster. *Chinese Journal of Emergency Medicine* **2005**, *14*, 549–551.

Zhou, J.; Qiu, J.; Wang, S. Summary of the third national conference on traffic tnjury and trauma database. *Chinese Journal of Traumatology* **2010**, *26*, 657–658.

Zhou, J.; Yin, Z.; Zhu, P. Research and development of computer trauma scoring software and trauma case database. *Chinese Journal of Traumatology* **1998**, *14*, 142.

Zhou, Y.; Wang, Z.; Wang, X.; *et al*. Comparison of scoring method of injury severity score and improvement of trauma severity in 1016 cases. *Chinese Journal of Traumatology* **1999**, *15*, 386–387.

Zhu, P. To further promote the development of china's trauma score. *Chinese Journal of Traumatology* **1998**, *14*, 131–134.

Chapter 3 Basic data for investigation on trauma occurrence and evolution

Wenya Yu[1]*, Zhifeng Zhang*[2] *and Lulu Zhang*[1]

[1] *Department of Military Health Service Management, College of Military Health Service Management, Second Military Medical University, Shanghai 200433, China*

[2] *Division of Medical Administration and Medical Service Regulation, Shanghai Municipal Commission of Health and Family Planning, Shanghai 200125, China*

3.1 Design and implementation of the investigation

3.1.1 Design of a trauma database

Although Taiwan has established the Taiwan Trauma Registry System, which provides a good foundation and platform for trauma research and development (Qiu *et al.*, 2014), mainland China has yet to establish a large-scale trauma database that meets national standards (Yao, 2006; Zen *et al.*, 2010). It was only in the late 1980s that China began its efforts in building and developing Chinese trauma databases. However, these have always been regional or single-type trauma databases. In the mid-1990s, West China University of Medical Sciences was the first to establish the "West China Severe Trauma Database". The Third Military Medical University and Chongqing Emergency Medical Center developed the "Chongqing Traffic Injury Database", "Eye Trauma Database", and "Trauma Database". The Lanzhou Tiexi Hospital established a regional "Railway and Road Injury Database" (Qiu *et al.*, 2014; Liang *et al.*, 2005; Zhou, 2012). Zhongshan Emergency Center established the Zhongshan Trauma Database (Ning *et al.*, 2014). The First People's Hospital Affiliated with Shanghai Jiao Tong University created a pelvic trauma clinical database (Wang *et al.*, 2012; Wang *et al.*, 2011). Sichuan Zigong Emergency Center custom designed and developed a prehospital emergency trauma database for trauma casualties (Liu *et al.*, 2012). In 2000, West China Hospital, Third Military Medical University Research Institute of Traffic Medicine, and Chongqing Medical Emergency Center jointly launched the "Chinese Trauma Database" project (Qiu *et al.*, 2014; Liang *et al.*, 2005; Zhou, 2012). However, this database still contains only regional trauma information, and has not been instituted on a national level, as it does not include different regions nationwide and different grades of hospitals and trauma centers, and does not contain records of nationally representative trauma data.

Considering that the trauma databases in China are currently regional databases, the information recorded tends to be unrepresentative. In the years since its establishment, the NTDB has refined and perfected its system. Its scientific and rational database framework was the result of many years of practical testing. The NTDB has become the standard and norm for database construction and maintenance systems. Therefore, the research group based the design of the trauma database framework on the NTDB, and made suitable adjustments in accordance with specific national conditions in China.

3.1.2 Pre-investigation

Before the formal collection of trauma data, the research group performed a preliminary survey on the trauma patients of a tertiary hospital in Shanghai. By collecting the medical records of these patients and recording their data based on the pre-designed database framework, it was possible to verify the practicality of the database framework and the feasibility of data collection. A total of 834 entries of trauma data were recorded in the preliminary survey. Based on these data, the research group modified a few unreasonable items in the trauma database and added items that were more in line with the medical recording habits of trauma centers in China. In summary, the pre-design trauma database framework was found to have good applicability, allowed the convenient entry of trauma patient information, and was highly compatible with one of the most well-developed databases in the world–the NTDB. However, modifications were also made based on the specific national conditions in China. Therefore, this survey had good feasibility, with a scientific and rational framework design and research ideas.

3.1.3 Investigation implementation

Based on the results of sample size estimation, basic profile analysis of Shanghai regional trauma centers, and the survey subjects selected, the research group implemented a survey designed according to the database framework. Data were collected from January 2011 to January 2015, and the main sources were the medical records of individual hospitals and trauma centers. The medical records of each patient were examined according to trauma type using medical record retrieval systems, and the records of trauma patients who met the inclusion criteria were exported. All patients who were enrolled were informed of the research objectives prior to hospital admission and provided written consent. Patients' complete medical history was obtained by the research group after discharge. After obtaining the original medical records, the research group members collated each set of trauma data according to the database framework, and entered the information based on the standards of database building.

After data entry was completed, the data entries were inspected and records that did not meet the inclusion criteria for trauma were deleted. Data entries with large amounts of missing information were also deleted. After the second data inspection and collation, the research group members determined the methods of data analysis, data mining planning and data processing software based on the data characteristics.

3.2 Basic data for the investigation

3.2.1 Target of the investigation

Based on the research design framework, the survey area was delineated as Shanghai, China. The survey subjects included 3 tertiary hospitals in Shanghai (CHH, CZ, SY), and 4 trauma centers (burn trauma emergency center, bone trauma emergency center, trauma emergency center, and trauma emergency center & emergency critical care unit). The data collection period was between January 2011 and January 2015.

The trauma data of survey subjects that met the inclusion criteria were appropriate for recording in the trauma database. Inclusion criteria: (1) Meeting the definition of trauma, *i.e.*, "Trauma is the tissue or organ damage caused by mechanical factors applied to the human body"; (2) Trauma was limited to injuries resulting from six causes, *i.e.*, traffic injuries, high-level fall injuries, machinery-related injuries, sharp-instrument injuries, ground-level fall injuries, and firearm injuries; and (3) Collection of medical data was screened using the ICD-10, which included 136 major categories of 400 disease types with diagnosis codes S00.001 to T35.701.

3.2.2 Content of the investigation

Survey content was based on the NTDB 2015 Annual Report (American College of Surgeons), which comprised 6 dimensions, including facility information, demographic information, injury characteristics, outcome information, regional analysis, and comparative analysis. Among these dimensions, facility information included 8 items: bed size, trauma level, region, Length of Stay (LOS), isolated hip fracture, death on arrival, transfer in and transfer out. Demographic information included 5 items: age, gender, alcohol abuse, drug abuse, and primary payment source. Injury characteristics included 12 items: mechanism of injury, trauma incidence, fatality rate, trauma severity score, work-related injuries, injury intent, location e-code, body region, and protective devices. Outcome information included 12 items: prehospital time and mechanism of injury, prehospital time and ISS, LOS and ISS, ventilator days and mechanism of injury, Intensive Care Unit (ICU) days and mechanism of injury, ICU days and ISS, Emergency Department (ED) discharge disposition, vital signs, discharge disposition, and hospital complications. Regional analysis included 6 items: analysis of regional trauma incidence, analysis of regional fatality rate, analysis of regional mechanism of injury, analysis of regional ISS, rural trauma incidence and fatality rate, rural mechanism of injury and rural ISS. Comparative analysis included 25 items: number of cases, fatality rate, percentage of patients with ISS ≥ 16, data completeness and number of complications per facility for Level I, Level II, Level III, and Level IV facilities.

By combining the factors above with China's national conditions, this research group used 3 dimensions from the NTDB (demographic information, injury characteristics, and outcome information) to design the database framework. However, some of the items were adjusted based on the current socioeconomic status of Shanghai, China. As the research area was limited to Shanghai in this study, the regional analysis in the NTDB was not included in the database framework. As all hospitals in this survey had the same rate, comparative analysis was also not included in the database framework. The final survey content included 5 dimensions with 21 indicators:

1. Demographic information: Gender, age, and marital status;
2. Injury characteristics: Injured body region, injury condition, mechanism of injury,

Glasgow Coma Scale (GCS) score, AIS, ISS;
3. Treatment information: Admission pathway, prehospital time, LOS, outcome, complication;
4. Comorbidity: Diabetes, hypertension, osteoporosis;
5. Facility information: Hospital rating, trauma center size, number of beds, number of medical personnel.

3.2.3 Sample size of the investigation

A total of 9,976 preliminary medical records were collected in this survey. After eliminating entries that did not meet the inclusion criteria and those with large amounts of missing information, the final number of trauma entries included in the database was 8,273. Among these, there were 6,385 entries of single injury (77.18%) and 1,888 entries of multiple injuries (22.82%).

3.3 Investigation results

3.3.1 Demographic characteristics

(1) Gender

Among the trauma patients in this survey, there were more men than women for both single and multiple injuries. This statistical result indicates that compared with women, men are a high-risk group for trauma, and awareness of strategies for trauma prevention should be strengthened in this group.

Table 3.1. Gender.

Injury	Male	Female
Single injury	3441(53.9)	2944(46.1)
Multiple injuries	1293(68.5)	595(31.5)
Total	4734(57.2)	3539(42.7)

(2) Age

The statistical results indicate that in terms of the overall survey population, the probability of trauma increased with age. This indicates that the elderly is a high-risk group for trauma. In terms of patients with single injuries, the incidence of trauma increased with age as well, a trend was consistent with that of the overall population. However, among patients with multiple injuries, the incidence of trauma was highest among those aged 55–64 years and the 45–54-year-old middle-aged population, whereas the incidence of multiple injuries for the elderly (≥65 years) was significantly lower than that for single injuries.

Table 3.2. Age.

Injury	0–14 y	15–24 y	25–34 y	35–44 y	45–54 y	55–64 y	≥65 y
Single injury	94(1.5)	371(5.8)	524(8.2)	721(11.3)	1,091(17.1)	1,479(23.2)	2,105(33.0)
Multiple injuries	27(1.4)	142(7.5)	231(12.2)	300(15.9)	412(21.8)	418(22.1)	358(19.0)
Total	121(1.5)	513(6.2)	755(9.1)	1,021(12.3)	1,503(18.2)	1,897(22.9)	2,463 29.8)

(3) Marital status

Among the surveyed trauma patients, married individuals constituted the highest proportion of patients. However, the probability of single injuries among divorced or widowed individuals was higher, whereas the probability of multiple injuries was very low.

Table 3.3. Marital status.

Injury	Divorced/widowed	Single	Married
Single injury	1,038(16.3)	1,275(20.0)	4,072(63.8)
Multiple injuries	4(0.2)	290(15.4)	1,594(84.4)
Total	1,042(12.6)	1,565(18.9)	5,666(68.5)

3.3.2 Injury characteristics

(1) Injured body region

The survey of single-injury patients found that the majority had injuries on the extremities, followed by the head and spine. The number of single-injury patients with injuries on the thorax, pelvis, and abdomen was relatively low. Analysis of the survey results among multiple-injury patients indicated that the head was the most commonly injured region, followed by the thorax, upper extremities, lower extremities, and spine. These 5 regions were the main sites for multiple-injury patients. Compared with these 5 high-incident body regions, abdominal and pelvic injuries were not common among multiple-injury patients.

Table 3.4. Injured body region (single injury).

N (%)	Head	Thorax	Abdomen	Spine	Pelvis	Extremity
Single injury	1,166(18.2)	201(3.1)	48(0.8)	618(9.7)	100(1.6)	4,252(66.6)

Table 3.5. Injured body region (multiple injuries).

N (%)	Head	Thorax	Abdomen	Upper extremity	Lower extremity	Spine	Pelvis
Multiple injuries	1,108(58.7)	944(50.0)	275(14.6)	873(46.2)	799(42.3)	664(35.2)	303(16.0)

(2) Injury condition

According to the statistical results for injury condition, for single-injury, multiple-injuries, and all patients, the number of individuals with Fracture and Joint Injuries (FJI) was the highest, followed by Skin and Soft Tissue Injuries (SSTI), and Central Nervous system injuries (CNSI). In addition, among single-injury patients, the injuries were also mainly from these 3 categories. Among multiple-injury patients, there were also relatively high incidences of Pulmonary Contusion (PC) and Traumatic Hemopneumothorax (TH). As for the overall population, in addition to the 3 main categories of injury conditions above, PC and TH also showed relatively high incidences.

Table 3.6. Injury condition.

Injury	FJI	SSTI	DT*	CNSI	PC	TH	TOI*
Single injury	5,297(83.0)	1,843(28.9)	69(1.1)	953(14.9)	113(1.8)	61(1.0)	40(0.6)
Multiple injuries	1,740(92.2)	1,245(65.9)	40(2.1)	656(34.7)	504(26.7)	262(13.9)	166(8.8)
Total	7,037(85.1)	3,088(37.3)	109(1.3)	1,609(19.4)	617(7.5)	323(3.9)	206(2.5)

*DT = Destruction; TOI = Traumatic Organ Injuries.

(3) Mechanism of injury

There were differences in the composition of the mechanism of injury under different circumstances. Among single-injury patients, the majority of injuries were ground-level falls, followed by traffic injuries, and a small proportion of patients experienced high-level falls and sharp-instrument injuries. Among multiple-injury patients, traffic injuries were the most common, followed by high-level falls and ground-level falls. In terms of the overall population, ground-level falls were the most common mechanism of injury, followed by traffic injuries, high-level falls, machinery-related injuries, and sharp-instrument injuries. However, under all circumstances, firearm injuries were rare in China, and this was not a common mechanism of injury among Chinese patients.

Table 3.7. Mechanism of Injury.

Injury	Firearm	Ground-level fall	Sharp-instrument	Machinery-related	High-level fall	Traffic
Single injury	11(0.2)	4,063(63.6)	144(2.3)	399(6.2)	344(5.4)	1,424(22.3)
Multiple injuries	4(0.2)	363(19.2)	46(2.4)	122(6.5)	380(20.1)	973(51.5)
Total	15(0.2)	4,426(53.5)	190(2.3)	521(6.3)	724(8.8)	2,397(29.0)

(4) Mechanism of injury and injured body region

Analysis of the mechanism of injury and injured body region among single injuries indicated that although different mechanisms of injury displayed similar trends in injured body regions, there were differences in the injured body region with the highest incidence for each mechanism. High-incident body regions for ground-level falls, machinery-related injuries, and traffic injuries were the extremities, head, and spine. Firearm injuries occurred mainly in the head and extremities. Sharp-instrument injuries were mainly observed in the extremities, head, and thorax. The most common body regions for high-level falls were the spine, extremities, and head.

Analysis of the mechanism of injury and injured body region among multiple injuries indicated that there were differences in the injured body region with the highest incidence for each mechanism, and the injury characteristics were different from those of single injuries. The most common body regions for firearm injuries were the upper extremities, head, and thorax. High-incident body regions for ground-level falls were the upper extremities, lower extremities, and head. Sharp-instrument injuries were mainly observed in the thorax, upper extremities, and lower extremities. High-incident regions for machinery-related injuries were the thorax, spine, and lower extremities. The most common regions for high-level falls were the spine, head, and chest. The most common regions for traffic injuries were the head, thorax, and upper extremities.

Table 3.8. Mechanism of injury and body region (single injury).

Mechanism of injury	Head	Thorax	Abdomen	Spine	Pelvis	Extremity
Firearm injury	9(81.8)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	2(18.2)
Ground-level fall injury	444(10.9)	126(3.1)	11(0.3)	316(7.8)	43(1.1)	3,123(76.9)
Sharp-instrument injury	52(36.1)	20(13.9)	14(9.7)	0(0.0)	2(1.4)	56(38.9)
Machinery-related injury	106(26.6)	2(0.5)	2(0.5)	28(7.0)	3(0.8)	258(64.7)
High-level fall injury	80(23.3)	11(3.2)	4(1.2)	127(36.9)	9(2.6)	113(32.8)
Traffic injury	475(33.4)	42(2.9)	17(1.2)	147(10.3)	43(3.0)	700(49.2)

Table 3.9. Mechanism of Injury and Body Region (multiple injuries).

Mechanism of injury	Head	Thorax	Abdomen	Upper extremity	Lower extremity	Spine	Pelvis
Firearm injury	3(75.0)	3(75.0)	1(25.0)	4(100.0)	0(0.0)	0(0.0)	0(0.0)
Ground-level fall injury	150(41.3)	107(29.5)	16(4.4)	218(60.1)	186(51.2)	89(24.5)	18(5.0)
Sharp-instrument injury	17(37.0)	32(69.6)	18(39.1)	26(56.5)	19(41.3)	3(6.5)	2(4.3)
Machinery-related injury	50(41.0)	66(54.1)	25(20.5)	40(32.8)	60(49.2)	61(50.0)	33(27.0)
High-level fall injury	211(55.5)	211(55.5)	46(12.1)	163(42.9)	130(34.2)	235(61.8)	87(22.9)
Traffic injury	677(69.6)	525(54.0)	169(17.4)	422(43.4)	414(42.5)	276(28.4)	163(16.8)

(5) Mechanism of injury and injury condition

Analysis of the mechanism of injury and injury condition among single injuries indicated that although the common injury conditions showed similar trends among different mechanisms of injury, there were differences in the composition of injury conditions among the different mechanisms. Patients with ground-level and high-level falls and traffic injuries were prone to FJI, SSTI, and CNSI. Patients with firearm injuries were prone to SSTI, FJI, and CNSI. SSTI were most common among patients with sharp-instrument injuries, followed by FJI, and TH. Patients with machinery-related injuries were prone to SSTI, FJI, and DT.

Analysis of the mechanism of injury and injury condition among multiple injuries indicated that there were differences in the composition of injury conditions among the different mechanisms, which differed slightly from those of single injuries. Patients with ground-level and high-level falls and traffic injuries were more prone to FJI, SSTI, and CNSI. Patients with firearm injuries were prone to SSTI, FJI, DT, and TOI. Patients with sharp-instrument injuries were more prone to SSTI, FJI, and TH. Patients with machinery-related injuries were prone to FJI, SSTI, and PC.

Table 3.10. Mechanism of injury and injury condition (single injury).

Mechanism of injury	FJI	SSTI	DT	CNSI	PC	TH	TOI
Firearm injury	3(27.3)	11(100.0)	0(0.0)	2(18.2)	0(0.0)	0(0.0)	0(0.0)
Ground-level fall injury	3,658(90.0)	576(14.2)	0(0.0)	379(9.3)	8(0.2)	32(0.8)	10(0.2)
Sharp-instrument injury	15(10.4)	137(95.1)	0(0.0)	4(2.8)	1(0.7)	13(9.0)	7(4.9)
Machinery-related injury	254(63.7)	270(67.7)	40(10.0)	33(8.3)	8(2.0)	1(0.3)	2(0.5)
High-level fall injury	297(86.3)	111(32.3)	0(0.0)	94(27.3)	27(7.8)	10(2.9)	3(0.9)
Traffic injury	1,070(75.1)	738(51.8)	29(2.0)	441(31.0)	113(7.9)	61(4.3)	18(1.3)

Table 3.11. Mechanism of injury and injury condition (multiple injuries).

Mechanism of injury	FJI	SSTI	DT	CNSI	PC	TH	TOI
Firearm injury	312(75.0)	4(100.0)	1(25.0)	0(0.0)	0(0.0)	0(0.0)	1(25.0)
Ground-level fall injury	339(93.4)	143(39.4)	0(0.0)	71(19.6)	34(9.4)	11(3.0)	10(2.8)
Sharp-instrument injury	13(28.3)	44(95.7)	1(2.2)	0(0.0)	4(8.7)	12(26.1)	11(23.9)
Machinery-related injury	115(94.3)	88(72.1)	14(11.5)	24(19.7)	36(29.5)	22(18.0)	9(7.4)
High-level fall injury	366(96.3)	237(62.4)	3(0.8)	142(37.4)	138(36.3)	83(21.8)	31(8.2)
Traffic injury	904(92.9)	729(74.9)	21(2.2)	419(43.1)	292(30.0)	134(13.8)	104(10.7)

(6) GCS score

This survey found that very few patients had GCS scores, and approximately 95% of patients were not graded using the GCS. According to the statistical results for GCS scores, among patients who were graded using the GCS, the highest proportion received scores of 3–8 points. This indicates that the majority of trauma patients with Disturbance of Consciousness (DC) were in a more severe condition, and were already in a state of unconsciousness. Among single-injury patients, those who were conscious and had no DC accounted for a larger percentage, but some patients still had mild to moderate DC. The GCS scores among multiple-injury patients differed from those of patients with single injuries. The multiple-injury patients had more severe injuries. In addition to patients in a severe coma, who accounted for the highest percentage, a fairly large number of patients had moderate DC. In terms of the overall population, patients with severe coma accounted for the highest percentage, followed by patients with no DC and moderate DC.

Table 3.12. GCS scores.

Injury	< 3	3–8	9–12	13–14	15	NA
Single injury	15(0.2)	103(1.6)	32(0.5)	34(0.5)	76(1.2)	6,125(95.9)
Multiple injuries	7(0.4)	62(3.3)	28(1.5)	9(0.5)	14(0.7)	1,768(93.6)
Total	22(0.3)	165(2.0)	60(0.7)	43(0.5)	90(1.1)	7,893(95.4)

(7) AIS

According to the statistical results of AIS, the majority of single-injury patients had serious and moderate injuries and a small proportion had minor injuries, while very few patients had severe or critical injuries. These results indicate that the condition of single-injury patients was generally more stable and rarely critical.

Table 3.13. AIS.

Injury	1	2	3	4	5	6
Single injury	469(7.3)	2,650(41.5)	3,009(47.1)	135(2.1)	115(1.8)	7(0.1)

(8) ISS

The ISS of multiple-injury patients was evenly distributed, but most patients had moderate injuries, followed by severe and critical injuries, whereas the number of patients with minor injuries was very small. These statistical results indicate that multiple-injury patients tended to have more serious injuries.

Table 3.14. ISS.

N (%)	1–8	9–15	16–24	⩾25
Multiple injuries	308(16.3)	637(33.7)	510(27.0)	433(22.9)

3.3.3 Treatment

(1) Admission pathway

The majority of trauma patients in this survey were directly admitted to the medical facilities via the ED. However, there were slight differences in the distribution of Referral from Hospitals in Other Cities (RHOC) and in Shanghai for single- and multiple-injury patients. Among single-injury patients, there were slightly more Referrals from Hospitals in Shanghai (RHS) than RHOC. In contrast, for multiple-injury patients, there were slightly more RHOC than RHS. However, in the overall population, there were more RHS.

Table 3.15. Admission pathway.

Injury	RHOC	RHS	EDA
Single injury	1,038(16.3)	1,275(20.0)	4,072(63.7)
Multiple injuries	528(28.0)	441(23.4)	919(48.7)
Total	1,566(18.9)	1,716(20.7)	4,991(60.3)

EDA = Emergency Department Admission.

(2) Prehospital time and mechanism of injury

Using hours (h) as the unit for the average prehospital time: The statistical results for the relationship of the prehospital time with the mechanism of injury showed that aside from sharp-instrument injuries, the average prehospital time for single-injury patients was shorter than that for multiple-injury patients. Comparison of the average prehospital time for different mechanisms of injury showed that among single-injury patients, sharp-instrument injuries had the shortest average prehospital time, followed by firearm and machinery-related injuries, while high-level falls had the longest. Among multiple-injury patients, sharp-instrument injuries had the shortest average prehospital time as well, followed by traffic injuries and ground-level falls, while firearm injuries had the longest average prehospital time, which was 3 times that of single-injury patients.

Using days as the unit for the average prehospital time: The statistical results for the relationship of this time with the mechanism of injury showed that there were significant differences in the average prehospital time for different mechanisms for both single-injury and multiple-injury patients. ground-level falls had the shortest average prehospital time among single-injury patients, while sharp-instrument injuries had the shortest average prehospital time among multiple-injury patients. Firearm injuries had the longest average prehospital time among single-injury patients, while traffic injuries had the longest among multiple-injury patients. Single-injury patients had shorter average prehospital time than multiple-injury patients for ground-level falls, high-level falls, and traffic injuries. Multiple-injury patients had shorter average prehospital time than single-injury patients for firearm, sharp-instrument, and machinery-related injuries.

Table 3.16. Average prehospital time (hour) and mechanism of injury.

Injury	Firearm	Ground-level fall	Sharp-instrument	Machinery-related	High-level fall	Traffic-related
Single injury	5	6.92	4.61	5.91	7.85	6.8
Multiple injuries	15	7.35	4.58	9.6	8.22	7.17

Table 3.17. Average prehospital time (day) and mechanism of injury.

Injury	Firearm	Ground-level fall	Penetrating	Machinery-related	High-level falls	Traffic-related
Single injury	28	6.69	8.85	13.42	7.43	9.83
Multiple injuries	8.72	8.71	3.81	9.44	9.43	11.24

(3) Average prehospital time and admission pathway

Regardless of whether days or hours was used as the unit of the average prehospital time, the shortest average prehospital time for both single- and multiple-injury patients resulted from direct EDA, followed by RHS, and the longest was associated with RHOC.

Table 3.18. Average prehospital time (hour) and admission pathway.

Injury	RHOC	RHS	EDA
Single injury	15.79	10.55	5.65
Multiple injuries	17.65	10.09	5.56

Table 3.19. Average prehospital time (day) and admission pathway.

Injury	RHOC	RHS	EDA
Single injury	9.29	7.56	5.86
Multiple injuries	12.49	8.37	4.34

(4) LOS

Patients with different injuries showed slight differences in LOS. Among single-injury patients, the LOS of most patients was 8–14 days, followed by 4–7 days and 15–30 days; there were very few patients with LOS ≤ 3 days or more than 1 month. The LOS of multiple-injury patients was slightly longer than that of single-injury patients. The number of patients with LOS of 15–30 days was the highest, followed by 8–14 days and 4–7 days, while a relatively high number stayed for more than 1 month. In the overall population, the LOS of the majority of patients was concentrated around 8–14 days, 4–7 days, and 15–30 days, whereas a very small number of patients stayed ≤ 3 days or more than 1 month.

Table 3.20. LOS.

Injury	0–3 d	4–7 d	8–14 d	15–30 d	≥31 d
Single injury	563(8.8)	1,829(28.6)	2,249(35.2)	1,440(22.6)	304(4.8)
Multiple injuries	93(4.9)	316(16.7)	545(28.9)	635(33.6)	299(15.8)
Total	656(7.9)	2,145(25.9)	2,794(33.8)	2,075(25.1)	603(7.3)

(5) Outcome

According to the statistical results for outcomes, the majority of trauma patients were cured at the time of discharge, but a large proportion had improved at the time of discharge and needed further recovery. The numbers of ineffective treatments and mortalities were relatively low, but the mortality rate for multiple-injury patients was higher than that for single-injury patients. Among single-injury patients, the mortality rate was 1.6%; among multiple-injury patients, the mortality rate was 2.0%; and among the overall population, the mortality rate of trauma patients was 1.7%.

Table 3.21. Outcome.

Injury	Dead	Invalid	Improved	Cured
Single injury	99(1.6)	279(4.4)	1,449(22.7)	4,558(71.4)
Multiple injuries	38(2.0)	60(3.2)	727(38.5)	1,063(56.3)
Total	137(1.7)	339(4.1)	2,176(26.3)	5,621(67.9)

(6) Hospital complications

Among the trauma patients in this study, 14 types of complications were involved, including Hemorrhagic Shock (HS), DC, apnea, Cardiac Arrest (CA), Cerebral Hernia (CH), paraplegia, Ardent Fever (AF), Water and Electrolyte Disturbance (WED), Acid-Base Imbalance (ABI), Acute Respiratory Distress Syndrome (ARDS), Acute Renal Failure (ARF), Multiple Organ Dysfunction Syndrome (MODS), Multiple Organ Failure (MOF), and Bacterial Infection (BI). Among the surveyed patients, nearly one-third presented with complications, and the 3 complications with the highest incidences were DC, BI, and paraplegia.

Table 3.22-1. Hospital complications.

Injury	HS	DC	Apnea	CA	CH	Paraplegia	AF
Single injury	61(1.0)	685(10.7)	7(0.1)	6(0.1)	19(0.3)	137(2.1)	16(0.3)
Multiple injuries	151(8.0)	592(31.4)	12(0.6)	12(0.6)	5(0.3)	155(8.2)	26(1.4)
Total	212(2.6)	1,277(15.4)	19(0.2)	18(0.2)	24(0.3)	292(3.5)	42(0.5)

Table 3.22-2. Hospital Complications (continued).

Injury	WED	ABI	ARDS	ARF	MODS	MOF	BI
Single injury	28(0.4)	4(0.1)	1(0.1)	24(0.4)	3(0.1)	28(0.4)	156(2.4)
Multiple injuries	53(2.8)	17(0.9)	8(0.4)	27(1.4)	39(2.1)	0(0.0)	233(11.8)
Total	81(1.0)	21(0.3)	9(0.1)	51(0.6)	42(0.5)	28(0.3)	389(4.7)

3.3.4 Comorbidities

The comorbidities in this survey mainly included diabetes, hypertension, and osteoporosis. Among the patients surveyed, approximately one-third had comorbidities. Of these, the number of patients with hypertension was the highest, followed by diabetes, with osteoporosis the least common.

Table 3.23. Comorbidities.

Injury	Diabetes	Hypertension	Osteoporosis
Single injury	507(7.9)	1,009(15.8)	48(0.8)
Multiple injuries	120(6.4)	218(11.5)	0(0.0)
Total	627(7.6)	1,227(14.8)	48(0.6)

3.3.5 Medical institution information

(1) Hospital rating and trauma center size

The three public hospitals surveyed in Shanghai were all tertiary A hospitals. These three hospitals are the most advanced hospitals in Shanghai, with high medical standards, operational capacity, and social reputations. (1) CHH hospital has 57 departments, and is currently the largest single hospital in Shanghai. In 2015, the hospital ED admitted more than 3.5 million outpatients, admitted over 464,000 emergency patients, discharged 96,000 patients, and completed over 53,000 surgeries. CHH hospital participated in the emergency response to numerous Mass Casualty Incidents (MCIs), including the “11.15” Shanghai Fire, the “6.22” Shanghai Shooting, the “6.24” Shanghai chemical plant explosion, the “8.31” Shanghai liquid ammonia leak, and the “8.2” Kunshan factory explosion. (2) CZ Hospital currently has 47 departments, including 35 clinical departments and 12 ancillary departments. This hospital specializes in 6 fields: orthopedics, neurosurgery, nephrology, urology, plastic surgery, and emergency medicine. It has advanced network information systems and remote consultation centers, forming a three-dimensional (prehospital emergency–in-hospital emergency–ICU ward) and wartime emergency response system. It has the capacity for 24-hour treatment of mass casualties. (3) SY hospital became one of the first tertiary A hospitals in 1993. This hospital has 3 national key clinical specialties, 1 Shanghai priority key clinical specialty, 2 Shanghai clinical medical centers, 1 Shanghai nursing quality control center, 1 Shanghai bone cancer institute, and 1 Shanghai stroke prevention center. The 4 trauma centers surveyed included a burn trauma emergency center, a bone trauma emergency center, a trauma emergency center, and a trauma emergency center & emergency critical care unit. These four centers have unique characteristics in different fields of trauma emergency treatment. (1) The burn trauma emergency center was founded by the Shanghai Health and Family Planning Commission in 2011. It is currently a comprehensive, large-scale, fully equipped burn center that combines medicine, teaching, and research. It is a leader in the global standards for the treatment of large-area deep burn wounds. It has also obtained numerous successes in saving critically wounded patients from MCIs (e.g., Kunshan explosion incident), and is highly praised by the government and the people. (2) The bone trauma emergency center is involved in the treatment of complex trauma. It has achieved high national standards for the surgical treatment of complex pelvic and acetabular fractures, minimally invasive treatment of limb fractures, control of severe traumatic injuries, surgical treatment of nonunions, treatment of war wounds, and repair of spinal cord injury. This trauma center was responsible for important medical security and medical treatment tasks during the Wenchuan Earthquake, World’s Fair, military exercises, and public emergencies. (3) The trauma emergency center was approved by the Shanghai Health and Family Planning Commission in 2004 as the Shanghai Trauma Emergency Center, and in 2005 as a Shanghai Emergency Medicine Key Specialty. Features of this center include the integration of emergency treatment for critical injuries, standardized construction of ED and ICU, and serialization of monitoring technology. This center features several of the leading medical technologies in China: (a) Monitoring technology for oxygen metabolic kinetics in critically ill patients, with a rescue rate of 87%; (b) Comprehensive treatment technology for multiple injuries, which has successfully treated more than 1,600 cases of multiple injuries in the past 5 years with a success rate of 89.2%; (c) Integration of traditional Chinese and Western medicine for the prevention and treatment of MODS/MOF, which has successfully treated 508 cases of MOD in the past 5 years with a success rate of 82.5%, and a success rate of 31.6% for patients with failure of 3 or more organs; 1,673 cases treated for gastrointestinal dysfunction using Da Huang showed a cure rate of 66.3%, and reduced the incidence of MODS; and (d) Cardiopulmonary cerebral resuscitation technology, which obtained a success rate of 48% (226 cases) for in-hospital cardiopulmonary resuscitation, and 9% (21 cases) for cerebral resuscitation.(4) The trauma emergency center and emergency critical care unit were approved by the Shanghai Health and Family Planning Commission in 2009 as the Shanghai Acute Trauma Center (note: the Tenth People’s Hospital is also a trauma emergency center, also known as the emergency critical care unit). This center is composed of 3 major components: ICU, emergency area (including EICU and emergency wards) and emergency rescue rooms (including emergency reception, rescue and resuscitation rooms, and observation rooms). The medical personnel are experienced in emergency treatment, and form an excellent integrated emergency model composed of prehospital emergency treatment, in-hospital emergency treatment, and ICU. This center specializes in the diagnosis and treatment of various acute critical illnesses, including organ support in critically ill patients, treatment of severe infections, clinical nutrition, and treatment of disturbances of the internal environment. Moreover, it has a unique advantage in respiratory support for acute respiratory failure, circulatory support, severe trauma, severe infections, and cardiopulmonary cerebral resuscitation.

(2) Number of beds and medical personnel

Table 3.24. Number of beds and medical personnel.

Hospital/Trauma center	Number of beds	Number of medical personnel
CHH hospital	2,200	2,000
CZ hospital	-	-
SY hospital	1,775	2,469
Burn trauma emergency center	76(17 ICU)	85
Bone trauma emergency center	36	38
Trauma emergency center	98	160
Trauma emergency center & emergency critical care unit	-	-

3.4 Summary

The database designed in this study included 5 dimensions and 21 indicators. The final number of trauma records included in the trauma database was 8,273, of which 6,385 entries (77.2%) were single injuries and 1,888 entries (22.8%) were multiple injuries.

In terms of demographic information, males (Cao *et al.*, 2013; WHO, 2014) and middle-aged individuals were high-risk groups for trauma, which indicates that awareness of strategies for trauma prevention should be strengthened in these populations. The capacity of middle-aged individuals to respond and act will diminish with age (Etehad *et al.*, 2015; Gelbard *et al.* 2014). Hence, they are more prone to accidents owing to slow reaction speeds in sudden situations, which resulted in higher incidences of trauma. Although married individuals accounted for a larger proportion of the trauma patients, this might be because the majority of patients in the overall population were married. Therefore, the impact of marital status on the incidence of trauma will require further investigation.

As for the dimension of injury characteristics, the extremities, head, and spine were high-incident regions for trauma. FJI, SSTI, and CNSI were common injury conditions. ground-level falls, traffic injuries, and high-level falls were the most common mechanisms of injury (Martinez *et al.*, 2013; WHO, 2014). However, owing to the differences in the nature and characteristics of different mechanisms, there were also slight differences in the composition of body region and injury condition for different mechanisms. Furthermore, after the occurrence of trauma, patients' injury severity showed differences due to different injury characteristics (Martinez *et al.*, 2013; Christensen *et al.*, 2008; Control *et al.*, 2008; Martin *et al.*, 2012; Davis *et al.* 2013; Tran *et al.*, 2015; de Almeida *et al.*, 2016; Banerjee *et al.*, 2013). Some of the patients also showed DC and coma (Corral *et al.*, 2012), and the coma grades of these patients mostly indicated severe coma. The DC and coma of multiple-injury patients were generally more severe than those of single-injury patients. Injury severity is another important indicator (McMillan and Teasdale, 2007). Analysis of the ISS indicated that multiple-injury patients had more severe injuries, and their scores were mostly graded as severe and critical. Therefore, based on the analysis of the survey on injury characteristics, the patient's DC and coma status should be rapidly graded during the trauma emergency response. Rapid identification of patients with severe DC can enable the swift implementation of medical intervention and monitoring of vital signs, and can improve treatment survival rates (Wang *et al.*, 2008). On the other hand, the key points of trauma prevention can be pinpointed based on the characteristics, patterns, and high-risk groups for different mechanisms of injury (Kidher *et al.*, 2012; Gelbard *et al.*, 2014). Firstly, based on the incidences of different trauma, particular emphasis should be placed on the prevention of ground-level falls, traffic injuries, and high-level falls. Increasing the protective devices in buildings and other environments (WHO, 2014) can effectively reduce the incidences of ground-level and high-level falls. The incidence of traffic accidents can be effectively reduced with interventional measures, such as implementing stricter traffic laws, strengthening the traffic safety awareness of pedestrians and motorists, increasing and improving the use and seatbelts and helmets, and so on (Peden, 2004).Secondly, understanding the high-incident body regions and injury characteristics of different mechanisms of injury can effectively promote the implementation of accurate medical interventions by emergency medical personnel, which will enhance the efficiency and efficacy of emergency treatment. With regard to the dimension of treatment information, the majority of trauma patients opted for direct admission to the medical facility via the ED. Among single-injury patients, the percentage of RHS was higher than RHOC. In contrast, among multiple-injury patients, the percentage of RHOC was higher. This phenomenon might be related to the less severe injuries of single-injury patients. Shanghai is where the best medical resources are concentrated. Hence, Chinese patients with severe injuries or complicated conditions will choose to transfer to Shanghai from other cities. This medical habit (He *et al.*, 2010; Ma *et al.*, 2009; Wang *et al.*; 2010a) can explain the phenomenon of more referrals from other cities among multiple-injury patients. These findings indicate that the medical technology of facilities in other regions should be strengthened. The uneven distribution of medical resources in different regions indicates that China's current medical system is unfair (Liu, 2007; Chi and Zhai, 2007). Foreign studies have shown that the length of prehospital time plays a crucial role in the outcomes of trauma patients (Papadimitriou *et al.*, 1994; Brown *et al.*, 2016; Sampalis *et al.*, 1993). However, studies on the impact of prehospital time on trauma outcome are scarce in China. In addition, this study showed that it is very difficult to achieve the prehospital emergency standard of "platinum ten and golden hour" for trauma emergency care in China (Zhang *et al.*, 2006). The average prehospital time for different mechanisms of injury and admission pathways was far lower than this standard, and the average duration was nearly always more than 5 hours. Among different mechanisms of injury, only the average prehospital time of patients with penetrating injuries was relatively short. In contrast, the average prehospital times for traffic-related injuries, high-level falls, and ground-level falls, which have higher incidences, are not promising. These results indicate that current prehospital emergency care in China still has much room for improvement. In particular, the effective reduction of prehospital time is the key to optimizing prehospital emergency care (Xi *et al.*, 2002). According to the Chinese National Health and Family Planning Commission statistical yearbook (China, 2013), the average LOS for tertiary A hospitals in 2011 was 12.0 days. This survey found that the LOS of most trauma patients was 8–14 days, which was consistent with the overall situation in China. Thus, the hospitals and trauma centers in this survey complied with the specifications for in-hospital treatment, and the LOS was reasonable. According to the results of this survey, although most patients were cured at the time of discharge, the mortality rate of trauma patients was far higher than the national average (national mortality rate due to external injuries and poisoning in 2011 was 33.93 [1/100,000]) (China, 2013). These results indicate that the mortality rates of trauma patients admitted to medical facilities in Shanghai were higher. This phenomenon might have resulted from the high medical standards in Shanghai facilities, which allowed them to receive patients with more severe conditions. However, it also indicates that further measures should be taken to strengthen prevention and enhance emergency efficiency, in order to reduce the mortality rate of trauma patients. Furthermore, among the surveyed trauma patients, nearly one-third presented with complications, the three most common of which were DC, specific BI, and paraplegia (Haider *et al.*, 2015; Mackenzie *et al.*, 1990; O'Keefe *et al.*, 1997). These results indicate that the incidence of complications was relatively high within the survey region, and traumatic injuries were severe. However, these findings also imply that hospital control measures should be further strengthened to reduce infection rates in hospitals.

As for comorbidities, only hypertension, diabetes, and osteoporosis were examined in this study. However, nearly one-third of the trauma patients surveyed had existing comorbidities, with the highest incidences for hypertension and diabetes. As chronic diseases will lead to physical dysfunction, this will exacerbate the condition and restrict the treatment measures for trauma patients, which will ultimately influence the patient's outcome (Chesnut *et al.*, 1993; Morris *et al.*, 1990; Bochicchio *et al.*, 2006). Therefore, these results indicate that incidence of chronic diseases in China is too high. Hence, prevention and health care management of chronic diseases should be further improved to reduce their threat to the life and health of the population.

In terms of facility information, the 3 public hospitals and 4 trauma centers surveyed in this study had high standards of medical technology. They have rich experience in trauma emergency and have participated in the medical emergency rescue in different public emergencies. The 3 hospitals were all large-scale public hospitals with immense medical operations and large numbers of trauma patients. The 4 trauma centers each had their own unique features and covered a variety of trauma patients. Therefore, using these medical facilities as research subjects had high research value and reliability.

References

American College of Surgeons: National Trauma Data Bank. Available online: https://www.facs.org/quality-programs/trauma/ntdb (accessed on 13 November 2016).

Banerjee, M.; Bouillon, B.; Shafizadeh, S.; *et al.* Epidemiology of extremity injuries in multiple trauma patients. *Injury* **2013**, *44*, 1015–1021.

Bochicchio, G.V.; Joshi, M.; Bochicchio, K.; *et al.* Incidence and impact of risk factors in critically ill trauma patients. *World Journal of Surgery* **2006**, *30*, 114–118.

Brown, J.B.; Rosengart, M.R.; Forsythe, R.M.; *et al.* Not all prehospital time is equal: influence of scene time on mortality. *The Journal of Trauma and Acute Care Surgery* **2016**, *81*.

Cao, Y.; Krause, J.; Dipiro, N. Risk factors for mortality after spinal cord injury in the USA. *Spinal Cord* **2013**, *51*, 413–418.

Centers for Disease Control and Prevention (CDC). Nonpharmaceutical fentanyl-related deaths–multiple states, April 2005–March 2007. *Morbidity and Mortality Weekly Report* **2008**, *57*, 793–816.

Chesnut, R.M.; Marshall, L.F.; Klauber, M.R.; *et al.* The role of secondary brain injury in determining outcome from severe head injury. *The Journal of Trauma* **1993**, *34*, 216–222.

Chi, X.Z.; Zhai, Q. The multi-level opposite and interactive relathionship between medical equity and efficiency. *Health Economics Research* **2007**, 16–17.

Christensen, M.C.; Nielsen, T.G.; Ridley, S.; *et al.* Outcomes and costs of penetrating trauma injury in England and Wales. *Injury* **2008**, *39*, 1013–1025.

Corral, L.; Javierre, C.F.; Ventura, J.L.; *et al.* Impact of non-neurological complications in severe traumatic brain injury outcome. *Critical Care* **2012**, *16*, 1.

Davis, J.S.; Castilla, D.M.; Schulman, C.I.; *et al.* Twenty years of pediatric gunshot wounds: an urban trauma center's experience. *Journal of Surgical Research* **2013**, *184*, 556–560.

De Almeida, C.E.R.; De Sousa Filho, J.L.; Dourado, J.C.; *et al.* Traumatic brain injury epidemiology in Brazil. *World Neurosurgery* **2016**, *87*, 540–547.

Etehad, H.; Yousefzadeh-Chabok, S.; Davoudi-Kiakalaye, A.; *et al.* Impact of road traffic accidents on the elderly. *Archives of Gerontology and Geriatrics* **2015**, *61*, 489–493.

Gelbard, R.; Inaba, K.; Okoye, O.T.; *et al.* Falls in the elderly: a modern look at an old problem. *The American Journal of Surgery* **2014**, *208*, 249–253.

Haider, A.H.; Gupta, S.; Zogg, C.K.; *et al.* Beyond incidence: costs of complications in trauma and what it means for those who pay. *Surgery* **2015**, *158*, 96–103.

He, Y.F.; Qiu, W.K.; Zhou, X.H.; *et al.* Survey of families' wills to medical treatment and its influencing factors in Xiacheng district, Hangzhou. *Zhejiang Preventive Medicine* **2010**, *22*, 7–10.

Kidher, E.; Krasopoulos, G.; Coats, T.; *et al.* The effect of prehospital time related variables on mortality following severe thoracic trauma. *Injury* **2012**, *43*, 1386–1392.

Liang, G.Y.; Shi, Y.K.; Yang, J.; *et al.* Discussion on a new injury severity score for throax penetrating injury. *Chinese Journal of Trauma* **2005**, *21*, 112–115.

Liu, D.E. Discussion on government responsibilities for health resource allocation and medical equity. *Chinese Health Service Management* **2007**, *23*, 451–454.

Liu, J.H.; Zhang, C.; Xu, P.; *et al.* Construction and application of prehospital emergency trauma database. *Hainan Medical Journal* **2012**, 6–8.

Ma, C.F.; Song, X.H.; Chen, X.W.; *et al.* Analysis of influencing factors and countermeasures of residents' choice of health institutions.*Chinese Hospital Management* **2009**, 42–43.

Mackenzie, E.J.; Morris Jr, J.A.; Smith, G.S.; *et al.* Acute hospital costs of trauma in the United States: implications for regionalized systems of care. *Journal of Trauma and Acute Care Surgery* **1990**, *30*, 1096–1103.

Martin, C.A.; Unni, P.; Landman, M.P.; *et al.* Race disparities in firearm injuries and outcomes among Tennessee children. *Journal of Pediatric Surgery* **2012**, *47*, 1196–1203.

Martinez, R.J.A.; Voth, A.H.; Fernandez, C.M.; *et al.* Evolution and complications of chest trauma. *Archivos de Bronconeumologia* **2013**, *49*, 177–180.

Mcmillan, T.; Teasdale, G. Death rate is increased for at least 7 years after head injury: a prospective study. *Brain* **2007**, *130*, 2520–2527.

Morris, J.A.; Mackenzie, E.J.; Edelstein, S.L. The effect of preexisting conditions on mortality in trauma patients. *Jama* **1990**, *263*, 1942–1946.

NHFPC. *Statistic Yearbook of National Health and Family Planning of the People's Republic of China*; Pecking Union Medical College Press: Beijing, China, 2013.

Ning, Y.; Jiang, C.H.; Yin, G.; *et al.* Study on establishing trauma database in Zhongshan, China. *Lingnan Journal of Emergency Medicine* **2014**, 318–319.

O'keefe, G.E.; Maier, R.V.; Diehr, P.; *et al.* The complications of trauma and their associated costs in a level I trauma center. *Archives of Surgery* **1997**, *132*, 920–924.

Papadimitriou, D.; Mathur, M.; Hill, D. A survey of rural road fatalities. *Australian and New Zealand Journal of Surgery* **1994**, *64*, 479–483.

Peden, M. *World Report on Prevention of Road Traffic Injuries*; WHO: Geneva, Switherland, 2004.

Qiu, J.; Yuan, D.F.; Yao, Y.; *et al.* History and current situation of Chinese trauma database. *Journal of Trauma and Emergency Medicine* **2014**, *2*, 10–13.

Sampalis, J.S.; Lavoie, A.; Williams, J.; *et al.* Impact of on-site care, prehospital time, and level of in-hospital care on survival in severely injured patients. *The Journal of Trauma* **1993**, *34*, 252–261.

Tran, T.M.; Fuller, A.T.; Kiryabwire, J.; *et al.* Distribution and characteristics of severe traumatic brain injury at Mulago National Referral Hospital in Uganda. *World Neurosurgery* **2015**, *83*, 269–277.

Wang, F.; Yang, Q.; Wang, Q.G.; *et al.* Discussion on establishing pelvic trauma life cycle clinical database. *Chinese Journal of Trauma* **2011**, *27*, 307–310.

Wang, L.; Li, J.; Li, Y.P.; *et al.* Systematic review on casualty classification in massive casualty incidents. *Chinese Journal of Evidence-based Medicine* **2008**, *8*, 469–476.

Wang, M.; Zhang, K.J.; Jiang, L.; *et al.* Impact factors model of medical behavior of Chinese urban and rural residents. *Chinese General Practice* **2010**, *13*, 2127–2129.

Wang, Q.; Wang, F.; Hu, X.F. Establishment of the whole professional process database for pelvic trauma *Journal of Shanghai Jiaotong University* **2012**, *32*, 1558.

WHO. *Injuries and Violence: The Facts 2014*; WHO: Geneva, Switherland, 2014.

Xi, Y.L.; He, K.; Lin, Q.N.; *et al.* Influence of prehospital time on the treatment of road traffic injuries. *Journal of Zhengzhou Univeristy* **2002**, *37*, 843–845.

Yao, Y. *Study of the Establishment of Trauma Database and the Input and Analysis of Trauma Data*; Third Military Medicine University: Chongqing, China, 2006.

Zen, J.M.; Yan, H.; Zhang, Y.Y. Arrangement of visual elements in interface design of art database. *Art Grand View* **2010**, 208–209.

Zhang, J.B.; Ma, J.X.; He, Z.J.; *et al.* Trauma first aid platinum for ten minutes-rapid diagnosis of trauma condition and starting up trauma group. *Chinese Journal of Critical Care Medicine* **2006**, *26*, 339–341.

Zhou, J.H. Improvement of trauma database and deepening study on trauma severity score and outcomes. *Chinese Journal of Trauma* **2012**, 577–579.

Chapter 4 Investigation of traffic injury occurrence and evolution

Yipeng Lv, Yuan Liu and Lulu Zhang
Department of Military Health Service Management, College of Military Health Service Management, Second Military Medical University, Shanghai 200433, China

4.1 Overview

4.1.1 Investigation background

According to the statistics by the WHO, approximately 1.25 million people die from road traffic accidents each year, another 20 to 50 million people suffer from non-fatal injuries, and many sustain injuries leading to disability. However, 90% of traffic-related deaths occur in low- and middle-income countries, and traffic injuries are the primary cause of death in young people aged 15–29 years. According to the forecasts of the WHO, if timely and effective measures are not taken, then traffic accidents will become the seventh leading cause of death by 2030 (Peden, 2005). Road traffic injuries often have a severe impact on families, and the costs incurred in each country constitute nearly 3% of the gross national product. These figures could reach up to 5% in certain low- and middle-income countries (De Ona *et al.*, 2011). To a family, the economic losses caused by road traffic injuries are not limited to treatment fees, but also the loss of working days, which has an immense impact on families. The United Nations has also published a “Global Status Report on Road Safety” to encourage countries to adopt positive and effective response measures against frequent road traffic damages. Road traffic injuries are anthropogenic and preventable injuries, which have a specific pattern. Hence, in-depth investigation of the mechanism of injury caused by road traffic accidents, the spectrum of traffic injuries, and their pattern of progression is of utmost importance to the effective prevention of traffic injuries and to rapid interventional therapy.

Shanghai is one of the fastest-developing cities in China. Its car ownership per capita is one of the highest in China, and the incidence of traffic injuries each year is very high. Shanghai not only has a world-leading elevated expressway system, it also has an advanced road traffic safety management system. As a result of continuous practice and improvements, Shanghai’s road safety management has a relatively complete emergency response and rescue system, with rich experience in the prevention and rescue of traffic injuries (Ma *et al.*, 2012). Therefore, analyzing and collating the traumatic injury information of major hospitals in Shanghai can serve as a reference for global emergency response and rescue in traffic injuries. Hence, this chapter will analyze the information on traffic injuries from major hospitals in Shanghai in order to provide a reference for the prevention and treatment of traffic injuries.

4.1.2 Definition and characteristics of traffic injury

WHO defined traffic injury as follows: "A road traffic injury is a fatal or non-fatal injury incurred as a result of a collision on a public road involving at least one moving vehicle. Children, pedestrians, cyclists, and the elderly are among the most vulnerable of road users."

The latest "2015 Global Status Report on Road Safety" released by WHO pointed out that the causes of traffic accidents include: speeding, drunk driving, motorcycle helmets, seatbelts and child restraints, and distracted driving. The traffic injuries caused by these behaviors are different, with each having their own features. Individuals may be afflicted with different injuries due to impact, crushing, throwing, dragging, and explosion. In terms of injury type, these may include crush injury, avulsion injury, abrasion, burns, and blunt force trauma. Generally speaking, impact injuries are the most likely to occur. As traffic injuries have differing causes, the injury conditions are more complex. Thus, the injury conditions of traffic injuries involve multiple situations corresponding to different injury conditions, and thus can be regarded as "many to many" injury characteristics (2004, Bereckigisolf *et al.*, 2013; Brugge *et al.*, 2002). Therefore, combining the injury characteristics with the type analysis of injury causes has been regarded as a more scientific and rational method to analyze traffic injuries.

Past studies have shown that the common characteristics of traffic injuries are:

(1) Diverse causes of injury: Unsafe driving behaviors can easily lead to different types of injuries, and is a "many to many" injury model.

(2) Prone to multi-target and multi-factor injuries: Multi-target injuries refer to the same injury factor causing simultaneous or successive injuries in 2 or more anatomical regions based on concise injury classification standards. Multi-factor injuries refer to injuries caused by 2 or more injury factors acting simultaneously or successively; such injuries may be single or multiple injuries (Fang, 2015). In traffic-related injuries, due to the diversity of injury causes, the occurrence of injuries is often complicated, and the probability of multi-target and multi-factor injuries is above 50%. Injuries often involve important regions and organs, such as the head, thorax, abdomen, spine, extremities, and pelvis. Injury type includes contusion, lacerations, crush injury, and closed fractures.

(3) Frequently causing sudden group injuries: The occurrence of traffic accidents often leads to injuries involving several people, especially after public transport malfunction, which could lead to mass fatalities. The treatment of mass casualties involves triage and rapid disposal, and the procedures involved are far more complex than those for individual casualties, with more complicated injury conditions. The treatment of mass casualties is an important test of the medical emergency response system.

(4) High mortality and disability rate: Due to the special body positions during traffic accidents, traffic-related injuries often involve trauma to the head and bones, followed by the abdomen and thorax. Traffic accidents have a wide scope of injury, involve massive blood loss and are accompanied by a high incidence of shock, and the rescue process is difficult. Severe head and chest trauma frequently lead to death among the casualties, whereas the high incidence of fractures contributes directly to the high disability rate.

(5) Traffic injuries have a regular pattern and can be prevented: Traffic injuries are the

result of socioeconomic development. The continual increase in different types of vehicles, the lack of education regarding traffic safety, and the poor safety awareness of pedestrians and drivers have led to the frequent occurrence of traffic injuries. Through the rational teaching of traffic safety and the establishment of scientific road safety rules, the occurrence of traffic injuries can be limited, to a large extent (Wen and Pu, 2008).

4.1.3 Basic data for the investigation

(1) Research aims: This survey aimed to collect treatment information and medical records of patients with traffic injuries in Shanghai, in order to analyze the epidemiological characteristics and injury patterns of traffic injuries. Statistical descriptive analysis and analysis of influencing factors were performed to further investigate the mechanism of injury and pattern of injury characteristics in traffic injuries. Based on these analyses, recommendations were provided to improve the rescue of individual and group casualties in traffic incidents. A scientific and rational plan was also proposed for the prevention and emergency treatment of traffic injuries.

(2) Survey information: The research group began data collection in January 2011. All data were obtained from the four largest trauma centers in Shanghai. All patients included in the study were informed of the research aims prior to hospital admission and provided written consent. Data collection involved screening the medical records systems of 4 trauma centers (burn trauma emergency center, bone trauma emergency center, trauma emergency center, and trauma emergency center & emergency critical care unit) for data that met the inclusion criteria. The medical records of patients with traffic injuries between January 2011 and January 2015, who met the inclusion criteria and provided written consent, were collected for this survey. Data collection was based on the ICD-10 and the rules of the Chinese hospital medical records registry systems. Medical records that met the inclusion criteria were selected and the valid information was extracted. The data were collated using the hospital information system and Excel tables. Then, the medical history of patients with traffic injuries was recorded in a unified coding and data entry format. The final number of valid survey samples collected was 2,397 cases, with 973 cases of multiple injuries and 1,424 cases of single injuries.

Due to the large differences in the body regions of multiple and single injuries, there were disparities in the injury condition and development trend between the two injury types. In mass traffic injuries, an important aspect of treatment is triage, which has a substantial impact on the establishment of subsequent treatment strategies and medical resource allocation for mass traffic injuries. Therefore, traffic injuries were divided into multiple and single injuries in this study for analyses.

4.2 Investigation results of traffic injury occurrence and evolution

4.2.1 Demographic characteristics of traffic injury patients

As described by WHO, traffic injuries are the primary cause of death among individuals less than 40 years of age. Studies have generally indicated that the epidemiological and demographic characteristics of traffic injuries showed a certain pattern. Therefore, exploring the demographic characteristics of traffic injuries has significant implications for the targeted development of traffic safety education. In this chapter, the 2,397 cases of traffic injuries will be divided and compared based on single and multiple injuries.

(1) Single injury

Table 4.1. Gender of single-injury patients with traffic injuries.

Gender	N	%
Male	915	64.3
Female	509	35.7

Among patients with single traffic injuries, men accounted for 64.3% and women accounted for 35.7%. The percentage of men in traffic injuries was nearly twice that of women, but this cannot be taken to directly indicate that men are more prone to traffic injuries.

Table 4.2. Age of single-injury patients with traffic injuries.

Age (year)	N	%
0–14	27	1.9
15–24	134	9.4
25–34	176	12.4
35–44	228	16.0
45–54	318	22.3
55–64	365	25.6
≥65	176	12.4

The age range encompassing the highest number of patients with single traffic injuries was 55–64 years, accounting for 25.6%. Young adults below 44 years accounted for 39.7%, while patients above 44 years accounted for 60.3%. These results are not consistent with the higher percentages of young adults reported in the literature (Macbeth, 1975; Zhan *et al.*, 2015). This discrepancy is mainly related to the severe aging population in Shanghai, and the developed emergency medical network in Shanghai, where the elderly is usually able to receive timely and effective treatment after traffic accidents. Therefore, the proportion of elderly individuals will be higher in later clinical surveys.

Table 4.3. Marital status of single-injury patients with traffic injuries.

Marital status	N	%
Divorced/widowed	5	0.4
Single	353	24.8
Married	1,066	74.9

Among single-injury patients, those who were married accounted for 74.9%, while those who were single accounted for 24.8%.

(2) Multiple injuries

Table 4.4. Gender of multiple-injury patients with traffic injuries.

Gender	N	%
Male	669	68.8%
Female	304	31.2%

Among patients with multiple traffic injuries, men accounted for 68.8% and women accounted for 31.2%. The percentage of men in traffic injuries was nearly twice that of women.

The age range encompassing the highest number of patients with multiple traffic injuries was 55–64 years, accounting for 25.0%. Young adults below 44 years accounted for 35.6%, while patients above 44 years accounted for 64.4%. The overall distribution was similar to that for patients with single injuries.

Table 4.5. Age of multiple-injury patients with traffic injuries.

Age (year)	N	%
0–14	19	2.0%
15–24	64	6.6%
25–34	118	12.1%
35–44	145	14.9%
45–54	238	24.5%
55–64	243	25.0%
≥ 65	146	15.0%

Table 4.6. Marital status of multiple-injury patients with traffic injuries.

Marital status	N	%
Divorced/widowed	2	0.2%
Single	151	15.5%
Married	820	84.3%

Among multiple-injury patients, those who were married accounted for 84.3%, while those who were single accounted for 15.5%.

4.2.2 Injury characteristics of traffic injury patients

The distribution of injury characteristics is an important aspect to consider in exploring the development pattern of traffic injuries and the further investigation of the mechanisms of injury. In general, traffic injuries often involve the spine and multiple limb fractures, accompanied by head, abdominal, and thoracic injuries, with complex mechanisms of injury and critical conditions (Meng, 2001; Organization, 2004; Peden, 2005). Therefore, this chapter will describe the injury characteristics of patients with traffic injuries and provide a comprehensive analysis of the injury region and injury severity of traffic injuries. The analyses mainly included four aspects: injured body region, injury condition, GCS score, and AIS/ISS.

(1) Single injury

The most common body region for traffic injuries was the limbs, accounting for 49.2%, followed by head injuries, accounting for 10.3%. These results are consistent with the common regions of traffic injuries reported in the literature.

Table 4.7. Injured body region of single-injury patients with traffic injuries.

Injured body region	N	%
Head	475	33.4%
Thorax	42	2.9%
Abdomen	17	1.2%
Spine	147	10.3%
Pelvis	43	3.0%
Limb	700	49.2%

The most common injury conditions among patients with traffic injuries were FJI (75.1%), SSTI (51.8%), and CNSI (31.0%). The injury conditions were mainly related to the injured body regions. Hence, the more likely injury conditions will often lead to damage in the organs involved.

Table 4.8. Injury condition of single-injury patients with traffic injuries.

Injury condition	N	%
FJI	1,070	75.1
SSTI	738	51.8
DT	29	2.0
CNSI	441	31.0
PC	27	1.9
TH	10	0.7
TOI	18	1.3

The most common GCS score among patients with traffic injuries was 3–8, accounting for 45.3% of patients. It can also be seen from the table that 51.1% of patients had GCS scores lower than 8, indicating that the majority of patients were in a severe coma upon admission. This finding can be explained by the fact that the patients were often in a state of shock with DC.

Table 4.9. GCS scores of single-injury patients with traffic injuries.

GCS scores	N	%
3–8	63	45.3
9–12	21	15.1
13–14	19	13.7
15	28	20.1

The AIS is a single-injury coding and grading method. The most common AIS score was 3 points (45.7%). Scores of 3 points and above represent serious injuries. Hence, the results indicate that traffic injuries are usually serious and non-fatal, often leading to impaired function or even disability.

Table 4.10. AIS of single-injury patients with traffic injuries.

AIS	N	%
1	94	6.6
2	549	38.6
3	676	47.5
4	49	3.4
5	52	3.7
6	4	0.3

(2) Multiple injuries

The injured body regions for traffic injuries were mainly the head (incidence of 69.6%), thorax (incidence of 54.0%), upper limb (incidence of 43.4%), and lower limb (incidence of 42.5%). These results are consistent with the common regions of traffic injuries reported in the literature. Therefore, in the overall population, injuries to the extremities are the most common, followed by head injuries. As head injuries often lead to fatal damage, greater observation and care should be given to patients with head injuries (Petrucelli, 1991; Pless, 2004).

Table 4.11. Injured body regions of multiple-injury patients with traffic injuries.

Injured body regions	N	%
Head	677	69.6
Thorax	525	54.0
Abdomen	169	17.4
Upper limb	422	43.4
Lower limb	414	42.5
Spine	276	28.4
Pelvis	163	16.8

The most common injury conditions among multiple-injury patients with traffic injuries were FJI (incidence of 92.9%), SSTI (incidence of 73.9%), CNSI (incidence of 43.1%), and PC (incidence of 30.0%). The injury conditions were mainly related to the injured body regions.

Table 4.12. Injury condition of multiple-injury patients with traffic injuries.

Injury condition	N	%
FJI	904	92.9
SSTI	729	74.9
DT	21	2.2
CNSI	419	43.1
PC	292	30.0
TH	134	13.8
TOI	104	10.7

On the GCS, a score of 13–14 points indicates mild coma, 9–12 points indicate moderate coma, and 3–8 points indicate severe coma. The percentages of patients with GSC scores of 3–8, 9–12, 13–14, and 15, were 4.0%, 2.3%, 0.6%, and 0.8%, respectively. The majority of coma patients had severe coma, which indicates that the coma caused by traffic injuries is mainly severe coma.

Table 4.13. GCS scores of multiple-injury patients with traffic injuries.

GCS scores	N	%
3–8	39	4.0
9–12	22	2.3
13–14	6	0.6
15	8	0.8
NA*	898	92.3

* NA means GCS scores missing.

The ISS is a coding and grading method for multiple and composite injuries. Patients with ISS indicating minor injuries accounted for 15.4%, severe injuries accounted for 27.5%, and critical injuries accounted for 23.4%.

Table 4.14. ISS of multiple-injury patients with traffic injuries.

ISS	N	%
1	150	15.4
2	327	33.6
3	268	27.5
4	228	23.4

4.2.3 Treatment of traffic injury patients

Basic treatment information mainly investigates information related to a patient's injury, which can be used to explore factors influencing the injury condition. This includes the patient's admission pathway, prehospital time, LOS, outcome, and complications.

(1) Single injury

The admission pathway of patients with traffic injuries was mainly through EDA (54.8%), followed by RHS (22.2%) and RHOC (23.0%). This is because the surveyed hospitals were mainly tertiary A hospitals that had advanced medical standards, and hence were better able to treat patients with traffic injuries, which led to the transfer of patients from other hospitals for treatment.

Patients with a prehospital time more than 3 hours accounted for 82.1% of patients. Traffic injuries often lead to massive bleeding and even shock. Head injuries are also common in traffic accidents, and patients with this type of injury will deteriorate with time. In addition, limb replantation is generally required to be performed within 6 hours (Racioppi, 2004; Saidi *et al.*, 2014). Rapid and effective implementation of precise treatments is an important factor influencing patient outcome. Based on the analyses above, the time taken for patients to receive treatment is not ideal.

Table 4.15. Admission pathway of single-injury patients with traffic injuries.

Admission pathway	N	%
RHOC	327	23.0
RHS	316	22.2
EDA	781	54.8

Table 4.16. Prehospital time of single-injury patients with traffic injuries.

Prehospital time (hour)	N	%
⩽1	23	1.6
1–3	232	16.3
3–24	599	42.1
>24	570	40.0

The majority of patients were hospitalized for 8–30 days, specifically, patients with LOS of 8–14 days accounted for the most, followed by LOS of 4–7 days and 15–30 days. LOS was mainly related to the occurrence of complications.

Table 4.17. LOS of single-injury patients with traffic injuries.

LOS (day)	N	%
0–3	106	7.4
4–7	361	25.4
8–14	470	33.0
15–30	346	24.3
≥31	141	9.9

Patients whose outcome was death accounted for 2.0%, those with a negative outcome accounted for 4.4%, those with a positive outcome accounted for 31.7%, and those who were cured accounted for 61.9%. The percentage of patients with positive outcomes and better accounted for 93.6%. This finding is mainly related to the treatment standards of the hospitals.

Table 4.18. Outcome of single-injury patients with traffic injuries.

Outcome	N	%
Dead	29	2.0
Invalid	62	4.4
Improved	452	31.7
Cured	881	61.9

The most common complication in patients was DC (24.5%), a finding basically consistent with the literature. The main reason for this finding is that severe injuries are often accompanied by shock or DC (Jiong, 2008; Li, 2006).

Table 4.19. Complications of single-injury patients with traffic injuries.

Hospital complications	N	%
HS	23	1.6
DC	349	24.5
Apnea	2	0.1
CA	2	0.1
CH	14	1.0
Paraplegia	41	2.9
AF	6	0.4
WED	3	0.2
ARF	5	0.4
MOF	1	0.1
MODS	8	0.6
BI	60	4.2

(2) Multiple injuries

The admission pathway of multiple-injury patients with traffic injuries was mainly through EDA (47.1%), followed by RHS (22.6%) and RHOC (30.3%).

Table 4.20. Admission pathway of multiple-injury patients with traffic injuries.

Admission pathway	N	%
RHOC	295	30.3
RHS	220	22.6
EDA	458	47.1

The percentages of patients with prehospital time of less than 1 h, 1–3 h, 3–24 h, and >24 h were 1.6%, 26.3%, 42.1%, and 40.0%, respectively. The distribution was consistent with that of single traffic-injuries.

Patients with LOS of 0–3 days accounted for 4.4%, LOS of 4–7 days accounted for 15.6%, LOS of 8–14 days accounted for 27.3%, LOS of 15–30 days accounted for 32.9%, and LOS of ≥ 31 days accounted for 19.7%. The distribution was consistent with that of single traffic-injuries.

Table 4.21. Prehospital time of multiple-injury patients with traffic injuries.

Prehospital time (hour)	N	%
⩽1	55	5.7
1–3	144	14.8
3–24	400	41.1
>24	374	38.4

Patients whose outcome was death accounted for 2.3%, those with negative outcomes accounted for 2.5%, those with positive outcomes accounted for 40.2%, and those who were cured accounted for 55.1%. The percentage of patients with positive outcomes and greater accounted for 95.3%. The distribution of outcomes was consistent with that of single traffic-injuries.

Table 4.22. LOS of multiple-injury patients with traffic injuries.

LOS (day)	N	%
0–3	43	4.4
4–7	152	15.6
8–14	266	27.3
15–30	320	32.9
⩾31	192	19.7

Table 4.23. Outcome of multiple-injury patients with traffic injuries.

Outcome	N	%
Dead	22	2.3
Invalid	24	2.5
Improved	391	40.2
Cured	536	55.1

The most common complication in patients was DC (24.5%), which was mainly because severe injuries are often accompanied by shock or DC.

Table 4.24. Hospital complications of multiple-injury patients with traffic injuries.

Hospital complications	N	%
HS	83	8.5
DC	381	39.2
Apnea	8	0.8
CA	8	0.8
CH	2	0.2
Paraplegia	56	5.8
AF	13	1.3
WED	29	3.0
ABI	6	0.6
ARDS	6	0.6
ARF	14	1.4
MODS	26	2.7
BI	126	12.9

4.2.4 Comorbidity in traffic injury patients

(1) Single injury

The main comorbidities of single-injury patients with traffic injuries were diabetes (6.0%) and hypertension (11.5%).

Table 4.25. Comorbidities of single-injury patients with traffic injuries.

Comorbidity	N	%
Diabetes	86	6.0
Hypertension	164	11.5
Osteoporosis	1	0.1

(2) Multiple injuries

The main comorbidities of multiple-injury patients with traffic injuries were diabetes (6.8%) and hypertension (11.1%). These findings are mainly the result of the patient age group and place of residence. Shanghai is facing a serious aging problem, and diabetes and hypertension mainly occur in the elderly. Hence, the main comorbidities of patients in this survey were diabetes and hypertension.

Table 4.26. Comorbidities of multiple-injury patients with traffic injuries.

Comorbidity	N	%
Diabetes	66	6.8
Hypertension	108	11.1

4.2.5 Outcomes of traffic injury patients

SPSS software (version 21.0, SPSS Inc., Chicago, IL, USA) was used to analyze the influencing factors, in order to examine the factors influencing the prognosis and outcome of patients with traffic injuries. During the analysis, the Mann-Whitney U test was performed to compare two independent samples, the Kruskal-Wallis H test was performed to compare multiple independent samples, and Spearman rank correlation test was performed for correlation analysis. Patient outcome (death, invalid, improved, or cured) was taken as the outcome variable. As the factors were all categorical data, non-parametric tests were performed for analysis. Specifically, the type of grouping variables in the R*C tables was used to select the statistical method: binary categorical variables were compared using Mann-Whitney U tests; unordered multi-way categorical variables were compared using Kruskal Wallis H tests. Ordered variables were compared using Spearman rank correlation analysis.

4.2.5.1 Single injury

(1) Comparison of binary categorical independent variables using the Mann-Whitney U test

Gender was not statistically significantly related to the outcomes of patients with single traffic injury. The improved and cured rates of men and women were both higher than 90%, indicating that the surveyed units had good therapeutic efficacy for single traffic injury.

For different injury conditions, the presence of FJI, SSTI, CNSI, PC, and TOI led to statistically significant differences in outcome. The cured rate of patients with fractures was 66.5%, that of soft tissue injuries was 53.8%, that of CNSI was 37%, that of PC was 33.3%, and that of organ rupture was 27.8%. These results indicate that the timely and effective treatment of these injuries will improve the cured rates of patients to a large extent.

Table 4.27. Comparison of outcomes between different genders among patients with single traffic injury.

Gender	Dead	Invalid	Improved	Cured	U-value	p-value
Male	17	39	295	564	232183	0.914
Female	12	23	157	317	-	-

For different complications, the presence of DC, apnea, CH, ARF, MOF, MODS, and BI led to statistically significant differences in outcome. It can be seen that these complications are rapidly progressing, dangerous diseases that directly threaten the patient's life and safety. The onset of such complications is mainly the result of head injuries and severe compression of the body. Therefore, when treating patients with severe traffic injuries, not only should symptomatic treatment be provided to buy more time for subsequent surgery, it is also necessary to identify the disease etiology for treatment (Wen and Pu, 2008; Zhang *et al.*, 2011).

Table 4.28. Comparison of outcomes among different injury conditions of patients with single traffic injury.

Injury condition	Dead	Invalid	Improved	Cured	p-value
FJI					<0.001
No	13	15	157	169	
Yes	16	47	295	712	
SSTI					<0.001
No	5	35	162	484	
Yes	24	27	290	397	
DT					0.087
No	29	62	445	859	
Yes	0	0	7	22	
CNSI					<0.001
No	2	38	225	718	
Yes	27	24	227	163	
PC					0.010
No	29	62	434	872	
Yes	0	0	18	9	
TH					0.152
No	28	62	447	877	
Yes	1	0	5	4	
TOI					0.003
No	28	61	441	876	
Yes	1	1	11	5	

In addition, BI is another important factor that will influence the treatment and outcome of patients with single traffic injuries. Infection is a key factor leading to death in the later stages. Traffic injuries often lead to limb amputation, which has a large wound area that allows for rapid BI and proliferation. Hence, the wound area should be fully debrided and protected during the early stages of emergency treatment, with close monitoring for BI (Zhan *et al.*, 2015; Li, 2006).

For patients with single traffic injury, the presence of diabetes showed a statistically significant relationship with the patient's outcomes. The mortality rate of patients with diabetes was higher than that of non-diabetic patients.

Table 4.29. Comparison of outcomes among different complications of patients with single traffic injury.

Complication	Dead	Invalid	Improved	Cured	p-value
HS					0.178
No	26	61	445	869	
Yes	3	1	7	12	
DC					<0.001
No	3	43	283	746	
Yes	26	19	169	135	
Apnea					0.005
No	27	62	452	881	
Yes	2	0	0	0	
CA					0.391
No	28	62	452	880	
Yes	1	0	0	1	
CH					0.001
No	24	60	450	876	
Yes	5	2	2	5	
Paraplegia					0.356
No	29	60	435	859	
Yes	0	2	17	22	
AF					0.119
No	28	62	449	879	
Yes	1	0	3	2	
WED					0.394
No	29	62	450	880	
Yes	0	0	2	1	
ABI					-
No	29	62	452	881	
Yes	0	0	0	0	
ARDS					-
No	29	62	452	881	
Yes	0	0	0	0	
ARF					0.048
No	26	62	452	879	
Yes	3	0	0	2	
MOF					0.047
No	28	62	452	881	
Yes	1	0	0	0	
MODS					<0.001
No	24	61	451	880	
Yes	5	1	1	1	
BI					< 0.001
No	20	60	420	864	
Yes	9	2	32	17	

Table 4.30. Comparison of outcomes among different comorbidities of patients with single traffic injury.

Comorbidity	Dead	Invalid	Improved	Cured	p-value
Diabetes					0.032
No	24	57	421	836	
Yes	5	5	31	45	
Hypertension					0.425
No	23	59	393	785	
Yes	6	3	59	96	
Osteoporosis					0.440
No	29	62	452	880	
Yes	24	57	421	836	

(2) Comparison of multiple categorical independent variables using the Kruskal Wallis H test

The differences in outcomes among individuals with different marital status were not significant for patients with single traffic injury. However, owing to the small number of divorced patients, it was not possible to determine directly whether the cured rate of divorced patients was higher than that of patients with other marital status. This determination requires analyses using an expanded sample size.

The differences in outcomes among patients from different admission pathways were not significant. The improved and cured rates of patients from all admission pathways were above 90%. In comparison, the mortality rate of patients from EDA was relatively high.

The differences in outcomes among the different injured body regions for patients with single traffic injury were statistically significant. This study found that the mortality and invalid rates for patients with head and abdominal injuries were higher. For the survey subjects, no one with spine, pelvis, or extremities injuries were dead. Head injury is the common cause of death in single traffic injury, as the head injury will often be accompanied by brain herniation, which is a dangerous condition with rapid progression. Patients will often lose the opportunity to undergo emergency surgery due to their serious condition, which will lead to death. Furthermore, abdominal injuries often result in massive bleeding that can easily lead to death (Wang and Jiang, 2002; Wang and Jiang, 2003).

Table 4.31. Comparison of outcomes among different marital status of patients with single traffic injury.

Marital status	Dead	Invalid	Improved	Cured	Chi-square	p-value
Divorced/widowed	0	0	0	5	8.118	0.017
Single	5	22	126	200	-	-
Married	24	40	326	676	-	-

Table 4.32. Comparison of outcomes among different admission pathways of patients with single traffic injury.

Admission pathway	Dead	Invalid	Improved	Cured	Chi-square	p-value
RHOC	1	21	115	190	2.314	0.314
RHS	6	14	100	196	-	-
EDA	22	27	237	495	-	-

Table 4.33. Comparison of outcomes among different injured body regions of patients with single traffic injury.

Injured body region	Dead	Invalid	Improved	Cured	Chi-square	p-value
Head	27	27	252	169	261.299	<0.001
Thorax	1	0	29	12	-	-
Abdomen	1	1	8	7	-	-
Spine	0	4	41	102	-	-
Pelvis	0	3	14	26	-	-
Extremities	0	27	108	565	-	-

(3) Comparison of ordinal categorical independent variables using the Spearman rank correlation test

The differences in outcomes among different age groups were not significant for patients with single traffic injury. The age group with the highest cured and improved rates was 35–44 years, with a combined rate of 96.9%, whereas the age group with the lowest rate was children below 14 years, with a combined rate of 80.5%. Similarly, the cured and improved rates for the elderly were also relatively low.

Table 4.34. Correlation analysis between age and outcomes among patients with single traffic injury.

Age	Dead	Invalid	Improved	Cured	r_s	p-value
≤14	1	4	4	18	0.008	0.760
15–24	0	7	54	73	-	-
25–34	2	8	56	110	-	-
35–44	0	7	78	143		-
45–54	8	17	92	201	-	-
55–64	11	13	111	230	-	-
≥65	7	6	57	106	-	-

The prehospital time of patients with single traffic injury did not have an impact on their outcome. This result differs from findings reported in the literature, as the literature indicated that the length of prehospital time will affect the patient's prognosis. Moreover, an injury duration of more than 3 hours will increase patient mortality. However, in this study, the improved and cured rates tended to be relatively high. The improved and cured rates for 1 hour or less were 87%, while the rates for other prehospital times were over 90%. It is speculated that these results may be related to the study subjects to a certain extent. As tertiary A hospitals were selected for this study, their capacity for emergency trauma treatment is relatively strong, and they are experienced in MCIs and emergency management. Hence, casualties could receive timely and effective treatment after admission. Therefore, prehospital emergency treatment is a key aspect of improving the success rate of emergency rescue and reducing the mortality and disability rates (Li *et al.*, 2012; Fang, 2015).

Table 4.35. Correlation analysis between prehospital time and outcomes among patients with single traffic injury.

Prehospital time (hour)	Dead	Invalid	Improved	Cured	r_s	p-value
⩽1	2	1	11	9	−0.022	0.411
1–3	13	10	62	147	-	-
3–24	10	18	182	389	-	-
>24	4	33	197	336	-	-

The differences in outcomes among the different lengths of stay for patients with single traffic injury were statistically significant. Patients with LOS greater than 8 days had cured and improved rates of 97.9%, whereas patients with LOS between 0–3 days had lower cured and improved rates (62.2%). As this was an observational study, the severity of single injuries was not controlled, hence based on the feedback on the first page of the medical records, the main reason for short hospital stays was because cases of death or minor injuries were immediately discharged. Hence, the cured rate was relatively low.

Table 4.36. Correlation analysis between LOS and outcomes among patients with single traffic injury.

LOS (day)	Dead	Invalid	Improved	Cured	r_s	p-value
0–3	11	29	37	29	0.203	<0.001
4–7	9	22	126	204	-	-
8–14	3	7	143	317		-
15–30	4	3	106	233	-	-
⩾31	2	1	40	98	-	-

The relationship between GCS scores and outcomes was statistically significant among patients with single traffic injury. GCS was performed for patients in coma or with head injuries. The mortality of patients with GCS scores between 3–8 was 25.4%, followed by a mortality of 4.8% among patients with scores of 9–12. These results also indicate that coma induced by head injuries is an important factor leading to patient death. Therefore, improving the treatment of head injury and coma patients is an important factor in reducing the mortality rates of patients with single traffic injuries.

Table 4.37. Correlation analysis between GCS and outcomes among patients with single traffic injury.

GCS	Dead	Invalid	Improved	Cured	r_s	p-value
3–8	16	7	23	17	0.262	0.021
9–12	1	1	12	7	-	-
13–14	0	1	11	7	-	-
15	0	0	23	5	-	-

The differences in the outcomes of patients with different AIS scores were statistically significant. In the AIS scoring, patients were divided into 6 levels: minor, moderate, serious, severe, critical, and maximal injuries. A higher level implies that the patient's injuries were more severe. This study demonstrated that mortality showed an increasing trend with increases in AIS scores.

Table 4.38. Correlation analysis between AIS and outcomes among patients with single traffic injury.

AIS	Dead	Invalid	Improved	Cured	r_s	p-value
1	0	2	40	52	−0.163	<0.001
2	0	32	120	397	-	-
3	16	19	246	395	-	-
4	2	3	22	22	-	-
5	11	6	21	14	-	-
6	0	0	3	1	-	-

4.2.5.2 Multiple injuries

(1) Comparison of binary categorical independent variables using the Mann-Whitney U test

Gender showed no statistically significant relationship with outcomes of patients with multiple traffic injuries. The improved and cured rates of men and women were both higher than 90%, indicating that the surveyed units had good therapeutic efficacy for single traffic injuries.

Table 4.39. Comparison of outcomes between different genders among patients with multiple traffic injuries.

Gender	Dead	Invalid	Improved	Cured	p-value
Male	17	20	265	367	0.600
Female	5	4	126	169	-

The differences in outcomes among the different injured body regions for patients with multiple traffic injuries were statistically significant. The cured rate of patients with head injury was 50.2%, and that of uninjured patients was 66.2%. The cured rate of patients with thoracic injury was 49.7%, and that of uninjured patients was 61.4%. The cured rate of patients with abdominal injury was 43.2%, and that of uninjured patients was 57.6%. The cured rate of patients with upper limb injury was 59.0%, and that of uninjured patients was 52.1%. The cured rate of patients with lower limb injury was 60.4%, and that of uninjured patients was 51.2%.

For different injury conditions, the presence of FJI, SSTI, CNSI, PC, and TOI led to statistically significant differences in outcome. The cured rate of patients with fractures was 56.2%, and that of uninjured patients was 40.6%. The cured rate of patients with SSTI was 65.2%, and that of uninjured patients was 61.5%. The cured rate of patients with CNSI was 41.8%, and that of uninjured patients was 65.2%. The cured rate of patients with TOI was 29.8%, and that of uninjured patients was 58.1%. These results indicate that the timely and effective treatment of these injury types will improve the cured rates of patients.

Table 4.40. Comparison of outcomes among different injured body regions of patients with multiple traffic injuries.

Injured body region	Dead	Invalid	Improved	Cured	p-value
Head					< 0.001
No	3	7	90	196	
Yes	19	17	301	340	
Thorax					< 0.001
No	6	10	157	275	
Yes	16	14	234	261	
Abdomen					< 0.001
No	15	16	310	463	
Yes	7	8	81	73	
Upper limb					0.025
No	15	15	234	287	
Yes	7	9	157	249	
Lower limb					0.003
No	15	16	242	286	
Yes	7	8	149	250	
Spine					0.420
No	20	17	268	392	
Yes	2	7	123	144	
Pelvis					0.199
No	18	22	331	439	
Yes	4	2	60	97	

Regarding different complications, the presence of DC, apnea, CA, CH, WED, ARF, MODS, and BI led to statistically significant differences in outcome. The cured rate of patients with DC was 43.3%, and that of patients without was 62.7%. The cured rate of patients with apnea was 0, and that of patients without was 55.5%. The cured rate of patients with CA was 0%, and that of patients without was 55.2%. The cured rate of patients with CH was 0%, and that of patients without was 55.2%. The cured rate of patients with water and electrolyte imbalance was 13.8%, and that of patients without was 56.4%. The cured rate of patients with ABI was 16.7%, and that of patients without was 55.3%. The cured rate of patients with ARF was 28.6%, and that of patients without was 55.5%. The cured rate of patients with MODS was 11.5%, and that of patients without was 56.3%. The cured rate of patients with BI was 32.5%, and that of patients without was 58.4%.

Outcome analysis of complications revealed that patients with multiple traffic injuries were easily influenced by various complications, and had more influencing factors than patients with single injuries. Therefore, the monitoring and control of complications should be strengthened for patients with multiple injuries, in order to prevent ineffective treatment or even death caused by these complications.

Table 4.41. Comparison of outcomes among different injury conditions of patients with multiple traffic injuries.

Injury condition	Dead	Invalid	Improved	Cured	p-value
FJI					0.020
No	1	2	38	28	
Yes	21	22	353	508	
SSTI					0.018
No	0	9	85	150	
Yes	22	15	306	386	
DT					0.319
No	21	24	385	522	
Yes	1	0	6	14	
CNSI					< 0.001
No	5	12	176	361	
Yes	17	12	215	175	
PC					0.002
No	12	18	254	397	
Yes	10	6	137	139	
TH					0.330
No	19	19	334	467	
Yes	3	5	57	69	
TOI					< 0.001
No	16	18	330	505	
Yes	6	6	61	31	

Table 4.42. Comparison of outcomes among different complications of patients with multiple traffic injuries.

Complication	Dead	Invalid	Improved	Cured	p-value
HS					0.079
No	15	20	360	495	
Yes	7	4	31	41	
DC					< 0.001
No	7	15	199	371	
Yes	15	9	192	165	
Apnea					< 0.001
No	19	23	387	536	
Yes	3	1	4	0	
CA					< 0.001
No	19	22	388	536	
Yes	3	2	3	0	
CH					0.038
No	21	24	390	536	
Yes	1	0	1	0	
Paraplegia					0.430
No	22	23	363	509	
Yes	0	1	28	27	

Table 4.42. *Cont.*

Complication	Dead	Invalid	Improved	Cured	p-value
AF					0.213
No	21	24	384	531	
Yes	1	0	7	5	
WED					< 0.001
No	21	18	373	532	
Yes	1	6	18	4	
ABI					0.016
No	21	23	388	535	
Yes	1	1	3	1	
ARDS					0.103
No	21	23	389	534	
Yes	1	1	2	2	
ARF					0.013
No	19	24	384	532	
Yes	3	0	7	4	
MODS					<0.001
No	15	16	321	495	
Yes	7	8	70	41	
BI					<0.001
No	15	20	360	495	
Yes	7	4	31	41	

For patients with multiple traffic injuries, the presence of diabetes and hypertension did not lead to statistically significant differences in patient outcomes.

Table 4.43. Comparison of outcomes among different comorbidities of patients with multiple traffic injuries.

Comorbidity	Dead	Invalid	Improved	Cured	p-value
Diabetes					0.594
No	20	22	368	497	
Yes	2	2	23	39	
Hypertension					0.458
No	18	20	348	479	
Yes	4	4	43	57	

(2) Comparison of multiple categorical independent variables using the Kruskal Wallis H test

The differences in outcomes among patients of different marital status were not significant for patients with multiple traffic injuries. However, owing to the small number of divorced patients, it was not possible to determine directly whether the cured rate of divorced patients was higher than that of patients with other marital status. This requires analyses using an expanded sample size.

The differences in outcomes among patients from different admission pathways were statistically significant. The improved and cured rates of referrals from other cities were

94.9%, those of referrals from Shanghai were 95.5%, and those of EDA were 95.4%.

Table 4.44. Comparison of outcomes among different marital status of patients with multiple traffic injuries.

Marital status	Dead	Invalid	Improved	Cured	Chi-square	p-value
Divorced/widowed	0	0	2	0	2.043	0.360
Multiple	5	0	65	81	-	-
Married	17	24	324	455	-	-

Table 4.45. Comparison of outcomes among different admission pathways of patients with multiple traffic injuries.

Admission pathway	Dead	Invalid	Improved	Cured	Chi-square	p-value
RHOC	1	14	144	136	13.596	0.001
RHS	3	7	73	137	-	-
EDA	18	3	174	263	-	-

(3) Comparison of ordinal categorical independent variables using the Spearman rank correlation test

The differences in outcomes among the different numbers of injured body regions for patients with multiple traffic injuries were statistically significant. Patients with 7 injured body regions had the highest mortality of 100%, while patients with 6 injured body regions had the lowest mortality and ineffective rate of 0%.

Table 4.46. Correlation analysis between number of injured body regions and outcomes among patients with multiple traffic injuries.

Number of injured body regions	Dead	Invalid	Improved	Cured	Chi-square	p-value
2	13	13	186	299	11.778	0.038
3	5	6	125	158	-	-
4	1	4	52	56	-	-
5	2	1	18	20	-	-
6	0	0	10	3	-	-
7	1	0	0	0	-	-

The differences in outcomes among different age groups were statistically significant for patients with multiple traffic injuries. The age group with the highest cured and improved rates was patients aged 35–44 years, with a combined rate of 96.9%, whereas the age group with the lowest rate was children below 14 years, with a combined rate of 80.5%. Similarly, the cured and improved rates for the elderly were also relatively low. As age increased, the mortality and invalid rates increased gradually, while the cured and improved rates decreased. The mortality and invalid rates for children below 14 years were 0, whereas those of the elderly above 65 years were 12.3%. These results are different from those of patients with single injuries. Multiple traffic injuries are associated with complex mechanisms, dangerous conditions, high mortality, and numerous acute complications.

Hence, these could be fatal to older patients, and could easily induce MOF (Ma *et al.*, 2012).

Table 4.47. Correlation analysis between age and outcomes among patients with multiple traffic injuries.

Age (year)	Dead	Invalid	Improved	Cured	r_s	p-value
⩽14	0	0	11	8	−0.08	0.013
15–24	1	0	17	46	-	-
25–34	1	1	56	60		-
35–44	2	4	55	84	-	-
45–54	2	7	95	134		-
55–64	4	6	94	139	-	-
⩾65	12	6	63	65	-	-

The different prehospital times of patients with multiple traffic injuries had a statistically significant impact on their outcome. Unlike patients with single injuries, these results indicate that the cured and improved rates of patients with prehospital time of 3–24 hours were the highest, at 97%, while those of patients with prehospital time more than 24 hours were the lowest, at 95.8%. As it has been generally reported in the literature that prehospital time is related to prognosis to a certain extent, the prompt transfer of patients to the hospital will increase their cure and survival rates. However, the cured and improved rates of patients with short prehospital time were the not the highest, a finding that might be related to the prehospital emergency treatment prior to admission in Shanghai.

Table 4.48. Correlation analysis between prehospital time and outcomes among patients with multiple traffic injuries.

Prehospital time (hour)	Dead	Invalid	Improved	Cured	r_s	p-value
⩽1	3	0	15	37	−0.117	<0.001
1–3	7	1	51	85	-	-
3–24	8	4	151	237	-	-
>24	4	19	174	177	-	-

The differences in outcomes among the different lengths of stay for patients with multiple traffic injuries were not significant. The mortality and invalid rates for 0–3 days of LOS were 46.5%, whereas those for more than 1 month were the lowest, at 1%. Owing to the greater severity of multiple traffic injuries, patients with a LOS shorter than 3 days are generally not discharged but have died to the severity of their condition.

Table 4.49. Correlation analysis between LOS and outcomes among patients with multiple traffic injuries.

LOS (day)	Dead	Invalid	Improved	Cured	r_s	p-value
0–3	12	8	14	9	0.174	< 0.001
4–7	2	6	72	72	-	-
8–14	2	6	103	155	-	-
15–30	5	3	144	168	-	-
⩾31	1	1	58	132	-	-

The relationship between GCS scores and outcomes was statistically significant among patients with multiple traffic injuries. Analysis of GCS scores for patients in coma showed that lower GCS scores were correlated with higher rates of mortality and ineffective treatment.

Table 4.50. Correlation analysis between GCS scores and outcomes among patients with multiple traffic injuries.

GCS	Dead	Invalid	Improved	Cured	r_s	p-value
3–8	7	8	120	192	0.292	0.011
9–12	6	3	110	149	-	-
13–14	9	9	118	92	-	-
15	0	0	0	0	-	-

The differences in outcomes of patients with different ISS were statistically significant. The ISS is a specialized scoring system for multiple injuries, and is calculated by taking the square of the highest AIS scores for different body regions. Scores of 16 and below indicate minor injuries, scores above 16 indicate severe injury, and scores above 25 indicate critical injury. Patients with ISS scores above 20 will have significantly increased fatality rates, while patients scoring above 50 rarely survive. The sample also showed that the increase in ISS scores led to the continuous increase in mortality and invalid rates.

Table 4.51. Correlation analysis between ISS and outcomes among patients with multiple traffic injuries.

ISS	Dead	Invalid	Improved	Cured	r_s	p-value
Minor	0	4	43	103	−0.176	<0.001
Moderate	7	8	120	192	-	-
Severe	6	3	110	149	-	-
Critical	9	9	118	92	-	-

4.3 Summary

Socioeconomic development and improvements in medical and health care technology have increased the human lifespan and enhanced patient quality of life. However, the incidence of traffic accidents has also risen continually with the advances in transportation networks, which has caused traffic injuries to become a threat to humans, especially among young adults below 40 years of age (Organization, 2004). This study collected the treatment information and medical records of patients with traffic injuries in order to analyze the epidemiological characteristics and injury patterns of traffic injuries. Statistical analysis was also performed to further investigate the mechanism of injury and treatment strategies in large-scale traffic accidents, which will enhance the improved and cured rates of patients with traffic injuries.

(1) Description of basic trauma information

In the descriptive analysis of basic trauma information, patients with single injuries mainly had limb and head injuries; the top three injury conditions were FJI, SSTI, and CNSI. Among coma patients, the GCS scores were mainly 3–8, which indicated severe coma. The maximum AIS score was 3, indicating that severe, non-fatal injuries were more common, which often led to functional impairment and even disabilities. Patients with multiple injuries most commonly had head, thoracic, and upper and lower limb injuries. The main injury conditions were FJI, SSTI, and CNSI. Among coma patients, the GCS scores were mainly 3–8, which indicated severe coma. The ISS scores indicated that most patients had moderate injuries.

Treatment information of traffic injuries showed that the patients were mainly EDAs. The prehospital times of single-injury patients were mostly greater than 3 hours, the most common LOS was 8–14 days, and patients with improved or cured outcomes accounted for more than 90%. The most common complication in patients with single injuries was DC. For multiple-injury patients, the prehospital time was mostly greater than 3 hours, the most common LOS was 15–30 days, and patients with improved or cured outcomes accounted for more than 50%. The most common complications in patients with multiple injuries were DC and BI.

(2) Analysis of factors influencing patient outcome

The analysis of factors influencing patient outcome showed that there were differences in the factors influencing single and multiple injuries. In terms of demographic factors and outcome, the marital status and LOS of single-injury patients had an impact on patient outcome. In contrast, among multiple-injury patients, age distribution, admission pathway, prehospital time, and LOS had an impact on patient outcome. With regard to injury characteristics, the body region of single-injury patients and the number of body regions of multiple-injury patients had an impact on patient outcome. The mortality rate of patients with head and abdominal injuries was high, while the incidence of limb injury was high. Therefore, particular attention should be given to examination of these regions during the treatment of traffic injuries (Pin *et al.*, 2006). The analysis of injury type revealed that FJI, SSTI, CNSI, and TOI could influence the outcomes of both single-injury and multiple-injury patients. PC also showed a statistically significant impact on the outcome of patients with multiple injuries. These injury types often lead to coma, massive bleeding, and BI, with dangerous and rapid disease progression. Hence, rapid, timely, and effective treatments are required (Li, 2006). The impact of complications on the outcome of traffic injuries should not be neglected, as different complications could have a direct influence on the prognosis of patients in regard to improvement and cure. These complications can be caused directly by the injury or produced later during the nursing process; hence, the treatment of traffic injuries should not stop according to the efficacy of surgery after admission, but should also focus on strengthening the nursing and functional recovery in the later stages. These efforts will help to increase the patient's quality of life to a large extent (Li, 2010; Tang *et al.*, 2016).

In addition, head injury is an important factor leading to death after traffic injuries. Coma or even shock induced by the injury has an immense impact on patient outcome.

Therefore, for both single and multiple-injury patients, GCS scores will have a significant influence on patient prognosis (Saidi *et al.*, 2014). Scoring of injury severity is a comprehensive indicator of the patient's basic condition. It is also an important basis for prehospital treatment and triage after MCIs. When dealing with MCIs, patients need to receive orderly and standardized emergency treatment; therefore, placing greater emphasis on triage can effectively reduce the time taken for patients to receive effective treatment, thus increasing patient survival rates.

References

Bereckigisolf, J.; Collie, A.; Mcclure, R. Work disability after road traffic injury in a mixed population with and without hospitalisation. *Accident Analysis & Prevention* **2013**, *51*, 129.

Brugge, D.; Lai, Z.; Hill, C.; *et al.* Traffic injury data, policy, and public health: lessons from Boston Chinatown. *Journal of Urban Health-bulletin of the New York Academy of Medicine* **2002**, *79*, 87–103.

De Ona, J.; Mujalli, R.O.; Calvo, F. Analysis of traffic accident injury severity on Spanish rural highways using Bayesian networks. *Accident Analysis & Prevention* **2011**, *43*, 402–411.

Fang, W. Disposal of traffic injury in pre hospital emergency. *Chinese Community Doctors* **2015**, *31*, 64–65.

Jiong, Z. Emergency nursing and experience of group injury caused by traffic accident. *Public Medical Forum Magazine* **2008**, 504–505.

Li, T.L. Clinical report of 288 cases of severe multiple injury in traffic accidents. *Clinical Medicine* **2010**, *30*, 62–63.

Li, T.L. Treatment of severe multiple injuries. *Chinese Journal of Spine and Spinal Cord* **2006**, 479–480.

Ma, S.; Li, Q.; Zhou, M.; *et al*. Road traffic injury in china: a review of national data sources. *Traffic Injury Prevention* **2012** *13*, 57–63.

Macbeth, W.A. Christchurch traffic trauma survey: Part 2, victims and statistics. *The New Zealand Medical Journal* **1975**, *81***,** 543.

Meng, X. Traffic injury or attempted infanticide. *Forensic Science International* **2001**, *122*, 73–74.

Peden, M. Global collaboration on road traffic injury prevention. *International Journal of Injury Control and Safety Promotion* **2005**, *12*, 85–91.

Petrucelli, E. Traffic injury: a public health concern worldwide. *Ite Journal* **1991**, *61*, 15–20.

Pin, H.; Yunchao, G.; Qinyun, W. Analysis of 346 multiple injury resulted from traffic accident. *Journal of Chinese Community Doctors* **2006**, 95–96.

Pless, B. Road traffic injury prevention. *BMJ* **2004**, *328*, 846.

Racioppi, F. *Preventing Road Traffic Injury: A Public Health Perspective for Europe*; WHO: Geneva, Switzerland, 2004.

Saidi, H.; Mutiso, B.K.; Ogengo, J.A. Mortality after road traffic crashes in a system with limited trauma data capability. *Journal of Trauma Management & Outcomes* **2014**, *8*, 4.

Tang, Z.F.; Li, B.; Ruan, H.L.; *et al*. Application of standardized treatment model in severe traffic injury. *Chinese Journal of Disaster Medicine* **2016**, *4*, 186–189.

Wang, Z.; Jiang, J. An overview of research advances in road traffic trauma in China. *Traffic Injury Prevention* **2003**, 4.

Wang, Z.; Jiang, J. Epidemiology of road traffic trauma in China-1998 in retrospect. *Traffic Injury Prevention* **2002**, 3.

Wen, L.; Pu, Y. The curation of the traffic injury. *Chinese Journal of Emergency Medicine* **2008**, *17*, 559–560.

WHO. *World Report on Road Traffic Injury Prevention*; WHO: Geneva, Switherland, 2004.

Zhan, G.W.; Mu, F.G.; Zhong, W.D. Analysis of risk factors of severe traffic injury and its prognosis. *World Latest Medicine Information* **2015**, *15*, 77–78.

Zhang, X. The epidemiological analysis and field first aid of 120 traffic trauma disease in Beijing. *Journal of Trauma Surgery* **2012**, *14*, 308–310.

Zhang, X.; Xiang, H.; Jing, R.; *et al.* Road traffic injuries in the People's Republic of China, 1951–2008. *Traffic Injury Prevention* **2011**, *12*, 614.

Chapter 5 Investigation of high-level fall injury occurrence and evolution

Qiangyu Deng, Xu Liu and Lulu Zhang
Department of Military Health Service Management, College of Military Health Service Management, Second Military Medical University, Shanghai 200433, China

5.1 Overview

5.1.1 Study background

As society develops, an increasing number of high-rise buildings have been built or are under construction. In addition to accidental incidents, suicides, and violent crimes, high-level fall have become a frequent cause of injury (Zhang, 2004) and are also one of the leading causes of accidental death (Gulati *et al.*, 2012).

A recent study showed that in Brazil, injuries due to high-level fall accounted for 12.2% of all injuries. Another study in Taiwan revealed that between 1996 and 1999, injuries in high-level fall accounted for 38.2% and 39.2% of total fatal injuries in males and females, respectively. In Singapore, injuries due to high-level fall accounted for 10.35% of injuries from all causes. High-level fall, after traffic accidents, have become one of the most common causes of fatality and serious injury, including serious injury to the head, neck, thorax, and extremities, resulting in poor prognosis, and high mortality and disability rates (Yudoyono *et al.*, 2015; Wui *et al.*, 2014; Parreira *et al.*, 2014; Tuma *et al.*, 2013; Wen, 2011).

Therefore, it is imperative to investigate the occurrence of high-level fall and the mechanism of injury. This involves analyzing the distribution of epidemiological characteristics and mechanism of injury, summarizing the risk factors and reasonable preventive measures, examining the key factors affecting patient outcome, identifying the key intervention points and treatment measures for persons sustaining injuries, optimizing treatment plans and improving outcome of victims.

5.1.2 Definition and characteristics of high-level fall injury

Injuries in high-level fall refer to bodily injuries resulting from collision with the ground or other objects after falling from a height. Prehospital emergency treatment is challenging, as the majority of cases involve multiple injuries in complex situations and occult injuries that are often overlooked (Ren, 2010; Kidher *et al.*, 2012).

Fall from height is a specific type of trauma. High-level fall may occur in any age ranges but in the majority of cases, falls involve middle-aged people and young people, followed by children. Most patients are males. In the majority of patients, injuries are multiple and may involve any part of the body, although fractures of the extremities and/or spinal cord injury combined with craniocerebral injury, visceral rupture, ribs, and bone and pelvic fractures are the most common (Ren, 2010). Bone fracture and cervical spine injury are the primary causes of fatality from injuries in high-level fall (Hino, 2012). The patient's condition is usually complicated and critical (Wang *et al.*, 2010b), rapidly changing (Van Heijl *et al.*, 2009), with high rates of misdiagnosis, mortality, coma, and life threatening complications. However, timely and accurate treatment can lower mortality rates (Yudoyono *et al.*, 2015).

There are three major causes of injury in high-level fall: accidents, suicide (Wollner *et al.*, 2015), and violent crime (Fenge *et al.*, 2015). Severity and mortality of injuries in fall from height are affected by many factors, including height of fall, age of fall victims (Adams *et al.*, 2011), physical health condition, medical treatment condition. Physical location of the injury is affected by the height of the fall (Atanasijevic *et al.*, 2005). The outcome is affected by the pre-existing health of the fall victim and medical treatment administered.

5.1.3 Basic data for the investigation

(1) Research purposes

This study examined the epidemiological characteristics and mechanism of injury in high-level fall by collecting the following data: basic personal information about the patient, clinical status and location of injuries, medical treatment, and injury outcome. Furthermore, this study analyzed the key factors affecting patient outcome to provide specific recommendations for the improvement of medical rescue of high-level fall injuries.

(2) Research information

In January 2011, the task group began to collect data from the four largest trauma centers in Shanghai City. All patients included in the study were informed about the research purposes before enrolment and provided their written consent. Data was obtained from the medical record systems of four trauma centers (burn trauma emergency center, bone trauma emergency center, trauma emergency center, and trauma emergency center & emergency critical care unit) and all records met the data eligibility criteria. Eligible medical records data were collected for the present study, with the written consent of victims of traffic accidents occurring between January 2011 and January 2015. Collected data were based on the ICD-10 and the medical records registration system procedures adopted by the Chinese hospitals. Data were then screened according to inclusion criteria to ensure the quality of the information. In-patient medical information on cases of high-level fall were extracted from the hospital information system. Standardized data encoding and input formatting were adopted for data entry of patient records in high-level fall. The final number of study samples collected was 724. As injury severity and outcome vary significantly according to whether injury is single or multiple, single injury and multiple injuries were discussed separately in this study. Of the total of 724 samples, there were 344 cases of single injury and 380 cases of multiple injuries.

5.2 Investigation results of high-level fall injury occurrence and mechanism

5.2.1 Demographic characteristics of high-level fall injury patients

There are many relevant demographic characteristics in the patients sustaining injuries due to high-level fall. The present study classified the demographic characteristics according to gender, age, and marital status.

(1) Single injury

Men accounted for 87.2% of patients with single injury in high-level fall compared to 12.8% of women, indicating that preventive and protection measures should focus on the male group.

Table 5.1. Gender of single-injury patients with high-level fall injuries.

Gender	N	%
Male	300	87.2
Female	44	12.8

The incidence of single injury in high-level fall gradually increased with age and then sharply decreased. The highest rate of injuries (25.9%) occurred in the 45–54 years age group, followed by the 55–64 years age group (23.8%). The lowest rate of injuries occurred in the 0–14 years age group (1.5%). The 65 years and older age group also had very low rates of injuries (7.3%). These incidence rates were closely related to the activities engaged in by the different age groups.

Table 5.2. Age of single-injury patients with high-level fall injuries.

Age (year)	N	%
0–14	5	1.5
15–24	25	7.3
25–34	46	13.4
35–44	72	20.9
45–54	89	25.9
55–64	82	23.8
≥65	25	7.3

Among patients with single injury in high-level fall, the majority of patients were married (73.3%) and there were no divorced/widowed patients. Patients who were single accounted for approximately one-fourth of patients (26.7%). These results may reflect Chinese culture as the majority of Chinese adults are married.

Table 5.3. Marital status of single-injury patients with high-level fall injuries.

Marital status	N	%
Divorced/widowed	0	0
Single	92	26.7
Married	252	73.3

(2) Multiple injuries

Among 380 patients sustaining multiple injuries in high-level fall, 325 (85.5%) were men compared to 14.5% of women. The prevalence of men was slightly lower than in patients with single injury.

Table 5.4. Gender of multiple-injury patients with high-level fall injuries.

Gender	N	%
Male	325	85.5
Female	55	14.5

The occurrence rate of multiple injuries in high-level fall gradually increased with age and then sharply decreased. The highest rate (25.9%) of multiple injuries occurred in the 45–54 years age group, as with single injury. The second highest rate (23.4%) was observed in the 35–44 years age group. In single injury, the second highest rate of injury occurred in the 55–64 years age group, suggesting multiple injuries were more likely in the younger age groups than single injury. The lowest rate (1.5%) of multiple injuries occurred in the 0–14 age group while the rate of multiple injuries among 65 years and older group was 5.5%.

Table 5.5. Age of multiple-injury patients with high-level fall injuries.

Age (year)	N	%
0–14	7	1.8
15–24	49	12.9
25–34	52	13.7
35–44	89	23.4
45–54	100	26.3
55–64	62	16.3
≥65	21	5.5

Among patients with multiple injuries in high-level fall, there was one divorced/widowed patient (0.3%). The majority of patients were married (79.2%), which was comparable to the marital status of patients with single injury.

Table 5.6. Marital status of multiple-injury patients with high-level fall injuries.

Marital status	N	%
Divorced/widowed	1	0.3
Single	78	20.5
Married	301	79.2

5.2.2 Injury characteristics of high-level fall injury patients

Characteristics of injuries in patients following high-level fall were categorized according to injured body region, injury condition, GCS, and AIS.

(1) Single injury

The primary injured body region in patients with a single injury sustained in high-level fall was as follows: spine (36.9%), extremities (32.8%), and head (23.3%). The surface areas of these anatomical sites are relatively large upon contact with the external environment during a fall and their structures are relatively hard, with limited protection, making these structures prone to serious injury. Abdominal injuries accounted for only 1.2% of injuries.

In the majority of the 344 patients with single injury, most injuries were fractures and joint injuries (86.3%), followed by SSTI (32.3%), and CNSI (27.3%). No patient sustained disintegration of the body (0.0%) and a limited proportion of patients sustained TOI (0.9%), TH (1.5%), and PC (2.3%).

When assessing GCS of patients with single injury sustained after high-level fall, the majority (2.9%) of patients were seriously ill (GCS 3–8). Only 0.6% of patients were moderately ill (GCS 9–12) and 0.6% were mildly ill (GCS 13–14).

Table 5.7. Injured body region of single-injury patients with high-level fall injuries.

Injured body region	**N**	**%**
Head	80	23.3
Thorax	11	3.2
Abdomen	4	1.2
Spine	127	36.9
Pelvis	9	2.6
Extremities	113	32.8

Table 5.8. Injury condition of single-injury patients with high-level fall injuries.

Injury condition	**N**	**%**
FJI	297	86.3
SSTI	111	32.3
DT	0	0
CNSI	94	27.3
PC	8	2.3
TH	5	1.5
TOI	3	0.9

Table 5.9. GCS scores of single-injury patients with high-level fall injuries.

GCS	**N**	**%**
3–8	10	2.9
9–12	2	0.6
13–14	2	0.6
15	4	1.1
NA	326	94.8

Overall injury severity in patients with single injury following high-level fall exhibited a normal distribution. The majority of patients were seriously ill (AIS = 3, 52%), followed by moderately ill patients (AIS = 2, 30.5%). All patients survived.

Table 5.10. AIS of single-injury patients with high-level fall injuries.

AIS	N	%
1	12	3.5
2	105	30.5
3	179	52.0
4	23	6.7
5	25	7.3
6	0	0

(2) Multiple injuries

Injured body regions in patients with multiple injuries in high-level fall largely involved the torso, as follows: spine (61.8%), head (55.5%), and thorax (55.5%). The upper and lower extremities accounted for 42.9% and 34.2%, respectively, of injuries (Table 5.11).

In patients with multiple injuries, the distribution by injury condition was as follows: FJI (96.3%), SSTI (62.4%), DT (0.8%), CNSI (37.4%), PC (36.3%), TH (21.8%), and TOI (8.2%). These findings suggest that, compared to single injury, the condition of patients with multiple injuries was more complicated and severe.

Patients with multiple injuries due to high-level fall with available GCS scores had relatively severe injuries. In 4.2% of cases patients were seriously ill patients (GCS of 3–8), while in only 0.5% of cases, injury was mild (GCS of 14).

Unlike the normal distribution of AIS scores of patients with single injury in high-level fall, the ISS of patients with multiple injuries showed that the majority of patients had higher ISS, suggesting that injury severity was greater in patients with multiple injuries. Patients with mild injury (ISS of 1–8) accounted for the lowest proportion of patients (4.7%) while critically ill patients (ISS ≥ 25) accounted for the highest proportion of patients (33.9%).

Table 5.11. Injured body regions of multiple-injury patients with high-level fall injuries.

Injured body region	N	%
Head	211	55.5
Thorax	211	55.5
Abdomen	46	12.1
Spine	235	61.8
Pelvis	87	22.9
Upper extremities	163	42.9
Lower extremities	130	34.2

Table 5.12. Injury condition of multiple-injury patients with high-level fall injuries.

Injury condition	N	%
FJI	366	96.3
SSTI	237	62.4
DT	3	0.8
CNSI	142	37.4
PC	138	36.3
TH	83	21.8
TOI	31	8.2

Table 5.13. GCS scores of multiple-injury patients with high-level fall injuries.

GCS	N	%
3–8	16	4.2
9–12	5	1.3
13–14	2	0.5
15	6	1.6
NA	351	91.8

Table 5.14. ISS of multiple-injury patients with high-level fall injuries.

ISS	N	%
1–8	18	4.7
9–15	111	29.2
16–24	122	32.1
≥25	129	33.9

5.2.3 Treatment of high-level fall injury patients

This study evaluated the standard treatment for patients following high-level fall according to the following variables: admission pathway, prehospital time, LOS, outcome, and complications.

(1) Single injury

The admission pathway of patients with single injury in high-level fall was evenly distributed and was primarily via the ED (39.0%). RHS and RHOC accounted for 24.4% and 36.6%, respectively, indicating that the treatment level for injuries following high-level fall in the surveyed hospitals is highly influential in the neighboring region.

For patients with single injury in high-level fall, a prehospital time was generally longer. Prehospital time more than 24 hours accounted for 52.9% of cases, while a prehospital time of 1 hour or less accounted for the lowest proportion of cases (0.6%).

Most patients with single injury in high-level fall remained in hospital for 1–2 weeks. Specifically, 34.3% of patients had a hospital stay of 8–14 days and 34% had a hospital stay of 4–7 days. These findings indicated that injury was less severe in patients with single injury and the course of treatment was shorter.

Table 5.15. Admission pathway of single-injury patients with high-level fall injuries.

Admission pathway	N	%
RHOC	126	36.6
RHS	84	24.4
EDA	134	39.0

Table 5.16. Prehospital time of single-injury patients with high-level fall injuries.

Prehospital time (hour)	N	%
≤1	2	0.6
1–3	45	13.1
4–24	115	33.4
>24	182	52.9

Table 5.17. LOS of single-injury patients with high-level fall injuries.

LOS (day)	N	%
0–3	25	7.3
4–7	117	34.0
8–14	118	34.3
15–30	63	18.3
≥31	21	6.1

Among the patients with single injury in high-level fall, 65.7% recovered and were discharged, while only a small proportion died (0.3%), indicating that injury in patients with singly injury was less severe and that the medical treatment level in Shanghai City was generally better.

Table 5.18. Outcome of single-injury patients with high-level fall injuries.

Outcome	N	%
Dead	1	0.3
Invalid	19	5.5
Improved	98	28.5
Cured	226	65.7

The rates of hospital complications in patients with singly injury in high-level fall were as follows: DC (21.8%), and paraplegia (11.3%). None of the following complications were observed in this study: ABI, ARDS, MODS, and MOF.

Table 5.19. Hospital complications in patients with single injury in high-level fall.

Hospital complications	N	%
HS	2	0.6
DC	75	21.8
Apnea	2	0.6
CA	2	0.6
CH	2	0.6
Paraplegia	39	11.3
AF	1	0.3
WED	3	0.9
ABI	0	0.0
ARDS	0	0.0
ARF	3	0.9
MOF	0	0.0
MODS	0	0.0
BI	18	5.2

(2) Multiple injuries

The admission pathway of patients with multiple injuries and patients with single injury in high-level fall was primarily via the ED. RHS accounted for 26.8% of admissions and RHOC accounted for 34.5%.

Table 5.20. Admission pathway of multiple-injury patients with high-level fall injuries.

Admission pathway	N	%
RHOC	131	34.5
RHS	102	26.8
EDA	147	38.7

The prehospital time of patients with multiple injuries was relatively shorter than that of patients with single injury, although it remained significant. Prehospital time was distributed as follows: >24 hours in 42.6% of cases, 4–24 hours in 39.5% of cases, and ≤1 hour in 6.1% of cases. These findings suggest that hospital emergency evacuation capabilities in handling patients are in urgent need of improvement.

Table 5.21. Prehospital time of multiple-injury patients with high-level fall injuries.

Prehospital time (hour)	N	%
≤1	23	6.1
1–3	45	11.8
4–24	150	39.5
>24	162	42.6

Compared to patients with single injury, LOS of patients with multiple injuries was generally longer, typically between 2–3 weeks. The majority of patients (38.4%) had a hospital stay of 15–30 days, followed by 28.4% of patients with a hospital stay of 9–14 days.

Table 5.22. LOS of multiple-injury patients with high-level fall injuries.

LOS (day)	N	%
0–3	16	4.2
4–7	62	16.3
8–14	108	28.4
15–30	146	38.4
≥31	48	12.6

The majority of patients with multiple injuries in high-level fall recovered and were discharged (53.2%), these finding were comparable to those in patients with single injury. Only a small proportion of patients died (1.1%), suggesting that the standard of treatment in Shanghai City is relatively high.

Table 5.23. Outcome of multiple-injury patients with high-level fall injuries.

Outcome	N	%
Dead	4	1.1
Invalid	11	2.9
Improved	163	42.9
Cured	202	53.2

The highest proportion of hospital complications in patients with multiple injuries in high-level fall were associated with DC (33.7%, which was greater than that in single-injury patients), followed by paraplegia (17.6%), BI (13.9%). Of note, ARDS was not reported in this study. These findings indicated that hospital complications were more complicated and serious in patients with multiple injuries.

Table 5.24. Hospital complications of multiple-injury patients with high-level fall injuries.

Hospital complications	N	%
HS	32	8.4
DC	128	33.7
Apnea	1	0.3
CA	1	0.3
CH	3	0.8
Paraplegia	67	17.6
AF	7	1.8
WED	16	4.2
ABI	5	1.3
ARDS	0	0.0
ARF	4	1.1
MODS	6	1.6
BI	53	13.9

5.2.4 Comorbidities in high-level fall injury patients

The pre-existing physical condition of patients was significantly correlated with the severity of injury and outcome in patients following high-level fall. In the current study, the following comorbidities were examined: diabetes, hypertension, and osteoporosis in patients with single injury; and diabetes and hypertension in patients with multiple morbidities.

(1) Single injury

Among patients with single injury in high-level fall, 7.5% of patients had comorbidities. The most frequent comorbidity observed was hypertension (5.8%), followed by diabetes (1.7%). No patients with osteoporosis were identified in this study.

Table 5.25. Comorbidity of single-injury patients with high-level fall injuries.

Comorbidity	N	%
Diabetes	6	1.7
Hypertension	20	5.8
Osteoporosis	0	0.0

(2) Multiple injuries

Comorbidity rates between patients with multiple injuries and single injury in high-level fall were comparable: overall comorbidity rate was 7.3% among patients with multiple injuries and specifically, hypertension accounted for the highest proportion of comorbidity (5.5%), followed by diabetes (1.8%).

Table 5.26. Comorbidity of multiple-injury patients with high-level fall injuries.

Comorbidity	N	%
Diabetes	7	1.8
Hypertension	21	5.5

5.2.5 Patient outcomes and impact factors in high-level fall injuries

The current study used SPSS software (version 17.0, SPSS Inc., Chicago, IL, USA) for univariate factor analysis to explore the factors that impacted patient outcomes in high-level fall injuries (statistical significance was set at $p < 0.05$). Patient outcomes in high-level fall injuries (dead, invalid, improved, cured) were treated as outcome variables using nonparametric tests. The original data were arranged in a R*C table, where the rows represented grouping variables and the columns represented outcome variables. Different statistical methods were selected, based on the type of grouping variables in the R*C table: the Mean-Whitney U test comparing two independent samples was used for binary grouping variables; the Kruskal Wallis H test comparing multiple independent samples was used for categorical variables; and the Spearman rank correlation test was used for ordinal variables when ranking of variables was relevant.

5.2.5.1 Single injury

(1) Comparison of binary categorical independent variables using the Mann-Whitney U test

Gender had no statistically significant effect on the outcome of patients with single injury in high-level fall ($p = 0.516$). The recovery rate and death rate in male patients were 66.3% and 0.3%, respectively. The recovery rate and death rate in female patients were 61.4% and 0.0%, respectively.

Table 5.27. Comparison of outcomes between different genders among patients with single high-level fall injury.

Gender	Dead	Invalid	Improved	Cured	U-value	p-value
Male	1	16	84	199	6266.5	0.516
Female	0	3	14	27	-	-

The impact of different injury conditions in patients with single injury in high-level fall on patient outcomes was variable. The following conditions had no statistically significant impact on patient outcome: FJI, PC, TH, and TOI. Recovery rates were significantly lower with the following conditions: SSTI (70.4% *vs.* 55.9% without SSTI) and CNSI (72.0% *vs.* 48.9% without CNSI) ($p < 0.05$).

Table 5.28. Comparison of outcomes among different injury conditions of patients with single high-level fall injury.

Injury condition	Dead	Invalid	Improved	Cured	U-value	p-value
FJI					6026.5	0.071
No	0	0	23	24		
Yes	1	19	75	202		
SSTI					11298.5	0.023
No	0	16	53	164		
Yes	1	3	45	62		
CNSI					9159.0	<0.001
No	0	14	56	180		
Yes	1	5	42	46		
PC					1330.0	0.952
No	1	19	95	221		
Yes	0	0	3	5		
TH					656.5	0.299
No	1	19	95	224		
Yes	0	0	3	2		
TOI					496.5	0.916
No	1	19	97	224		
Yes	0	0	1	2		

The recovery rates of patients with single injury in high-level fall were lower when associated with the following conditions: paraplegia (43.6% vs. 68.5% without paraplegia), WED (0.00% vs. 66.3% without WED), ARF (0.00% vs. 66.3% without ARF), and BI (27.8% vs. 67.8%) ($p < 0.05$). These findings indicate that the role of the conditions above is crucial.

The impact of HS, DC, apnea, CA, CH, AF, ABI, ARDS, MOF, and MODS on the outcomes of patients with single injury following high-level fall was not statistically significant.

The impact of comorbidity (including diabetes and hypertension) on outcomes of patients with single injury in high-level fall was not statistically significant.

Table 5.29. Comparison of outcomes among different complications of patients with single high-level fall injury.

Hospital complication	Dead	Invalid	Improved	Cured	U-value	p-value
HS					224.0	0.312
No	1	19	98	224		
Yes	0	0	0	2		
DC					8981.0	0.081
No	0	17	68	184		
Yes	1	2	30	42		
Apnea					136.0	0.078
No	1	19	96	226		
Yes	0	0	2	0		
CA					68.5	0.213
No	1	19	97	226		
Yes	0	0	1	0		
CH					224.0	0.312
No	1	19	98	224		
Yes	0	0	0	2		
Paraplegia					4684.5	0.009
No	1	19	76	209		
Yes	0	0	22	17		
AF					68.5	0.213
No	1	19	97	226		
Yes	0	0	1	0		
WED					144.0	0.010
No	1	18	96	226		
Yes	0	1	2	0		
ABI					-	-
No	1	19	98	226		
Yes	0	0	0	0		
ARDS					-	-
No	1	19	98	226		
Yes	0	0	0	0		
ARF					202.5	0.030
No	1	19	95	226		
Yes	0	0	3	0		
MOF					-	-
No	1	19	98	226		
Yes	0	0	0	0		
MODS					-	-
No	1	19	98	226		
Yes	0	0	0	0		
BI					1831.5	0.001
No	1	18	86	221		
Yes	0	1	12	5		

Table 5.30. Comparison of outcomes among different comorbidities of patients with single high-level fall injury.

Comorbidity	Dead	Invalid	Improved	Cured	U-value	p-value
Diabetes					882.0	0.511
No	1	19	95	223		
Yes	0	0	3	3		
Hypertension					2800.0	0.221
No	1	19	88	216		
Yes	0	0	10	10		
Osteoporosis					-	-
No	1	19	98	226		
Yes	0	0	0	0		

(2) Comparison of multiple categorical independent variables using the Kruskal Wallis H test

The impact of marital status on the outcomes of patients with single injury in high-level fall was not statistically significant ($p = 0.383$). The recovery rate of single patients was 62.0%, while the recovery rate of married patients was 67.1%.

Table 5.31. Comparison of outcomes among different marital status of patients with single high-level fall injury.

Marital status	Death	Negative	Positive	Recovery	Chi-square	p-value
Divorced/widowed	0	0	0	0	0.761	0.383
Single	0	6	29	57	-	-
Married	1	13	69	169	-	-

The impact of the admission pathway on the outcomes of patients with single injury in high-level fall was not statistically significant ($p = 0.628$). Recovery rates according to admission pathway were as follows: RHOC (65.9%), RHS (69.0%), and admissions via the ED (63.4%).

Table 5.32. Comparison of outcomes among different admission pathways of patients with single high-level fall injury.

Admission pathway	Dead	Invalid	Improved	Cured	Chi-square	p-value
RHOC	0	4	39	83	0.929	0.628
RHS	0	5	21	58	-	-
EDA	1	10	38	85	-	-

There was a statistically significant correlation between injured body region and outcomes in patients with single injury in high-level fall ($p < 0.05$). The lowest (45.5%) recovery rates were observed in patients with thoracic injuries and the highest (77.9%) recovery rates were observed in injuries of the extremities, indicating that the condition of patients with thoracic injuries was more critical.

Table 5.33. Comparison of outcomes among different injured body regions of patients with single high-level fall injury.

Injured body region	Dead	Invalid	Improved	Cured	Chi-square	p-value
Head	1	3	37	39	15.665	0.008
Thorax	0	0	6	5	-	-
Abdomen	0	0	1	3	-	-
Spine	0	4	39	84	-	-
Pelvis	0	0	2	7	-	-
Extremity	0	12	13	88	-	-

(3) Comparison of ordinal categorical independent variables using the Spearman rank correlation test

Age did not significantly correlate with outcomes of patients with single injury in high-level fall ($p = 0.356$). Nevertheless, an inverse association was found between recovery rates and age. Patients ≤14 years of age had the highest recovery rate (80.0%), while patients ≥65 years of age had the lowest recovery rate (44.0%).

Table 5.34. Correlation analysis between age and outcomes among patients with single high-level fall injury.

Age (year)	Dead	Invalid	Improved	Cured	r_s	p-value
≤14	0	0	1	4	-0.050	0.356
15–24	0	1	7	17	-	-
25–34	0	3	14	29	-	-
35–44	0	3	21	48	-	-
45–54	1	6	20	62	-	-
55–64	0	4	23	55	-	-
≥65	0	2	12	11	-	-

Prehospital time did not significantly correlate with the outcome of patients with single injury in high-level fall ($p = 0.126$). Nevertheless, patients with a prehospital time of ≤1 hour had the highest recovery rate (100%), while patients with a prehospital time of 3-24 hours had the lowest recovery rate (60.9%).

Table 5.35. Correlation analysis between prehospital time and outcomes among patients with single high-level fall injury.

Prehospital time (hour)	Dead	Invalid	Improved	Cured	r_s	p-value
≤1	0	0	0	2	0.083	0.126
1–3	1	3	13	28	-	-
3–24	0	10	35	70	-	-
>24	0	6	50	126	-	-

The impact of LOS correlated significantly with the outcomes of patients with single injury in high-level fall ($p < 0.001$). The recovery rate of patients with a hospital stay of 0–3 days was the lowest (20.0%), while the recovery rate of patients with a hospital stay of 8–14 days was the highest (78.0%), suggesting that a longer hospital stay was conducive to improvement in patient outcome.

Table 5.36. Correlation analysis between LOS and outcomes among patients with single high-level fall injury.

LOS (day)	Dead	Invalid	Improved	Cured	r_s	p-value
0–3	1	11	8	5	0.211	<0.001
4–7	0	7	37	73	-	-
8–14	0	0	26	92	-	-
15–30	0	0	20	43	-	-
≥31	0	1	7	13	-	-

The GCS score did not significantly correlate with outcomes of patients with single injury in fall from height (p = 0.872); however, less severe injuries were associated with a higher recovery rate.

Table 5.37. Correlation analysis between GCS and outcomes among patients with single high-level fall injury.

GCS	Dead	Invalid	Improved	Cured	r_s	p-value
3–8	1	1	2	6	0.162	0.872
9–12	0	0	2	0	-	-
13–14	0	0	0	2	-	-
15	0	0	2	2	-	-

AIS scores did not significantly correlate with the outcomes of patients with single injury in high-level fall (p = 0.113). The recovery rate of patients with mild injury (AIS = 1) was 33.33%, while the recovery rate of patients with critical injury was 40.0%.

Table 5.38. Correlation analysis between AIS and outcomes among patients with single high-level fall injury.

AIS	Dead	Invalid	Improved	Cured	r_s	p-value
1	0	0	8	4	−0.086	0.113
2	0	8	19	78	-	-
3	1	11	46	121	-	-
4	0	0	10	13	-	-
5	0	0	15	10	-	-
6	0	0	0	0	-	-

5.2.5.2 Multiple injuries

(1) Comparison of binary categorical independent variables using the Mann-Whitney U test

Gender had no statistical significance on the outcome of patients with multiple injuries in high-level fall. The recovery rate and death rate of male patients were 53.5% and 0.9%, respectively. The recovery rate and death rate in female patients were 50.9% and 1.8%, respectively.

Table 5.39. Comparison of outcomes between different genders among patients with multiple high-level fall injuries.

Gender	Dead	Invalid	Improved	Cured	U-value	p-value
Male	3	9	139	174	8636.5	0.649
Female	1	2	24	28	-	-

The impact of injured body region on outcomes of patients with multiple injuries in high-level fall was variable. Lower recovery rates were observed among patients with the following injuries: head injury (47.4% *vs.* 60.4% without head injury), thoracic injury (47.9% *vs.* 59.8% without thoracic injury), abdominal injury (39.1% *vs.* 55.1% without abdominal injury). However, the recovery rate of patients with multiple injuries in high-level fall with injury of the lower extremities was higher (65.4%) than that in patients without injury to the lower extremities (46.8%). Injuries of the spine, pelvis, or upper extremities had no statistically significant effect on outcome of patients with multiple injuries in high-level fall.

Table 5.40. Comparison of outcomes among different injured body regions of patients with multiple high-level fall injuries.

Injured body region	Dead	Invalid	Improved	Cured	U-value	p-value
Head					15806.5	0.030
No	1	8	58	102		
Yes	3	3	105	100		
Thorax					15648.5	0.020
No	2	3	63	101		
Yes	2	8	100	101		
Abdomen					6295.5	0.024
No	1	10	139	184		
Yes	3	1	24	18		
Spine					15793.5	0.173
No	2	6	52	85		
Yes	2	5	111	117		
Pelvis					11651.0	0.166
No	4	8	131	150		
Yes	0	3	32	52		
Upper extremity					17515.0	0.855
No	3	7	90	117		
Yes	1	4	73	85		
Lower extremity					13327.5	0.001
No	4	6	123	117		
Yes	0	5	40	85		

The recovery rate of patients with multiple injuries in high-level fall were significantly lower when associated with the following types of injury: SSTI (47.3% *vs.* 62.9% without SSTI), CNSI (41.5% *vs.* 60.1% without CNSI), PC (43.5% *vs.* 58.7% without PC), and TH (33.7% *vs.* 58.6% without TH). FJI, and DT had no statistically significant effect on outcome of patients with multiple injuries in high-level fall.

The death rates of patients with multiple injuries in high-level fall were significantly higher when associated with the following conditions: HS (6.3% *vs.* 0.6% without HS), DC (2.3% *vs.* 0.4% without DC), and MODS (33.3% *vs.* 0.5% without MODS). The recovery rates of patients with multiple injuries in high-level fall were significantly lower when associated with the following: paraplegia (29.9% *vs.* 58.1% without paraplegia) and BI (41.1% *vs.* 55.0% without BI). The impact of complications due to apnea, CH, AF, WED, ABI, ARDS, and ARF on the outcome of patients with multiple injuries in high-level fall was also statistically insignificant.

The impact of diabetes and hypertension on the outcome of patients with multiple injuries in high-level fall was not statistically significant.

Table 5.41. Comparison of outcomes among different injury conditions of patients with multiple high-level fall injuries.

Injury condition	Dead	Invalid	Improved	Cured	U-value	p-value
FJI					2348.0	0.546
No	0	0	8	6		
Yes	4	11	155	196		
SSTI					14420.5	0.006
No	1	5	47	90		
Yes	3	6	116	112		
DT					467.5	0.556
No	4	11	161	201		
Yes	0	0	2	1		
CNSI					14025.5	0.002
No	2	9	84	143		
Yes	2	2	79	59		
PC					14215.5	0.006
No	3	6	91	142		
Yes	1	5	72	60		
TH					9051.0	<0.001
No	2	6	115	174		
Yes	2	5	48	28		
TOI					3965.5	0.005
No	1	10	146	192		
Yes	3	1	17	10		

Table 5.42. Comparison of outcomes among different complications of patients with multiple high-level fall injuries.

Hospital complications	Dead	Invalid	Improved	Cured	U-value	p-value
HS					4125	0.006
No	2	10	144	192		
Yes	2	1	19	10		
DC					14026.5	0.018
No	1	6	101	144		
Yes	3	5	62	58		

Table 5.42. *Cont.*

Hospital complications	Dead	Invalid	Improved	Cured	U-value	p-value
Apnea					9.0	0.061
No	4	10	163	202		
Yes	0	1	0	0		
CA					9.0	0.061
No	4	10	163	202		
Yes	0	1	0	0		
CH					298.5	0.109
No	4	11	163	199		
Yes	0	0	0	3		
Paraplegia					7610.0	<0.001
No	4	8	119	182		
Yes	0	3	44	20		
AF					1230.0	0.765
No	4	11	160	198		
Yes	0	0	3	4		
WED					2606.5	0.418
No	4	10	155	195		
Yes	0	1	8	7		
ABI					835.0	0.632
No	4	11	160	200		
Yes	0	0	3	2		
ARDS					-	-
No	4	11	163	202		
Yes	0	0	0	0		
ARF					578.5	0.366
No	4	11	162	199		
Yes	0	0	1	3		
MODS					554.5	0.015
No	2	11	160	201		
Yes	2	0	3	1		
BI					7377.0	0.048
No	4	7	136	180		
Yes	0	4	27	22		

Table 5.43. Comparison of outcomes among different comorbidities of patients with multiple high-level fall injuries.

Comorbidity	Dead	Invalid	Improved	Cured	U-value	p-value
Diabetes					1198.5	0.672
No	4	11	159	199		
Yes	0	0	4	3		
Hypertension					3543.0	0.598
No	4	11	154	190		
Yes	0	0	9	12		

(2) Comparison of multiple categorical independent variables using the Kruskal Wallis H test

There was no significant correlation between marital status and outcomes of patients with multiple injuries in high-level fall (p = 0.486). The recovery rate and death rate of single patients were 57.7% and 1.3%, respectively, while the recovery rate and death rate of married patients were 51.8% and 1.0%, respectively.

Table 5.44. Comparison of outcomes among different marital status of patients with high-level fall injuries.

Marital status	Dead	Invalid	Improved	Cured	Chi-square	p-value
Divorced/widowed	0	0	0	1	1.443	0.486
Single	1	3	29	45	-	-
Married	3	8	134	156	-	-

There was no significant correlation between admission pathway and outcomes of patients with multiple injuries in high-level fall (p = 0.754). The recovery rates were comparable: 51.9% for RHOC; 51% for RHS; and 55.8% for admissions via the ED.

Table 5.45. Comparison of outcomes among different admission pathways of patients with multiple high-level fall injuries.

Admission pathway	Dead	Invalid	Improved	Cured	Chi-square	p-value
RHOC	0	7	56	68	0.565	0.754
RHS	2	0	48	52	-	-
EDA	2	4	59	82	-	-

(3) Comparison of ordinal categorical independent variables using the Spearman rank correlation test

Number of injured body regions had not statistical significance on the outcome of patients with multiple injuries in high-level fall (p = 0.288); the more the number of injured body regions, the lower the recovery rate. When the number of injured body regions was 2, the recovery rate was 56.0%; when the number of injured body regions was 6, the recovery rate was 20.0%.

There was no significant correlation between age and outcomes of patients with multiple injuries in high-level fall (p = 0.953). The highest recovery rate (71.4%) was found among patients ≤14 years while the lowest recovery rate (47.6%) was found among patients ≥65 years.

Table 5.46. Correlation analysis between number of injured body regions and outcomes among patients with multiple high-level fall injuries.

Number of injured body regions	Dead	Invalid	Improved	Cured	r_s	p-value
2	2	5	73	102	−0.078	0.128
3	1	5	40	61	-	-
4	1	1	35	27	-	-
5	0	0	11	10	-	-
6	0	0	4	1	-	-
7	0	0	0	1	-	-

Table 5.47. Correlation analysis between age and outcomes among patients with multiple high-level fall injuries.

Age (year)	Dead	Invalid	Improved	Cured	r_s	p-value
≤14	0	1	1	5	0.003	0.953
15–24	1	1	22	25	-	-
25–34	0	3	23	26	-	-
35–44	0	3	38	48	-	-
45–54	1	1	43	55	-	-
55–64	2	0	27	33	-	-
≥65	0	2	9	10	-	-

There was no significant correlation between pre-hospital time and outcomes of patients with multiple injuries in high-level fall ($p = 0.569$). The highest recovery rate (60.9%) was found among patients with a prehospital time less than1 hour while the lowest recovery rate (48.9%) was found among patients with a prehospital time of 1–3 hours.

Table 5.48. Correlation analysis between prehospital time and outcomes among patients with multiple high-level fall injuries.

Prehospital time (hour)	Dead	Invalid	Improved	Cured	r_s	p-value
≤1	1	2	6	14	−0.029	0.569
1–3	0	0	23	22	-	-
3–24	3	3	60	84	-	-
>24	0	6	74	82	-	-

There was no significant correlation between LOS and outcomes of patients with multiple injuries in high-level fall ($p = 0.053$). Patients with a hospital stay of 0–3 days had the lowest recovery rate (12.5%) while patients with a hospital stay more than31 days had the highest recovery rate (62.5%).

Table 5.49. Correlation analysis between LOS and outcomes among patients with multiple high-level fall injuries.

LOS (day)	Dead	Invalid	Improved	Cured	r_s	p-value
0–3	3	6	5	2	0.099	0.053
4–7	1	1	23	37	-	-
8–14	0	1	50	57	-	-
15–30	0	2	68	76	-	-
≥31	0	1	17	30	-	-

There was no significant correlation between GCS and outcomes of patients with multiple injuries in high-level fall ($p = 0.089$). The recovery rate of patients with mild head injury (GSC 13–14) was 100%.

The ISS correlated significantly with the outcomes of patients with multiple injuries in high-level fall ($p < 0.001$). The recovery rate of patients, according to injury severity were as follows: 61.1% for mild injury (ISS 1–8); 68.5% for moderate injury (ISS 9–15); 52.5% for serious injury (ISS 16–24) 39.5% for critical injury (ISS ≥ 25).

Table 5.50. Correlation analysis between GCS scores and outcomes among patients with multiple high-level fall injuries.

GCS	Dead	Invalid	Improved	Cured	r_s	p-value
3–8	2	2	9	3	0.255	0.089
9–12	0	0	1	4	-	-
13–14	0	0	0	2	-	-
15	0	0	5	1	-	-

Table 5.51. Correlation analysis between ISS and outcomes among patients with multiple high-level fall injuries.

ISS	Dead	Invalid	Improved	Cured	r_s	p-value
1–8	0	1	6	11	−0.226	<0.001
9–15	1	1	33	76	-	-
16–24	1	3	54	64	-	-
≥25	2	6	70	51	-	-

5.3 Summary

The demographic characteristics between patients with single injury and multiple injuries in high-level falls were similar. The majority of the patients were male (87.2% with single injury; 85.5% with multiple injuries). These findings reflect the characteristics of social life and are consistent with study conducted abroad (Tuma *et al.*, 2013). Men are more likely to engage in dangerous work at height, therefore, injury prevention and protection measures should focus on men and high-level fall. Over 25% of patients were aged between 45 and 54 years. Three-quarters of patients were married. However, this result does not suggest that married persons are prone to high-level fall injuries; it reflects the married status of the majority of adults in China, characteristic of Chinese culture.

Characteristics of injury conditions in patients of high-level fall were: primary injured body regions in patients with single injury was focused on the spine (36.9%) and extremities (32.8%); primary injury conditions were fracture (86.3%) and SSTI (32.3%), which were consistent with the study results from other researchers (Gulati *et al.*, 2012; Kihiko *et al.*, 2010). Kihiko analyzed the injury conditions in children of 1–13 years of age in Kenyatta National Hospital with primary injured body regions in the head and extremities, and the primary injury condition being fracture. GCS score was a key diagnostic indicator for severely injured patients of high-level fall (Lapostolle *et al.*, 2004). The GCS was mostly concentrated in the range of 3-8 and AIS of 3 accounted for the highest percentage (52.0%). Multiple injuries primarily happened in the spine (61.8%), head (55.5%), and thorax (55.5%), which were the same as in the research results of Tuma, M.A. who studied construction workers who were injured from high-level fall in Qatar. In Japan, percentage of head injury from high-level fall was even higher that accounted for 70% of all fatal injuries in high-level fall (Hino, 2012). Injury condition and GCS of patients with multiple injuries were similar to the situation in patients with single injury. The higher the percentage of patients in the high ISS interval, the higher the percentage of

ISS ≥ 25 (33.9%). These results indicate that injury condition in patients with multiple injuries in high-level fall is generally severe.

Basic treatment information on injuries following high-level fall: the admission pathway for patients with single injury was primarily admission via the ED with relatively long prehospital times (52.9% of patients for over 24 hours of waiting). LOS was characterized by a normal distribution, with the most frequent LOS ranging from 3 to 14 days (68.3%). Recovery occurred in 65.7% of patients, with only one case of death due to failure to respond to treatment (0.3%). Major hospital complications were DC (21.8%) and paraplegia (11.3%). The admission pathway, prehospital time, outcome, and hospital complications of patients with multiple injuries were similar to those in patients with single injuries. The only differences observed were in the LOS (14–30 days in 38.4% of patients with multiple injuries) and the rate of BI (13.9% in patients with multiple injuries), suggesting that injury was more severe in these patients. Injuries sustained following high-level fall were often critical, with most fatalities occurring at the scene of accident and in the early stages of treatment (Lapostolle *et al.*, 2004). Therefore, timely and effective prehospital treatment is crucial.

Comorbidity in patients who sustain high-level fall has been widely discussed (Leenen, 2015). The current study examined three comorbidities, namely diabetes, hypertension, and osteoporosis, as these conditions have an important impact on patient outcome. Hypertension was the primary comorbidity in both patients with single injury (5.8%) and with multiple injuries (5.5%).

Outcome of patients and impact factors in high-level fall: factors that significantly affected the outcome in patients with single injury included injury condition, complications, and injured body region. Outcome correlated significantly with LOS in patients with single injury while correlations between outcome and other variables were not statistically significant. In patients with multiple injuries, outcome was significantly associated with injured body region, injury condition, complications, and ISS. Correlations between outcome and other variables were not statistically significant. Contrary to the findings reported by Lapostolle *et al.* (2004), the current study did not establish a significant correlation between GCS and outcome. In a case study, Zasa *et al.* (2015) reported the rescue and successful treatment of a 16-year-old boy who fell from a height of 15 meters. However, the current study did not find any significant correlation between age and outcome of patients sustaining high-level fall. This study found that the recovery rate of patients with multiple injuries who also sustained a head injury (47.4%) was lower that the recovery rate of patients (60.4%) with no head injury. These results indicate that the death rate among patients with head injuries is higher because the head is where the brain and other important organs are located and injury to the brain is likely to be life-threatening. These results are similar to the findings reported by (Parchani *et al.*, 2014). In a four-year epidemiological study of high-level fall, Parchani found that the death rate of patients with subarachnoid hemorrhage was even higher. The impact of LOS was statistically significant in patients with single injury in high-level fall ($r_s = 0.211$, $p < 0.001$). This finding indicates that an increase in LOS is conducive to improvement in patient outcomes. Therefore, compared to patients with multiple injuries, patients with single injury have a milder form; provided that the condition is curable, an increase in number of LOS combined with reasonable treatment time could improve recovery rate. The recovery rate of patients with single injury with CNSI (48.9%) was significantly lower than that of patients without CNSI (72.0%) ($p < 0.05$). This was also observed in patients with multiple injuries (recovery rate with CNSI (41.5%); recovery rate without CNSI (60.1%); ($p < 0.05$)). These results indicate that CNSI significantly affect patient outcome and recovery is difficult. This study examined hospital complications and found that the recovery rate of patients with paraplegia or BI was significantly lower than that of patients without these complications ($p < 0.05$), irrespective of single or multiple injuries. As paraplegia and BI often lead to serious sequelae, making patient recovery challenging and leading to lower recovery rates, treatment and management of patients following high-level fall should be improved. The risk of BI should be minimized, particularly in the early treatment stage; the testing method of CRASHPLAH should be adopted for a comprehensive examination of patients to minimize the chance of overlooking occult injuries and necessary anti-infection treatment should be performed on all injured locations.

High-level fall begins with a series of risks that usually leads to high mortality and creates huge economic burdens to the family and society (Tuma *et al.*, 2013). Medical personnel should carefully consider the impact of injured body region, injury condition and severity, complications, and comorbidities on patient outcome to facilitate timely and accurate treatment of patients during the rescue process. Furthermore, comprehensive preventive measures should be planned and education and management should be strengthened; workplace safety management should be in place to minimize the occurrence of high-level fall and workers working at height should be provided with adequate safety measures and equipment (Werntz, 2008).

References

Adams, J.M.; Bilaniuk, J.W.; Siegel, B.K.; *et al.* Does patient age and height of fall alone require trauma team activation? *The American Surgeon* **2011**, *77*, 1201–1205.

Atanasijevic, T.C.; Savic, S.N.; Nikolic, S.D.; *et al.* Frequency and severity of injuries in correlation with the height of fall. *Journal of Forensic Sciences* **2005**, *50*, 608–612.

Fenge, Z.; Peipei, S.; Shengnan, D.; *et al.* The study of emergency nurse for patient fall from high. *Nurse Research* **2015**, *6*, 566.

Gulati, D.; Aggarwal, A.N.; Kumar, S.; *et al.* Skeletal injuries following unintentional fall from height. *Turkish Journal of Trauma & Emergency Surgery* **2012**, *18*, 141–146.

Hino, Y. Fundamental study on relationship between human injury probability due to fall and the fall height. *Work* **2012**, *41*, 3339–3342.

Kihiko, D.; Mutiso, V.M.; Kiboi, J.G. Patterns of injuries in children who fall from a height as seen at Kenyatta National Hospital. *East African Medical Journal* **2010**, *87*, 330–334.

Lapostolle, F.; Borron, S.W.; Gere, C.; *et al.* Victims of fall from height: Study of 287 patients and determination of clinical prognostic factors. *Annales Francaises D'anesthesie et de Reanimation* **2004**, *23*, 689–693.

Leenen, L.P. More complications after a fall from height in patients with a mental disorder. *Ned Tijdschr Geneeskd* **2015**, *159*, A9481.

Na, S. The evaluation of severity and emergency nurse for injury from high fall. *Nurse Research* **2012**, *14*, 308.

Parchani, A.; El-Menyar, A.; Al-Thani, H.; *et al.* Traumatic subarachnoid hemorrhage due to motor vehicle crash versus fall from height: a 4-year epidemiologic study. *World Neurosurgery* **2014**, *82*, 639–644.

Parreira, J.G.; Kanamori, L.R.; Valinoto, G.C.; *et al.* Comparative analysis between identified injuries of victims of fall from height and other mechanisms of closed trauma. *Journal of the Brazilian College of Surgeons* **2014**, *41*, 285–291.

Ren, X.H. The study of prehospital emergency for injury from high fall. *Medical Ingormation* **2010**, 3198–3199.

Tuma, M.A.; Acerra, J.R.; El-Menyar, A.; *et al.* Epidemiology of workplace-related fall from height and cost of trauma care in Qatar. *International Journal of Critical Illness and Injury Science* **2013**, *3*, 3–7.

Van Heijl, M.; Saltzherr, T.P.; Van Berge Henegouwen, M.I.; *et al.* Unique case of esophageal rupture after a fall from height. *BMC Emergency Medicine* **2009**, *9*, 24.

Wang, Q.; Ishikawa, T.; Michiue, T.; *et al.* Fatal facial-intracranial impalement injury in an accidental fall from a height: an autopsy case report with a review of the literature. *Forensic Science International* **2010**, *200*, e21–e24.

Wen, X.H. The spot emergency for injury from high fall. *Modern Occupation Safety* **2011**, *7*, 110–111.

Werntz, C.L. Workers at height are required to use fall prevention systems. What are the health risks from being suspended in a harness? *Journal of Occupational and Environmental Medicine* **2008**, *50*, 858–859.

Wollner, K.; Ortmann, J.; Kernbach-Wighton, G.; *et al.* Suicidal fall from height after restraint or accident? *Archiv Fur Kriminologie* **2015**, *236*, 130–135.

Wui, L.W.; Shaun, G.E.; Ramalingam, G.; *et al.* Epidemiology of trauma in an acute care hospital in Singapore. *Journal of Emergencies, Trauma and Shock* **2014**, *7*, 174–179.

Yudoyono, F.; Dahlan, R.H.; Tjahjono, F.P.; *et al.* Hollow-organ perforation following thoracolumbar spinal injuries of fall from height. *International Journal of Surgery Case Reports* **2015**, *11*, 110–112.

Zasa, M. Fall from height: a case report. *Acta Bio-Medica* **2015**, *86*, 198–199.

Zhang, Q.Z. The early emergency and nursing for severe injured patient. *Journal of Nurse of Chinese People's Liberation Army* **2004**, *21*, 69–70.

Chapter 6 Investigation of machinery-related injury occurrence and evolution

Junqiang Dong, Yi Zhang and Lulu Zhang
Department of Military Health Service Management, College of Military Health Service Management, Second Military Medical University, Shanghai 200433, China

6.1 Overview

6.1.1 Study background

Machinery-related injury refers to injuries caused by contact between the human body and an operating or stationery piece of mechanical equipment by crushing, collision, spill, shearing, entangling, twisting, detachment, cutting, and piercing; these exclude auto injury and lifting injury (Chen, 2013; NBO, 1986).

Machinery-related injury is one of the most common forms of accidents relating to company safety and resulting in significant damage every year. The death toll from machinery-related injury in China was estimated at 5,800, with 31,000 people sustaining serious injuries and 212,100 people sustaining mild injuries (NBO, 1986). Machinery-related injury are always regarded as a key factor in systemic pain (Harkness *et al.*, 2004). Previous studies have indicated that sensitivity to mechanical stimulus is a clinical sign of neuropathic pain (Momcilovic *et al.*, 2011). Improper machinery operation, extended working hours, and lack of concentration in machinery operation will increase the risk of machinery-related injury.

6.1.2 Definition and characteristics of machinery-related injury

Machinery-related injury can generally be classified as injuries caused by crushing, collision and spill, shearing, entangling, twisting, detachment and blow, cutting, and piercing (Zhang *et al.*, 2014).

The most common types of mechanical equipment causing bodily damage include conveyor belts, mixer, pumps, food processers, drum sieves. Significant damage to the human body results as a combination of multiple factors, specifically, the considerable size of these types of mechanical equipment, the chaotic work sites; and operator error (Zhang, 2013).

Generally, the causes of machinery-related injury are classified into direct and indirect. Direct causes primarily refer to the unsafe behavior of the operator and the unsafe condition of mechanical equipment. Indirect causes include environmental factors (such as temperature, humidity, and air flow in the environment) and the management policy (Zhang *et al.*, 2014; Chen, 2013; Zhang, 2013).

6.1.3 Basic data for the investigation

The purpose of the current study was to assess the occurrence of injuries and treatment strategies in Shanghai City, examine the characteristics and mechanisms of injury, and identify the key factors affecting patient outcome and therefore, provide a theoretical basis for the development of effective prevention and treatment of machinery-related injury.

In January 2011, the task group began to collect data from the four largest trauma centers in Shanghai City. All enrolled patients were informed about the research purposes before admission and provided written consent. Data was extracted from the medical record systems of the four trauma centers (burn trauma emergency center, bone trauma emergency center, trauma emergency center, and trauma emergency center & emergency critical care unit). Medical record data of victims of road traffic accidents occurring between January 2011 and January 2015, satisfying the study eligibility criteria, were collected with the signed written consent of the patients. Data were collected based on the ICD-10 and the rules of the medical record registration system adopted by the Chinese hospitals. The data were then screened, according to eligibility criteria. A total of 521 patient records of mechanical related injuries were identified, including 399 cases of single injury and 122 cases of multiple injuries.

6.2 Investigation results of machinery-related injury occurrence and evolution

6.2.1 Demographic characteristics of machinery-related injury patients

(1) Single injury

Male patients accounted for 85.7% of patients with single injury, which was six times the proportion of female patients (4.3% of cases).

Table 6.1. Gender of single-injury patients with machinery-related injuries.

Gender	N	%
Male	342	85.7
Female	57	14.3

The age of patients with single mechanical injury generally followed a normal distribution, with the majority of patients in the 35–54-year-old group, accounting for 49.9% of patients surveyed.

Table 6.2. Age of single-injury patients with machinery-related injuries.

Age (year)	N	%
0–14	11	2.8
15–24	55	13.8
25–34	76	19.0
35–44	97	24.3
45–54	102	25.6
55–64	45	11.3
≥65	13	3.3

Among the surveyed patients with single machinery-related injury, 72.2% of patients were married, 27.6% were single, and 0.2% were divorced/widowed.

Table 6.3. Marital status of single-injury patients with machinery-related injuries.

Marital status	**N**	**%**
Divorced/widowed	1	0.2
Single	110	27.6
Married	288	72.2

(2) Multiple injuries

Among patients with multiple injuries, 110 were male (90.2%) while 12 were female (9.8%).

Table 6.4. Gender of multiple-injury patients with machinery-related injuries.

Gender	**N**	**%**
Male	110	90.2
Female	12	9.8

The age distribution of patients with multiple injuries and those with a single injury were comparable (35–54 years). This accounted for 50% of the total patients.

Table 6.5. Age of multiple-injury patients with machinery-related injuries.

Age (hour)	**N**	**%**
0–14	1	0.8
15–24	7	5.7
25–34	20	16.4
35–44	31	25.4
45–54	30	24.6
55–64	26	21.3
≥65	7	5.8

Among patients with multiple injuries, 91% were married and 9% were single. There were no divorced/widowed patients.

Table 6.6. Marital status of multiple-injury patients with machinery-related injuries.

Marital status	**N**	**%**
Divorced/widowed	0	0
Single	11	9.0
Married	111	91.0

6.2.2 Injury characteristics of machinery-related injury patients

The characteristics of machinery-related injury were categorized according to injured body region, injury condition, GCS, and AIS/ISS.

(1) Single injury

In patients with a single machinery-related injury, the injured body regions most commonly involved were the extremities (65%) and the head (27%).

Table 6.7. Injured body region of single-injury patients with machinery-related injuries.

Injured body region	N	%
Head	106	26.6
Thorax	2	0.5
Abdomen	2	0.5
Spine	28	7.0
Pelvis	3	0.8
Extremity	258	64.7

SSTI were the primary injury types in single-injury patients (67.7%), followed by FTI (63.7%), DT (10%), CNSI (8.3%), and the combination of PC, TH, and TOI (<1%).

Table 6.8. Injury condition of single-injury patients with machinery-related injuries.

Injury condition	N	%
FJI	254	63.7
SSTI	270	67.7
DT	40	10
CNSI	33	8.3
PC	1	0.3
TH	1	0.3
TOI	2	0.2

The GCS was adopted to evaluate injury severity in patients with reduced level of consciousness following injury. Patient status was categorized as follows: severe (GCS 3–8), moderate (GCS 9–12), mild (GCS 13–14), and normal (GCS 15). Among patients with single injury, GCS scores were available for only 4 patients: 3 (0.7%) patients with a GCS between 3 and 8 (*i.e.*, moderate condition) and 1 (0.3%) patient with a GCS score of 15 (*i.e.*, normal).

Table 6.9. GCS scores of single-injury patients with machinery-related injuries.

GCS	N	%
3–8	3	0.7
9–12	0	0
13–14	0	0
15	1	0.3
NA	395	99

The AIS (range 1–6) was adopted to evaluate injury severity in patients with single machinery-related injury as minor (AIS = 1), moderate (AIS = 2), serious (AIS = 3), severe

(AIS = 4), critical (AIS = 5), and maximum, virtually unsurvivable (AIS = 6) injury. The distribution of AIS scores was as follows: AIS = 2, AIS = 1, AIS = 3, AIS = 5, AIS = 4. The majority of injuries were of moderate severity (AIS = 2), while a limited proportion of injuries were severe and critical.

Table 6.10. AIS of single-injury patients with machinery-related injuries.

AIS	N	%
1	123	30.8
2	160	40.1
3	98	24.6
4	7	1.8
5	11	2.8

(2) Multiple injuries

The distribution of the number of injured body regions in patients with multiple injuries was as follows: 2 injured body regions (55%), 3 (30.3%), 4 (8.2%), and 5 (6.5%).

Table 6.11. Number of injured body regions of multiple-injury patients with machinery-related injuries.

Number of injured body regions	N	%
2	67	55.0
3	37	30.3
4	10	8.2
5	8	6.5

The primary injured body region in patients with multiple machinery-related injuries was the thorax (54.1%), followed by the spine (50%), head (41%), and lower extremities (41%). The proportion of upper extremity injuries (32.8%) was lower than that of lower extremity injuries. Injuries of the pelvis and abdomen accounted 27% and 20.5%, respectively, of injuries.

Table 6.12. Injured body regions of multiple-injury patients with machinery-related injuries.

Body region	N	%
Head	50	41.0
Thorax	66	54.1
Abdomen	25	20.5
Upper extremities	40	32.8
Lower extremities	50	41.0
Spine	61	50
Pelvis	33	27.0

The most common primary injury condition in patients with multiple injuries were FJI (94.3%), followed by SSTI (72.2%). Compared to patients with single injury, other injury conditions in patients with multiple injuries were more common: PC (29.5%), TH (18%), CNSI (19.7%), DT (11.5%), and traumatic organ (7.4%).

Table 6.13. Injury condition of multiple-injury patients with machinery-related injuries.

Injury condition	N	%
FJI	115	94.3
SSTI	88	72.1
DT	14	11.5
CNSI	24	19.7
PC	36	29.5
TH	22	18.0
TOI	9	7.4

The GCS scores of 120 patients with multiple injuries were not available. There was one case of minor injury severity and one case of moderate injury severity, each accounting for 0.8% of cases.

Table 6.14. GCS scores of multiple-injury patients with machinery-related injuries.

GCS	N	%
<3	0	0
3–8	1	0.8
9–12	0	0
13–14	1	0.8
15	0	0
NA	120	98.4

The ISS was used to evaluate injury severity in patients with multiple injuries. Severity was graded as follows: minor (ISS = 1–8), moderate (ISS = 9–15), severe (ISS = 16–24), critical (ISS ≥ 25). The majority of patients had an ISS ≥ 25 (35%), followed by an ISS of 16–24 (32%). Patients with an ISS of 1–8 accounted for the lowest proportion of injuries (8%). Patients with an ISS of 9–15 accounted for 25% of injuries. Most patients with multiple injuries had injuries above the moderate level, and the majority of injuries were critical or severe.

Table 6.15. ISS of multiple-injury patients with machinery-related injuries.

ISS	N	%
1–8	10	8.2
9–15	30	24.6
16–24	39	32
≥25	43	35.2

6.2.3 Treatment of machinery-related injury patients

Treatment information of patients with machinery-related injury was described by the following variables: admission pathway, prehospital time, LOS, outcome, and complications.

(1) Single injury

Among patients with single machinery-related injury, 54.6% of patients were admitted via the EDA, 25.8% were RHOC, and 19.5% were RHS.

Table 6.16. Admission pathway of single-injury patients with machinery-related injuries.

Admission pathway	N	%
RHOC	103	25.8
RHS	78	19.5
EDA	218	54.6

The distribution of prehospital time in patients with single machinery-related injury, was as follows: over 24 hours (42.6%), 3–24 hours (36.8%), 1–3 hours (19%), less than 1 hour (1.5%).

Table 6.17. Prehospital time of single-injury patients with machinery-related injuries.

Prehospital time (hour)	N	%
≤1	6	1.5
1–3	76	19.0
3–24	147	36.8
>24	170	42.6

Most patients with single machinery-related injury had a LOS of 8–14 days, followed by 4–7 days, and 15–30 days. Patients discharged from hospital after 3 days or less accounted for 9%. These results indicated that most injuries (95%) in patients with single machinery-related injury were classified as severe or at a lower level of severity. However, hospital stay in 15.5% of patients was over 31 days.

Table 6.18. LOS of single-injury patients with machinery-related injuries.

LOS (day)	N	%
0–3	36	9.0
4–7	91	22.8
8–14	126	31.6
15–30	84	21.1
≥31	62	15.5

For single injury patients, 74.9% of patients recovered after treatment, 23% felt better, and only 1.5% were not responsive to treatment.

Table 6.19. Outcome of single-injury patients with machinery-related injuries.

Outcome	N	%
Dead	0	0
Invalid	6	1.5
Improved	94	23.6
Cured	299	74.9

Hospital complications in patients with machinery-related injury included HS, DC, paraplegia, AF, WED, ABI, ARF, MODS, MOF, and BI. Among patients with single injury, the most common complication was DC, as the most common site of injury these patients was the head. The extremities were the next most common site of injury, which are likely explain the high proportion of paraplegia and HS in machinery-related injuries.

Table 6.20. Complications of single-injury patients with machinery-related injuries.

Complication	N	%
HS	13	3.3
DC	27	6.8
Paraplegia	16	4.0
AF	2	0.5
WED	5	1.3
ABI	2	0.5
ARF	3	0.8
MOF	1	.0.3
MODS	1	0.3
BI	9	2.3

(2) Multiple injuries

The Admission pathway of patients with multiple machinery-related injuries was primarily via RHOC (45.9%); the proportions of admissions via RHS and *via* emergency departments were lower, accounting for 25.4% and 28.7% respectively.

Table 6.21. Admission pathway of multiple-injury patients with machinery-related injuries.

Admission pathway	N	%
RHOC	56	45.9
RHS	31	25.4
EDA	35	28.7

The distribution of prehospital time between patients with multiple injuries and single injury was the same: pre-hospital time >24 hours accounted for the highest proportion of patients, followed by prehospital time of 3–24 hours. Prehospital time of 3 hours or less accounted for the lowest proportion (11.5%) of patients.

LOS of multiple-injury patients was mostly concentrated around the 15–30 day range; 32% of patients stayed in the hospital for more than 31 days; 20.5% of patients stayed in hospital for 8–14 days; and 26.5% of the patients stayed in hospital for a week or less. These results were mainly due to the distribution of injury severity in patients with multiple injuries, which were largely at and above the moderate level. The majority of injuries were critical and severe, while minor conditions only accounted for a small proportion of cases.

Table 6.22. Prehospital time of multiple-injury patients with machinery-related injuries.

Prehospital time (hour)	N	%
≤1	5	4.1
1–3	9	7.4
3–24	44	36.1
>24	64	52.5

Table 6.23. LOS of multiple-injury patients with machinery-related injuries.

LOS (day)	N	%
0–3	4	3.3
4–7	7	5.7
8–14	25	20.5
15–30	47	38.5
≥31	39	32.0

Among patients with multiple injuries, 58.2% recovered after receiving treatment and 37.7% of patients reported an improvement in symptoms.

Table 6.24. Outcome of multiple-injury patients with machinery-related injuries.

Outcome	N	%
Dead	2	1.6
Invalid	3	2.5
Improved	46	37.7
Cured	71	58.2

Patients with multiple injuries had an increased susceptibility to specific BI. This may be explained by the fact that their injuries were more complicated and critical.

Table 6.25. Complications of multiple-injury patients with machinery-related injuries.

Complications	N	%
HS	18	14.8
DC	25	20.5
Paraplegia	24	19.7
AF	3	2.5
WED	4	3.3
ABI	4	3.3
ARF	4	3.3
MOF	0	0
MODS	4	3.3
BI	24	19.7

6.2.4 Comorbidities in machinery-related injury patients

Patients with machinery-related injuries were evaluated for comorbidities, specifically diabetes and hypertension.

(1) Single injury

In single-injury patients, the prevalence of hypertension was 4.8% and the prevalence of diabetes was 1.3%.

Table 6.26. Comorbidities of single-injury patients with machinery-related injuries.

Comorbidity	N	%
Diabetes	5	1.3
Hypertension	19	4.8

(2) Multiple injuries

In patients with multiple machinery-related injuries, the prevalence of hypertension was 5.7% and the prevalence of diabetes was 1.6%.

Table 6.27. Comorbidities of multiple-injury patients with machinery-related injuries.

Comorbidity	N	%
Diabetes	2	1.6
Hypertension	7	5.7

6.2.5 Outcomes of machinery-related injury patients

The current study adopted SPSS software (version 17.0, SPSS Inc., Chicago, IL, USA) for univariate factor analysis to examine factors affecting patient outcomes in machinery-related injuries (statistical significance was set at $p < 0.05$ was). Patient outcomes in machinery-related injury (dead, invalid, improved, cured) were treated as outcome variables using nonparametric tests. The original data were arranged in a R*C table, where the rows represented grouping variables and columns represented outcome variables. Different statistical methods were selected based on the type of grouping variables in the R*C table: the Mean-Whitney U test was used to compare two independent samples of binary grouping variables, the Kruskal Wallis H test was used to compare multiple independent samples of categorical variables, and the Spearman rank correlation test was adopted for ordinal variables when the ranking of the variables was relevant.

6.2.5.1 Single injury

(1) Comparison of binary categorical independent variables using the Mann-Whitney U test

The impact of gender was not statistically significant to the outcome of patients with single machinery-related injury. The proportion of patients with a negative response to treatment was 1.9% for male patients and 1.8% for female patients. The recovery rate for male patients was 76.6% and the recovery rate for female patients was 76.8%.

Table 6.28. Comparison of outcomes between different genders among patients with single machinery-related injury.

Gender	Invalid	Improved	Cured	U-value	p-value
Male	5	75	262	8617.0	0.062
Female	1	19	37	-	-

CNSI and DT affected treatment outcome in patients with single machinery-related injury. The recovery rate in patients without CNSI (70.9%) was significantly higher than the recovery rate of patients with CNSI (4.0%). The recovery rate of patients without DT (65.7%) was significantly higher than the recovery rate of patients with DT (9.3%).

Complications including HS, AF, ABI, ARF, MOF, and MODS had no statistically significant effect on patient outcome. However, complications from DC, paraplegia, and BI significantly affected patient outcome. The recovery rate of patients with DC (3.8%) was significantly lower than that of patients without DC (71.2%); the recovery rate of patients with paraplegia (1.8%) was significantly lower than that of patients without paraplegia (73.2%); the recovery rate of patients with BI (0.3%) was significantly lower than that of patients without BI (74.2%).

Diabetes and hypertension had no statistically significant impact on the outcome of patients with single machinery-related injury. Recovery rates of patients with and without diabetes were 1.0% and 73.9%, respectively. Recovery rates of patients with and without hypertension were 4.0% and 70.9%, respectively.

Table 6.29. Comparison of outcomes among different injury conditions of patients with single machinery-related injury.

Injury condition	Invalid	Improved	Cured	U-value	p-value
FJI				17699.5	0.391
No	1	32	112		
Yes	5	62	187		
SSTI				16913.5	0.536
No	5	24	100		
Yes	1	70	199		
CNSI				4298.5	<0.001
No	5	78	283		
Yes	1	16	16		
PC				52.5	0.091
No	6	93	299		
Yes	0	1	0		
TH				149.0	0.564
No	6	94	298		
Yes	0	0	1		
TOI				297.0	0.414
No	6	94	297		
Yes	0	0	2		
DT				5769.5	0.007
No	6	91	262		
Yes	0	3	37		

Table 6.30. Comparison of outcomes among different complications of patients with single machinery-related injury.

Complication	Invalid	Improved	Cured	U-value	p-value
HS				2373.0	0.659
No	6	90	290		
Yes	0	4	9		
DC				4014.0	0.021
No	6	82	284		
Yes	0	12	15		
Apnea				-	-
No	6	94	299		
Yes	0	0	0		
CA				-	-
No	6	94	299		
Yes	0	0	0		
CH				-	-
No	6	94	299		
Yes	0	0	0		
Paraplegia				2095.0	0.004
No	6	85	292		
Yes	0	9	7		

Table 6.30. *Cont.*

Complication	Invalid	Improved	Cured	U-value	p-value
AF				297.0	0.414
No	6	94	297		
Yes	0	0	2		
WED				645.5	0.078
No	6	91	297		
Yes	0	3	2		
ABI				300.5	0.430
No	6	93	298		
Yes	0	1	1		
ARDS				-	-
No	6	94	299		
Yes	0	0	0		
ARF				351.0	0.105
No	6	92	298		
Yes	0	2	1		
MOF				149.0	0.752
No	6	94	298		
Yes	0	0	1		
MODS				149.0	0.752
No	6	94	298		
Yes	0	0	1		
BI				976.0	0.002
No	5	89	296		
Yes	1	5	3		

Table 6.31. Comparison of outcomes among different comorbidities of patients with single machinery-related injury.

Comorbidity	Invalid	Improved	Cured	U-value	p-value
Diabetes				931.5	0.781
No	6	93	295		
Yes	0	1	4		
Hypertension				3249.5	0.329.
No	6	91	283		
Yes	0	3	16		
Osteoporosis				-	-
No	6	94	299		
Yes	0	0	0		

(2) Comparison of multiple categorical independent variables using the Kruskal Wallis H test

Marital status had no statistically significant impact on the outcome of patients with single machinery-related injury. The treatment response rate (labeled as “positive”) among divorced/widowed patients was 0.3%; the recovery rate of single patients was 19.3% and treatment response rate (positive) was 8.0%; the recovery rate of married patients was 55.6% and treatment response rate treatment (positive) was 15.8%.

Table 6.32. Comparison of outcomes among different marital status of patients with single machinery-related injury.

Marital status	Invalid	Improved	Cured	Chi-square	p-value
Divorced/widowed	0	1	0	5.161	0.076
Single	3	30	77	-	-
Married	3	63	222	-	-

Admission pathway had no statistically significant impact on the outcome of patients in single machinery-related injury ($p = 0.085$). The recovery rate in patients RHOC was 17.3% and the positive response rate was 8.0%. The recovery rate in patients RHS was 14.8% and the positive response rate was 4.3%. The recovery rate in patients admitted via the ED was 42.9% and the positive response rate was 11.3%.

Table 6.33. Comparison of outcomes among different admission pathways of patients with single machinery-related injury.

Admission pathway	Invalid	Improved	Cured	Chi-Square	p-value
RHOC	1	32	69	4.929	0.085
RHS	2	17	59	-	-
EDA	2	45	171	-	-

Injured body region had a statistically significant impact on the outcome of patients with single mechanical injury. The lowest (0.3%) recovery rate was associated with thoracic injuries, followed injuries of the pelvis and abdomen (0.5%). The highest (50.6%) recovery rate was associated with injuries of the extremities of patients, followed by head injuries (19.5%) and injuries of the spine (3.5%).

Table 6.34. Comparison of outcomes among different injured body regions of patients with single machinery-related injury.

Injured body region	Invalid	Improved	Cured	Chi-square	p-value
Head	1	27	78	12.249	0.032
Thorax	0	1	1	-	-
Abdomen	0	0	2	-	-
Spine	1	13	14	-	-
Pelvis	0	1	2	-	-
Extremity	4	52	202	-	-

(3) Comparison of ordinal categorical independent variables using the Spearman rank correlation test

Age had no statistically significant impact on the outcomes of patients with single machinery-related injury. The recovery rate of patients, according to age, were as follows: ≤14 years, 1.8%; 15–24 years, 9.8%; 25–34 years, 13.5%; 35–44 years, 19.0%; 45–54 years, 20.8%; 55–64 years, 7.5%; ≥65 years, 2.5%.

Table 6.35. Correlation analysis between age and outcomes among patients with single machinery-related injury.

Age (year)	Invalid	Improved	Cured	r_s	p-value
≤14	0	4	7	0.046	0.362
15–24	1	15	39	-	-
25–34	1	21	54	-	-
35–44	2	19	76	-	-
45–54	2	17	83	-	-
55–64	0	15	30	-	-
≥65	0	3	10	-	-

Prehospital time had no statistically significant impact on the outcomes of patients with single machinery-related injury. With a prehospital time of 1 hour or less, patient recovery rate was 0.8%; with a prehospital time of 1–3 hours, recovery rate 14.0% and the negative rate was 0.3%; with a prehospital time of 3–24 hours, recovery rate was 28.8% and the negative rate was 0.5%; with a prehospital time more than 24 hours, recovery rate was 31.3% and the negative rate was 0.8%.

Table 6.36. Correlation analysis between prehospital time and outcomes among patients with single machinery-related injury.

Prehospital time (hour)	Invalid	Improved	Cured	r_s	p-value
≤1	0	3	3	−0.004	0.941
1–3	1	19	56	-	-
3–24	2	30	115	-	-
>24	3	42	125	-	-

LOS had a statistically significant impact on the outcomes of patients with single machinery-related injury. With a LOS of 8–14 days, the recovery rate of patients was 24.3%; with a LOS of 15–30 days, recovery rate was 18.3%; with a LOS of 0–3 days, the negative rate was the highest at 0.5% and recovery rate was the lowest at 4.3%.

Differences in GCS scores had no statistical significance on the outcomes of patients with single machinery-related injury. The recovery rate of severely ill patients (GSC = 3–8) was 0.3% and the positive rate was 0.5%.

Table 6.37. Correlation analysis between LOS and outcomes among patients with single machinery-related injury.

LOS (day)	Invalid	Improved	Cured	r_s	p-value
0–3	2	17	17	0.155	0.002
4–7	2	23	66	-	-
8–14	1	28	97	-	-
15–30	1	10	73	-	-
≥31	0	16	46	-	-

Table 6.38. Correlation analysis between GCS and outcomes among patients with single machinery-related injury.

GCS	Invalid	Improved	Cured	r_s	p-value
3–8	0	2	1	0.577	0.423
15	0	0	1	-	-

Differences in AIS scores had no statistical significance on the outcomes of patients with single machinery-related injury. The recovery rate of mildly ill patients (AIS = 1) was 23.8% and the negative rate was 0.3%; recovery rate of moderately ill patients (AIS = 2) was 31.1% and the negative rate was 1.0%; recovery rate of seriously ill patients (AIS = 3) was 18.0% and the negative rate was 0.3%; recovery rate of severely ill patients (AIS = 4) was 0.8%; and the recovery rate of critically ill patients (AIS = 5) was 1.3%.

Table 6.39. Correlation analysis between AIS and outcomes among patients with single machinery-related injury.

AIS	Invalid	Improved	Cured	r_s	p-value
1	1	27	95	−0.084	0.093
2	4	32	124	-	-
3	1	25	72	-	-
4	0	4	3	-	-
5	0	6	5	-	-

6.2.5.2 Multiple injuries

(1) Comparison of binary categorical independent variables using the Mann-Whitney U test

Gender had no statistically significant impact on the outcomes of patients with multiple machinery-related injuries. The recovery and death rates of male patients were 52.5% and 1.6%, respectively. The recovery rate of female patients was 5.7%.

Table 6.40. Comparison of outcomes between different genders among patients with multiple machinery-related injuries.

Gender	Dead	Invalid	Improved	Cured	U-value	p-value
Male	2	3	41	64	646.5	0.893
Female	0	0	5	7	-	-

Injured body region had a statistically significant impact on the outcomes of patients with multiple machinery-related injuries. The recovery rate of patients with abdomen injury (15.6%) was significantly lower than that of patients without it (42.6%). The recovery rate of patients with spine injury (24.6%) was significantly lower than that of patients without it (33.6%).

CNSI had a statistically significant impact on the outcomes of patients with multiple machinery-related injuries. The recovery rate of patients with CNSI (4.9%) was significantly lower than that of patients without CNSI (53.33%).

Table 6.41. Comparison of outcomes among different injured body regions of patients with multiple machinery-related injuries.

Injured body region	Dead	Invalid	Improved	Cured	U-value	p-value
Head					1744.0	0.736
No	2	1	28	41		
Yes	0	2	18	30		
Thorax					1639.0	0.215
No	0	2	18	36		
Yes	2	1	28	35		
Abdomen					926.0	0.036
No	2	3	40	52		
Yes	0	0	6	19		
Spine					1524.0	0.047
No	0	2	18	41		
Yes	2	1	28	30		
Pelvis					1319.5	0.321
No	2	1	37	49		
Yes	0	2	9	22		
Upper extremities					1580.5	0.708
No	2	2	31	47		
Yes	0	1	15	24		
Lower extremities					1661.0	0.403
No	2	2	28	40		
Yes	0	1	18	31		

Table 6.42. Comparison of outcomes among different injury conditions of patients with multiple machinery-related injuries.

Injury condition	Dead	Invalid	Improved	Cured	U-value	p-value
FJI					399.5	0.970
No	0	0	3	4		
Yes	2	3	43	67		
SSTI					1348.5	0.331
No	2	1	13	18		
Yes	0	2	33	53		
CNSI					683.5	<0.001
No	1	2	30	65		
Yes	1	1	16	6		
PC					1451.5	0.531
No	0	2	33	51		
Yes	2	1	13	20		
TH					932.0	0.196
No	1	3	35	61		
Yes	1	0	11	10		
TOI					504.0	0.959
No	2	3	42	66		
Yes	0	0	4	5		
DT					679.0	0.475
No	2	2	40	64		
Yes	0	1	6	7		

Paraplegia, WED, ABI, ARF, MODS, and BI had a statistically significant impact on the outcomes of patients with multiple machinery-related injuries. The recovery rate of patients with paraplegia (7.4%) was significantly lower than that of patients without paraplegia (50.8%); the recovery rate of patients without WED was 58.2%; the recovery rate of patients without ABI (57.4%) was significantly higher than that of patients with ABI (0.8%); the recovery rate of patients without ARF was 58.2%; the recovery rate of patients without MODS (58.2%) was significantly higher than that of patients with MODS (0%); the recovery rate of patients with BI (41%) was significantly lower than that of patients without BI (54.1%).

Diabetes and hypertension had no statistically significant impact on the outcomes of patients with multiple machinery-related injuries. The recovery rate of patients without diabetes was 56.6% and the recovery rate of patients without hypertension was 54.1%.

Table 6.43. Comparison of outcomes among different complications of patients with multiple machinery-related injuries.

Complication	Dead	Invalid	Improved	Cured	U-value	p-value
HS					785.5	0.209
No	2	2	37	63		
Yes	0	1	9	8		
DC					1065.0	0.280
No	2	2	34	59		
Yes	0	1	12	12		
Apnea					27.5	0.459
No	2	3	45	71		
Yes	0	0	1	0		
CA					27.5	0.459
No	2	3	45	71		
Yes	0	0	1	0		
Paraplegia					883.5	0.030
No	1	3	32	62		
Yes	1	0	14	9		
AF					89.0	0.149
No	2	1	46	70		
Yes	0	2	0	1		
WED					55.0	0.003
No	2	1	44	71		
Yes	0	2	2	0		
ABI					113.5	0.042
No	2	1	45	70		
Yes	0	2	1	1		
ARDS					27.5	0.459
No	2	3	45	71		
Yes	0	0	1	0		
ARF					111.0	0.038
No	2	3	45	71		
Yes	0	0	1	0		

Table 6.43. *Cont.*

Complication	Dead	Invalid	Improved	Cured	U-value	p-value
MODS					52.5	0.002
No	1	2	44	71		
Yes	1	1	2	0		
BI					549.0	<0.001
No	0	0	32	66		
Yes	2	3	14	5		
CH						
No	2	3	46	71		
Yes	0	0	0	0		

Table 6.44. Comparison of outcomes among different comorbidities of patients with multiple machinery-related injuries.

Comorbidity	Dead	Invalid	Improved	Cured	U-value	p-value
Diabetes					69.0	0.341
No	2	3	46	69		
Yes	0	0	0	2		
Hypertension					341.0	0.434
No	2	3	44	66		
Yes	0	0	2	5		

(2) Comparison of multiple categorical independent variables using the Kruskal Wallis H test

Marital status had no statistically significant impact on the outcomes of patients with multiple machinery-related injuries. The recovery rate of single patients was 5.7%, while the recovery rate of married patients was 52.5% and the death rate was 1.6%.

Table 6.45. Comparison of outcomes among different marital status of patients with multiple machinery-related injuries.

Marital status	Dead	Invalid	Improved	Cured	Chi-square	p-value
Single	0	0	4	7	0.231	0.631
Married	2	3	42	64	-	-

Admission pathway had no statistically significant impact on the outcome of patients with multiple machinery-related injuries. The recovery rate of patients RHOC was 27.0% and the positive rate (positive) was 16.4%; the recovery rate of patients RHS was 13.1% and the positive rate was 10.7%; the recovery rate of patients admitted via the ED was 18.0% and the positive rate was 10.7%.

The number of injured body regions had no statistically significant impact on the outcomes of patients with multiple machinery-related injuries. The recovery rate of patients with two injured body regions was 32.8%; the recovery rate of patients with three injured body regions was 15.6%; the recovery rate of patients with four injured body regions was 4.9%; and the recovery rate of patients with five injured body regions was 4.9%.

Table 6.46. Comparison of outcomes among different admission pathways of patients with multiple machinery-related injuries.

Admission pathway	Dead	Invalid	Improved	Cured	Chi-square	p-value
RHOC	0	3	20	33	1.217	0.544
RHS	2	0	13	16	-	-
EDA	0	0	13	22	-	-

Table 6.47. Comparison of outcomes among different numbers of injured body regions of patients with multiple machinery-related injuries.

Number of injured body regions	Dead	Invalid	Improved	Cured	Chi-square	p-value
2	2	1	24	40	1.822	0.948
3	0	2	16	19	-	-
4	0	0	4	6	-	-
5	0	0	2	6	-	-

(3) Comparison of ordinal categorical independent variables using the Spearman rank correlation test

The recovery rate of patients with single machinery-related injury, according to age, were as follows: ≤14 years, 0.8%; 15–24 years, 3.3%; 25–34 years, 10.7%; 35–44 years, 15.6%; 45–54 years, 12.3%; 55–64 years 11.5%; ≥65 years, 0.8%.

Table 6.48. Correlation analysis between age and outcomes among patients with multiple machinery-related injuries.

Age (year)	Dead	Invalid	Improved	Cured	r_s	p-value
≤14	0	0	0	1	−0.056	0.538
15–24	0	0	3	4	-	-
25–34	0	0	7	13	-	-
35–44	1	2	9	19	-	-
45–54	0	0	14	15	-	-
55–64	1	0	11	14	-	-
≥65	0	0	2	5	-	-

Prehospital time had no statistically significant impact on the outcomes of patients in multiple machinery-related injuries. The recovery rate of patients with a prehospital time of one hour or less was 3.3%; the recovery rate of patients with a prehospital time between 1 and 3 hours was 5.7 %; the recovery rate of patients with prehospital time between 3 and 24 hours was 19.7%; the recovery rate of patients with prehospital time greater than 24 hours was 29.5% and the death rate was 18.9%.

LOS had a statistically significant impact on the outcomes of patients with multiple machinery-related injuries. The recovery rate was the highest (23.0%) with a LOS between 15 and 30 days, followed by a recovery rate of 22.1% with a LOS over 31 days.

Table 6.49. Correlation analysis between prehospital time and outcomes among patients with multiple machinery-related injuries.

Prehospital time (hour)	Dead	Invalid	Improved	Cured	r_s	p-value
≤1	0	0	1	4	−0.106	0.244
1–3	0	0	2	7	-	-
3–24	0	0	20	24	-	-
>24	2	3	23	36	-	-

Table 6.50. Correlation analysis between LOS and outcomes among patients with multiple machinery-related injuries.

LOS (day)	Dead	Invalid	Improved	Cured	r_s	p-value
0–3	0	1	2	1	0.196	<0.031
4–7	0	0	4	3	-	-
8–14	0	0	13	12	-	-
15–30	1	2	16	28	-	-
≥31	1	0	11	27	-	-

Outcome was positive in one case of severe injury and one case of mild injury.

Table 6.51. Correlation analysis between GCS and outcomes among patients with multiple machinery-related injuries.

GCS	Dead	Invalid	Improved	Cured	r_s	p-value
3–8	0	0	1	0	-	-
13–14	0	0	1	0	-	-

Differences in ISS had no statistically significant impact on the outcomes of patients with multiple machinery-related injuries. The recovery rates of patients, according to ISS, were as follows: minor machinery-related injury (ISS = 1–8), 5.7%; moderate machinery-related injury (ISS = 9–15), 18.0% with a death rate of 0.8%; severe machinery-related injury (ISS = 16–24), 15.6%; critical machinery-related injury (ISS ≥ 25), 18.9% with a death rate of 0.8%.

Table 6.52. Correlation analysis between ISS and outcomes among patients with multiple machinery-related injuries.

ISS	Dead	Invalid	Improved	Cured	r_s	p-value
1–8	0	0	3	7	−0.158	0.081
9–15	1	0	7	22	-	-
16–24	0	1	19	19	-	-
≥25	1	2	17	23	-	-

6.3 Summary

For patients with single machinery-related injury, injury condition, injured body region, complications, and LOS are key factors affecting outcome. These were also key factors affecting outcome in patients with multiple machinery-related injuries.

A total of 452 (86.8%) male patients and 69 (13.2%) female patients were surveyed in the present study. Most patients with machinery-related injuries were aged between 35–54 years. Of all patients with machinery-related injuries surveyed, 76.6% were married.

Characteristics of injury are key factors for patient outcome in machinery-related injuries. First, injured body region is an important factor and previous studies have revealed that the extremities and the head were the most vulnerable body parts to injury (Momcilovic *et al.*, 2011), largely incurred as a result of carelessness of workers using inappropriate operating tools and equipment, without adopting the correct protection measures. The recovery rate in patients with machinery-related injury of the thorax and spine was the lowest (Cristante *et al.*, 2012), followed by the recovery rate of pelvic injuries. Conversely, the recovery rate of patients with injuries to the abdomen was the highest, followed by the recovery rate of injuries to the extremities and the head. Secondly, complications from DC, paraplegia, WED, ABI, ARF, MODs, and BI also affect treatment outcome. The recovery rate of patients with DC was significantly lower than that in patients with no DC; the recovery rate of patients with paraplegia was significantly lower than that of patients without paraplegia; the recovery rate of patients with BI was significantly lower than that of patients without BI.

Injury treatment factors also affect patient outcome in machinery-related injuries due to the following reasons. First, the recovery rate of patients with machinery-related injury with a LOS of 15 days was the highest (Coldwell *et al.*, 2001), followed by the recovery rate of patients with a LOS of 8–14 days; the negative rate in patients with a LOS of 3 days or less was the highest and the corresponding recovery rate was the lowest. Second, CNSI and DT will significantly impact treatment outcome in patients with machinery-related injury (Abegg, 2007); recovery rate of patients without CNSI was significantly higher than that of patients with CNSI and the recovery rate of patients without DT was significantly higher than that of patients with DT.

Based on the major findings in the present study, during the rescue and treatment process, medical staff should triage patients promptly based on injured body regions, injury condition and complications, to make accurate treatment, improve recovery rates, and lower mortality.

References

Abegg, M.H. Rhythmic synaptic activity induced by mechanical injury of rat CA3 hippocampal area. *Journal of Neurotrauma* **2007**, *24*, 1536–1542.

Cemalovic, N.; Rosic, S.; Toromanovic, N. Analysis of the causes of occupational injuries and application of preventive measures. *Materia Socio-Medica* **2016**, *28*, 51–52.

Chen, Z.Y. Discussion on the causes of machinery-related injury and preventive measures. *Work Safety & Supervision* **2013**, 38–40.

Colwell, C.W.J.; D'lima, D.D.; Hoenecke, H.R.; *et al.* In vivo changes after mechanical injury. *Clinical Orthopaedics and Related Research* **2001**, *391*, S116–S123.

Cristante, A.F.; Barros Filho, T.E.P.D.; Marcon, R.M.; *et al.* Therapeutic approaches for spinal cord injury. *Clinics* **2012**, *67*, 1219–1224.

Harkness, E.F.; Macfarlane, G.J.; Nahit, E.; *et al.* Mechanical injury and psychosocial factors in the work place predict the onset of widespread body pain: a two-year prospective study among cohorts of newly employed workers. *Arthritis and Rheumatism* **2004**, *50*, 1655–1664.

Momcilovic, D.; Prokes, B.; Slavnic, N. The most frequent injury with mechanical corn picker during harvest–possibility of prevention. *Medicinski Pregled* **2011**, *64*, 148–151.

NBO. Standard for Classification of Casualties in Enterprises. GB6441–1986, 1986.

Zhang, Z.G.; Wu, F.D.; Ye, M.Q.; *et al.* Analysis of causes and countermeasures of mechanical injury. *China Building Materials Science & Technology* **2014**, 102–106.

Zhang, Z.M. On the causes of mechanical injury accident cases and safety management measures. *Building Materials & Decoration* **2013**.

Chapter 7 Investigation of sharp-instrument injury occurrence and evolution

Zhenqing Xu[1], Peng Kang[2] and Lulu Zhang[2]

[1] *No. 22nd Hospital of PLA, Glomud 816099, China*

[2] *Department of Military Health Service Management, College of Military Health Service Management, Second Military Medical University, Shanghai 200433, China*

7.1 Overview

7.1.1 Investigation Background

Traumatic injury is a globally prevalent condition that causes large-scale morbidity and mortality each year. In the United States, more than 12,000 children and adolescents (younger than 19 years of age) die of accidental injuries each year, which has led to huge economic and personal losses. The economic impact of trauma is estimated to be billions of US dollars globally. A study on more than 740,000 trauma cases showed that patients with sharp-instrument injury accounted for 7.4% of the total patients investigated (Nielsen *et al.*, 2016). During regular work and life, hand injuries and other regions of the body caused by wooden splinters, bamboo strips, nails, knives, axes, scissors, daggers, and pieces of glass and metal are quite common (Zhu *et al.*, 2015). Since the 21st century, the incident rate of sharp-instrument injury has presented a growing trend, and the mortality rate of sharp-instrument injury has continued to rise every year. According to a study conducted by the Institute of Forensic Medicine at the University of Freiburg, sharp-instrument injury accounted for 10-20% of total annual clinical forensic examinations and is usually associated with crimes resulting in injury (Schmidt, 2010). Stabbing is a frequent physical injury related to dispute as well as the most common form of murder in the United Kingdom (Bolliger *et al.*, 2016).

More studies have been conducted on sharp-instrument injury in other countries than in China. Injuries of medical workers, injuries caused by weapons, injuries that led to suicide and homicide, and injuries accidentally incurred have been investigated (Qin *et al.*, 2008) and involved various body regions, as well as victims of all ages. Given that China has a huge population base, the frequency of various types of injury incidents is relatively high. However, existing studies on sharp-instrument injury remain at an initial research stage; the depth and breadth of the investigations are still limited. Moreover, most of the studies tended to focus on sharp-instrument injury suffered by medical staff (Chai *et al.*, 2013; Goniewicz *et al.*, 2012); research studies that have been conducted from an epidemiological perspective are scarce.

7.1.2 Definition and characteristics of sharp-instrument injury

(1) Definition of sharp-instrument injury

According to the Mediterranean Forensic Pathology Research, a sharp-instrument injury refers to the injury caused by a sharp edge, blade, or tip of an object, leading to rupturing of the skin and subcutaneous tissues, and usually forms open wounds (Kemal *et al.*, 2013). When objects with a sharp edge or pointed tip become the cause of an injury, they are called sharp instruments (Au and Beh, 2011). Generally, sharp instruments are made of metal. The most common examples include knives, arrows, axes, scissors, daggers, and pieces of glass and metal (Zyck *et al.*, 2016); however, bone needles, bamboo spears, and wood thorns with a sharp edge and/or tip are also regarded as sharp instruments. Sharp instruments are generally categorized into several basic categories, including stabbing, chopping, incision, and scissor instruments. Each type can be further divided into long blade, short blade, and irregular blade, or single blade, double blade, and multi-blade instruments. Due to variations in application of force and movement of the instruments, sharp instruments can cause different types of sharp-instrument injur, based on instrument category, and the way force is applied. The injuries can be categorized into incised wounds, chop wounds, stab wounds, scissor wounds (Lockyer *et al.*, 2013), and combined wounds (e.g., incised chop wounds, incised stab wounds, scissor stab wounds, and scissor incised wounds) (Chen, 2009).

(2) Characteristics of sharp-instrument injury

There is a wide variety of sharp instruments; each instrument tends to cause distinctive patterns of injury. For example, a wound caused by a dagger has a clean-cut edge, usually with even sides, a “V”-shaped base that is apparently shorter than the edge, and the length of the wound is smaller than its depth.

Typically, sharp instruments can cause stab wounds, incised wounds, chop wounds, and scissor wounds. The characteristics of these four types of wounds are as follows (1) Stab wounds, they are small but deep and usually involve damage to the internal organs or major blood vessels, and thereby causing life-threatening damages. The shape of the wound normally corresponds to the cross-sectional shape of the sharp instrument; the shape of a superficial wound caused by stab on outer skin layers can reflect the shape of the stab instrument more accurately. Due to elasticity and retraction of human skin, the surface of the wound is generally slightly smaller than its cross-section; (2) Incised wounds, they are spindle-shaped and everted, with sharp ends. When the two edges of the wound are closed, they form a thin line. Incised wounds are generally long, some even longer than the length of blade of the sharp instruments, and the wound length is greater than its depth; (3) Chop wounds, they are severe in nature, as they are deep and usually combined with serious damage to bones and internal organs. The wounds are generally diamond-shaped, with abrasions at the edges. The ends can be sharp at one side and blunt at the other, and may be triangular in shape; and (4) Scissor wounds, they have distinctive patterns such as melon-seed-shaped, S-shaped, V-shaped, diamond-shaped, and figure-eight-shaped (Chen, 2009).

Compared with blunt force injuries (Sledge *et al.*, 2013), sharp-instrument injury possesses the following features (Qiu *et al.*, 2009; Luo *et al.*, 2010; Sobnach *et al.*, 2015).

- clear-cut edges, no obvious contusions, little intradermal bleeding, and no laceration at the edges;

- sharp ends and neat surface;
- the side of the instrument that has no blade may result in a rounded edge, with slight bifurcation, and rarely leads to astral-shaped, irregular edges;
- smooth sides, generally there is no inter-tissue bridge, no tissue laceration, and the wound walls reflect the direction of the force;
- neat wound floor, with no tissue laceration;
- can be a deep wound or a surface wound;
- can be elongated or short, generally with a regular pattern;
- can be formed on any human body part;
- may be accompanied with fractures, where there are stab wounds, incisions, or chop wound traces at the bone section, and the fracture usually has a regular shape;
- few foreign substances in the wound, and hair strands are cut clean;
- neurovascular bundles have been severed.

7.1.3 Basic data for the investigation

(1) Research purposes

This research was a retrospective study. Samples were acquired from Shanghai, China to investigate the demographic characteristics of patients with sharp-instrument injury, the characteristics of the injuries, treatment, and comorbidity, as well as the influence of various factors on the outcome of these patients. The purpose of this study was to explore the characteristics, conditions, and treatment of sharp-instrument injuries, as well as the current capacity of the emergency response system in China to improve the efficiency and effectiveness of the first aid system, optimize the allocation of related resources, and minimize mortality and permanent disabilities among patients with sharp-instrument injury.

(2) Research data

The data collection process began in January 2011 and lasted until January 2015. All data were acquired from the four largest trauma centers in Shanghai Burn Center, Orthopedic Trauma Center, Acute Trauma Center, and Trauma Emergency Center. The samples were selected according to the predefined screening criteria. Medical records of all eligible patients with sharp-instrument injury from January 2011 to January 2015 were collected. All patients were informed of the purpose of the study and had signed a written consent form before their information was included in the study. All samples were individually screened by the researcher, after referring to the ICD-10 and rules governing the registration of medical records in Chinese hospital information systems. The corresponding medical records were then exported. This study collected medical records of 190 participants, of whom 144 had a single injury and 46 had multiple injuries.

7.2 Investigation results of sharp-instrument injury occurrence and evolution

7.2.1 Demographic characteristics of sharp-instrument injury patients

Single injury

(1) Gender

There were 144 patients with a single injury, including 122 men (84.7%) and 22 women (15.3%).

Table 7.1. Gender of single-injury patients with sharp-instrument injuries.

Gender	N	%
Men	122	84.7
Women	22	15.3

(2) Age

Subjects aged between 45 and 54 years had the highest proportion among single-injury patients (35, 24.3%).

Table 7.2. Age of single-injury patients with sharp-instrument injuries.

Age (year)	N	%
≤14	5	3.5
15–24	25	17.4
25–34	27	18.8
35–44	29	20.1
45–54	35	24.3
55–64	13	9.0
≥65	10	6.9

(3) Marital status

Among the single-injury patients, 85 (59.0%) were married, 58 (40.3%) were single, and one (0.7%) was divorced/widowed.

Table 7.3. Marital status of single-injury patients with sharp-instrument injuries.

Marital status	N	%
Divorced/widowed	1	0.7
Single	58	40.3
Married	85	59.0

Multiple injuries

(1) Gender

Among the 46 patients with multiple injuries, 37 (80.4%) were male and 9 (19.6%) were female, suggesting that men were at a higher risk of multiple sharp-instrument injuries.

Table 7.4. Gender of multiple-injury patients with sharp-instrument injuries.

Gender	N	%
Men	37	80.4
Women	9	19.6

(2) Age

It showed that the incidence of multiple injuries declined with increasing age.

Table 7.5. Age of multiple-injury patients with sharp-instrument injuries.

Age (year)	N	%
15–24	11	23.9
25–34	14	30.4
35–44	8	17.4
45–54	7	15.2
55–64	2	4.3
≥65	4	8.7

(3) Marital status

Among the multiple-injury patients, 31 (67.4%) were married and 15 (32.6%) were single.

Table 7.6. Marital status of multiple-injury patients with sharp-instrument injuries.

Marital status	N	%
Single	15	32.6
Married	31	67.4

7.2.2 Injury characteristics of sharp-instrument injury patients

(1) Single injury

The injured body regions among the single-injury patients, in descending order, included extremities (56, 38.9%), head (52, 36.1%), thorax (20, 13.9%), abdomen (14, 9.7%), and pelvis (2, 1.4%). The number of injuries to the extremities and head was significantly higher than injuries to other regions of the body.

Table 7.7. Body region of single-injury patients with sharp-instrument injuries.

Body region	N	%
Head	52	36.1
Thorax	20	13.9
Abdomen	14	9.7
Spine	0	0.0
Pelvis	2	1.4
Extremities	56	38.9

The injury conditions among the single-injury patients, in descending order, included SSTI (95.1%), FJI (10.4%), TH (9.0%), PC (5.6%), TOI (4.9%), and CNSI (2.8%). SSTI were noticeably higher than other types of injuries.

Table 7.8. Injury condition of single-injury patients with sharp-instrument injuries.

Injury condition	**N**	**%**
FJI	15	10.4
SSTI	137	95.1
DT	0	0
CNSI	4	2.8
PC	8	5.6
TH	13	9.0
TOI	7	4.9

The single-injury patients who did not have a head injury were not included in the GCS scoring. Only one patient received a score of 15, the rest of the patients with head injuries did not receive a GCS score.

Table 7.9. GCS scores of single-injury patients with sharp-instrument injuries.

GCS	**N**	**%**
15	1	0.7
NA	143	99.3

An AIS score of “1” indicates minor injury, “2” means moderate injury, “3” is serious injury, “4” represents severe injury, “5” specifies critical injury, and “6” is the maximum injury. The majority (62.5%) of the single-injury patients suffered minor injuries.

Table 7.10. AIS of single-injury patients with sharp-instrument injuries.

AIS	**N**	**%**
1	90	62.5
2	31	21.5
3	17	11.8
4	3	2.1
5	3	2.1

(2) Multiple injuries

The majority (63.0%) of multiple-injury patients had 2 injured body regions, followed by patients with 3 body regions; patients with 4 or more injured body regions were of relatively smaller number.

Table 7.11. Number of injured body regions of multiple-injury patients with sharp-instrument injuries.

Number of injured body regions	**N**	**%**
2	29	63.0
3	11	23.9
4	4	8.7
5	2	4.3

The injured body regions among multiple-injury patients, in a descending order, included thorax (69.6%), upper extremities (56.5%), lower extremities (41.3%), abdomen (39.1%), head (37.0%), spine (6.5%), and pelvis (4.3%). Injuries to the thorax and upper extremities were found in more than half of the patients.

Table 7.12. Injured body regions of multiple-injury patients with sharp-instrument injuries.

Injured body region	N	%
Head	17	37.0
Thorax	32	69.6
Abdomen	18	39.1
Spine	3	6.5
Pelvis	2	4.3
Upper extremities	26	56.5
Lower extremities	19	41.3

The injury conditions among multiple-injury patients were as follows in descending order SSTI (95.7%), fractures and joint injury (28.3%), TH (26.1%), TOI (23.9%), PC (8.7%), and DT (2.2%). The majority (95.7%) of patients with multiple injuries had suffered SSTI.

Table 7.13. Injury condition of multiple-injury patients with sharp-instrument injuries.

Injury condition	N	%
FJI	13	28.3
SSTI	44	95.7
DT	1	2.2
CNSI	0	0.0
PC	4	8.7
TH	12	26.1
TOI	11	23.9

The majority (97.8%) of the patients did not have a GCS score; one patient had a GCS score of less than 8, which indicates that the patient was comatose.

An ISS of “1” indicates minor injury, “2” is moderate injury, “3” is for serious injury, and “4” is severe injury. The majority (76.1%) of the multiple-injury patients suffered minor to moderate injuries.

Table 7.14. GCS scores of multiple-injury patients with sharp-instrument injuries.

GCS	N	%
3–8	1	2.2
NA	45	97.8

Table 7.15. ISS of multiple-injury patients with sharp-instrument injuries.

ISS	N	%
1	16	34.8
2	19	41.3
3	4	8.7
4	7	15.2

7.2.3 Treatment of sharp-instrument injury patients

(1) Single injury

The single-injury patients were mainly admitted from the ED (76.4%).

The majority (91%) of the single-injury patients had a prehospital time longer than 1 hour.

Table 7.16. Admission pathway of single-injury patients with sharp-instrument injuries.

Admission pathway	N	%
RHOC	18	12.5
RHS	16	11.1
EDA	110	76.4

Table 7.17. Prehospital time of single-injury patients with sharp-instrument injuries.

Prehospital time (hour)	N	%
≤1	13	9.0
2–3	37	25.7
4–24	56	38.9
≥25	38	26.4

Most of the patients stayed in hospital for less than 30 days, and the number of patients who remained in the hospital between 4 and 14 days accounted for the largest proportion. The distribution of the LOS presented a normal distribution.

Table 7.18. LOS of single-injury patients with sharp-instrument injuries.

LOS (day)	N	%
0–3	24	16.7
4–7	47	32.6
8–14	46	31.9
15–30	25	17.4
≥31	2	1.4

The majority (76.4%) of the single-injury patients were cured; the cure rate was relatively high. It may be attributable to the simplicity of the injury, the mortality of these patients was comparatively low, only 0.7%.

Table 7.19. Outcome of single-injury patients with sharp-instrument injuries.

Outcome	N	%
Dead	1	0.7
Invalid	3	2.1
Improved	30	20.8
Cured	110	76.4

The incidence rates of complications in the form of HS and DC were higher among patients with single injury than other types of complications.

Table 7.20. Complications of single-injury patients with sharp-instrument injuries.

Complications	N	%
HS	13	9.0
DC	7	4.9
Apnea	0	0
CA	0	0
CH	0	0
BI	1	0.7
Paraplegia	0	0
AF	0	0
ARDS	0	0
ARF	0	0
WED	0	0
ABI	0	0
MODS	0	0
MOF	0	0

(2) Multiple injuries

Compared to RHOC or RHS, EDA was the most common admission pathway for patients with multiple injuries.

Table 7.21. Admission pathway of multiple-injury patients with sharp-instrument injuries.

Admission pathway	N	%
RHOC	6	13.0
RHS	9	19.6
EDA	31	67.4

The prehospital time of the majority (93.5%) of patients with multiple injuries was 24 hours or less, of which, the most common prehospital time was between 3 and 24 hours.

The majority (69.5%) of multiple-injury patients' LOS was between 8 and 30 days, and a LOS between 8 and 14 days was accounted for the most. Compared with patients with single injury, patients with multiple injuries had longer stays in the hospital.

Table 7.22. Prehospital time of multiple-injury patients with sharp-instrument injuries.

Prehospital time (hour)	N	%
≤1	14	30.4
2–3	13	28.3
4–24	16	34.8
≥25	3	6.5

Table 7.23. LOS of multiple-injury patients with sharp-instrument injuries.

LOS (day)	N	%
0–3	3	6.5
4–7	6	13.0
8–14	18	39.1
15–30	14	30.4
≥31	5	10.9

Among the multiple-injury patients, 37 (80.4%) were cured. The mortality was relatively low, whereas the cure rate was relatively high.

Table 7.24. Outcome of multiple-injury patients with sharp-instrument injuries.

Outcome	N	%
Dead	1	2.2
Invalid	2	4.3
Improved	6	13.0
Cured	37	80.4

Complications in the form of HS were found in 32.6% of multiple-injury patients and DC were found in 17.4% of the patients. Patients with multiple injuries were more likely to develop HS complications and DC than were single-injury patients.

Table 7.25. Complications of multiple-injury patients with sharp-instrument injuries.

Complications	N	%
HS	15	36.2
DC	8	17.4
Apnea	0	0
CA	0	0
CH	0	0
BI	2	4.3
AF	0	0
ARDS	0	0
ARF	0	0
Paraplegia	0	0
WED	1	2.2
ABI	1	2.2
MODS	1	2.2

7.2.4 Comorbidities in sharp-instrument injury patients

(1) Single injury

The most common form of comorbidity among single-injury patients was hypertension; cases of diabetes and osteoporosis were fewer.

Table 7.26. Comorbidities of single-injury patients with sharp-instrument injuries.

Comorbidity	N	%
Diabetes	2	1.4
Hypertension	8	5.6
Osteoporosis	1	0.7

(2) Multiple injuries

The most common comorbidity among multiple-injury patients was hypertension; cases of diabetes were fewer.

Table 7.27. Comorbidities of multiple-injury patients with sharp-instrument injuries.

Comorbidity	N	%
Diabetes	2	4.3
Hypertension	4	8.7

7.2.5 Outcomes of sharp-instrument injury patients

This study utilized SPSS software (version 17.0, SPSS Inc., Chicago, IL, USA) and adopted a single-factor statistical analysis method to explore influential factors on the outcome of sharp-instrument injury patients. The statistical significance was defined as $p < 0.05$. All tests were bilateral. The outcomes of patients were divided into dead, invalid, improved, and cured. A nonparametric testing method was adopted throughout. The raw data were organized into an $R \times C$ table, in which the headings of the rows were the independent variable groups and columns were the dependent variable (the outcomes) classifications. The statistical methods used for the analyses were selected according to the type of independent variable the Mann–Whitney U test was applied when the independent variable was dichotomous; the Kruskal-Wallis H test was applied when the independent variable was of multiple categories and non-ordinal; and the Spearman's Rank-Order Correlation test was applied when the independent variable was ordinal.

7.2.5.1 Single injury

(1) Comparison of binary categorical independent variables using the Mann-Whitney U test

The influence of gender on the outcomes was not statistically significant ($p = 0.995$). The cure rate in male patients (76.2%) was comparable to that in female patients (77.3%). The improvement rate in male patients (21.3%) was slightly higher than in female patients (18.2%).

Table 7.28. Comparison of outcomes between different genders among patients with single sharp-instrument injury.

Gender	Dead	Invalid	Improved	Cured	U-value	p-value
Male	1	2	26	93	1334.5	0.995
Female	0	1	4	17	-	-

FJI were found to have a significant effect on the outcomes (p = 0.026). The cure rate of patients with FJI (53.3%) was lower than that of patients without such injuries (79.1%); however, improvement rate of patients with FJI (40.0%) was higher than that of patients without such injuries (18.6%). Injuries to the central nervous system had a substantial impact on the outcomes (p = 0.009). The cure rate of patients with injuries to the central nervous system (25.0%) was much lower than that of patients without such injuries (77.9%); however, the improvement rate of patients with injuries to the central nervous system (50.0%) was higher than that of patients without such injuries (20.0%).

Table 7.29. Comparison of outcomes among different injury conditions of patients with single sharp-instrument injury.

Injury condition	Dead	Invalid	Improved	Cured	U-value	p-value
FJI					716.0	0.026
No	1	2	24	102		
Yes	0	1	6	8		
SSTI					458.5	0.792
No	0	0	2	5		
Yes	29	12	243	292		
CNSI					121.5	0.009
No	1	2	28	109		
Yes	0	1	2	1		
PC					540.0	0.962
No	1	3	28	104		
Yes	0	0	2	6		
TH					700.5	0.154
No	1	3	29	98		
Yes	0	0	1	12		
TOI					440.0	0.619
No	0	3	29	105		
Yes	1	0	1	5		

Complications were found to have no obvious effect on the outcomes. No evidence was found to show that the presence of complications such as HS, DC, and BI reduced the cure rate.

The influence of diabetes on the outcomes was not statistically significant (p = 0.588). The cure rate of patients with diabetes as a comorbidity (100.0%) was higher than that of patients without diabetes (76.1%), whereas the improvement rate of patients with diabetes (0.0%) was lower than that of patients without diabetes (21.1%). The effects of hypertension on the outcomes was not statistically significant (p = 0.382). The cure rate of patients with hypertension as a comorbidity (62.5%) was lower than that of patients without hypertension

(77.2%), whereas the improvement rate of patients with hypertension as comorbidity (37.5%) was higher than that of patients without hypertension (19.9%). The effect of osteoporosis on the outcomes was not statistically significant (p = 0.264). The cure rate of patients with osteoporosis as a comorbidity (0.0%) was lower than that of patients without osteoporosis (76.9%), whereas the improvement rate of patients with osteoporosis as comorbidity (100.0%) was higher than that of patients without osteoporosis (20.3%).

Table 7.30. Comparison of outcomes among different complications of patients with single sharp-instrument injury.

Complication	Dead	Invalid	Improved	Cured	U-value	p-value
HS					844.0	0.944
No	0	3	28	100		
Yes	1	0	2	10		
DC					4440.0	0.619
No	0	3	29	105		
Yes	1	0	1	5		
BI					54.5	0.764
No	3	3	30	109		
Yes	0	0	0	1		

Table 7.31. Comparison of outcomes among different comorbidities of patients with single sharp-instrument injury.

Comorbidity	Dead	Invalid	Improved	Cured	U-value	p-value
Diabetes					108.0	0.588
No	1	3	30	108		
Yes	0	0	0	2		
Hypertension					470.0	0.382
No	1	3	27	105		
Yes	28	36	185	549		
Osteoporosis					18.5	0.264
No	1	3	29	110		
Yes	0	0	1	0		

(2) Comparison of multiple categorical independent variables using the Kruskal-Wallis H Test

The effect of marital status on the outcomes was not statistically significant (p = 0.795). The cure rates were the highest among all outcomes. No apparent association was found between the outcomes and marital status.

Table 7.32. Comparison of outcomes among different marital status of patients with single sharp-instrument injury.

Marital status	Dead	Invalid	Improved	Cured	Chi-square	p-value
Divorced/widowed	0	0	0	1	1.0	0.795
Single	1	1	8	48	-	-
Married	0	2	22	61	-	-

Admission pathway was found to have no statistically significant effect on the outcomes ($p = 0.323$). The patients who were admitted through the ED had the highest cure rate (80.1%), and the improvement rate of these patients was 16.4%.

Table 7.33. Comparison of outcomes among different admission pathways of patients with single sharp-instrument injury.

Admission pathway	Dead	Invalid	Improved	Cured	Chi-square	p-value
RHOC	0	0	7	11	8.0	0.323
RHS	0	1	5	10	-	-
EDA	1	2	18	89	-	-

There was no significant difference in the outcomes among patients with various injured body regions ($p = 0.288$). Patients with an injury to the pelvis had the highest cure rate, followed by abdomen, thorax, extremities, head, and spine in descending order. The improvement rate of body regions from high to low was head, thorax, extremities, abdomen, pelvis, and spine.

Table 7.34. Comparison of outcomes among different injured body regions of patients with single sharp-instrument injury.

Injured body region	Dead	Invalid	Improved	Cured	Chi-square	p-value
Head	1	3	30	110	14.2	0.288
Thorax	0	2	14	36	-	-
Abdomen	0	0	4	16	-	-
Spine	1	0	1	12	-	-
Pelvis	0	0	0	0	-	-
Extremities	0	1	11	44	-	-

(3) Comparison of ordinal categorical independent variables using the Spearman rank correlation test

Age was found to have statistically significant correlation with the outcomes of single-injury patients ($p = 0.011$). Patients aged between 15 and 24 years had the highest cure rate (96.0%), and those aged 65 years and older had the lowest cure rate (60%). The improvement rate was highest among patients aged 65 years and older.

Table 7.35. Correlation analysis between age and outcomes among patients with single sharp-instrument injury.

Age (year)	Dead	Invalid	Improved	Cured	r_s	p-value
≤14	0	0	1	4	−0.212	0.011
15–24	0	0	1	240	-	-
25–34	0	0	5	22	-	-
35–44	0	1	8	20	-	-
45–54	1	1	2	10	-	-
55–64	0	32	186	749	-	-
≥65	0	1	3	6	-	-

The correlation between prehospital time and the outcomes was statistically significant ($p = 0.021$). The highest cure rate (86.5%) was seen in patients with 1–3 hours of prehospital time, whereas the lowest cure rate (60%) was seen in patients with a prehospital time greater than 24 hours. The improvement rate was highest among patients with a prehospital time greater than 24 hours.

Table 7.36. Correlation analysis between prehospital time and outcomes among patients with single sharp-instrument injury.

Prehospital time (hour)	Dead	Invalid	Improved	Cured	r_s	p-value
≤1	0	0	3	10	−0.192	0.021
1–3	0	1	4	32	-	-
3–24	0	1	10	45	-	-
>24	1	1	13	23	-	-

The LOS was found to have no apparent correlation with the outcomes ($p = 0.500$). Patients who stayed in hospital for 31 days or longer had the highest cure rate (100.0%), and those who stayed for 3 days or less had the lowest cure rate (58.3%). The improvement rate was highest among patients who stayed in hospital for 3 or less days.

Table 7.37. Correlation analysis between LOS and outcomes among patients with single sharp-instrument injury.

LOS (day)	Dead	Invalid	Improved	Cured	r_s	p-value
0–3	0	1	9	14	0.057	0.500
4–7	0	0	9	38	-	-
8–14	0	0	6	40	-	-
15–30	1	2	6	16	-	-
≥31	0	0	0	2	-	-

The AIS score was found to have no obvious correlation with the outcomes ($p = 0.500$). Patients with critical injuries had the highest cure rate (100.0%), whereas patients with serious injuries had the lowest cure rate (64.7%). The improvement rate was highest among patients with serious injuries.

Table 7.38. Correlation analysis between AIS and outcomes among patients with single sharp-instrument injury.

AIS	Dead	Invalid	Improved	Cured	r_s	p-value
1	0	0	18	72	−0.119	0.500
2	0	3	6	22	-	-
3	0	0	6	11	-	-
4	1	0	0	2	-	-
5	0	0	0	2	-	-
6	0	0	0	0	-	-

7.2.5.2 Multiple injuries

(1) Comparison of binary categorical independent variables using the Mann-Whitney U test

The difference in the outcomes among multiple-injury patients of different genders was statistically significant ($p < 0.05$). The cure rate in male patients (86.5%) was greater than in female patients (55.6%). The improvement rate in male patients (8.1%) was lower than in female patients (33.3 %).

Table 7.39. Comparison of outcomes between different genders among patients with multiple sharp-instrument injuries.

Gender	Dead	Invalid	Improved	Cured	U-value	p-value
Male	0	2	3	32	115.5	0.041
Female	1	0	3	5	-	-

None of the injured body regions (head, thorax, upper extremities, lower extremities, pelvis, and spine) was found to have a statistically significant influence on the outcomes of patients with multiple injuries ($p > 0.05$). No substantial differences were found in the cure rates between patients with or without a given injured body region. The cure rates were the highest among all groups. No apparent association was found between outcomes and injured body regions.

The injury condition was found to have no significant influence on the outcomes. No apparent differences were found in the cure rate of patients with or without fractures and joint injuries, SSTI, PC, TH, and TOI. The outcomes of patients with multiple injuries and injury conditions had no obvious association.

Complications were found to have a statistically significant influence on the outcomes of patients with multiple injuries. Complications, such as HS and DC, were found to have a negative influence on the cure rate in patients. However, the effects of WED, ABI, multiple organ dysfunction, and BI on the outcomes were not statistically significant; hence, these complications had no correlation with the outcomes.

The influence of diabetes on the outcomes was not statistically significant ($p = 0.661$). Regardless of the presence of diabetes as comorbidity, “cured” had the highest proportion among all outcomes, suggesting no obvious correlation between diabetes as comorbidity and the outcomes of the treatment. The effect of hypertension on the outcomes was not statistically significant ($p = 0.895$). Regardless of the interaction of hypertension as comorbidity, “cured” had the highest proportion among all outcomes, suggesting no obvious correlation between hypertension as comorbidity and the outcomes of the treatment.

Table 7.40. Comparison of outcomes among different injured body regions of patients with multiple sharp-instrument injuries.

Injured body region	Dead	Invalid	Improved	Cured	U-value	p-value
Head					238.5	0.792
No	1	1	4	23		
Yes	0	1	2	14		
Thorax					214.5	0.743
No	0	2	1	11		
Yes	1	0	5	26		
Abdomen					216.0	0.241
No	0	1	3	24		
Yes	1	1	3	13		
Spine					252.0	0.884
No	1	2	5	35		
Yes	0	0	1	2		
Pelvis					31.5	0.526
No	1	2	5	36		
Yes	0	0	1	1		
Upper extremities					233.0	0.387
No	1	1	3	15		
Yes	0	1	3	22		
Lower extremities					252.0	0.884
No	1	1	3	22		
Yes	0	1	3	15		

Table 7.41. Comparison of outcomes among different injury conditions of patients with multiple sharp-instrument injuries.

Injury condition	Dead	Invalid	Improved	Cured	U-value	p-value
FJI					203.0	0.685
No	1	1	5	26		
Yes	0	1	1	11		
SSTI					31.5	0.526
No	0	0	1	1		
Yes	1	2	5	36		
DT					13.0	0.826
No	0	0	0	1		
Yes	1	2	6	36		
PC					37.5	0.069
No	1	2	3	36		
Yes	0	0	3	1		
TH					193.0	0.690
No	1	2	4	27		
Yes	0	0	2	10		
TOI					193.0	0.690
No	0	1	5	29		
Yes	1	1	1	8		

Table 7.42. Comparison of outcomes among different complications of patients with multiple sharp-instrument injuries.

Complication	Dead	Invalid	Improved	Cured	U-value	p-value
HS					157.5	0.011
No	0	0	3	28		
Yes	1	2	3	9		
DC					67.0	0.012
No	0	0	4	34		
Yes	1	2	2	3		
WED					1.5	0.087
No	1	2	6	37		
Yes	0	1	0	0		
ABI					1.5	0.087
No	1	2	6	37		
Yes	0	1	0	0		
MODS					1.5	0.087
No	1	2	6	37		
Yes	0	1	0	0		
BI					27.5	0.406
No	1	1	6	36		
Yes	0	13	0	1		

Table 7.43. Comparison of outcomes among different comorbidities of patients with multiple sharp-instrument injuries.

Comorbidity	Dead	Invalid	Improved	Cured	U-value	p-value
Diabetes					35.0	0.661
No	1	2	6	35		
Yes	0	0	0	2		
Hypertension					80.5	0.895
No	1	2	5	34		
Yes	04	0	1	3		

(2) Comparison of multiple categorical independent variables using the Kruskal Wallis H test

The effect of marital status upon the outcomes was not statistically significant (p = 0.611). Regardless of whether the patients were single or married, "cured" was the highest proportion of the outcomes, indicating that marital status and the outcomes of the treatment had no apparent association.

Table 7.44. Comparison of outcomes among different marital status. of patients with multiple sharp-instrument injuries

Marital status	Dead	Invalid	Improved	Cured	Chi-square	p-value
Single	1	1	0	13	0.259	0.611
Married	0	1	6	24	-	-

The influence of admission pathways on outcomes was not statistically significant (p =

0.538). Regardless of the admission pathway used, "cured" had the highest proportion among all outcomes, showing that admission pathway and the outcomes of the treatment had no significant correlation.

Table 7.45. Comparison of outcomes among different admission pathways of patients with multiple sharp-instrument injuries.

Admission pathway	Dead	Invalid	Improved	Cured	Chi-square	p-value
RHOC	0	1	1	4	1.241	0.538
RHS	0	0	1	8	-	-
EDA	1	1	4	25	-	-

(3) Comparison of ordinal categorical independent variables using the Spearman rank correlation test

There was also no significant difference in the outcomes among patients with a different number of injured body regions ($p = 0.910$). Regardless of the number of injured body regions, "recovery" was the greatest proportion among all outcomes, suggesting that outcomes and the number of injured body regions were not significantly correlated.

Table 7.46. Correlation analysis between age and outcomes among patients with multiple sharp-instrument injuries.

N	Dead	Invalid	Improved	Cured	r_s	p-value
2	1	2	3	23	0.017	0.910
3	0	0	1	10	-	-
4	0	0	1	3	-	-
5	0	0	1	1	-	-

Age was found to have no statistically significant correlation with the outcomes of patients with multiple injuries ($p = 0.504$). Regardless of age, "recovery" had the highest proportion among all outcomes; hence, age and outcomes had no apparent association.

Table 7.47. Correlation analysis between age and outcomes among patients with multiple sharp-instrument injuries.

Age (year)	Dead	Invalid	Improved	Cured	r_s	p-value
15–24	1	0	0	10	−0.101	0.504
25–34	0	2	1	11	-	-
35–44	0	1	1	7	-	-
45–54	0	0	3	4	-	-
55–64	0	0	1	1	-	-
≥65	0	0	0	4	-	-

The correlation between prehospital time and outcomes of patients with multiple injuries was statistically significant ($p = 0.044$). Patients with one hour or less of prehospital time had the highest cure rate (92.9%), whereas patients with over 24 hours of prehospital time had the lowest cure rate (33.3%). The proportion of positive outcome was highest among patients with a prehospital time of greater than 24 hours. Therefore, the prehospital time and outcomes were found to be correlated.

Table 7.48. Correlation analysis between prehospital time and outcomes among patients with multiple sharp-instrument injuries.

Prehospital time (hour)	Dead	Invalid	Improved	Cured	r_s	p-value
≤1	0	1	0	13	−0.299	0.044
1–3	0	0	2	11	-	-
3–24	1	0	3	12	-	-
>24	0	1	1	1	-	-

The LOS of patients with multiple injuries was found to have no apparent correlation with the outcomes (p = 0.601). Regardless of the LOS, "cured" had the highest proportion among all outcomes, suggesting that LOS and outcomes were not significantly correlated.

Table 7.49. Correlation analysis between LOS and outcomes among patients with multiple sharp-instrument injuries.

LOS (day)	Dead	Invalid	Improved	Cured	r_s	p-value
0–3	1	1	0	1	0.079	0.601
4–7	0	1	031	5	-	-
8–14	0	0	247	16	-	-
15–30	0	0	2	12	-	-
≥31	0	0	2	3	-	-

ISS were found to have no statistically significant correlation with the outcomes of patients with multiple injuries (p = 0.557). Regardless of the ISS, "cured" had the highest proportion among all outcomes, indicating that ISS and outcomes were not significantly associated.

Table 7.50. Correlation analysis between ISS and outcomes among patients with multiple sharp-instrument injuries.

ISS	Dead	Invalid	Improved	Cured	r_s	p-value
1–8	1	0	1	14	−0.089	0.557
9–15	0	1	452	14	-	-
16–24	0	0	0	4	-	-
≥25	0	1	1	5	-	-

7.3 Summary

In general, most sharp-instrument injuries are caused by accidents. Apart from elderly patients and patients with other underlying diseases and patients with no vital organ damages but without timely treatment, the ratios of sharp-instrument injury patients who are sent to the hospital in an appropriate timeframe and successfully treated have been gradually increasing (Cheng *et al.*, 2000). The mortality rates of the subjects in this study were relatively low, only 2 of 190 patients were deceased. Sharp-instrument injury incidence is comparatively lower among female patients than among male patients (Aromatario *et al.*, 2016). Sharp-instrument injury caused by acts of violence usually involves intent by the attacker to kill the victim; hence, involves injuries in multiple body regions (Jacovides *et al.*, 2013). Sharp-instrument injury can occur to any body system (McManus, 2014; Pasley and Demetriades, 2012; Sampson, 2016; Hornez *et al.*, 2016; Laing *et al.*, 2014; Cestare *et al.*, 2015; Adam *et al.*, 2015).

7.3.1 Patients with single injury

(1) Demographic characteristics: Most of the patients who were investigated were male, aged 45–54 years old, and married. (2) Injury characteristics: Most of the investigated patients had an injury in the extremities; most of the injuries were minor according to the AIS. (3) Basic information of treatment: There were more patients admitted from the ED than other admission pathways, with an interval of 4–24 hours between being injured and sent to the hospital, and with an average hospital stay of 4–7 days. Most of the patients with single sharp-instrument injury were cured and discharged, and the mortality rate was low. (4) Comorbidities: The most commonly identified comorbidities were hypertension, diabetes, and osteoporosis. (5) Outcomes and influential factors: Factors that had a statistically significant correlation with the outcome included age, prehospital time, number of fractures and joint injuries, and whether the patient had suffered from the CNSI.

7.3.2 Patients with multiple injuries

(1) Demographic characteristics: Most of the investigated patients were male, aged 25–34 years old, and married. (2) Injury characteristics: Being injured in two body regions, as well as being injured in the thorax, combined with SSTI, were the most common cases among the patients with multiple injuries. Most of the investigated patients had moderate injuries according to the ISS. (3) Basic information of treatment: More investigated patients were admitted from the ED than other admission pathways, with an interval of 4–24 hours between being injured and sent to hospital, and with an average hospital stay of 8–14 days. The majority were cured and discharged, and the mortality rate was low. (4) Comorbidities: The most common comorbidities were hypertension and diabetes. (5) Outcomes and influential factors: Factors that had a statistically significant correlation with the outcome include age, prehospital time, HS, and DC.

The occurrence of sharp-instrument injury is extremely common, and the causes and outcomes differentiate by regions (Minei *et al.*, 2010). Younger patients tend to have a better prognosis (José, 2011). Effective prehospital treatment can reduce morbidity and mortality of sharp-instrument injury. In the past 10 years, the probability of occurrence and mortality rates of sharp-instrument injury have continued to decline (Barber *et al.*, 1998; Pereira *et al.*, 2013; Seamon *et al.*, 2013). According to a retrospective study conducted by the Mediterranean Forensic Pathology Research team, head, cheek, and back injuries are the most common injuries involved in homicide cases, and injuries in the abdomen and extremities occurred more frequently in suicide cases (Kemal *et al.*, 2013). In addition, approximately 10% of abdominal injury cases involve sharp instruments, which mainly affect the gastrointestinal system, especially the jejunum, ileum, duodenum, colon, and stomach (Arslan *et al.*, 2016). Sharp-instrument injury are less common than blunt force injuries. Patients with sharp-instrument injury who stay in hospital for longer periods of time are more prone to complications, have higher mortality rate, and are more likely to require surgical intervention or blood transfusion. The resources needed in treating sharp-instrument injury are age-related. According to the current medical situation in China, a major focus should be placed on improving the quality of medical care and efficiency of resource utilization, as well as placing an extra emphasis on research outcomes of trauma treatment.

This study is a small-scale, retrospective study, hence, possesses certain limitations. However, it serves to promote in-depth management and optimization of the medical system, contribute to the rational allocation of public resources to improve the outcomes of treatment, and reduce mortality rates, as well as relieve the burden on the public health sector. The data collected can be used to guide quality improvements and prevention efforts in the future.

References

Adam, N.; Sorensen, V.; Skinner, R. Not all intestinal traumatic injuries are the same: a comparison of surgically treated blunt *vs.* penetrating injuries. *Injury* **2015**, *46*, 115–118.

Aromatario, M.; Cappelletti, S.; Bottoni, E.; *et al.* Weapon identification using antemortem CT with 3D reconstruction, is it always possible?—A report in a case of facial blunt and sharp injuries using an ashtray. *Legal Medicine* **2016**, *18*, 1–6.

Arslan, S.; Okur, M.H.; Arslan, M.S.; *et al.* Management of gastrointestinal perforation from blunt and penetrating abdominal trauma in children analysis of 96 patients. *Pediatric Surgery International* **2016**, *32*, 1067–1073.

Au, K.I.; Beh, S.L. Injury patterns of sharp instrument homicides in Hong Kong. *Forensic Science International* **2011**, *204*, 201–204.

Barber, C.W.; Ozonoff, V.V.; Schuster, M.; *et al.* Massachusetts weapon-related injury surveillance system. *American Journal of Preventive Medicine* **1998**, *15*, 57–66.

Bastos, R.L.; Baisden, C.E.; Harker, L.; *et al*. Penetrating thoracic trauma. *Seminars in Thoracic and Cardiovascular Surgery* **2008**, *20*, 19–25.

Bolliger, S.A.; Kneubuehl, B.P.; Thali, M.J.; *et al.* Stabbing energy and force required for pocket-knives to pierce ribs. *Forensic Science, Medicine and Pathology* **2016**, *12*, 1–5.

Cestare, T.P.; Hill, F.C.; Venkatesan, K. Bladder injury from penetrating trauma of the inner thigh. *Urology Case Reports* **2015**, *3*, 226–229.

Chai, M.Z.; Fei, P.P.; Lei, Z. Status of sharp instrument injuries and corresponding protective measures. *Nursing Journal of Chinese People's Liberation Army* **2013**, *30*, 10–13.

Cheng, B.C.; Tu, Z.F.; Mao, Z.F.; *et al.* Treatments in patients with penetrating injuries of the lower chest a review of 502 cases. *Journal of Emergency Medicine* **2000**, *5*, 302–304.

Cruvinel, N.J.; Dedivitis, R.A. Prognostic factors of penetrating neck trauma. *Brazilian Journal of Otorhinolaryngology* **2011**, *77*, 121–124.

Goniewicz, M.; Wloszczak-Szubzda, A.; Niemcewicz, M.; *et al.* Injuries caused by sharp instruments among healthcare workers—international and Polish perspectives. *Annals of Agricultural and Environmental Medicine* **2012**, *19*, 523–527.

Hornez, E.; Monchal, T.; Boddaert, G.; *et al.* Penetrating pelvic trauma Initial assessment and surgical management in emergency. *Journal of Visceral Surgery* **2016**, *153*, 79–90.

Jacovides, C.L.; Bruns, B.; Holena, D.N.; *et al.* Penetrating trauma in urban women patterns of injury and violence. *Journal of Surgical Research* **2013**, *184*, 592–598.

Kemal, C.J.; Patterson, T.; Molina, D.K. Deaths due to sharp-instrument injury in Bexar county, Texas, with respect to manner of death. *The American Journal of Forensic Medicine and Pathology* **2013**, *34*, 253–259.

Laing, G.L.; Skinner, D.L.; Bruce, J.L.; *et al.* A multi faceted quality improvement programme results in improved outcomes for the selective non-operative management of penetrating abdominal trauma in a developing world trauma centre. *Injury* **2014**, *45*, 327–332.

Lockyer, A.; Oram, R.; Lopez, G.; *et al.* Patterns of injury in penetrating sharp trauma in a Provincial KwaZulu-Natal Hospital. *African Journal of Emergency Medicine* **2013**, *3*, 67–70.

Luo, G.D.; Cao, Y.K.; Lin, Z. Clinical analysis of 21 patients with sharp instrument injury of the anal tube and rectum. *Medical Journal of West China* **2010**, *10*, 1896–1897.

Minei, J.P.; Schmicker, R.H.; Kerby, J.D.; *et al.* Severe traumatic injury. *Annals of Surgery* **2010**, *252*, 149–157.

Nielsen, J.W.; Shi, J.; Wheeler, K.; *et al.* Resource use in pediatric blunt and penetrating trauma. *Journal of Surgical Research* **2016**, *202*, 436–442.

Pasley, J.D.; Demetriades, D. Penetrating fetal trauma with late complications a case report. *Journal of Pediatric Surgery* **2012**, *47*, e9–e11.

Pereira, B.M.T.; Nogueira, V.B.; Calderan, T.R.A.; *et al.* Penetrating cardiac trauma 20-y experience from a university teaching hospital. *Journal of Surgical Research* **2013**, *183*, 792–797.

Qin, X.; Wang, L.Y.; Li, A.P. Analysis and suggestions of sharp instrument injury on 271 medical workers. *Chinese Nursing Management* **2008**, *8*, 53–54.

Qiu, Z.T.; Zhang, Y.Z.; Huang, X.; *et al.* The analysis of diagnosis and treatment on 35 patients with thoraco-abdominal injury. *China Modern Doctor* **2009**, *13*, 53–54.

Sampson, C.S. Penetrating injury from an arrow to the oropharynx in a child. *Visual Journal of Emergency Medicine* **2016**, *4*, 1–2.

Schmidt, U. Sharp-instrument injury in "clinical" forensic medicine. *Forensic Science International* **2010**, *195*, 1–5.

Seamon, M.J.; Doane, S.M.; Gaughan, J.P.; *et al.* Prehospital interventions for penetrating trauma victims-a prospective comparison between advanced life support and basic life support. *Injury* **2013**, *44*, 634–638.

Sledge, J.; Andrew Graham, W.; Westmoreland, S.; *et al.* Spinal cord injury models in non human primates-Are lesions created by sharp instruments relevant to human injuries? *Medical Hypotheses* **2013**, *81*, 747–748.

Sobnach, S.; Segobin, R.; Nicol, A.; *et al.* Penetrating trauma to the kidney and Meckel's Diverticulum in a patient with unilateral renal agenesis. *International Journal of Surgery Case Reports* **2015**, *17*, 136–138.

Zhu, L.; Wu, Z.; Dong, F.; *et al.* Two kinds of ocular trauma score for paediatric traumatic cataract in penetrating eye injuries. *Injury* **2015**, *46*, 1828–1833.

Zyck, S.; Toshkezi, G.; Krishnamurthy, S.; *et al.* Treatment of penetrating nonmissile traumatic brain injury, case series and review of the literature. *World Neurosurgery* **2016**, *91*, 297–307.

Chapter 8 Investigation of ground-level fall injury occurrence and evolution

Haiping Chen[1], *Chen Xue*[2] *and Lulu Zhang*[2]

[1] *Department of Science and Education, Shanghai Children's Hospital, Shanghai 200062, China*

[2] *Department of Military Health Service Management, College of Military Health Service Management, Second Military Medical University, Shanghai 200433, China*

8.1 Overview

8.1.1 Investigation background

Falls are sudden, involuntary, unintentional postural changes where an individuals' body collapses, striking the ground, or drops from a height to lower ground. According to the ICD-10, falls include the following two categories (1) falling from one plane to another plane, and (2) falling within the same plane.

The risk of falls is high, and every person that falls may be injured. Moreover, age, gender, working conditions, level of alcohol or drug intake, physical health, and social environmental factors tend to affect individuals' likelihood of suffering falls, as well as influence the types, severity, and prognosis of the injuries involved (Stewart *et al.*, 2016; Bhatti *et al.*, 2015; Chen *et al.*, 2005; Chen, *et al.*, 2015; Er *et al.*, 2015). Age is one of the leading risk factors for falls. Elderly adults are at the greatest risk of death or serious injury due to falls. In the United States, 20–30% of elderly adults that fall suffer minor or serious injuries, mostly involving SSTI in the extremities, hip fractures, and wounds to the head (Hegeman *et al.*, 2009).

8.1.2 Definition and injury characteristics of ground-level fall injury

Fall injuries are fatal or non-fatal injuries, which have a high incidence rate and can cause severe harm to the human body (Saadat *et al.*, 2016). According to data released by the WHO in 2012, there are approximately 37.3 million cases of severe fall-related injuries that require medical treatment every year, which has led to a reduction in disability-adjusted life years among 17 million individuals. The three age groups that have the highest incidence rate of falls are 65 years or older, between 15 and 29 years, and younger than 15 years. In addition, among the total disability-adjusted life years reductions worldwide, approximately 40% happen to children (Naghavi *et al.*, 2015).

Falls are the second largest cause of death due to unintentional injury, next to only traffic injuries. There are roughly 42.4 million people deceased due to falls every year globally. More than 80% of these deadly falls occurred in low-income countries, and more than 75% occurred in the Western Pacific and Southeast Asia. In addition, direct and indirect economic losses caused by falls can place a heavy burden on individuals, their families, and government finances. In Finland and Australia, for example, the average cost of health care expenditure for each elderly patient with a fall injury (age ≥65 years) was 3,611 and 1,049 US dollars per year, respectively. A survey conducted on falls in Canada has suggested that an effective prevention strategy can reduce the incidence of falls among children younger than 10 years of age by 20%, and save more than 120 million US dollars per year (Naghavi *et al.*, 2015).

This present study divides falls into two categories ground-level falls and high-level falls. ground-level falls refer to falls from a standing position, with little to no apparent difference between the height of the person standing and impact level, and high-level falls are defined as falls from a greater height than 15 feet. The focus of the present study is the ground-level falls.

8.1.3 Basic data for the investigation

(1) Research purposes

By collecting information of ground-level fall injury patients in Shanghai, the present study intended to explore the epidemiological characteristics, distribution, and causes of falls, analyzing the key influential factors of corresponding outcomes through statistical analyses to propose scientific suggestions on the improvement of the medical rescue system.

(2) Research data

During January 2011 and January 2015, the project team collected the medical information of 4,426 fall-injury cases, including 4,063 cases of single injury and 363 cases of multiple injuries, from the 4 largest trauma centers in Shanghai (burn trauma emergency center, bone trauma emergency center, trauma emergency center, and trauma emergency center & emergency critical care unit). Samples were selected from the hospital information systems, according to the predefined screening criteria, with reference to the ICD-10 and regulations on the registration of medical records in the Chinese hospital information system. Each patient was informed of the research purpose and had signed a written consent.

8.2 Investigation results of ground-level fall injury occurrence and evolution

8.2.1 Demographic characteristics of ground-level fall injury patients

(1) Single injury

There were more female patients with a single injury (56.9%) than male patients (43.1%).

Table 8.1. Gender of single-injury patients with ground-level fall injuries.

Gender	N	%
Male	1,753	43.1
Female	2,310	56.9

The proportion of single-injury patients seemed to increase by age group; patients aged 65 years or older had the highest proportion (46.3%), whereas patients aged between 0 and 14 years had the lowest proportion (1.1%).

Table 8.2. Age of single-injury patients with ground-level fall injuries.

Age (year)	N	%
0–14	45	1.1
15–24	130	3.2
25–34	199	4.9
35–44	292	7.2
45–54	545	13.4
55–64	972	23.9
≥65	1,880	46.3

The majority (85.7%) of the patients were married, whereas patients who were divorced or widowed were in the minority (0.3%).

Table 8.3. Marital status of single-injury patients with ground-level fall injuries.

Marital status	N	%
Divorced/widowed	12	0.3
Single	571	14.1
Married	3,480	85.7

(2) Multiple injuries

There were more female patients (59.2%) with multiple injuries than male patients (40.8%).

Table 8.4. Gender of multiple-injury patients with ground-level fall injuries.

Gender	N	%
Male	148	40.8
Female	215	59.2

With increasing age, the proportion of multiple-injury patients tended to rise; patients aged 65 years or older had the highest proportion (49.6%), followed by patients aged 55–64 years (23.4%).

Table 8.5. Age of multiple-injury patients with ground-level fall injuries.

Age (year)	N	%
0–14	0	0
15–24	9	2.5
25–34	27	7.4
35–44	25	6.9
45–54	37	10.2
55–64	85	23.4
≥65	180	49.6

The proportion of married and single multiple-injury patients were 90.9% and 9.1%, respectively.

Table 8.6. Marital status of multiple-injury patients with ground-level fall injuries.

Marital status	N	%
Divorced/widowed	0	0
Single	33	9.1
Married	330	90.9

8.2.2 Injury characteristics of ground-level fall injury patients

The characteristics of ground-level fall injury were investigated from injured body regions, injury conditions, GCS score, and AIS/ISS.

(1) Single injury

The most common injured body regions among patients with a single injury were to the extremities (76.9%), head (10.9%), and spine (7.8%).

Table 8.7. Injured body region of single-injury patients with ground-level fall injuries.

Injured body region	N	%
Head	444	10.9
Thorax	126	3.1
Abdomen	11	0.3
Spine	316	7.8
Pelvis	43	1.1
Extremities	3,123	76.9

The most common injury condition among single-injury patients was FJI (90.0%). No patients with DT were found.

Table 8.8. Injury condition of single-injury patients with ground-level fall injuries.

Injury condition	N	%
FJI	3,658	90.0
SSTI	576	14.2
DT	0	0
CNSI	379	9.3
PC	69	1.7
TH	32	0.8
TOI	10	0.2

Only 2.2% of the patients with a single injury had a GCS score. Among the 2.2% of patents, those with no brain injury composed the highest proportion (1.0%), followed by severe head injury (0.7%).

Table 8.9. GCS score of single-injury patients with ground-level fall injuries.

GCS	N	%
3–8	27	0.7
9–12	9	0.2
13–14	12	0.3
15	41	1.0
NA	3,974	97.8

Based on AIS scores of 3 or less, the majority (98%) of the single-injury patients were not severely injured; most had either a serious injury (AIS = 3, 50.1%) or moderate injury (AIS = 2, 44.3%). The proportion of patients with severe or worse injuries was relatively low.

Table 8.10. AIS of single-injury patients with ground-level fall injuries.

AIS	N	%
1	147	3.6
2	1,800	44.3
3	2,036	50.1
4	53	1.3
5	24	0.6
6	3	0.1

(2) Multiple injuries

The majority (86.2%) of the patients with multiple injuries were injured in two body regions, with a maximum of 4 injured body regions among the investigated patients.

Table 8.11. Number of injured body regions of multiple-injury patients with ground-level fall injuries.

Number of injured body regions	N	%
2	313	86.2
3	42	11.6
4	8	2.2

The incidence of injuries to the upper and lower extremities was 60.1% and 51.2%, respectively. In addition, the proportion of patients with injuries to the head was not insubstantial (41.3%).

As many as 93.4% of the patients suffered fractures and bone and joint injuries. In addition, the proportion (39.4%) of SSTI was also high.

Only 1.6% of the patients with multiple injuries had a GCS score. Among 1.6% patients, the majority (1.4%) were found to have severe brain injuries, and those with moderate brain injuries accounted for the lowest proportion (0.3%).

Table 8.12. Injured body region of multiple-injury patients with ground-level fall injuries.

Injured body region	N	%
Head	150	41.3
Thorax	107	29.5
Abdomen	16	4.4
Upper extremities	218	60.1
Lower extremities	186	51.2
Spine	89	24.5
Pelvis	18	5.0

Table 8.13. Injury condition of multiple-injury patients with ground-level fall injuries.

Injury condition	N	%
FJI	339	93.4
SSTI	143	39.4
DT	0	0
CNSI	71	19.6
PC	34	9.4
TH	11	3.0
TOI	10	2.8

Table 8.14. GCS scores of multiple-injury patients with ground-level fall injuries.

GCS	N	%
3–8	5	1.4
9–12	1	0.3
NA	357	98.4

Most of the injuries were mild to moderate, with 31.1% of the patients having mild injuries and 41.3% having moderate injuries. The proportion (6.6%) of severely injured patients was the lowest.

Table 8.15. ISS of multiple-injury patients with ground-level fall injuries.

ISS	N	%
1–8	113	31.1
9–15	150	41.3
16–24	76	20.9
≥25	24	6.6

8.2.3 Treatment of ground-level fall injury patients

Treatment of ground-level fall injury patients was analyzed from admission pathway, prehospital time, LOS, outcome, and complications.

(1) Single injury

The majority (69.5%) of the patients with a single injury were admitted from the ED, patients who were RHOC accounted for 11.3%, and 19.2% of the patients were RHS.

Table 8.16. Admission pathway of single-injury patients with ground-level fall injuries.

Admission pathway	N	%
RHOC	459	11.3
RHS	779	19.2
EDA	2,825	69.5

The proportion of patients with a prehospital time of 3–24 hours was 42.0%, followed by patients with more than 24 hours of prehospital time (37.7%), whereas patients with less than 1 hour and 1–3 hours of prehospital time accounted for 1.0% and 19.4%, respectively.

Table 8.17. Prehospital time of single-injury patients with ground-level fall injuries.

Prehospital time (hour)	N	%
≤1	40	1.0
1–3	787	19.4
3–24	1,705	42.0
>24	1,531	37.7

The majority (36.6%) of the single-injury patients stayed in hospital between 8 and 14 days, and 89.1% of the patients had a LOS between 4 and 30 days.

Table 8.18. LOS of single-injury patients with ground-level fall injuries.

LOS (day)	N	%
0–3	370	9.1
4–7	1,210	29.8
8–14	1,486	36.6
15–30	922	22.7
≥31	75	1.8

The majority (74.7%) of the patients with a single injury had been cured by the time of discharge, and 19.0% required further rehabilitation. Only a very small number (68; 1.7%) of patients were dead.

Table 8.19. Outcome of single-injury patients with ground-level fall injuries.

Outcome	N	%
Dead	68	1.7
Invalid	188	4.6
Improved	770	19.0
Cured	3,037	74.7

DC was most the common hospital complication among patients with a single injury (5.6%), followed by BI (1.7%), paraplegia (1.0%), MODS (0.5%), and WED (0.4%).

Table 8.20. Complications of single-injury patients with ground-level fall injuries.

Hospital complications	N	%
HS	10	0.2
DC	226	5.6
Apnea	3	0.1
CA	3	0.1
CH	3	0.1
Paraplegia	41	1.0
AF	7	0.2
WED	17	0.4
ABI	2	0.0
ARDS	1	0.0
ARF	13	0.3
MOF	1	0.0
MODS	19	0.5
BI	68	1.7

(2) Multiple injuries

Most patients with multiple injuries were admitted via the ED of the hospital (68.0%). The proportion of patients RHS and RHOC accounted for 21.5% and 10.5%, respectively.

Table 8.21. Admission pathway of multiple-injury patients with ground-level fall injuries.

Admission pathway	N	%
RHOC	38	10.5
RHS	78	21.5
EDA	247	68.0

Only 2.8% of the patients had a prehospital time of less than 1 hour, and 47.1% of patients were admitted by the hospital within 3–24 hours of injury.

Table 8.22. Prehospital time of multiple-injury patients with ground-level fall injuries.

Prehospital time (hour)	N	%
≤1	10	2.8
1–3	98	27.0
3–24	171	47.1
>24	84	23.1

The number of patients who stayed in hospital for 8–14 days held the highest proportion (35.0%), followed by patients who stayed for 15–30 days (29.8%) and 4–7 days (24.5%).

Table 8.23. LOS of multiple-injury patients with ground-level fall injuries.

LOS (days)	N	%
0–3	27	7.4
4–7	89	24.5
8–14	127	35.0
15–30	108	29.8
≥31	12	3.3

Most of the patients (59.0%) with multiple injuries had been cured upon discharge, 33.1% required further rehabilitation, and only a very small proportion of the patients' dead (2.5%).

Table 8.24. Outcome of multiple-injury patients with ground-level fall injuries.

Outcome	N	%
Dead	9	2.5
Invalid	20	5.5
Improved	120	33.1
Cured	214	59.0

The most common complications among patients with multiple injuries were DC (13.8%), BI (5.0%), paraplegia (2.2%), ARDS (1.4%), ARF (1.4%).

Table 8.25. Complications of multiple-injury patients with ground-level fall injuries.

Complications	N	%
HS	2	0.6
DC	50	13.8
Apnea	2	0.6
CA	2	0.6
CH	0	0
Paraplegia	8	2.2
AF	3	0.8
WED	3	0.8
ABI	1	0.3
ARDS	5	1.4
ARF	5	1.4
MOF	0	0
MODS	2	0.6
BI	18	5.0

8.2.4 Comorbidities in ground-level fall injury patients

Three comorbidities were examined among ground-level fall injury patients, including diabetes, hypertension, and osteoporosis.

(1) Single injury

The most common comorbidity among patients with a single injury was hypertension (19.6%), followed by diabetes (10.0%), and osteoporosis was of the lowest proportion (1.1%).

Table 8.26. Comorbidities of single-injury patients with ground-level fall injuries.

Comorbidity	N	%
Diabetes	407	10.0
Hypertension	798	19.6
Osteoporosis	46	1.1

(2) Multiple injuries

The proportion of hypertension and diabetes as a comorbidity among multiple-injury patients were 11.8% and 21.5%, respectively.

Table 8.27. Comorbidities of multiple-injury patients with ground-level fall injuries.

Comorbidity	N	%
Diabetes	43	11.8
Hypertension	78	21.5

8.2.5 Outcomes of ground-level fall injury patients

In this study, SPSS software (version 17.0, SPSS Inc., Chicago, IL, USA) was utilized for single factor statistical analyses, to investigate the factors that influence the outcomes of fall-injury patients ($p < 0.05$ was considered statistically significant). The outcomes were divided into dead, invalid, improved, and cured. A nonparametric method was adopted for the testing. The raw data were organized into an R × C table, where the headings of the rows were the groups of independent variables and that in the columns were the classifications of the dependent variable (the outcomes). The statistical methods used for the analyses were selected according to the type of the independent variables the Mann–Whitney U test was applied when the independent variable was dichotomous; the Kruskal-Wallis H test was applied when the independent variable was multiple categorical and non-ordinal; and the Spearman's Rank-Order Correlation test was applied when the independent variable was ordinal.

8.2.5.1 Single injury

(1) Comparison of binary categorical independent variables using the Mann-Whitney U test

Gender was found to have a statistically significant effect on the outcomes ($p = 0.001$). The cure rate was lower among male patients (31.1%) than that among female patients (43.7%).

Table 8.28. Comparison of outcomes between different genders among patients with single ground-level fall injury.

Gender	Dead	Invalid	Improved	Cured	U-value	p-value
Male	34	80	377	1,262	1930427.5	0.001
Female	34	108	393	1,775	-	-

The influence of injury conditions on outcomes appeared to be statistically significant ($p < 0.05$ for all conditions). The mortality of patients with FJI (1.0%) were higher than that of patients without a corresponding condition (0.6%). Patients without SSTI had a substantially higher cure rate (67.6%) than those with such injuries (7.2%). The cure rate was significantly lower among patients with CNSI (3.4%) than in patients without such injuries (71.3%). Patients with PC had a clearly lower cure rate (0.7%) than patients without PC (74.0%). The cure rate among patients with TH (0.4%) was much lower than among patients without TH (74.3%). The cure rate of patients with TOI (0.7%) was much lower than patients without TOI (74.6%).

Complications were found to have a clearly visible effect on the outcomes ($p < 0.05$). The presence of all the following complications, such as HS, DC, apnea, CA, CH, WED, ARDS, ARF, MODS, and BI, was found to reduce the cure rate.

Table 8.29. Comparison of outcomes among different injury conditions of patients with single ground-level fall injury.

Injury condition	Dead	Invalid	Improved	Cured	U-value	p-value
FJI					534661.0	<0.001
No	24	7	177	197		
Yes	44	181	593	2,840		
SSTI					735799.0	<0.001
No	39	176	527	2,745		
Yes	29	12	243	292		
CNSI					419047.5	<0.001
No	39	186	562	2,897		
Yes	29	2	208	140		
PC					96443.0	<0.001
No	67	188	731	3,008		
Yes	1	0	39	29		
TH					51752.5	0.011
No	67	188	756	3,020		
Yes	1	0	14	17		
TOI					13495.0	0.016
No	68	187	765	3,033		
Yes	0	1	5	4		

Table 8.30. Comparison of outcomes among different complications of patients with single ground-level fall injury.

Complication	Dead	Invalid	Improved	Cured	U-value	p-value
HS					6046.0	<0.001
No	62	187	769	3,035		
Yes	6	1	1	2		
DC					255768.0	<0.001
No	38	185	659	2,955		
Yes	30	3	111	82		
Apnea					704.5	<0.001
No	66	188	769	3,037		
Yes	2	0	1	0		
CA					704.5	<0.001
No	66	188	769	3,037		
Yes	2	0	1	0		
CH					2608.0	0.024
No	66	188	770	3,036		
Yes	2	0	0	1		
Paraplegia					74324.5	0.152
No	67	188	756	3,011		
Yes	1	0	14	26		
AF					10173.0	0.087
No	68	188	766	3,034		
Yes	0	0	4	3		
WED					19663.0	<0.001
No	67	188	759	3,032		
Yes	1	0	11	5		
ABI					3035.0	0.415
No	68	188	770	3,035		
Yes	0	0	0	2		
ARDS					33.5	0.025
No	67	188	770	3,037		
Yes	1	0	0	0		
ARF					4689.0	<0.001
No	59	188	767	3,036		
Yes	9	0	3	1		
MOF					1518.0	0.564
No	68	188	770	3,036		
Yes	0	0	0	1		
MODS					1679.5	<0.001
No	51	188	768	3,037		
Yes	17	0	2	0		
BI					49327.0	<0.001
No	46	185	739	3,025		
Yes	22	3	31	12		

Having diabetes ($p = 0.041$) and hypertension ($p < 0.001$) as comorbidities was found to have a statistically significant effect on the outcomes. The cure rate among patients with diabetes as a comorbidity (7.1%) was greatly lower compared with patients without any such comorbidities (67.7%). Patients with hypertension had a substantially lower cure rate (13.5%) than patients without hypertension (61.2%). The cure rate of patients with osteoporotic (0.9%) was significantly lower than that of patients without osteoporosis (73.9%).

Table 8.31. Comparison of outcomes among different comorbidities of patients with single ground-level fall injury.

Comorbidity	Dead	Invalid	Improved	Cured	U-value	p-value
Diabetes					709278.5	0.041
No	55	169	683	2,749		
Yes	13	19	87	288		
Hypertension					1203897.5	<0.001
No	40	152	585	2,488		
Yes	28	36	185	549		
Osteoporosis					88914.0	0.562
No	67	187	762	3,001		
Yes	1	1	8	36		

(2) Comparison of multiple categorical independent variables using the Kruskal-Wallis H Test

The effect of marital status on the outcomes was not statistically significant among patients with a single injury (p = 0.268). Patients who were divorced or widowed had a cure rate of 0.3%. The patients who were single had a cure rate of 10.7% and a mortality rate of 0.1%. Among married patients, the cure rate of was 63.8% and mortality rate was 1.6%.

Table 8.32. Comparison of outcomes among different marital status of patients with single ground-level fall injury.

Marital status	Dead	Invalid	Improved	Cured	Chi-square	p-value
Divorced/widowed	0	0	1	11	2.6	0.268
Single	5	31	100	435	-	-
Married	63	157	669	2,591	-	-

The influence of admission pathways on the outcomes was not statistically significant (p = 0.797). The patients who were RHOC had a cure rate of 8.4% and an improvement rate of 2.3%. The patients who were RHS had a cure rate of 14.1% and an improvement rate of 4.0%. Among patients who were admitted through ED, the cure rate of was 52.2% and improvement rate was 12.6%.

The injured body region was found to substantially influence on the outcomes (p < 0.001). Patients with injuries in the abdomen had the lowest cure rate (0.1%), whereas patients who were injured in the extremities had the highest cure rate (63.5%).

Table 8.33. Comparison of outcomes among different admission pathways of patients with single ground-level fall injury.

Admission pathway	Dead	Invalid	Improved	Cured	Chi-square	p-value
RHOC	7	15	95	342	2.6	0.268
RHS	15	28	163	573	-	-
EDA	46	145	512	2,122	-	-

Table 8.34. Comparison of outcomes among different injured body regions of patients with single ground-level fall injury.

Injured body region	Dead	Invalid	Improved	Cured	Chi-square	p-value
Head	36	5	245	158	500.7	<0.001
Thorax	3	3	67	53	-	-
Abdomen	0	0	5	6	-	-
Spine	2	15	80	219	-	-
Pelvis	0	3	19	21	-	-
Extremities	27	162	354	2,580	-	-

(3) Comparison of ordinal categorical independent variables using the Spearman rank correlation test

The influence of age on the outcomes of patients with a single injury was statistically significant ($p < 0.001$). Both mortality and cure rate increased with age. Patients aged 65 or older had the highest cure rate (33.2%) as well as the highest mortality rate (1.5%).

Table 8.35. Correlation analysis between age and outcomes among patients with single ground-level fall injury.

Age (year)	Dead	Invalid	Improved	Cured	r_s	p-value
≤14	0	1	7	37	−0.068	<0.001
15–24	1	4	20	105	-	-
25–34	0	11	41	147	-	-
35–44	0	16	51	225	-	-
45–54	3	24	92	426	-	-
55–64	5	32	186	749	-	-
≥65	59	100	373	1,348	-	-

The correlation between prehospital time and the outcomes of patients with a single injury was statistically significant ($p = 0.016$). Patients who had a prehospital time between 3–24 hours had the highest cure rate (31.2%) and a lower mortality rate (0.7%). Patients with a prehospital time of 1 hour or less had the lowest cure and improvement rates (0.6% and 0.2%, respectively).

The LOS of patients with a single injury was found to be significantly correlated with the outcomes ($p < 0.001$). The mortality rate was the lowest (0.2%) among patients who stayed in hospital for 31 or more days, however, their cure rate was also the lowest (1.3%). Patients who stayed in hospital for between 8–14 days had the highest cure rate (28.7%). Patients who had a 0–3 day stay had the highest mortality rate (0.7%).

Table 8.36. Correlation analysis between prehospital time and outcomes among patients with single ground-level fall injury.

Prehospital time (hour)	Dead	Invalid	Improved	Cured	r_s	p-value
≤1	2	3	10	25	−0.038	0.016
1–3	12	37	112	626	-	-
3–24	29	87	320	1,269	-	-
>24	25	61	328	1,117	-	-

Table 8.37. Correlation analysis between LOS and outcomes among patients with single ground-level fall injury.

LOS (day)	Dead	Invalid	Improved	Cured	r_s	p-value
0–3	27	112	115	116	0.250	<0.001
4–7	11	47	245	907	-	-
8–14	15	22	284	1,165	-	-
15–30	8	6	111	797	-	-
≥31	7	1	15	52	-	-

Table 8.38. Correlation analysis between GCS and outcomes among patients with single ground-level fall injury.

GCS	Dead	Invalid	Improved	Cured	r_s	p-value
3–8	12	1	8	6	0.289	0.006
9–12	3	0	1	5	-	-
13–14	0	0	8	4	-	-
15	1	0	27	13	-	-

There was a statistically significant correlation between AIS score and the outcomes ($p < 0.001$). Patients with serious injuries (AIS = 3) had the highest cure rate (36.2%), as well as mortality rate (1.3%). The cure rate of patients with moderate injuries (AIS = 2) was also higher (35.5%) than the cure and improvement rate among patients with severe injuries (AIS = 4) and (AIS = 5) critical injuries.

Table 8.39. Correlation analysis between AIS and outcomes among patients with single ground-level fall injury.

AIS	Dead	Invalid	Improved	Cured	r_s	p-value
1	6	8	48	85	-0.077	<0.001
2	3	93	260	1,444	-	-
3	51	85	428	1,472	-	-
4	3	0	20	30	-	-
5	5	1	13	5	-	-
6	0	1	1	1	-	-

8.2.5.2 Multiple injuries

(1) Comparison of binary categorical independent variables using the Mann–Whitney U Test

Gender was found to have no statistical significance on the outcomes of patients with multiple injuries (p = 0.084). The cure and mortality rates for male patients were 21.8% and 1.4%, respectively, and for female patients were 37.2% and 1.1%, respectively.

Table 8.40. Comparison of outcomes between different genders among patients with multiple ground-level fall injuries.

Gender	Dead	Invalid	Improved	Cured	U-value	p-value
Male	5	8	56	79	14430.5	0.084
Female	4	12	64	135	-	-

Injured body regions (head, thorax, upper extremities, and lower extremities) were found to be statistically correlated with the outcomes of patients with multiple injuries (p < 0.05). Patients who sustained injuries to the head had a cure rate of 18.7%, lower than the cure rate of patients who did not sustain injuries to the head (40.2%). Patients who were injured on the thorax had a lower cure rate (13.8%) than patients without injuries to the thorax (45.2%). The cure rate of patients who were injured on the upper extremities (41.9%) was higher cure rate than that of patients without injuries in the upper extremities (17.1%). The cure rate of patients who were injured in the lower extremities (34.7%) had a higher cure rate than that of patients who were not injured in the lower extremities (24.2%).

Table 8.41. Comparison of outcomes among different injured body regions of patients with multiple ground-level fall injuries.

Injured body region	Dead	Invalid	Improved	Cured	U-value	p-value
Head					12529.0	<0.001
No	3	14	50	146		
Yes	6	6	70	68		
Thorax					11335.0	0.003
No	6	12	74	164		
Yes	3	8	46	50		
Abdomen					2213.5	0.116
No	8	20	111	208		
Yes	1	0	9	6		
Spine					11025.0	0.119
No	8	10	89	167		
Yes	1	10	31	47		
Pelvis					2830.0	0.467
No	9	16	116	204		
Yes	0	4	4	10		
Upper extremities					11105.0	<0.001
No	7	15	61	62		
Yes	2	5	59	152		
Lower extremities					13746.5	0.002
No	4	10	75	88		
Yes	5	10	45	126		

CNSI ($p < 0.001$) and PC ($p = 0.007$) were found to have a statistically significant effect on the outcomes. The cure rate was pointedly lower among patients with CNSI (5.5%), compared with patients without CNSI (53.4%). Patients with PC had an obviously lower cure rate (3.3%) than patients without PC (55.6%).

Table 8.42. Comparison of outcomes among different injury conditions of patients with multiple ground-level fall injuries.

Injury condition	Dead	Invalid	Improved	Cured	U-value	p-value
FJI					3433.5	0.143
No	1	0	13	10		
Yes	8	20	107	204		
SSTI					14240.5	0.08
No	3	16	62	139		
Yes	6	4	58	75		
CNSI					6366.0	<0.001
No	4	15	79	194		
Yes	5	5	41	20		
PC					4227.5	0.007
No	8	18	101	202		
Yes	1	2	19	12		
TH					1753.5	0.541
No	9	20	114	209		
Yes	0	0	6	5		
TOI					1675.0	0.752
No	9	20	115	209		
Yes	0	0	5	5		

Complications were found to have a statistically significant influence on the outcomes of patients with multiple injuries. The presence of all the following complications, such as DC, apnea, CA, AF, ARF, MODS, and BI, was found to reduce the cure rate.

Table 8.43. Comparison of outcomes among different complications of patients with multiple ground-level fall injuries.

Complication	Dead	Invalid	Improved	Cured	U-value	p-value
HS					176.0	0.151
No	9	20	118	214		
Yes	0	0	2	0		
DC					4598.5	<0.001
No	4	15	93	201		
Yes	5	5	27	13		
Apnea					21.5	0.008
No	8	19	120	214		
Yes	1	1	0	0		
CA					21.5	0.008
No	8	19	120	214		
Yes	1	1	0	0		

Table 8.43. *Cont.*

Complication	Dead	Invalid	Improved	Cured	U-value	p-value
Paraplegia					1111.0	0.227
No	9	19	116	211		
Yes	0	1	4	3		
AF					192.5	0.028
No	9	19	118	214		
Yes	0	1	2	0		
WED					262.5	0.078
No	9	20	117	214		
Yes	0	0	3	0		
ABI					88.5	0.311
No	9	20	119	214		
Yes	0	0	1	0		
ARDS					106.5	0.414
No	9	20	120	213		
Yes	0	0	0	1		
ARF					430.5	0.022
No	7	20	118	213		
Yes	2	0	2	1		
MODS					91.5	0.037
No	8	20	119	214		
Yes	1	0	1	0		
BI					1729.0	<0.001
No	7	17	111	210		
Yes	2	3	9	4		

The influence of diabetes as a comorbidity on outcomes was statistically significant (p = 0.045). The cure rate among patients with diabetes as a comorbidity (5.2%) was clearly lower than patients without such a comorbidity (63.7%).

Table 8.44. Comparison of outcomes among different comorbidities of patients with multiple ground-level fall injuries.

Comorbidity	Dead	Invalid	Improved	Cured	U-value	p-value
Diabetes					5752.0	0.045
No	6	19	100	195		
Yes	3	1	20	19		
Hypertension					10533.0	0.416
No	5	17	92	171		
Yes	4	3	28	43		

(2) Comparison of multiple categorical independent variables using the Kruskal-Wallis H Test

Marital status of patients with multiple injuries was found to have no statistical association with the outcomes (p = 0.462). Single patients had a cure rate of 4.7% and a mortality rate of 0.3%, and the cure rate and mortality rate of married patients were 54.3% and 2.2%, respectively.

Table 8.45. Comparison of outcomes among different marital status of patients with multiple ground-level fall injuries.

Marital status	Dead	Invalid	Improved	Cured	Chi-square	p-value
Single	1	1	14	17	0.5	0.462
Married	8	19	106	197	-	-

The influence of admission pathway on outcomes was not statistically significant among patients with multiple injuries (p = 0.414). The cure rate and improvement rate of patients who were RHOC were both 5.0%. The patients who were RHS had a cure rate of 12.1% and an improvement rate of 8.0%. The patients who were admitted through the ED had a cure rate of 41.9% and an improvement rate of 20.1%.

Table 8.46. Comparison of outcomes among different admission pathways of patients with multiple ground-level fall injuries.

	Dead	Invalid	Improved	Cured	Chi-square	p-value
RHOC	0	2	18	18	1.8	0.414
RHS	0	5	29	44	-	-
EDA	9	13	73	152	-	-

(3) Comparison of ordinal categorical independent variables using the Spearman rank correlation test

Age was found to have no statistical correlation with the outcomes of patients with multiple injuries (p = 0.972). Patients aged 65 years old or older had the highest cure rate (29.2%) as well as highest mortality rate (2.2%). Patients aged between 15 and 24 years had the lowest cure rate (0.3%).

Table 8.47. Correlation analysis between age and outcomes among patients with multiple ground-level fall injuries.

Age (year)	Dead	Invalid	Improved	Cured	r_s	p-value
15–24	0	1	7	1	0.002	0.972
25–34	0	1	8	18	-	-
35–44	0	1	10	14	-	-
45–54	1	2	10	24	-	-
55–64	0	7	27	51	-	-
≥65	8	8	58	106	-	-

Prehospital time was found to have no statistical influence on the outcomes of patients with multiple injuries (p = 0.222). Patients with a prehospital time of 1 hour or less had a cure rate of 1.1%. Patients who had a prehospital time between 1–3 hours had a cure rate of 17.4% and a mortality rate of 0.8%. The cure and mortality rates of patients who had a prehospital time between 3–24 h were 29.2% and 1.4%, respectively. Patients who had a prehospital time greater than 24 hours had a cure rate of 11.3% and a mortality rate of 0.3%.

Table 8.48. Correlation analysis between prehospital time and outcomes among patients with multiple ground-level fall injuries.

Prehospital time (hour)	Dead	Invalid	Improved	Cured	r_s	p-value
≤1	0	1	5	4	−0.064	0.222
1–3	3	7	25	63	-	-
3–24	5	7	53	106	-	-
>24	1	5	37	41	-	-

The LOS of patients with multiple injuries was statistically correlated with the outcomes ($p < 0.001$). The mortality rate of patients with 0–3 days of hospital stay was relatively high (0.6%), and their cure rate (1.1%) was lower than the improvement rate (3.0%). Patients who had a LOS of 4–7 days and 15–30 days had the highest mortality rate (both 0.8%), whereas those who stayed in hospital between 15 and 30 days had the highest cure rate (21.2%).

Table 8.49. Correlation analysis between LOS and outcomes among patients with multiple ground-level fall injuries.

LOS (day)	Dead	Invalid	Improved	Cured	r_s	p-value
0–3	2	10	11	4	0.199	<0.001
4–7	3	3	31	52	-	-
8–14	0	4	47	76	-	-
15–30	3	1	27	77	-	-
≥31	1	2	4	5	-	-

There was no obvious correlation between the number of injured body regions and the outcomes of patients with multiple injuries ($p = 0.754$). Patients with 2 injured body regions had a cure rate of 51.2% and an improvement rate of 27.8%. Patients with 3 injured body regions had a cure rate of 6.9% and an improvement rate of 3.9%. The cure and improvement rates of patients with 4 injured body regions were 0.8% and 1.4%, respectively.

Table 8.50. Correlation analysis between the number of injured body regions and outcomes among patients with multiple ground-level fall injuries.

Number of injured body regions	Dead	Invalid	Improved	Cured	r_s	p-value
2	9	17	101	186	−0.016	0.754
3	0	3	14	25	-	-
4	0	0	5	3	-	-

GCS score was found to have no obvious influence on the outcomes of patients with multiple injuries ($p = 0.242$). Patients with severe brain injuries (GCS 3–8) had a cure rate of 16.7% and a mortality rate of 13.5%.

There was statistical significance in the difference of ISS and the outcomes ($p < 0.001$). With the increase of ISS, the cure rate of patients showed a downward trend. Patients with mild to moderate injuries had relatively higher cure rates. Patients with severe injuries (ISS ≥ 25) had the lowest cure rate (2.8%) and a mortality rate of 0.6%.

Table 8.51. Correlation analysis between GCS and outcomes among patients with multiple ground-level fall injuries.

GCS	Dead	Invalid	Improved	Cured	r_s	p-value
3–8	1	3	1	0	−0.566	0.242
9–12	1	0	0	0	-	-

Table 8.52. Correlation analysis between ISS and outcomes among patients with multiple ground-level fall injuries.

ISS	Dead	Invalid	Improved	Cured	r_s	p-value
1–8	2	5	29	77	−0.182	<0.001
9–15	1	6	52	91	-	-
16–24	4	7	29	36	-	-
≥25	2	2	10	10	-	-

8.3 Summary

Gender, age, injury conditions, body regions, complications, comorbidities, prehospital time, LOS, GCS score, and AIS score were all found to be influential factors of treatment outcomes in single ground-level fall injury patients. Injury conditions, body regions, complications, comorbidities, LOS, and ISS were found to be the influential factors of treatment outcomes in multiple ground-level fall injury patients.

The influence of demographic factors on the outcomes of ground-level fall injury patients was found to be statistically significant. First, the proportion of women to have a single ground-level fall injury was higher than that of men; however, the mortality rate was higher for men. This result is different from the findings of studies in countries outside China, which found that, since men engage more in dangerous tasks, they are more likely to have fall injuries (Stevens, 2005). Second, individuals aged 65 years and older have the highest probability of suffering from fall injuries, and their mortality rate was also the highest proportionally. This is consistent with the research findings in other countries, that age has an influence on the occurrence, conditions, and outcomes of fall injuries (Joseph *et al.*, 2015). A report released by the WHO also showed that approximately 42.4 million people deceased in 2012, due to falls, more than half of whom were over 60 years old, and people over the age of 70 accounted for 40%. Elderly adults are at a high-risk group for falls. Hence, it is necessary to strengthen fall-prevention measures and improve safety education among the elderly population (Chisholm and Harruff, 2010; Er *et al.*, 2016).

Injury characteristics are important factors influencing the outcomes of patients with ground-level fall injuries. Firstly, patients with head and thorax injuries have a lower cure rate than patients with injuries in the extremities (Helling *et al.*, 1999; Hartshorne *et al.*, 1997). Secondly, conditions, such as CNSI, PC, TH, and TOI, will significantly reduce the cure rate of patients (Kelly and Kelly, 2012). Thirdly, the outcomes of ground-level fall injury patients are closely correlated with the level of severity of the injury. The higher the GCS score, the more likely the patient can be cured, whereas the higher the AIS and ISS, the less likely patients will be cured (Cook *et al.*, 2012; Pöyry *et al.*, 2012).

Medical treatment is also correlated with patient outcome. First, the mortality rate of ground-level fall injury patients tends to increase with prehospital time. Thus, shortening prehospital time can effectively reduce the mortality of patients (Ambrose *et al.*, 2013). Second, the LOS affects the outcome of patients. Patients with ≤3 days or ≥31 days of hospital stay were found to have a relatively lower cure rate, whereas patients who stayed in hospital for 8–14 days and 15-30 days were found to have a higher cure rate. This may be due to a higher proportion of critically injured patients stay in hospital for ≤3 days or ≥31 days, which led to a higher mortality rate. However, patients who had a hospital stay between 8 and 30 days mainly had mild to moderate injuries; hence, the cure rate was relatively higher (Ayoungchee *et al.*, 2014). Third, the presence of complications, such as HS, DC, apnea, CA, CH, WED, ARDS, ARF, MODS, and BI, may reduce the cure rate (Spaniolas *et al.*, 2010; Ambrose *et al.*, 2013).

The influence of comorbidities on the outcome of ground-level fall injury patients is statistically significant. The development of diabetes and hypertension as comorbidities can reduce the cure rate of patients (Cook *et al.*, 2012).

Identification of high-risk groups based on ground-level fall injuries, injury characteristics, and influential factors of the outcomes, medical personnel are suggested to take full consideration of the demographic characteristics, injured body regions, injury conditions, injury severity, complications, and comorbidities when considering patient outcomes to facilitate rapid diagnosis and accurate treatment of the wounded, as well as improve the cure rate overall.

References

Ambrose, A.F.; Paul, G.; Hausdorff, J.M. Risk factors for falls among older adults: a review of the literature. *Maturitas* **2013**, *75*, 51–61.

Ayoungchee, P.; Mcintyre, L.; Ebel, B.E.; *et al.* Long-term outcomes of ground-level falls in the elderly. *Journal of Trauma & Acute Care Surgery* **2014**, *76*, 498–503.

Bhatti, J.A.; Farooq, U.; Majeed, M.; *et al.* Fall-related injuries in a low-income setting Results from a pilot injury surveillance system in Rawalpindi, Pakistan. *Journal of Epidemiology & Global Health* **2015**, *5*, 283–290.

Chen, Y.P.; Zhong, J.M.; Jiang, G.J.; *et al.* Cross-sectional study on falls in residents of four communities in Zhejiang Province, China. *Chinese Journal of Preventive Medicine* **2005**, *39*, 45–47.

Chen, Y.Y.; Zhu, L.P.; Ai, L.I. Analysis on the epidemic situation of fall injuries among residents in Jiangxi Province. *Practical Preventive Medicine* **2014**, *21*, 268–271.

Chisholm, K.M.; Harruff, R.C. Elderly deaths due to ground-level falls. *American Journal of Forensic Medicine & Pathology* **2010**, *31*, 350–354.

Cook, A.; Cade, A.; King, B.; *et al.* Ground-level falls 9-year cumulative experience in a regionalized trauma system. *Proceedings* **2012***, 25*, 6–12.

Er, Y.; Duan, L.; Wang, Y.; *et al.* Analysis on data from Chinese National Injury Surveillance System, 2008–2013 on the characteristics of falls. *Zhonghua Liu Xing Bing Xue Za Zhi* **2015**, *36*, 12–16.

Er, Y.L.; Duan, L.L.; Ye, P.P. Epidemiologic characteristics of fall in old population Results from national injury surveillance in China, 2014. *Chinese Journal of Epidemiology* **2016**, *37*, 24–28.

Hartshorne, N.J.; Harruff, R.C.; Jr, A.E. Fatal head injuries in ground-level falls. *American Journal of Forensic Medicine & Pathology* **1997**, *18*, 258–264.

Hegeman, J.; Bemt, B.J.; Duysens, J.;*et al.* NSAIDs and the risk of accidental falls in the elderly. *Drug Safety an International Journal of Medical Toxicology & Drug Experience* **2009**, *32*, 489–498.

Helling, T.S.; Watkins, M.; Evans, L.L.; *et al.* Low falls an underappreciated mechanism of injury. *Journal of Trauma* **1999**, *46*, 453–456.

Joseph, B.; Pandit, V.; Khalil, M. Managing older adults with ground-level falls admitted to a trauma service the effect of frailty. *Journal of the American Geriatrics Society* **2015**, *63*, 745–749.

Kelly, D.W.; Kelly, B.D. A novel diagnostic sign of hip fracture mechanism in ground level falls two case reports and review of the literature. *Journal of Medical Case Reports* **2012**, *6*, 1–5.

Naghavi, M.; Wang, H.; Lozano, R.; *et al.* Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990–2013 a systematic analysis for the global burden of disease study 2013. *Lancet* **2015**, *385*, 117–171.

Pyry, T.; Luoto, T.M.; Kataja, A.; *et al.* Acute assessment of brain injuries in ground-level falls. *Journal of Head Trauma Rehabilitation* **2012**, *28*, 89–97.

Saadat, S.; Hafezi-Nejad, N.; Ekhtiari, Y.S.; *et al.* Incidence of fall-related injuries in Iran-a population-based nationwide study. *Injury-International Journal of the Care of the Injured* **2016**, *47*, 1404–1409.

Spaniolas, K.; Cheng, J.D.; Gestring, M.L.; *et al.* Ground level falls are associated with significant mortality in elderly patients. *Journal of Trauma* **2010**, *69*, 821–825.

Stevens, E.S. Gender differences for non-fatal unintentional fall related injuries among older adults. *Injury Prevention* **2005**, *11*, 115–119.

Stewart, B.T.; Lafta, R.; Shatari, S.A.; *et al.* Fall injuries in Baghdad from 2003 to 2014-results of a randomised household cluster survey. *Injury-International Journal of the Care of the Injured* **2016**, *47*, 244–249.

Chapter 9 Investigation of firearm injury occurrence and evolution

Wei Liu[1]*, Bihan Tang*[2] *and Lulu Zhang*[2]

[1] *No. 25 Hospital of PLA, Jiuquan 735000, China*

[2] *Department of Military Health Service Management, College of Military Health Service Management, Second Military Medical University, Shanghai 200433, China*

9.1 Overview

9.1.1 Investigation background

A firearm is an instrument that discharges projectiles using the force generated by a considerable amount of hot gas produced by the combustion of explosive substances. Any damage to the human caused by explosion of gunpowder from a firearm is called a firearm injury. Based on the types of damage, firearm injuries can be divided into shotgun injuries, blunderbuss injuries, and blast injuries. According to the ICD-10, firearm injuries can also be further divided into the following two standards: (1) injuries caused by projectiles of firearms, and (2) injuries caused by explosives.

The number of and the impacts of firearm injuries upon a global scale should not be underestimated. The global burden of fatalities due to weapons is between 196,000 and 229,000 per year. In 2003, nearly 30,000 people were killed due to gunshot injuries in the United States, including 16,859 suicides and 11,599 homicides (Weiner *et al.*, 2007). A survey has indicated that among the patients with an injury caused by a firearm, the number of men is 9 times higher than that of women, and the number of victims aged 18–29 years is 3 times higher than that of other age groups (Cuellar *et al.*, 2006). Since private citizens are not permitted to possess guns in China, firearm injuries are not common. Some hospitals have only had 50 patients with firearm injuries in over 30 years. Therefore, most domestic research on firearm injuries focuses on the treatment of individual cases.

9.1.2 Definition and injury characteristics of firearm injury

Firearm injuries refer to the injuries caused by projectiles (such as bullets and shells) fired or detonated through instruments that are powered by gunpowder.

Firearm injuries are generally very serious. Given that the bullets or shrapnel that cause firearm injuries usually have a great impact force, the temporary cavity created by the impact can cause serious tunneling wound to the body and its surrounding tissue. In addition, when a bullet hits a bone, it can disintegrate immediately; fragments of broken bone or teeth caused by the explosion serve as secondary shrapnel that worsen the damage to the surrounding tissue, resulting in severe injuries in soft tissue and bone. The second characteristic of firearm injuries is the high occurrence of perforating injuries. In most cases, the entrance of a perforating wound is small and the corresponding exit is relatively larger. In the case of a perforating injury to the jaw, the entrance mostly involves small hole-shaped fractures whereas the exit often involves comminuted fractures, accompanied with displacement of fractures and extensive soft tissue damage. In case of a perforating injury to soft tissue, the difference in the size of the entrance and exit wound is not clearly visible. Close range firearm injuries normally have a larger entrance wound and smaller exit wound. The third characteristic of firearm injuries is the residuals of the foreign objects that remain in the human body, especially in a blind-ended injury. The bullet or shrapnel that causes a firearm injury to the maxilla is often blocked by the cheekbones or the maxillary bones and can change direction or slows down its movement, causing the foreign object to stay in the maxillary sinus, the temporal fossa, or the base of skull. Foreign objects in the mandible are often embedded in the bone or soft tissue around the jaw. Fragments of the bullet or shrapnel can be widely scattered in the tissue of the maxillofacial region. Apart from metal, teeth fragments, and crushed stone can also act as the foreign objects involved in a firearm injury. The fourth characteristic of firearm injuries is the BI in the wound. Bacteria can be brought into the injured tissue by the object that caused the injury; in particular, the shrapnel of a ground explosion can carry bacteria from the earth into the wound. When a tunneling wound passes the oral cavity, nasal cavity, or maxillary sinus, the damaged regions can be infected by the bacteria within the sinus and cavities.

The present study divided firearm injuries into civilian and wartime injuries. This study focused on civilian injuries.

9.1.3 Basic data for the investigation

(1) Research purposes

The present study collected information of patients with firearm injuries in Shanghai, using statistical analyses to examine the epidemiological characteristics and causes of firearm injuries, and analyzed the key influential factors of corresponding outcomes, with the purpose of providing scientific suggestions to the improvement of the medical rescue system.

(2) Research data

Utilizing the medical records between January 2011 and January 2015 from the hospital information systems of the four largest trauma centers in Shanghai (burn trauma emergency center, bone trauma emergency center, trauma emergency center, and trauma emergency center & emergency critical care unit), with reference to the ICD-10 and rules on the registration of medical records in Chinese hospital information systems, the present study collected 15 cases of firearm injuries, including 11 single-injury and 4 multiple-injury cases. All patients were informed of the research purposes and had given written consent.

9.2 Investigation results of firearm injury occurrence and evolution

9.2.1 Demographic characteristics of firearm injury patients

(1) Single injury

The proportion of male and female patients who had a single injury was 81.8% and 18.2%, respectively.

Table 9.1. Gender of single-injury patients with firearm injuries.

Gender	N	%
Male	9	81.8
Female	2	18.2

Patients aged between 35 and 44 years had the highest proportion (27.3%), and patients aged 25–34 years had the lowest proportion.

Table 9.2. Age of single-injury patients with firearm injuries.

Age (year)	N	%
0–14	1	9.1
15–24	2	18.2
25–34	0	0.0
35–44	3	27.3
45–54	2	18.2
55–64	2	18.2
≥65	1	9.1

Most of the single-injury patients were married (54.5%), followed by patients who were single. No investigated patients were divorced or widowed.

Table 9.3. Marital status of single-injury patients with firearm injuries.

Marital status	N	%
Divorced/widowed	0	0.0
Single	5	45.5
Married	6	54.5

(2) Multiple injuries

Patients with multiple injuries caused by firearms were all male.

Table 9.4. Gender of multiple-injury patients with firearm injuries.

Gender	N	%
Male	4	100.0
Female	0	0.0

Half of the patients were between 15 and 24 years old, and the other half were between 35 and 44 years old.

The proportion of the married, divorced or widowed patients with multiple injuries were both 25%; the remaining 50% of the patients were single.

Table 9.5. Age of multiple-injury patients with firearm injuries.

Age (year)	N	%
0–14	0	0.0
15–24	2	50.0
25–34	0	0.0
35–44	2	50.0
45–54	0	0.0
55–64	0	0.0
≥65	0	0.0

Table 9.6. Marital status of multiple-injury patients with firearm injuries.

Marital status	N	%
Divorced/widowed	1	25.0
Single	2	50.0
Married	1	25.0

9.2.2 Injury characteristics of firearm injury patients

The characteristics of firearm injuries were analyzed from injured body regions, injury conditions, GCS score, and AIS/ISS.

(1) Single injury

Most of the injuries were to the head (81.8%), and the others were to the extremities (18.2%).

Table 9.7. Injured body region of single-injury patients with firearm injuries.

Injured body region	N	%
Head	9	81.8
Extremities	2	18.2

Although all of the patients with a single injury were wounded in the head, only 2 patients had a GCS score, and both were defined as having mild brain injury (GCS ≥ 13).

The proportion of patients with an AIS score of 2 was 45.4%. The proportions of patients whose AIS score was 3 and 1 were both 27.3%.

Table 9.8. AIS of single-injury patients with firearm injuries.

AIS	N	%
1	3	27.3
2	5	45.4
3	3	27.3

(2) Multiple injuries

Most of the patients (75.0%) with multiple injuries were injured in 3 body regions, which were also the maximum number of injured body regions among the investigated patients.

Table 9.9. Number of injured body regions of multiple-injury patients with firearm injuries.

Number of injured body regions	N	%
2	1	25.0
3	3	75.0

The injured body regions among patients with multiple injuries included the upper extremities (36.4%), head (27.3%), thorax (27.3%) and abdomen (9.1%).

Table 9.10. Injured body region of multiple-injury patients with firearm injuries.

Injured body region	N	%
Head	3	27.3
Thorax	3	27.3
Abdomen	1	9.1
Upper extremities	4	36.4

The proportion of injury conditions among multiple-injury patients were as follows, in descending order SSTI (44.4%), FJI (33.3%), DT (11.1%), and TOI (11.1%). No cases of CNSI, PC, and TH (0.0%) were observed.

Table 9.11. Injury condition of multiple-injury patients with firearm injuries.

Injury condition	N	%
FJI	3	33.3
SSTI	4	44.4
DT	1	11.1
CNSI	0	0.0
PC	0	0.0
TH	0	0.0
TOI	1	11.1

None of the four patients with multiple injuries had a GCS score. The ISS showed that patients with multiple injuries caused by a firearm generally had a more severe level of injury, patients with an ISS greater than 16 accounted for 75%, half of whom had a ISS equal or greater than 25.

Table 9.12. ISS of multiple-injury patients with firearm injuries.

ISS	N	%
1–8	1	25.0
9–15	0	0.0
16–24	1	25.0
≥25	2	50.0

9.2.3 Treatment of firearm injury patients

The treatment of firearm-injury patients was analyzed from admission pathway, prehospital time, LOS, outcome, and complications.

(1) Single injury

The majority (45.4%) of the patients with a single injury were RHOC, 36.4% of the patients were admitted from the ED, and 18.2% of the patients were RHS.

Table 9.13. Admission pathway of single-injury patients with firearm injuries.

Admission pathway	N	%
RHOC	5	45.4
RHS	2	18.2
EDA	4	36.4

The prehospital time was generally long among patients with a single firearm injury; 45.5% of the patients had a prehospital time of 3–24 hours, and patients with a prehospital time of greater than 24 hours accounted for 54.5%.

Table 9.14. Prehospital time of single-injury patients with firearm injuries.

Prehospital time (hour)	N	%
≤1	0	0.0
1–3	0	0.0
3–24	5	45.5
>24	6	54.5

The LOS of 45.5% of the patients was limited to 7 days. The majority (72.7%) of the patients had a LOS of less than 2 weeks. Patients who were hospitalized for more than one month accounted for 27.3% of total single-injury patients.

Table 9.15. LOS of single-injury patients with firearm injuries.

LOS (day)	N	%
0–3	2	18.2
4–7	3	27.3
8–14	3	27.3
15–30	0	0.0
≥31	3	27.3

Most of the patients (45.5%) with a single injury had been cured upon discharge, and 45.5% needed further rehabilitation. Only a very small number of patients were unchanged (9.1%).

Table 9.16. Outcome of single-injury patients with firearm injuries.

Outcome	N	%
Dead	0	0
Invalid	1	9.1
Improved	5	45.5
Cured	5	45.5

(2) Multiple injuries

The proportion of patients who were admitted via the ED or RHS both accounted for 25% of total multiple-injury patients. There were more patients RHOC (50%).

Table 9.17. Admission pathway of multiple-injury patients with firearm injuries.

Admission pathway	N	%
RHOC	2	50.0
RHS	1	25.0
EDA	1	25.0

Half of the patients were sent to hospital within 3–24 hours after being injured, and the remaining half had a prehospital time of more than 24 hours.

Table 9.18. Prehospital time of multiple-injury patients with firearm injuries.

Prehospital time (hour)	N	%
≤1	0	0.0
1–3	0	0.0
3–24	2	50.0
>24	2	50.0

Patients with multiple firearm injuries tend to have a longer hospital stay; 75% of patients were hospitalized for more than 1 month and 25% of patients were hospitalized for more than half a month.

Table 9.19. LOS of multiple-injury patients with firearm injuries.

LOS (day)	N	%
0–3	0	0.0
4–7	0	0.0
8–14	0	0.0
15–30	1	25.0
≥31	3	75.0

The majority (75.0%) of patients with gunshot wounds were cured and discharged, and the remaining 25% had an improved condition when discharged.

Table 9.20. Outcome of multiple-injury patients with firearm injuries.

Outcome	N	%
Dead	0	0.0
Invalid	0	0.0
Improved	1	25.0
Cured	3	75.0

Only one patient with multiple firearm injuries developed a complication from HS.

9.2.4 Comorbidities in firearm injury patients

(1) Single injury

No cases of hypertension and osteoporosis were found among patients with a single firearm injury, and only one patient developed diabetes as a comorbidity.

(2) Multiple injuries

No comorbidities were found among patients with multiple firearm injuries.

9.2.5 Outcomes of firearm injury patients

SPSS software (version 17.0, SPSS Inc., Chicago, IL, USA) was utilized in the present study, and single factor statistical analyses were applied to investigate the influential factors of the outcomes of the firearm-injury patients (p-value < 0.05 was considered statistically significant). The outcomes were divided into dead, invalid, improved, and cured. A nonparametric method was adopted in testing. The raw data were organized into an R × C table, where the headings in the rows were the groups of the independent variables and the columns were the classifications of the dependent variable (the outcomes). The statistical methods used for the analyses were selected according to the type of the independent variables the Mann–Whitney U test was applied when the independent variable was dichotomous; the Kruskal-Wallis H test was applied when the independent variable was multiple categorical and non-ordinal; and the Spearman's Rank-Order Correlation test was applied when the independent variable was ordinal.

9.2.5.1 Single injury

(1) Comparison of binary categorical independent variables using the Mann-Whitney U test

Gender was found to have no statistically significant effect on the outcomes (p = 0.297). FJI were found to have no statistical significance on the outcomes (p = 0.821). Injuries to the head appeared to have no obvious effect on the outcomes. DC was not found to be a significant influence on the outcomes. No statistically significant correlation was found between diabetes as a comorbidity and the outcomes (p = 0.294).

Table 9.21. Results of the Mann-Whitney U test among patients with single firearm injury.

Independent variable	Dead	Invalid	Improved	Cured	U-value	p-value
Sex					5.0	0.297
Male	0	1	3	5		
Female	0	0	2	0		
Fracture					11.0	0.821
No	0	1	4	4		
Yes	0	0	1	1		
Traumatic brain injury					5.0	0.297
No	0	1	3	5		
Yes	0	0	2	0		
DC					3.0	0.484
No	0	1	5	4		
Yes	0	0	0	1		
Diabetes					2.0	0.294
No	0	1	4	5		
Yes	0	0	1	0		

(2) Comparison of multiple categorical independent variables using the Kruskal Wallis H test

Marital status was found to have no statistically significant effect on the outcomes (p = 1.000). The cure rate in single patients was 40%, and in married patients was 50%.

Table 9.22. Comparison of outcomes among different marital status of patients with single firearm injury.

Marital status	Dead	Invalid	Improved	Cured	Chi-square	p-value
Single	0	0	3	2	0.0	1.000
Married	0	1	2	3	-	-

Admission pathway had no statistical significance on the outcomes (p = 0.343). Patients who were RHOC had a cure rate of 20.0% and an improvement rate of 80.0%. The cure rate of patients RHS was 50.0%. Patients who were admitted through the ED had a cure rate of 75.0% and an improvement rate of 25.0%.

Table 9.23. Comparison of outcomes among different admission pathways of patients with single firearm injury.

Admission pathway	Dead	Invalid	Improved	Cured	Chi-square	p-value
RHOC	0	0	4	1	0.5	0.343
RHS	0	1	0	1	-	-
EDA	0	0	1	3	-	-

Injured body regions were found to have no statistically significant influence on the outcomes (p = 0.118).

Table 9.24. Comparison of outcomes among different injured body regions of patients with single firearm injury.

Injured body region	Dead	Invalid	Improved	Cured	Chi-square	p-value
Head	0	1	5	3	2.4	0.118
Extremities	0	0	0	2	-	-

(3) Comparison of ordinal categorical independent variables using the Spearman rank correlation test

Age was found to have no statistical correlation with the outcomes ($p = 0.697$).

The correlation between prehospital time and the outcomes of patients with a single injury was statistically significant ($p = 0.035$). Patients who had a prehospital time of less than 24 hours had the highest cure rate (80.0%). The cure rate of patients who had more than one day of prehospital time was the lowest (16.7%).

Table 9.25. Correlation analysis between prehospital time and outcomes among patients with single firearm injury.

Prehospital time (hour)	Dead	Invalid	Improved	Cured	r_s	p-value
≤1	0	0	0	0	−0.638	0.035
1–3	0	0	0	0	-	-
3–24	0	0	1	4	-	-
>24	0	1	4	1	-	-

The LOS of patients with a single injury was found to have no apparent correlation with the outcomes ($p = 0.138$).

Table 9.26. Correlation analysis between LOS and outcomes among patients with single firearm injury.

LOS (day)	Dead	Invalid	Improved	Cured	r_s	p-value
0–3	0	0	2	0	0.477	0.138
4–7	0	1	1	1	-	-
8–14	0	0	1	2	-	-
15–30	0	0	0	0	-	-
≥31	0	0	1	2	-	-

The AIS score was found to have no statistically significance on the outcomes ($p = 0.525$).

9.2.5.2 Multiple injuries

(1) Comparison of binary categorical independent variables using the Mann-Whitney U test

Injured body regions (thorax and abdomen) were found to have no statistical correlation with the outcomes of patients with multiple injuries ($p > 0.05$).

(2) Comparison of multiple categorical independent variables using the Kruskal Wallis H test

Marital status was found to have a statistical significance on the outcomes (p = 0.223). Both patients who were divorced/widowed and single had a cure rate of 100.0%.

Table 9.27. Comparison of outcomes among different marital status of patients with multiple firearm injuries.

Marital status	Dead	Invalid	Improved	Cured	Chi-square	p-value
Divorced/widowed	0	0	0	1	3.0	0.223
Single	0	0	0	2	-	-
Married	0	0	1	0	-	-

Admission pathway had no significant influence on the outcomes (p = 0.607).

Table 9.28. Comparison of outcomes among different admission pathways of patients with multiple firearm injuries.

Admission pathway	Dead	Invalid	Improved	Cured	Chi-square	p-value
RHOC	0	0	1	1	1.0	0.607
RHS	0	0	0	1	-	-
EDA	0	0	0	1	-	-

(3) Comparison of ordinal categorical independent variables using the Spearman rank correlation test

The number of injured body regions and the outcomes of multiple-injury patients were found to have no obvious correlation (p = 0.564).

Table 9.29. Correlation analysis between number of injured body regions and outcomes among patients with multiple firearm injuries.

Number of injured body regions	Dead	Invalid	Improved	Cured	Chi-square	p-value
2	0	0	0	1	0.3	0.564
3	0	0	1	2	-	-

Age was found to have no statistical correlation with the outcomes of patients with multiple injuries (p = 0.423). Prehospital time was found to have no statistical correlation with the outcomes (p = 0.423). LOS was found to have no statistically significant influence on the outcomes (p = 0.667). ISS and the outcomes were also not statistically correlated (p = 0.456).

9.3 Summary

Studies done in the United States and other developed countries showed that in more than 60% of homicide cases, more than 25% were the result of violent attacks, more than 35% were caused by robberies, and almost 50% were suicide cases, which involved the use of firearms. A report released by the National Crime Records Bureau in India showed that, in 2008, 4,101 people were killed by firearms, accounting for 12.2% of the total 33,727 homicide cases (Crandall *et al.*, 2016).

According to forensic studies, firearms are a frequent cause of suicide cases, especially in Europe and the United States. In Western Europe, firearm suicide is a common cause of death. Among the male suicide cases between 2000 and 2005, the use of firearms accounted for 9.7% (Le Garff *et al.*, 2015). In addition, gunshot injuries are the leading cause of death among children and adolescents in the United States. Some reports claim that at least one-third of families in the US with children have guns (Faulkenberry and Schaechter, 2015).

Given that civilians are not legally allowed to possess firearms in China, firearm injuries in China are not as common as they are in Europe, the United States, and India. For that reason, the sample size of the present study was small, which may lead to certain biases in the statistical analyses. According to these results, sex, age, injury conditions, injured body regions, complications, comorbidities, LOS, GCS score, and AIS/ISS had no apparent influence on the outcomes of patients with firearm injuries. However, statistical analysis revealed that prehospital time is an important influential factor of the outcomes.

According to the descriptive analysis, there were nine male patients and two female patients with a single injury, and the four cases of multiple injuries were all male. This finding is consistent with similar studies, which suggest that men account for most of the victims of firearm injuries. In this study, the 25–34-year-old age group had the lowest incidence of firearm injuries, dissimilar to the findings of other studies that claimed that this age group is the most likely to be subjected to firearm injuries (1989). Most single-injury patients were wounded in the head, and the head and extremities were the most commonly injured body regions among patients with multiple injuries.

Our findings revealed that the most common admission pathway for firearm-injury patients was from RHOC. More than half of the patients with a single injury had a prehospital time of more than 24 hours, most patients were hospitalized for 8–14 days, and more than 90% either were cured or had an improved condition upon discharge. The most common complication among patients with single injury was DC. The duration of stay of patients with multiple injuries was significantly longer; most of the patients stayed in hospital for more than 30 days. All patients either had an improved condition or were cured when they were discharged.

References

American Medical Association Council on Scientific Affairs. Firearms injuries and deaths a critical public health issue. *Public Health Reports* **1989**, *104*, 111–120.

Crandall, M.; Eastman, A.; Violano, P.; *et al.* Prevention of firearm-related injuries with restrictive licensing and concealed carry laws-an eastern association for the surgery of trauma systematic review. *Journal of Trauma and Acute Care Surgery* **2016**, *81*, 952–960.

Cuellar, A.E.; Stranges, E.; Stocks, C. *Hospital Visits in the U.S. for Firearm-Related Injuries 2009*; Agency for Healthcare Research and Quality: Rockville, MD, USA, 2006.

Faulkenberry, J.G.; Schaechter, J. Reporting on pediatric unintentional firearm injury–who's responsible. *Journal of Trauma and Acute Care Surgery* **2015**, *79*, S2–S8.

Le Garff, E.; Delannoy, Y.; Mesli, V.; *et al.* Homemade firearm suicide with dumbbell pipe triggering by an air-compressed gun case report and review of literature. *The American Journal of Forensic Medicine and Pathology* **2015**, *36*, 257–261.

Weiner, J.; Wiebe, D.J.; Richmond, T.S.; *et al.* Reducing firearm violence a research agenda. *Injury Prevention* **2007**, *13*, 80–84.

Chapter 10 Case studies of massive casualty incidents

Haiping Chen[1]*, Fangjie Zhao*[2] *and Lulu Zhang*[2]

[1] *Department of Science and Education, Shanghai Children's Hospital, Shanghai 200062, China*

[2] *Department of Military Health Service Management, College of Military Health Service Management, Second Military Medical University, Shanghai 200433, China*

10.1 Connotations and overview of massive casualty incidents

10.1.1 Research background

Greater transport diversification in daily life and the extensive application of modernized machinery in production have accelerated the mechanization of society. Transport systems have become more crowded, urban populations continue to increase in density, and more people are living in high-rise residential buildings. Therefore, the probability of MCIs in cities, especially megacities, has gradually been rising in recent years. Within the last decade, numerous large-scale public emergencies have occurred around the world, including the September 11th attacks in the USA in 2001, the Indian Ocean earthquake and tsunami in 2004, and the 2008 Sichuan earthquake in China. These incidents have inflicted severe damage on the lives and health of urban residents. Hence, it is necessary to provide care and attention to residents, and to establish preventive measures early on.

MCIs generate a sudden, large influx of casualties simultaneously and involve a high number of patients, variable conditions, and serious injuries. In addition, the human, material, and financial resources of local emergency medical services become limited. Thus, it is critical to rapidly and effectively implement emergency rescue following MCIs (Zhang *et al.*, 2012). Measures to swiftly and efficiently allocate emergency resources, optimize emergency procedures, and provide timely and accurate treatment will help satisfy the treatment needs of more casualties, save a greater number of lives, and reduce disability rates.

10.1.2 Definitions of massive casualty incidents

According to the ISO 9000 quality standards, an MCI occurs when more than 5 casualties seek treatment at the same time. Mistovich *et al.* stated that, "A mass casualty incident (often shortened to MCI and sometimes called a multiple-casualty incident or multiple-casualty situation) is any incident in which emergency medical services resources, such as personnel and equipment, are overwhelmed by the number and severity of casualties" (Mistovich *et al.*, 2013). In the health care field, the term mass casualty event is used when hospital resources are overwhelmed by the number or severity of casualties (Mattox, 2013).

In the "Classification Criteria of Especially Serious Public Emergency Incidents" issued by the State Council, a mass incident is defined as an event leading to more than 3 and fewer than 10 deaths, or more than 10 and fewer than 30 injured people. Xu Guiqin *et al.* said that MCIs often involve one or more factors of injury, leading to more than 3 casualties at the same time (Xu *et al.*, 2005). Li Sumin *et al.* defined MCIs as one or more factors of injury resulting in more than 4 casualties at the same time (Li *et al.*, 2007). By combining the State Council's classification criteria for public emergency incidents with the definitions of mass incidents found in Chinese and international trauma researches, this study defined MCIs as occurrences leading to more than 3 deaths or more than 10 injured individuals.

10.1.3 Overview of massive casualty incidents

In foreign studies, MCIs mainly involve injuries and poisoning (e.g., substances such as alcohol, pesticides, or food), while the main types of urban injuries include those related to traffic, violence, and ground-level and high-level falls (Mccaig and Ly, 2002). As for mass casualties caused by emergency incidents, Briggs pointed out that the primary goal of mass casualty emergency rescue is to save the maximum number of casualties in the shortest possible time (Gan and Zhang, 2007). To save more casualties simultaneously, health authorities have analyzed each step of the treatment process after the occurrence of MCIs, and focused on research to improve bottleneck areas; for example, the early design of emergency response plans (including detailed preparation, in addition to multiple response plans) (Okumura and Ohta, 2003; Adini *et al.*, 1996), regularly executing emergency training and drills (Ray *et al.*, 2010), implementing more standardized triage methods during the treatment process, and more rapid and accurate medical treatment measures (Kelen *et al.*, 2006). These studies have been extremely helpful in identifying swifter and more effective pre-triage methods, the reasonable allocation of emergency resources, shorter duration of pre-hospital treatment and hospital diagnostic tests, and enhancing treatment efficiency. This will facilitate the early confirmation of patients' conditions, and the provision of targeted treatment, thereby reducing patient disability and death (Hirshberg *et al.*, 1999; Hirshberg *et al.*, 2005).

In China, research on mass casualties mainly focuses on natural disasters (such as earthquakes, floods, and mudslides) and MCIs (Zhao and Svanström, 2003). Poisoning and traffic accidents predominate among urban MCIs, followed by production accidents and public security incidents (Hong *et al.*, 2007). Zhu Jinsong *et al.* examined the proportion of poisoning incidents among 1,884 mass casualty individuals treated in 6 tertiary A hospitals; the most common cause was carbon monoxide poisoning (Zhu *et al.*, 2015). Among sudden incidents in Beijing, the main reason for mass casualties is traffic accidents (Fan *et al.*, 2006). As for studies on the emergency rescue of mass casualties, Zhang Hongyan *et al.* applied the "$N+1$" treatment model for the rescue of mass casualties after the 2008 Sichuan earthquake, which involved collaborative management between one treatment center and multiple departments (Zhang *et al.*, 2008). Zhang Lulu *et al.* analyzed the complex causative factors for mass casualties after earthquakes, and proposed a "two phases, three level" post-disaster treatment model (Zhang *et al.*, 2012). Xu Guiqin *et al.* classified mass casualties and suggested a “three-level triage (mild, moderate, severe), three-level doctor division (junior, intermediate, senior), three phases (early, mid and late)” treatment (Xu *et al.*, 2005). Sun Haichen *et al.* applied workflow restructuring, which entailed integrated improvements in three dimensions, “structure—process—outcome” to enhance medical service quality, thereby optimizing the overall emergency procedures for mass casualties (Sun *et al.*, 2009).

MCIs lead to a sudden surge in medical burden for hospitals within the respective region in a short period of time. Health authorities can implement the scientific triage of casualties, reasonably allocate local emergency medical services, and improve hospitals’ treatment outcomes (e.g., by accumulating more quality medical care for the ED, mobilizing the discharge of existing patients and expanding hospital capacity, and establishing temporary beds in the ICU to satisfy the needs of seriously injured casualties). These measures have important implications for mitigating the pressure on emergency medical services and accelerating the treatment of casualties (Ginzburg *et al.*, 2008).

10.2 Basic information of the 2011 collision along Line 10 of the Shanghai Metro

The basic features of the collision that happened along Line 10 of the Shanghai Metro on September 27, 2011 were collected using data resources from the literature and the Internet. The data were combined with the inpatient medical records of 9 casualties from the subway accident admitted to Shanghai CZ Hospital (8 cases of a single injury, and 1 case of multiple injuries). Descriptive analysis was performed based on three dimensions: (1) demographic information; (2) injury characteristics; and (3) treatment of the injury. The first dimension included 3 items (gender, age, and marital status); the second one was comprised of 4 items (the injury mechanism, injured body region, injury condition, and severity score of the injury); the third dimension was made up of 5 items (admission pathway, prehospital time, LOS, patient outcomes, and complications).

10.2.1 Demographic characteristics of massive casualty incident patients

Among the 9 casualties, the percentages of males and females were 66.7% and 33.3%, respectively.

Among the 9 casualties, the percentages of the 25–34 and ≥65 age groups were higher, at 33.3% each, respectively.

Among the 9 casualties, the percentage of married individuals was the highest (77.8%).

Table 10.1. Gender of patients in the 2011 metro collision.

N (%)	Males	Females
Single injury	5(62.5)	3(37.5)
Multiple injuries	1(100.0)	0(0)

Table 10.2. Age of patients in the 2011 metro collision.

N (%)	15–24 y	25–34 y	45–54 y	≥65 y
Single injury	2(25.0)	3(37.5)	1(12.5)	2(25.0)
Multiple injuries	0(0)	0(0)	0(0)	1(100.0)

Table 10.3. Marital status of patients in the 2011 metro collision.

N (%)	Single	Married
Single injury	2(25.0)	6(75.0)
Multiple injuries	0(0)	1(100.0)

10.2.2 Injury characteristics of massive casualty incident patients

Among the 9 casualties, 40% were hurt by falls during the accident, and 20% were harmed due to impacts from machinery.

Table 10.4. Injury mechanisms of patients in the 2011 metro collision.

N (%)	Ground-level fall	Machinery	Traffic-related
Single injury	4(50.0)	2(25.0)	2(25.0)
Multiple injuries	0(0)	0(0)	1(100.0)

Among the 9 casualties, the most common injured body region for casualties with single injury was the head (62.5%), followed by the thorax (25.0%). The most common injured body regions for casualties with multiple injuries were the thorax (50.0%) and lower extremities (50.0%).

Table 10.5. Injured body region of patients in the 2011 metro collision.

N (%)	Head	Thorax	Abdomen	Lower extremities
Single injury	5(62.5)	2(25.0)	1(12.5)	0(0)
Multiple injuries	0(0)	1(50.0)	0(0)	1(50.0)

Among the 9 casualties, the incidence of SSTI was the highest (77.8%), followed by FJI (44.4%).

Table 10.6. Injury conditions of patients in the 2011 metro collision.

N (%)	FJI	SSTI	CNSI	TOI
Single injury	3(25.0)	6(50.0)	2(16.7)	1(8.3)
Multiple injuries	1(50.0)	1(50.0)	656(34.7)	166(8.8)

The injury severity of casualties with single injury was scored using the AIS. Most single injury was relatively minor (patients with an AIS score of ≤3 accounted for 87.5%), while the proportion of patients with critical injuries (AIS = 5) was relatively low (12.5%). The injury severity of casualties with multiple injuries was scored using the ISS, which showed that these patients were hurt to a minor extent (ISS = 2).

Table 10.7. AIS and ISS of patients in the 2011 metro collision.

N (%)	1	2	3	5
Single injury	6(75.0)	0(0)	1(12.5)	1(12.5)
Multiple injuries	0(0)	1(100.0)	0(0)	0(0)

10.2.3 Injury treatment of massive casualty incident patients

Among the 9 casualties, 88.9% were admitted directly to the ED of Shanghai CZ Hospital, while 11.1% were RHS.

Table 10.8. Admission pathway of patients in the 2011 metro collision.

N (%)	RHS	EDA
Single injury	1(12.5)	7(87.5)
Multiple injuries	0(0)	1(100.0)

The mean pre-hospital time of the 9 casualties was 6 hours. Only 37.5% were admitted within 2 hours after becoming injured.

Table 10.9. Prehospital time of patients in the 2011 metro collision.

N (%)	2 h	3 h	4 h	6 h	24 h
Single injury	3(37.5)	2(25.0)	2(25.0)	0(0)	1(12.5)
Multiple injuries	0(0)	0(0)	0 (0)	1(100.0)	0(0)

Among the 9 casualties, the percentage of patients who stayed in the hospital for 8–14 days was the highest (44.4%), followed by 15–30 days (33.3%).

Table 10.10. LOS of patients in the 2011 metro collision.

N (%)	0–3 d	4–7 d	8–14 d	15–30 d
Single injury	1(12.5)	1(12.5)	4(50.0)	2(25.0)
Multiple injuries	0(0)	0(0)	0(0)	1(100.0)

Among the 9 casualties, more than half (55.5%) were cured upon discharge, while only 44.4% needed further recovery.

Table 10.11. Outcomes of patients in the 2011 metro collision.

N (%)	Improved	Cured
Single injury	3(37.5)	5(62.5)
Multiple injuries	1(100.0)	0(0)

Among the 9 casualties, only 2 single-injury patients had complications, which were both a DC.

Table 10.12. Complications of patients in the 2011 metro collision.

N (%)	Yes	No
Single injury	2(25.0)	6(75.0)
Multiple injuries	0(0)	1(100.0)

10.2.4 Evaluation of massive casualty incident patients

A retrospective analysis was performed on the hazards and post-trauma rescue of a typical MCI in Shanghai, the goal being to reveal the patterns of the occurrence and development of MCIs. No one died in the 2011 collision along Line 10 of the Shanghai Metro. A total of 271 casualties were admitted to hospitals, of whom 30 were discharged after being observed for 24 hours in the ED; 180 were discharged within 72 hours, and 61 are still in the hospital (Zhang *et al.*, 2012).

(1) Injury hazards

Most casualties of this accident had minor injuries; the causes included bump and falls. The region of injury included the head, thorax, and extremities. The injury conditions were mainly fracture and SSTI (Zhang *et al.*, 2012).

(2) Medical treatment

Following the collision, the treatment process at Shanghai CZ Hospital was analyzed to observe the process of medical emergency rescue. Casualties were transported to the hospital within 1 hour after the accident. In contrast, after the 2012 Shanghai stampede, Shanghai CZ Hospital admitted 16 batches of casualties within 3 hours (for a total of 40 casualties). Of these, 5 batches were transported by the 120 Ambulance Service, while others traveled to the hospital by themselves. The mean number of casualties for each batch was (2.5 ± 1.4) individuals, and the mean interval between each batch was (5.93 ± 4.77) minutes. A rescue model, which involved "initial diagnosis by nurses, treatment in the ED, and distribution to patient wards," was applied. After being examined and treated, among the 40 casualties, 23 (57.5%) were discharged that same day; 17 (42.5%) were admitted to patient wards for systematic treatment, with 6 going to the neurosurgery department, 4 to the ED, 4 to the orthopedic department, and 3 to the thoracic surgery department. After 2–5 days of treatment, these 17 individuals were cured upon discharge (Zhang *et al.*, 2012).

10.3 Basic information of the 2012 Shanghai stampede

The basic features of the stampede in Shanghai on December 31, 2012 were collected using data resources from the literature and the Internet. The data were combined with the inpatient medical records of 9 casualties who were admitted to Shanghai CZ Hospital (0 cases of a single injury, 9 cases of multiple injuries). Statistical analysis was performed based on three dimensions: (1) demographic information; (2) injury characteristics; and (3) injury treatment. The first dimension was comprised of 3 items (gender, age, and marital status); the second dimension was made up of 4 items (the injury mechanism, injured body region, injury condition, and severity score of the injury); the third dimension included 5 items (admission pathway, prehospital time, LOS, patient outcomes, and complications).

10.3.1 Demographic characteristics of massive casualty incident patients

Among the 9 casualties, the percentages of males and females were 44.4% and 55.6%, respectively.

Table 10.13. Gender of patients in 2012 Shanghai stampede.

Gender	N	%
Male	4	44.4
Female	5	55.6

The ages of the 9 casualties with multiple injuries were mostly in the 25–34 age group (88.9%).

Table 10.14. Age of patients in 2012 Shanghai stampede.

Age (year)	N	%
15–24	8	88.9
25–34	1	11.1

The 9 casualties were all single.

Table 10.15. Marital status of patients in 2012 Shanghai stampede.

Marital status	N	%
Single	9	100.0
Married	0	0

10.3.2 Injury characteristics of massive casualty incident patients

More than half (55.6%) of the casualties had injuries in 2 regions of the body, with the highest number of regions being 4.

Table 10.16. Number of injured body regions of patients in 2012 Shanghai stampede.

Number of injured body regions	N	%
2	5	55.6
3	3	33.3
4	1	11.1

Among the 9 casualties with multiple injuries, the incidence of thoracic injuries was 100.0%, while head and abdominal injuries were also relatively high, at 44.4% each, respectively.

The 9 casualties with multiple injuries all had SSTI (100.0%), while PC and TOI accounted for 22.2% each, respectively.

Among the 9 casualties with multiple injuries, only 1 case was scored using the GCS

(GCS = 7, minor head injury).

Table 10.17. Injured body regions of patients in 2012 Shanghai stampede.

Injured body region	**N**	**%**
Head	4	44.4
Thorax	9	100.0
Abdomen	4	44.4
Upper extremities	2	22.2
Lower extremities	3	33.3
Spine	0	0
Pelvis	1	11.1

Table 10.18. Injury conditions of patients in 2012 Shanghai stampede.

Injury condition	**N**	**%**
SSTI	9	100.0
CNSI	1	11.1
PC	2	22.2
TOI	2	22.2

Table 10.19. GCS of patients in 2012 Shanghai stampede.

GCS	**N**	**%**
3–8	1	11.1
NA	8	88.9

The 9 casualties mainly had mild to moderate injuries, of whom 66.7% had mild injuries, while 22.2% had moderate ones.

Table 10.20. ISS of patients in 2012 Shanghai stampede.

ISS	**N**	**%**
1–8	6	66.7
9–15	2	22.2
16–24	1	11.1

10.3.3 Injury treatment of massive casualty incident patients

The 9 casualties were admitted directly to the ED of Shanghai CZ Hospital. The mean prehospital time was 2.16 hours; 88.8% of casualties were admitted within 3 hours of becoming hurt, but only 44.4% were admitted within 1 hour of becoming injured.

Table 10.21. Prehospital time of patients in 2012 Shanghai stampede.

Prehospital time (hour)	**N**	**%**
≤1	4	44.4
1–3	4	44.4
3–24	1	11.1

Among the 9 casualties, the percentage of patients who stayed at the hospital for 4–7 days was the highest (55.6%), followed by 8–14 days (22.2%) and 15–30 days (22.2%), respectively.

Among the 9 casualties, more than half (55.6%) were cured upon discharge, while only 44.4% needed further recovery.

Table 10.22. LOS of patients in 2012 Shanghai stampede.

LOS (day)	N	%
4–7	5	55.6
8–14	2	22.2
15–30	2	22.2

Table 10.23. Outcomes of patients in 2012 Shanghai stampede.

Outcome	N	%
Improved	4	44.4
Cured	5	55.6

Among the complications of the 9 casualties with multiple injuries, DC accounted for the most (77.8%), followed by HS (22.2%) and BI (2.22%), respectively.

Table 10.24. Complications of patients in 2012 Shanghai stampede.

Complication	N	%
HS	2	22.2
DC	7	77.8
ABI	1	11.1
BI	2	22.2

10.3.4 Evaluation of massive casualty incident patients

In another stampede in Shanghai on December 31, 2014, 49 individuals were injured (13 seriously) and 36 were killed. During the emergency rescue process, the 120 emergency center deployed 19 ambulances to participate, with the earliest time interval being 12 minutes. The number of casualties treated on-scene and transferred was 31; 16 people died, 2 had traumatic head injuries, 1 had thoracic trauma, 2 had lumbar spine injuries, 1 had asthma, and 9 had minor injuries. On-scene procedures performed by emergency personnel included cardiopulmonary resuscitation, tracheal intubation, establishing venous access, negative-pressure fracture fixation, and oxygen therapy. In addition, the emergency green channels of the four nearest hospitals were opened, and timely alerts about the conditions of the casualties were provided. This enabled the hospitals to implement early rescue preparations and enhance their treatment efficacy (Xuan *et al.*, 2015). Within two weeks, the diagnosis and treatment of the casualties were as follows: 46 individuals were discharged, including 11 of the 13 seriously injured ones (Shan, 2015).

(1) Injury hazards

The mass deaths and injuries caused by stampedes could negatively impact society.

Stampede casualties often have injuries in multiple body regions including the thorax, head, abdomen, and lower extremities. The injury conditions that may result include fractures, skin and tissue injuries, external bleeding, abdominal organs, liver and spleen ruptures, cardiopulmonary injuries due to rib fracture, and cerebral ischemia and hypoxia. Furthermore, DC is relatively frequent, mainly due to traumatic asphyxia whereby compression of the thoracic cavity reduces the space for expansion; respiratory movement cannot be performed, which leads to hypoxia and asphyxia, resulting in DC, brain injury, and even death (Xuan *et al.*, 2015).

(2) Medical treatment

The treatment process of Shanghai CZ Hospital during the stampede was analyzed. After the stampede, the mean pre-hospital time of casualties transferred to Shanghai CZ Hospital was 2.16 hours. The individuals were mainly transported by ambulances. Shanghai CZ Hospital admitted 18 casualties (including 6 with moderate to serious injuries) within 6 hours after the stampede, mainly crush injuries. The hospital treatment process involved three aspects. Firstly, the hospital emergency treatment plan was initiated, then treatment command and professional treatment teams were established to coordinate emergency resources (human, material, and spatial). Secondly, the casualties who arrived in batches underwent triage, airway management, establishment of venous access, examination of vital signs, and examination by ancillary departments. Finally, appropriate treatment was rapidly given to the patients such as triage and treatment of casualties, multidisciplinary consultation for casualties with serious injuries, and psychological counseling. After being treated, 7 people with minor injuries had recovered and were discharged within 24 hours (Wang, 2015).

By performing a retrospective analysis on the data of typical MCIs, we could categorize, summarize, and analyze the relevant injury factors, emergency process, and emergency outcomes. This allowed us to explore the patterns involved in the onset and development of MCIs, which permitted us to formulate early emergency plans, implement a reasonable allocation of medical resources, standardize prehospital treatment procedures, enhance the treatment efficiency of casualties, and improve the outcomes of medical rescue. In turn, these measures will lower the mortality and disability rates of the casualties.

References

Adini, B.; Goldberg, A.; Laor, D.; *et al.* Assessing levels of hospital emergency preparedness. *Medical Engineering & Physics* **1996**, *18*, 79–87.

Fan, K.; Wang, X.H.; Wu, G.P.; *et al*. The research of mass casualties' characteristics and rescue in emergency (Beijing). *Chinese Journal of Care Medicine* **2006**, *26*, 698–700.

Gan, J.X.; Zhang, M.Z. *The Medica Reply of Pubic Emergency Incident: Manual of Disaster's Rescue*; Zhejiang University Publication: Hangzhou, China, 2007.

Ginzburg, E.; Chong, C.K.; Rich, N.M. Current therapy of trauma and surgical critical care. *Current Therapy of Trauma & Surgical Critical Care* **2008**, *249*, 763–785.

Hirshberg, A.; Scott, B.G.; Granchi, T.; *et al.* How does casualty load affect trauma care in urban bombing incidents? A quantitative analysis. *Journal of Trauma* **2005**, *58*, 694–695.

Hirshberg, A.; Stein, M.; Walden, R. Surgical resource utilization in urban terrorist bombing: a computer simulation. *Journal of Trauma & Acute Care Surgery* **1999**, *47*, 545–550.

Hong, J.F.; Yao, Z.H.; Lin, J.G.; *et al*. EpldemioIogical characteristics and emergency measures of sudden group accidents: a study in quanzhou city. *Chjnese Genera Practice* **2007**, *10*, 1723–1725.

Kelen, G.D.; Kraus, C.K.; Mccarthy, M.L.; *et al.* Inpatient disposition classification for the creation of hospital surge capacity: a multiphase study. *Lancet* **2006**, *368*, 1984–1990.

Li, S.M.; He, H.; Ma, Y.L. The experience of mass casualties' rescue. *Journal of Medica Forum* **2007**, *28*, 111.

Mattox, K.L. *Trauma*,7th ed.; McGraw-Hill: New Yrok, NY, USA, 2013.

Mccaig, L.F.; Ly, N. National hospital ambulatory medical care survey: 2000 emergency department summary. *Advance Data* **2002**, *326*, 67–70.

Mistovich, J.; Karren, K.; Hafen, B. *Prehospital Emergency Care: Pearson New International Edition*; Pearson: London, UK, 2013.

Okumura, T.; Ohta, N.N.M. The chemical disaster response system in Japan. *Prehospital and Disaster Medicine* **2003**, *18*, 189–192.

Ray, S.K.; Pawlikowski, K.; Sirisena, H. Handover in mobile WiMAX networks: the state of art and research issues. *IEEE Communications Surveys & Tutorials* **2010**, *12*, 376–399.

Shan, C. The research and thinking of 2014 Shanghai stampede. *Jiangsu Social Sciences* **2015**, 1–6.

Sun, H.C.; Shao, D.B.; Wang, H.J.; *et al*. The optimizing of the rescue process of mass casualties. *Trauma Surgery Journal* **2009**, *11*, 104–106.

Wang, Z.F. Rescue of 2014 Shanghai stampede (within 60 hours)-the documentary of the rescue process of 18 casualties in Changzheng Hospital (the affiliated hospital of The Second Military Medical Unversity). *Every One is Well* **2015**, 46–47.

Xu, G.Q.; He, Z.J.; Ma, J.X.; *et al*. The application of "three types diagnosis-three regions-three stages" model in mass casualties' rescue. *Chinese Nursing Research* **2005**, *40*, 854–855.

Xuan, G.; Jiong, J.; Wen, C.; *et al.* The Reflection of the emergency rescue in 2014 Shanghai stampede. *Chinese Journal of Emergency Resusce Disaster Medicine* **2015**, *10*, 671–672.

Zhang, B.S.; Gui, L.; Cui, H.B.; *et al.* Investigation on emergency rescuing mode for mass casualties in hospital. *Nursing Journal of Chinese People's Liberation Army* **2012**, *29*, 58–60.

Zhang, H.Y.; Wu, H.; Chen, H.; *et al*. Exploration of the "1 + N" mode in the rescue of mass earthquake disaster. *Chinese Hospital Management* **2008**, *28*, 75–76.

Zhang, L.; Liu, X.; Li, Y.; *et al.* Emergency medical rescue efforts after a major earthquake: lessons from the 2008 Wenchuan earthquake. *Lancet* **2012**, *379*, 853–861.

Zhao, Z.; Svanstr, M.L. Injury status and perspectives on developing community safety promotion in China. *Health Promotion International* **2003**, *18*, 247–253.

Zhu, J.S.; Chen, Z.; Yang, H.W.; *et al*. Construction of a hospital first-aid model for batches of patients with carbon monoxide poisoning. *JournaI of Nursing Science* **2015**, *30*, 40–42.

Chapter 11 Preliminary investigation of modeling the massive casualty emergency medical system

Wenya Yu[1], Zhipeng Liu[2] and Lulu Zhang[1]

[1] *Department of Military Health Service Management, College of Military Health Service Management, Second Military Medical University, Shanghai 200433, China*

[2] *No. 305 Hospital of PLA, Beijing 100017, China*

11.1 Research background and design

11.1.1 Research background and significance

Research has been rapidly progressing on the occurrence of urban trauma and trauma emergency treatment technology. However, research on the patterns of trauma occurrence and trauma emergency systems have mostly been limited to statistical and qualitative analysis, with a distinct lack of complex, system-level studies. These studies are unable to satisfy actual demands, and cannot provide effective and specific emergency plans and resource allocation recommendations to emergency rescue systems. On the other hand, there have been significant urban changes owing to a large influx of people into cities and the acceleration of industrialization in society. Thus, there have been more frequent occurrences of MCIs, which have placed greater demands on cities' MCI emergency response systems (Wang *et al.*, 2007; Ma *et al.*, 2007; Tang and Wen, 1999). However, current trauma emergency systems lack the experience and plans needed for MCI emergency response. This conflict between demand and actual ability imply that more research on MCI emergency response systems is urgently needed.

This chapter will implement system modeling to investigate MCI emergency response systems. Our aim is to perform structural analysis and behavioral simulation of MCI emergency systems at the level of complex systems. This will provide quantitative analysis and evidence-based decision-making for the formulation of emergency response plans and health resources allocation.

11.1.2 Overall research design

Research on urban trauma emergency response systems is an important field in emergency medical management, which has an especially important significance for the effective management of MCIs. The successful organization of trauma emergency response systems can effectively reduce the mortality and disability rates caused by MCIs. This can promote timely, competent handling of sudden public safety incidents.

This study adopted a complexity perspective and analyzed individual, environmental, rescue system, rescue force, and other internal and external system factors. Based on this, the key factors and mechanisms influencing the outcomes of MCIs can be obtained for multiple structures and levels of the overall system. Quantitative analysis can then be performed on the system behavior and basic patterns after the occurrence of MCIs to explore the key aspects that can reduce the patient mortality rate. System dynamics modeling was performed to achieve the aims of this study. A system dynamics model was built to create an experimental platform for MCI emergency response systems. This enabled the overall analysis and dynamic behavioral simulation of the trauma emergency network system, and the screening of key interventional “targets” that can influence the efficiency of trauma emergency response systems. Following this, a policy intervention experiment related to MCI emergency response was implemented to verify the effects of the intervention policy on the outcome measures. Finally, based on the results of the policy intervention experiment, different scales and types of MCI emergency response plans and strategies for allocating health resources were formed to provide preventive measures for MCIs in megacities.

Due to considerations for this book’s general plan and objectives, this chapter will only describe the construction of the overall model, conceptual model, and logic model, followed by the preliminary integration to form a system dynamics model. This chapter will not discuss the dynamic simulation of the system model and policy intervention experiment.

11.1.3 Modeling methods and foundation

Jay W. Forrester of the Massachusetts Institute of Technology created system dynamics modeling in 1956. It was initially applied in industry to investigate the dynamic characteristics of changes in system behavior over time (Wang, 1988; Wang, 1992). System dynamics modeling is especially suitable for studying dynamic shifts in the system behavior of a complex system within a fixed period (short-term or long-term). It can be used to predict the development trends of systems, test the impacts of a specific policy on the system within a period, and evaluate the effects of interventional measures on multiple system behaviors. This method has been extensively applied in the complex systems of engineering, ecology, the environment, social development, and other domains. However, its application and research in medical and health care are still in the preliminary phase (Homer and Hirsch, 2006; Rauner and Schaffhauser-Linzatti, 2002; Taylor *et al.*, 2005).

System dynamics modeling includes four elements: (1) stock variables; (2) flow variables; (3) converters; and (4) connectors. A system dynamics model is mainly composed of causal loop diagrams and Stock and Flow Diagrams (SD). Stock variables are also known as state variables, and flow variables are also called rate variables, which indicate the rate of change. SD models are established based on causal loop diagrams. SD models contain several causal loops, and these closed causal loops are known as feedback loops, which reflect the mutual relationships between different variables in the system (Ni, 2011; Cai, 2008). Generally, the construction of a system dynamics model is performed using software such as Vensim, iThink, or Stella. In this study, Vensim was most commonly used to build the system dynamics model of MCI emergency response systems.

The core factors of constructing a system dynamics model are its data and logic foundations. This study provided the underlying data for the system model based on the supply-side and demand-side perspectives. The demand-side data came from research data of various casualty types in Shanghai, combined with retrospective research data of MCIs in Shanghai over the past five years. The supply-side data consisted of the existing trauma emergency resources in Shanghai including resources of medical institutions, treatment technology, treatment equipment, statistical data, and human resources. This foundation was combined with a literature review and meta-analysis to supplement the key underlying data with MCIs in other local and foreign regions. These underlying data not only provide a foundation for building the system model, but also a basis for analyzing the system structure and levels, the quantitative relationship between the agent and its factors, and the mechanism of action.

The system dynamics model of MCI emergency response systems is based on the data and logic relationships mentioned above. The public health policy model system proposed by the research group was used to construct a platform as the foundation, while the organizational and resource structures of Shanghai's existing emergency system were used as a basis for construction. The system's stability, sensitivity, and reliability were determined using the current emergency system as the baseline. The system model was then tested to ensure that the system was modified to produce the most stable and reliable state that is closest to objective reality. This ensured the normal operation of the system model, which may serve as a reference for subsequent policy intervention experiments and planning.

11.2 Establishment of the system dynamics model

11.2.1 Model description

The model consisted of four agents. Specifically, this included casualties, hospitals, the government, and the emergency center. As would be the case in reality, the four agents interacted with each other within the model. The severity of the injured determined the overall medical demand, the emergency rescue capability of hospitals decided the hospital rescue efficiency, the information and response of the government influenced the organization and command efficiency, and the emergency center was responsible for the prehospital emergency rescue efficiency and emergency health resource allocation.

11.2.2 Causal-loop diagram

A search of the literature revealed that pre-hospital and hospital rescue, scale of MCIs, injury severity, medical rescue time, and emergency decision-making were key factors of mortality. Therefore, based on the basic situation of China and the investigation on MCIs in Shanghai, factors included in this study were the scale of MCIs, pre-hospital time, hospital rescue capability, and efficiency of organization and command. Figure 11.1 reflects the interaction of these factors. The specific meaning of casual loop diagram was as follows.

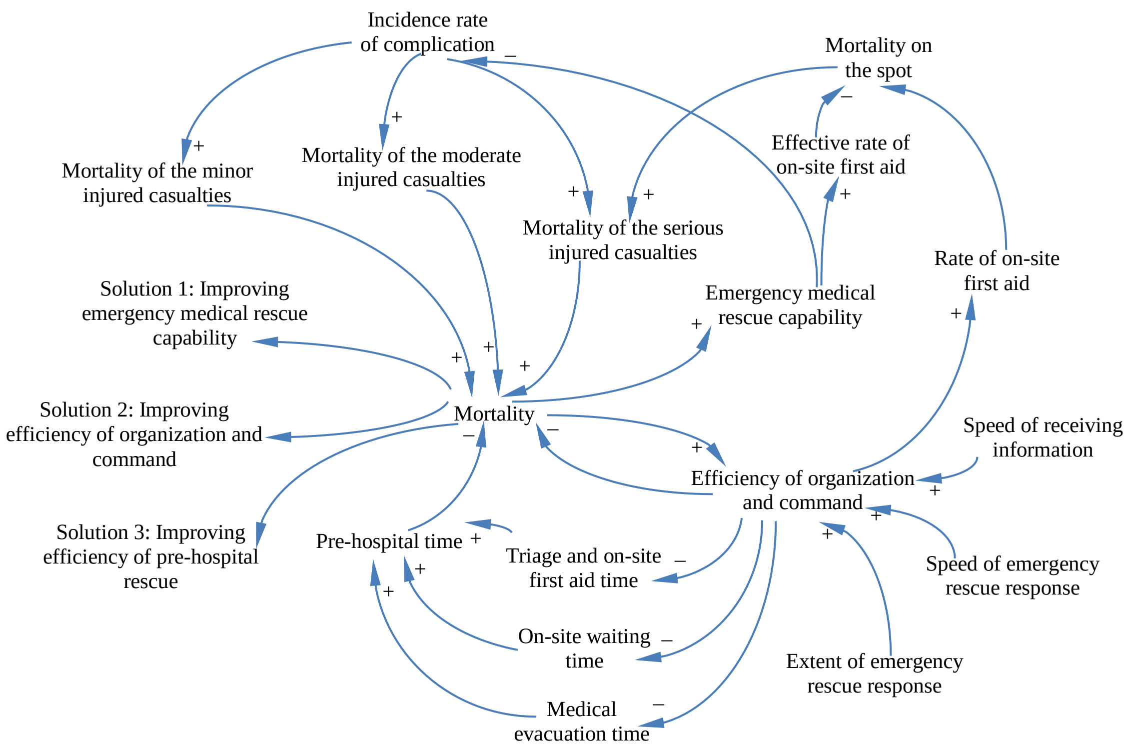
The scale of MCIs and injury characteristics. Mortality of individuals involved in MCIs was directly influenced by the severity of injury. Mortalities of minor injuries, moderate injuries, and serious injuries varied, and the proportion of the three types of casualties determined the medical demand. Moreover, some critically injured casualties shared the risk of death on the spot, which was primarily affected by on-site first aid measures.

Organization and command of MCIs rescue. The efficiency of organization and command was influenced by the speed that the ED received MCIs information, the speed and the extent of emergency response. In addition, the efficiency would indirectly affect mortality by pre-hospital and hospital rescue. Mortality would be lower with an increase in efficiency.

Pre-hospital emergency rescue of MCIs. The key to significantly reducing mortality was the decreasing prehospital time, which included the on-site waiting time, triage and on-site first aid time, and medical evacuation time. Mortality would increase with an increase in pre-hospital time.

Hospital rescue of MCIs. Hospital rescue capability decided the success rate of treatment and the incidence rate of complication. Higher incidence rates of complication would increase the mortality of individuals involved in MCIs.

Figure 11.1. Casual loop diagram.



11.3 Plans for subsequent modeling research

In subsequent steps, an SD model for MCI emergency response systems will be built based on the conceptual and logic models established above. The construction of the SD model will involve clarifying and concretizing variables in the system, assigning initial values to the variables, and expressing the logic relations among them using different functions. Thus, the overall system model can be connected using simple and intuitive values and functions. The parameters of intervening variables can then be modified to observe the variations in the outcome variables of the overall system within the intervention period, thereby enabling the quantitative evaluation of the results of the intervention experiment. After establishing the SD model, dimensional and parameter testing, operation inspection, and sensitivity analysis will need to be performed to ensure the model's effectiveness. Dimensional and parameter tests are performed to check whether the dimensions of each equation will remain consistent in the absence of parameters with no practical significance, and whether the parameter value matches the descriptive and numerical aspects of the system. A built-in function found in the Vensim software package will be used to test the dimensions of each equation and modified until consistent dimensions are obtained. Then, based on expert interviews, statistical methods will be employed to test the parameters in order to ensure the accuracy of the parameter estimation. Operation inspection will be performed because most socioeconomic systems have numerous influencing factors with complex relationships among them. Hence, systems that are not sensitive to parameter variations and are resistant to policy changes indicate that systems are relatively stable. This stability is also suitable for MCI emergency response systems. This study will select 0.5 and 1 time steps (simulation time interval) for simulation to observe the stability of system behaviors. Sensitivity analysis involves modifying the model's parameters and structure, then running and comparing the model output to analyze the sensitivity of model behaviors in comparison with the assumptions. This involves analyzing both structural and parameter sensitivity. If the model behaviors are extremely sensitive to small changes in any two parameters, then we should suspect that the model only applies to certain scenarios, and the fit of simulation results may only be a coincidence, or whether the special restrictions on these parameters truly conform to reality. Structural analysis mainly examines the impact of changes in causal relationships on model behavior. The aim is to identify the basic mechanisms of system operations by observing model behaviors, or to comment on the impact of controversial causal relationships. Parameter sensitivity analysis involves investigating the sensitivity of model behavior to parameter changes within reasonable limits, the goal being to test whether model behaviors will change due to minute fluctuations in certain parameters. This study will conduct sensitivity analysis on key constant parameters in the model by using −5%–5% of parameter changes to simulate the rate of change in key parameters, the aim being to measure their sensitivity.

Once the model's effectiveness has been verified, the policy intervention experiment will be implemented. Due to the high complexity of the MCI emergency response system and the fact that successfully operating the system will impact the efficient treatment of MCI casualties, competent decision-making by the command and decision-making center will play a key role in system behavior and outcomes. Therefore, by building a system model and adjusting the variable parameters of different decision plans, we can observe the changes in system behavior and variables during the policy intervention experiment.

This will allow us to predict and judge the effectiveness of the decisions made by the command and decision-making center, followed by a screening of the most effective policy plans.

Finally, based on the MCI emergency response system model and the results of the policy intervention experiment, we will propose emergency plans for the Shanghai MCI emergency system, and clarify the applicable conditions and quantitative analysis for different plans. Furthermore, we will provide a solution for the optimal allocation of emergency resources, and decrease the mortality rate of casualties.

11.4 Summary

This study combined on-scene research methods, a literature review, expert interviews, statistical methods, complex adaptive theories, systems thinking, and system dynamics modeling. Based on theoretical research, a preliminary investigation was conducted on the agents, system boundaries, and logic relations of MCI emergency response systems. This study has laid the foundation for the subsequent construction of a complete system model, and the empirical analysis of MCI emergency response systems. This study ultimately aims to distinguish the agent behaviors in MCI emergency response systems and the evolutionary patterns of system structure. By building a system dynamics model of MCI emergency response systems, we can address the lack of policy laboratories in this area. By performing a policy intervention simulation experiment of MCI emergency response systems, we can establish policy targets to optimize emergency response procedures and enhance the efficiency of MCI emergency response policies. In addition, it will be possible to clarify the consequences of each policy based on which policy suggestions can be proposed. This will provide a theoretical basis and the possibility for resolving the high mortality rates of casualties during MCI emergency response.

References

Cai, L. *The Application of System Dynamics in the Research of Sustainable Development*; China Environmental Science Press: Beijing, China, 2008.

Homer, J.B.; Hirsch, G.B. System dynamics modeling for public health: background and opportunities. *American Journal of Public Health* **2006**, *96*, 452–458.

Ma, X.L.; Jiang, Y.G.; Huang, X.K.; *et al.* Practices and experience of establishing regional trauma emergency network in Chongqing, China. *Journal of Traumatic Surgery* **2007**, *9*, 185–186.

Ni, J.J. *Theory and Application of Multi-Agent Modeling and Control of Complex System*; Publishing House of Electronics Industry: Beijing, China, 2011.

Rauner, M.S.; Schaffhauser-Linzatti, M.M. Impact of the new Austrian inpatient payment strategy on hospital behavior: a system-dynamics model. *Socio-Economic Planning Sciences* **2002**, *36*, 161–182.

Tang, A.P.; Wen, A.H. Concept and grade of natural disasters. *Journal of Natural Disasters* **1999**, *8*, 61–65.

Taylor, K.; Dangerfield, B.; Grand, J.L. Simulation analysis of the consequences of shifting the balance of health care: a system dynamics approach. *Journal of Health Services Research & Policy* **2005**, *10*, 196–202.

Wang, G.S.; Xie, G.A.; Ye, N. Discussion on trauma emergency patterns in Anhui provincial hospitals. *Zhejiang Journal of Traumatic Surgery* **2007**, *2*, 92–93.

Wang, Q.F. *Complex System Dynamics Analysis of Social and Economic System*; Fudan University Press: Shanghai, China, 1992.

Wang, Q.F. *System Dynamics*; Tsinghua University Press: Beijing, China, 1988.

Chapter 12 Conclusions

Lulu Zhang and Wenya Yu
Department of Military Health Service Management, College of Military Health Service Management, Second Military Medical University, Shanghai 200433, China

12.1 Evolution of trauma caused by different mechanisms

Trauma has resulted in an immense burden on the health of populations and national economies worldwide, especially among low to mid-income developing countries. In recent years, the mortality rate due to trauma has been increasing among the Chinese population, and especially threatens urban young adults aged 20–45. Furthermore, with greater socioeconomic development, urban MCIs have become more frequent; their large scale and severe damage should attract the attention of countries around the globe.

This study focused on the most developed city in China–Shanghai–to investigate the evolution of high-level and ground-level falls, as well as injuries due to machinery, traffic, sharp instruments, and firearms. The aim was to identify the injury features caused by different mechanisms and the factors influencing mortality rates. On the one hand, this study has provided a theoretical basis for the effective rescue of patients with the six types of injuries examined. On the other hand, the results have laid the foundation for data and a theoretical basis for deeper research into MCIs. Overall, this study aims to enhance the capacity of the trauma emergency system by tracing the development of injuries, thereby reducing mortality and disability rates.

12.1.1 Evolution of traffic injury

Among patients with traffic injuries, the factors influencing the outcomes of patients with single or multiple injuries differed. Injured body region, injury diagnosis, coma status, complications, and time affected patient outcomes. In terms of injured body region, patients with head and abdominal injuries had the highest mortality rate, whereas the incidence of extremity injuries was relatively high. Therefore, when traffic injuries are treated, greater emphasis should be placed on examining the injury conditions at these sites; this is especially true for head injuries, as injury-related coma or even shock will have an immense impact on patient outcomes. Injury treatment should focus on FJI, skin and soft tissue contusions, CNSI, organ injuries, and PC. Patients are most likely to be diagnosed with these types of injuries, which often lead to comas, bleeding, and BI. Their disease progression is dangerous and rapid; hence they require quick, timely, and effective treatment. In addition, we should not ignore how complications impact the outcomes of traffic injuries, as different complications can directly affect a patient’s prognosis and cure rate. Therefore, strengthening patients’ post-acute care and functional recovery is extremely beneficial in terms of improving their quality of life.

Furthermore, the proficient use of scoring tools in the emergency rescue of patients with traffic injuries can facilitate successful, swift triage and treatment. For coma patients, the GCS should be properly applied to determine their injury conditions. To comprehensively identify injury conditions, injury scoring tools (such as the AIS and ISS) can be used, especially after an MCI, as they comprise one of the important bases for quick, competent pre-hospital treatment and triage of mass casualties.

12.1.2 Evolution of high-level fall injury

The factors influencing the outcomes of high-level fall patients with single or multiple injuries showed similar trends, but had slight differences. Injured body region, injury diagnosis, and complications affected patient outcomes. The LOS was linked to the outcomes of patients with single injuries, while ISS impacted the outcomes of patients with multiple injuries. Among injured body regions, we should especially pay attention to patients with head injuries since the mortality rate of this group was higher. As for injury conditions, patients diagnosed with CNSI should be closely monitored, as the injuries of this group are often more critical and difficult to cure. Regarding complications, we should emphasize preventing paraplegia and BI, as these two complications occur frequently among patients who have suffered high-level falls, and often lead to difficulty recovering. Furthermore, the LOS for patients with single injuries should be handled accurately. The appropriate extension of hospital stays and a reasonable increase in treatment time will improve the cure rate of a patient’s injuries.

High-level falls lead to dangerous injuries and high mortality rates, often placing an immense economic burden on a patient’s family and society. During the emergency rescue of high-level falls, medical personnel should fully consider the impact of a patient’s injured body region, injury conditions, injury severity, complications, and comorbidities on their outcomes, which will improve the efficiency of emergency rescue. In addition, preventive measures should be implemented by strengthening education and management, especially in terms of safely overseeing construction sites. Those working at heights should be provided with sufficient safety measures and equipment to reduce the occurrence and post-incident severity of high-level falls.

12.1.3 Evolution of machinery-related injury

The factors influencing the outcomes of patients with single or multiple machinery-related injuries were consistent. Both groups were affected by injured body region, injury diagnosis, complications, and LOS. The most common injured body regions of machinery-related injuries were the extremities and head. The cure rates of thoracic and spinal injuries were the lowest, followed by pelvic injuries; the cure rate of abdominal injuries was the highest, followed by that of the extremities and the head. Patients diagnosed with central nervous system and destructive injuries had significantly lower cure rates. Patients with complications such as DC, paraplegia, fluid and electrolyte disturbance, ABI, ARF, MODS, and BI showed significantly higher mortality rates. Therefore, the prevention and control of hospital complications should be strengthened during clinical treatment.

Research has also shown that attention should be paid to the LOS, since patients with machinery-related injuries who stayed in the hospital for more than 15 days had higher cure rates, whereas those who stayed for fewer than 3 days had the lowest cure rates.

Patients harmed by machinery generally have a higher pain level following injuries that involve higher complexity and severity. Therefore, protection should be strengthened. After the occurrence of machinery-related injuries, medical personnel should combine the development of the injury conditions in such patients to perform rapid triage and provide accurate treatment. This will reduce the incidence of complications, increase the patient's cure rate, and decrease the mortality rate.

12.1.4 Evolution of sharp-instrument injury

Currently, most injuries due to sharp instruments in China are accidental. Unless the patient is too old and suffers from other underlying illnesses, or has sustained damage to vital organs that could not be saved in time, the success rates of patients who are transferred to the hospital and receive timely treatment have been gradually increasing. The factors influencing the outcomes of patients with single or multiple injuries from sharp instruments differed significantly. The outcomes of patients with single injury are influenced by the patient's age, LOS, FJI, and CNSI. The outcomes of patients with multiple injuries are influenced by the patient's gender, LOS, HS, and DC. Male and young patients often have a better prognosis. Therefore, female and elderly patients with sharp instrument injuries should be monitored more closely to enhance the injury outcomes for these groups. In addition, effectively shortening the prehospital time can significantly reduce the patient's mortality rate. Furthermore, patients with fracture and joint or CNSI that are accompanied by complications (such as HS and DC) should be more closely monitored.

Compared to blunt instruments, sharp instrument injuries are relatively less common. However, patients tend to have longer hospital stays, more complications, higher mortality rates, a higher probability of needing surgical intervention or blood transfusions, and a greater need for medical resources. Based on the health care condition in China, there is a need to focus on improving the quality of care and resource utilization rate, which will enhance the efficiency and ability to rescue patients with sharp instrument injuries.

12.1.5 Evolution of ground-level fall injury

The factors influencing the outcomes of patients with single or multiple injuries from ground-level falls were different. The outcomes of both groups were affected by injured body region, injury conditions, complications, comorbidities, LOS, and injury severity. However, the outcomes of patients with single injuries were also impacted by gender, age, prehospital time, and GCS score.

The outcomes of patients with single injuries were closely linked with their demographic factors. The mortality rate was higher for females, but males had a greater incidence of falls. The elderly is at high risk for falls; hence, special attention should be given to prevention and providing the elderly with safety education. Among patients with fall injuries, emphasis should be placed on strengthening the treatment of head and thoracic injuries to reduce the mortality rates caused by these two sites. It should also be noted that CNSI, PC, TH and TOI will significantly reduce a patient's cure rates. In addition, patients with more severe injury conditions, complications, and concomitant hypertension and diabetes have significantly higher mortality rates. The cure rates of patients who stayed in the hospital for 8-14 days and 15-30 days were higher.

Therefore, by combining high-risk populations of ground-level fall injury, injury characteristics, and factors that influence outcomes, during the rescue process, medical personnel should fully consider a patient's demographic traits, injured body region, injury conditions, injury severity, complications, and comorbidities. This will facilitate the rapid triage and accurate treatment of patents, thereby improving their cure rates.

12.1.6 Evolution of firearm injury

Unlike European and American countries, it is illegal for civilians to own firearms in China. Hence, the incidence of firearm injuries in China is comparatively low. The sample size collected in this study was relatively small. Preliminary analysis showed that the prehospital time will influence the patient's outcomes. The results demonstrated that males had a higher probability of having firearm injuries. The most common injured body regions were the head and extremities, and DC was the most common complication. A shorter prehospital time significantly decreased mortality rate. This indicates that for patients with firearm injuries, enhancing the timeliness of emergency response will improve the patient's cure rate.

Although this survey had a small sample of firearm injuries and the statistical results might be biased, the present study aimed to investigate firearm injuries to provide Chinese clinicians with a basis for emergency rescue and treatment for this uncommon injury type. This will lay the foundation for broader and deeper investigations in the future.

12.2 Research on massive casualty incidents and trauma emergency medical system

12.2.1 Massive casualty incidents

Preliminary analyses were performed in regards to the 2011 collision on the Shanghai Metro and the 2014 Shanghai stampede to obtain basic information on the patterns of injuries caused by MCIs and the emergency response. Retrospective analysis revealed that for the subway collision, the majority of casualties had minor injuries that were mostly due to impacts and falls. The injured body regions included the head, thorax, and extremities. Injury conditions were mainly fractures, as well as SSTI. The reaction speed of emergency medical services was relatively fast. Shanghai CZ Hospital, which admitted the MCI casualties, had good triage mechanisms, and was thus able to rapidly and effectively cope with these MCIs. The injuries of the stampede were more serious and the medical resources needed were also much more. Casualties from the stampede mostly had multiple injuries including to the thorax, head, abdomen, and lower extremities. The injury conditions included fractures, SSTI, cardiopulmonary injuries due to rib fractures, and cerebral ischemia and hypoxia. DC was also relatively high. Due to the high input of emergency medical resources and rapid response speed, emergency personnel were able carry out effective, on-scene cardiopulmonary resuscitation, tracheal intubation, establishment of venous access, negative-pressure fracture fixation, oxygen therapy, and other emergency medical measures. Shanghai also opened emergency green channels in four hospitals which allowed them to execute triage, airway management, establishment of venous access, examination of vital signs, and ancillary department examinations for the casualties admitted. Appropriate treatment was rapidly administered, such as triage and treatment of casualties, multidisciplinary consultation for casualties with serious injuries, and psychological counseling.

The retrospective analysis revealed the injury characteristics, outcome analysis, and emergency response of the MCIs. It also provided the basis of data analysis for current MCI research and the capability of emergency medical services in Shanghai. Analyzing typical cases of MCIs has enabled the exploration of MCI occurrence and development patterns, the early establishment of emergency plans, the reasonable allocation of medical resources, the standardization of pre-hospital treatment procedures, the shortening of emergency medical response times to sudden public incidents, and the improvement of casualty and hospital treatment efficacy. These measures will ultimately lay the foundation for the reduction of casualty mortality and disability rates.

12.2.2 Massive casualty emergency medical system

This study combined on-scene research methods, a literature review, expert interviews, statistical methods, complex adaptive theories, systems thinking, and system dynamics modeling. Based on theoretical research, a preliminary investigation was conducted on the agents, system boundaries, and logic relations of MCI emergency response systems. This study has laid the groundwork for the subsequent construction of a complete system model, and the empirical analysis of MCI emergency response systems. This study ultimately aims to determine the agent behaviors in MCI emergency response systems and the evolutionary patterns of system structure. By building a system dynamics model of MCI emergency response systems, we can address the lack of policy laboratories in this area. By performing a policy intervention simulation experiment of MCI emergency response systems, we can establish policy targets to optimize emergency response procedures and enhance the competence of MCI emergency response policies. In addition, it will be possible clarify the consequences and impacts of each policy based on which policy suggestions can be proposed. This will provide a theoretical foundation and possibility for resolving the high mortality rates of casualties in MCI emergency response.

To summarize the above, preliminary, exploratory analyses were performed on the injuries caused by six mechanisms which were combined with surveys of two MCI cases in the region to investigate the injury characteristics and development patterns of different trauma types. In addition, system dynamics modeling was used to investigate the complex modeling and simulation of MCI emergency response systems. This study aimed to apply statistical analysis, case analysis, and system modeling to conduct an in-depth exploration of the onset and development of different injury types. Thus, we could provide a theoretical basis for clinical rescue and a reference for urban MCI emergency response plans. Based on the foundation established by this entire book, we will deepen and refine our research to achieve the ultimate goal of significantly reducing injury mortality rates.