Modeling the Injury Flow and Treatment after Major Earthquakes

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Chapter 1
Introduction

Bihan Tang and Lulu Zhang

Abstract Earthquakes have a devastating impact on affected regions and their populations, often causing death and serious personal injury. They often result in incalculable environmental damage, loss of life, and threats to health. China is an earthquake-prone country located at the intersection of the circum-Pacific seismic zone and the Eurasian seismic zone. After the Wenchuan earthquake, China began to build an emergency medical rescue system for natural disasters. Tremendous progress has been made in response to many medical challenges resulting from these disasters. However, emergency medical rescue is complicated, and substantial emphasis should be placed on its organization to achieve optimal results. Further studies should focus on medical rescue efforts in terms of emergency response, collaboration and cooperation, large-scale transportation and rehabilitation of sick and wounded people, the public health response, and the effect on mental health and social institutions.

1.1 Background

1.1.1 Medical Relief System in China

1.1.1.1 System and Status of Chinese Earthquake Emergency Rescue Work

Chinese earthquake emergency rescue work began following the 1966 Xingtai earthquake. It has undergone multiple stages, such as establishment of the concept of earthquake emergency formation, proposition of earthquake emergency

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measures, legalization of earthquake emergency rescue, and systematization of earthquake emergency work. Now, there exists an earthquake emergency response system and operation mechanism with a unified government under the leadership of the earthquake comprehensive coordination departments at all levels, the division responsible for the relevant departments, in which the general population, the military, and the police all participate. The established earthquake emergency rescue system is supported by laws and regulations and based on contingency plans. The core technology is an emergency command structure that is supported by the emergency response platform, with an emergency rescue team as the backbone and emergency equipment and materials as the protection.[1]

In China, especially after major emergencies, the State Council, as a chief leading organization of national emergency management, usually coordinates the relationships between various departments of the State Council by establishing or initiating permanent or temporary agency headquarters. For example, the State established the "earthquake relief headquarters" after the Wenchuan earthquake. Meanwhile, the General Office of the State Council also set up the State Emergency Management Office to undertake comprehensive emergency management coordination responsibilities. According to the notification of deliberation and coordination mechanism by State Council (Guo Fa [2008] No. 13), the State Council earthquake relief headquarters is the coordinating agency in the State for procedures in the sequence of specific work by State institutions, which is undertaken by the China Seismological Bureau.

As a coordinating body for procedures, the State Council earthquake relief headquarters does not establish substantive offices—it currently only establishes the Office of the State Council Earthquake Relief Headquarters in the State Seismological Bureau. Only after the earthquake and after approval from the State Council is the usual joint meeting of the leadership of the State Council earthquake disaster reduction and dispatching earthquake disaster reduction transferred to the earthquake relief headquarters of the State Council, which is responsible for earthquake disaster and emergency relief work (Zhang et al. 2012).

In the earthquake emergency rescue process, in accordance with the earthquake "national earthquake emergency plan," governments and departments at all levels bear their respective earthquake emergency command tasks in response to the grading requirements. Among them, level I emergency response occurs after a major earthquake, enacted specifically by the People's Government leaders of the affected areas of the province (autonomous regions and municipalities), as well as the State Council earthquake relief headquarters unified organizational leadership, with direction and coordination of the national earthquake emergency work headed by the State Council leaders. Level II emergency response occurs after a major earthquake and is enacted by the People's Government leaders of the affected areas of the province (autonomous regions and municipalities); the China Seismological

[1] Gao Xing, Emergency mechanism for medical assistance in May 12 Wenchuan earthquake [J], CHINA JOURNAL OF EMERGENCY RESUSCITATION AND DISASTER MEDICINE, Vol.3, No.6

Bureau, under the leadership of the State Council, is responsible for organizing and coordinating national earthquake emergency work. Level III emergency response occurs after a major earthquake and is enacted by the People's Government leaders of the affected areas of the city (prefecture, league); the China Seismological Bureau organizes and coordinates the work of the national earthquake emergency, and the Deputy Secretary is in charge of the China Seismological Bureau. Level IV emergency response occurs after a general earthquake and is enacted by the People's Government leaders of the affected areas of the province (autonomous regions and municipalities) and the Municipal People's Government (prefecture, league). Earthquake emergency work is implemented under the support of People's Government leadership and the county disaster area (city, district, and flag). The China Seismological Bureau organizes and coordinates the work of the national earthquake emergency, and the Deputy Secretary is in charge of the China Seismological Bureau (Zhang et al. 2011).

1.1.1.2 Effectiveness and Issues with Chinese Earthquake Emergency Rescue System

After 40 years of efforts, China's earthquake emergency rescue work has made considerable progress. Particularly in the first decade of the twenty-first century, earthquake emergency rescue work, as one of the three working earthquake disaster mitigation systems, has achieved rapid development. It effectively responded to the 2008 Wenchuan earthquake and the 2010 Yushu earthquake; however, some problems and shortcomings were also exposed. Practice is the sole criterion for testing truth. The Wenchuan and Yushu earthquakes were two major challenges of China's ability to deal with unexpected disasters. They also allow for comprehensive examination of the effectiveness of the earthquake emergency rescue system.

Rapid Earthquake Response

The sudden and devastating traits of earthquake disasters, especially major earthquake disasters, determine the importance of timing in earthquake emergency rescue, which is the key to reducing casualties and economic losses. Fast earthquake disaster response depends primarily on whether the acquisition is timely and the decision is scientific. The China Seismological Bureau made a quick report and initiated level I response 13 min after the Wenchuan earthquake. Then, the State Council established earthquake relief headquarters more than 1 h after the disaster. The China Seismological Bureau made a quick report and initiated level II (after 1 h, it was changed to level I) response 11 min after the Wenchuan earthquake. Then, the State Council established an earthquake relief headquarters no more than 1 h after the disaster. The response to these two earthquakes was relatively quick and timely, but that to the Yushu earthquake was faster (Kang et al. 2012).

It is undeniable, however, that there remains room for improvement in Chinese earthquake emergency response, and the key is that the disaster information must be continuous, accurate, and dynamic. Although Chinese authorities have established the appropriate seismic monitoring system to carry out work related to forecasting and early warning of disaster risk, the utilization of disaster risk information, analysis, evaluation, and forecasting is inadequate; the risk evaluation index system is imperfect, which is not conducive to comprehensive mitigation and early warning. During the Wenchuan earthquake, the access to disaster information was singular and backward, and the disaster quick report network failed to play its intended role. The communication system was affected by large-scale paralysis, blocking submission of the disaster information, and information of severe damage in Beichuan County was received 24 h after the disaster. Further, China lacks a forecasting system for seismic intensity and satellite, aerial reconnaissance means, which seriously affected the policy-making departments in the ability to make prompt and accurate determinations during the disaster. After 2 years, during the Yushu earthquake, the progress of information techniques and the application of satellite remote-sensing technology enhance the speed and accuracy of disaster information acquisition. However, it cannot fully meet the needs of emergency rescue, and as a result, receiving disaster information quickly and accurately to facilitate quick response in the earthquake remains an important issue.

Professional Rescue Force

A major earthquake can release tremendous energy in a moment, resulting in many buildings collapsing. Meanwhile, it may bring about many secondary disasters, resulting in greater difficulties in disaster rescue work. Obviously, the rescue task cannot be competent without multifaceted rescue forces in considerable quantity and quality. Over the years, China has established a professional rescue team of more than 50 million people to deal with a variety of unexpected disasters, which has played a critical role in emergency rescue during earthquakes, floods, landslides, fires, mining accidents, hazardous chemical explosions, and other disasters. Although the formation time of the professional rescue time is rather short, it has become the elite troop in the previous earthquake relief work with its advanced concepts, high-quality skills, and professional equipment. The Wenchuan earthquake was one of the largest tests for our professional rescue forces. China devoted up to 2.6 million professional rescue people to the Wenchuan earthquake, including 20 national and provincial earthquake disaster emergency rescue teams, 41 mine rescue teams, and 29 fire brigades, all of whom engaged in difficult tasks, successfully rescuing 7439 survivors buried under the ruins. During the Yushu earthquake, nine national and provincial earthquake disaster emergency rescue teams rushed to the disaster area, and their equipment level and rescue efficiency all had improved relative to the Wenchuan emergency relief, but overall, China's major professional rescue forces still cannot meet the needs of earthquake disaster emergency rescue. First, most professional rescue teams still lack specialized rescue training, earthquake relief equipment, and field experience. Second, the total quantity of seismic specialized rescue teams remains inadequate, and they cannot reach the initial disaster areas, let alone launch a massive search and rescue for a large number of buried people in major disasters. Third, it remains unsatisfactory for conducting rescues under mountain plateaus and in poisonous circumstances. Further, there remain gaps in our earthquake relief efforts compared with developed countries. Professional rescuers only accounted for 3 % of the total population, and the percentage is even smaller in the western seismogenic zone. The level of technical equipment and training of various professional rescue forces cannot meet modern complex rescue needs under difficult conditions. Therefore, further expansion of the earthquake professional rescue teams and strengthened professional rescue forces of earthquake drills are imperative.

People's Self-Aid and Mutual Aid

In earthquakes, the general public in addition to emergency rescuers themselves are the direct victims of emergency rescue. We can say that people's self-help and mutual aid is the first form of earthquake disaster emergency rescue at the scene. Practice at home and abroad shows that, in the majority of earthquake disasters, many lives are saved from self-help and mutual aid. In the Tangshan earthquake of 1976, 86 % (about 60 million) of the citizens were buried in the ruins. Among them, about 48 million people were saved by self-help and mutual aid from the disaster grassroots organizations and common people. In the Wenchuan earthquake of 2008, survivors who were saved by self-help and mutual aid made up 80 % of the total survivors. Thus, in the golden time after an earthquake, the stricken areas in particular are isolated from the outside world, and public awareness of self-help and mutual aid and the degree of organization are of crucial significance for removing individuals from danger and saving lives. According to statistics, 20 min after an earthquake, buried people are rescued at a 98 % success rate, which drops to 63 % 1 h after the earthquake. Among those who had not been rescued with 2 h after an earthquake, 58 % died of suffocation (Kang et al. 2012). Thus, self-help and mutual aid is the quickest and most effective method to alleviate casualties, as rescue between neighbors is fastest, most convenient in space, and most familiar in terms of living environment. In developing countries, mobilizing people to actively participate in rescue to fully engage community relief organizations is a major feature and highlight of emergency disaster management. In China, information on earthquake disaster reduction is inadequately disseminated. There is a lack of education regarding society-wide risk prevention and emergency management disposal and specific requirements for training and drill measures that are in place are unclear. Especially in vast rural and small-town areas, earthquake emergency training is generally lacking, and people's awareness of their own social crisis, risk awareness, and first-aid knowledge and skills are very weak, professional representation is poor, and unawareness is large. These factors together result in weak earthquake disaster prevention and practical ability. Above all, recruiting the public, implementing earthquake preparedness at the grassroots level, establishing rescue volunteers, and active engagement in first-aid skills training are vital to minimizing casualties after earthquakes.

Earthquake Emergency Plan

Preparedness ensures success and unpreparedness spells failure. The earthquake emergency plan is the basis of the work carried out during earthquake emergencies, including emergency action guidelines and an emergency command program. Inner and outer earthquake disaster mitigation shows that establishing a sound scientific and practical contingency plan is the basic necessity for efficient and orderly enactment of earthquake emergency rescue and an important safeguard in reducing the impact of earthquake disasters. In early 1988, we began to advance formulations of contingency plans in some earthquake surveillance and protection zones and have formed a national earthquake emergency plan that combines vertical and horizontal systems, which has played an important role in previous earthquake disaster emergency rescues. In the Wenchuan earthquake, the State Council and local governments at all levels and relevant departments quickly activate contingency plans, form various types of command structure, carry out emergency relief operations effectively, and ensure the order and efficiency of the relief work. Those schools, hospitals, and stadiums that emphasize earthquake emergency plan exercises usually respond rapidly at the time of the earthquake, greatly reducing casualties. As handling of the Yushu earthquake was informed by lessons learned during the Wenchuan earthquake, its emergency plan was more comprehensive, which played an important role in organization of various emergency resources, rescue and recovery work in production, and living order. Overall, however, there are still significant deficiencies in the pertinence, coordination, and comprehensiveness of the Chinese earthquake emergency plan. First, there are significant deficiencies in the earthquake catastrophe system, as it lacks specific disaster grading and corresponding measures. The command system and operation mechanism could not adapt to disaster emergency needs for the Wenchuan earthquake. Second, existing types of emergency plans at all levels lack interrelationships across different levels and departments, and the headquarters lacks plan-level responsibility constraints. Third, preplanning does not contain enough comprehensive elements, and various rescue forces and volunteers across regional organizations are not included in coordination and management. After Wenchuan, the Yushu earthquake emergency plan with regard to preparation and revision of all localities and departments has been put on the agenda. In the future, we must accelerate progress and improve the mechanism to establish a dynamic and continuously improving emergency plan for combat and maneuverability.

1.1.2 Significance of China's Medical Relief Effort from Earthquakes

1.1.2.1 Worldwide Earthquakes as a Frequent Threat to Human Life and Property Safety

Earthquakes are natural phenomena, but they also cause a great deal of harm given the force of natural disasters. Earthquakes cause seismic ground shaking through shock waves, resulting in damage and collapse of buildings, roads, and bridges,

Table 1.1 Public safety requirements for emergency rescue

Disaster type	Pre-alarm or emergency time	Occurrence season	Occurrence location
Floods	Several days to 10 days of warning time	Rainy season	River basin
Landslides, mudslides	Hours to days of continuous rainfall	Rainy season	Mountains
Typhoons	1 week to 10 days of warning time	Summer	Along the sea
Forest fire	Several hours	Dry season	Forest zone
Earthquakes	Usually zero	Year round	Nationwide
Fire	Usually zero, predictable prone points	Year round	Place with people
Public health	Zero to dozens of days	Year round	Nationwide
Production safety	Zero	Year round	Productive place

breaking and tilting of the ground, landslides, debris flow, and tsunamis. Meanwhile, due to the damage to buildings after earthquakes, they also result in fire, flammable gas leaks, damaged nuclear facilities and nuclear leaks, and other secondary disasters. China is located in two seismic zones—the intersecting parts of the circum-Pacific seismic belt and the Eurasian seismic zone with high frequency of seismic activity, high strength, light source, and wide distribution. Accordingly, China is frequently hit by earthquakes. In 2008, an 8.0 earthquake on the Richter scale occurred in Sichuan, China, causing 6.9 million deaths and 37.6 million people injured, resulting in the most casualties since the Tangshan earthquake (Kang et al. 2012). In less than 2 years, on April 14, 2010, a 7.1 magnitude earthquake occurred in the Tibetan Autonomous Prefecture of Yushu region, ultimately resulting in 2698 deaths and 12,135 people injured. Earthquakes appear to have become an unconventional social emergency that threatens human life and property safety.

Due to its vast and complex geological features, China has always been a highly earthquake-affected country. Earthquake disasters are frequent and high in strength, resulting in heavy casualties and widespread features. In the twentieth century, the total number of global deaths due to earthquakes is nearly 1.2 million, of which China accounts for nearly half (600,000). From 1949 to 2000, the number of deaths caused by natural disasters of all kinds was about 550,000, while earthquakes caused more than half of these (about 280,000). The Chinese earthquake death toll is the highest in the world, ranking first among all kinds of natural disasters.

We can see from Table 1.1 that the emergency rapid response capability for earthquakes is the most difficult. With the advent of the information age, post-earthquake emergency response situations for devastating earthquakes (e.g., 2008 Wenchuan earthquake, Yushu earthquake) are always amplified by the media. In emergency response work, response speed of the relevant emergency departments and the quality of multi-sectored coordination between emergency rescue workers not only play an important role in the success of disaster response but also can easily become the focus of public questioning. Therefore, our study on responses to devastating earthquake emergencies is of substantial research value.

1.1.2.2 Earthquake Emergency Medical Rescue Law and Establishing a Scientific Rescue System

Scientific research on rules for earthquake emergency medical rescue contributes to the accumulation of valuable experience in the practice of medical rescue following earthquake emergencies, promotes proper function of the health emergency system and working mechanism, and scientifically improves the national emergency medical rescue capabilities. Since the event of "atypical pneumonia," the Chinese government has continued to accumulate emergency medical rescue practice from public health emergencies and natural disasters. Over the past decade, health emergency departments have conducted extensive research, teaching, and training on public health emergencies and natural disaster emergency medical rescue issues.

After the Wenchuan earthquake, the Chinese government profoundly summarized and reflected on earthquake emergency medical relief operations and conducted extensive research and capacity building on emergency organization and command, rescue forces and deployment pumping groups, and casualty treatment and evacuation (Zhang et al. 2011). However, comprehensive and systematic research at the national level for natural disaster relief medicine is lacking, which leads to serious deficiencies in the accumulation and consolidation of valuable experience. Consequently, efficient emergency medical rescue operations for disaster relief remain insufficient. Thus, the Chinese health emergency system should transfer from the "framework" of a gradual transition to a "standardized management" stage as soon as possible, expand extensive research on public health emergencies and natural disasters emergency medical problems, and seek to grasp the special rules under the particular background of "emergency medical rescue." This work presents a higher health emergency requirement: we should implement quality control and performance management thinking in every action, including the development of plans of action to carry out, inspect, and evaluate by implementing gradual adjustment. Our study is not only a summary and retrospective analysis of pre-natural medical disaster relief work but also an accumulation and exploration of evaluation system establishment, which will provide a reference on methods and paths of emergency medical aid for future work.

1.1.2.3 Modeling of Earthquake Emergency Medical Rescue and Improvement of Rescue Efficiency

Through empirical analysis of the earthquake emergency medical discoveries, we can see that the "two phases" of earthquake casualties (i.e., the growth phase and stable phase) and "three-stage" feature of rescue operations (i.e., emergency period, effective period, and maintenance period) constitute a general law of earthquake emergency medical rescue. Conducting seismic emergency medical rescue organization and command, power organization and management, task switching, and power construction according to this law can help improve the efficiency of earthquake emergency medical rescue. Research on earthquake casualties that occur is essential for improving earthquake emergency medical rescue. According to the investigation of the reported death toll in various earthquakes domestically and abroad, we found that the reported death toll is associated with timing of deaths. Rescue personnel rescue those who are trapped in the rubble, need to clean, find, rescue survivors in every house, and simultaneously conduct the search for victims. Therefore, the number of deaths and injuries has a good correlation with the curves presented by their reported time, respectively. More deaths reflect an increased amount of time to rescue the buried and later time to quoted time. The later the rate of casualties stabilized, the more inadequate the disaster aid and the longer the issue will be extended. Practice at home and abroad shows that the survival rate is high in early rescue with a sharp decline in the survival rate of later rescue. Through a review analysis of several earthquakes, we found that survival rate is a function of the wounded after tune of the earthquake. The inflection point of the two phases of earthquake casualties is related to the elements such as earthquake scale and location; as a result, forecasting the inflection point of earthquake casualties with relevant data is highly important to earthquake emergency medical relief organization decisions, especially in the use of power, medical evacuation, and so on.

1.2 Study Design and System Thinking

China is an earthquake-prone country located in the intersection area of the circum-Pacific seismic belt and the Eurasian seismic zone. In recent years, the 2008 Wenchuan earthquake and the 2010 Yushu earthquake caused a considerable number of deaths, health deficits, and environmental damage. The Chinese health system is in need of theoretical guidance on emergency medical relief. Although medical science has undergone substantial development, disaster medicine has not received enough attention. Major disaster relief always permits acquisition of valuable experience and lessons to be learned, which was gained only through the blood and lives of millions of victims and rescue workers. Emergency medical rescue relief is an extremely complex system to engineer. The problem of emergency medical rescue relief is extremely complex, involving a wide range, such as the occurrence of earthquake casualties, medical evacuation, allocation of medical rescue forces, organization and command of earthquake rescue forces, location and distribution of medical rescue institutions, and so on. Whether effective coping mechanisms and plans for a variety of disasters are established will directly affect the speed, capacity, and efficiency of the emergency medical rescue. Speed is not a substitute for efficiency, and improving efficiency must rely on the scientific method, relying on theoretical research support. Thus, it is essential to establish a corresponding model to support the improvement of the disaster rescue system.

1.2.1 Study Design and Technology Roadmap

This book applied numerous modeling methods to analyze in detail the occurrence of earthquake casualties, hospital length of stay, medical evacuation, medical rescue force allocation, organization and command of earthquake rescue forces, location and distribution of medical support institutions, peacetime to wartime in hospitals, and so on. This book aims to find the intervention targets of earthquake rescue through simulation and modeling intervention, thus effectively improving rescue efficiency and providing a theoretical basis for future rescue capabilities.

1.2.2 Previous Research

Our investigation group began following the 2008 “5.12” Wenchuan earthquake, focusing on earthquake emergency medical rescue operations (Zhang et al. 2012). We went deep into earthquake-stricken areas for data collection and field research and completed the *Wenchuan Earthquake Relief Medical Service Investigation Report*, which was published in the *Liberation Army Daily Internal Reference*. After the 2010 “4.14” earthquake in Yushu, Qinghai Province, we assumed the Ministry of Health (now the State Planning Commission Guardian)’s mandatory subject task project, “Yushu earthquake emergency medical rescue external evaluation,” and sent the investigation team to earthquake-stricken areas for on-site research and data collection. Based on the “two main lines,” wounded flow and rescue forces, we launched systematic research from three levels: strategic, operational, and disastrous. We focused on casualties, on-site treatment, medical evacuation, hospital treatment, epidemic prevention, and psychological rescue, which refer to “wounded” as the main line. Further, we focused on rescue forces and deployment, structure, organization and command, and allocative efficiency, which refer to “rescue forces” as the main line of content. We submitted *Chinese Qinghai Yushu earthquake relief medicine evaluation report* to the Ministry of Health and published *An Empirical Study of Earthquake Medical Rescue* (Science Press). In 2013, Sichuan Province underwent another earthquake, “4.20” Lushan earthquake. We went to the disaster area 3 months after the event for investigation. Compared to the previous two investigations, the focus of this study was more forward and covered the IX intensity stricken areas in depth. We constructed a large-scale questionnaire study for earthquake-hit residents, focusing on earthquake relief reactivity and accessibility. This investigation covered the two most severely stricken towns, distributing 6200 questionnaires and recycling 5800 questionnaires. During the same time, we launched an investigation among different levels of rescue personnel about their behavior and studied earthquake-related relief and rescue needs.

1.2.3 *Aims and Objectives of the Project*

1.2.3.1 Objectives of the Project

Since the emergency rescue studies on the 2008 earthquake, our group has sustained attention on the three major earthquakes of Wenchuan, Yushu, and Lushan, accumulating a great deal of valuable experience and background data. To find the key technologies of earthquake emergency rescue, this book focuses on the modeling, simulation, and policy intervention of injury flow and its rescue process. It fills gaps in the field of international medical relief in disaster response modeling and provides valuable guidance and reference for the practice of medicine and theoretical study of disaster relief. This book is designed mainly for professionals in the field of international health emergency rescue and provides scientific policy support and informative experience for the international medical rescue earthquake emergency rescue and provides strong technical support for emergency operations related to international disaster relief agencies.

The book consists of seven parts. The first is a general section (Chap. 1), mainly outlining the background of the study, the purpose and significance of the data sources, and describing the method of system dynamics and its related principles. The second part (Chaps. 2, 3, 4, 5, 6, 7, and 8) covers models on the occurrence of earthquake casualties, the length of stay among hospitalized patients, medical evacuation after earthquakes, medical rescue force allocation after earthquakes, organization and command of earthquake rescue forces, location and distribution of medical rescue institutions, and from peacetime to wartime in hospital. Each chapter includes an introduction to the casualty data, data source, construction of the conceptual model, logical model and SD model, reality simulation, modeling intervention, and a summary. The third part (Chap. 9) summarizes and provides scientific policy recommendations according to the results of our modeling and simulation.

1.2.3.2 Project Objectives

To further improve and perfect health emergency system and its working mechanism and to provide policy recommendations for international emergency rescue, the research group members have been to Wenchuan, the Ministry of Health, Yushu in Qinghai Province, Lushan, and other places in Sichuan for earthquake emergency medical rescue scene investigation. Based on large-scale field research and data collection, we scientifically evaluated the occurrence of earthquake casualties, the length of stay among hospitalized patients, medical evacuation after earthquakes, medical rescue force allocation after earthquakes, the organization and command of earthquake rescue forces, and location and distribution of medical support institutions through scientific analysis and systemic evaluation, elucidating the earthquake medical rescue experience and summarizing the Chinese earthquake relief efforts and policy intervention targets. The book focuses on systemic research of Chinese earthquake disaster emergency medical rescue operations, summarizing valuable experience with earthquake disaster emergency medical rescue to establish the occurrence and treatment of the background of wounded streaming data, systematically and comprehensively proposing earthquake rescue methodology, and forming a theoretical earthquake emergency rescue framework model. Accordingly, we established a decision support platform to assess the efficiency of rescue forces configured with scientific thinking and advanced theoretical methods. Our study has produced valuable knowledge for international natural disaster emergency relief work and complements international disaster emergency intervention model building and policy gap simulation, which has far-reaching significance.

1.2.4 Data Resource and Collection

1.2.4.1 Existing Data Collection

1. Relevant documents issued by the National Ministry of Health
2. Duty information from the National Ministry of Health
3. The overall condition of medical health workers and the vehicle sent during the Qinghai Yushu earthquake
4. Information tables reported by the National Ministry of Health
5. Information statistics from health and epidemic prevention work group
6. Meeting abstract of the health emergency leading group from the Yushu Ministry of Health in Qinghai Province
7. Information table of reconstruction
8. Epidemic report of material dispatching

1.2.4.2 On-Site Research Data

According to the evaluation plan of our research group, we went to Sichuan and Qinghai Provinces for emergency medical rescue field investigation. Our research mainly focused on “three levels,” “two lines,” and “three kinds of objects,” that is, local rescue forces, regional support, and strategy support force; the “wounded flow” of injury, treatment, and prevention of mental evacuation and “rescue forces” command and force deployment; command structure, rescue squad, and rescue personnel (Gautschi et al. 2008).

Our investigation data contain the following: (1) the occurrence of casualties during earthquakes; (2) investigation of headquarters of national regional disaster medical emergency, including the National Ministry of Health, Provincial Health Office, Army General Logistics Department of the Ministry of Health, Ministry of

Health, Joint Logistics Department of Military, and part of the rescue squad commander; (3) data on the national pumping group, local disaster emergency medical rescue forces, and the wounded admitted to the hospital; (4) interviews with medical experts and people in charge of emergency medical rescue workers at all levels; (5) forum for wounded individuals admitted to the hospital, rescue squad, and emergency medical personnel at all levels of command; (6) questionnaires for the medical support team, medical staff air transit station, local rescue workers, victims, and so on; and (7) related document reports.

1.2.4.3 Document Retrieval

We retrieved information from ProQuest, PubMed, and Chinese Biomedical Literature Database with the following search terms: Wenchuan earthquake or Yushu earthquake or earthquake and medical rescue or earthquake and management or earthquake and casualty or earthquake and evacuation or earthquake and public health or earthquake and PTSD or earthquake and health policy. These search terms produced a preliminary set of articles consistent with the study purpose. Then, we selected strong research from the preliminary articles that met content standards as references. Meanwhile, the research group searched other relevant information on hand, such as documents, statistics, announcements, special reports, news reports, evaluation reports, conference information, and publications issued by the China's State Council, the Chinese Ministry of Health, Government of Sichuan Province, the Qinghai provincial government, relief medical treatment groups, the earthquake rescue teams, and so on.

References

Gautschi, Oliver P et al. Earthquakes and trauma: review of triage and injury-specific, immediate care. Prehospital Disaster Med. 23.02(2008):195–201.

Kang P, Zhang L, Liang W, Zhu Z, Liu Y, Liu X, Yang H. Medical evacuation management and clinical characteristics of 3,255 inpatients after the 2010 Yushu earthquake in China. J Trauma Acute Care Surg. 2012;72(6):1626–33.

Zhang L, Liu Y, Liu X, Zhang Y. Rescue efforts management and characteristics of casualties of the Wenchuan earthquake in China. Emerg Med J: EMJ. 2011;28(7):618–22.

Zhang L, Liu X, Li Y, Liu Y, Liu Z, Lin J, Shen J, Tang X, Zhang Y, Liang W. Emergency medical rescue efforts after a major earthquake: lessons from the 2008 Wenchuan earthquake. Lancet. 2012;379(9818):853–61.

Chapter 2
Modeling the Occurrences of Earthquake Casualties

Zhipeng Liu and Lulu Zhang

Abstract In the short period after the earthquake, the outside relief forces know nothing about the casualties in the stricken area, which causes a lot of trouble to the medical relief work. Analyzing the impact factors of earthquake casualties, finding the earthquake casualties occurrence pattern, establishing the casualties model, and predicting the earthquake casualties have a significant impact on the rapid implementation of the earthquake medical relief and saving casualties.

After many factors of seismic casualties such as earthquake magnitude, building damage after the earthquake, earthquake occurrence time, personnel in the room rate, medical relief situation, and casualty evacuation situation were analyzed, we selected appropriate variables, using data of Yushu earthquake casualty, and established a Pareto model in MATLAB software. Through analyzing simulated earthquake casualty incidence, we expected earthquake casualty rescue efficiency can be improved to some extent.

2.1 Introduction

2.1.1 Background

2.1.1.1 Earthquakes and Consequent Casualties

Earthquakes are one of the most threatening natural disasters, as they are both sudden and unpredictable (Yi 2010). With devastating power, earthquakes can destroy buildings and infrastructure, resulting in casualties and economic loss. In addition to causing heavy casualties themselves, they are often accompanied by secondary disasters, such as fire damage, pollution, toxic and hazardous substances, mudslides, lake,

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Table 2.1 The seven most deadly earthquakes since 2001 (EM-DAT)

Date	Country	Disaster type	Death rate (%)	Persons dead or missing	Affected persons	Economic loss (millions)
01/26/2001	India	Earthquake	0.32	20,005	6,321,812	2623
12/26/2003	Iran	Earthquake	10.01	26,796	267,628	500
12/26/2004	Indonesia	Earthquake with tsunami	31.10	165,708	532,898	4451.6
10/08/2005	Pakistan	Earthquake	1.43	73,338	5,128,309	5200
05/12/2008	China	Earthquake	0.19	87,476	45,976,596	85,000
01/12/2010	Haiti	Earthquake	6.02	222,570	3,700,000	8000
03/11/2011	Japan	Earthquake with tsunami	5.70	28,050	492,000	309,000

Table 2.2 Earthquake casualties in China between 2000 and 2010 (China Earthquake Networks Center)

Year	Number of earthquakes	Injured	Deaths
2000	10	2987	10
2001	12	750	9
2002	5	362	2
2003	21	7465	319
2004	11	696	8
2005	13	882	15
2006	10	229	25
2007	3	422	3
2008	17	374,176	69,197
2009	8	407	3
2010	12	13,795	2705

landslides, and plague, which lead to significant damage to residents' production and living areas. Coastal or deep-sea earthquakes may also cause tsunamis, leading to more casualties. Between 2001 and 2011, there have been 16 great earthquakes of more than 1000 deaths worldwide. The total death count was 700,000, and 70 million people were affected, with economic losses totaling $430 billion (Table 2.1).

China is located at the intersection of two seismic zones—the circum-Pacific seismic zone and the Eurasian seismic zone. It is severely affected by earthquakes, with high-frequency, high-intensity, widely distributed seismic intensity and superficial quake sources. Since the twentieth century, approximately 35 % of earthquakes greater than magnitude 7 on the Richter scale that have occurred worldwide have been in China. From 1949 to 1991, the total deaths from earthquakes accounted for 54 % of the total number of deaths from all kinds of natural disasters. Since 1949, there have been 59 earthquakes of at least 6.5 magnitude. The two largest, the Tangshan earthquake and the Wenchuan earthquake, resulted in 24.2 million and 6.9 million deaths, respectively, with as many as 164,000 and 374,000 injuries. From 2000 to 2010, China had more than 50 million casualties due to earthquakes, representing a serious threat to people's lives (Table 2.2).

2.1.1.2 Occurrence Patterns of Earthquake Casualties

After an earthquake suddenly occurs, most people are unable to leave buildings in sufficient time and are ultimately trapped or buried beneath. Some are quickly rescued by local rescuers, but a considerable number of people remain buried inside damaged buildings. Shortly after the earthquake, the outside rescue force has minimal understanding of the situation of the stricken area (e.g., disaster area, casualties, rescue force needs, and relief supply needs). Even after outside rescue forces run into the disaster areas, they still need a few hours to several days to clarify the situation. This directly affects the earthquake relief command layer, who has difficulty making rescue decisions. With mass casualties following the earthquake, the medical demand peaks in the first 24–48 h. In the 1988 Armenia earthquake, 97 % of the wounded were hospitalized in 6 days (Klain et al. 1990). Pretto's study (Pretto et al. 1994) showed that timely medical treatment within 6 h after earthquakes can save the lives of many wounded individuals. Therefore, timely and effective medical rescue of the wounded is critical. According to the available information, analysis of factors affecting seismic casualties, discovering the occurrence pattern of casualties, and establishing a casualty occurrence model can predict the distribution of the number and type of earthquake victims relatively accurately for quick implementation of earthquake medical rescue, guiding disaster relief personnel to save lives of the wounded. Therefore, establishing a strong predictive model to predict earthquake casualty changes has always been a hot research topic.

Factors affecting the occurrence of wounded individuals following an earthquake have long been studied internationally. The focal depth of the earthquake itself, the intensity, the local geological conditions, and so on will affect the number of wounded individuals, while local population density and age structure will also affect occurrence of casualties. In the 1990s, Schultz (1996) discovered that in earthquakes with substantial numbers of casualties, the number of wounded individuals concentrated within the first 24–48 h shows rapid growth and medical demand peaks in this period. From a survey investigating treatment of wounded individuals following the 2005 Pakistan earthquake (Mulvey et al. 2008), the number of wounded showed a clear linear growth pattern in the first 72 h after the earthquake. After observing medical treatment following several earthquakes, the international community has generally concluded that the occurrence pattern of wounded earthquake victims shows stepwise variation. Studies on the distribution of casualty locations have come to the following conclusions: (1) It is a priority to figure out the earthquake situation and the local geological conditions. (2) After the earthquake, most of the wounded are concentrated in the vicinity of collapsed buildings, but not evenly distributed in the affected area. (3) The ability to quickly clear the position of collapsed buildings can effectively reduce the waiting time for treatment. (4) The early establishment of geographic information systems (GISs) can play a role in disaster relief. (5) David Alexander (2000) of the University of Massachusetts pointed out that the basic types of geographical distribution of earthquake injuries are in line with the Gaussian distribution, binomial distribution, exponential distribution, and so on.