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Chapter 5

THE MEDICAL RELIEF OF EARTHQUAKE DISASTER IN CHINA: MOVING THROUGH THE DISASTER

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ABSTRACT

The Sichuan province of China has sequentially been struck by the Wenchuan Earthquake (Richter magnitude scale 8.0) on May 12, 2008 and the Lushan Earthquake (Richter magnitude scale 7.0) on April 20, 2013. The former resulted in 69,227 deaths, 17,923 missing and 96,544 injured; and the latter led to 196 deaths, 21 missing, and 13,484 injured. Although the two earthquakes occurred in the same area in the same season, the characteristics of casualties and injuries varied quite differently due to the different magnitude scales. Because relevant rescue experiences have been well learned from the Wenchuan Earthquake, significant progress has been made during the emergency rescue of the wounded, the categorized delivery, the comprehensive treatment for the

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critically wounded, and subsequent rehabilitation after Lushan Earthquake. The so-called "four centralizations principle", i.e., "Assembling the wounded, Pooling the experts, Gathering the resources, and Centralized rescue" played a key role during the rescue and treatment process of Lushan Earthquake.

This chapter comprehensively compared and analyzed the epidemiological characteristics of the injuries and the operating processes of medical assistance system in the two earthquakes, and raised the concerns that should be improved in the rescue and treatment processes of earthquake disaster, which will provide valuable experience for the rescue and treatment of the earthquake-caused injuries in the future.

INTRODUCTION

China is an earthquake-prone country, and has suffered three earthquakes greater than *Richter magnitude scale 7.0* over the past five years, including the 2008 Wenchuan, the 2010 Yushu, and the 2013 Lushan earthquakes. Earthquakes and their secondary disasters often lead to substantial casualties, physical disability, and mental illness, significantly affecting the survival and quality of life of the injured. In Sichuan Province, two great earthquakes struck on May 12, 2008 and April 20, 2013 in the counties of Wenchuan and Lushan, respectively. Although both earthquakes caused heavy casualties [1–3], Sichuan had gained valuable experience after the Wenchuan earthquake in the organization and implementation of disaster relief and sustained rehabilitation. Thus, when the Lushan earthquake struck, disaster relief work was implemented in a timely and orderly manner, which increased the success rate of treatment for those critically injured [4]. A comparative study on the two earthquakes regarding the casualties and the organization and implementation of disaster relief will contribute to the continuous improvement of relief work and the reduction of the number of disaster casualties.

1. SEISMIC REGIME OF THE WENCHUAN AND LUSHAN EARTHQUAKES

Wenchuan and Lushan both belong to the Longmenshan Fault associated with relatively high seismic activity. The Wenchuan earthquake struck at 14:28 on May 12, 2008, with the epicenter located in Yingxiu Township (Wenchuan County, Aba Tibetan and Qiang Autonomous Prefecture), *Richter*

magnitude scale 8.0, an epicentral intensity of XI and a focal depth of 10 km. The most severe disaster areas mainly involved ten counties, including Wenchuan, Beichuan, Mianzhu, Shifang, and Qingzhou; and human casualties in the earthquake amounted to 69,227 dead, 17,923 missing, and 96,544 injured [5]. The Lushan earthquake struck at 8:02 on April 20, 2013, with the epicenter in Longmen Township (Lushan County, Ya'an City), *Richter magnitude scale* 7.0, epicentral intensity of IX, and a focal depth of 13 km. The severe disaster areas involved mainly the Lushan, Baoxing, and Tianquan counties; and human casualties in the earthquake amounted to 196 dead, 21 missing, and 13,484 injured [4].

During the Wenchuan earthquake, a large number of high-rise buildings collapsed, causing many deaths and serious injuries. In contrast, the Lushan seismic zone was mainly located within rural areas where the housing was dominated by bungalows or low-rise buildings. The majority of the houses that collapsed or were seriously damaged in the Lushan earthquake were old, and most of the people injured were single cases. Additionally, special seismic measures had been taken in constructing new houses after the Wenchuan earthquake. Thus, there was no serious collapse of housing in the Lushan earthquake, with a small number of people injured indoors. The numbers of dead, missing, and injured that resulted from the Wenchuan earthquake were 353, 853, and 27 times, respectively, those that resulted from the Lushan earthquake. However, the number of those seriously injured from the Lushan earthquake was 1.9 times that from Wenchuan (7.38% *vs.* 3.87%). This finding indicates that although the Lushan earthquake had a higher survial proportion of injured, the disaster relief provided more timely and efficient rescue and treatment than for previous disasters [5].

2. RELIEF FORCE FOR WENCHUAN AND LUSHAN EARTHQUAKES

After a major earthquake disaster, local medical systems are generally damaged in the severest hit disaster areas, and the majority of medical relief forces are those from supporting forces from other regions. In the less severe disaster areas, however, the relief forces are mainly from local systems. After the Wenchuan earthquake, up to 50,456 medical personnel were involved in rescue and treatment of the injured, including 81.73% from Sichuan Province, 11.83% from other regions, and 0.93% (nine medical teams) from Hong Kong,

Macao, and other countries [2]. After the Lushan earthquake, local medical personnel dominated the medical relief forces, with approximately 5% consisting of supporting forces from national departments and other provinces [5]. After both earthquakes, the Huaxi Hospital received the highest number of critically injured. For transportation of the injured from the Wenchuan earthquake, ambulances accounted for the greatest proportion (60.56%) followed by other means (25.96%), including car, boat, police car, fire engine, walking, and being carried. Airplanes accounted for the lowest proportion (13.47%), including 29% by helicopter for the critically injured [6].

In Wenchuan, a total of 370,000 injured were rescued and treated, including nearly 100,000 that were admitted to hospital. Because high numbers of injured visited the major hospitals in the disaster areas, the severely damaged hospitals declared an emergency and medical facilities within Sichuan Province were unable to guarantee timely and sound treatment. Commissioned by the medical and health headquarters for earthquake relief, the Sichuang Provincial Health Department promptly established transport teams for the injured and developed a plan for interprovincial transport of the casualties. By May 31, 2008, a total of 10,373 injured had been transported interprovincially by car, train, and airplane [7]. The Lushan earthquake caused fewer injuries and all were treated within Sichuan Province.

3. TRAUMATIC CONDITIONS AFTER WENCHUAN AND LUSHAN EARTHQUAKES

In an earthquake disaster, the collapse of various types of buildings causes different traumatic conditions. Therefore, post-disaster hospitalization in the earthquake zone and out of the earthquake zone can vary substantially. After the Wenchuan earthquake, Deyang City People's Hospital, which was the only tertiary hospital nearest to the severe disaster areas of Hanwang Township in Mianzhu City and Hongbai Township in Shifang City, rescued and treated 1,950 injured. The injuries included 283 cases of head and facial trauma (20.91%), 361 cases of torso trauma (26.78%), 614 cases of limb trauma (45.57%), 10 cases of crush syndrome (0.74%), and 80 cases of unknown trauma (5.93%). Bone fractures accounted for 45.85% of all earthquake-related traumas. On the day of the earthquake and three days, one week, and two weeks after the earthquake, 827, 1280, 1403, and 1870 injured were treated, respectively [8].

Located at the back of the Wenchuan earthquake disaster area, Huaxi Hospital received and treated 1,861 casualties. The average duration between the occurrence of an injury and hospital admission was 8.3 days, with a delayed peak of admissions and extended hospitalization. On the day of the earthquake and three days, one week, and two weeks after the earthquake, 34, 511, 983, and 1530 injured visited the hospital, respectively, accounting for 1.8%, 27.5%, 53.0%, and 82.4% of the total number of hospitalized patients, respectively. There were 198 cases of head and facial trauma (10.7%), 466 cases of torso trauma (25,1%), 911 cases of limb trauma (49.1%), 17 cases of crush syndrome (0.9%), 79 cases of unknown trauma (4.3%), and 171 cases of non-trauma (9.2%). Among all traumas, there were 1018 cases of bone fractures (54.8%) [9]. Another general tertiary hospital that received the majority of the injured after the Wenchuan earthquake was Sichuan Provincial People's Hospital, which admitted and hospitalized 2196 casualties. Of these, only 8.9% were admitted on the day of the earthquake, while 62.8% were admitted within one week after the earthquake [10].

After the Lushan earthquake, the No. 42 Hospital of Chinese People's Liberation Army received 1113 injured within 72 h following the earthquake. Of these, 650 injured (58.4%) were admitted into hospital on the day of the earthquake, indicating that the majority of injured received medical aid in a timely manner within 24 h after the earthquake. There were 748 cases of smashing (67.21%), 282 cases of a fall from a height or falling over (25.34%), and 83 cases of other causes (7.46%). Soft tissue injury accounted for the largest proportion (59.65%) of the traumas followed by a variety of bone fractures (23.99%) [11]. Located at the back of the Lushan earthquake disaster area, Huaxi Hospital received 392 injuries, of which 321 were admitted and treated further. After the Lushan earthquake, the average duration between the injury and hospital admission was 2.1 days, with an early peak in admissions that lasted a short period [5]. Despite the occurrence of many landslides, the Lushan earthquake zone was not completely blocked from the outside, thus ensuring prompt transport of most of the injured to the hospital for medical treatment or to safe areas. Because of the timely disaster relief, the injured were buried in the rubble for a relatively short period with a short duration of limb compression, accounting for the significantly reduced incidences of crush syndrome, multiple organ failure, wound infection, and amputation compared to the situation in the Wenchuan earthquake [12]. Among the 199 injured receiving orthopedic treatment, there were 185 cases of bone fracture and 14 cases of simple soft tissue injury. Additionally, there was one case of crush syndrome, caused by 9 h of compression of the lower limbs. There were four

cases of compartment syndrome. All these four patients had single lower limb injuries and underwent decompression therapy, including amputation in three cases. Traumas were caused by smashing or being buried (39.2%) and by a fall from a height and falling over (56.8%). Incidences of foot, spinal, and multiple fractures resulting from the Lushan earthquake were higher than those resulting from the Wenchuan earthquake, while incidences of open and lower-leg fracture resulting from the Lushan disaster were lower than those from the Wenchuan disaster [12].

In Deyang City People's Hospital, 48 of 1950 Wenchuan earthquake-related injuries died, including 30 pre-hospital deaths, 10 during emergency treatment, and 8 hospitalization deaths [9]. In the Huaxi Hospital, 33 of 1861 earthquake-related injuries died, including 5 pre-hospital deaths, 1 emergency death, and 27 hospitalization deaths. Mortality among the casualties after hospitalization was 1.45%, and after-hospitalization death was most likely to occur within four weeks after the earthquake (70%). Within one week of the earthquake the direct cause of death was mainly severe traumatic brain injury or crush syndrome, and one week after the earthquake death was mainly caused by the underlying disease and coexistent infection [10]. At the Sichuan Provincial People's Hospital, 27 of 2196 injured in the earthquake died, of which 11.1% died from severe traumatic brain injury and multiple fractures, 55.6% died from earthquake-related compound injuries, and 33.3% died from complications and infection [11]. After the Lushan earthquake, the severely injured were all admitted to three general hospitals in Chengdu (Huaxi Hospital, Sichuan Provincial People's Hospital, General Hospital of Chengdu Military Command) for centralized treatment, with no death occurring within 20 days after the earthquake [6].

4. BLOOD TRANSFUSION IN HOSPITAL AFTER WENCHUAN AND LUSHAN EARTHQUAKES

After an earthquake, trauma and bone fractures cause varying degrees of blood loss that are serious or even life-threatening [13]. Timely and safe blood transfusions are one of the important means of post-disaster medical treatment. After large-scale disasters, such as earthquakes, early medical treatment by blood transfusion uses mainly erythrocyte-based blood products. As the treatment progresses, large amounts of fresh frozen plasma (FFP), an

appropriate amount of platelets and cryoprecipitate are needed for the treatment of critical conditions.

After the Wenchuan earthquake, a total of 320 casualties in Deyang received 1442 units of blood transfusions, including 34.5% type A, 16. 6% type B, 38.9% type O, and 10.0% type AB; 64 units of whole blood, 1000 units of erythrocytes, and 378 units of plasma. The most transfusions were required on May 13, 2008. The elderly, those over 60 years old, accounted for the largest portion of the injured and received the most blood transfusions. Bone fractures accounted for the highest number of blood transfusions (44.87%). An average of 14.76 units were used for one case of crush syndrome [14]. In the Sichuan Provincial People's Hospital, 230 out of 2065 earthquake-related casualties received a total of 4248 units of blood transfusions. The transfused blood products included erythrocytes (1435 units), FFP (1987 units), platelets (456 units), and cryoprecipitate (370 units). Immediately following the disaster, there was a high demand for erythrocyte transfusions on day 3 after the earthquake (May 14, 2008), whereas overall the amount of FFP transfusions was the highest, approaching a peak on May 20, 2008. The average amount of blood required to treat a crush syndrome was 79 units per person, which in total accounted for 65.1% of the total blood transfusions for all the earthquake-related casualties [15]. For the injuries resulting from the Lushan earthquake, mainly erythrocyte products were needed in blood transfusions, followed by plasma and platelets. Detailed data have not been reported to date.

5. Medical Care and Rehabilitation of Special Populations in Earthquake Disasters

Children are the most vulnerable population in natural disasters. When casualties arrive for treatment in large numbers and at the same time, children must be given priority for medical care, in particular, critically injured and unaccompanied children [16]. Pediatricians should go to the disaster site as quickly as possible. Reports indicate that the special care required by children has been overlooked in previous disaster relief [17]. In the Wenchuan earthquake zone, approximately 7000 schools were destroyed, causing many child casualties in the attending classes [18]. Fortunately, the Lushan earthquake occurred at the weekend, and injuries to children (mainly pre-school children) were mostly restricted to those that occurred in the collapse of

residential buildings. In the Lushan earthquake, the major cause of injuries in children was the collapse of houses or walls. Because rural housing structures were significantly weaker than urban housing, the children suffered a relatively low incidence of severe injury, low degree of injury, and little damage to vital organs in the Lushan earthquake.

After the Wenchuan earthquake, a rescue team from the Third Military Medical University established a field hospital within the central earthquake zone of Deyang City. A total of 882 patients were admitted into the field hospital, including 192 (21.8%) children under 18 years old. Most of these children were injured on their limbs, mainly with open wounds and bone fractures. According to the classification of pediatric trauma scores, of the total injuries 63.0% were minor, 29.7% moderate, 4.2% severe, and 3.7% fatal. Seven pediatric patients (3.6%) died, including four cases of severe open head injury and three cases of severe thoracic and abdominal crush injuries. There was no significant difference in the survival rate between children and adults [19].

After the Wenchuan earthquake, Huaxi Hospital received 116 injured children with an average age of 9 ± 3 years, accounting for 6.2% of the total casualties. The average duration from the moment of injury to hospital admission was 79 ± 56 h. After the Lushan earthquake, 34 injured children were admitted and treated in the hospital, with an average age of 6 ± 3 years and accounting for 10.7% of the total casualties. The average duration from the moment of injury to hospital admission was 32 ± 35 h. The majority (79.3%) of children injured in the Wenchuan earthquake had simple limb injuries, including 12 cases of amputation; 58.8% of the children injured in the Lushan earthquake had simple limb injuries, with no case of amputation. The proportion of traumatic brain injury in children was 9.5% after the Wenchuan earthquake, which was significantly lower than that after the Lushan earthquake (29.5%). The majority (75%) of the critical pediatric cases was related to traumatic brain injury, and 11.8% of the patients suffered neurological dysfunction [20].

During the Lushan earthquake, several hospitals within the disaster area provided unacceptable treatment with rough dressing for the injured wounds. On the one hand, this issue was related to the lack of pediatric orthopedists and pediatric surgeons in the disaster area. On the other hand, this reflects the fact that general orthopedists and trauma surgeons treated the children according to their experience with adults, not fully understanding the differences. Thus, we recommend the implementation of centralized treatment for pediatric patients

in future disaster relief and increasing the establishment of specialized pediatric treatment groups.

In addition to children, the elderly are among the vulnerable populations in natural disasters and have a higher incidence of complications and mortality than other age groups [13]. After the Wenchuan earthquake, the elderly accounted for a large proportion of the total injured. In Deyang City People's Hospital, casualties aged over 65 years accounted for 20.21% of patients with earthquake-related injuries. In Sichuan Provincial People's Hospital, patients over 60 years of age accounted for the largest proportion of the 2,196 hospitalized earthquake-related casualties. Specifically, men over 60 years old accounted for 23.5% of total the total male casualties that were hospitalized, and females of the same age group accounted for 23.5% of total female casualties that were hospitalized. Fifteen deaths were recorded for the over 60-year-old age group, accounting for 55.5% of the earthquake-related death toll. In Huaxi Hospital, the median ages of the earthquake-related deaths were 60 years for males and 77 years for females. There were sixteen deaths within one week after hospitalization, of which 14 patients were elderly with an average age of 73.4 ± 16.1 years. Of the 14 elderly, 75% had underlying diseases and 62.5% had concurrent infection, which ultimately caused death despite the low incidence of head injury and crush syndrome. In the Wenchuan earthquake, elderly casualties had low degrees of crush injury but were prone to acute kidney injury, with age as an independent risk factor for death [21]. In Huaxi Hospital, patients over 65 years old accounted for 17.1% of the total injured from the Lushan earthquake, most having serious underlying diseases and severe lung infection after the earthquake [22]. Because of the underlying diseases and reduced compensatory capacity of various organs, the elderly are prone to new complications. Thus, enhancing the skills of geriatric staff for post-disaster medical treatment is another aspect that should be emphasized for similar disaster relief in the future.

6. REHABILITATION

An epidemiology study investigated 28008 casualties of the Wenchuan earthquake, who were hospitalized within Sichuan Province, which included 50.7% limb and pelvic trauma, 18.6% craniocerebral trauma, 12.3% peripheral nerve injury, 9.3% spinal trauma, and 8.1% thoracic and abdominal organ injuries. Among 255 amputees (0.9%), 200 required hospitalization rehabilitation post-surgery.

Additionally, there were 2,614 casualties with spinal injuries, including 206 cases of paraplegia. At that time, Sichuan Province had only 600 professionals and approximately 500 beds for modern medical rehabilitation. These limited resources were mainly allocated to general hospitals in the capital of Sichuan (Chengdu) and secondary central cities, posing enormous challenges for the rehabilitation work.

On May 27, 2008, Sichuan Province established a rehabilitation center for earthquake-related injuries. With the help of rehabilitation medical teams from other provinces, Sichuan constructed a four-level rehabilitation network to fully carry out the rehabilitation work, with district, county, and community rehabilitation centers under the guidance of the provincial rehabilitation center. By February 5, 2009, a total of 28000 patients with earthquake-related injuries had received regular rehabilitation therapy. The hospital discharge rate was approximately 98%, including 318 cases of prosthesis [23].

Compared with the aftermath of the Wenchuan earthquake, the rehabilitation work following the Lushan earthquake had a quick response and was increasingly standardized, which emphasized early rehabilitation. On the second day after the earthquake, the Department of Rehabilitation Medicine of Huaxi Hospital initiated rehabilitation assessment and therapy for earthquake-related injured in 12 earthquake-affected hospitals in Ya'an City and surrounding areas.

By the third day after the earthquake, the Department of Rehabilitation Medicine of Huaxi Hospital had begun early rehabilitation for the injured after their release from hospital, and up to 94% of those hospitalized for earthquake-related injuries received rehabilitation relief. On the fourth day after the earthquake, the Sichuan Provincial Health Department established a medical rehabilitation expert group to implement early treatment and rehabilitation, early bedside rehabilitation and classified rehabilitation. Additionally, a strategy for training staff in the use of rehabilitation technology was launched in three approaches: centralized training, decentralized training, and technical guidance for the disaster areas.

The earthquake-related casualties with relatively severe injuries were transferred to provincial rehabilitation hospital for medical treatment, and those with relatively minor conditions received individualized rehabilitation therapy locally [24].

7. URGENT NEED TO STRENGTHEN AND SPREAD NATIONWIDE EDUCATION OF DISASTER PREVENTION AND AVOIDANCE

The earthquake-related casualties comprise a small proportion of the injuries caused by non-direct earthquake damage. According to the clinical data from Huaxi Hospital, 161 casualties were caused by a fall from a height and 108 were caused by falling over during the Wenchuan earthquake, which make up 11.4% and 7.7% of the total earthquake-related injuries, respectively. In the Lushan earthquake, 71 patients were injured by a fall from a height and 42 patients injured by falling over, making up 35.7% and 21.1% of the total earthquake-related injuries, respectively. In addition, six (3%) patients were injured by other causes, including being cut by glass or injuries sustained in a car crash during the earthquake. Injuries caused by a fall from a height occurred mainly when people jumped off high buildings in extreme fear of the earthquake, causing for example bilateral calcaneal fractures and chest injuries [12]. Thus, it is necessary to provide nationwide disaster education with the aim to inform the general people to learn the appropriate skills to escape and survive as the disaster approaches, ultimately avoiding injuries caused by collateral damage unrelated to the disaster.

Earthquakes cause many different disasters. Summing up traumatic conditions and treatment experiences in previous earthquakes, continuously improving the organization, medical treatment, and rehabilitation levels of disaster relief, and strengthening nationwide education of disaster prevention and avoidance will help to reduce disaster-related and unrelated casualties.

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