Challenges for rear hospital care of Wenchuan Earthquake casualties: experience from West China Hospital

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**Abstract** To review the challenges and countermeasures in the hospital care for Wenchuan earthquake casualties and draw lessons for the protective response in the future. Medical records and laboratory findings of the victims admitted in West China Hospital (WCH) were retrospectively analyzed. Related data were compared between beforemath and aftermath of the earthquake and between WCH and frontier county hospitals. One thousand and thirty-one earthquake survivors were hospitalized, 1 358 victims underwent surgery and 142 victims were transferred to intensive care unit. The incidence of infection, crush syndrome and multiple organ dysfunction syndrome (MODS) was 39.6%, 20.7% and 2.3% respectively. Wound classification showed that the incidence of extremity damage was 72%, while the incidence of chest trauma, abdominal trauma and brain trauma was less than 10% respectively. Isolating rates of environmental pathogens were increased in the aftermath of earthquake, and the spectrum of the pathogens and related antibiotic sensitivities were quite different from those in the beforemath of earthquake. The social economic and population conditions in the earthquake-stricken areas affected the composition of the victims and the geographic features restricted the efficiency of rescue. Trauma-induced MODS, crush syndrome and severe infections all constituted the dilemma for the hospital care, to resolve whether the multidiscipline team work was proved to be an optimizing choice. For a more effective disaster protective response in the future, the study on rescue plan and the ladder therapies for massive casualties should be potentiated.

**Key words:** Earthquakes; Wounds and injuries; Multiple organ failure; Crush syndrome; Communicable diseases

61 At 2:28 pm, May 12th, 2008, an earthquake of magnitude 8.0 hit Sichuan province in Southwest China, striking an area of 57 915 square miles. The most severely affected geographical regions were Wenchuan, Yingxiu, Dujiangyan and Deyang, where 45 million people were directly affected. The seismic focus lied 12 miles underground and the seismic intensity was estimated at 11 degree. This extraordinarily strong earthquake was named as the Wenchuan earthquake for its epicenter was located in Wenchuan County, which is 46 miles in straight distance to Chengdu, the provincial capital city. Until June 12th, 2008, Wenchuan earthquake had led to 69 159 deaths, 17 469 missing, 374 141 wounded and 95 516 hospitalizations. West China Hospital (WCH) is a national-level academic medical center in Chengdu with 4 300 sickbeds, 168 ICU beds and 62 operating rooms running 60 000 operations annually. From May 12th to June 11th, 2 702 earthquake victims were transferred to WCH and 1 831 of them were hospitalized, including 965 males and 866 females with a median age of 46.3 years (Figure 1). Of these, 1 358 victims underwent surgical therapy, 142 were transferred to intensive care unit (ICU) and 77 accepted hemodialysis. The hospital mortality was 1.69% (31/1 831). This review was conducted retrospectively to illustrate the challenges and our countermeasures during hospital care for the earthquake casualties and draw lessons for future protective response.
Challenges to hospital care and medical rescue

Difficult geographic situations The road distance between Wenchuan County and WCH is 93 miles which is only a two-hour drive in usual time. But Wenchuan is in mountain area with a drop height up to 6,562 feet. Most of the traffic and communication lines to Wenchuan were constructed along the cliffs and river banks and most villages were located in deep valleys. These geographic features facilitated the earthquake-induced landslides and mud-rock flows, causing tremendous destruction, especially to the traffic and communication systems, and exacerbating the difficulty for the ground rescue (Figure 2). Given the foggy weather, unpredictable turbulence and unmarked electric cables in deep valleys, air rescue proved to be very difficult and had been postponed until the post earthquake day (PED) 3. Thus, the ideal window of the first 24 h-48 h after earthquake for rescue was lost and most of the people with critical injury died during this phase.

Transfer of casualties to rear medical center was delayed Transferring casualties in a large scale to the rear medical center had not begun until the PED 5 and the frontier local community and county hospitals were beyond their capacities due to the sudden and large influx of casualties. Taken People’s Hospital of Deyang city (DCH) for example, from May 12th to June 11th, it admitted 1,327 victims, 82.8% of which were admitted within 48 hours after earthquake (Figure 3A). WCH met its first casualty influx peak on PED 2 as victims from the earthquake-affected plain area were transferred in. The second peak occurred on PED 8 as victims from the earthquake-affected mountain area were transferred in. And the third peak happened on PED 14 as victims were transferred in mainly because of multiple organ dysfunction syndrome (MODS) and refractory nosocomial infections which could not be well controlled in the frontier county hospitals (Figure 3A). The demand for ICU was paralleled with the casualty influx, but on PED 14 as victims were transferred in mainly because of multiple organ dysfunction syndrome (MODS) and refractory nosocomial infections which could not be well controlled in the frontier county hospitals (Figure 3A). The demand for ICU was paralleled with the casualty influx, but on PED 14 as victims were transferred in mainly because of multiple organ dysfunction syndrome (MODS) and refractory nosocomial infections which could not be well controlled in the frontier county hospitals (Figure 3A). The distance between WCH and DCH is only 40-minute drive and the highway there was intact when the earthquake happened. Nevertheless, compared with DCH, the onset of the first casualty peak in WCH was delayed for 48 hours and the altitude of that peak was 2.9 times less (Figure 3A).

Trauma-induced life-threatening MODS and crush syndrome Of all injuries, 71% were extremity trauma and the incidence of cranial trauma, spinal trauma, thoracic trauma, abdominal trauma, pelvic trauma and multiple traumas was less than 10% respectively (Figure 4A). Transfer to ICU was mandatory for 140 (7.6%) traumatic patients whose mean acute physiology and chronic health evaluation (APACHE) II score was 20.24 and 42 (30.0%) of them progressed to suffer MODS, causing 15 hospital deaths. The mortality resulted from MODS was associated with the numbers of the dysfunctional organs and increased from 12.5% in two-organ dysfunction to 100% in six-organ dysfunction (Figure 4B). Because of the excessively long time compression, delayed medical management as well as poor nutrition, 379 victims were complicated with crush trauma and 103 of them progressed to suffer crush syndrome (Figure 4C). The incidence of crush-syndrome related hyperkalemia, hypocalcemia, acute renal failure, ARDS and MODS was 36.0%, 68.0%, 64.1%, 1.9% and 1.9% respectively. Continuous renal replacement therapy (CRRT) was mandatory for 49 cases of crush syndrome related renal failure, and was maintained over 20 days in 32 cases. Twenty-three victims experienced crush syndrome related massive hemorrhage from the open wounds, consuming blood transfusion at a mean volume of 3,500 ml and 10 of them progressed to suffer hemorrhage shock. Arteriography and transcatheter angiographic embolization were applied to control the massive bleeding successfully.

Severe infections and unusual bacteria spectrum The infection rate in the hospitalized victims was 39.6% (725 patients) and 12 senile patients (mean 82 years) died of refractory bacteremia, attributing 38.7% of all hospital deaths. Most of the earthquake victims suffered open wounds which had been contaminated by the soil and building debris in the scene. Accordingly the isolation ranking number of aeromonas hydrophila, an environmental bacteria abounded in the soil and water in the scene, was promoted from the 36th day before earthquake to the 7th day after earthquake. Hospital infection control was also challenged by the elevated prevalence of extended-spectrum beta-lactamase (ESBL)-producers and multi-drug resistant (MDR) bacteria. This bacteria spectrum was different from both what we routinely encountered prior to earthquake (Figures 5A and 5B) and what the other natural disasters such as tsunami had resulted in. To
prevent gas gangrene from spreading, 2 135 wound swabs were completed among all 2 702 victims as a method of the pre-hospital pathogen screening and 113 cases (0.98%) of gram-positive thick bacilli and 21 cases (5.3%) of gram-positive thick spore bacilli were identified. All these 134 patients with high contagious risk were quarantined immediately. All 1 831 hospitalized victims pus and wound secretion cultures were performed, presenting 725 (39.60%) non-duplicate isolates. From them, the top 5 most frequently isolated pathogens were *A. baumannii*, *E. coli*, *S. aureus*, *E. cloacae* and *P. aeruginosa* with an isolation rate of 17.9% (130/725), 16.4% (119/725), 12.4% (90/725), 8.8% (64/725) and 9.2% (67/725) respectively. Piperacillin-tazobactam, Amikacin and Imipenem showed adequate efficacy against most of the pathogens (Figure 5C). And Imipenem was confirmed to be effective against the multi-drug resistant *A. baumannii* with a bactericidal rate of almost 70% (Figure 5C). Therefore the empirical use of antibiotics, such as the second-generation Cephalosporine, Fluoroquinolones and Trimethoprim-sulphamethoxazolem, was proven to be insufficient in controlling the earthquake-associated contagious disease.

**Anti-crisis measures applied during rear hospital care**

**Control of contagious disease** Given the wound contamination and the delayed transfer, the incidence of wound infection was high. Antibiotic treatment was increasingly difficult in the rear hospital care due to the development of MDR and ESBL producers. Therefore, the comprehensive assessment of the contagious disease in the victims with open wounds is of paramount importance. Our algorithm of offering proper treatment in accordance to the varieties of traumas and simultaneously screening out high contagious risk victims is demonstrated in Figure 6. In brief, upon admission, the clothes of all victims were removed and burned, and patients were given clean hospital gowns in exchange. All victims underwent general physical examination and the swabs for culture were required if any open wounds were discovered. Urine, blood or sputum samples for culture, anaerobic culture and vascular catheter culture were performed following the Clinical and Laboratory Standards Institute (CLSI, 2008) guidelines. Vic-

tims found with thick bacilli were quarantined immediately, otherwise they would be referred to the specialists according to the injury types. For following up all contagious cases and screening out occult infections, a multidisciplinary team for supervising infection control was organized.

**Multidisciplinary teamwork** To coordinate teamwork among physicians in different healthcare professions with specialized skills and expertise for offering a better hospital care, 67 multidisciplinary teams (MTs) have been organized in WCH since 1997. And as an important part of quality guarantee for hospital care, the MTs also direct residency training, practice supervision and prognosis follow-up in WCH. The MTs played important roles for earthquake victims’ hospital care especially in controlling contagious disease, MODS therapy and even new clinical discovery. A renal-failure-care MT composed of specialists from orthopedics, urology, critical care unit, nephrology and evidence-based health care department was set up to deal with the severe crush syndrome, to which the intensive bedside hemodialysis was suggested and successfully applied. An MODS-control MT was responsible for organizing the ward round to find out, among the mass casualties, the sedated victims suffering organ deficiency. An imaging-diagnosis MT composed of physicians from radiology and neurology discovered that the significant alterations in victims’ brain function, similar in many ways to those observed in posttraumatic stress disorders, can be seen shortly after earthquake.4

![Figure 1. Age distribution of casualties.](image-url)
Lessons learned

Successful medical rescue relied on rapid governmental response and coordination. The collision between Indian Ocean Plate and Eurasian Plate creates the high mountains and deep valleys in southwest China together with series of earthquake belts evident in the earthquakes happened in Sichuan, Yunan, Tibet and Guizhou provinces in southwest China. The complicated geographic features make the access to the site a major issue and most of severely injured have died in the scene within 24-48 hours after earthquake. This partially explained why both the hospital mortality (1.69%) and the proportions (each <10%) of the life-threatening traumas, such as chest trauma, abdomen trauma and brain trauma in the admitted victims were low. However, compared with hospitals functioning on a non-disaster mode, our mortality is still lower. This satisfying prognosis acquired in WCH is a reflection of the rapid response to natural disaster of Chinese central government.5

Figure 2. Geographic challenges to medical rescue. A, B: The traffic and communication lines were constructed along the cliffs and the river banks through the mountain area in a drop height up to 6,562 feet and completely destroyed by the landslides and mudrock flows. C: Wenchuan county in the valley base. D: Ground rescue was hard.

Figure 3. Characteristics of casualty influx. A: Casualty flow to DCH. B: Casualty influx to WCH and new transfer to ICU. The demand for ICU was paralleled with the casualty influx.
The geographic characteristics restricted traffic condition constituted the pivotal restriction for earthquake rescue. Transferring the victims from mountain area to WCH costs 6 more days than that in plain area. In the mountain area, all traffic lines built along the cliffs and valley bases were completely destroyed by the earthquake and the reconstruction was repeatedly interrupted by the subsequent landslides and mud-rock flows. Therefore, the early rescue in mountain area depends on helicopters but the complicated weather there constituted a major challenge which had resulted in rescue aircraft crash.

Besides traffic issue, the insurmountable earthquake-induced communication interruption and lack of an efficient commanding system also contributed to the delay of transfer to the rear medical center. This delay also indicated, at least in some degree, an ignorance of the principle of ladder management for massive casualties. On PED 14 and PED 21, victims had to be transferred to WCH mainly because of complications which could not be well controlled in the frontier county hospitals. Actually, to optimize the casualties’ prognosis as a whole, the casualties should be classified and transferred to hospitals at different levels according to the severity and types of their wounds. In this process, the well equipped rear medical center should be responsible to offer the advanced and definitive treatment while the frontier hospitals should be obligated for classifying traumas, casualty transfer as well as life-saving emergency operations.

Multidisciplinary teams are required considering the economic demographic and epidemiologic characteristics of earthquake trauma. The economical situation in the earthquake-stricken area also impacted the composition of the victims. Most of the populations in earthquake-stricken area are of agricul-
ture but their per capita land area is less than 5,000 square feet. Therefore, it is a very common economic phenomenon in Sichuan province that most of the adult farmers make livings for families as the migrant workers in urban area. The families in the countryside without any adults at home account for about 19.8% and the children living only with their grandparents are over 1 million and 92% of them are elementary or middle school students. Since it was just the class time when Wenchuan earthquake happened on 2:28 pm May 12th, the collapsed school buildings and houses took the lives of most of the students and the old people. As for the adults, however, most of them survived because of being not at home town. This explained, in some way, why the wounded teenagers and old people were less than the wounded adults in the admitted survivors.

The trauma-induced life-threatening MODS, crush syndrome and severe infections constituted the major dilemma in hospital care. To maximize the therapeutic effects and acquire the long-term satisfying prognosis, the coordination of hospitals at different levels as well as multidisciplinary team works is discussed. Our new discovery of brain function damages evident in the earthquake victims provides the solid evidence highlighting the need for early psychological evaluation and intervention for earthquake survivors.

REFERENCES


