Research and design of the smart field digital surgery system for emergency medical rescue

Xiuguo Zhao\textsuperscript{1,}\textsuperscript{a}, Lingshuai Meng\textsuperscript{2}, Shulin Tan\textsuperscript{3}, Chen Su\textsuperscript{4}, Junshu Han\textsuperscript{5}, Jinggong Sun\textsuperscript{6}\textsuperscript{*}

\textsuperscript{1}China National Biological Protection Engineering Center Tianjin, 300161, China
\textsuperscript{2}China National Biological Protection Engineering Center Tianjin, 300161, China
\textsuperscript{3}Institute of Systems Engineering Beijing, 100166, China
\textsuperscript{4}China National Biological Protection Engineering Center Tianjin, 300161, China
\textsuperscript{5}China National Biological Protection Engineering Center Tianjin, 300161, China
\textsuperscript{6}Institute of Systems Engineering Beijing, 100166, China
\textsuperscript{a}michaelzhao@tjyysbxjs.onexmail.com
\textsuperscript{*}Corresponding author’s e-mail: sunjg@vip.sina.com

Abstract—Natural disasters happened frequently around the world resulted in vast injured persons. The injured needs immediate on-site treatment to either save life or decrease mortality rate. The field surgery system, constructing a complete field on-site treatment force, is the fundamental to provide immediate medical care for the injured. In this paper, a smart field digital surgery system, integration with remote consultation system, medical information system and self-support system, was constructed to satisfy the demand of fast surgical treatment for emergency medical rescue in complex regional environment. The field digital surgical treatment technology platform for the injured in emergency was established based on taking the control of the cleanliness of the surgical cabin, designing a remote consultation system, developing the medical information system, as well as designing miniaturization magnet of field magnetic resonance imaging (MRI) system, which significantly improved the surgical treatment capability of the field digital surgery system.

1. INTRODUCTION
Recent years saw all kinds of natural disasters happened around world such as typhoo, earthquake, tsunami, and other emergency public health event related to serous infection disease, which usually caused incredible damages such as person injuries, person death, property loss and environmental damage, finally seriously affected society steady and economy development. For example, the Wenchuan earthquake caused more than 370,000 casualties, [1,2] and the typhoon stroked the Philippines on November 8, 2013, which was the strongest in local history, causing massive destruction and 25 million people were affected.[3] The Japan 2011 Tōhoku earthquake and tsunami, the most powerful earthquake ever recorded in Japan, and the fourth most powerful earthquake in the world since modern record-keeping began in 1900, resulted in more than 19,000 death.[4] Tremendous injured patients caused by these disasters need immediate on-site treatment to guarantee life safety[5,6].
In order to cope with the real demand of treating injured patients, the related on-site medical facilities must be developed to either treat or stabilize patients. Emergency medical rescue equipment is an important material basis for emergency medical support, which is related to people's livelihood. In recent years, the state has gradually increased investment in science and technology in this field, but for the time being, it can only be covered locally. Therefore, it is urgent to carry out the research and application demonstration of packaged emergency medical rescue equipment in order to promote related industrial development. The field surgery system, as typical emergency medical rescue equipment, could operate a remote workforce camp located hundreds of miles away from the nearest medical facilities and it is the fundamental to providing immediate medical care for the injured patient.[7,8] In this paper, the smart field digital surgery system, integration with remote diagnosis, medical information system and self-support system, was constructed to satisfy the demand of fast surgery for the injured in emergency medical rescue in the complex regional environment.

2. DESIGN OF SMART FIELD DIGITAL SURGERY SYSTEM

2.1. System configuration

The developed smart digital field surgery system was equipped to the highest medical standards for rescue with performance of self-loading and self-support, which built a smart small field hospital featuring high mobility, rapid deployment, and perfect treatment ability. The surgery system plays a very important role in treating injured person by constructing good circumstance for treating injured person. The surgery system consisting of surgical treatment module, medical technology module and medical imaging examination module, built both systematic and complete surgical treatment in the field. In term of digital medical function, the surgery system not only constructed relative complete reginal medical information system but also built remote consultation system to invite remote experts to guide the on-site operation for the injured. In detail, the smart digital field surgery system was composed of three medical vehicles including the surgery vehicle, the medical technology vehicle and the magnetic resonance imaging (MRI) vehicle, which could implement emergency surgery, MRI examination, X-ray examination, clinical examination and sterilization. Besides the medical facilities, the surgery system was also equipped with the air-conditioning system to guarantee good environment for the person inside the vehicle and the generator to provide electricity to the entire system.

2.2. Design of surgery vehicle

The surgery vehicle had capacity of on-site surgery for the injured caused by the natural disasters. The surgery vehicle consisted of the surgery shelter and the chassis based on the north Benz ND2250FD536Z00 chassis used to transport shelter. The shelter could be loaded and unloaded by the installed electric lifting mechanism on the shelter. The shelter was comprised of two major parts, the fixed part and the extension part. The fixed part was installed medical information devices related remote diagnose used to carried out remote diagnosis and share medical information of patient. And the extension part was used to implement surgery on patient with larger room by designing the two-side extension structure to enlarge inner operation room and utilizing the technology of manual push-pull flap to operate it. The surgery cabinet was equipped with surgical facilities including operation bed, operation lamp, anesthesia machine, multi-parameter patient monitor, infusion pump, suction machine, nebulizer, defibrillator, automatic portable ventilator, emergency drugs and supplies. The air cleanliness inside the extendable area reached the level of ten thousand cleanliness by designing laminar flow purification system, which protected the wound against infection to improve the efficiency of the surgery for the patients.
2.3. Design of medical technology vehicle

The medical technology vehicle, supporting surgery for patient, had ability of X-ray examination, clinical examination and sterilization. Similar to the surgery vehicle, the medical technology vehicle was also comprised of the shelter and the chassis used to transport the shelter. The shelter was also divided into the fixed part for medical person to operate X-ray machine and the extension part with double-extended extension structure equipped with medical facilities including X-ray machine, high temperature sterilizer, ultrasonic cleaning center, hematology analyzer, semi-automatic biochemical analyzer, hemagglutination instrument, micro-environment control system and electrical system. According to its functions, the extension area inside shelter was divided into X-ray diagnosis area, disinfection and sterilization area and clinical examination area. The functional area division of the medical technology shelter was shown in Fig. 2 and Fig. 3.

Figure 2. Functional area division of the medical technology vehicle.

1. X-ray machine 2. examining table 3. chest stand 4. high-voltage generator 5. foldable desk 6. table 7. ultrasonic cleaning center 8. high temperature sterilizer 9. cabinet 10. equipment integration 11. film printer 12. Chair
2.4. Design of MRI vehicle
The MRI vehicle consisting of fixed shelter and chassis used to transport shelter could carry out magnetic resonance imaging examination for the injured. Compared with the MRI used in fixed hospital, the designed MRI installed in the MRI vehicle featured several improvements including the design of miniaturized magnet, the developed seismic and impact resistant of magnets and the design of gradient coil. Also the electromagnetic shielding shelter was well designed to protect person against magnetic emission. The MRI shelter was divided into operation room, examination room and equipment room, among which the equipment room was divided into upper and lower floors. The upper floor was used to install the on-board air conditioning equipment, while the lower floor was used to install the MRI cabinet, water cooler, power generation and heater, etc. The internal layout of MRI shelter was shown in Fig. 4 and Fig. 5.

3. CONCLUSION
Natural disasters in China are numerous, widespread and frequent, and accidents, disasters and social security incidents occur from time to time, which puts forward higher requirements for the research and development of emergency medical rescue equipment in China. It is in response to this urgent demand, the smart vehicular field digital surgery system was developed in order to improve all kinds of unexpected natural disasters in the injured site, strengthen surgery treatment ability, reduce casualties and morbidity caused by the unexpected natural disasters, strengthen ability of dealing with all kinds of
sudden natural disasters. Meanwhile it also helps to cope with the international humanitarian disaster relief.

The field digital surgery system was constructed by developing the digital surgery vehicle, the medical technology vehicle as well as the MRI vehicle in order to solve the problem which was difficult to treat injuries effectively under complex field conditions. Finally, the field digital surgical treatment technology platform was established to treat the injured in emergency.

The surgery vehicle was developed based on taking the control of the cleanliness inside the surgical cabin, designing the remote consultation system and developing the medical information system, which improved the surgical treatment capability of the digital surgery vehicle.

The miniaturization design of the field MRI diagnosis system was innovatively carried out. Innovation design for the miniaturization magnet of the MRI diagnosis system made its weight is lower than 7 tons. The maximum gradient was greater than 14 mT/m and the maximum gradient switching rate was greater than 40 mT/m/ms due to the innovative design of miniaturized gradient coil.

ACKNOWLEDGMENT

The work was supported by National key research and development project 2017YFC0806405. We thank Yukun Han, Hongwei Meng, and Yandong Chen for help in the work.

National key research and development project 2017YFC0806405.

REFERENCES

[1] Zhang, L., Liu, X., Li, Y., et al. (2012) Emergency medical rescue efforts after a major earthquake: lessons from the 2008 Wenchuan earthquake. Lancet,379(9818):853-861.
[2] Yang, J., Chen, J., Liu, H. et al. (2013) The Chinese national emergency medical rescue team response to the Sichuan Lushan earthquake. Nat Hazards 69, 2263–2268.
[3] Feng, L., Ye, Zh., Cai, W.W., et al. (2014) Medical emergency rescue in disaster: The international emergency response to the Haiyan typhoon in Philippines. BioScience Trends, 8(6):350-353.
[4] Clarke, R.A., Eddy, R.P. (2017). Warnings: Finding Cassandras to stop catastrophe. Harper Collins. p. 77
[5] Mohebbi, HA, Mehrvarz S, Saghafinia M et al (2008) Earthquake related injuries: assessment of 854 victims of the 2003 Bam disaster transported to tertiary referral hospitals. Prehospital Disast Med 23(6):510–515.
[6] Lu-Ping Z, Rodriguez-Llanes JM, Qi W et al (2012) Multiple injuries after earthquakes: a retrospective analysis on 1, 871 injured patients from the 2008 Wenchuan earthquake. Crit Care 16(3):1–9
[7] Starnes, Benjamin W., Bruce, Jon M. (2000) Popliteal Artery Trauma in a Forward Deployed Mobile Army Surgical Hospital: Lessons Learned from the War in Kosovo. The Journal of Trauma: Injury, Infection, and Critical Care: 48(6):1144-1147.
[8] Maj. Booker King, Col. Ismail Jatoi. (2005) The Mobile Army Surgical Hospital (MASH): A Military and Surgical Legacy. Journal of the National Medical Association: 97(5):648-656.