Journal of Microbiology, Immunology and Infection (2017) 50, 1–3

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.e-jmii.com

PERSPECTIVES

Toward sustainable and effective control: Experience of China Ebola Treatment Center in Liberia

Yang Luo [a,*], Caiping Song [b], Hongyan Zhang [c], Yungui Wang [d,**], Hao Wu [c,***]

[a] *Medical Research Center, Southwest Hospital, Third Military Medical University, Chongqing, China*
[b] *Bureau of Nursing, Xinqiao Hospital, Third Military Medical University, Chongqing, China*
[c] *Bureau of Medical Affairs Administration, Southwest Hospital, Third Military Medical University, Chongqing, China*
[d] *Third Military Medical University, Chongqing, China*

Received 25 August 2015; received in revised form 21 January 2016; accepted 19 April 2016
Available online 13 May 2016

China ETC help curb the Ebola epidemic

With 10,666 contracted cases and 4806 deaths claimed in Liberia, the country most stricken with Ebola virus disease (EVD), where the epidemic reached a peak in September 2015, was formally declared Ebola-free by the World Health Organization (WHO) on May 9, 2015.[1] The success in promptly reversing the devastating epidemic could be attributed to the joint Training Department efforts from the Liberian authorities and other countries such as the United States, Germany, and China, and organizations including African Union and Médecins Sans Frontières that have established numerous Ebola treatment centers (ETCs) in facilitating diagnosis and treatment of involved cases.[2]

The China ETC, independently run by the Chinese Government in response to the EVD epidemic crisis, has been formally transferred to local government as scheduled on May 13, 2015, symbolizing its decommissioning after stopping the EVD epidemic. China ETC has admitted 177 suspected, probable, or confirmed EVD cases; among which, 60% of confirmed EVD patients were cured within a 6-month mission. Additionally, the dedicated "zero infection" of 444 China ETC healthcare workers (359 Chinese medical staff and 85 local employees) further revealed the success of China in fighting against several deadly contagious diseases such as EVD and malaria. Besides adopting WHO recommended standards for wearing personal protection equipment (PPE), China ETC has provided some unique and invaluable experience in infection control and treatment center operation, which could accelerate the response to newly emerging infectious diseases; particularly in resource-constrained countries where medical supplies are nearly inadequate or exhausted.

Design and construction of semi-permanent prefabricated ETC

China ETC is a 100-bed facility that was situated at the Samuel K. Doe Sports Complex in Paynesville for convenience of transportation of EVD patients. Targeted to provide the

* Corresponding author. Medical Research Center, Southwest Hospital, Third Military Medical University, Gaotanyan Street 30, Shapingba, Chongqing 400038, China.
** Corresponding author. Training Department, Third Military Medical University, Gaotanyan Street 29, Shapingba, Chongqing 400038, China.
*** Corresponding author. Bureau of Medical Affairs Adminstration, Southwest Hospital, Third Military Medical University, Gaotanyan Street 30, Shapingba, Chongqing 400038, China.
E-mail addresses: luoyang@tmmu.edu.cn (Y. Luo), wygui@sina.cn (Y. Wang), wuhao@tmmu.edu.cn (H. Wu).

http://dx.doi.org/10.1016/j.jmii.2016.04.003

most effective healthcare for EVD patients, China ETC is designed to comply with the highest standards available for communicable diseases prevention and control in resource-constrained areas. Equipped with one observation ward and two treating wards within 18 independent buildings covering an area of 2200 km^2, China ETC provides better isolation of suspected and confirmed cases. Unlike other ETCs constructed using tents or prefabricated buildings, China ETC used a semi-permanent prefabricated strategy that provided a few distinctive strengths: enhanced robustness of the building; and constant zones corresponding to respective functions and in-depth personal protection, which are also believed to be of benefit to epidemic prevention.[3] Additionally, modernized facilities such as air conditioning and regular medical instruments were also provided so as to enable rapid response when necessary. Compared with tent-based wards that accommodate nearly 10 EVD patients in one tent, China ETC restricted the patient number to two in a single room, with separation of suspected, probable, and confirmed cases, by which potential nosocomial infections could be minimized. Although ventilation becomes less adequate in these semi-permanent buildings, air conditioning can significantly overcome such weakness. Meanwhile, long-distance observation of patients in the wards is difficult, and can be overcome by using an installed video monitoring system so that the status of the inpatients can be directly monitored from outside.

Strict layout of three zones and two routes

Medical staff are vulnerable to EV infection through their frequent contact with patients because the virus spreads only by direct contact with the blood or body fluids of individuals who have developed symptoms of the disease. Discouraged by the report of 378 Liberian health workers who contracted EVD, a scientifically sound and rational layout and workflow were necessary for effective EVD control in the ETC area. Integrated by the successful experience in fighting against severe acute respiratory syndrome (SARS), a viral respiratory disease caused by the SARS corona virus that led to 8096 cases and 774 deaths worldwide between November 2002 and July 2003, China ETC has conducted strict infection control measures. Considering that previous outbreaks of EVD had a much higher overall fatality rate than SARS (65.4% vs. 11%),[4,5] various measures have been advocated such as a traffic control building from Taiwanese for infection control.[6] A new three zones and two routes strategy was promoted in China ETC (Figure 1): Clean zone (green zone) refers to the area free of any EV contamination, including doctors' offices and nurses' stations; Contaminated zone (red zone) refers to the area with patients with suspected or confirmed EV infection, where PPE must be wore by health workers; Semi-contaminated zone (yellow zone) is an area with a low risk of EV contamination, such as a treatment room and store house. Most of the newly established or provisionally transformed ETCs comprise only a red zone and a green zone to meet the standard recommended by WHO. The exclusively separated yellow zone functions as a buffer zone in minimizing infection risk and improving the tolerance of healthcare workers, as only inner garments are required there. Despite the fact that the yellow zone plays a critical role in infection control, the increased complicity in putting on or taking off PPE may increase the workload of the health workers. To further reduce the risk of hospital infection in our ETC, two divided one-way routes were designed and clearly indicated for carrying clean and contaminated materials through the wards.

Establishment of distinctive ETC information systems

A state-of-the-art information system comprising a medical information system, video monitoring system, and ward calling system was set up in China ETC to meet the needs of patients, medical affairs, and infection control. The ETC medical information system achieved digital storage and transmission of any electronic medical records or documentation produced during the ETC practice. The video monitoring encapsulated the following functions: (1) real-time monitoring of the status of inpatients within ETC

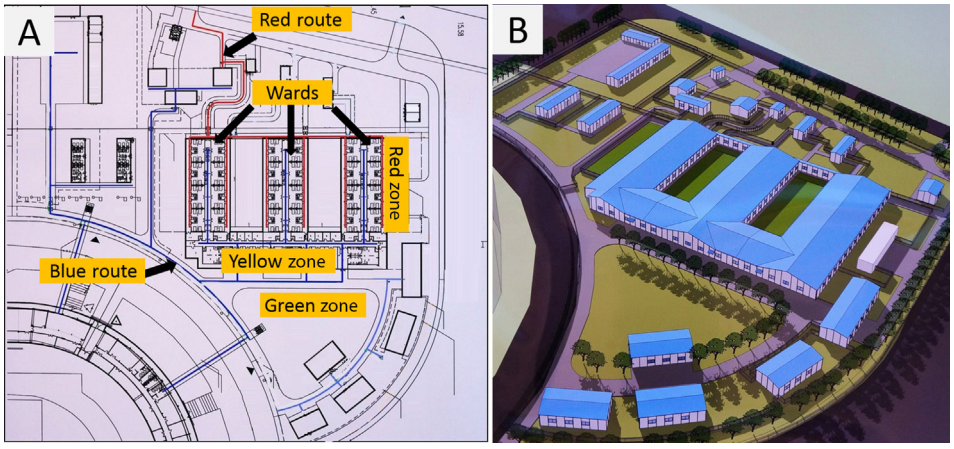

Figure 1. The design of three zones and two routes. (A) Contaminated zone (red zone) that has a high risk of EVD contamination; semi-contaminated zone (yellow zone) that is an area with relatively low risk; and green zone that is free of EVD contamination. Red route denotes a one-way system for inpatients, while the blue route refers to another one-way system only for healthcare workers. (B) Colorful 3D blue print of China Ebola Treatment Centre. EVD = Ebola virus disease.

Table 1 Major steps for Ebola control by China ETC.

	Measures	Useful effects
1	Standard protocols of PPE	No healthcare workers have Ebola virus disease
2	Strict disinfection measures	No nosocomial infection is present
3	Unique layout of 3 zones & 2 routes	Reduce risk of nosocomial infection
4	Strict supervision on personal protection	(1) Enhance confidence of healthcare workers in self protection (2) Avoid any trivial mistakes during putting on & removing PPE
5	Robust video information system	(1) Emotional communication between patients & their families (2) Emotional communication between patients & healthcare workers (3) First aid to patients in emergency
6	Semi-permanent prefabricated ETC	(1) Provide modernized facilities such as air conditioning (2) Conveniently transferred to a local healthcare center when Ebola is down

ETC = Ebola Treatment Center; PPE = personal protective equipment.

wards so as to provide first aid in emergencies; (2) supervising the whole process of putting on or taking off PPE in the red zone so as to minimize any potential contamination risk caused by improper wearing of protective clothing; (3) real-time healthcare workers communication between wards in red zone and office in green zone; and (4) direct communication between the inpatients and their families so as to relieve fear and panic.

The fulfillment of the ETC information system not only eradicated the transmission of paper-based documents but also fully stored all the electronic records of diagnosis and treatment. Moreover, medical staff could observe and accurately record the activities and status of patients, make case investigations, inquire of the patients, and give psychological comfort in the green zone with the help of a ward call intercom system, which has proven to be particularly important in cases in which patients cannot clearly relate their symptoms or they cannot even talk. Lastly, the ETC information system overcame the drawbacks of conventional prefabricated mobile buildings in ward management and protection monitoring (Table 1).

Strict supervision of personal protection

A three-level safety supervision program was established according to the operating condition of China ETC. The first level supervision referred to mutual supervision of paired members including employed Liberian nurses and hygienists, who were trained to keep an eye on each other in the yellow and red zones, such as wearing the correct PPE. The second-level was daily supervision by the medical personnel on duty through video monitoring. The third-level, namely hospital-level supervision, was undertaken by a 10-member expert team that was responsible for long-term inspection of ECT workers. The supervision team had responsibility for video monitoring and tracing of activities, 24-hour continuous supervision, and problem correction. By the end of the mission of China ETC, a total of 476 problems from nearly 3300 monitored activities were promptly fixed on site. Undoubtedly, the strict supervision program also played a vital role in achieving the aim of zero infection.

Regardless of the fact that Liberia reached zero EVD cases, the epidemics in Guinea and Sierra Leone epidemic are not over. In addition, actions are needed to restore their basic health services and reignite their economies, which requires resilient health systems in these resource-constrained West African countries, where substantial fundamental medical facilities are inaccessible. The handover of the semi-permanent construction of China ETC with modernized facilities to the local government would greatly help Liberia recover its healthcare system and improve its capability to respond to various natural disasters or other mass-casualty events. Only when sustainable epidemic control measures have been carried out can those African countries be properly strengthened to deal with natural disasters.

Conflicts of interest

We declare no competing interests. All co-authors are members of the China Ebola Treatment Center in Liberia.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (81371899, 71540020, 71373280). We thank all the members in the China Ebola Treatment Center in Liberia for their contribution.

References

1. World Health Organization (WHO) Ebola Response Team. Ebola virus disease in West Africa — the first 9 months of the epidemic and forward projections. *N Engl J Med* 2014;**371**:1481—95.
2. Chowell G, Viboud C. Controlling Ebola: key role of Ebola treatment centres. *Lancet Infect Dis* 2015;**15**:139—41.
3. Murthy S, Ebola Clinical Care authors group. Ebola and provision of critical care. *Lancet* 2015;**385**:1392—3.
4. Lefebvre A, Fiet C, Belpois-Duchamp C, Tiv M, Astruc K, Glélé LA. Case fatality rates of Ebola virus diseases: a meta-analysis of World Health Organization data. *Med Mal Infect* 2014;**44**:412—6.
5. World Health Organization (WHO). Consensus document on the epidemiology of severe acute respiratory syndrome (SARS). Available at: http://www.who.int/csr/sars/en/WHOconsensus.pdf?ua=1. [accessed 17.05.16].
6. Yen MY, Schwartz J, Hsueh PR, Chiu AWH, Armstrong D. Traffic control bundling is essential for protecting healthcare workers and controlling the 2014 Ebola epidemic. *Clin Infect Dis* 2015;**60**:823—5.