



A Systematic Approach for Regional Trauma System Development

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ABSTRACT

Background: International experiences have shown that trauma system development significantly reduces preventable deaths and disabilities. During the 9-year study, the aim was to find solutions for trauma system development in Shenzhen, China, so as to reduce trauma mortality and morbidity.

Methods: Introducing the Advanced Trauma Life Support® (ATLS®) program to mainland China was started in 2013. A geospatial analysis of traumatic incidents was conducted in 2015. A regional trauma center was illustrated as an example to be used as a reference. The trauma audit meeting was introduced as an approach to continuous trauma quality improvement. The Shenzhen Trauma Surgery Committee was established to finalize the plan for designation of trauma care hospitals. The American College of Surgeons Trauma System Development Guidelines were translated into Chinese.

Results: ATLS® provider course was held in Shenzhen and totally 221 doctors received training. A regional trauma center where adopted ATLS® principles as the standard for trauma resuscitation and early trauma care, with results showing significant improvements in trauma team organization, trauma resuscitation, definitive trauma care and a significant reduction in mortality among major trauma patients. The trauma audit meeting was introduced to 8 hospitals. A new trauma system plan for Shenzhen was set up and a consensus was reached on trauma center designation. The American College of Surgeons' "Resources for Optimal Care of the Injured Patient" was translated into Chinese and published in November 2020. Six trauma networks are recommended combined with geospatial analysis technology and major trauma monitor system was established in November 2021.

Conclusion: The systematic approach for the development of a regional trauma system includes: trauma care training for providers, geospatial analysis of regional trauma accidents, development of standardized trauma center, designation of regional trauma center, development of trauma quality improvement program and establishment of major trauma monitor system. Shenzhen has been demonstrated as a successful example and this practical approach can be replicated in other countries or regions seeking to establish a trauma system.

Keywords: ATLS® ; Geospatial Analysis; Trauma Center Designation; Trauma System

INTRODUCTION

According to the World Health Organization, injuries account for 9% of global mortality and road traffic injuries alone will become the fifth leading cause of death in 2030 [1,2]. It is estimated that by 2030, annual and cumulative GDP losses in low- and middle-income countries affected by injuries will be the second leading causal factor, accounting for losses of up to US\$0.6 trillion annually

[3]. Since the mid-1990s in China, deaths caused by traffic accidents alone have been estimated at ranging from 200,000 to 400,000 persons per year, and nowadays traffic-related fatalities account for 80% of accidental deaths [4]. China's National Health Commission released a guideline in June 2018 calling for the development of trauma centers and trauma systems across mainland China [5].

As defined by Prof. Hoyt and Prof. Coimbra, a trauma system is

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an organized approach to severely injured patients. It should occur within a defined geographic area and provide optimal care that is integrated with the local or regional Emergency Medical Services (EMS) system [6]. The trauma system has been widely reported to reduce trauma-related mortality, including preventable trauma deaths [7-10]. A famous study by MacKenzie, et al. [7] showed that the mortality rate of severely injured patients could be reduced by 25% if they were treated in a trauma center as opposed to a non-trauma center institution. Prof. Maier noted in his presidential address at the 61st Annual Meeting of the American Association for the Surgery of Trauma in 2002 that “The number of Level I and Level II trauma centers should be based on the needs of patients; duplication of high-level trauma centers dilutes the patient volume and leads to unreasonable competition and resource allocation. It also limits the trauma science development capacity of the region” [11].

Located in southeastern China, Shenzhen was designated as China’s first Special Economic Zone in 1979 and has now become one of the best economic cities in China and one of the fastest growing cities in the world. In 2019, Shenzhen has 10.8 million residents and a further 9 million residents in the surrounding metropolitan area [12]. Both total number of trauma patients and emergency medical services has been on the increase in Shenzhen during the period of 2010-2017, and trauma only accounted for 47.0% and 38.4% in 2010 and 2017, respectively [13]. A study [14] conducted in 2015 showed patients who were considered to have suffered major trauma, from the scene to the hospital, as 8.5% were taken to a university teaching hospital, 13.6% to a regional general hospital, 42.6% to a public community hospital and 35.3% to a private hospital. The prehospital system in Shenzhen was sending trauma patients to the nearest hospital, which has resulted in some major trauma patients being sent to hospitals that do not have adequate resources and treatment capacity.

Trauma system development is not only dependent on medical professionals but also based on political decisions. A systematic approach is needed for a newly developing trauma system. This report describes the efforts to develop a trauma system in Shenzhen in the past 9 years.

MATERIALS AND METHODS

Introducing the ATLS® program to mainland China

In September 2013, with the authorization of the American College of Surgeons (ACS), a team including faculty from the ACS China-Hong Kong Chapter and the University of Hong Kong-Shenzhen Hospital (HKU-SZH) was established. The process included organizing a team to translate the ATLS® Student Manual (9th edition) into Chinese, establishing a surgical skills center in HKU-SZH for ATLS® teaching, training Chinese Mandarin-speaking ATLS® instructors from Shenzhen, and changing the language of ATLS® teaching from English courses to English-Chinese hybrid courses, followed by Chinese courses.

Performing geospatial analysis of traumatic incidents in Shenzhen

In order to understand the characteristics of trauma incidents and to help design and designate trauma care hospitals. in Shenzhen, a geospatial trauma incident analysis was performed in 2015. Data were obtained from the Shenzhen “120” EMS center, which records information on all patients requiring an ambulance during pre-hospital care. The EMS registry recorded both diagnoses and

incident locations as electronic free text. Virtually all injury-related diagnoses contained the word “伤” (injury), which facilitated the identification of incidents involving trauma. Anonymized information was extracted, including demographic and physiological data, diagnoses, other necessary clinical details, and incident location. To further evaluate the geographical distribution of incidents, a combination of automated and manual geocoding (using Google maps) was used to geocode the incident location free text fields to longitude and latitude.

Establishing a regional trauma center

A Regional Trauma Center was formally established in HKU-SZH on November 30, 2018 in order to provide better trauma services for local trauma patients and to serve as a reference for other hospitals in Shenzhen. The trauma center adopted ATLS® principles as the standard trauma resuscitation process for early trauma management, including the MIST handover process between pre-hospital care and the emergency department, ABCDE priority principles for trauma resuscitation, bedside chest and pelvic X-ray, FAST examination, and a team approach. A multidisciplinary trauma team was established to provide formal trauma services, with the first layer comprising a general surgeon, ED physician, orthopedic surgeon, ICU doctor, radiologic technician, three trauma nurses and other well-trained colleagues. A trauma ward was also established within the general surgery ward. Important protocols and trauma service manuals were developed, including early Type “O” blood transfusion, massive transfusion protocol, and management protocol for severe pelvic injuries that are hemodynamically unstable.

Trauma quality improvement program

The trauma audit meeting has been introduced as a way to improve the quality of trauma in HKU-SZH at the time of establishing the trauma center. Meetings were organized on a regular monthly or bi-monthly basis. During the meetings, trauma management flow, decision making and trauma management skills were reviewed for each trauma death and for any major trauma patients who may have made errors or mistakes in the management process. Data were collected to compare trauma preventable deaths before and after the trauma center was established.

China trauma care training and trauma surgery committee in Shenzhen

Chinese Medical Doctor Association Committee on Trauma (CMDA COT) officially established its own trauma course – China Trauma Care Training (CTCT®)-in July 2016. After several years of development, CTCT® has become the standard course for trauma care in mainland China. With the support of CMDA COT, the CTCT® course has been introduced to Shenzhen and HKU-SZH has been approved as one of the three major teaching bases in Guangdong Province. CMDA COT also supported the establishment of a Trauma Surgery Committee in Shenzhen under the CMDA framework. A group of eight hospitals led by HKU-SZH applied to establish a trauma academic organization in Shenzhen in December 2019. The purpose of this organization is to organize and improve trauma academic activities in Shenzhen and to involve the major trauma service hospitals. Meanwhile, the Shenzhen Health Commission organized expert panel meetings on the development of trauma centers in Shenzhen and discussed plans for designating trauma care hospitals based on the traumatic incident location, hospital location, hospital level, previous trauma patient volume and trauma care resources. Baseline information

regarding different trauma care hospitals was collected to develop criteria for regional trauma center and trauma care hospitals

Learning from international experiences

After discussions with leaders of the American College of Surgeons (ACS) and the ACS Committee on Trauma, a team from CMDA COT was approved and granted permission to translate “Resources for Optimal Care of the Injured Patient” (2014) into the Chinese version so that colleagues from China in the field of trauma could learn from the American experience, especially regarding the standards for trauma centers and trauma system development.

Data sources and statistical analysis

Data were obtained from HKU-SZH and Shenzhen EMS. Data were collated using Microsoft Excel for Mac 2011, Version 14.4.6 (Microsoft, Redmond, WA). QGIS (2.12.1 Lyon) and ArcGIS® (10.4.1) were used for further geospatial analysis. Data were analyzed using SPSS® 24.0 for Windows® (SPSS Inc. IBM Corp.).

RESULTS

ATLS® program in mainland China

The ATLS® Student Manual was translated into the Chinese version by a team from HKU-SZH. The Chinese version was published by People's Medical Publishing House Co., Ltd in August 2016. The first ATLS® provider course was held at HKU-SZH in September 2016 (Figure 1). By December 2021, a total of 221 doctors from 11 provinces in China had received ATLS® training at HKU-SZH. Table 1 shows which city and department the students came from. A questionnaire survey was sent to 121 students in October 2018 and 103 respondents were received. The study showed that 96.1% of the respondents found the ATLS® course helpful in clinical work, 87.3% found the ATLS® course influential in deciding whether to intubate a patient, 86.4%

found the ATLS® course influential in chest tube insertion and 85.4% found the ATLS® course influential in resuscitating a traumatic shock patient.

Decrease in trauma death and preventable trauma death

HKU-SZH trauma center was established on November 30, 2018. Major trauma patients (ISS>15 or activated a multidisciplinary trauma team) during 2019 to 2021 are significantly more than 2016 to 2018. The trauma deaths during 2019 to 2021 are much lower than the ones during 2016 to 2018, with 8, 7, 8, 5, 3, 3 trauma deaths during 2016 to 2021, respectively (Figure 2). In 2018, a total of 1913 trauma patients were admitted to HKU-SZH, including 82 major trauma patients (ISS>15 or activated multidisciplinary trauma team). There were 8 trauma deaths, accounting for 9.8% of major trauma patients, and 1 patient with preventable trauma death was recognized based on regular trauma audit meetings. In 2019, HKU-SZH admitted 1919 trauma patients, of which 153 were major trauma patients (ISS>15 or activated multidisciplinary trauma team). There were 5 trauma deaths, accounting for 3.3% of major trauma patients, and 1 potentially preventable trauma death was recognized based on regular trauma audit meetings (Table 2).

Geospatial analysis of trauma incidents and establishment of trauma networks

A total of 49082 trauma patients were found between January 01, 2014 and December 31, 2014. Of these patients, 3513 (7.1%) were retrospectively classified as having met the criteria for either Step 1 or Step 2 of the Field Triage Decision Scheme (FTDS) and were therefore likely to have suffered a major trauma. Figure 3 shows a dot map of the geographical distribution of trauma incidents and hospitals receiving trauma patients. Incidents are mostly concentrated in the western and central part of Shenzhen, bordering Hong Kong. The nearest neighbor index was 0.048, indicating a high degree of clustering.



Figure 1: ATLS® manual Chinese version and ATLS® team from China.

Table 1: ATLS® training in mainland China (September 2016-December 2021).

| City | Number of students | Department(s) | | | | | |
|-----------|--------------------|---------------|----|-----|------------|------------|-----------|
| | | Surgery | ED | ICU | Anesthesia | Orthopedic | Education |
| Shenzhen | 140 | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Beijing | 24 | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Huizhou | 14 | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Hangzhou | 6 | ✓ | | | | | |
| Nanjing | 7 | ✓ | ✓ | ✓ | | | |
| Zhongshan | 4 | | ✓ | | ✓ | ✓ | ✓ |
| Chengdu | 3 | | ✓ | | | | |
| Dongguan | 3 | | ✓ | | | | |

| | | | | | |
|-----------|-----|---|---|---|---|
| Hengyang | 3 | | ✓ | ✓ | ✓ |
| Wuhan | 2 | ✓ | | ✓ | |
| Meizhou | 2 | | ✓ | | |
| Changzhou | 1 | | | | ✓ |
| Nantong | 1 | | ✓ | | |
| Suzhou | 1 | | ✓ | | |
| Qingdao | 1 | | | | |
| Tianjin | 1 | | | | |
| Liuyang | 1 | | ✓ | | ✓ |
| Guilin | 2 | | ✓ | | |
| Yunnan | 2 | ✓ | | | |
| Qingyuan | 3 | | ✓ | | |
| Total | 221 | | | | |

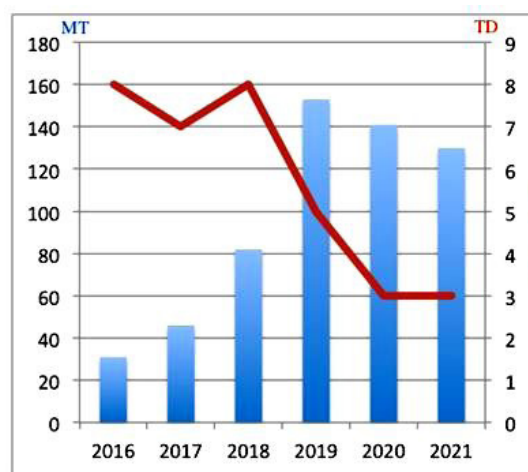


Figure 2: Major trauma and trauma death during 2016 to 2021. Note: (■) Number of Major Trauma (MT); (—) Number of Trauma Death (TD).

Table 2: Demographic data and outcomes of trauma services during January 2018-December 2019.

| | January 2018-December 2018 | | | | January 2019-December 2019 | | | | P ₁ | P ₂ |
|--|----------------------------|-----------------------|-------------------|---------------|----------------------------|-----------------------|-------------------|---------------|----------------|----------------|
| | 1913 patients | 82 MTP (4.3%*) | 8 Deaths (9.8%**) | 1 PDP | 1919 patients | 153 MTP (8.0%*) | 5 Deaths (3.3%**) | PPDP | 0 | 0.401 |
| Gender | Male 1157 (60.5%) | Male 58 (70.7%) | Male 7 (87.5%) | Male 1 (100%) | Male 1183 (61.6%) | Male 121 (70.7%) | Male 4 (80.0%) | Male 1 (100%) | 0.152 | 0.641 |
| | Female 756 (39.5%) | Female 24 (29.3%) | Female 1 (12.5%) | | Female 736 (38.4%) | Female 32 (29.3%) | Female 1 (20.0%) | | | |
| Mean age (years) | 38.48 (SD 22.86) | 41.17 (SD 21.23) | 41.63 (SD17.64) | 32 | 39.58 (SD 22.13) | 37.13 (SD 18.48) | 29 (SD16.45) | 50 | 0 | 0 |
| Mechanism of Injury | 1804 Blunt (94.3%) | 56 Penetrating (2.9%) | 53 Burn (2.8%) | | 1747 Blunt (91.0%) | 99 Penetrating (5.2%) | 73 Burn (3.8%) | | 0.58 | 0.046 |
| Median ISS (IQR) | | 29 (IQR 20) | 59 (IQR 25) | 29 | | 21 (IQR 17) | 66 (IQR 10) | 30 | 0 | 0 |
| Cause of death | | | | | | | | | | |
| Neurological | | | 6 (75%) | | | | 2 (40%) | | | |
| Hypovolemic shock | | | | 1 (12.5%) | | | 2 (40%) | | | 0.293 |
| Multiorgan failure | | | 0 | | | | 0 | | | |
| Respiratory cardiac | | | 1 (12.5%) | | | | 0 | | | |
| Hypovolemic shock with Myocardial infarction | | | | | | | | 1 (20%) | | |

Note: *Proportion from the entire patient group; **Proportion from MTP group; P₁: MTP between January 2018-December 2018 and January 2019-December 2019; P₂: Deaths between January 2018-December 2018 and January 2019-December 2019
 Abbreviations: ISS: Injury Severity Score; MTP: Major Trauma Patient; PDP: Preventable Death Patient

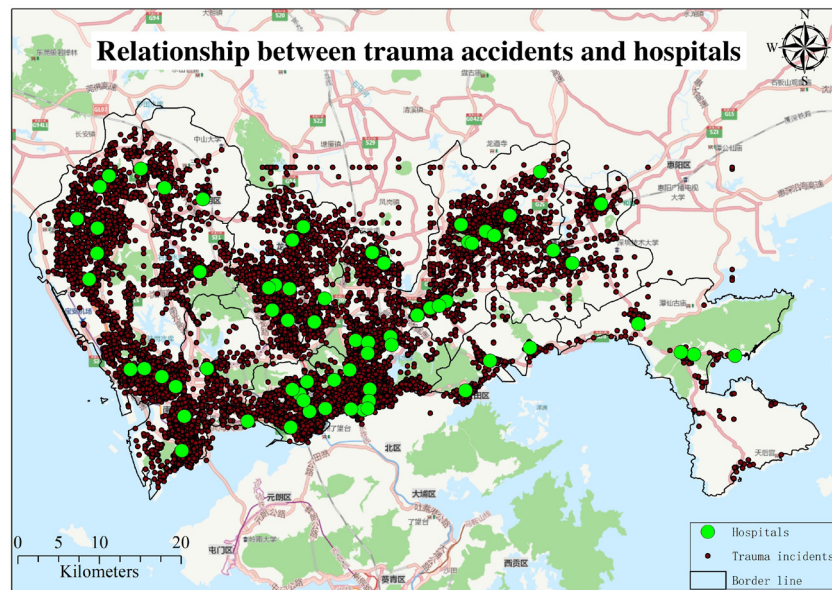


Figure 3: Geographical distribution of trauma incidents and hospitals receiving trauma patients.

The Shenzhen Trauma Surgery Committee under CMDA was officially approved and established in June 2020. The committee includes almost all hospitals that receive trauma patients and Shenzhen EMS. The committee has already conducted six hospital visits with the aim of reviewing trauma service processes and management flow, and identifying challenging parts of the hospitals visited so that further actions can be taken to address the trauma care deficit. A few committee meetings were arranged and the trauma system development in Shenzhen was discussed with the support of the National Center for Trauma Medicine (NCTM) in Beijing. The Shenzhen Trauma System was developed using NCTM's regionalization and "1+X" concept. Six regional trauma networks were recommended by the committee and one leading hospital in the regional network is being used for trauma clinical care Figure 4. Except for clinical trauma care, HKU-SZH is being recommended as the tertiary trauma teaching and training hospital in Shenzhen.

Trauma quality improvement program in Shenzhen

When the Trauma Center was established in November 2018, trauma audit meetings were introduced as an approach to improve the quality of trauma at HKU-SZH. This has proven to be an effective way to identify deficiencies in the trauma care process, as well as to identify measures for improvement. The author's institutional study on preventable deaths in multiple trauma patients [15] was published in February 2020, and it recommended that every trauma care hospital should adopt some approach to continuously improve its trauma care, and the trauma audit meeting is one of the recommended approach. Since July 2019, this program has been introduced to other hospitals in Shenzhen and propagated to seven other hospitals in late 2019. Today, many trauma care hospitals in Shenzhen have made reference to this program and have established their own methods and policies to improve trauma care. A further multicenter study on preventable deaths in major trauma patients has been planned and is being

conducted in Shenzhen, which will reveal results in Shenzhen over the next two years.

Major trauma monitor system

A major trauma monitor system has been set up at HKU-SZH. Pre-hospital care providers scan a major trauma symbol and put in major trauma patients' data, including accidental address. Then a dynamic dot map is showing in the major trauma monitor system screen based on geospatial analysis technology. The system will show where the accidents happen, what level of hospital the patient goes to, how the trauma care process is and what is the outcome of the patient. The next step is to extend this system to the whole Shenzhen city. It will provide valuable information for Shenzhen Health Commission and other related government departments so that they can manage trauma accidents more reasonable and to further decrease mortality and morbidity for trauma patients.

The Chinese version of "Resources for Optimal Care of the Injured Patient"

With the generous support of the American College of Surgeons, a team from CMDA COT was approved and granted permission to translate and publish "Resources for Optimal Care of the Injured Patient" (2014). The Chinese version of the book was completed and published in November 2020 Figure 5. In June 2018, China's National Health Commission released guidelines instructing the development of its trauma centers and trauma systems throughout mainland China. This piece of work must bring invaluable information to colleagues in the trauma field in China and be valuable to the development of its trauma centers and trauma systems. Deep appreciation must be expressed to the American College of Surgeons and to all the international trauma experts who assisted in this work.

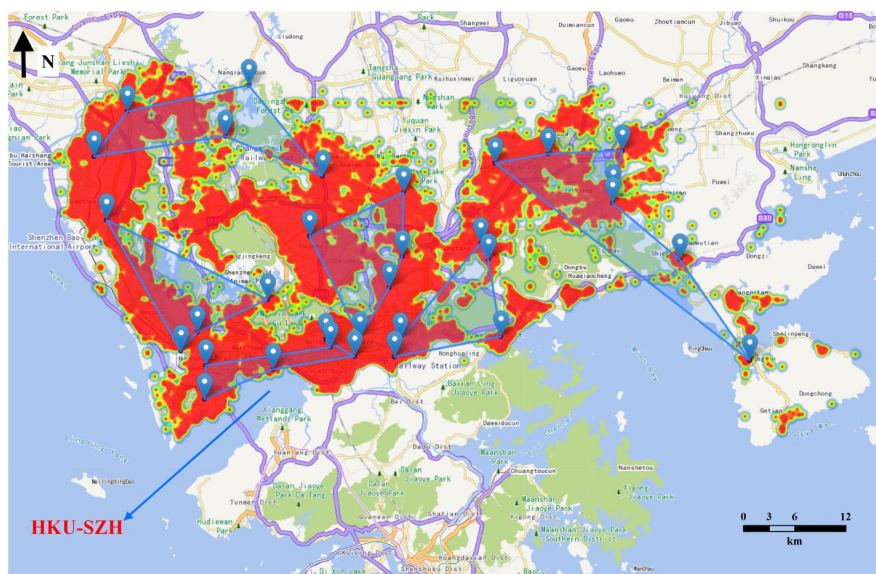


Figure 4: Six regional trauma networks recommended in Shenzhen.



Figure 5: Release Ceremony of the Chinese Version of “Resources for Optimal Care of the Injured Patient” (2014).

Note: From left to right: Dr. Guixi Zhang, Prof. Xiaobing Fu, Prof. Lianyang Zhang, Prof. Baoguo Jiang.

DISCUSSION

As noted in the American College of Surgeons “Resources for Optimal Care of the Injured Patient” (6th edition, 2014) [16], the trauma system should contain different parts and functions to run and maintain optimal trauma care, including trauma centers, pre-hospital care, inter-hospital transfer, trauma organization and trauma programs, subspecialty trauma care capabilities (e.g., general surgery, emergency medicine, neurosurgery, orthopedic surgery, etc.), pediatric trauma care, multidisciplinary trauma collaboration, rehabilitation, rural trauma care, burn services, trauma registries, performance improvement and patient safety programs, trauma education, prevention, trauma research, trauma academic organization and activities, organ donation programs, and trauma center verification programs. The development of trauma centers and trauma systems in China is still in its early stages and there is much to be learned from the international community, particularly experiences from the United States. Despite the differences in economic situations and social policies between the United States and China, the concepts and components of the trauma system should be very much the same.

In the past few years, China has made some major milestones in trauma medicine, including the establishment of the Chinese Medical Doctor Association Committee on Trauma in November 2014, the establishment and propagation of the China Trauma Care Training (CTCT®) since July 2016, the publication of the National Trauma System Development Guideline by the China’s National Health Commission in June 2018, and appointment of the National Center for Trauma Medicine by the National Health Commission in August 2019. Prof. Wang Zhengguo, Prof. Fu Xiaobing, Prof. Jiang Baoguo and Prof. Zhang Lianyang are the most important and absolutely top trauma leaders in China, who have significantly and incredibly contributed to the country.

Prof. Maier and his colleagues found that the effect of regionalization on mortality from motor vehicle accidents reduced the risk of death by 8%, but it took over 10 years for this to manifest itself. Although it is likely that a gradual process of quality improvement was observed, significant reductions in trauma-related mortality were not measurable until several years after implementation of the trauma system [17]. The great ambitious goal of the United States since April 2017 has been to establish a national trauma system

and achieve zero preventable trauma deaths nationwide [18,19]. Based on the experiences of the American College of Surgeons Committee on Trauma-Trauma Verification Program, our next step is to establish a national trauma center verification program in China. In recent years, several Chinese provinces have established their own trauma center development policies. In September 2016, China Trauma Rescue and Treatment Association (CTRTA) was founded and has since established a trauma center development program across China. In the year 2020, CTRTA became one of the components of the National Center for Trauma Medicine (NCTM) located in Peking University People's Hospital in Beijing. As mentioned above, NCTM was founded by China's National Health Commission [20] to lead the development of a national trauma center, trauma system, and trauma science. Ideally and undoubtedly, NCTM will become the appropriate organization to establish a nationwide trauma center verification program.

Trauma training is the foundation for trauma care. ATLS® has been developed by the ACS COT for over 40 years and has driven the development of trauma science worldwide. One of the most important characteristics of the ATLS® course is its strict and high quality teaching. The small class, usually 16 students per class, is the standard arrangement. In the past decade, trauma training has been in high demand in China, and ATLS® was not introduced in mainland China until September 2016, so China has developed its own trauma course, "China Trauma Care Training (CTCT®)", to provide the necessary trauma knowledge and skills training for medical and nursing personnel who take care of trauma patients. As mentioned above, ATLS® was introduced to mainland China in September 2016, and a total of 221 providers have received training from the author's institution. Looking to the future, the CTCT® and ATLS® courses will assume primary responsibility for providing trauma care training to medical and nursing personnel in mainland China. As stated by Prof. John Wong, "...perhaps, those who wish to receive local trauma training using CTCT®, and those who wish to receive the international standard trauma care course using ATLS® ..." In the author's institution, the mortality rate patients with major trauma in 2019 was significantly lower than that in 2018, which was mainly due to the organization of the multidisciplinary trauma team and the formal establishment of the trauma center in November 2018. All trauma team members received ATLS® training and the ATLS® "common language" was adopted as an early management principle. The timely response of the trauma team and the well-organized trauma resuscitation and following definitive care play a major role for the improvement of trauma quality.

Geospatial analysis has been widely used in the field of trauma for the development of trauma systems internationally [21-25]. Such studies can identify the distribution characteristics of trauma incidents in a particular region or country, as well as the distribution of trauma care resources. It is a very useful approach to find a reasonable timeline for a particular trauma incident in a region. It can be presented as a heat map and can easily demonstrate the appropriateness of a regional trauma system framework to medical personnel, health and government officials, and policy makers. Mainland China is still in the early stages of trauma center and trauma system development, and the rationale for such a study would be very helpful for trauma system design, especially in providing invaluable information for a region to consider its new trauma system configuration. A similar study was carried out in Shenzhen in 2015, and the outcomes of the study were published in 2017 [14]. These outcomes have been adopted as one of the new

Shenzhen trauma system design guidelines.

The World Health Organization and the International Association for Trauma Surgery and Intensive Care's "Guidelines for trauma quality improvement programs" (WHO, 2009) [26] state that techniques for improving trauma quality include 1) Morbidity and Mortality (M&M) conferences, 2) preventable death panel reviews, 3) tracking of audit filters, complications, errors, adverse events, and sentinel events, 4) statistical methods: risk-adjusted mortality, 5) corrective strategies and closing the loop, 6) system-wide and pre-hospital quality improvement, 7) role of medical records and trauma registries, 8) appropriateness of using different techniques at different levels of the health care system. Although the concept of trauma auditing and the audit process is new in mainland China, every hospital in mainland China has long adopted a policy based on "discussion of death and difficult cases". Despite the differences in the process and format of the discussion, the rationale behind it is virtually the same. The trauma audit meeting process usually includes a panel from the hospital trauma committee or regional trauma committee, and reviews specific trauma death cases or any other major trauma cases that could possibly be further improved. The review content usually includes management flow, medical decision making and appropriateness of medical skills. At the end of the meeting, every member of the committee will be required to draw a conclusion as to whether it was an unpreventable death, a potentially preventable death or a preventable death, or whether the management process was appropriate or not, and if not, where the error was/mistakes occurred. Finally, an improvement action protocol and follow-up plan will be developed for further improvement in the future work. Every hospital that takes care of trauma patients should have its own policies and programs for improving the quality of trauma. The purpose of the policy and program should be to continuously identify deficiencies or errors in the trauma care process, and then to develop the action protocol for improvement and an avoidance of recurrence of the same errors.

As mentioned above, the Shenzhen Trauma Surgery Committee has recommended six regional trauma networks. There are a number of reasons behind this. First of all, it is an inclusive trauma system, with six trauma networks covering the entire population of Shenzhen. Shenzhen EMS has 74 network hospitals, including tertiary teaching hospitals, regional general hospitals, community public hospitals and private hospitals. All of these hospitals attend to traumatic incidents and provide primary care to trauma patients. For those hospitals without adequate trauma resources, they either transfer trauma patients from the scene to other major hospitals or, after providing primary trauma care at their own institutions, to other major hospitals if necessary. Secondly, Shenzhen is a city with a population of nearly 20 million and covers an area of 1997.47 square kilometers. Although the air ambulance system was officially established on November 22, 2019, road ambulances are almost the only pre-hospital transfer method for trauma patients. It will be reasonable and feasible for road ambulances to transfer trauma patients to the appropriate hospital within a reasonable timeframe through the six trauma networks' plans. Thirdly, each trauma network will adopt the concept of "1+X", with "1" indicating the top hospital leading trauma services for that network and "X" indicating the other hospitals within the same network. The criteria for the top hospitals will include both hard and soft criteria. The hard criteria will include trauma surgery and multidisciplinary trauma teams, trauma resuscitation bays, CT in the emergency department, trauma ICUs, trauma wards,

department of rehabilitation, and all trauma team members taking care of trauma patients who have received either CTCT® or ATLS® training. The soft criteria will include trauma teaching and research capabilities. A new Shenzhen trauma network program is underway, which will be completed by the Shenzhen Trauma Surgery Committee. This work will be completed and submitted to the Shenzhen Health Commission by June 30, 2021. It is anticipated that the new Shenzhen Trauma System will be fully operational from January 01, 2022.

CONCLUSION

The systematic approach for the development of a regional trauma system includes: trauma care training for providers, geospatial analysis of regional trauma accidents, development of standardized trauma center, designation of regional trauma center, development of trauma quality improvement program and establishment of major trauma monitor system. Shenzhen has been demonstrated as a successful example and this practical approach can be replicated in other countries or regions seeking to establish a trauma system. The effectiveness of this study has been demonstrated and there is value in extending it to other parts of mainland China.

ETHICAL APPROVAL

This study was approved by the PLA Medical School and the University of Hong Kong-Shenzhen Hospital (Reference LUN(2016)45).

CONSENT FOR PUBLICATION

Personal consent for publication obtained.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

COMPETING INTERESTS

The authors declare that they have no competing interests.

FUNDING

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AUTHOR’S CONTRIBUTIONS

GZ developed the concept for the study, organized to obtain the data, conducted the analysis, and wrote the first draft of the manuscript. GL assisted with data collecting, contributing to data statistics and analysis, and contributed to the writing of the manuscript, especially for the part of ATLS training. CL assisted with the data collecting, contributing to the tables, and contributed to the writing of the manuscript, including the ATLS part and the trauma clinical service part. RL assisted with the data collecting, contributing to the tables, and contributed to the writing of the manuscript, mainly for the ATLS part. JW assisted with the data collecting, contributing to the tables, and contributed to the writing of the manuscript, mainly for the ATLS part. RM assisted with the data collecting, contributing to the tables and figures, and contributed to the writing and correction of the manuscript,

including the ATLS part, Shenzhen trauma system map part and the translation part of “Resources for Optimal Care of the Injured Patient”. EB assisted with the data collecting, contributing to the figures, and contributed to the writing and correction of the manuscript, especially for the translation part (Chinese version) of “Resources for Optimal Care of the Injured Patient” and correction for many details for the whole manuscript. JF: Helped to develop the concept for the study, provided background information on ATLS training, trauma audit meeting, trauma services and trauma academic organization in Shenzhen, assisted with the processing and analysis of the data, and contributed to the writing of the manuscript. XF helped to develop the concept for the study, provided background information on trauma training, trauma system development, international experiences and the Chinese version of “Resources for Optimal Care of the Injured Patient” from American College of Surgeons, assisted with the processing and analysis of the data, and contributed to the writing of the manuscript.

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