Biomed Environ Sci, 2014; 27(7): 537-543

Policy Forum

Comprehensive Level One Trauma Center Could Lower In-hospital Mortality of Severe Trauma in China*

CAI Bin[1,†], Burruss SIGRID[3,†], Britt REDICK[4,†], JIANG Hua[1,†,#], SUN Ming Wei[2], YANG Hao[1], Charles Damien LU[1], Mitchell Jay COHEN[1,4,†,#], Henry CRYER[1,3,†,#], and ZENG Jun[1,2,†,#]

Trauma is a major health and social problem in the US and China. It constitutes the main cause of death in people aged 45 or under in both countries[1-2]. There is clear evidence from clinical studies that a large percentage of these deaths are needless and preventable if better treatment and prevention programs are available[2-3].

There is evidence from US studies that well-organized level one trauma centers reduce mortality in severe trauma patients[3-4]. But in China, there is still no trauma center accreditation system like American College of Surgeon Committee for Trauma (ACS-COT). Various initiatives have been undertaken to improve trauma care in China, but a comprehensive trauma network made up of accredited trauma centers is still under development[1].

Sichuan Provincial People's Hospital of Sichuan Academy of Medical Sciences (SAMS) established its trauma service in 1992 and has since become one of the largest trauma centers in China. It currently operates an integrated, comprehensive trauma service system in its East Branch. There are similarities between the SAMS trauma service and level one trauma centers designated by ACSCOT in US, such as having a multidisciplinary, integrated medical team, a special intensive care unit (ICU) facility for severe trauma patients and a data management system which could be used for continuing analysis and quality improvement. But the environments of two countries (China and US) also have many differences, in areas such as medical regulations for trauma service, financial support, and infrastructure for pre-hospital emergency medical service.

A comparison based on data from US and China trauma services is valuable for both sides for the following reasons: 1) Verifying the efficacy of an international recognized trauma service standard in China and providing evidence-based recommendation for the development of relevant policies for the designation of trauma centers in China; 2) Providing an international aspect on the role of leading trauma centers for relevant regions. For these reasons, we conducted a comparison study that compares outcomes following major traumas managed by UCLA, UCSF, and SAMS trauma services.

Chengdu is one of the biggest cities in southwest China with a population of 11.49 million and is that approximately 7 million people lives in metropolitan area (at the end of year 2010)[5]. SAMS trauma service is the only designated trauma center in Chengdu and its East Branch is operating according to level one trauma center standard established by ACS-COT. Local emergency medical service system has been established since the end of 1990s. The transportation of trauma patients followed 'closest first' principle, but for those who are evaluated as severe or complicated poly-injury will be sent to nearest advanced comprehensive hospital (grade 3A hospital). The East Branch of SAMS serves two major urban districts: Jin Jiang District and Long Quan-yi District, where has a combined population of approximately 1.02 million[4]. It established a trauma registry database for collecting information on all trauma patients admitted since December of 2009.

Los Angeles (LA) is the second-most populous city in the United States with a population of 3.79 million. It has an area of 1 215 km^2, and is located in Southern California. There are five ACS-COT verified

doi: 10.3967/ bes2014.084

1. Department of Computational Mathematics and Bio-statistics, Metabolomics and Multidisciplinary Laboratory for Trauma Research, Institute for Disaster and Emergency Medicine Research, Sichuan Provincial People's Hospital, Sichuan Academy of Medical Sciences, Chengdu 610101, Sichuan, China; 2. Trauma Surgery Center, East Branch, Sichuan Provincial People's Hospital, Sichuan Academy of Medical Sciences, Chengdu 610101, Sichuan, China; 3. Trauma Center, University of California Los Angeles, Los Angeles, CA 90095, US; 4. Department of Surgery, San Francisco General Hospital, University of California San Francisco, San Francisco, CA 94110, US

Level One trauma centers in LA region. Each Level one trauma center is a comprehensive regional resource that is a tertiary care facility central to the trauma system. And it is capable of providing total care for every aspect of injury, from prevention through rehabilitation. UCLA Trauma Center is a major trauma center in state of California and US; the number of trauma patients receiving treatment from this center is around 1 000 per year.

San Francisco (SF) is the biggest city of Northern California with a population of 0.82 million. It has an area of 121 km^2. Trauma Center of San Francisco General Hospital (SFGH) is affiliated to UCSF. It is the only ACS-COT verified Level One trauma center in SF. It is serving around 3 900 patients each year. SFGH and its trauma center is also a major trauma service provider in US.

The study cohorts were retrospectively identified and the data extracted from the SAMS, UCLA, and UCSF trauma registries for the one year period from January 1st to December 31st 2010. All three databases contain all primary (transported directly to trauma center from trauma scene) and secondary admitted (transported to trauma center after admission to other hospitals) trauma patients, with an Injury Severity Score (ISS) ≥16 and positive signs of life on arrival at the trauma center. No burn patients or patients <15 years are included in this study.

Demographic data included gender and age. Mechanism of injury, ISS, blood transfusion, physiological biochemical and blood cell test at admission were used to determine injury patterns at each center. ISS-adjusted mortality was used as major outcome.

The research protocol was approved by medical ethical committee at SAMS and institutional research board at UCLA and UCSF.

Data was described as mean±standard deviation ($\bar{x}\pm s$) or as median and inter quartile range (IQR) in the case of a skewed distribution. Differences between groups were analyzed with the *t*-test for data presented as means or used ANOVA for data presented as medians, respectively. Differences in counts or percentages were evaluated with the chi-square test. Differences were considered significant if a two-tailed *P* value is <0.05.

Multivariate logistic regression was used to identify independent mortality related factors. To improve the accurate of mortality related risk factor estimation, we introduced partial least square (PLS)[5-6], an advanced statistic tool and generated a statistic variable called Variable importance in the Project (VIP) scores (Formula 1).

$$VIP_j = \sqrt{\frac{p}{Rd(Y;t_1,\ldots,t_m)}\sum_{h=1}^{m} Rd(Y;t_h)w_{hj}^2}$$

$$Rd(y_k;u_h) = r(y_k;u_h)$$

$$w_{hj} = weighting(h, j)$$

Formula 1. Variable importance in the Project (VIP).

VIP scores measure the correlation between variables and the result, the larger VIP scores the stronger the correlation. We set VIP scores >1 as the threshold. We used PLS to screen candidate variables that could be used for multivariate logistic regression[7].

The *t*-test or Mann-Whitney *U* test, chi-square test, multivariate logistic regression and PLS are performed by using the R (version 2.15.2). All computation process has operated at a high performance computing platform (HPC, CPU Xeon E7-8848 *4, 512GB DDR3 1333Mhz; Environment: Unbutu 12.04).

In total 829 cases were enrolled for analysis (SAMS=78, UCLA=200, UCSF=551). Table 1 showed demographics of patients in three centers. Patients' age and gender distribution were similar in three centers; most of them were male (72.6%).

Although all cases were severe traumas, the severity of injuries was different between three centers. Two US centers have significantly more patients with higher ISS scores (Percentage of Patients whose ISS>25: SAMS=24.4%, UCLA=39%, UCSF=46.5%, *P*=0.004).

ISS adjusted mortality was not significantly different between the three centers (SAMS=12.1%, UCLA=19.9%, and UCSF=12.8%, respectively; *P*=0.065).

The mechanisms of injury (MOI) are significantly different between SAMS, UCLA, and UCSF (Table 2, Figure 1). In Chengdu, the most common causes of trauma were fall (FA, 28.2%), motorcycle (MM, 21.8%), and enclosed vehicle (EV, 17.9%). In Los Angeles, the most common causes of trauma were pedestrian/bike *vs*. vehicle (42.6%), FA (23.1%), and EV (18.5%). In San Francisco, the most common causes of trauma were FA (37.9%), EV (29.8%), and assault (AS, 19.9%).

A multivariate logistic regression analysis (Table 3) showed that the risk of injury related death in SAMS is not significantly higher than UCLA (*OR* 0.933, *P*=0.141) or UCSF (*OR* 0.978, *P*=0.599).

Table 1. The Demographic Characteristics, Injury Severity, Transfusion, Biochemistry, and Blood Cell Test and Outcome of Severe Trauma Patients from Chengdu, Los Angeles, and San Francisco

Variables	SAMS, *n*=78 Mean (IQR)	UCLA, *n*=200 Mean (IQR)	UCSF, *n*=551 Mean (IQR)	*P* Value
Age (years)	48.8 (35.0, 62.0)	47.9 (28.0, 66.0)	47.9 (29.0, 63.0)	0.933
Gender				0.091
Male (%)	63 (80.8)	151 (75.5)	388 (70.4)	
Female (%)	15 (19.2)	49 (24.5)	163 (29.6)	
SBP(%)				0.805
<90 mm Hg	6 (7.7)	17 (9.2)	41 (7.7)	
≥90 mm Hg	72 (92.3)	167 (90.8)	489 (92.3)	
BT	36.6 (36.4, 36.8)	36.4 (36.1, 36.7)	36.2 (35.7, 36.7)	<0.001
BUN	5.87 (4.80, 7.10)	15.0 (12.0, 21.0)	15.0 (12.5, 19.0)	<0.001
Cr	72.5 (63.0, 82.7)	88.4 (79.6, 106.1)	92.8 (67.2, 111.4)	0.099
SB	21.6 (20.0, 23.7)	22 (20.0, 24.0)	21.1 (17.1, 23.7)	0.077
HCT	0.384 (0.320, 0.424)	0.398 (0.359, 0.433)	0.4 (0.359, 0.433)	0.069
HGB	121 (105, 141)	131 (121, 148)	129 (116, 146)	0.007
HR (%)				0.511
<60	1 (1.3)	3 (1.6)	2 (0.3)	
60-90	5 (6.5)	14 (7.6)	39 (7.4)	
≥90	72 (92.2)	167 (90.8)	489 (92.3)	
ISS (%)				0.004
16-26	59 (75.6)	122 (61.0)	305 (55.4)	
26-40	11 (14.1)	63 (31.5)	198 (35.9)	
≥40	8 (10.3)	15 (7.5)	48 (8.7)	
$PaCO_2$	40.3 (33.0, 45.3)	41.5 (35.0, 46.0)	46.6 (37.0, 51.0)	0.008
pH	7.30 (7.13, 7.39)	7.34 (7.26, 7.40)	7.29 (7.16, 7.34)	<0.001
WBC	12.0 (9.20, 15.7)	10.8 (8.20, 14.2)	10.6 (8.05, 12.9)	0.106
Blood Transfusion (u)	3.75 (3.00-6.37)	6.00 (2.00-14.0)	4.00 (2.00-9.00)	0.251
ICU Admission (%)	100	90.9	63.0	<0.001
ICU length of stay	3.00 (1.00-6.00)	7.00 (4.00-13.00)	3.00 (1.00-7.00)	0.128
Length of Hospitalization	19.0 (5.25-27.75)	11.0 (5.75-17.00)	6.00 (2.00-13.00)	<0.001
MOI (%)				<0.001
EV	14 (17.9)	20 (18.5)	164 (29.8)	
FA	22 (28.2)	25 (23.1)	209 (37.9)	
PB	9 (11.5)	46 (42.6)	13 (2.4)	
AS	8 (10.3)	4 (3.7)	110 (19.9)	
OT	1 (1.3)	2 (1.9)	10 (1.8)	
MM	17 (21.8)	10 (9.3)	29 (5.3)	
SI	6 (7.7)	0 (0)	16 (2.9)	
SP	1 (1.3)	1 (0.9)	0 (0)	
Major Outcome				
Raw Survive (%)	69 (88.5)	163 (81.5)	475 (86.2)	0.194
Death	9	37	76	
Expected Death	9	40	71	
Raw Mortality (%)	11.5	18.5	13.8	
ISS-adjusted Mortality (%)	12.1	19.9	12.8	0.065

Note. All physiological and biochemical variables were collected at admission. Abbreviations: BT: body temperature; BUN: blood urea nitrogen; Cr: creatinine; HCT: hematocrit; HGB: hemoglobin; HR: heart ratio; MOI: mechanisms of injury; EV: enclosed vehicle; FA: fall; PB: Pedestrian/bike *vs.* vehicle; AS: assault; EX: extrication; MM: motorcycle; PS: passenger space intrusion; SB: standard bicarbonate; SP: sport injury; SI: self-inflicted intentional; EJ: ejected; OT: other.

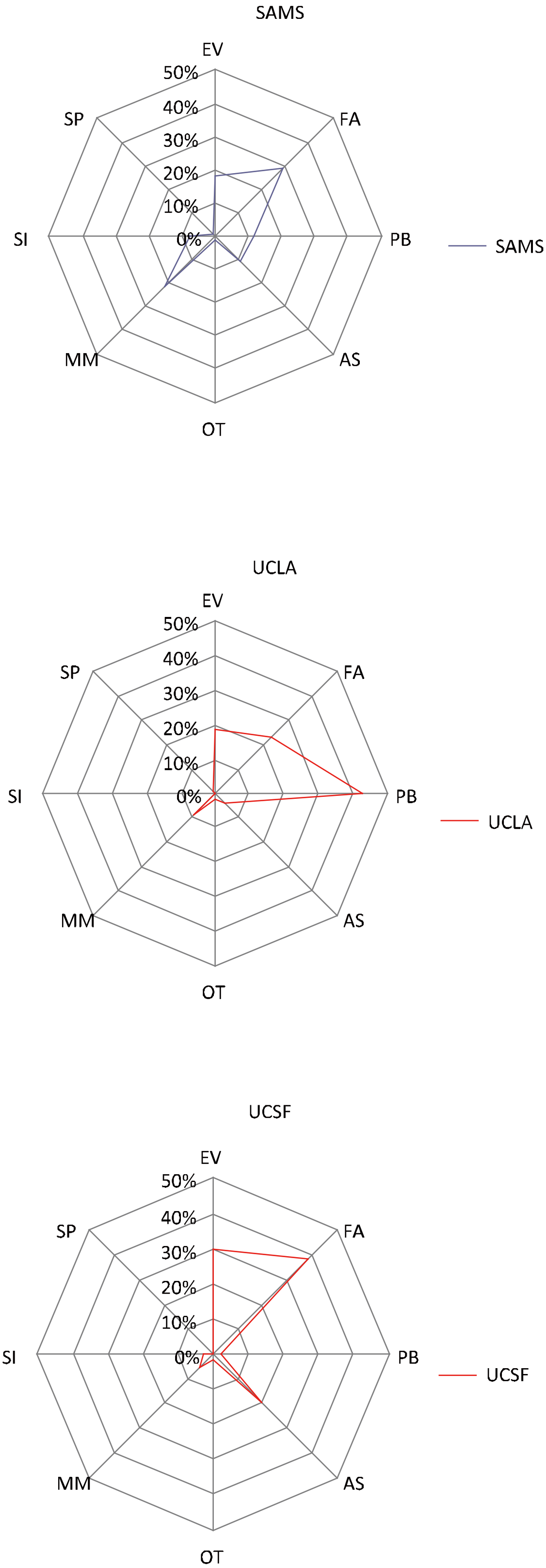

Figure 1. Pattern of Mechanisms of Injuries in SAMS, UCLA, and UCSF.

After PLS regression, we found five physiological and biochemical variables that could be used as candidate independent risk factor for further multivariate logistic regression analysis (Tables 4, and 5).

Using these five variables for multivariate logistic regression, we found that higher age, higher ISS scores and lower HGB were identified as independent predictors for injury-related death.

This study demonstrated that ISS-adjusted mortality of severe trauma patients admitted in a trauma center that operating according to ACS-COT level 1 standard in China is similar with that of the two major ACS-COT verified level 1 trauma centers in California, US. These data suggest that a new trauma center adopting ACS-SCOT standards in China can achieve outcomes comparable to similar trauma centers in long-standing trauma systems in US.

Table 2. Top Three Mechanisms of Injury (MOI) of Patients in Three Trauma Center

Facilitates	MOI: No.1	MOI: No.2	MOI: No.3	*P* Value
SAMS	FA (28.2%)	MM (21.8%)	EV (17.9%)	
UCLA	PB (42.6%)	FA (23.1%)	EV (18.5%)	<0.001
UCSF	FA (37.9%)	EV (29.8%)	AS (19.9%)	

Table 3. Multivariate Logistic Regression for mortality of SAMS and UCLA, UCSF

Variables	Odd Ratio	95% CI	*P* Value
UCLA	0.933	0.850-1.023	0.141
UCSF	0.978	1.023-1.063	0.599
SAMS	Reference		

Table 4. ANOVA for Variables that Screened by PLS (VIP>1)

Variables	*F* Value	*P* Value
Age	10.47	0.001
PaO_2	0.253	0.616
ISS	177.7	<0.001
HGB	13.53	<0.001
Cr	0.166	0.684

Table 5. Odd Ratio for Death Risk Factors

Candidate Risk actor	Odd Ratio	95% CI	*P* Value
Age	1.003	1.000-1.006	0.014
PaO_2	0.999	0.999-0.999	0.620
ISS	1.013	1.013-1.009	<0.001
HGB	0.997	0.997-0.995	0.020
Cr	0.999	0.999-0.999	0.217

In the past two decades, China has successfully established a pre-hospital emergency medicine service and system (EMSS)[7-8]. However there is not a uniform trauma system[9]. Currently, there are three different trauma service models operating in China. The first and most common are called the 'triage model'. In this model, all injured patients are triaged at emergency medicine departments according to the anatomic site of injury (e.g. abdominal trauma will be triaged to General Surgery, chest trauma to Thoracic Surgery, etc). For poly traumas, patients will be triaged according to the injury priorities (which injury is life threaten or most severe), surgeons from other specialties may be asked to consult in the operation room. Similarly, if the poly injury diagnose is identified during operation (e.g., a penetrating injury to the Chest is discovered during operation in an abdominal trauma patient), then a relevant surgeon will be asked to operate.

The second model is called 'integrated model', where a trauma surgery ward is established, and a group of general surgeons are designated to work on caring for abdominal trauma (in few facilitates, thoracic surgeons are included) patients. And an emergency intensive care unit could be used for severe trauma patients.

The third model is more like level one trauma centers in the US: it includes a multidisciplinary trauma surgeon team covering all specialties relevant to injury care, a designated trauma intensive care unit, protocols on poly/severe trauma service, trauma service quality evaluation and data registry[10]. To our best knowledge, trauma surgery center of the East Branch of SAMS, is the first and only facilitate operating according to this model in west China.

In China, there is no national trauma registry and no reliable national data on mortality from severe trauma[11]. According to official national mortality registry (Ministry of Health, Vital Registration) and expert's estimates, the number of injury-related deaths is around 840 000 per year in China and the average mortality of severe trauma is twice as high as in developed countries in North America or Europe[12-13]. Study by MacKenzie EJ et al. has demonstrated that the risk of death from trauma was at least 25% lower when trauma patients are cared for in a comprehensive level 1 trauma center in the US[3]. And severely injured patients take more advantages from level one trauma centers. Generally, 40% deaths are injury-related deaths[14]. In China, this represents 330 000 in-hospital deaths annually. We can therefore infer that the establishment of level 1 center may prevent at least 80 000 injury-related deaths per year.

Indeed, we have a good example from Hong Kong, a special administration region (city) of China. It established its designated trauma centers in 2004[15]. One survey has found that the establishment of designated trauma centers has successfully improved the outcome of patients[16]. The management and operation of the health system in Hong Kong is much more like a city in a developed country. But there is no any study existed to test the possibility and efficacies of a designate trauma facilitate that operating by a standard as ACS-COT level one trauma center in a developing region in China.

The patterns of mechanisms of injury were significantly different in Chengdu and other two cities in US. Severe injuries made by motorcycles were much more in Chengdu than that in US. Most of such injuries were occurred at a major express-way close-by SAMS ('San Huan Lu or the 3rd Cycle Express Way of Chengdu'). Hundreds of thousands of low-income workers take motorcycles to their workplaces every morning and and come back home in evening (speed normally excess legal limitation). For most of them did not wear hamlet. Indeed, traffic related trauma is made up the biggest portion of injury related death in China and is still increasing[12]. The result of current study indicates that relevant injury prevention program is needed urgently.

In San Francisco, we found assault is the third most common cause of severe injury. For most of them, is made by gunshot. We also found similarity in MOI patterns: for three cities, fall and enclosed vehicle appeared in top 3 most common MOI. Most of fall is occurred in construction workplace in Chengdu.

We introduced partial square least (PLS) as a tool to establish mortality risk factors screening model. Traditionally, in a clinical multivariate data analysis process, researchers chose candidate factors for logistic regression by empirically or used univariate analysis. In these two scenarios, the logistic model becomes unstable when there is strong dependence among predictors so that it seems that no one variable is important when all the others are in the model (multi-collinearity challenge)[6]. It is reasonable to conclude that in this mode, estimation of the model parameters given by most statistical packages becomes too inaccurate because of the need to invert near-singular and ill-conditioned information matrices. As a consequence, the interpretation of the relationship between the response and each explicative variable in terms of odds ratios may be erroneous[7]. PLS regression is an advanced multivariate statistical model that was developed by Wold H et al.[19]. It is widely used in various disciplines such as computational chemistry, metabolomics, sensory evaluation, financial and economics[17-19]. The robustness of this method on resolving dimension disaster is well demonstrated. Hence we used it to improve the modeling process for trauma-related mortality risk factor identification. In our new model, we found that elder age, high ISS scores and low hemoglobin were made up independent predictor of death outcome.

Despite the fact that this work is the first trauma service quality comparison study between China and the US, the limitation of this work is that the amount of the samples from SAMS is significantly less than the other two US trauma centers. Comparing with the other two US trauma centers with decades of operation history, 2010 is the first operating year of trauma center of SAMS, during which not so many severe trauma patients were transported to SAMS. In the year of 2011 and 2012, the amount of severe trauma patients who admitted to SAMS was increasing. A further study is now being initiated that aims to evaluate the trauma service quality in these three years (2010-2012) and we will report the result of this study in the near future.

In summary, the performance of SAMS trauma center is comparable to two ACS-COT verified level 1 trauma centers in the US. Considering China's demographic scale and speedy development, the trauma related death is increasingly becoming a major public health challenge. The present study suggests that the adoption of ACS-COT standard in the establishment, accreditation and operations of level 1 trauma centers for metropolitan areas in China is a reasonable solution for the reduction of injury related death.

*This work was supported by grants from Sichuan Department of Science and Technology (No. 2011SZ0139, 2011SZ0336, 2012SZ0181), Chengdu Municipality of Bureau of Science and Technology (No. 11PPYB099SF-289, 12PPYB181SF-002) and grants from Sichuan Department of Health (No.100552 and No. 100553).

#Correspondence should be addressed to: 1) ZENG Jun, zengjun@medmail.com.cn; 2) JIANG Hua, cdjianghua@gmail.com; 3) Mitchell Jay COHEN, mcohen@sfghsurg.ucsf.edu; 4) Henry CRYER, HCryer@mednet.ucla.edu

†These authors contributed equally to this work.

Biographical note of the first author: CAI Bin, male, born in 1969, MBBS, majoring in trauma surgery and emergency medicine.

Received: January 14, 2014;
Accepted: February 27, 2014

REFERENCES

1. Group for Trauma Emergency Care and Multiple Injuries, Trauma Society of Chinese Medical Association. Current state and future perspectives of trauma care system in mainland China. Injury, 2011; 42, 874-8.
2. MacKenzie EJ, Rivara FP, Jurkovich GJ, et al. A national evaluation of the effect of trauma-center care on mortality. N Engl J Med, 2006; 354, 366-78.
3. Celso B, Tepas J, Langland-Orban B, et al. A systematic review and meta-analysis comparing outcome of severely injured patients treated in trauma centers following the establishment of trauma systems. J Trauma, 2006; 60, 371-8.
4. Chengdu Bureau of Statistics. Annual Statistic Report of 2010. http://www.cdstats.chengdu.gov.cn/detail.asp?ID=67369&ClassID=020703. Accessible at January 12, 2013.
5. Yang H, Jiang H, Sun MW, et al. Establishing a trauma outcome prediction model using Partial Least Square algorithm: a methodological study. Sichuan Med J, 2011; 32, 449-52. (In Chinese)
6. Aguilera A, Escabias M, and Valderrama MJ. Using principal components for estimating logistic regression with high-dimensional multicollinear data. Comput Stat Data Anal, 2006; 50, 1905-23.
7. Jiang GY. Twenty years of Chinese emergency medicine. Chin J Emerg Med, 2006; 15, 485-6. (In Chinese)
8. He XH and Li CS. Current status of China emergency medicine and its future. Practical Journal of Clinical Medicine, 2006; 3, 8-10. (In Chinese)
9. Fitzharris M, Yu J, Hammond N, et al. Injury in China: a systematic review of injury surveillance studies conducted in Chinese hospital emergency departments. BMC Emerg Med, 2011; 11, 18.
10. Committee on Trauma, American College of Surgeons. Resources for optimal care of the injured patient, 2006. American College of Surgeons, Chicago, IL 60611, 2006.
11. Fitzharris M, Zhong W, Myburgh J, et al. The status of trauma registry systems in Chinese hospitals. Inj Prev, 2011; 17, 419-21.
12. Wang SY, Li YH, Chi GB, et al. Injury-related fatalities in China: an under-recognised public-health problem. Lancet, 2008; 372, 1765-73.
13. Xin Hua News Agency: Injury-related mortality is too high in

China, experts called to enhance trauma care service. http://news.xinhuanet.com/health/2011-10/22/c_122186100.htm. Accessible at January 12, 2013.
14. Kleber C, Giesecke MT, and Tsokos M. Overall Distribution of Trauma-related Deaths in Berlin 2010: Advancement or Stagnation of German Trauma Management? World J Surg, 2012; 36, 2125-30.
15. Leung GK, Chang A, Cheung FC, et al. The first 5 years since trauma center designation in the Hong Kong special administrative region, People's Republic of China. J Trauma, 2011; 70, 1128-33.
16. Cheng CH, Graham CA, Gabbe BJ, et al. A comparison of trauma care in Victoria, Australia, and Hong Kong, China. Ann Surg, 2008; 247, 335-42.
17. Wold S, Ruhe A, Wold H, et al. The collinearity problem in linear regression. The partial least squares (PLS) approach to generalized inverses. SIAM, 1984; 5, 735-43.
18. Wold S, Sjöström M, and Eriksson L. PLS-regression: a basic tool of chemometrics. Chemometrics and Intelligent Laboratory Systems, 2001; 58, 109-30.
19. Fonville JM, Richards SE, Barton RH, et al. The evolution of partial least squares models and related chemometric approaches in metabonomics and metabolic phenotyping. J Chemometrics, 2010; 24, 636-49.