



Universiteit
Leiden
The Netherlands

Polytrauma patient management: Processes and performance in the Netherlands and beyond

Dijkink, S.

Citation

Dijkink, S. (2020, October 29). *Polytrauma patient management: Processes and performance in the Netherlands and beyond*. Retrieved from <https://hdl.handle.net/1887/137986>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/137986>

Note: To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/137986> holds various files of this Leiden University dissertation.

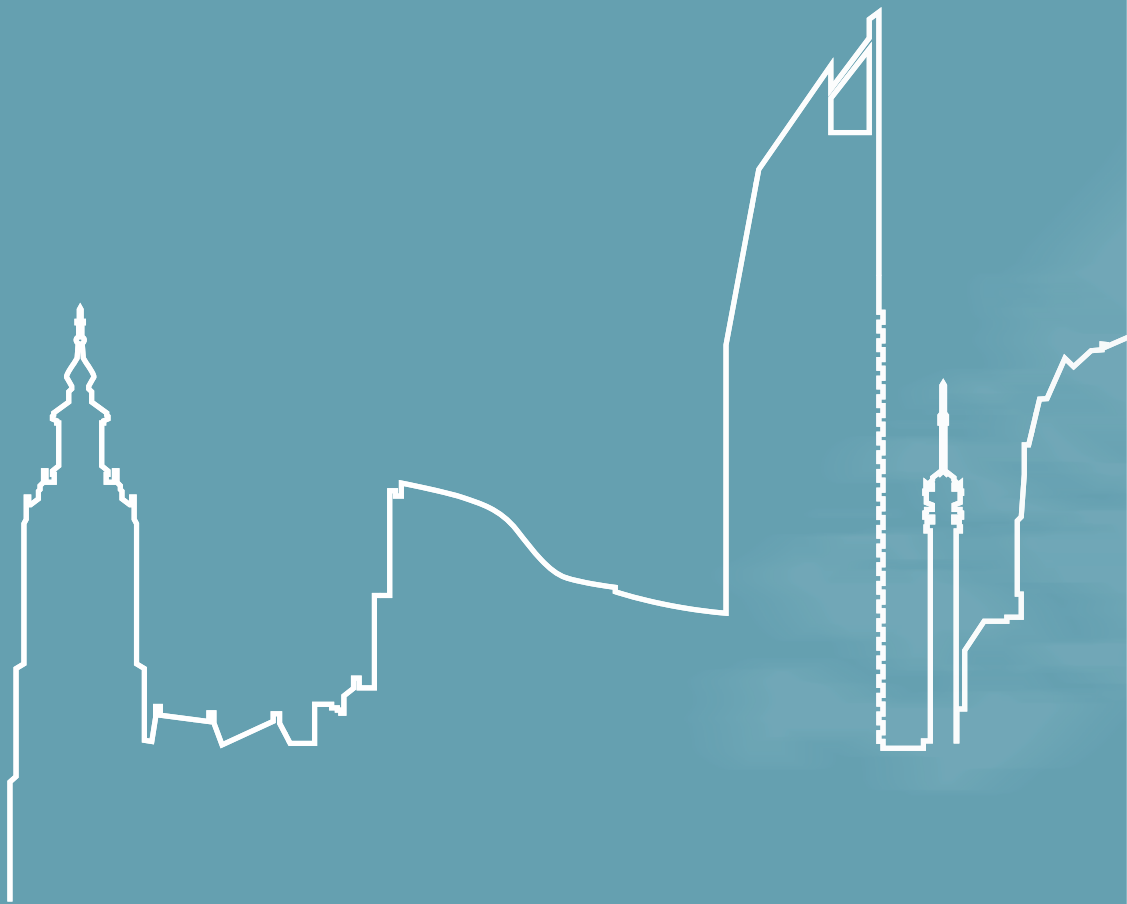
Author: Dijkink, S.

Title: Polytrauma patient management: Processes and performance in the Netherlands and beyond

Issue Date: 2020-10-29

PART I

EVALUATION OF TRAUMA CARE SYSTEMS



2

Trauma systems around the world: A systematic overview



S. Dijkink
C.J. Nederpelt
P. Krijnen
G.C. Velmahos
I.B. Schipper

Journal of Trauma and Acute Care Surgery. 2017 Nov;83(5):917-925.

ABSTRACT

Background

Implementation of trauma care systems has resulted in improved patient outcomes, but international differences obviously remain. Improvement of care can only be established if we recognize and clarify these differences. The aim of the current review is to provide an overview of the recent literature on the state of trauma systems globally.

Methods

The literature review over the period 2000 to 2016 was conducted following the Preferred Reporting Items for Systematic reviews and Meta-Analyses guidelines. Prehospital care, acute hospital care and quality assurance were classified using the World Health Organization Trauma System Maturity Index in four levels from I (least mature) to IV (most mature).

Results

The search yielded 93 articles about trauma systems in 32 countries: 23 high-income (HI), 8 middle-income (MI) countries and 1 low-income (LI) country. Trauma-related mortality was highest in the MI and LI countries. Level IV prehospital care with Advanced Life Support was established in 19 HI countries, in contrast to the MI and LI countries where this was only reported in Brazil, China, and Turkey. In 18 HI countries, a Level III/IV hospital-based trauma system was implemented, whereas in nine LI- and MI countries Level I/II trauma systems were seen, mostly lacking dedicated trauma centers and teams. A national trauma registry was implemented in 10 HI countries.

Conclusion

Despite the presence of seemingly sufficient resources and the evidence-based benefits of trauma systems, only nine of the 23 HI countries in our review have a well-defined and documented national trauma system. Although 90% of all lethal traumatic injuries occur in middle and LI countries, according to literature which our study is limited to, only few of these countries hold formal trauma system or trauma registry. Much can be gained concerning trauma systems in these countries, but unfortunately, the economic situation of many countries may render trauma systems not at their top priority list.

INTRODUCTION

Trauma is a major health problem worldwide and the leading cause of death in people younger than 45 years.¹ Each year about 5 million people die as a result of traumatic injuries, of which 90% occur in low-income (LI) and middle-income (MI) countries.² A study by Mock et al.³ showed that mortality due to trauma is inversely related to the economic level of a country. According to their results, an injured patient in Ghana is almost twice as likely to die as a patient with the same injuries in the United States. These differences are even more dramatic for multiple injuries patients (Injury Severity Score ≥ 16), for whom the mortality rate is six times higher in LI countries compared with high-income (HI) countries.⁴

In HI countries, the implementation of trauma care systems has led to a significant decrease in mortality and disability. It is estimated that improvements in trauma care systems worldwide may prevent about one third of injury-related deaths.¹ However, these improvements come at a cost, and the economic situation of many countries may render trauma systems not at their top priority list. The World Health Organization (WHO) published guidelines for essential trauma care and for trauma quality improvement programs to reduce the trauma-related mortality differences between the HI and LI countries.² Still, the management of trauma requires personnel for a preferably multidisciplinary approach, not only within the hospital, but also for prehospital care. The American College of Surgeons-Committee on Trauma (ACS-COT) identified several aspects as crucial for optimal trauma care.⁵ Education, adequate resources, and an organized system need to be in place. The presence or absence of all of these individual parts of the chain of trauma care determines the potential for existence of a trauma system. The goal of this review is to give an overview of the similarities and differences of trauma systems around the world, based on the available literature. In this review, we focused on prehospital care, acute hospital care, and quality assurance.

MATERIALS AND METHODS

The review was conducted according to the preferred reporting items for systematic reviews and meta-analyses statement.⁶

Search Strategy and Article Selection

An extensive literature search in PubMed was performed with the help of an experienced medical librarian in June 2016. We used the following search terms: "Traumatology/organization and administration," "trauma management," "trauma system," "emergency medical services," "emergency medical service," "trauma care system," "trauma care," "prehospital

care," "trauma registry," "national," "nationwide," "global," "worldwide." The exact search strategy is provided in the Appendix. Title and abstract of identified articles were screened for relevancy. Articles from 2000 until June 2016 were included. The full text of selected articles was retrieved. Articles providing descriptive national data on trauma epidemiology, prehospital care, acute hospital care, and quality assurance were included in the definite selection. To provide a comprehensive overview, we aimed to include at least one article from a country in every continent. Articles that primarily focused on pediatric trauma systems were excluded. Also, when an article provided information about just one parameter (prehospital care, acute hospital care, or quality assurance), this article was excluded from the review. Furthermore, only articles in English, German, and Dutch were included. The reference lists of the included articles were screened for additional relevant articles. Also, official websites mentioned in the publications (ACS, WHO, German Trauma Register, Canadian Institute for Health Information) were accessed to obtain recent and valid data.

Classification of Trauma Systems

The level of prehospital care, acute hospital care, and quality assurance in each country was scored according to the Trauma System Maturity Index. This index was developed by the WHO to assess and determine the maturity of trauma systems within countries, according to a classification in four levels ranging from Level I maturity (least mature) to Level IV maturity (most mature) (Table 1).⁷ It is of interest to note that this classification is the opposite of the classification of trauma centers by the ACS-COT, in which the Level I trauma centers provide the highest level of trauma care. If there were differences noted in trauma system implementation within countries, such as in the United States, we generalized the information based on the available literature to be able to classify the country within one level.

Prehospital Care

The level of prehospital trauma care and the level of education and training of emergency medical services (EMS) personnel are both important factors for the outcome of patients.⁸ Level of prehospital care was scored according to the Trauma System Maturity Index (Table 1). Levels I and II of the prehospital care maturity index reflect "unorganized prehospital care." In these levels, no formal Emergency Medical Service (EMS) system is implemented, and patients are transported to the hospitals mostly by private or public vehicles.⁹ Levels III and IV of the prehospital care maturity index reflect well-established and organized prehospital care systems with the difference that in Level IV systems, a formal lead agency and legislative system is established.

Two types of EMS systems and prehospital care training were distinguished, based on an article by Roudsari et al.⁹ In Basic Life Support (BLS) EMS systems, noninvasive care is given by emergency medical technicians, whereas in Advanced Life Support (ALS) EMS

systems, more sophisticated and invasive therapy is given by either medical technicians or physicians (Doc-ALS). For countries where prehospital care is not provided by personnel with a training, the type of EMS system was scored as “no formal training.”

Acute Hospital Care

The level of facility-based trauma care was scored according to the WHO Trauma System Maturity Index (Table 1). In contrast to the ACS-COT criteria, the Level I and II maturity categories of the WHO Trauma System Maturity Index concerns acute hospital care for which no formal hospital-based trauma system is implemented. Also, resources are not always available, and the methods of referring patients are not always clear. Level III hospital-based care provides comprehensive trauma care but without a formal network, with a lead agency but no formal accreditation and verification by the (federal) government in place. In Level IV hospital-based trauma care verification and accreditation by the government is in place, and a lead agency is established with mandate to supervise trauma care. Also, the presence of dedicated Level I trauma centers according to the ACS-COT guidelines and of dedicated trauma teams were scored.

Education and Training

Besides the level of the facility-based trauma care, the level of education and training of hospital personnel according to the WHO Trauma System Maturity Index (Table 1) and the implementation of Advanced Trauma Life Support (ATLS) or equivalent courses were scored for each country.

Quality Assurance

The level of quality assurance was scored according to the WHO Maturity Index (Table 1). Also, the presence or absence of a trauma registry was recorded, since this is considered to be a key element of a mature trauma care system and to form the basis of quality assurance programs.¹⁰

Data Extraction

Two independent readers (S.D. and C.N.) classified the trauma systems according to the parameters described above. They classified data from the included papers and other mentioned sources using a predesigned data extraction form. Disagreement on scores was resolved by consensus discussion, if needed with involvement of the senior authors.

The trauma-related mortality rate in each country was derived from data of the WHO.¹¹

The development of trauma systems comes at a cost, and the economic welfare is possibly related to the development of trauma systems. Therefore, the economic income level of the countries described in the selected articles was classified according to data of the World Bank.¹²

Table 1. WHO Maturity Index Trauma System⁷

| | Level I | Level III | Level III | Level IV |
|----------------------------|--|---|---|---|
| Prehospital Trauma Care | <ul style="list-style-type: none"> No mapping of prehospital resources No formal EMS, unavailability or duplication of prehospital services No defined communication system | <ul style="list-style-type: none"> Prehospital resources are identifiable No coordination between public and private providers of prehospital care No universal access number, weak links of communication | <ul style="list-style-type: none"> Formal EMS present Universal Access Number available Coordination seen between various agencies for prehospital care delivery Well defined communication | <ul style="list-style-type: none"> Formal EMS controlled by a lead agency National universal access number Legislative mechanism in place to govern EMS and allow universal coverage |
| Education and Training | <ul style="list-style-type: none"> No identified health personnel to offer primary trauma care in community | <ul style="list-style-type: none"> Identified health personnel in the community for emergency trauma care No definite training requirement for health workers or ambulance personnel | <ul style="list-style-type: none"> Health professionals and paramedics are trained in provision of emergency trauma care Training courses are available for trauma education | <ul style="list-style-type: none"> Educational standards and training for emergency trauma care providers laid down Licensing and renewal norms for different levels of paramedics are in place |
| Facility based Trauma care | <ul style="list-style-type: none"> Role of secondary and tertiary facilities unclear Health facilities lack human and physical resources No clear referral linkages | <ul style="list-style-type: none"> Roles of various health care facilities are clear Referral linkages are present No documentation or needs assessment of facilities in line with EsTC guidelines No lead agency in the system | <ul style="list-style-type: none"> Health facilities in the systems are assessed in line with EsTC guidelines Guidelines and documented human and physical resources are available and ensured round the clock Lead agency present | <ul style="list-style-type: none"> Mechanism of hospital verification and accreditation is in place through Ministry of Health or professional bodies Lead agency established with mandate to supervise trauma care |
| Quality Assurance | <ul style="list-style-type: none"> No injury surveillance or registry mechanism in place to get comprehensive data | <ul style="list-style-type: none"> Injury data available but no formal attempts to document and analyze the data No initiative for Quality Assurance program | <ul style="list-style-type: none"> Basic Quality Assurance programs in line with EsTC guidelines Guidelines are in place | <ul style="list-style-type: none"> Formal Quality Assurance programs are in place and are mandated in prehospital and facility based services |

EsTC, Essential Trauma Care Project.

RESULTS

Selection of Articles

The search identified 2,728 articles. After removal of duplicates and screening the titles and abstracts for relevance, 231 full-text articles were screened for eligibility. After application of the exclusion criteria, 63 articles on trauma systems in 32 countries were included (Fig. 1). Additionally, 30 references were identified through the other sources. Articles with data from countries in all continents were included. All 14 included European countries as well as two North-American countries and two countries in Oceania were classified as HI. Of the included countries in Africa, one was classified as HI, one as LI, and two as MI countries. Four countries in Asia were classified as HI, and five as MI (Table 2). The trauma-related mortality rates are summarized also by sex in Table 2.

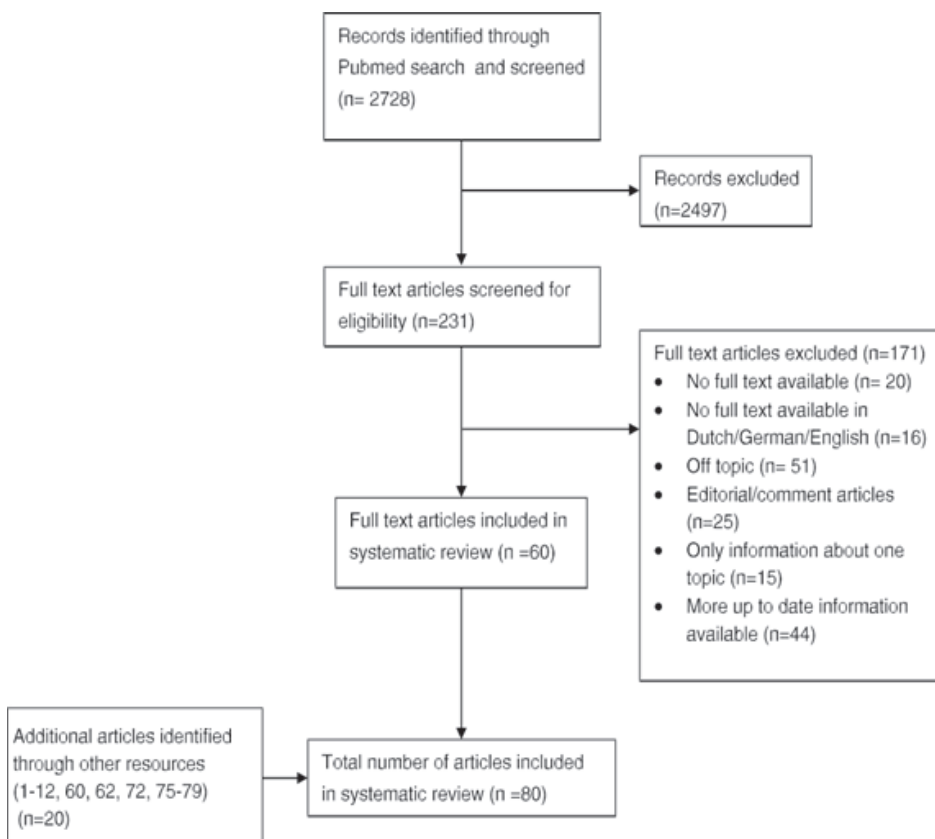


Figure 1. Flowchart search strategy

Prehospital Care

In all low and middle economic income level countries described in this review, a well-organized prehospital care system is absent or still in its early stages, and a substantial part of the injured patients is not transported to hospital by specialized EMS vehicles (Table 2).^{13,16,36} In most of these countries, the persons involved in the transport of injured patients had not followed any form of certified training.^{19,25,36} Differences in access to prehospital care between the cities and rural areas were reported for some countries.^{19,27} The Seychelles Islands formed an exception in this group being an HI country lacking a prehospital system.¹⁵

Levels III and IV of the prehospital care were typically found in HI countries and upcoming upper MI countries, such as Brazil, China, and Turkey (Table 2). In China and Turkey, an educational system for paramedics was implemented, and in Brazil, the government was prioritizing education programs on emergency medicine.^{20,37,68} In these EMS systems, certified EMS personnel provided BLS or ALS. In many countries with formally trained EMS personnel, such as New Zealand, Croatia, and Saudi Arabia, the organization of prehospital care, and type and skills of EMS personnel was dependent on the national geography, with a lower level of life support available in the more rural areas.^{33,40,72} Although the prehospital care trauma systems in HI countries were well established and organized, they were not entirely similar. Differences existed not only with regard to EMS personnel training skills but also in the organization of prehospital care. In many European countries, ambulances were staffed with both highly trained paramedics and physicians, depending on the severity of the injuries^{29,38,41,45,50,54,57,59,60,63} whereas in, for example, the United States, Hong Kong, and Japan, the EMS system was entirely run by paramedics.^{23,31,65} In most countries, ground ambulances formed the core of the EMS system. Differences were noticed in the number of helicopters and dispatch criteria for helicopter EMS. Mostly, helicopters were used to enable rapid transportation of severely injured patients to the trauma center.^{63,65} The use of helicopters was not only dependent on the earlier mentioned criteria but also on the geographical differences between countries. Helicopters were used less frequently in the smaller and more densely populated countries, whereas countries, such as Canada, Australia, and the Scandinavian countries with less densely populated areas relied more on air transport.^{8,41,45,46,51,60,63,70}

Acute Hospital Care

Facility-Based Trauma Care

Levels I and II hospital-based trauma care based on the WHO Trauma System Maturity Index was mostly found in LI and MI countries with maturing trauma systems, such as India, Iran, Saudi Arabia, Brazil, Thailand, Ghana, and China (Table 2). In many countries, a formal hospital trauma care pathway was lacking and surgical residents or general

surgeons were responsible for the initial care of the injured patients. Their availability, however, was far less than 24/7 in many hospitals.^{14,19,21,36} Differences between hospitals in the urban and rural areas were seen within countries, well-trained personnel and advanced facilities were available in large hospitals located in more urban areas, resembling level III facility based care, but were not available in rural regions of, for example, Saudi-Arabia, India, and Iran.^{26,28,34}

In most HI countries, some form of hospital trauma care pathway was documented. In WHO Trauma System Maturity Index Level III hospital-based care, severely injured patients were often attended to by a physician trained in emergency medicine or by a general surgeon. Several differences between countries were found. For example, a trauma team was implemented in 88% of the hospitals that receive trauma patients in Norway, but only in 20% of those hospitals in Finland.^{41,42,53} The care in the majority of trauma receiving hospitals is organized ad hoc, mostly without having legislation and protocols for transfer, triage and management in place.^{37,38,40,44,50,51,58,72,73} A different situation is found in South Africa, which had seven specialized trauma centers spread over the country with an experienced general surgeon and immediately available surgical facilities, however, without a formal network.¹⁷

Level IV hospital-based care according to the WHO Trauma System Maturity Index was primarily seen in the HI countries with dedicated trauma centers and trauma teams. Many countries based their trauma system and the distribution of trauma centers on the criteria set by the American College of Surgeons-Committee on Trauma (ACS-COT) published in 1999.⁵ As a consequence of the implementation of these guidelines, trauma care became increasingly regionalized first in the United States, and subsequently in many other countries, such as Canada, Hong Kong, Australia, The United Kingdom, Israel, the Netherlands, and Germany.^{24,45,46,54,61,63,66,70} However, other organizational models are seen, for instance, in Japan, where a three-tiered trauma care system has been implemented.³² Despite the well-implemented trauma systems in these countries, there are still differences in organization of trauma care and the distribution of trauma centers due to local policies, population density, and geographical differences.^{46,63} At a facility base level, it was seen that what all these countries have in common is that they implemented a system with dedicated trauma centers and dedicated trauma teams (Table 2). Various studies in numerous countries have shown that inclusive trauma systems result in an overall lower mortality risk for severely injured patients.^{55,56,74}

Education and Training

ATLS courses are given in 28 of the 32 countries included in this review⁷⁵, although this training has not been implemented nationwide in many LI and MI countries. However, efforts for improvement are undertaken, for instance, in India which participated in the Essential Trauma Care Project since 2003 and in Saudi Arabia where a trauma system

Table 2. Trauma System Characteristics

| Continent/ Country | Economic income level ¹² | Trauma- related mortality per 100,000 Population ¹¹ | Prehospital care | | Acute Hospital Care | |
|-------------------------------|---|--|---|--|--|---|
| | | | WHO level of Prehospital Trauma Care ⁷ | Education and training of EMS Personnel ⁹ | WHO level of Facility Based Trauma Care ⁷ | Dedicated level-1 trauma centers |
| Africa | | | | | | |
| Ghana ^{13,14} | Lower Middle | ♂ 100.1 ♀ 41.1 | I | No formal training | I/II | No |
| Seychelles ¹⁵ | High | ♂ 81.7 ♀ 17.2 | I/II | No formal training | I/II | No |
| South Africa ¹⁶⁻¹⁸ | Upper Middle | ♂ 93.9 ♀ 34.7 | II/III | No formal training | II/III | Yes |
| Zimbabwe ¹⁹ | Low | ♂ 86.8 ♀ 26.9 | II | No formal training | I | No |
| Asia | | | | | | |
| China ²⁰⁻²² | Upper Middle | ♂ 86.3 ♀ 53.1 | III | ALS/BLS | I/II | No |
| Hongkong ^{23,24} | High | ♂ n/a ♀ n/a | IV | ALS | IV | Yes |
| India ^{25,26} | Lower Middle | ♂ 103.0 ♀ 26.6 | I/II | No formal training | I/II | No |
| Iran ^{27,28} | Lower Middle | ♂ 108.4 ♀ 43.2 | I/II | No formal training | I/II | No |
| Israel ^{29,30} | High | ♂ 37.8 ♀ 17.4 | IV | ALS/BLS | IV | Yes |
| Japan ^{31,32} | High | ♂ 76.1 ♀ 46.4 | IV | ALS | IV | Yes |
| Saudi Arabia ³³⁻³⁵ | High | ♂ 89.9 ♀ 26.9 | II | BLS | I/II | No |
| Thailand ³⁶ | Upper Middle | ♂ 169.9 ♀ 46.3 | I/II | No formal training | II | No |
| Turkey ³⁷ | Upper Middle | ♂ 42.8 ♀ 13.6 | IV | ALS | II/III | No |
| Europe | | | | | | |
| Belgium ^{38,39} | High | ♂ 72.7 ♀ 44.6 | IV | ALS | III | No |
| Croatia ^{39,40} | High | ♂ 92.1 ♀ 45.1 | III | ALS/BLS | III | Yes |
| Finland ⁴¹⁻⁴³ | High | ♂ 114.7 ♀ 45.6 | IV | ALS | III | No |
| France ⁴⁴ | High | ♂ 74.1 ♀ 44.5 | IV | ALS | III | No |
| Germany ⁴⁵⁻⁴⁷ | High | ♂ 48.6 ♀ 29.3 | IV | ALS | | Yes |

| Trauma team | WHO level of Education and Training ⁷ | ATLS or equivalent course ⁶⁰ | Quality assurance | |
|-----------------------|--|---|---|--|
| | | | WHO level of Quality Assurance ⁷ | Trauma registry |
| | | | I/II | No national trauma registry |
| No | II | Yes (Mass Casualty Incident Responder Course) | | |
| No | II/III | Yes | II | Hospital-based registries |
| | II | | | |
| | | | II | Initiatives for, Chinese National Injury Surveillance System |
| Yes | IV | Yes | III | Trauma registries in trauma centres, no central system |
| No | II | Yes | II | Hospital based registries |
| No | II | Yes | I | No trauma registry established. |
| Yes | IV | Yes | IV | Israel National Trauma Registry |
| No | IV | Yes (and JATEC) | IV | Japan Trauma Data Bank |
| | I/II | Yes | II | Currently building a nationwide surveillance system for injury |
| No | II | Yes | | |
| No | III | No (Turkish Association for Trauma and Emergency) | | |
| No | IV | Yes (European trauma course) | | |
| No | II/III | No | III | Joining EuroTARN |
| Yes (20% trauma team) | III | Yes | III | Hospital based registries, some hospitals join TARN |
| No | III | Yes | III | Regional and hospital based Registries |
| Yes | IV | Yes | IV | TraumaRegister DGU |

Table 2. Trauma System Characteristics (continued)

| Continent/ Country | Economic income level ¹² | Trauma- related mortality per 100,000 Population ¹¹ | Prehospital care | | Acute Hospital Care | |
|----------------------------------|---|--|---|--|--|---|
| | | | WHO level of Prehospital Trauma Care ⁷ | Education and training of EMS Personnel ⁹ | WHO level of Facility Based Trauma Care ⁷ | Dedicated level-1 trauma centers |
| Greece ^{48,49} | High | ♂ 54.0 ♀ 14.3 | III | ALS | | No |
| Italy ^{39,50} | High | ♂ 49.7 ♀ 32.6 | IV | ALS | | No |
| Ireland ^{51,52} | High | ♂ 52.6 ♀ 21.7 | III | ALS/BLS | | No |
| Norway ^{41,43,53} | High | ♂ 62.3 ♀ 39.3 | IV | ALS/BLS | | No |
| the Netherlands ⁵⁴⁻⁵⁶ | High | ♂ 36.8 ♀ 28.2 | IV | ALS | | Yes |
| Scotland ^{57,58} | High | ♂ 43.2 (= UK numbers) ♀ 26.8 | III | ALS | | No |
| Spain ⁵⁹ | High | ♂ 45.6 ♀ 26.4 | IV | ALS | | No |
| Sweden ^{41,43} | High | ♂ 64.1 ♀ 37.6 | IV | ALS | | No |
| United Kingdom ⁶⁰⁻⁶² | High | ♂ 43.2 ♀ 26.8 | IV | ALS | | Yes |
| North America | | | | | | |
| Canada ^{63,64} | High | ♂ 52.7 ♀ 29.9 | IV | ALS | | Yes |
| USA ⁶⁵⁻⁶⁷ | High | ♂ 83.3 ♀ 38.0 | IV | ALS | | Yes |
| South America | | | | | | |
| Brazil ^{68,69} | Upper Middle | ♂ 125.7 ♀ 27.5 | II/III | BLS | | No |
| Oceania | | | | | | |
| Australia ^{24,67,70,71} | High | ♂ 50.0 ♀ 24.8 | IV | ALS | | Yes. |
| New Zealand ⁷¹⁻⁷³ | High | ♂ 56.8 ♀ 28.2 | III | ALS/BLS | | Yes |

JATEC, Japan advanced trauma evaluation and care course;
NTRC, National Trauma Registry Consortium; STAG, Scotland Trauma Audit Group;
TARN, Trauma Audit & Research Network.

| Trauma team | WHO level of Education and Training ⁷ | ATLS or equivalent course ⁶⁰ | Quality assurance | |
|-------------|--|--|---|--|
| | | | WHO level of Quality Assurance ⁷ | Trauma registry |
| No | II/III | Yes | II | Hospital and multiregional registries |
| | IV | Yes | III | Hospital based registries, initiatives to implement national trauma registry, EuroTARN |
| | | Yes | IV | Collaborating with the TARN, implementing Major Trauma Audit |
| Yes | IV | Yes | III | Individual or hospital based registries, working toward national registry (Kvalitetsregister i traumasjukvården (Kvittra)) |
| Yes | IV | Yes | IV | National Trauma Registry |
| No | III | Yes | IV | STAG |
| No | III | Yes | II | No nationwide trauma registry, initiatives in autonomous regions |
| | IV | Yes | III | Individual or hospital based registries, initiatives for national registry |
| Yes | IV CNIII | Yes | IV | TARN |
| Yes | III | Yes | III | Canadian National Trauma Registry (1997–2014), currently regional trauma registries |
| Yes | IV | Yes | IV | National Trauma Data Bank |
| | | Yes | I/II | No National Trauma Data Bank |
| Yes | IV | Yes (and Emergency Management of Severe Trauma course) | IV | NTRC |
| No | III | Yes (and Emergency Management of Severe Trauma course) | IV | NTRC |

with internationally accepted trauma courses was being implemented since 2010.^{26,34} Although, in South Africa, a similar situation is seen, where not every surgeon is being trained according to ATLS course, this seems to be compensated for by the high exposure and experience with trauma.¹⁷

In the HI countries, differences regarding the implementation of trauma courses were noticed as well. Some countries, such as Turkey, have implemented their own course or combined the ATLS course with another course. Examples of such courses included the Emergency Management of Severe Trauma in Australia and New Zealand, the Japan Advanced Trauma Evaluation and Care course in Japan and the European Trauma Course in Belgium.^{37,38,72,73} The availability of a training program in a country did not necessarily mean that all trauma care doctors in a hospital were trained accordingly.^{40,41,45,48,54}

Quality Assurance

Despite the major trauma burden, in LI and MI countries, trauma registries are generally not part of the trauma care system (Table 2).⁷⁶ Apart from local and private initiatives in some of these countries, there was no nationwide trauma registry in India, South Africa, Iran, Brazil, Saudi Arabia, Spain, Ghana, and China at the dates of publication of these articles.^{14,18,20,22,26,28,69} In many countries, the need for a trauma registry is acknowledged, for example, in 2015, Saudi Arabia initiated plans for a nationwide trauma registry.³⁵

Mainly, the HI countries had nationally implemented trauma registries based on strict criteria, which subsequently would be classified as a Level IV trauma registry.^{24,30,45,58,67} Several international collaborations in the field of trauma registries were seen. Some contribute to the German Trauma Register-DGU, United Kingdom and Ireland are collaborating within the Trauma Audit & Research Network, Australia and New Zealand established the binational National Trauma Registry Consortium, and the Scandinavian countries are collaborating in the Scandinavian Trauma Registry.^{43,47,51,62,67,71} Some European countries that were classified as having Level III quality assurance, such as Croatia and Italy, did not have a national trauma registry but worked together since 2007 in creating a European database, the EuroTARN.³⁹ In other countries without a nationwide trauma registry, local initiatives were present, for example, in Greece, only 40% of the health care facilities contributed to the trauma registry, and in 2009, some autonomous regions in Spain had shown initiatives to implement a registry.^{49,59} In contrast, the Canadian National Trauma Registry, which was established in 1997, was closed in 2014 for diverse reasons, such as availability of data elsewhere and changing priorities.⁶⁴

DISCUSSION

The goal of this article is to give an international overview of the trauma systems worldwide, based on the available literature over the past 16 years. Despite internationally accepted standards and several initiatives by the WHO, it is apparent that there are still important differences between the organization and maturity of trauma care systems worldwide. Mature trauma systems are implemented in all included HI countries, whereas these are absent in most of the LI and MI countries, despite their high trauma burden. It seems that improvements in trauma care are, at least in part, related to a country's level of economic welfare. Mock et al.³ suggested that increased economic welfare most likely first led to a reduction of prehospital trauma deaths due to improvements in prehospital care. This assumption is supported by historic data from the United States, where a decrease in prehospital deaths was seen over time.⁷⁷ On the other hand, a global rise in motor vehicle ownership in countries with increasing welfare is expected to lead to an increase in deaths due to road traffic crashes from 1.3 million deaths currently to 1.9 million deaths worldwide in 2020.⁷⁸ Although this is not a part of the trauma system, also preventive measures including legislation and improvement of infrastructure are needed to decrease trauma-related mortality in upcoming economies.⁷⁸ Research has shown that measures aimed at prevention, prehospital care, and in-hospital care are cost-effective in decreasing mortality of injured patients.³

Several initiatives, such as the Essential Trauma Care Project, have been initiated by the WHO to improve trauma care worldwide with affordable and reasonable minimum standards of care. Basic innovations have had a major effect on trauma care which offers leads for further development of trauma systems in several countries. For example, the collaboration between the government of Ghana and the Essential Trauma Care Project has led to initiatives to implement a National Ambulance.⁷⁹ A systematic review by La-Grone et al.⁸⁰ concerning the implementation of the guidelines of the Essential Trauma Care project showed that 40% of all LI countries and 30% MI countries documented some form of implementation of the Essential Trauma Care Project Guidelines. However, in only 14% of the countries, this implementation led to the formulation of policy. This trend is also seen in the implementation of trauma registries. It has been acknowledged worldwide that trauma registries are important for assessing and evaluating the development and improvement of global trauma care and quality assurance programs.¹⁰ However, this review showed that a nationwide trauma registry is absent in most countries, especially in MI and LI countries (Table 2). The implementation of a trauma registry not only requires a central organization but also a digital infrastructure and trained staff. Subsequently maintaining an implemented trauma registry is costly.¹⁰ However, the lack of any form of trauma registry has a negative impact on the development of a mature trauma system and the implementation of rules and regulations concerning trauma

care.²⁶ The development and worldwide implementation of an internationally accepted minimum set of data on trauma patients could facilitate and improve future trauma care improvement projects.

Limitations

This review has some limitations. First, we used the most commonly used instrument for classifying trauma systems, the WHO trauma system maturity index.⁷ We had difficulty, however, to apply the level criteria of the index for some countries information. Especially if specific criteria were not mentioned and some of the criteria within one level were not met. If we hesitated between two levels, we chose to assign the higher level. A classification system with less composite levels and clearer criteria would help to classify trauma systems in a less ambiguous manner. For countries in which trauma care is organized on a federal or regional level, such as the United States, possible differences in the levels of care between the federal or regional trauma systems could not be identified due to a lack of data. Second, the literature on which we based the review was published over a period of 16 years. Although we did our best to retrieve the most up-to-date information available and did not include articles published before to the year 2000, some countries will have improved their trauma systems since the publication of the selected articles in this review. Improvements that had not been published and of which we were not aware could thus not be addressed in this review. Similarly, some countries may not have published about their trauma system at all. Finally, the methodological quality of the selected articles could not be assessed, because we are not aware of an instrument that can be used to evaluate the quality of this type of descriptive literature.

CONCLUSION

Despite the presence of seemingly sufficient resources and the evidence-based benefits of trauma systems, only nine of the 23 HI countries in our review have a well-defined and documented national trauma system. In most MI and LI countries, a formal trauma system is absent despite the high trauma burden in these countries. Much can be gained by improving trauma systems in these countries, but unfortunately, it also is apparent that trauma system development depends, at least in part, on the economic welfare.

REFERENCES

1. Mock C, Joshipura M, Arreola-Risa C, Quansah R. An estimate of the number of lives that could be saved through improvements in trauma care globally. *World J Surg.* 2012;36(5):959–963.
2. Mock C, Brundage S, Goosen J, Joshipura M. Guidelines for trauma quality improvement programmes. *World Health Organization; Geneva.* 2009.
3. Mock CN, Jurkovich GJ, Amon-Kotei D, Arreola-Risa C, Maier RV. Trauma mortality patterns in three nations at different economic levels: implications for global trauma system development. *J Trauma.* 1998;44(5): 804–812. discussion 12–4.
4. Mock CN, Adzotor KE, Conklin E, Denno DM, Jurkovich GJ. Trauma outcomes in the rural developing world: comparison with an urban level I trauma center. *J Trauma.* 1993;35(4):518–523.
5. *Resources for Optimal Care of the Injured Patients.* Chicago: American College of Surgeons' Committee on Trauma; 1999.
6. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med.* 2009;6(7):e1000097.
7. World Health Organization. Trauma system maturity index. http://apps.who.int/violence_injury_prevention/services/traumacare/maturity_index/en/index.html. Accessed May 15, 2016.
8. Harmsen AM, Giannakopoulos GF, Moerbeek PR, Jansma EP, Bonjer HJ, Bloemers FW. The influence of prehospital time on trauma patients outcome: a systematic review. *Injury.* 2015;46(4):602–609.
9. Roudsari BS, Nathens AB, Cameron P, Civil I, Gruen RL, Koepsell TD, Lecky FE, Lefering RL, Liberman M, Mock CN, et al. International comparison of prehospital trauma care systems. *Injury.* 2007;38(9):993–1000.
10. O'Reilly GM, Gabbe B, Moore L, Cameron PA. Classifying, measuring and improving the quality of data in trauma registries: a review of the literature. *Injury.* 2016;47(3):559–567.
11. World Health Organization. Disease and injury country estimates. In: *Global burden disease death estimates sex 2008*, editor. Excel. Switzerland 2008.
12. The World Bank Group. <http://data.worldbank.org/>. Accessed July 17 2016.
13. Mock CN, Tiska M, Adu-Ampofo M, Boakye G. Improvements in prehospital trauma care in an African country with no formal emergency medical services. *J Trauma.* 2002;53(1):90–97.
14. Quansah R. Essential trauma care in Ghana: adaptation and implementation on the political tough road. *World J Surg.* 2006;30(6):934–939.
15. Savitsky E, Rehnberg GB, Ibarra K. Emergency medical services development in the Seychelles Islands. *Am J Emerg Med.* 2000;18(3):332–335.
16. MacFarlane C, van Loggerenberg C, Kloock W. International EMS systems in South Africa—past, present, and future. *Resuscitation.* 2005; 64(2):145–148.
17. Goosen J, Veller M. Trauma and emergency surgery: South African model. *World J Surg.* 2008;32(8):1622–1625.
18. Laing GL, Bruce JL, Aldous C, Clarke DL. The design, construction and implementation of a computerised trauma registry in a developing South African metropolitan trauma service. *Injury.* 2014;45(1):3–8.
19. Thomson N. Emergency medical services in Zimbabwe. *Resuscitation.* 2005;65(1):15–19.
20. Zong ZW, Li N, Cheng TM, Ran XZ, Shen Y, Zhao YF, Guo QS, Zhang LY. Current state and future perspectives of trauma care system in mainland China. *Injury.* 2011;42(9):874–878.
21. Kong G, Yin X, Wang T, Body R, Chen YW, Wang J, Cao L, Wu S, Gao J, Wang G, et al. Current state of trauma care in China, tools to predict death and ICU admission after arrival to hospital. *Injury.* 2015;46(9):1784–1789.

22. Fitzharris M, Zhong W, Myburgh J, Xuezhong Y, Yu J, Hammond N, Finfer SR, Taylor C, Wu Y. The status of trauma registry systems in Chinese hospitals. *Inj Prev*. 2011;17(6):419–421.
23. Lo CB, Lai KK, Mak KP. Prehospital care in Hong Kong. *Hong Kong Med J*. 2000;6(3):283–287.
24. Cheng CH, Graham CA, Gabbe BJ, Yeung JH, Kossmann T, Judson RT, Rainer TH, Cameron PA. Trauma care systems: a comparison of trauma care in Victoria, Australia, and Hong Kong, China. *Ann Surg*. 2008;247(2): 335–342.
25. Garg RH. Who killed Rambhor?: the state of emergency medical services in India. *J Emerg Trauma Shock*. 2012;5(1):49–54.
26. Joshipura MK. Trauma care in India: current scenario. *World J Surg*. 2008; 32(8):1613–1617.
27. Khashayar P, Amoli HA, Tavakoli H, Panahi F. Efficacy of pre-hospital care in trauma patients in Iran. *Emerg Med J*. 2010;27(6):430–432.
28. Zargar M, Kalantar Motamedi SM, Karbakhsh M, Ghodsi SM, Rahimi- Movaghar V, Panahi F, Saadat S, Khaji A, Davachi SM, Ganji S, et al. Trauma care system in Iran. *Chin J Traumatol*. 2011;14(3):131–136.
29. Soffer D, Klausner JM. Trauma system configurations in other countries: the Israeli model. *Surg Clin North Am*. 2012;92(4):1025–1040, x.
30. Aharonson-Daniel L, Avitzour M, Giveon A, Peleg K. A decade to the Israel National Trauma Registry. *Isr Med Assoc J*. 2007;9(5):347–351.
31. Tanigawa K, Tanaka K. Emergency medical service systems in Japan: past, present, and future. *Resuscitation*. 2006;69(3):365–370.
32. Mashiko K. Trauma systems in Japan: history, present status and future perspectives. *J Nippon Med Sch*. 2005;72(4):194–202.
33. Al-Ghamdi AS. Emergency medical service rescue times in Riyadh. *Accid Anal Prev*. 2002;34(4):499–505.
34. Al-Naami MY, Arafah MA, Al-Ibrahim FS. Trauma care systems in Saudi Arabia: an agenda for action. *Ann Saudi Med*. 2010;30(1):50–58.
35. Alanazi F, Hussain SA, Mandil A, Alamro N. Towards an electronic national injury surveillance system in Saudi Arabia. *East Mediterr Health J*. 2015;21(2): 140–146.
36. Bavonratanavech S. Trauma care systems in Thailand. *Injury*. 2003;34(9): 720–721.
37. Taviloğlu K, Ertekin C. Current status and future options for trauma and emergency surgery in Turkey. *Ulus Travma Acil Cerrahi Derg*. 2008;14(1): 10–13.
38. Nijs SJ, Broos PL. Trauma care systems in Belgium. *Injury*. 2003;34(9): 652–657.
39. Edwards A, Di Bartolomeo S, Chierigato A, Coats T, Della Corte F, Giannoudis P, Gomes E, Groenborg H, Lefering R, Leppaniemi A, et al. A comparison of European Trauma Registries. The first report from the EuroTARN Group. *Resuscitation*. 2007;75(2):286–297.
40. Antoljak T, Dobric I, Bakota B, Zigman T, Rajacic D, Ehrenfreund T. A plea for Croatian trauma system. *Injury*. 2013;44(Suppl 3):S3–S6.
41. Kristiansen T, Søreide K, Ringdal KG, Rehn M, Krüger AJ, Reite A, Meling T, Naess PA, Lossius HM. Trauma systems and early management of severe injuries in Scandinavia: review of the current state. *Injury*. 2010; 41(5):444–452.
42. Handolin L, Leppaniemi A, Vihtonen K, Lakovaara M, Lindahl J. Finnish Trauma Audit 2004: current state of trauma management in Finnish hospitals. *Injury*. 2006;37(7):622–625.
43. Ringdal KG, Lossius HM. Feasibility of comparing core data from existing trauma registries in scandinavia. Reaching for a Scandinavian major trauma outcome study (MTOS). *Scand J Surg*. 2007;96(4):325–331.

44. Masmajeán EH, Faye A, Alnot JY, Mignon AF. Trauma care systems in France. *Injury*. 2003;34(9):669–673.
45. Sturm JA, Pape HC, Dienstknecht T. Trauma care in Germany: an inclusive system. *Clin Orthop Relat Res*. 2013;471(9):2912–2923.
46. Oestern HJ, Garg B, Kotwal P. Trauma Care in India and Germany. *Clin Orthop Relat Res*. 2013;471(9):2869–2877.
47. DGU Trauma Register. Teilnehmende Länder 2016. http://www.traumaregister-dgu.de/de/startseite_tr.html. Accessed June 6, 2016.
48. Theodorou D, Toutouzas K, Drimousis P, Larentzakis A, Kleidi E, Georgiou G, Gymnopoulos D, Kandylikis S, Theodoraki ME, Katsaragakis S. Emergency room management of trauma patients in Greece: preliminary report of a national study. *Resuscitation*. 2009;80(3):350–353.
49. Katsaragakis S, Theodoraki ME, Toutouzas K, Drimousis PG, Larentzakis A, Stergiopoulos S, Aggelakis C, Lapidakis G, Massalis I, Theodorou D. The implementation of a national trauma registry in Greece. Methodology and preliminary results. *J Trauma*. 2009;67(6):1421–1425.
50. Pace A. Trauma care systems in Italy. *Injury*. 2003;34(9):693–698.
51. Balasubramanian I, Mohan HM, Whelan RJ, McDermott F, Winter DC. Restructuring an evolving Irish trauma system: what can we learn from Europe and Australia? *Surgeon*. 2016;14(1):44–51.
52. Deasy C, Cronin M, Cahill F, Geary U, Houlihan P, Woodford M, Lecky F, Mealy K, Crowley P. Implementing major trauma audit in Ireland. *Injury*. 2016;47(1):166–172.
53. Dehli T, Gaarder T, Christensen BJ, Vinjevoll OP, Wisborg T. Implementation of a trauma system in Norway: a national survey. *Acta Anaesthesiol Scand*. 2015;59(3):384–391.
54. ten Duis HJ, van der Werken C. Trauma care systems in The Netherlands. *Injury*. 2003;34(9):722–727.
55. Spijkers AT, Meylaerts SA, Leenen LP. Mortality decreases by implementing a level I trauma center in a Dutch hospital. *J Trauma*. 2010;69(5): 1138–1142.
56. Twijnstra MJ, Moons KG, Simmermacher RK, Leenen LP. Regional trauma system reduces mortality and changes admission rates: a before and after study. *Ann Surg*. 2010;251(2):339–343.
57. Newton AI, Adams JR, Simpson KE, Egan G, Gowens PA, Donald MJ. Capability of Scottish emergency departments to provide physician-based prehospital critical care teams: a national survey. *Eur J Emerg Med*. 2013; 20(6):387–390.
58. Morrissey BE, Delaney RA, Johnstone AJ, Petrovick L, Smith RM. Do trauma systems work? A comparison of major trauma outcomes between Aberdeen Royal Infirmary and Massachusetts General Hospital. *Injury*. 2015;46(1):150–155.
59. Queipo de Llano E, Mantero Ruiz A, Sanchez Vicioso P, Bosca Crespo A, Carpintero Avellaneda JL, de la Torre Prado MV. Trauma care systems in Spain. *Injury*. 2003;34(9):709–719.
60. Black JJ, Davies GD. International EMS systems: United Kingdom. *Resuscitation*. 2005;64(1):21–29.
61. Metcalfe D, Perry DC, Bouamra O, Salim A, Woodford M, Edwards A, Lecky FE, Costa ML. Regionalisation of trauma care in England. *Bone Joint J*. 2016;98-B(9):1253–1261.
62. Racy M, Al-Nammari S, Hing CB. A survey of trauma database utilisation in England. *Injury*. 2014;45(3):624–628.
63. Zakrisson T, Ball CG, Kirkpatrick AW. Trauma in Canada: a spirit of equity & collaboration. *World J Surg*. 2013;37(9):2086–2093.
64. Canadian Institute for Health Information, 2014. <http://www.cihi.ca/CIHI-ext-portal/internet/EN/TabbedContent/types+of+care/specialized+services/trauma+and+injuries/cihi010639>. Accessed June 29 2016.
65. Pozner CN, Zane R, Nelson SJ, Levine M. International EMS systems: the United States: past, present, and future. *Resuscitation*. 2004;60(3):239–244.

66. Blackwell T, Kellam JF, Thomason M. Trauma care systems in the United States. *Injury*. 2003;34(9):735–739.
67. Zeckey C, Hildebrand F, Probst C, Krettek C. Trauma care systems in Germany, USA and Australia. An international comparison. *Unfallchirurg*. 2010;113(9):771–774. 6–7.
68. Timerman S, Gonzalez MM, Zaroni AC, Ramires JA. Emergency medical services: Brazil. *Resuscitation*. 2006;70(3):356–359.
69. Masella CA, Pinho VF, Costa Passos AD, Spencer Netto FA, Rizoli S, Scarpelini S. Temporal distribution of trauma deaths: quality of trauma care in a developing country. *J Trauma*. 2008;65(3):653–658.
70. Delprado AM. Trauma systems in Australia. *J Trauma Nurs*. 2007;14(2): 93–97.
71. Palmer CS, Davey TM, Mok MT, McClure RJ, Farrow NC, Gruen RL, Pollard CW. Standardising trauma monitoring: the development of a minimum dataset for trauma registries in Australia and New Zealand. *Injury*. 2013;44(6):834–841.
72. Christey GR. Trauma care in New Zealand: it's time to move ahead. *World J Surg*. 2008;32(8):1618–1621.
73. Paice R. An overview of New Zealand's trauma system. *J Trauma Nurs*. 2007;14(4):211–213.
74. MacKenzie EJ, Rivara FP, Jurkovich GJ, Nathens AB, Frey KP, Egleston BL, Salkever DS, Scharfstein DO. A national evaluation of the effect of trauma-center care on mortality. *N Engl J Med*. 2006;354(4):366–378.
75. American College of Surgeons. <https://www.facs.org/quality%20programs/trauma/atls>. Accessed October 20 2016.
76. O'Reilly GM, Cameron PA, Joshipura M. Global trauma registry mapping: a scoping review. *Injury*. 2012;43(7):1148–1153.
77. Evans JA, van Wessem KJ, McDougall D, Lee KA, Lyons T, Balogh ZJ. Epidemiology of traumatic deaths: comprehensive population-based assessment. *World J Surg*. 2010;34(1):158–163.
78. World Health Organization. Decade of Action for Road Safety 2011–2020 *Saving millions of lives*. 2011.
79. Charles Mock CJ, Manjul Joshipura, Jacques Goosen. *Strengthening Care for the Injured: Success Stories and Lessons Learned From Around the World*. Vienna: World Health Organization; 2010.
80. LaGrone L, Riggle K, Joshipura M, Quansah R, Reynolds T, Sherr K, Mock C. Uptake of the World Health Organization's trauma care guidelines: a systematic review. *Bull World Health Organ*. 2016;94(8):585–598c.

APPENDIX I: SEARCH STRATEGY

Years: 2000-2016

("trauma management"[ti] OR "Traumatology/organization and administration"[Mesh] OR "trauma system"[ti] OR "trauma systems"[ti] OR "polytrauma"[ti] OR "polytraumas"[ti] OR "poly trauma"[ti] OR "poly traumas"[ti] OR "trauma care systems"[ti] OR "trauma care system"[ti] OR "trauma care"[ti] OR "emergency medical services"[ti] OR "emergency medical service"[ti] OR "prehospital care"[ti] OR "pre-hospital care"[ti] OR "trauma registry"[ti] OR "trauma registries"[ti]) AND ("Geographic Locations"[Mesh] OR "national"[tw] OR "nationwide"[tw] OR "global"[tw] OR "worldwide"[tw])