The Impact of Trauma Care Systems in Low- and Middle-Income Countries

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Abstract

Injury is a leading cause of death globally, and organized trauma care systems have been shown to save lives. However, even though most injuries occur in low- and middle-income countries (LMICs), most trauma care research comes from high-income countries where systems have been implemented with few resource constraints. Little context-relevant guidance exists to help policy makers set priorities in LMICs, where resources are limited and where trauma care may be implemented in distinct ways. We have aimed to review the evidence on the impact of trauma care systems in LMICs through a systematic search of 11 databases. Reports were categorized by intervention and outcome type and summarized. Of 4,284 records retrieved, 71 reports from 32 countries met inclusion criteria. Training, prehospital systems, and overall system organization were the most commonly reported interventions. Quality-improvement, costing, rehabilitation, and legislation and governance were relatively neglected areas. Included reports may inform trauma care system planning in LMICs, and noted gaps may guide research and funding agendas.

INTRODUCTION

Every year, more than 5 million people die from injury—more than one and a half times the number of deaths from HIV, tuberculosis, and malaria combined (97)—and nearly one billion people sustain injuries that require health care (38). For every injury death, there are 20–50 nonfatal injuries that result in some form of disability, impacting quality of life, productivity, and financial security (31, 95).

Although prevention is ideal—and there are many effective and cost-effective injury prevention strategies (96)—no system will prevent all injuries, and strong evidence indicates that well-organized trauma care can save lives once injury has occurred (58, 74, 81). Estimates derived from the Global Burden of Disease data suggest that nearly 2 million lives could be saved every year if case fatality rates among seriously injured persons in low- and middle-income countries (LMICs) were similar to those achieved in high-income countries (61). Of particular relevance to resource-constrained settings, much of the evidence from high-income countries relates to organizational and administrative aspects that could be implemented with limited input of new material resources: planning of systems for trauma management (e.g., regulation to designate trauma centers, prehospital triage protocols, and transfer criteria), and verification and accreditation of trauma care services (32, 63).

However, despite the fact that nearly 90% of injuries occur in LMICs, most of the research on the impact of trauma care comes from high-income countries where systems have been implemented with few resource constraints. Assessments in LMICs have consistently identified enormous gaps in the resources needed to provide adequate care for the injured (26, 39, 104), but little context-relevant guidance exists to help policy makers and planners set priorities in LMICs, where components of trauma care systems may be implemented in distinct ways.

We aimed to systematically review the evidence, identifying reports that evaluate the impact of a trauma care system or system components in LMICs. By doing so, we have identified context-relevant reports on specific trauma system components and have characterized regional and topical research gaps to help guide future research, policy, and funding agendas.

METHODS

Search Strategy

The search strategy and study protocol were registered with PROSPERO (University of York, United Kingdom National Institute for Health Research, United Kingdom of Great Britain and Northern Ireland) on April 20, 2015 (CRD-42015019685) (80). In order to retrieve all relevant records, the initial search string (available on request) comprised only a series of general terms for injury and an LMIC filter.

For inclusion, we have used a broad definition of trauma care systems to include any component among those outlined in World Health Organization (WHO) (63, 85, 101) guidelines:

- regulatory or legislative structure;
- facility inspection, verification, and designation;
- prehospital care, hospital-based care, and rehabilitation;
- use of clinical and organizational protocols, including triage;
- training; and
- data collection, registries, and quality-improvement audits.

We did not include reports on specific clinical interventions that were neutral to the existence of a trauma system; for example, a comparative study of two different types of orthopedic hardware to

treat fracture would not have been included, but the establishment of a new referral protocol for orthopedic care would have been. A report was considered to document impact if it described the effect of an intervention on trauma care system structure or process or on clinical or population-health outcomes among the injured. Included reports were classified by this schema, which is described in detail below.

We included reports from any country designated as low- or middle-income by the World Bank as of 2010 (105). We chose 2010 rather than more recent classifications so that we did not miss studies performed in middle-income countries that may have since become high-income countries.

Reports from military organizations were excluded if they were limited to military personnel or battlefield reports. Thus, a report on a military program delivering care exclusively within a combat zone would not be included, whereas a report on a military-run program delivering care broadly to a civilian LMIC population would.

We included reports in any language as long as there was either an abstract or full-text article available through the WHO or any of several major university libraries available to the authors. Conference abstracts were included. Review articles were not included as such, but all relevant reviews were examined for citations of reports that had not already been captured by our search. Animal studies were excluded.

Search and Data Collection

We searched the following databases: PubMed, EMBASE, CABI Global Health Database, WorldCat, Scopus, WHO Global Index Medicus, WHO IRIS, African Index Medicus, Index Medicus for the Eastern Mediterranean Region, Index Medicus for the South-East Asian Region, and Latin American and Caribbean Health Sciences literature (LILACS). The search was current as of January 28, 2016. Reference lists of included full-text reports and systematic reviews were cross-checked for relevant records.

We imported the retrieved records from each database into EndNote [Thomson Reuters, United States of America (USA)] and removed duplicates. At least two reviewers (I.H. Drewett, S. Salerno, H. Sawe, B. Stewart) screened the titles and abstracts; a senior reviewer (T. Reynolds) resolved classification conflicts. Similarly, two reviewers (S. Salerno, B. Stewart) assessed full-text reports and extracted data, and a senior reviewer (T. Reynolds) resolved classification conflicts. We used Google Forms (Google Inc., USA) to extract the data, which included first author; publication year; title; structured brief summary of report; intervention evaluated; type of impact; and direction of demonstrated impact (i.e., positive, neutral, negative). We classified the impact type as affecting

- Structure—resulting in sustained change in the physical or human resources needed to provide trauma care (e.g., increased availability of materials after a change in supply chain management or increased capacity sustained over time after an educational intervention) or sustained improvement in trauma care administration;
- Process—influencing aspects of care delivery, such as time intervals to trauma care (e.g., time from injury to first provider, or from injury to intervention), appropriate use of vital interventions (e.g., airway maneuvers for patients with obstructed airways, chest tube placement for pneumothorax), or protocol compliance; and/or
- Clinical or population-health outcome—influencing individual patient outcomes (e.g., death, disability, quality of life) or other population-health outcomes (e.g., condition-specific mortality).

We did not include descriptive reports on educational initiatives unless they reported changes in capacity that were sustained over time (classified as a structural impact on human resource capacity)

or reported an impact on process or outcomes. Thus, we did not include descriptive reports on educational initiatives when the only outcome reported was end-of-training exam performance.

Data Analysis

We classified the included reports by year of publication, country/countries of origin, type of intervention, and category of impact. A brief summary is provided for each report. We also tagged reports with broad cross-cutting categories of potential use to LMIC trauma care system stakeholders: (*a*) prehospital care, (*b*) lay providers, (*c*) pediatric care, and (*d*) cost-effectiveness analysis or costing. These categories were not mutually exclusive. Given the limited literature on this topic, we did not filter the reports on the basis of quality or risk of bias, and we decided a priori not to perform pooled analyses of results in light of the broad inclusion strategy and the expected marked heterogeneity.

RESULTS

We retrieved 4,284 records from the systematic search of all databases and identified an additional 11 records by reviewing the citations of systematic reviews. After removing 224 duplicates, 2,625 irrelevant titles, and 1,260 abstracts that did not meet the inclusion criteria, we reviewed 186 full-text reports. Among these 186 reports, an additional 115 failed to meet the inclusion criteria; in total, we included 71 reports from 32 LMICs (**Figure 1**). One compendium of trauma care system case studies met inclusion criteria and was counted as a single publication, though its components are discussed separately in the relevant discussion sections. The number of reports published per year generally increased after 1993, and the majority (63%) were published after 2006 (**Figure 2**). **Table 1** shows the characteristics of included reports.

Training, development of prehospital systems, and overall system organization initiatives were the interventions most commonly reported, followed by initiatives to implement clinical protocols and improve the availability of specialty care (e.g., orthopedic or neurosurgical care). **Table 2** shows a summary of all included articles, interventions assessed, and outcomes.

Training

Twenty-five reports from 18 countries described the impact of training programs. Many of these demonstrated sustained structural impacts: For example, a two-year training program designed around the WHO Guidelines for Essential Trauma Care and implemented across government hospitals in Botswana resulted in sustained changes in availability of physical and human resources (40). Many of these reports also demonstrated improvements to process measures: An educational symposium in South Africa led to increased compliance with universal barrier precautions at a tertiary hospital trauma unit (20). Other reports assessed the impact of training on mortality and morbidity: At a Médecins Sans Frontières–run first-level referral hospital in Masisi, Democratic Republic of the Congo, training nonspecialists to perform toileting of open fractures and external fixation decreased amputation rates among open fractures from 100% to 21% over 7 years (18). A surgical skills training program for nondoctors in Cambodia showed substantial reductions in postoperative infection rates and trauma mortality (93).

Prehospital Systems

Fifteen reports from 11 countries assessed the impact of establishing or organizing prehospital systems, ranging from lay-provider-based systems, to city- or country-wide formal

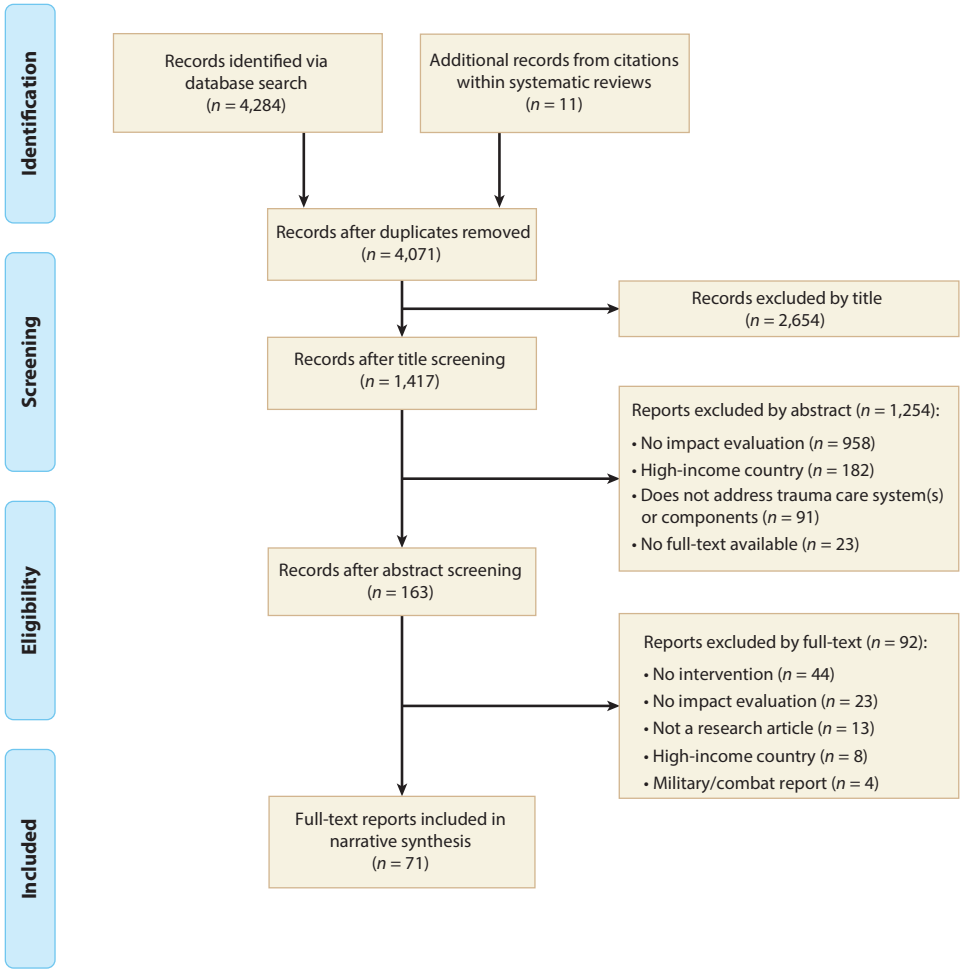

Figure 1

Flow diagram of the systematic search results.

prehospital systems, to aeromedical transport systems. These reports described improvements in structure, process, and health outcomes, even with severe resource limitations. For example, a new community-based prehospital system in rural Uganda reported sustained staff retention and functional ambulances over six months (30), while a prehospital care system using paramedics and laypersons in rural Iraq found increased use and acceptance of the system by the local population over time (103), as well as a significant reduction in mortality and improvement in severity scores after the intervention (71).

Two reports specifically addressed the impact of establishing or reorganizing dispatch systems to improve access to care. In Monterrey, Mexico, an increase from 2 to 4 ambulance dispatch stations decreased mean response time by 40%; coupled with training, these prehospital care improvements cost only US$77,600 per year (16% of the annual system budget) (13). A new dispatch algorithm implemented in Tehran, Iran (Islamic Republic of), improved utilization of existing resources and resulted in a 16% decrease in unnecessary trauma responses (7).

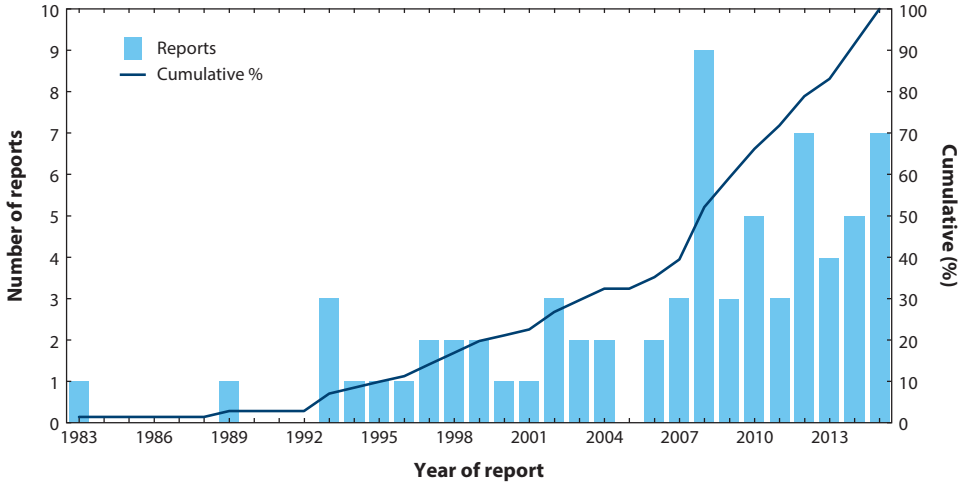

Figure 2

Year of publication of included reports.

Overall System Organization

An additional 15 reports in 12 countries addressed overall system organization, including incorporation of standardized guidelines for trauma care systems (e.g., WHO Guidelines for Essential Trauma Care) and mechanisms for designation of trauma centers. The reports ranged from a modeling study to estimate the overall global impact of integrated trauma care systems—which suggested that nearly two million lives could be saved annually if global survival rates from severe injury mirrored those in high-income countries (61)—to a spatial analysis of access to trauma care in Haiti and Namibia (92).

Other reports examined the impact of using WHO guidelines for assessment and planning of trauma services (52): In Viet Nam, trainings targeted to deficiencies that were identified through a WHO-based assessment led to sustained structural improvements (87). Two reports specifically assessed the impact of designating trauma centers (23, 91), including one that demonstrated differential outcomes at designated pediatric trauma care centers: In Moscow, Russia, children who suffered a road traffic injury and were cared for by prehospital providers with pediatric-specific training and were taken to pediatric trauma centers were significantly less likely to die than were children who were cared for by the general trauma care system (91).

Clinical Protocols

Six reports in four countries assessed the impact of introducing clinical protocols on mortality and a range of other clinical outcomes. The protocols ranged from using a locally adapted South African Triage Score in Botswana to reduce over- and undertriage rates (68) to implementing standardized protocols for resuscitation and brain injury management at a level 1 trauma center in Colombia (53, 54). Other reports had multipronged interventions: For example, a tertiary hospital in Shanghai, China, performed a three-pronged intervention that included (*a*) making specialist surgeons part of the initial bedside management of the severely injured; (*b*) promoting an interdisciplinary approach to patient care; and (*c*) performing resuscitation, evaluation, and testing in parallel. This intervention bundle resulted in a decrease in severity-adjusted mortality rate, in emergency department length of stay, and in time from admission to operation (57).

Table 1 Characteristics of included reports

Report characteristics	Number (%[b]) of reports (n = 71)
Year	
2010– (3, 7, 10, 17, 18, 23, 27, 28, 30, 33, 35, 37, 40, 41, 45, 51, 53, 54, 61, 62, 68, 69, 70, 71, 77, 86, 89, 90, 92, 94, 106)	31 (44)
2000–2009 (1, 12, 13, 15, 19, 21, 22, 24, 36, 48, 49, 50, 52, 57, 59, 60, 67, 73, 82, 83, 84, 87, 91, 93, 102, 103)	26 (37)
1990–1999 (4, 5, 6, 9, 14, 20, 34, 42, 43, 46, 64, 65)	12 (17)
1980–1989 (16, 29)	2 (3)
World Health Organization region	
Eastern Mediterranean (7, 9, 10, 33, 41, 69, 70, 71, 73, 82, 83, 84, 101, 103)	14 (20)
Americas (1, 4, 5, 6, 12, 13, 14, 15, 27, 51, 53, 54, 59)	13 (18)
Africa (20, 21, 22, 30, 34, 40, 50, 67, 68, 77, 89, 90)	12 (17)
Western Pacific (16, 23, 36, 43, 57, 87, 93, 94, 106)	9 (13)
South-East Asia (3, 28, 52, 86)	4 (6)
European (24, 91)	2 (3)
Multiple regions (17–19, 29, 35, 37, 42, 45, 46, 48, 49, 60, 61, 64, 64, 65, 92)	17 (24)
Main intervention	
Training (1, 4, 5, 6, 10, 12, 15, 18, 20, 27, 33, 34, 40, 50, 51, 67, 69, 71, 73, 77, 83, 84, 89, 93, 94)	25 (35)
Prehospital system (7, 9, 13, 20, 30, 43, 48, 49, 59, 71, 82, 86, 90, 101, 103)	15 (21)
System organization (3, 14, 22–24, 35, 45, 52, 60, 61, 64, 65, 87, 91, 92)	15 (21)
Clinical protocol (21, 42, 53, 54, 57, 68)	6 (8)
Specialty care availability (28, 29, 36, 37, 46)	5 (7)
Disaster response and preparedness (17, 19, 106)	3 (4)
Trauma care quality improvement (41, 64)	2 (2)
Impact classification[a]	
Structure (1, 3, 7, 10, 12, 24, 27, 30, 33, 34, 37, 40, 43, 46, 48, 50, 51, 52, 64, 67, 84, 86, 87, 89, 90, 92, 93, 101, 103)	29 (41)
Process (3, 5, 6, 9, 12, 13, 14, 15, 20, 21, 46, 50, 53, 54, 57, 64, 67, 68, 69, 71, 86, 93, 103)	23 (32)
Clinical or population health outcome (3, 4, 12, 14, 15, 16, 17, 18, 19, 22, 23, 24, 28, 29, 35, 36, 41, 42, 43, 45, 48, 49, 53, 54, 57, 59, 60, 61, 64, 64, 65, 69, 70, 71, 73, 77, 82, 83, 84, 86, 91, 93, 94, 103, 106)	47 (66)

[a]Some reports have more than one impact classification.
[b]Note: Percentages are rounded.

Specialty Care Availability

Five reports from seven countries examined the impact of increased availability of specialist care on a range of outcomes. For example, establishing a rapid response team for thoracic injuries in a tertiary hospital in Thailand reduced mortality (28), while the implementation of a telemedicine specialist program between the USA and two Armenian and Russian Federation medical centers immediately after disaster situations improved the accuracy of diagnoses and treatment plans (46).

Disaster Preparedness and Response

Only three reports examined the impact of disaster response and preparedness, two of which were based on modeling estimates. A report from China found that a facility's surge capacity

Table 2 Brief summary of included reports

First author	Year (reference)	Country	Brief summary
Training			
El-Shinawi	2015 (33)	Egypt	STEPS training program in a tertiary hospital in Egypt resulted in sustained structural changes (e.g., course run independently and locally for more than eight years).
Hanche-Olsen	2015 (40)	Botswana	BEST training in all government hospitals in Botswana was assessed after two years using a tool adapted from the WHO Guidelines for Essential Trauma Care; sustained structural changes in physical and human resources, infrastructure, trauma administrative functions, and QI activities were noted.
Stolz	2015 (89)	Uganda	A point-of-care ultrasound training program in a tertiary hospital in Uganda resulted in sustained structural changes (e.g., retention of trained nonradiologist sonographers for 4.5 years).
Petroze	2015 (77)	Rwanda	Two 3-day trauma education courses based on ATLS and TTT provided for faculty, residents, and nurses at a tertiary center in Rwanda reduced mortality among injured patients from 8.8% to 6.3% ($p = 0.09$) at a six-month evaluation. No significant increase in resource utilization was observed.
Bertol	2014 (18)	Afghanistan, Democratic Republic of the Congo, Haiti	A training program for nonspecialist surgeons that ensured the availability of external fixation resources reduced amputation rates among open fractures from 100% to 21% in an NGO hospital in Democratic Republic of the Congo and from 20% to <10% in NGO hospitals in Haiti and Afghanistan.
Amiri	2013 (10)	Iran (Islamic Republic of)	Implementation of PTC in a tertiary hospital in Iran resulted in sustained structural changes (e.g., knowledge and skill retention) at one year.
Murad	2012 (70)	Iraq	Prehospital care training for paramedics and laypersons in Iraq reduced the mortality rate from road traffic injury from 44% to 8% and improved admission PSS (6.8 to 10.9).
Carlson	2012 (27)	Haiti	A cost-effectiveness analysis of a 2-year orthopedic trauma care specialist training program for doctors in Haiti reported 12,213 DALYs averted per fellow trained, and US$134 per DALY averted by the trained providers.
Job	2011 (51)	Brazil	ATLS training for nonradiologist doctors improved their ability to interpret cervical spine and chest radiographs in Brazil (22% and 26% improvement in interpretation accuracy after ATLS, respectively; $p < 0.001$).
Murad	2010 (69)	Iraq	Prehospital care training for paramedics and laypersons in rural Iraq reduced mortality rates among injured patients who were cared for in the field by trained first responders compared with patients who did not receive first-responder care (9.8% versus 15.6%).
Wang	2010 (94)	China	Two years after ATLS training at a tertiary hospital in China, the mortality rate of injured patients decreased from 19.9% to 15.1% ($p < 0.05$) and time from ED admission to operation decreased from 90 minutes to 62 minutes ($p < 0.05$).
Jayaraman	2009 (50)	Uganda	A one-day basic prehospital trauma care course in Kampala for police, commercial drivers, and community leaders resulted in sustained structural changes at six months (e.g., knowledge and skill retention). The projected costs of scale-up were estimated to be US$0.12 per capita or US$25–75 per life-year saved.
Nafissi	2008 (73)	Iran (Islamic Republic of)	A two-day training course for physicians, nurses, EMTs, and laypersons in Iran reported that the PSS of patients who received care by the trained providers was significantly higher than those who did not (PSS difference 0.73; $p < 0.01$).

(*Continued*)

Table 2 (*Continued*)

First author	Year (reference)	Country	Brief summary
Training			
Saghafinia	2008 (83)	Iran (Islamic Republic of)	An animal model–based trauma training course for village health care workers in Mehran resulted in improved admission PSS (6.8 versus 7.5) and mortality rates (3% versus 7.3%; $p = 0.05$).
Saghafinia	2008 (84)	Iran (Islamic Republic of)	A short-term training program in Iran included (*a*) advanced trauma care courses for physicians and nurses, (*b*) complementary basic trauma care courses for EMTs and health workers, (*c*) basic trauma care for highly educated laypersons, and (*d*) first aid for other laypersons. After three years, mean PSS at admission was higher among those who had received prehospital trauma care (PSS 7.5) compared with those who did not (PSS 6.8; $p < 0.001$).
Van Heng	2008 (93)	Cambodia	A surgical skills training program for nondoctors in Cambodia reported no effect on the already low in-hospital trauma mortality rate and a 12% reduction in the postoperative infection rate; self-rated provider coping capacity improved after the training.
Aboutanos	2007 (1)	Ecuador	A basic trauma care course for remote health post, rural hospital and tertiary hospital staff in Ecuador reported sustained structural changes (e.g., knowledge and skill retention) at two years.
Arreola-Risa	2007 (15)	Mexico	An EMT training and certification program in Mexico demonstrated a decrease in PHI-adjusted mortality by 45% and improvements in the use of vital prehospital interventions (e.g., appropriate airway management, use of IV fluids) compared with before the certification program.
Arreola-Risa	2004 (12)	Mexico	Comparison of the benefits and cost-effectiveness of different prehospital training models (e.g., PHTLS, BTLS, ACLS, locally designed course) between two ambulance services in Mexico demonstrated process improvements at both sites (e.g., spinal immobilization, appropriate airway management, use of IV fluids) but showed only a reduction in mortality in the service that implemented the simplest and lowest-cost interventions. Costs ranged from US$150–400 per medic trained.
Mock	2002 (67)	Ghana	A 6-hour first-aid training course for commercial drivers in Ghana resulted in sustained structural change after a mean of 11 months (e.g., driver knowledge and skill retention), as well as in the provision of first aid: crash scene management (7% versus 35% of drivers before and after the course, respectively); airway management (2% versus 35%); external bleeding control (4% versus 42%); and splinting of injured extremities (1% versus 16%).
Brooks	1999 (20)	South Africa	The impact of an educational symposium on universal barrier precautions and risk of occupational transmission of HIV was evaluated using video observation of a trauma unit in South Africa and reported an increase in compliance from 48–83% ($p < 0.001$).
Ali	1997 (5)	Trinidad and Tobago	The PHTLS program in Trinidad and Tobago demonstrated improvements in the performance of vital prehospital interventions, including airway management (16% to 100% of patients), spinal immobilization (25% to 100%), splinting of injured extremities (34% to 100%), hemorrhage control (18% to 100%), and oxygen use (43% to 99%).
Erickson	1996 (34)	Rwanda	Locally organized trauma training courses for physicians, nurses, and medical assistants at a tertiary hospital in Rwanda improved the use of vital ED interventions (e.g., airway management, trauma assessment, wound management). However, many of the benefits of the courses were not sustained at two months; there was no change in the trauma-related mortality rate.

(*Continued*)

Table 2 (*Continued*)

First author	Year (reference)	Country	Brief summary
Training			
Ali	1994 (6)	Trinidad and Tobago	ATLS training at a tertiary hospital in Trinidad and Tobago significantly improved the appropriate use of vital ED interventions (e.g., endotracheal intubation, bladder catheterization, nasogastric decompression, thoracostomy) for patients with ISS ≥16.
Ali	1993 (4)	Trinidad and Tobago	Serial ATLS training in a tertiary hospital in Trinidad and Tobago decreased overall and ICU mortality (68% to 35% and 55% to 14%, respectively). The ratio of observed to expected mortality based on the MTOS database was lower post-ATLS (3.2 to 1.9).
Prehospital systems			
de Ramirez	2014 (30)	Uganda	A newly established, community-based prehospital system and training program in rural Uganda reported sustained structural changes (e.g., staff retention, functioning ambulances). The system's costs totaled US$90 per life saved. System implementation costs were US$0.93 per capita, and annual maintenance costs per capita were US$0.09.
Sharma	2013 (86)	Nepal	A layperson first-responder and motorcycle-based prehospital transport system for snakebite victims in rural Nepal reduced the case-fatality rate from 11% to <1%.
Murad	2012 (71)	Iraq	A prehospital care system and training program for medics and laypersons in rural Iraq reported a reduction in mortality from 17% to 4%; PSS scores also improved after the intervention.
Alizadeh	2012 (7)	Iran (Islamic Republic of)	A protocol to triage incoming trauma calls at an EMS system in Iran reduced the number of unnecessary ambulance runs by 16%.
Sun	2012 (90)	South Africa	A layperson prehospital care system in an urban setting in South Africa resulted in sustained structural changes (e.g., >70% knowledge and skill retention at 6 months) and improved use of vital prehospital care interventions (e.g., ensuring scene safety, calling for help, performing the ABC assessment, controlling external bleeding). The course was highly cost-effective (US$6,570 per year; US$5 per trainee).
Saghafinia	2009 (82)	Iran (Islamic Republic of)	A prospective evaluation of a four-level prehospital and trauma care training program in Iran after 2 years and 4,834 medical and layperson trainees reported improved PSS among land mine victims who received prehospital care compared with those who did not (PSS 7.4 versus 5.97, respectively; $p = 0.01$).
Wisborg	2008 (102)	Iraq	A qualitative evaluation of a prehospital care system and training for paramedics and laypersons in rural Iraq reported that villages used the system for more than care of land mine victims. The system adapted to suit local needs as they changed over time. Villagers reported that the system adaptation was vital for its long-term success.
Wisborg	2008 (103)	Iraq	Prehospital care training for paramedics and laypersons in rural Iraq resulted in sustained structural changes (e.g., more trained prehospital care providers; 72% retention rate), reduced time from injury to first medical help (2.4 h versus 6 h; $p = 0.002$), and improved PSS at hospital arrival ($p < 0.01$).
Husum	2003 (48)	Cambodia, Iraq	Training village health workers and laypersons in rural Iraq and Cambodia in prehospital injury care and equipping them with first-aid supplies reduced mortality rates (23% to 14%) over two years of follow-up. Additionally, the prehospital system replicated itself during the same period, demonstrating sustained structural change. Costs for 1 trained paramedic were US$300 in training expenses (3 training courses, 450 h) and US$800 in equipment (1 ATLS backpack kit). Costs for prehospital resuscitation and transport were US$26 per case.

(*Continued*)

Table 2 (*Continued*)

First author	Year (reference)	Country	Brief summary
Prehospital systems			
Husum	2003 (49)	Cambodia, Iraq	A prehospital care system and training program for nongraduate paramedics and laypersons in rural Iraq and Cambodia reduced mortality from 40% to 14% and trauma-specific mortality from 24% to 9%; PSS scores improved after the intervention.
Marson	2001 (59)	Brazil	Development of a prehospital care system in an urban area in Brazil reduced early trauma deaths (i.e., within the first hour; 54% to 41%).
Arreola-Risa	2000 (13)	Mexico	An increase in prehospital care dispatch sites (2 to 4 sites) in Monterrey, Mexico, reduced mean response time from 15 minutes to 10 minutes. The introduction of the PHTLS course resulted in increases in the use of vital prehospital interventions (e.g., airway management, placement of IV catheters), which did not affect mean scene time. Together, these interventions reduced prehospital mortality among transported patients from 8.2% to 4.7%. Total costs were estimated to be US$77,600 annually, which represented 16% of the overall budget of the ambulance system.
Altintaş	1999 (9)	Turkey	A cost-effectiveness analysis of the development of a citywide ambulance service in Ankara, Turkey, reported that the capital costs per year were US$85,170 and recurrent costs were US$833,710. The cost per ambulance run was US$163; the cost per injured patient was US$181.
Hauswald	1997 (43)	Malaysia	By examining the structure and costs of existing prehospital systems and inputs in the USA, investigators modeled that a comparable prehospital system in Kuala Lumpur, Malaysia would cost US$2.5 million per year.
Barss	1983 (16)	Papua New Guinea	An aeromedical prehospital care system in Papua New Guinea estimated that 63 of 92 patients who benefited from the service would have died prior to the system implementation. The mean cost per life saved was US$520; the cost of the service was US$0.12 per capita.
System organization			
Higashi	2015 (45)	Global	A modeling study estimated that 21% of the global injury burden is potentially avertable by essential trauma care. The authors suggest that increasing trauma care services to levels demonstrated by HICs might avert 52.3 million DALYs.
Tansley	2015 (92)	Haiti, Namibia	A modeling study demonstrated poor population-level spatial access to hospital-based trauma care in Namibia and Haiti. The authors suggested that strengthening capabilities of existing facilities would improve access to trauma care.
Cai	2014 (23)	China	Comparison of structure and injury-related outcomes between level 1 trauma centers in China and the USA suggested that system organization and center designation may have a positive impact on injury mortality.
Mock	2012 (61)	Ghana, Mexico, USA	A modeling study based on (*a*) case fatality rates for seriously injured persons in Seattle, USA; Monterrey, Mexico; and Kumasi, Ghana; and (*b*) data from the Global Burden of Disease Study estimated that between 1.73 and 1.97 million lives could be saved annually if case fatality rates among seriously injured persons could be reduced to those in HICs; this represented 34–38% of all injury deaths globally.
Agrawal	2012 (3)	India	The creation of a call center in New Delhi, India, that was integrated with the medical record system of a level 1 trauma center in India improved head-injured patients' satisfaction and waiting times at clinic visits and reduced unnecessary follow-up visits. The initial cost of outsourcing the call center was US$4,000, with recurring costs of US$2,000 per month.

(*Continued*)

Table 2 (*Continued*)

First author	Year (reference)	Country	Brief summary
System organization			
Georgoff	2010 (35)	Global	A modeling study compared trauma care structures, processes, and outcomes after TBI between HICs and LMICs and over time. The authors suggested that LMICs could improve TBI outcomes by strengthening treatment intensity and improving spatial access to care.
Suvorov	2009 (91)	Russian Federation	Pediatric trauma center designation in Moscow, Russia, achieved better outcomes than other hospitals (trauma-related mortality rate decreased from 8% to 5%; $p = 0.02$).
Calderale	2008 (24)	Italy, Romania	Comparative trauma care audit of level 1 trauma centers in Italy and Romania demonstrated structural differences (e.g., infrastructure, specialist care availability), and higher ISS-adjusted mortality rates in Romania. The authors suggest that mortality rates in Romania could be decreased by improving trauma care structures to be similar to those in Italy.
Joshipura	2006 (52)	India	After using the WHO Guidelines for Essential Trauma Care, a report from India described sustained structural changes, including a stakeholder strategy meeting after facility assessments.
Son	2006 (87)	Viet Nam	Training programs for hospital and ambulance staff targeted deficiencies uncovered by an assessment adapted from the WHO Guidelines for Essential Trauma Care in Hanoi, Vietnam, and resulted in sustained structural changes after one year (e.g., physical and human resources, infrastructure).
Mock	2003 (60)	Ghana, Mexico	A modeling study compared prehospital and hospital-based care in the USA, Mexico, and Ghana. The authors suggested that sustained structural changes in essential trauma care may reduce the number of deaths and disabilities.
Buntman	2002 (22)	South Africa	An aeromedical prehospital care system in South Africa decreased the number of preventable deaths when compared with road-transferred patients (2% versus 24%, respectively).
Mock	1998 (65)	Ghana, Mexico, USA	Trauma systems and patient outcomes were compared between cities in the USA, Mexico, and Ghana. Mortality rates declined with increasing income (63% of those seriously injured died in Ghana; 55% in Mexico; and 35% in the USA) and prehospital time declined similarly (102 minutes, 73 minutes, and 31 minutes, respectively). The authors suggest that structural and process improvements in LMICs might improve outcomes toward those achieved in HICs.
Arreola-Risa	1995 (14)	Mexico	A modeling study compared prehospital and ED care structure, processes, and outcomes between cities and tertiary hospitals in the USA and Mexico. The authors suggested that improvements should target prehospital and ED care to maximally reduce preventable deaths, given relative differences in scene and transport times, resuscitation practices, and locations of death between the two models.
Mock	1993 (64)	Ghana	Prehospital and hospital-based care and patient outcomes were compared between a first-level referral hospital in Ghana and a tertiary hospital in the USA. The authors suggested that a lack of prehospital care and long delays in transport are partially responsible for significant differences in admission ISS and mortality rates between the two hospitals.
Clinical protocols			
Mullan	2015 (68)	Botswana	Use of a locally adapted SATS in Botswana reduced both overtriage (53% to 38%; $p < 0.01$) and undertriage rates (47% to 16%; $p < 0.01$). There was no change in the mortality rate after the intervention, and ICU admission rates decreased from 0.35 to 0.06% ($p < 0.01$).

(*Continued*)

Table 2 (*Continued*)

First author	Year (reference)	Country	Brief summary
Clinical protocols			
Kesinger	2014 (53)	Colombia	Introduction of a standardized protocol for damage control resuscitation at a level 1 trauma center in Colombia decreased in-hospital mortality (38% to 18%; $p = 0.02$), increased discharge GCS (10 to 14; $p = 0.03$), and significantly increased the use of vital ED interventions for patients with severe TBI (e.g., bladder catheterization, use of hypertonic saline, blood transfusions).
Kesinger	2014 (54)	Colombia	A standardized protocol for damage control resuscitation at a level 1 trauma center in Colombia decreased all-cause mortality of injured patients (4% to 3%; $p = 0.09$), decreased length of stay for both surgical (13.4 days to 11.8 days, $p = 0.02$) and nonsurgical injured patients (4.4 days to 3.8 days, $p = 0.06$), and significantly increased the use of vital ED interventions for trauma patients (e.g., tetanus vaccination, placement of multiple large bore IV catheters, use of prophylactic antibiotics, use of analgesics).
Bruijns	2008 (21)	South Africa	Components of the Cape Triage Score were evaluated prospectively in South Africa at a secondary referral hospital. Altering the color code parameters, amending the discriminator list, and adding a trauma factor reduced undertriage from 24% to 12% (overtriage increased from 25% to 45%).
Li	2007 (57)	China	A program that implemented the ATP principle (i.e., attending surgeons providing initial management; teamwork; parallel resuscitation, evaluation, and testing) into trauma care at a tertiary hospital in China decreased ISS-adjusted mortality (39% to 20%; $p < 0.05$) and time to operation (140 minutes to 90 minutes; $p < 0.05$).
Hauswald	1998 (42)	Malaysia	A modeling study compared prehospital spinal immobilization, directness of transport, and discharge neurologic outcomes between tertiary hospitals in the USA and Malaysia. The authors estimated that prehospital spinal immobilization had a <2% chance of any beneficial effect.
Specialist availability			
Chittawatanarat	2013 (28)	Thailand	An RRTT for thoracic injuries in a tertiary hospital in Thailand reduced the ISS-adjusted mortality rate from 25% to 15%; $p = 0.01$). The RRTT also had a positive impact on the outcomes of maxillofacial, head, and orthopedic injuries.
Gosselin	2010 (37)	Haiti, Nigeria	A cost-effectiveness analysis of two Médecins Sans Frontières hospitals in Nigeria and Haiti demonstrated trauma care costs of US$172 and US$223 per DALY averted, respectively.
Gosselin	2008 (36)	Cambodia	A cost-effectiveness analysis at an NGO-run hospital providing orthopedic care to the war-injured (e.g., land mine victims) demonstrated that costs for trauma surgical care were US$77 per DALY averted.
Houtchens	1993 (46)	Armenia, Russian Federation	A telemedicine program between the USA and two Armenian and Russian medical centers used immediately after disaster situations positively influenced patient evaluations, accuracy of diagnoses, and treatment plans.
Colohan	1989 (29)	India	A modeling study compared structural differences in neurosurgical care between tertiary hospitals in the USA and India. The authors suggest that if improvements were made in the planning and organization of neuroprotection, the ISS-adjusted mortality rate among the head-injured in India (11%) may approach that in the USA (7.2%).

(*Continued*)

Table 2 (*Continued*)

First author	Year (reference)	Country	Brief summary
Disaster response and preparedness			
Barthel	2011 (17)	Global	A population kinetics model estimated that the availability of a pediatric trauma center in the event of a disaster could reduce the time to definitive treatment by approximately half, the time to completely treat all children affected by one-third, and the relative risk of mortality by 37%.
Xu	2011 (106)	China	The impact of level of care on the outcome of earthquake victims with serious head injuries in China was evaluated. Mortality and disability rates were higher among patients who were treated at local and referral hospitals that were unable to adapt to the surge of patients. Tertiary hospital care did not contribute to successful treatment of victims, given their distance from the earthquake. Mobile hospitals played an important role in initial triage and treatment.
Bissell	2004 (19)	Armenia, Japan, USA	A modeling study described structural differences between cities affected by earthquakes in the USA, Japan, and Armenia. The authors suggested that the injuries-per-death and deaths-per-100-injuries ratios from each city after their respective earthquakes were better in the HICs owing to the structural differences in disaster preparedness and response.
Trauma quality improvement			
Hashmi	2013 (41)	Pakistan	A trauma team with ATLS training in concert with the creation of a trauma registry and a QI program in Pakistan significantly reduced mortality rates: Injured patients were 4.9 times less likely to die and 2.6 times less likely to have a complication compared with those cared for before the interventions.
Compendium			
Mock	2010 (62)	Global	A compendium of successful trauma care strengthening initiatives from around the world highlighted a range of prehospital and hospital-based initiatives, including guidelines, protocols, quality improvement, and rehabilitation interventions.

Abbreviations: ABC, Airway, Breathing, Circulation; ACLS, Advanced Cardiac Life Support; ATLS, Advanced Trauma Life Support; BEST, Better and Systematic Team Training; BTLS, Basic Trauma Life Support; DALYs, disability-adjusted life-years; ED, emergency department; EMTs, emergency medical technicians; GCS, Glasgow Coma Scale; HICs, high-income countries; ICU, intensive care unit; ISS, Injury Severity Score; IV, intravenous; LMICs, low- and middle-income countries; MTOS, Major Trauma Outcomes Study; NGO, nongovernmental organization; PHI, Pre-hospital Index; PHTLS, Pre-hospital Trauma Life Support; PSS, Physiologic Severity Score; PTC, Primary Trauma Care; QI, quality improvement; RRTT, Rapid Response Trauma Team; SATS, South African Triage Scale; STEPS, Sequential Trauma Education Program; TBI, traumatic brain injury; TTT, Trauma Team Training; USA, United States of America; WHO, World Health Organization.

was important in determining mortality and disability outcomes among earthquake victims with serious head injuries (106). A comparative modeling study of three countries that had suffered earthquakes (Armenia, Japan, USA) found that differences in disaster preparedness and response were closely correlated with injury mortality and morbidity (19), and a global modeling study suggested that the availability of a pediatric trauma care center could decrease time to care and save lives during a disaster (17).

Establishing a Quality-Improvement Program

Only two reports directly assessed the impact of establishing a quality-improvement program. A tertiary hospital in Karachi, Pakistan, showed improved mortality after implementing several trauma quality-improvement initiatives: morbidity and mortality meetings, a trauma quality-improvement committee, and a trauma registry with regular audits (41). The program was also

paired with training and system organization improvements. In a tertiary hospital in Khon Kaen, Thailand, a trauma quality-improvement program included participatory action research, peer review, and an audit of a newly created trauma registry to identify problems with trauma care delivery, root causes of the problems, and potential solutions. Outcomes monitored over a subsequent six-year period showed a decrease in delayed diagnoses, incorrect diagnoses, medical errors, and mortality rates (62).

Rehabilitation

Only two reports from a single WHO compendium of "success stories" (62) described the impact of rehabilitation interventions. A small multidisciplinary rehabilitation team at a trauma center in Brazil began providing early rehabilitation on the trauma wards to improve mobility, teach self-care and use of adaptive devices, and coordinate patient follow-up with outpatient rehabilitation. Resulting improvements included decreased falls among the elderly, improved access to prostheses for amputees, and a substantial decrease in the rate of complications from spinal cord injury.

Cross-Cutting Areas

We also categorized reports into broad topical areas of potential interest for particular trauma care system stakeholders: Among the included reports, 32 addressed some aspect of the prehospital setting, 16 addressed lay providers, 15 extrapolated existing data to model the impact of trauma care interventions on LMICs, 13 evaluated cost-effectiveness or costing, and only 1 was specific to pediatric patients.

DISCUSSION

Our review returned 71 reports from 32 countries (**Figure 3**), which describe potentially useful interventions to strengthen care for the injured in LMICs. These 32 countries, however, represent only one-quarter of LMICs globally, which suggests a substantial research gap that spans all regions. Just over half of reports came from only eight countries: Iraq, Mexico, Ghana, Iran (Islamic Republic of), Cambodia, China, Haiti, and South Africa. Included reports describe a broad range of interventions, with types of impact relatively evenly distributed across trauma care structures, processes, and outcomes (see **Figure 4**).

Training

Included reports covered several trauma care training programs oriented to limited-resource settings and aimed at prehospital care providers, nurses, clinical officers, general practitioners, and specialists. These programs generally addressed conditions similar to those covered by the American College of Surgeons' Prehospital Trauma Life Support and Advanced Trauma Life Support, while providing alternatives to costly proprietary course materials and providing more context-relevant management protocols that do not assume the availability of advanced diagnostic and therapeutic resources (56, 79).

Reports on these programs described positive impacts on structural, process, and outcome measures (15, 34, 62, 66), including reduced trauma-related mortality and morbidity in a number of settings as well as sustained improvements in clinical care capacity in other settings. The clinical effectiveness and cost-effectiveness of the reported programs suggest that dedicated trauma care training should be integrated into initial and ongoing certification pathways for prehospital

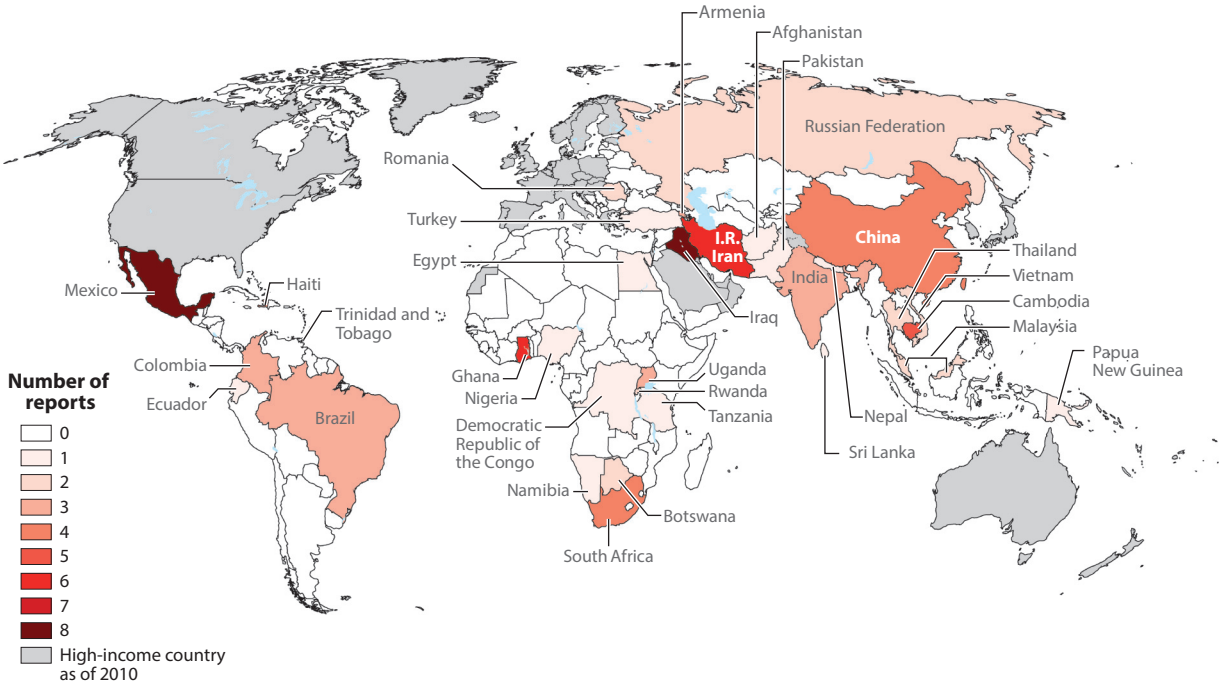

Figure 3

Map of countries described by included reports.

and hospital-based trauma care providers and that this may require alternatives to proprietary international courses.

Of note, multiple initiatives specifically addressed training to extend the scope of practice for providers (task shifting or task sharing) as a means of expanding access to timely emergency care for injury. In Cambodia, for example, nondoctor health care providers were trained to provide essential trauma surgical care at rural first-level referral hospitals (93), and the Médecins Sans Frontières–run program in Democratic Republic of the Congo greatly improved outcomes by training nonspecialists to deliver specialized orthopedic services such as toileting of open fractures and external fixation (18).

These reports suggest that task sharing may be an important mechanism for expanding the availability of services and improving quality and that training initiatives should be aligned with the frontline reality that emergency care for injury is delivered by a range of providers.

Prehospital Systems

Prehospital systems are essential to ensure timely access to emergency care, especially for severely injured patients. In some countries, as many as 80% of injury deaths occur prior to patients' arrival at a health care facility (61); thus, World Health Assembly resolution 68.15 on surgical and anesthesia care explicitly addresses the "primary level" of the health system, and the time-dependent targets of the Lancet Commission on Global Surgery, for example (8, 78), will never be met without prehospital systems and basic emergency care at lower levels of the health system. A recent review and meta-analysis estimated that prehospital systems can reduce injured patients' risk of death by 25% (44), and estimates for special situations, such as in combat zones, are even higher (47).

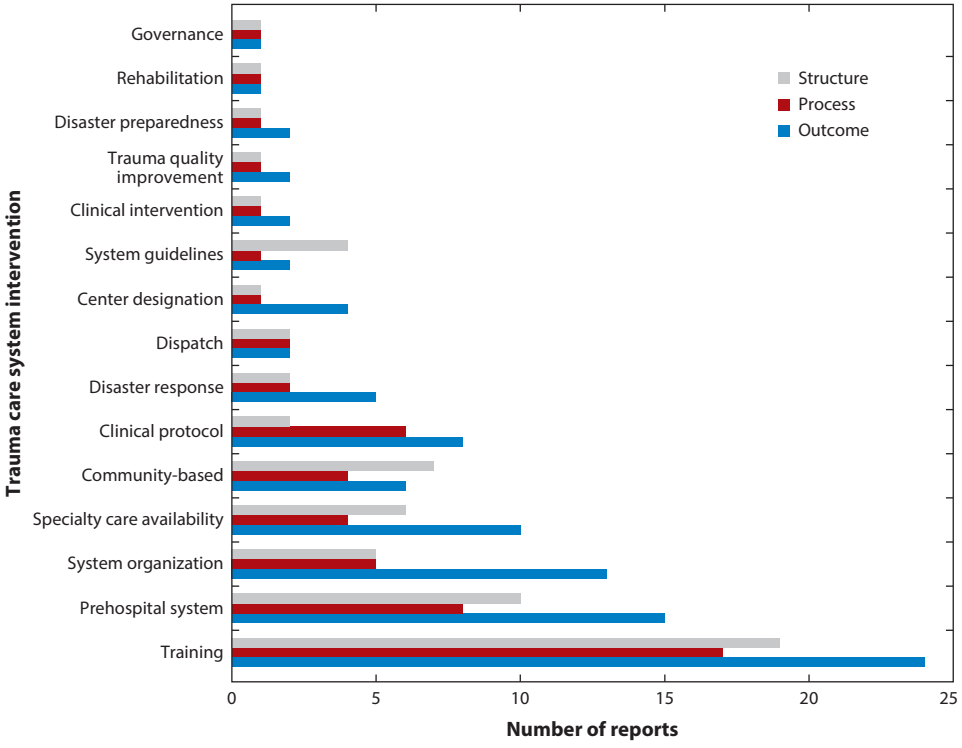

Figure 4

Impact types by detailed intervention types in included reports (a single report may describe multiple interventions and multiple impacts).

Unlike hospital-based trauma care services, which have long existed in some form in most systems and are usually expanded incrementally, many countries still lack formal prehospital services altogether, allowing investigators the possibility to study the initial establishment of the system itself. Multiple reports support the idea that the essential functions of a prehospital system can be achieved in many ways, depending on the context and available resources (96). While some reports address the impact of establishing formal professional prehospital systems (9, 59, 82), several reports describe innovative lay provider initiatives that led to improved mortality and other positive impacts. For example, a motorcycle-based prehospital transport system for snakebite victims in Nepal and the establishment of layperson prehospital care systems in Cambodia, Iraq, and South Africa illustrate the potential for prehospital care to be effective, even with resource-limited implementation (48, 49, 86, 90).

In particular, dispatch protocols emerge as a critical mechanism for strengthening prehospital care delivery. Included studies suggest that dispatch algorithms allow better alignment between existing prehospital resources and the clinical needs of injured patients, lowering costs and improving efficiency and outcomes (7, 13).

Prehospital care system improvements must always take local resource availability, disease burden, and geography into account. It is worth noting that the capital and operating costs in all the included reports were well beneath the WHO-CHOICE (Choosing Interventions that are Cost Effective) threshold values for cost-effectiveness by region and were similar to costs of other

recommended health interventions (e.g., bed nets for malaria prevention, antiretroviral therapy for HIV, aspirin and β-blocker for ischemic heart disease) (98).

Overall System Organization

Effective system organization ensures that injured patients receive timely care that is matched to their clinical needs, even when doing so requires bypassing lower levels of the health system. Five of the 15 reports in this section were modeling studies that extrapolate existing data to LMIC contexts, and they suggest that improvements in system organization could have a dramatic impact. While these models are based on a number of assumptions (about the capacity of trauma care systems in LMICs to approach outcomes seen in high-income countries), they are supported by the included studies that tested actual interventions in LMIC contexts.

The included reports demonstrate that improvements to system organization and planning can be feasible and sustainable, even in environments with very limited resources. In addition, one study from Ghana (excluded from our review because it did not specify an intervention) documented sustained improvements in the availability of critical trauma care resources at district and regional hospitals after broad changes in trauma care system governance and organization (88).

The benefits of improved coordination between trauma system components are well documented in high-income countries, and our review suggests that similar improvements in limited-resource settings may result in equally significant benefits. Indeed, these interventions may be even more valuable in contexts where maximizing the effectiveness of limited resources is critical.

Clinical Protocols

Clinical protocols provide guidance for a systematic approach to injury, improving early recognition of clinical needs and ensuring appropriate management. Included reports describing implementation of protocols for triage, assessment, management, and care coordination demonstrated improvements in care process and outcomes (53, 54, 68). These interventions may have particular importance in limited-resource settings where clinical volume is high and junior providers must often practice with limited supervision (63).

Specialist Availability

Trauma care is a multidisciplinary enterprise, and input from a range of specialty services (such as radiology, orthopedics and neurosurgery) is critical to providing a comprehensive response to injury. Several organizational aspects of a trauma system can affect the timeliness and availability of advanced specialty services. Included reports suggest that access can be improved by a range of low-cost (team organization, communication protocols) and higher-cost interventions (creation of new health care facilities).

Disaster Response and Preparedness

Preparing the everyday emergency care system to respond to extraordinary events ensures uninterrupted delivery of services in the face of increased demand. Not only do underprepared systems fail to deliver adequate and timely care during disasters, but they may also collapse in the face of system stressors, leading to additional secondary mortality and morbidity beyond that caused by the disaster itself. The few included reports on this topic suggest that the availability of specialized services can mitigate the impact of disasters but that there must be mechanisms in place to ensure that services can be rapidly disseminated where they are needed.

Trauma Quality-Improvement Programs

Although only two included reports specifically described the establishment of formal quality-improvement programs (41, 62), both demonstrated notable improvements in mortality and other positive impacts. Quality-improvement programs are integral to successful trauma care systems (101), are low-cost, and can be performed in nearly any setting where trauma care is provided.

Lay Providers

Incorporating lay providers into trauma care systems has been both clinically effective and cost-effective in multiple and disparate LMIC settings (25, 31). A notable number of included reports from our review (16 reports, mostly among those addressing training or prehospital initiatives) described the systematic use of lay providers to deliver emergency care services. Lay provider programs in Ghana, South Africa, and Uganda demonstrated long-term skill retention and utilization (50, 67, 90). Programs in rural Cambodia (49), Iraq (48), and Nepal (86) demonstrated improved mortality and were highly cost-effective.

Cost

Thirteen reports examined the cost or cost-effectiveness of the interventions assessed. Among the most cost-effective interventions are those that expand basic emergency care training to a range of lay and nondoctor providers (12), those that expand the scope of practice of nonspecialist providers (18), and those that target better organization of existing resources. Cost-based analysis will be critical to priority setting where resource limitations necessitate choices.

Evidence Gaps

Among the trauma system components identified in WHO guidelines, our review returned very few reports in the areas of rehabilitation and legislation and governance. In addition, only one report evaluated pediatric-specific trauma care mechanisms.

Rehabilitation. Disability after injury is 20–50 times more common than death; much of the resultant morbidity can be alleviated by early and appropriate rehabilitation services that increase functioning, prevent secondary complications (e.g., pressure sores, contractures), and promote independence (55). Rehabilitation is critical to maximizing the effectiveness of emergency and surgical care services for injury and should be an area of priority inquiry and planning.

Legislation, governance, and regulation. The only explicit example of a governance intervention identified in our search was the creation of the Trauma Secretariat in Sri Lanka, which was included in the WHO compendium of success stories (62). Through a series of assessments using WHO tools and consultative meetings with local technical experts, the Trauma Secretariat oversaw development of an action plan to build a comprehensive trauma system countrywide. The Secretariat catalyzed and coordinated expansion of a prehospital system; creation of a National Injury Sentinel Surveillance System; nationwide rollout of trauma care training; development of guidelines, protocols, and a system for trauma center designation; and creation of the Ministry of Disaster Management. While the Trauma Secretariat was partially supported both financially

and technically by international organizations, most of the work was done using local resources, expertise, and time, much of it volunteered.

Reports on these kinds of interventions are poorly represented in the scholarly literature in general, and their absence in this review should not be taken as an indication that they are not important. In addition to those mentioned above, critical legislative and governance interventions to improve care for the injured may include

- Establishing a lead government agency to coordinate emergency care (not limited to disaster response),
- Explicitly incorporating emergency care into the national health plan,
- Establishing national legislation ensuring access to emergency care without regard to ability to pay,
- Establishing dedicated certification pathways for prehospital providers, and
- Establishing a toll-free, universal access number for emergency care.

Pediatric trauma care. Injury is a leading cause of death among the young everywhere in the world and the top global killer of adolescents (100). Findings from high-income countries suggest that dedicated systems of care for injured children can avert deaths and disability (72, 76). In LMICs, pediatric-specific trauma care resources and expertise are more often deficient than those for general trauma care (2, 11, 75); planning and organizing care for injured children should be a priority area for research and system development, given the large burden of pediatric injury in LMICs.

LIMITATIONS

Our study has several limitations. Although we built the search strategy to be as inclusive as possible by using broad search terms (e.g., "wounds and injuries") and queried a range of the largest global databases, it remains a search of published, and primarily scholarly, literature. This limits our ability to capture interventions such as legislation and regulation that are less likely to be the subject of scholarly studies. In addition, some reports may have been missed without specific search terms for each trauma care system component, though it is unlikely that such reports would not have at least included the broader terms "trauma" or "injury." We did not search gray literature (e.g., theses, dissertations, government documents, working papers) but did include conference proceedings.

The included reports almost certainly reflect some degree of publication bias. Ninety-two percent of reports described positive outcomes and 8% described neutral outcomes; no report described negative outcomes. Although the generally positive outcomes may be a true reflection of the impact of trauma care system components, the lack of negative outcome reports suggests some publication bias. Many of the included studies were based on reported data, which may limit validity, and we did not exclude studies with small sample sizes, which may limit the generalizability of the trends discussed. Finally, a number of the studies were based on models, and this review did not attempt to evaluate the assumptions underlying the models.

Our search was intentionally limited to LMICs and to studies that demonstrated impact, as this was the focus of our inquiry. Therefore, our results should not be interpreted as a comprehensive survey of the evidence base for trauma care systems, nor as a comprehensive description of the current state of trauma care in LMICs, but as a summary of the current evidence for LMIC implementation with documented impact. Lessons from high-income countries regarding trauma system development, maturation, and specific system components are certainly also useful for LMICs and should be considered when planning research priorities. Despite these limitations,

the findings allow for reasonable conclusions about the potential impact of trauma care systems and system components in LMICs, provide context-relevant guidance for LMIC planners, and help identify topical gaps that necessitate specific study and funding.

CONCLUSION

This review has identified and described reports that evaluated the impact of trauma care systems and system components in LMICs. Although we identified 71 reports, the majority of LMICs had no reports at all. Reports that described the results of trauma care training, prehospital system establishment, overall system organization, and improvements to the availability of specialty care were more common than reports on other system components. These findings suggest several priority areas for research, program development, and funding. Specifically, there are a number of low-cost, high-value-added organizational interventions that involve only minimal input of new material resources. Quality-improvement, costing, rehabilitation, and legislation and governance are particularly neglected areas. We hope the results of this review will help guide more efficient and effective trauma care system development, as well as research and funding agendas.

DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review. The authors alone are responsible for the views expressed in this article and do not necessarily represent the views, decisions, or policies of the institutions with which they are affiliated.

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