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Improvement in trauma care for road traffic injuries: an assessment of the effect on mortality in low-income and middle-income countries

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Over 90% of the annual 1·35 million worldwide deaths due to road traffic injuries (RTIs) occur in low-income and middle-income countries (LMICs). For this Series paper, our aim was two-fold. Firstly, to review evidence on effective interventions for victims of RTIs; and secondly, to estimate the potential number of lives saved by effective trauma care systems and clinical interventions in LMICs. We reviewed all the literature on trauma-related health systems and clinical interventions published during the past 20 years using MEDLINE, Embase, and Web of Science. We included studies in which mortality was the primary outcome and excluded studies in which trauma other than RTIs was the predominant injury. We used data from the Global Status Report on Road Safety 2018 and a Monte Carlo simulation technique to estimate the potential annual attributable number of lives saved in LMICs. Of the 1921 studies identified for our review of the literature, 62 (3·2%) met the inclusion criteria. Only 28 (1·5%) had data to calculate relative risk. We found that more than 200 000 lives per year can be saved globally with the implementation of a complete trauma system with 100% coverage in LMICs. Partial system improvements such as establishing trauma centres (>145 000 lives saved) and instituting and improving trauma teams (>115 000) were also effective. Emergency medical services had a wide range of effects on mortality, from increasing mortality to saving lives (>200 000 excess deaths to >200 000 lives saved per year). For clinical interventions, damage control resuscitation (>60 000 lives saved per year) and institution of interventional radiology (>50 000 lives saved per year) were the most effective interventions. On the basis of the scarce evidence available, a few key interventions have been identified to provide guidance to policy makers and clinicians on evidence-based interventions that can reduce deaths due to RTIs in LMICs. We also highlight important gaps in knowledge on the effects of other interventions.

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Introduction

Road traffic injuries (RTIs) continue to be a leading cause of death and disability across the globe, resulting in approximately 1·35 million deaths a year.[1] Despite substantial global efforts, including the Decade of Action for Road Safety 2011–20[2] and the UN Sustainable Development Goals (SDGs) targeting a 50% reduction in road traffic deaths by the year 2020,[3] 104 countries showed an increase in the number of these deaths during the past 10 years. No low-income country and less than a quarter of middle-income countries saw a decrease in the number of deaths due to RTIs. National income remains a major predictor of road deaths: 93% of all global road deaths continue to occur in low-income and middle-income countries (LMICs).[1]

Strengthening trauma care systems is considered an essential intervention and was proposed as one of the five key pillars for the first Decade of Action.[3] It has been suggested that 2 million lives can be saved through the implementation of modern trauma systems in LMICs.[4,5] Strengthening trauma care systems in multiple settings in high-income countries (HICs) has already shown a gradual reduction in trauma mortality by as much as 15% after a trauma system's maturity.[6]

Life-saving trauma care is provided through a combination of health-care system and clinical interventions delivered together, most crucially during the first few hours of injury. Studies on trauma care interventions from LMICs have largely focused on process outcomes, such as the effect of training programmes or incorporating guidelines for trauma systems.[7] Even fewer studies have explored the benefit of individual components, such as pre-hospital care, use of triage criteria for transportation, or care at designated trauma centres versus general hospitals.[8] Challenges in gathering reliable information on this topic arise from the absence of data systems in LMICs and the disjointed implementation of individual components of a trauma system instead of implementation of the system as a whole. By assessing which interventions have the largest effect on mortality, scarce health-care resources can be efficiently invested to maximise health benefits.

The goal of this Series paper is to estimate the potential effect of improvements in trauma care on RTI-related mortality in LMICs. The specific objectives of this paper are to review evidence on the effectiveness of acute trauma care interventions and to estimate the potential number of lives saved through effective trauma care interventions for RTIs in LMICs. This analysis will review specific evidence on trauma care interventions, use it to assess the potential effect on deaths, and call for global evidence around trauma care for road safety in LMICs.

Overview of review approach

Data collection

For this Series paper, we defined trauma care interventions as any life-saving or limb-saving intervention done in the community by trained or untrained rescuers. These interventions could take place during transportation, in the emergency department, or in the hospital. Because of the heterogeneity of interventions for trauma patients, we divided all possible acute trauma care interventions into clinical interventions and system–level interventions. We included clinical interventions on the basis of what was measured in the available studies. We included studies addressing airway interventions (eg, orotracheal intubation), breathing interventions (eg, mechanical ventilation), and circulation interventions (eg, tranexamic acid or interventional radiology). As expected, these interventions apply to only certain types and severity of injuries, and the availability of these interventions is heavily dependent on the system of care where such interventions are possible.

For system-level interventions, we focused on four levels: bystander care; ambulances or medical transportation; emergency department care; and surgical care. In addition, we included interventions that described the establishment of trauma centres with trauma teams and the institution of a trauma system as a system intervention. Trauma team implementation and improvement could include a variety of changes including a transition to requiring emergency medicine training and board certification for all physicians and trauma surgery specialists[9] or implementing a specific set of criteria for trauma team activation.[10] We excluded post–acute care services (eg, rehabilitation services) from our analysis (panel).

We conducted a focused literature review to find a statistically significant effect of these interventions on mortality due to RTI. We searched MEDLINE, Embase, and Web of Science for papers published in English between Jan 1, 2000, and Dec 31, 2019 (20 years). For bystander care, keywords included “bystander care”, “bystander”, “civilian care”, “layperson”, “training”, “national training first aid”, “first aid training”, and “training first responders”.

For pre–hospital care, keywords included “prehospital”, “ambulance”, “patient transport”, “emergency medical service”, or “emergency medical services (EMS). Pre–hospital care keywords were combined with “scene airway management”, “airway management”, “ventilation”, “intubation”, “IV fluids”, “blood”, “availability of blood”, “tourniquet”, “continuous positive airway pressure (CPAP)/bilevel positive airway pressure (BiPAP)”, “tranexamic acid”, “chest tube”, “shock”, and “anti–shock garments”. For the search on emergency department interventions, keywords included “emergency department”, “ED”, or “emergency room”. Emergency department intervention keywords were combined with “mechanical ventilation”, “ventilation”, “advanced airway management”, “intubation”, “oxygen”, “availability of oxygen”, “trauma trained staff”, “trauma training”, “trauma team”, “trauma system”, “trauma center”, “advanced diagnostics”, “blood”, and “availability of blood”. For surgery, keywords included “neurosurgeon”, “surgical intensive care unit”, “surgical intensive care unit (ICU)”, “orthopedic surgery”, and “interventional radiology”. All search terms used were combined with: “mortality”, “death”, or “survival”; “emergency”, “trauma”, or “injury”; and “low- and middle-income country (LMIC)”, “low-income countries”, and “middle-income countries”.

We only selected studies where mortality was described as an outcome. If studies contained no data on mortality as an outcome or if they included interventions that targeted medical or surgical emergencies in addition to trauma they were removed from our analysis. The following interventions were not included in our analysis: national training in first aid; pre-hospital continuous positive airway pressure or bilevel positive airway pressure; pre-hospital chest tube; pre-hospital anti-shock garments; advanced airway management in the emergency department; oxygen in the emergency department, advanced diagnostics (eg, CT scan); availability of blood in the emergency department; surgical intensive care unit (ICU); and orthopaedic surgery. We also excluded studies that

Panel: Trauma care processes included in this Series paper

We considered specific interventions as crucial components of a trauma care system. For bystander care, we reviewed life-saving care by bystanders at the scene; national training in first aid; and training for first responders. For ambulance transport, we considered communication with an ambulance service, either through a universal or non–universal access number; dispatch–assisted care or support to the bystanders; formal or informal patient transport system; critical life-saving interventions at the scene and during transport, including management of airways; and restoration of breathing and circulation through the use of oxygen, chest tubes, intravenous fluids, and intravenous blood. We also included the use of airway equipment; bag–valve ventilation or non–invasive ventilation using continuous positive airway pressure or bilevel positive airway pressure; crystalloid–based or colloid–based resuscitation; tranexamic acid; anti-shock garments; tourniquet; and other interventions proposed by the Stop the Bleed Coalition. For emergency department care, we included availability of trauma centres; trauma training of staff; availability of a trauma team; availability of blood; advanced airway management; mechanical ventilation; supplemental oxygenation; management of shock; stopping the bleed through direct pressure; tourniquet; and emergency department–based procedures, including the use of advanced diagnostics (eg, CT scans and point–of–care ultrasonography). For acute care in the hospital, we reviewed the availability of a trauma team, surgical intensive care unit, neurosurgery, orthopedics, and interventional radiology.

focused on military care because this involves different patient demographics, injury types, trauma care systems, and available resources than the civilian trauma system.

Search terms focusing on bystander care brought up 522 articles, none of which were included. The pre-hospital search resulted in 466 articles, 32 (15%) of which were included. Search terms regarding care in the emergency department resulted in 865 articles, 26 (33%) of which were included. The surgery search brought up 118 articles, four (30%) of which were included (appendix p 1).

Data extraction

We extracted data on the type of intervention, study design, outcome measures, and mortality results (ie, 95% CIs and p-values). We also collected data on the hospital, region, and country where the study was done. Some papers described the effect of a bundle of interventions (eg, the implementation of a complete trauma system) and each intervention could not be disentangled. These papers were assessed separately.

We used the Joanna Briggs Institute critical appraisal tool[11] to score the quality of each study included in the review. Each study was assessed by two authors (KW and JB) independently and conflicts were resolved in the presence of a third author (JAR). When the quality-related item was found the specific item was given a score of 1. When the authors were unsure, or did not find the item, the specific item received a score of 0. The included studies were expected to score more than 50% of all items on the basis of the specific design (eg, analytical cross-sectional, cohort study design). Any study scoring less than 50% was not considered in the simulation analyses. Where applicable, we considered the hierarchy of evidence to aid in the selection of relative risk when multiple studies were available. The highest level of evidence was given to meta-analyses; followed by studies from LMICs on RTIs or blunt trauma; followed by HICs on RTIs or blunt trauma; followed by LMICs on mixed trauma (with >50% of patients with blunt injuries); and finally, HICs on mixed trauma (with >50% of patients with blunt injuries).

Mortality data

We used injury-related mortality estimates from the WHO Global Status Report on Road Safety 2018.[1] These status reports, which were published in 2009, 2013, 2015, and 2018, provide country-wide estimates for road traffic deaths using established statistical models. We used estimates for low-income countries, middle-income countries, and LMICs (combining both).

Statistical analysis

Using effect sizes on trauma mortality from the literature review, we estimated the number of lives saved per year in LMIC groups by each intervention. We only selected trauma care interventions that had an effect on mortality. To quantify the contribution of each intervention to mortality reduction, we used a population attributable fraction (PAF) estimation followed by a Monte Carlo Simulation to estimate the uncertainty of the PAF estimates.[12–14] For simulations, we assumed a triangular distribution for deaths and effect size—ie, minimum, maximum, and mean—for which all are the same when there is one value. Similar methods have been used in other studies to highlight the effect of injury prevention interventions.[12]

To estimate the PAF related to each intervention, we matched the effect size from the literature to the corresponding target population with the equation: $\text{lives saved}_{ijk} = (1 - \text{relative risk}[\text{RR}]_{jk}) \times \text{number of deaths}_{jk} \times \%\text{popLMIC}_i$. In this equation, the estimated number of lives saved is a function of the number of deaths by each country *i*, income status *k*, and mortality prevented by the intervention *j*.

See Online for appendix

To ascertain the appropriate denominator for each intervention, we first calculated the total number of deaths due to RTIs in LMICs and then used the available literature to estimate the number of deaths at the scene (up to 1 h after the road traffic crash), in the emergency department (up to 24 h after the crash), and in post-emergency care after the injury (days to weeks after the crash). According to the data, which are mostly from HICs, 30% of deaths occur at the scene of the crash before help arrives; 30% occur during transportation and within 1 h of arrival to the emergency department; 30% occur in the first 24 h after the crash; and 10% occur in days to weeks following the injury.[15] We also estimated the cause of death by type of trauma (eg, traumatic brain injury, haemorrhage, and sepsis; table 1). We selected the denominator that would apply to a certain intervention (eg, a trauma system intervention would apply to 70% of deaths because 30% of deaths would be assumed to happen at the scene).

We analysed clinical interventions that had available data on their effect on mortality. These interventions included: use of pre-hospital intravenous fluids; pre-hospital blood transfusion, use of tranexamic acid within 3 h of injury; use of tranexamic acid specifically for head injury; availability and use of interventional radiology; and use of damage control resuscitation (a strategy to minimise blood loss until definitive haemostasis is achieved). We included studies in which a heterogeneous group of injuries were studied together and in which RTIs contributed substantially to the case-mix. We excluded interventions which were found to be ineffective (eg, scene airway management) and interventions for which clear PAF was not available.

For system-wide interventions, we used population fraction estimation of 50%, 75%, and 100% to assess the effect on the basis of a population's access to the interventions. For example, if the availability of an intervention was assumed to be 50%, we used the equation: $\text{lives saved}_{ijk} = (1 - \text{RR}_{jk}) \times 0 \cdot 50 \times \text{number of}$

	Number of immediate deaths*†	Early deaths‡
Traumatic brain injury	328 050 (27%)	109 350 (9%)
Bleeding or haemorrhage	255 150 (21%)	182 250 (15%)
Other	145 800 (12%)	72 900 (6%)
Total RTI-related deaths in LMICs§	729 000 (60%)	364 500 (30%)

Data are n (%). LMIC=low-income and middle-income country. RTI=road traffic injury. *Immediate deaths are deaths that occur at the scene and within 1 h of the injury. †30% of deaths occurred at the scene and 30% of deaths occurred within 1 h of the injury. ‡Early deaths occur after the immediate phase but within the first 24 h following the injury. §Data are from the Global Status Report on Road Safety 2018.

Table 1: **Assumed distribution of deaths in the acute phase of injury in LMICs by cause of death**

	Country	Minimum effect	Maximum effect
Trauma system interventions			
Trauma system	USA and Netherlands	0·88	0·64
Health system interventions			
Establishing a trauma team	Thailand	0·69	0·69
Pre-hospital care including training and ambulances	Nigeria and Iraq	1·86	0·18
Trauma centres	USA	0·75	0·44
Clinical interventions			
Pre-hospital tourniquet	USA	0·75	0·36
Pre-hospital blood	USA	0·96	0·91
Tranexamic acid for suspected bleeding (<3 h after injury)	Multiple countries	0·89	0.89
Tranexamic acid for traumatic brain injury	Multiple countries	0·94	0·94
Interventional radiology	USA and Japan	0·70	0·44
Hypotensive resuscitation or damage control resuscitation	Multiple countries	0·61	0·50

Table 2: **Population attributable fraction for trauma care interventions for road traffic injuries**

$deaths_{jk} \times \%popLMIC_i$. A PAF of 100%, therefore, assumes that everyone has access to that specific trauma intervention.

For clinical interventions, we used the PAF on the basis of the potential frequency of the use of that intervention (according to the location of the patient and the type of injury). For example, for the use of traxenamic acid, we used a PAF of 14·8%, on the basis of the total number of patients who would be able to reach the hospital and would have subsequently died of haemorrhage.[16] LMIC groups were estimated seperately as low-income and middle-income. The two groups were combined for this analysis. Monte Carlo Simulations were used with 100 000 iterations to obtain uncertainty levels by intervention and by country.

We made several assumptions for our analyses, some of which mirror other analytic approaches on RTIs and injuries.[12,17] We did not account for the potential synergy of interventions. For example, mortality estimates for the availability of blood in the pre-hospital setting did not account for ultimate access to an emergency department with a trauma team. We also assumed that HICs had 100% access to all interventions. Furthermore, we assumed that each intervention had the same level of coverage for patients living in LMICs (eg, we assumed there were no rural or urban disparities).

The effect of trauma care interventions on RTI-related mortality in LMICs

We identified 1921 studies through our systematic literature search. 1859 studies were excluded because they did not have specific outcome data (figure 1). This exclusion process resulted in 62 applicable studies that covered 17 different countries. Of these 62 studies, one (2%) was from a low-income country, four (6%) were from low-middle income countries, five (8%) were from upper-middle-income countries, 48 were from HICs (29 [60%] of which were from the USA), six (10%) studies included data from multiple countries in different income groups, and one (2%) included one LMIC and one upper-middle-income country. Of the 62 studies with intervention data, 11 (18%) included only RTIs and 51 (82%) had data on mixed trauma, including RTIs (appendix pp 2–9). Of the 62 studies with intervention data, 35 (65%) did not allow for the calculation of relative risk because complete information about denominators and numerators were not available. Of the 62 studies with intervention data, 35 (65%) did not allow for the calculation of relative risk because complete information about denominators and numerators were not available, and four studies only provided percentages. We used the remaining 27 (45%) studies for our analysis. In these 27 studies, we found 14 interventions that had outcome data and only ten interventions for which there was any mortality benefit. Of these ten interventions, four (40%) were system-level interventions, and six (60%) were specific clinical interventions.

Table 2 shows the minimum and maximum PAF and countries from which these estimates originated, including the minimum and maximum effect size. Except for emergency medical services (EMS), which showed substantial variability in outcomes for trauma patients, most interventions had a relatively narrow difference between minimum and maximum effect size. For tranexamic acid, the CRASH II and III trials were the only trials used for our analysis, which meant that the same maximum and minimum effect size was used.

We present the effect of interventions on mortality assuming 100%, 75%, and 50% coverage (table 3). If a complete trauma system were to be implemented in all LMICs with 100% coverage, over 200 000 (95% CI 135 561–276 971) lives per year would be saved, resulting in a 19% reduction in mortality from RTIs. The more realistic scenario of 50% coverage would result in over 100 000 (67 974–138 467) lives per year saved or an 8% reduction in mortality (table 3). Ensuring the availability of trauma centres to 50% of those involved in

RTIs could save nearly 75 000 (55 077–94 168) lives per year, resulting in a 7% reduction in mortality. Ensuring the availability of trauma teams could save nearly 60 000 (57 411–58 674) lives per year, resulting in a 5% reduction in mortality. Calculating the effect of EMS on mortality was complex, because pre-hospital care can delay definitive care and can lead to increased morbidity and mortality.[18–23] The effect range for EMS was extremely wide and depended on its services and focus. We found that the implementation of EMS could result in over 3500 excess deaths per year to over 100 000 lives saved per year.

Table 4 shows the effect of some clinical trauma interventions on mortality. Damage control resuscitation has the highest likelihood of saving lives at 50% coverage (35 452 lives saved per year; 95% CI 35 390–35 514); followed by the availability and use of interventional radiology to control bleeding (29 089 lives saved per year; 29 027–29 151); traxenamic acid for patients with suspected bleeding (9999 lives saved per year; 9937–10 061); and pre-hospital tourniquet (5743 lives saved per year; 29 027–29 151). The use of intravenous fluids in the pre-hospital phase, on the other hand, could lead to over 6000 excess deaths per year.

	Lives saved per year at 100% coverage	Lives saved per year at 75% coverage	Lives saved per year at 50% coverage
Low-income countries			
Trauma system	28 756 (18 898 to 38 601)	21 532 (14 182 to 28 877)	14 374 (9466 to 19 298)
Establishing a trauma team	16 169 (15 993 to 16 344)	12 126 (11 994 to 12 258)	8084 (7997 to 8172)
Availability of ambulances	–1106 (–30 588 to 28 362)	–786 (–22 867 to 21 271)	–551 (–15 312 to 14 223)
Trauma centres	20 799 (15 362 to 26 225)	15 592 (11 528 to 19 677)	10 389 (7669 to 13 101)
Middle-income countries			
Trauma system	177 691 (117 214 to 238 533)	133 053 (87 521 to 178 730)	88 827 (58 554 to 119 190)
Establishing a trauma team	99 916 (98 830 to 100 995)	74 938 (74 121 to 75 751)	49 958 (49 416 to 50 501)
Availability of ambulances	–5870 (–188 178 to 175 583)	–4559 (–140 912 to 131 573)	–3291 (–94 361 to 87 862)
Trauma centres	128 465 (94 897 to 161 880)	96 449 (71 338 to 121 544)	64 255 (47 508 to 81 041)
Low-income and middle-income countries			
Trauma system	206 422 (135 561 to 276 971)	154 602 (101 598 to 207 770)	103 204 (67 974 to 138 467)
Establishing a trauma team	116 086 (114 825 to 117 345)	87 064 (86 122 to 88 009)	58 042 (57 411 to 58 674)
Availability of ambulances	–7060 (–218 811 to 203 633)	–5661 (–164 901 to 152 781)	–3638 (–109 512 to 102 102)
Trauma centres	149 329 (110 435 to 188 360)	112 031 (82 741 to 141 318)	74 626 (55 077 to 94 168)

Data are mean (95% CI).

Table 3: **Effect of health system interventions for trauma on road traffic injury mortality in low-income and middle-income countries by coverage level**

Conclusions

RTIs are a leading cause of death worldwide and the only cause of injury for which there are agreed global targets (eg, SDG target 3.6).[3] Although prevention remains the cornerstone for reducing RTI deaths, improved post-crash care is considered a key intervention for achieving these targets. Post-crash care could lead to a reduction in trauma mortality of up to 35%.[2,4,24,25] Our Series paper is the first detailed model of the potential effect of trauma care on RTI-related mortality in LMICs using global data. On the basis of an assumed coverage of an intervention as a proxy of improvement in the trauma care system, we estimated that 17% of RTI-related deaths in LMICs are avoidable, which is a substantial effect that showcases the importance of included interventions. However, our estimates of the effect of interventions on RTI-related deaths are lower than the effect assumed in other calculations.[26] Our estimates were made on the basis of multiple studies and RTI prevalence from 2018, whereas other estimates were made on the basis of a single study with data collected in three cities from 1992 to 1996, on less than 1500 patients representing all types of injuries.[26] These differences could explain the discrepancy in the effect of interventions on mortality.

We also identified a few key components of trauma care systems and clinical interventions, which, if implemented, could result in a substantial mortality benefit. Previous research on trauma care systems focused on process measures, looked at high-income settings, studied only one component of the trauma system or a few individual clinical interventions, and did not present a comprehensive analysis.[6–8,27–30] Additionally, although our estimation of populations that were likely to benefit from individual interventions was made on the basis of a subgroup analysis of the type of injury, we believe our estimates provide a more realistic effect of interventions than other studies on trauma care. For example, we only applied the potential mortality benefits of hospital-based interventions to patients who were expected to arrive at the hospital alive and not to all victims of RTIs, because many victims will probably die before reaching a hospital (as assumed in computations in previous papers). Furthermore, our methods and approach to calculating the lives saved by post-crash interventions builds on other published work on the mortality benefit of injury prevention strategies.[12]

In our Series paper, we attempted to capture the effects of both system-wide and clinical interventions. By covering both levels of interventions, we acknowledged both the complex, dynamic nature of health delivery and the simplified, somewhat reductionist, approach to individual clinical interventions. We hope that these

	Lives saved per year at 100% coverage	Lives saved per year at 75% coverage	Lives saved per year at 50% coverage
Low-income countries			
Pre-hospital intravenous fluids	–1797 (–1920 to –1674)	–1347 (–1440 to –1255)	–898 (–960 to –837)
Pre-hospital blood transfusion	1168 (861 to 1475)	876 (646 to 1107)	584 (431 to 737)
Tranexamic acid within 3 hours of injury	2786 (2768 to 2803)	2089 (2076 to 2102)	1393 (1384 to 1401)
Tranexamic acid for head injury	914 (903 to 924)	685 (677 to 693)	457 (452 to 462)
Interventional radiology	8103 (8086 to 8120)	6077 (6064 to 6090)	4052 (4043 to 4060)
Damage control resuscitation	9876 (9859 to 9893)	7407 (7394 to 7420)	4938 (4929 to 4947)
Middle-income countries			
Pre-hospital intravenous fluids	–11 100 (–11 859 to –10 342)	–8325 (–8897 to –7757)	–5551 (–5930 to –5171)
Pre-hospital blood transfusion	7222 (5328 to 9119)	5415 (3993 to 6829)	3606 (2655 to 4559)
Tranexamic acid within 3 hours of injury	17 213 (17 106 to 17 320)	12 910 (12 829 to 12 990)	8607 (8553 to 8660)
Tranexamic acid for head injury	5646 (5582 to 5711)	4234 (4186 to 4283)	2823 (2791 to 2855)
Interventional radiology	50 074 (49 968 to 50 181)	37 556 (37 476 to 37 636)	25 037 (24 983 to 25 091)
Damage control resuscitation	61 028 (60 921 to 61 135)	45 771 (45 691 to 45 851)	30 514 (30 460 to 30 568)
Low-income and middle-income countries			
Pre-hospital intravenous fluids	–12 898 (–13 781 to –12 016)	–9673 (–10 335 to –9009)	–6448 (–6889 to –6008)
Pre-hospital blood transfusion	8385 (6176 to 10 588)	6288 (4638 to 7939)	4195 (3097 to 5295)
Tranexamic acid within 3 hours of injury	19 998 (19 875 to 20 123)	14 999 (14 905 to 15 092)	9999 (9937 to 10 061)
Tranexamic acid for head injury	6560 (6485 to 6634)	4920 (4864 to 4976)	3280 (3242 to 3317)
Interventional radiology	58 178 (58 053 to 58 302)	43 633 (43 540 to 43 726)	29 089 (29 027 to 29 151)
Damage control resuscitation	70 904 (70 779 to 71 028)	53 178 (53 085 to 53 271)	35 452 (35 390 to 35 514)

Data are mean (95% CI).

Table 4: **Effect of clinical interventions for trauma on road traffic injury mortality in low-income and middle-income countries by coverage level**

distinctions can help stakeholders with scarce resources prioritise specific interventions. It is vital to acknowledge that the development of a trauma care system that can deliver these clinical interventions is ultimately the goal of such efforts. Furthermore, although there is unmeasured, yet quite substantial, interdependence between the trauma care system and individual interventions, system-wide implementation challenges can be overwhelming and could potentially discourage action. Our analysis showed that lives could be saved through both individual patient-based (eg, damage control resuscitation) and clinical unit-based interventions (eg, trauma team implementation). In our Series paper, we presented a few clinical interventions for which data were available to estimate their effect on RTI-related mortality. These clinical interventions primarily focused on haemorrhage control and early resuscitation and could offer a reasonable starting point for improving care practices. Our analysis was made on the basis of the available evidence and our inclusion of damage control resuscitation and interventional radiology in this analysis does not mean that these interventions should immediately be prioritised by all countries. Furthermore, many clinical interventions assume a functional medical system (eg, damage control resuscitation requires a robust multidisciplinary care system that is coordinated). Therefore, building effective trauma systems is sometimes not achievable, and well defined clinical interventions and simpler health system interventions can be practical starting points to save lives sooner.[5]

An important finding from our review of the literature was that there were few studies on trauma care interventions in LMICs, and the studies that did look at these interventions were of poor quality.[28] Out of 62 studies, only four (6%) were experimental trials and 15 (24%) were designed as prospective studies (appendix pp 2–9). Only one (2%) study was from a low-income country, and long-term mortality rates were reported in few studies. 11 (18%) studies reported 28-day or 30-day mortality rates, one (2%) study reported 6-month mortality rates, and one (2%) study reported mortality rates of up to one year. In addition, there is an overall absence of evidence evaluating specific components of the trauma system. For example, nurses are a crucial part of the trauma team, but our results did not include studies evaluating the effect of nursing care on trauma outcomes. Future research should prioritise assessing the true effect of nursing care, which could result in improved training and policies for nursing care. It is also important to emphasise that an absence of data on other trauma care interventions does not mean that these interventions have no clinical effectiveness. Trauma care interventions described as part of the current standard of care should be done according to standard guidelines unless future evidence questions their clinical effectiveness.

The potentially harmful effect of EMS can probably be explained by implementation challenges, such as the delay in access to definitive care or interventions which could increase morbidity and mortality (eg, the use of intravenous fluids). These implementation challenges are well described in HICs.[18–23]

Our Series paper has several limitations, driven mainly by the scarce evidence on RTI-related outcomes from LMICs and the model assumptions. First, we assumed that HICs have 100% access to all inverventions and that the effect sizes reported in the literature and found in specific settings are transferable to all LMICs. We also assumed that the same level of coverage exists for everyone in LMICs without considering potential disparities. The type and severity of injuries can vary substantially by region, depending on the vulnerability of road users (eg, countries with greater use of two-wheelers will probably have different types of road injuries than those with more people who drive cars). Similarly, trauma care is highly dependent upon the maturity of the overall health-care system, which is determined by the training of health-care personnel, the state of infrastructure, and the level of health-care financing. Therefore, the effect sizes described in this Series paper will be affected by the level of maturity of the health-care system and will evolve with appropriate investment and time. Second, by only estimating the effect of each intervention individually, we cannot predict whether two or more interventions implemented concurrently would yield results that are equal, inferior, or superior to the sum of the isolated effects of each intervention. For example, would pre-hospital care interventions implemented in isolation have different effect sizes than if they were implemented concurrently with improvement in hospital-based trauma care? Third, we used mortality data from the Global Status Reports on Road Safety for our analysis, which means that our results rely on the precision of the estimates of these reports (ie, modelled estimates that have been published and used by WHO for over a decade).[1] Fourth, the data used for our estimates on the effect of interventions on RTI-related mortality were global and mostly from HICs, where care was probably substantially better even before full trauma system implementation than the current baseline in many LMICs. It is therefore conceivable that our estimates on the effect of system changes on RTI-related mortality could be relatively high.[5] Because our simulation models permitted us to assess the variation of the effect on mortality on the basis of the coverage of the intervention, we ran the model assuming that LMICs would have 50% or 75% coverage. Because many LMICs are adapting these interventions in alignment with the first Decade of Action and SDGs, we believed it made sense to consider the coverage as 50% or 75% to mimic what might be happening in LMICs. Fifth, we focused our assessment on deaths during the first 24 h following a road traffic crash, during which 90% of RTI-related deaths occur in LMICs. We did not consider interventions after the acute phase of injury care. Finally, by only presenting data on fatal injuries, we observed the effectiveness of these interventions on mortality only. We expect that the effectiveness of these interventions would increase if non-fatal injuries were also considered.

There are several implications of our findings. For policy makers, the benefits of strengthening trauma care for road safety needs to be considered in view of their broader positive effect on other injuries (eg, injuries caused by firearms, falls, and drowning) and on other emergencies (eg, cardiac arrest, ischaemic heart disease, stroke, sepsis, and large-scale disasters). These interventions would involve improved access to training, improved access to equipment, maintenance of equipment, and continuous skill development. Implementing these interventions would also require a substantial investment of resources, a change in the culture of the health system, and patience. For clinicians in LMICs, focusing on strategies to control haemorrhage (eg, prehospital tourniquets, rapid transfer to the appropriate facility, and damage control resuscitation), and interventions to enhance access to surgery or interventional radiology could improve patient outcomes. Additionally, these interventions are multidisciplinary and would only be possible with substantial investment in improving teamwork and coordination at the clinical unit level.[31]

For researchers and research funders, our Series paper highlights the crucial need for supporting more, high-quality evidence on the effect of trauma care interventions for RTIs. This evidence is especially necessary in view of the second Decade of Action for Global Road Safety[32] and an upcoming high level meeting on road safety at the UN in June, 2022.[33] The generation of approporiate trauma care evidence is especially important in LMICs while they build their trauma systems and implement relevant system-wide and clinical interventions for road safety and injuries. Appropriate evidence on trauma care also requires universally agreed-upon definitions of interventions and clinically meaningful outcomes, with high-quality study designs and analyses. Although there are some efforts to promote research in these areas, much more needs to be done, including making trauma care a funding priority for research-granting organisations.[34] We join others in calling for greater attention and funding for trauma care research for RTIs in view of the high toll of ill health globally and the potential positive effect of interventions.[35,36]

Contributors

JAR was responsible for conceptualisation, formal analysis, investigation, methodology, project administration, supervision, writing the original draft, and revisions. JB was involved in data curation, formal analysis, methodology, and writing the Series paper. KW was involved in data curation, formal analysis, methodology, and project administration. KW also contributed to writing, editing, and reviewing the Series paper. MN was involved in the conceptualistion and original draft revisions. MRT was involved in data curation, formal analysis, and methodology. AAH was involved in conceptualisation, methodology, supervision, reviewing, and editing.

Declaration of interests

We declare no competing interests.

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