Does the implementation of a trauma system affect injury-related morbidity and economic outcomes? A systematic review

Michael F Bath 1,2, Laura Hobbs 1,2, Katharina Kohler 1,2,4, Isla Kuhn,5 William Nabulyato,1 Arthur Kwizera,6 Laura E Walker 7, Tom Wilkins,8 Daniel Stubbs,4 RM Burnstein,4 Angelos Kolias,2 Peter John Hutchinson 2, P John Clarkson,1,9 Sara Halimah,10 Tom Bashford 1,2,4,9

ABSTRACT
Background Trauma accounts for a huge burden of disease worldwide. Trauma systems have been implemented in multiple countries across the globe, aiming to link and optimise multiple aspects of the trauma care pathway, and while they have been shown to reduce overall mortality, much less is known about their cost-effectiveness and impact on morbidity.

Methods We performed a systematic review to explore the impact the implementation of a trauma system has on morbidity, quality of life and economic outcomes, in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. All comparator study types published since 2000 were included, both retrospective and prospective in nature, and no limits were placed on language. Data were reported as a narrative review.

Results Seven articles were identified that met the inclusion criteria, all of which reported a pre-trauma and post-trauma system implementation comparison in high-income settings. The overall study quality was poor, with all studies demonstrating a severe risk of bias. Five studies reported across multiple types of trauma patients, the majority describing a positive impact across a variety of morbidity and health economic outcomes following trauma system implementation. Two studies focused specifically on traumatic brain injury and did not demonstrate any impact on morbidity outcomes.

Discussion There is currently limited and poor quality evidence that assesses the impact that trauma systems have on morbidity, quality of life and economic outcomes. While trauma systems have a fundamental role to play in high-quality trauma care, morbidity and disability data can have large economic and cultural consequences, even if mortality rates have improved. The sociocultural and political context of the surrounding healthcare infrastructure must be better understood before implementing any trauma system, particularly in resource-poor and fragile settings.

WHAT IS ALREADY KNOWN ON THIS TOPIC
⇒ The implementation of a trauma system is known to improve overall mortality rates within a region.
⇒ Morbidity and disability data can have large economic and cultural consequences, even if mortality rates have improved.

WHAT THIS STUDY ADDS
⇒ Only limited poor-quality evidence is available that reports the impact trauma systems have on morbidity, quality of life and economic outcomes, all of which have been studied only in high-income settings.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY
⇒ Further research is needed to better understand and unpick how context-specific trauma systems can be best implemented, particularly in resource-poor and fragile settings.

INTRODUCTION
Trauma accounts for approximately 9% of all global deaths.1 It contributes to the greatest loss of disability-adjusted life years (DALY) for adolescents and young adults worldwide2 as well as more deaths than from HIV, tuberculosis and malaria combined.3 There remains a disproportionately high number of trauma-related casualties in low and middle-income countries (LMICs)4 and approximately two million lives each year could be saved if similar outcomes were achieved among seriously injured persons in LMICs as in high-income countries (HICs).5

Trauma systems have been variably defined,6 but can be considered as a framework to link and optimise multiple aspects of the trauma care pathway, from prehospital triage protocols and predefined transport links through definitive care and rehabilitation services, either as an inclusive or exclusive system, with the overall aim of improving trauma patient outcomes. Trauma systems have been implemented across multiple countries around the world for over 15 years,7–12 and multiple high-level estimates suggest that they significantly improve overall mortality rates in patients with trauma.13–15 However, trauma system development has mainly been driven from mortality data and much less is known about their cost-effectiveness and impact on morbidity and economic outcomes.
Given the benefits seen in survival outcomes, it may be reasonable to assume that morbidity and economic outcomes might also be improved with the implementation of a trauma system. However, improvements may conversely result in a greater burden of morbidity with increasing numbers of survivors requiring ongoing medical care. This is an important consideration for maturing healthcare settings when choosing whether or how to implement trauma systems. Indeed, much of the consensus on trauma system benefit has derived from HIC settings, which already have pre-existing and established systems of rehabilitation and social care. It is difficult to interpret this experience in the context of fragile health systems in LMICs, which, despite the greatest burden of traumatic disease, have a relative paucity of available literature on which to base trauma system implementation.

To understand the current evidence for trauma system impact beyond mortality rates, we performed a systematic review to explore the impact of the implementation of a trauma system on morbidity, quality of life and economic outcomes in the population served by that service.

METHODS

Literature search

A literature search was undertaken in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. The study was registered with PROSPERO (www.crd.york.ac.uk/prospero) prior to the initial literature search being undertaken and the full protocol has previously been published in an open-access peer-reviewed journal. The literature search was designed by a health librarian (IK) in collaboration with the lead author (MFB), using a combination of free text terms and subject headings where appropriate. No patients or public were involved in the design of the study.

We conducted searches using the following databases: MEDLINE via Ovid, Embase via Ovid, Web of Science Core Collection, PsycINFO via EbSCO, Global Health via EbSCO, SciELO via Web of Science, WHO Global Index Medicus, including African Index Medicus, Index Medicus for Eastern Mediterranean Region, Index Medicus for South-East Asian Region, Latin America and the Caribbean Literature on Health Sciences (Lilacs), and Western Pacific Region Index Medicus (the full search strategy is included in the online supplemental material). A grey literature search was also performed.

The study question was derived around the following PICO format: Population=all types of trauma patients; Intervention=implementation of an organised trauma system within a region; Comparison=no organised trauma system within a region; Outcome=any morbidity, quality of life, or economic outcomes.

Eligibility criteria

Any study that assessed the impact of the implementation of an organised trauma system on morbidity, quality of life, or economic outcomes was included. An organised trauma system was defined as any “pre-planned approach to the provision of the spectrum of trauma services”, and only studies that assessed the implementation of a full trauma system, not just a sub-component, were included. We took a pragmatic approach to study inclusion, such that those studies reporting on either formal or informal trauma systems in place (often termed a “hard” system vs a “soft” system) were included.

All comparator study types were included, both retrospective and prospective. Case studies or case series (<10 patients), reviews, and editorials were excluded, as were studies on the implementation of a specific technique or equipment involved in a trauma system (ie, not a whole-system intervention) or studies that reported outcomes for pre-existing trauma systems (ie, not newly implemented). Further details on the inclusion criteria are described in the previously published protocol.

Due to significant developments in trauma care in recent years, only studies published from January 2000 to August 2022 were included. No limits by publication type or language were applied, with any non-English language published manuscripts translated locally using University translation services where required.

Data analysis

Articles were screened initially by title and then abstract by two authors independently, with discrepancies resolved by consensus. The final data extraction of all included studies was performed by the lead author (MFB). Due to the mixed study populations involved and heterogeneous outcomes reported, no quantitative statistical assessment was possible, with data reported as a narrative review and conducted in accordance with the SWiM guidelines (online supplemental material). A risk of bias assessment for included studies was performed using the Risk of Bias in Non-randomised Studies of Interventions (ROBINS-I). Due to the high heterogeneity in the included study outcomes, publication bias was not feasible for assessment.

RESULTS

Following removal of duplicates, we identified 8087 articles for screening and an additional 94 articles through grey literature and reference searching, resulting in a total of 8181 articles screened (figure 1). Seven articles met the study inclusion criteria and were included in the final review.

All studies reported a pre and post-trauma system implementation comparison. Three articles reported all trauma patient types, two articles reported on patients with traumatic brain injury (TBI), one article reported on lower limb open fracture patients, and one article reported on penetrating thoracic trauma patients. In total, 17 137 patients were included across all studies (table 1).

We analysed studies including all trauma patient types, with a subset analysis for patients with TBI; we had originally planned to perform a subanalysis on paediatric cases, but no suitable studies were identified in the literature search; therefore, this could not be performed. All included studies demonstrated a severe risk of bias from the ROBINS-I assessment (table 2).

All trauma patients

Three studies were identified that reported specific morbidity outcomes. A study from the West Midlands, United Kingdom (UK), evaluated the implementation of a regional trauma system in 2012, assessing its impact on patients achieving a ‘good recovery’, which was defined as patients being discharged home to live independently, with no new arrangements for domiciliary care. The implementation of the trauma system showed a significant increase in the proportion of patients having a good recovery, from 55.5% to 62.3% (p<0.001).

A study from Suwon, South Korea, also reported morbidity outcomes, describing the impact of their regional trauma system implementation on trauma patients who suffered an open fracture below the knee and with Gustilo-Anderson classification type II or type III and rates of limb salvage. Limited details were provided on the specific trauma system implemented,
although trauma system care in South Korea has previously been well described. Limb salvage was defined as the resolution of soft tissue wounds without a requirement for major amputation. The study concluded that the establishment of the trauma centre significantly increased the lower limb salvage rate.

The final study that reported on morbidity outcomes focused on penetrating thoracic trauma patients, following the implementation of a regional trauma system in the Provence-Alpes-Cote-d’Azur region, France, in 2014. 28 Again, minimal details were provided of the trauma system itself, but it was described as being centred around ‘structural change in the management of severe trauma patients to modified and standardised the structural organisation for the management of severe trauma’. Minimal details were given on the exact composition of this outcome measure, yet the authors concluded that 30-day morbidity–mortality rates were unchanged with the trauma system implementation and only a minimal reduction in morbidity–mortality rates when adjusted for severity score and patient compliance.

Two studies were identified that reported specific health economic and cost-effectiveness outcomes. 22 23 A study from Alabama, USA, evaluated the impact of their regional trauma system implemented in 1996 on the average cost for trauma care provision. 22 Financial analysis was determined through total charges, total cost and direct costs, with linear regression models then used to estimate and compare average costs for pre and postsystem implementation, adjusting for changes in case mix. The authors concluded that there was a significant decrease in the average total costs after system implementation among patients with moderate to severe injuries.

The other study described the implementation of a regional trauma system in the state of Victoria, Australia, between 2000 and 2003 and evaluated its impact on DALY and cost savings made in road transport-related major trauma cases. 23 The study calculated DALYs through years of life lost (YLLs) and years lived with disability (YLDs), adjusted using disability weights calculated via an EQ-5D questionnaire, and cost per DALY was also calculated based on Gross Domestic Product (GDP) per capita or value of a statistical life year. The group reported a 28% reduction in DALYs with implementation of the trauma system, but this was comprised of a 43% reduction in YLLs and a 32% increase in YLDs. There was an overall cost saving in trauma care with implementation of the trauma system, estimating a saving of between A$209 750 and A$633 446 per case.

Patients with TBI
Two studies were identified that focused on the outcomes of patients with TBI with the implementation of a trauma system. 24 25

One study from Ohio, USA, evaluated the implementation of a regional trauma system on all patients with TBI aged >14 years with a head Abbreviated Injury Scale ≥3. 24 Their trauma

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Figure 1  PRISMA flow diagram. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.
Table 1

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Region</th>
<th>Study population</th>
<th>Comparison type</th>
<th>Patients Included</th>
<th>Outcome measures reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abernathy III et al</td>
<td>2002</td>
<td>Alabama, USA</td>
<td>All trauma patients</td>
<td>Before–after</td>
<td>3024</td>
<td>Total overall cost per case ($)</td>
</tr>
<tr>
<td>Gabbe et al</td>
<td>2015</td>
<td>Victoria, Australia</td>
<td>Road transport-related major trauma cases</td>
<td>Before–after</td>
<td>7828</td>
<td>Disability-adjusted life years (DALY) and total cost per case</td>
</tr>
<tr>
<td>et al</td>
<td>2015</td>
<td>Ohio, USA</td>
<td>Patients with TBI&gt;14 years with a head AIS score≥3</td>
<td>Before–after</td>
<td>3496</td>
<td>Functional Independence Measure scores at discharge</td>
</tr>
<tr>
<td>et al</td>
<td>2019</td>
<td>Ulsan, South Korea</td>
<td>Severe trauma (ISS&gt;15) with a TBI</td>
<td>Before–after</td>
<td>322</td>
<td>Glasgow Outcome Scale at 3 months</td>
</tr>
<tr>
<td>et al</td>
<td>2022</td>
<td>Suwon, South Korea</td>
<td>Open fracture below the knee level and Gustilo type II/IIIB</td>
<td>Before–after</td>
<td>273</td>
<td>Rates of limb salvage† during admission</td>
</tr>
<tr>
<td>Metcalfe et al</td>
<td>2014</td>
<td>West Midlands, UK</td>
<td>All major trauma patients</td>
<td>Before–after</td>
<td>1768</td>
<td>Rates of good recovery* at discharge</td>
</tr>
<tr>
<td>et al</td>
<td>2023</td>
<td>Provence-Alpes-Cote-dAzur, France</td>
<td>Penetrating traumatic patients and head AIS score&gt;3</td>
<td>Before–after</td>
<td>426</td>
<td>Combined 30-day morbidity-mortality rates</td>
</tr>
</tbody>
</table>

†Defined as the resolution of soft tissue wounds without a requirement for major amputation; *defined as patients being discharged home to live independently, with no new arrangements for domiciliary care.

**DISCUSSION**

Extensive evidence has shown that the implementation of a trauma system in a country or region can confer significant improvements to mortality outcomes. However, while often assumed to be the case, concurrent improvements to morbidity outcomes or cost-effectiveness do not necessarily go hand-in-hand with this. Our systematic review demonstrates a sparsity of high-quality evidence assessing the impact that trauma systems can have on these measures, despite a growing number of countries adopting trauma systems into their healthcare policy. Importantly, at present, the level of evidence suggesting any improvement to morbidity or cost-effectiveness outcomes with trauma system implementation is of poor quality. Indeed, the studies that were identified through our systematic review provide a mixed picture on trauma system implementation, with certain studies suggesting potential benefit, while others demonstrating no such advantage.

Assessing the impact of morbidity following trauma is a complex area, whether through assessing return to work rates or via disability prevalence. Previous work from the USA has shown trauma centre treatment improves the 3-month postinjury return to work rate, but such data are derived from a HIC setting, where pre-existing healthcare services are often sufficient in rehabilitation and care capacity to cope with increased survival numbers. Through our systematic review, we only identified two papers that analysed the impact of quality of life after trauma system implementation; however, Gabbe et al demonstrated that the implementation of a trauma system resulted in a 28% reduction in DALY following traumatic injury. As an example, however, within this latter study, the authors also reported that while there was a 43% reduction in YLLs, there was also a 32% increase in YLD. Similar conclusions of reducing YLLs with increasing YLDs have been identified from recent Global Burden of Disease studies within trauma. We reason that while an increase in YLDs may be acceptable to a healthcare system that has the capacity to support the increased rehabilitation costs and care requirements, for those with little or no such infrastructure, such a disability might prove economically challenging, bringing with it far-reaching societal challenges. Moreover, there are often cultural elements to the acceptability of long-term disability and increased care requirements that is highly context specific. Unfortunately, however, at present there is no primary data to support this.
While we do not question the direct effect trauma systems can have on mortality, we speculate that improved survival may confer increased rates of disability and a secondary trauma burden. In resource-poor countries, this might be an important cultural or financial consideration when deciding whether, or how, to implement trauma systems. Indeed, having an intervention that improves mortality with worsening morbidity is not unfamiliar territory in many aspects of trauma care. The RESCUEIcp study, published in the New England Journal of Medicine, compared the use of decompressive craniectomy versus ongoing medical care for patients with a TBI and elevated intracranial pressure; the study demonstrated that while there were indeed lower mortality rates with decompressive craniectomy, concomitant higher rates of vegetative state and severe disability were also observed, both at 6 months and 2 years. Indeed, from our systematic review, the two TBI-related papers we identified showed no significant benefit in morbidity outcomes with the implementation of a trauma system. If lives saved also lead to an increased public and economic burden, such detail and data must be considered by any government or health ministry prior to a trauma system being implemented. The cost-effectiveness of trauma system development does not solely relate to costs of in-hospital care, but those of ongoing rehabilitation and a delayed return to work. We identified only two studies that assessed the impact of trauma systems from a health economics aspect, with one study addressing in-hospital costs and one addressing the cost-per-DALY achieved. Both studies reported benefits in their respective cost-effectiveness outcomes, yet these studies were also based on HICs, which arguably does not accurately reflect the impact traumatic injuries may have in terms of DALY in an LMIC setting. Indeed, previous studies on the cost-effectiveness of trauma centres have predominantly been in HICs. We would further argue that the cost-per-DALY is also a context-specific outcome metric.

Our findings come with limitations. The small number of studies identified were of poor quality, with a severe risk of bias in all studies with many likely to be underpowered (as the primary outcome was often not morbidity-related). This supports our position that higher quality studies on trauma system implementation are required, exploring a range of outcomes beyond mortality. There was a high level of heterogeneity in the included studies’ designs and inconsistent outcome measures, including one study with a poorly described combined morbidity/mortality outcome measure: this had been provisionally expected and was accounted for in our protocol, and as such a prospective plan for a narrative review, rather than any meta-analyses, was opted for. The way by which a trauma system was defined did vary significantly between papers, some in keeping with a ‘hard’ system design while others describing a more ‘soft’ system; as a pragmatic approach, we kept our inclusion criteria broad and both were included. Finally, despite being planned for in our study protocol, a lack of available studies meant we were unable to report any specific paediatric data or study data from LMIC regions, emphasising the need for focused trauma research within these areas and highlighting the current caution that must be taken prior to implementing any trauma system.

As early as 2004, a formal review by the US Agency for Healthcare Research and Quality regarding the regionalisation of trauma care in the US concluded that ‘formalised protocols for prehospital and hospital care contribute to improved patient outcomes’. However, these conclusions were driven by survival figures and in-hospital costs from the USA, not by specific global morbidity or economic outcome measures. Subsequent recommendations from multiple trauma groups worldwide on trauma system implementation have made similar recommendations based on on mortality metrics only. As more and more countries aim to develop formalised trauma systems, a better understanding of the morbidity, economic impacts and associated strains to rehabilitation and healthcare services is required.

**Conclusion**

There is a lack of high-quality data that have accurately assessed the impact the implementation of trauma systems has on morbidity, quality of life and economic outcomes, and current studies on the topic paint a mixed picture on their benefit. While we believe that trauma systems do have a fundamental role to play in high-quality trauma care, care also needs to be taken to understand the sociocultural and political context of their surrounding healthcare infrastructure. We propose that a range of further research is required, both in terms of assessing benefit from existing trauma systems and in the methodological basis for rationally designing and implementing context-specific trauma systems, particularly in resource-poor and fragile settings.

**Author affiliations**

1International Health Systems Group, Department of Engineering, University of Cambridge, Cambridge, UK
2NIHR Global Health Research Group on Acquired Brain and Spine Injury, Division of Academic Neurosurgery, University of Cambridge, Cambridge, UK
3Department of Anaesthesia, East and North Hertfordshire NHS Trust, Stevenage, UK
4Department of Perioperative, Acute, Critical Care, and Emergency Medicine, Department of Medicine, University of Cambridge, Cambridge, UK
5University of Cambridge Medical Library, University of Cambridge, Cambridge, UK
6Department of Anaesthesia and Intensive Care, Makerere University College of Health Sciences, Kampala, Uganda
7Department of Emergency Medicine, Mayo Clinic, Rochester, Minnesota, USA
8School of Clinical Medicine, University of Cambridge, Cambridge, UK

### Table 2  Risk of bias assessment, using ROBINS-I tool

<table>
<thead>
<tr>
<th>Study</th>
<th>Confounding</th>
<th>Selection of participants into the study</th>
<th>Classification of interventions</th>
<th>Deviations from intended interventions</th>
<th>Missing data</th>
<th>Measurement of outcome</th>
<th>Selection of the reported result</th>
<th>Overall</th>
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</thead>
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<tr>
<td>Abernathy III et al23</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>NI</td>
<td>L</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Gabbe et al23</td>
<td>S</td>
<td>L</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>S</td>
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<tr>
<td>Kim J et al 2019</td>
<td>S</td>
<td>S</td>
<td>L</td>
<td>M</td>
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<td>S</td>
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<tr>
<td>Kelly et al4</td>
<td>S</td>
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<td>Kim M et al26</td>
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<tr>
<td>Metcalfe et al27</td>
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<td>M</td>
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<tr>
<td>Vasse et al28</td>
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<td>M</td>
<td>S</td>
<td>S</td>
</tr>
</tbody>
</table>

C, critical risk; L, low risk; M, moderate risk; NI, no information; S, severe risk.
Systematic review

9Cambridge Public Health Interdisciplinary Research Centre, University of Cambridge, Cambridge, UK

10Trauma Operational Advisory Team, World Health Organization, Cairo, Egypt

Twitter Michael F Bath @MikeFBath

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ORCID iDs Michael F Bath http://orcid.org/0000-0003-1879-1093
Laura Hobbs http://orcid.org/0000-0002-0995-2943
Katharina Kohler http://orcid.org/0000-0003-1919-0193
Laura E Walker http://orcid.org/0000-0002-1127-327X
Peter John Hutchinson http://orcid.org/0000-0002-2796-1835
Tom Bashford http://orcid.org/0000-0003-0228-9779

REFERENCES


