Global variation in patient factors, interventions, and postoperative outcomes for those undergoing trauma laparotomy: an international, prospective, observational cohort study

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Summary

Background **The trauma laparotomy is a definitive intervention for life-threatening abdominal injuries and a cornerstone of trauma care globally. The ability to perform an emergency laparotomy is a recognised marker of safe and effective surgical care within a health system. However, the global variation in the provision, context, and outcomes of the trauma laparotomy is unknown. This study aimed to identify the variation in patient factors, interventions, and postoperative outcomes of those undergoing a trauma laparotomy worldwide.**

Methods **We conducted a prospective international observational study in 187 hospitals across 51 countries between April 1 and Dec 31, 2024. Patients who presented with a blunt or penetrating traumatic injury and underwent a laparotomy within 5 days of presentation were eligible, with information on presentation, interventions, and outcomes collected. Countries were stratified by Human Development Index (HDI) tertile and the primary outcome measure was postoperative in-hospital mortality, measured to 30 days. Adjusted mortality risk was calculated using logistic regression analysis. The study was registered to ClinicalTrials.gov (NCT06180668).**

Findings **We included 1769 patients, comprising 563 patients (31·8%) from the lower HDI tertile, 714 patients (40·4%) from the middle HDI tertile, and 492 patients (27·8%) from the upper HDI tertile. Median age was 30 years (IQR 23–43) and 1512 patients (85·5%) were male. Patients from upper-HDI countries had a higher Injury Severity Score compared with those in middle-HDI or lower-HDI countries (median 16 [IQR 9–27] *vs* 9 [8–22] and 9 [4–16], respectively; p<0·0001). Crude mortality was similar across HDI tertiles, with 195 patients (11·0%) overall dying in hospital within 30 days of surgery. After adjustment, we observed higher mortality risk in the lower HDI tertile (odds ratio [OR] 3·57, 95% CI 1·78–7·28, p<0·001) and middle HDI tertile (OR 1·89, 1·06–3·43, p=0·033), compared with the upper HDI tertile.**

Interpretation **Patients undergoing a trauma laparotomy in lower-HDI settings were less severely injured and had a higher risk of postoperative death compared with those in higher-HDI settings. There remains an opportunity to improve trauma care globally and expanding access must be matched by the development of quality services.**

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Introduction

Trauma accounts for around one in ten of all global deaths.[1] Trauma disproportionately affects individuals of working age, resulting in the highest level of disability-adjusted life-years of any pathology, and is increasingly becoming a large component of disease burden and health expenditure.[2] Resource-poor areas suffer the highest rates of trauma and experience the worst outcomes, with approximately 90% of all trauma-related deaths occurring in low-income and middle-income countries.[3] Consequently, there is a strong argument for optimising trauma care in these regions, in terms of both health and economic outcomes.

In an attempt to reduce the impact of trauma, many high-income countries have implemented inclusive trauma systems to coordinate and optimise trauma care across the patient journey.[4,5] Comprehensive trauma care is the product of a complex system of intersecting processes and behaviours that share components with coexisting health-care services and regional infrastructure.[6] Ensuring optimal trauma care provision can therefore prove difficult, especially where health

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Research in context

Evidence before this study

We searched PubMed for all articles in English published from Jan 1, 2000, to Dec 31, 2023, with the search terms "trauma" and "laparotomy" and "mortality". We found no multicentre international studies that compared patient factors, interventions, and postoperative outcomes for those undergoing a trauma laparotomy. The majority of non-military studies identified were single-centre or single-country, organ-specific or procedure-specific, or retrospective in nature, with substantial heterogeneity among studies further preventing any direct comparison.

Added value of this study

The Global Outcomes After Laparotomy for Trauma (GOAL-Trauma) Study demonstrates significant variation in the patient cohort, preoperative interventions, and postoperative outcomes for those undergoing a trauma laparotomy worldwide. The overall 30-day postoperative in-hospital crude mortality rates were similar across settings at 11%; however, there was significant variation in the injury severity of those attending hospital, with patients in countries with a higher Human Development Index (HDI) more injured than those in countries with a lower HDI. Furthermore, after adjustment, mortality risk was higher in the lower and middle HDI tertiles compared with the upper HDI tertile. Only around half of patients who underwent the procedure were discharged home within 30 days to the same preinjury level of care.

Implications of all the available evidence

This study identifies significant variation in the care received globally by trauma laparotomy patients across their care pathway. Equitable trauma systems need to be implemented worldwide if improvements to patient outcomes are to be achieved.

systems are fragile or under-resourced. To identify areas for improvement across the trauma patient pathway, a holistic and functional assessment of the trauma system is required, and such assessments need to be conducted in parallel across an international population. However, there are few studies that globally benchmark trauma system structure, function, and outcomes.

Emergency laparotomy has previously been referenced as a Bellwether procedure for surgical systems.[7] In trauma, between 6% and 15% of patients sustain abdominal injuries,[8–10] and for those with evidence of uncontrolled haemorrhage or hollow viscus perforation, a trauma laparotomy is a life-saving intervention, in terms of both diagnosis and definitive management. To deliver a safe, timely, and effective trauma laparotomy, all elements of the trauma pathway must function effectively and in coordination.[11] As a result, the trauma laparotomy provides an opportune metric of trauma system functionality and variation on a global scale.

To explore this, the Global Outcomes After Laparotomy for Trauma (GOAL-Trauma) Collaborative designed and conducted an international, multicentre, prospective, observational cohort study that aimed to identify the variation in patient factors, interventions, and postoperative outcomes of those undergoing a trauma laparotomy worldwide.

Methods

Study design and participants

The GOAL-Trauma Study was a prospective, international, multicentre, observational study. It was conducted according to a publicly available, peer-reviewed study protocol[12] and has been reported in accordance with STROBE guidelines.[13] All study documents, including the protocol and case report form (appendix p 15), were developed in concordance with a patient and public advisory group and were made publicly available from the GOAL-Trauma website. The study protocol was prepared initially in English and translated into French, Hindi, Italian, Mandarin, Portuguese, Russian, Spanish, and Turkish.

The study received ethical approval from the Cambridge Psychology Research Ethics Committee (PRE.2023.119). The study was registered with ClinicalTrials.gov (NCT06180668) and was sponsored by the University of Cambridge (Cambridge, UK). Appropriate local approval was obtained by each contributing centre before enrolment into the study, according to respective local regulations. In some participating hospitals, informed patient consent was taken, whereas in other hospitals this was deemed not necessary, at the discretion of the local team. The conduct of the GOAL-Trauma study was overseen by an international steering committee consisting of expert clinical academic representatives across multiple economic and geographical settings.

Recruitment of hospitals was through open invitation, with potential collaborators contacted through a purposive snowballing technique, using pre-existing research networks, personnel contacts, and social media. Any health-care facility worldwide that could perform and manage a patient undergoing a trauma laparotomy was eligible to enrol. Each recruiting centre required a lead investigator (termed the "local lead") and site collaborators, along with a data validator at select centres. Local leads were asked to complete a site survey to provide further details and contextualise their respective clinical setting.

Investigators collected prospective data on all eligible patients throughout preselected 30-day period(s), chosen at the discretion of the local team(s), within the study data collection period. Patients of any age who presented with a blunt or penetrating traumatic injury and underwent a laparotomy within 5 days (120 h) of presentation to the treating hospital were eligible for inclusion. Patients were excluded if they were undergoing a repeat laparotomy at the recruiting centre (often termed a "relook laparotomy") within 30 days of the index procedure, or had been recently discharged from any hospital (including for non-trauma related admissions) and had presented within 30 days of discharge. Given the known variation in minimally invasive surgery seen worldwide,[14] we a priori excluded patients undergoing a laparoscopic (including laparoscopic converted to open), robotic, or image-guided procedures.

Procedures

Data variables were predetermined through a combination of existing literature, expert opinion, and discussions from patient and public groups. Pilot work was undertaken in both Cambridge, UK, and Kampala, Uganda, before the study to ensure the feasibility of both the methodology and data variables across varying settings. The data variables collected included timepoints, patient and injury factors, preoperative management, operative factors, and postoperative outcomes (appendix p 15), and were selected to ensure standardisation and objectivity across varying settings. Select variables from the accompanying site survey, such as the type of hospital facility and the size of population served, were also included in the final dataset. The American Society of Anesthesiologists (ASA) score was chosen as the marker of the patients' preoperative medical comorbidities, due to its wide acceptance of use globally and the otherwise high level of variation in ability to diagnose select comorbidities in certain areas. Injury severity was calculated using the Abbreviated Injury Scale (AIS) for each body region, with the overall degree of injury quantified through the summative Injury Severity Score (ISS).[15] As a summative marker of patient physiology, an adapted National Early Warning Score (NEWS-2; for those aged >16 years)[16] or Paediatric Early Warning System (PEWS; for those aged ≤16 years)[17] value was calculated from the patient physiology, both at the time of presentation to hospital and before induction of anaesthesia. Our pilot work suggested that patient temperature would not reliably be routinely collected globally; therefore, this measure was excluded from data collection and omitted for the calculation of the adapted NEWS-2 and PEWS values. Patients were followed up until discharge, death, or 30 days (if still an inpatient), whichever came first.

De-identified data were collected locally by collaborators at each centre and uploaded centrally onto a secure web-based system, REDCap cloud,[18,19] hosted by the University of Cambridge. Collaborators were given REDCap project server login details, allowing secure data entry and storage. Submitted data were checked centrally and where potential missing or inaccurate data were identified, local investigators were contacted and asked to check or complete the record. Any patient record with less than 70% of datapoints completed was excluded from the study. All data storage and analysis were conducted using secure facilities hosted by the University of Cambridge in accordance with institutional research data governance processes. Collaborators retained the right to their own facility-level data and were able to download these from REDCap before the end of the study period if required.

Validity of the data was ensured through two distinct mechanisms. Firstly, the web-based data collection forms on REDCap enforced data entry for critical variables. Secondly, select centres nominated a local independent collaborator (termed the data validator), who was not part of the data collection team, to quantitatively check data accuracy and case ascertainment during a single study period from that centre, then submit a validator report to the central study team. As the data validators were independent of their respective data collection teams, any errors identified by the data validator were not corrected for in the submitted data set.

See Online for appendix

For the **GOAL-Trauma** website see https://goaltrauma.org/

Outcomes

The primary outcome measure for the GOAL-Trauma Study was postoperative in-hospital mortality, measured to 30 days. The secondary outcome measures were patient discharge destination, the Adapted Clavien–Dindo in Trauma (ACDiT) morbidity score[20] (appendix p 19), and any return to theatre.

Statistical analysis

Contributing hospitals were stratified by their national Human Development Index (HDI),[21] with HDI being categorised into lower tertile, middle tertile, and upper tertile. Data were summarised with mean and SD, median and IQR, or number and percentage, where appropriate. Differences between HDI tertiles were assessed with the Kruskal–Wallis test or χ^2 test, where appropriate. A statistical analysis plan was determined before the start of the study and used as a template for the data analysis.

Mortality rates for those older than 16 years were analysed using Lasso regression,[22] given that the NEWS is validated in adult groups only. Patient-level effects were entered into the model on the basis of their known association with trauma laparotomy patient outcomes and corroborated with expert consensus: age,[23] sex,[23] hospital type,[24] ISS,[23,24] mechanism of injury,[23–26] ASA score,[27] arrival systolic blood pressure,[23,25,26,28,29] admission international normalised ratio (INR),[30] and time from injury to presentation,[26,29] along with HDI tertile. Lasso regression was performed, including five-fold cross validation, to select the parameters for subsequent logistic regression analysis.

Statistical tests were two-sided, and we considered $p<0\cdot05$ to show a significant difference. All analyses were done using R (version 4.4.1), using stats, dplyr, tidyverse, ggplot2, and glmnet packages.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Patients were identified for inclusion from 187 hospitals across 51 countries (figure 1), covering all six inhabited continents and HDI tertiles, between April 1 and Dec 31, 2024. The majority of recruiting hospitals were located in urban areas (173 [92·5%] of 187 hospitals; table 1) and were tertiary-level hospitals (139 [74·3%] of 187 hospitals). There were 54 hospitals from lower-HDI countries, 50 hospitals from middle-HDI countries, and 83 hospitals from upper-HDI countries.

Overall, 1769 patients met the inclusion criteria for final data analysis (figure 2); 563 patients (31·8%) from the lower HDI tertile, 714 patients (40·4%) from the middle HDI tertile, and 492 patients (27·8%) from the upper HDI tertile. The median age was 30 years (IQR 23–43 years; table 2), with 134 patients (7·6%) aged 16 years or younger, and the lower HDI tertile having the lowest median patient age at 26 years (IQR 20–35, $p<0\cdot0001$). The majority of patients were male (1512 [85·5%] of 1769 patients). Similar rates of blunt versus penetrating mechanisms for trauma were observed overall (46·0% *vs* 54·0% respectively); however, higher rates of penetrating injury were seen in the lower HDI tertile (337 [59·9%] of 563 patients, $p<0\cdot0001$) relative to the middle and upper HDI tertiles.

Most patients were transported to hospital either via land ambulance (1234 [70·0%] of 1764 patients) or private vehicle (369 [20·9%] of 1764 patients). There were 512 patients (28·9%) who attended another health-care facility before reaching the hospital where the index trauma laparotomy was performed. The median time from point of injury to presentation to hospital was 1·6 h (IQR 0·8–4·9). Blood tests were performed for the majority of patients (1719 [97·2%] of 1769 patients), with a relatively lower use of plain film radiographs (882 [49·9%] of 1769 patients) and CT imaging (900 [50·9%] of 1769 patients); CT imaging was performed proportionately more often in the upper-HDI settings (381 [77·4%] of 492 patients), compared with middle-HDI settings (377 [52·8%] of 714 patients) and lower-HDI settings (142 [25·2%] of 563 patients, $p<0\cdot0001$).

There was significant variation in the degree of injury sustained by patients, with the median ISS in the lower HDI tertile calculated as 9 (IQR 4–16), in the middle HDI tertile as 9 (8–22), and in the upper HDI tertile as 16 (9–27, $p<0\cdot0001$; figure 3). There were similar trends in abdominal-specific injuries across HDI tertiles, with those in the higher HDI tertiles showing higher abdominal AIS scores ($p=0\cdot0002$); however, no variation was seen in the non-abdominal AIS scores across tertiles (appendix p 20). Patient physiology on arrival was similar across settings, with the median adapted NEWS-2 value (for patients aged >16 years) on arrival at 5 (IQR 3–8) and the median adapted PEWS value (for patients aged ≤16 years) on arrival at 2 (1–5). The most common ASA scores overall were ASA 1 (674 [38·1%] of 1769 patients) and ASA 2 (446 [25·2%] of 1769 patients); however, there was significant variation across settings ($p<0\cdot001$), with

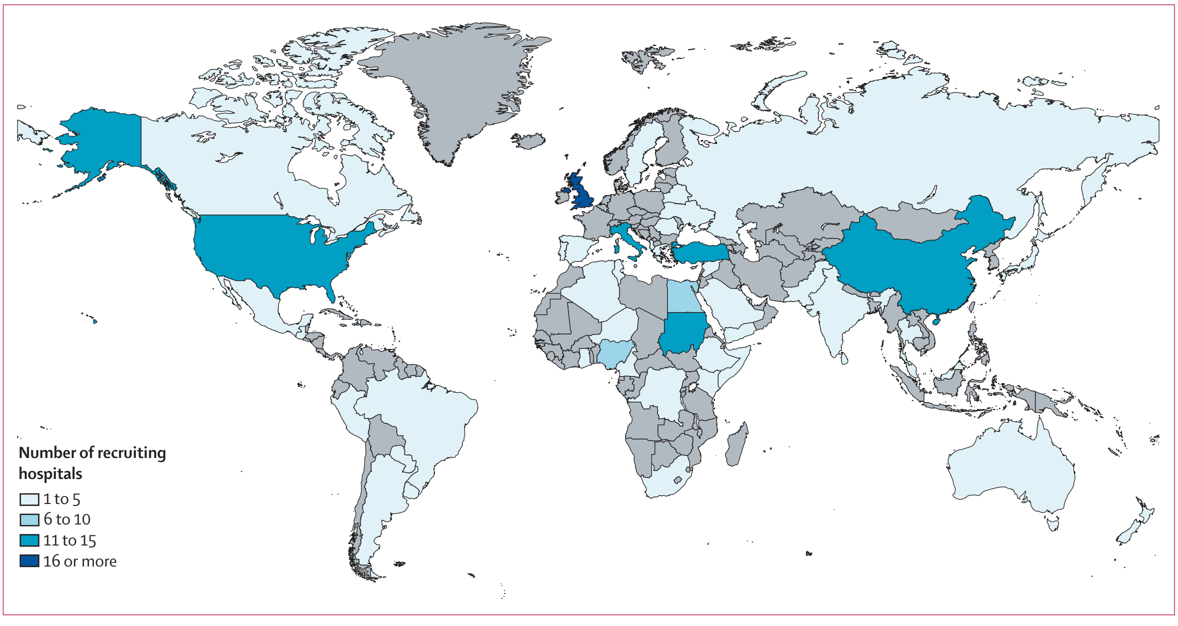

Figure 1: **Global distribution of recruiting centres, showing number of hospitals enrolled per country**

	Lower HDI tertile (n=54)	Middle HDI tertile (n=50)	Upper HDI tertile (n=83)	Total (n=187)	p value
Location	..	..	..	..	0·39
Urban	48 (88·9%)	46 (92·0%)	79 (95·2%)	173 (92·5%)	..
Rural	6 (11·1%)	4 (8·0%)	4 (4·8%)	14 (7·5%)	..
Facility type	..	..	..	..	0·20
Public	46 (85·2%)	46 (92·0%)	70 (84·3%)	162 (86·6%)	..
Private, for profit	3 (5·6%)	4 (8·0%)	4 (4·8%)	11 (5·9%)	..
Private, not for profit	5 (9·3%)	0 (0·0%)	9 (10·8%)	14 (7·5%)	..
Function	..	..	..	..	0·39
Primary	2 (3·7%)	4 (8·0%)	6 (7·2%)	12 (6·4%)	..
Secondary	15 (27·8%)	8 (16·0%)	13 (15·7%)	36 (19·3%)	..
Tertiary	37 (68·5%)	38 (76·0%)	64 (77·1%)	139 (74·3%)	..
Size of population served	..	..	..	..	0·086
<50 000 inhabitants	2 (3·7%)	1 (2·0%)	3 (3·6%)	6 (3·2%)	..
50 000–199 999 inhabitants	7 (13·0%)	6 (12·0%)	6 (7·2%)	19 (10·2%)	..
200 000–499 999 inhabitants	6 (11·1%)	8 (16·0%)	14 (16·9%)	28 (15·0%)	..
500 000–999 999 inhabitants	12 (22·2%)	3 (6·0%)	25 (30·1%)	40 (21·4%)	..
>1 000 000 inhabitants	27 (50·0%)	32 (64·0%)	35 (42·2%)	94 (50·3%)	..
Number of inpatient beds	..	..	..	..	<0·0001
0–249	17 (31·5%)	6 (12·0%)	8 (9·6%)	31 (16·6%)	..
250–499	16 (29·6%)	12 (24·0%)	12 (14·5%)	40 (21·4%)	..
500–999	12 (22·2%)	10 (20·0%)	39 (47·0%)	61 (32·6%)	..
≥1000	9 (16·7%)	22 (44·0%)	24 (28·9%)	55 (29·4%)	..

Data are n (%) unless otherwise indicated. HDI=Human Development Index.

Table 1: **Recruiting hospital characteristics**

higher proportions of ASA 3–5 patients seen in the upper HDI tertile.

For preoperative blood product use, 725 (41·0%) of 1769 patients received any type of blood product (table 3), with usage significantly higher in the upper HDI tertile (264 [53·7%] of 492 patients, p<0·0001). 529 (29·9%) of 1768 patients received preoperative tranexamic acid, with its use significantly higher in the upper HDI tertile (252 [51·3%] of 491 patients, p<0·0001). Antibiotics were given preoperatively in most cases (1452 [82·1%] of 1769 patients) and, where reported, the last dose was most commonly received before the patient arrival into theatre (844 [58·5%] of 1443 patients).

The median time from point of injury to operation was 6·3 h (IQR 2·9–15·2), with no significant differences across HDI tertiles (p=0·30). Small bowel procedures (537 [30·4%] of 1769 patients), lower gastrointestinal procedures (378 [21·4%] of 1769 patients), and splenectomy (330 [18·7%] of 1769 patients) were the most commonly performed operations, while negative laparotomies occurred in 128 (7·2%) of 1769 patients. The average blood loss reported was 1028 mL (SD 1600). The most senior surgeon present was a consultant or attending general surgeon in 73·8% of cases (1306 of 1769 patients) and the most senior anaesthetic provider was a consultant or attending anaesthetist in 56·8% of cases (1004 of 1769 patients); a non-medically qualified anaesthesia provider was the most senior individual present in 12·3% of cases (69 of 563 patients) in the lower HDI tertile.

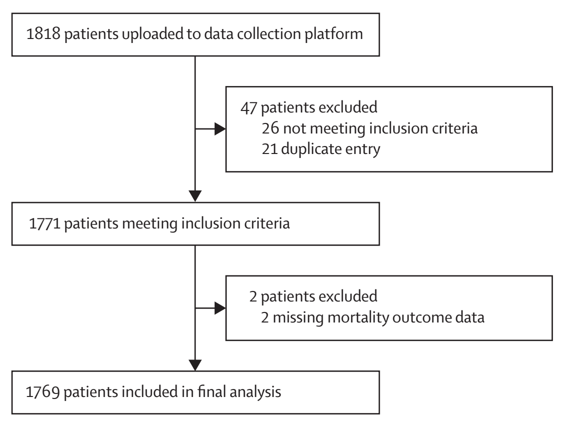

Figure 2: **Flowchart of patients included within the study**

Overall, 195 (11·0%) of 1769 patients died in hospital within 30 days of the operation (table 4), with no variation in the crude mortality rates across HDI tertiles (p=0·88). Of these, 32 (16·4%) died intraoperatively. The median time to death following the operation for those who died postoperatively was 58·9 h (IQR 18·8–189·4). 325 (18·4%) of 1769 patients underwent a concurrent non-abdominal procedure during the same period of anaesthesia, with the highest proportion in upper HDI

	Lower HDI tertile (n=563)	Middle HDI tertile (n=714)	Upper HDI tertile (n=492)	Total (n=1769)	p value
Age, years; median (IQR)	26 (20–35) (n=562)	32 (23–43) (n=714)	37 (26–52) (n=492)	30 (23–43) (n=1768)	<0·0001
Sex	..	..	..	..	0·0001
Male	488 (86·7%)	631 (88·4%)	393 (79·9%)	1512 (85·5%)	..
Female	75 (13·3%)	83 (11·6%)	99 (20·1%)	257 (14·5%)	..
Mechanism of injury	..	..	..	..	<0·0001
Blunt	226 (40·1%)	294 (41·2%)	294 (59·8%)	814 (46·0%)	..
Penetrating	337 (59·9%)	420 (58·8%)	198 (40·2%)	955 (54·0%)	..
Method of transport to hospital					
Land ambulance	286 (50·8%)	552/710 (77·7%)	396/491 (80·7%)	1234/1764 (70·0%)	..
Bystander support	29 (5·2%)	14/710 (2·0%)	3/491 (0·6%)	46/1764 (2·6%)	..
Private vehicle	218 (38·7%)	124/710 (17·5%)	27/491 (5·5%)	369/1764 (20·9%)	..
Police	20 (3·6%)	6/710 (0·8%)	3/491 (0·6%)	29/1764 (1·6%)	..
By foot	7 (1·2%)	10/710 (1·4%)	8/491 (1·6%)	25/1764 (1·4%)	..
Air ambulance	1 (0·2%)	6/710 (0·8%)	53/491 (10·8%)	60/1764 (3·4%)	..
Other or unknown	2 (0·4%)	2/710 (0·3%)	2/491 (0·4%)	6/1764 (0·3%)	..
Time to presentation from injury, h; median (IQR)	2·0 (0·8–6·0) (n=563)	2·4 (1·0–6·0) (n=708)	1·0 (0·6–1·9) (n=479)	1·6 (0·8–4·9) (n=1750)	0·38
NEWS-2 value, median (IQR)*					
On arrival	5 (3–8) (n=561)	5 (3–8) (n=714)	5 (3–9) (n=491)	5 (3–8) (n=1766)	0·31
Before induction	4 (3–7) (n=562)	5 (3–8) (n=714)	5 (3–8) (n=492)	5 (3–8) (n=1768)	0·0047
PEWS value, median (IQR)*					
On arrival	2 (1–5) (n=76)	3 (2–6) (n=47)	3 (2–9) (n=11)	2 (1–5) (n=134)	0·15
Before induction	3 (1–4) (n=76)	3 (2–5) (n=47)	5 (2–8) (n=11)	3 (1–5) (n=134)	0·079
ASA score	..	..	..	..	<0·0001
1	277 (49·2%)	277 (38·8%)	120 (24·4%)	674 (38·1%)	..
2	103 (18·3%)	209 (29·3%)	134 (27·2%)	446 (25·2%)	..
3	102 (18·1%)	121 (16·9%)	73 (14·8%)	296 (16·7%)	..
4	57 (10·1%)	57 (8·0%)	97 (19·7%)	211 (11·9%)	..
5	24 (4·3%)	50 (7·0%)	68 (13·8%)	142 (8·0%)	..
Abdominal Abbreviated Injury Scale, median (IQR)	3 (2–3)	3 (2–4)	3 (2–4)	3 (2–4)	0·0002
Injury Severity Score, median (IQR)	9 (4–16)	9 (8–22)	16 (9–27)	9 (5–20)	<0·0001
Blood tests on arrival					
Haemoglobin, g/L; mean (SD)	111 (31) (n=523)	114 (35) (n=661)	120 (31·2) (n=476)	115 (33) (n=1660)	..
Lactate, mmol/L; mean (SD)	2·1 (1·6) (n=132)	3·8 (3·1) (n=520)	4·6 (4·0) (n=432)	3·9 (3·5) (n=1084)	..
Base excess, mmol/L; mean (SD)	0·9 (7·2) (n=136)	–4·7 (5·9) (n=505)	–3·8 (7·3) (n=382)	–3·6 (6·9) (n=1023)	..
Creatinine, μmol/L; mean (SD)	112 (116) (n=383)	104 (83) (n=459)	97 (38) (n=438)	105 (83) (n=1280)	..
INR, mean (SD)	1·2 (0·3) (n=267)	1·2 (0·3) (n=373)	1·2 (0·9) (n=368)	1·2 (0·6) (n=1008)	..

Data are n (%) or n/N (%) unless otherwise indicated. Data are recorded for all patients unless n specified. ASA=American Society of Anesthesiologists. HDI=Human Development Index. INR=international normalised ratio. NEWS=National Early Warning Score. PEWS=Paediatric Early Warning System. *NEWS-2 for patients aged >16 years, PEWS for patients aged ≤16 years.

Table 2: **Patient and injury factors**

tertile (126 [25·6%] of 492 patients, p<0·0001), compared with the middle (108 [15·1%] of 714 patients) and lower (91 [16·2%] of 563 patients) HDI tertiles. Of those who survived the index procedure, the majority of patients received a primary closure of the abdomen (1507 [86·8%] of 1737 patients); higher rates of an open abdomen were observed in the upper HDI tertile (112 [23·5%] of 477 patients, p<0·0001) compared with the lower (51 [9·2%] of 557 patients) and middle (67 [9·5%] of 703 patients) HDI tertiles.

289 (16·6%) of 1737 patients returned to theatre for abdominal surgery in the 30-day postoperative period, with higher rates observed in the upper HDI tertile (134 [28·9%] of 477 patients) compared with the lower (52 [9·3%] of 557 patients) and middle (103 [14·7%] of 703 patients) HDI tertiles (p<0·0001; table 4). Of these repeat procedures, 203 (70·2%) of 289 were planned procedures and 86 (29·8%) were unplanned procedures; there was significant variation in the proportion of unplanned procedures across HDI tertiles, with the

highest percentage in the middle HDI tertile (40 [38·8%] of 103 patients, p=0·034), compared with the lower (11 [21·2%] of 52 patients) and upper (35 [26·1%] of 134 patients) HDI tertiles. The median day for all repeat laparotomies was postoperative day 3 (IQR 1–5), increasing to postoperative day 5 (2–10) for the unplanned procedures.

Overall, 1247 (70·5%) of 1769 patients were discharged to their usual place of residence following trauma laparotomy, with 928 (52·7%) of 1761 patients reporting a return to the same level of care. For those discharged to their usual place of residence within 30 days, the median length of stay was 6 days (IQR 4–10). There was significant variation in the postoperative complication rates observed across settings where reported (p<0·0001), with the highest postoperative severe complication rates (ACDiT score 3 or 4) in the upper HDI tertile (73 [19·8%] of 368 patients), compared with the middle (106 [16·8%] of 630 patients) and lower (71 [14·1%] of 503 patients) HDI tertiles.

For patients older than 16 years, Lasso regression identified HDI tertile, age, sex, ASA score, ISS, arrival systolic blood pressure, and admission INR as factors for the logistic regression. When compared with the upper HDI tertile, the adjusted odds ratio (OR) for mortality for the lower HDI tertile was 3·57 (95% CI 1·78–7·28, p=0·0004) and for the middle HDI tertile was 1·89 (1·06–3·43, p=0·033; figure 4). Other statistically significant predictors for mortality were age (OR 1·03 [95% CI 1·01–1·04], p=0·0009), ASA score (1·71 [1·41–2·09], p<0·0001), ISS (1·04 [1·02–1·06], p<0·0001), arrival systolic blood pressure (0·99 [0·98–1·00], p=0·015), and admission INR (1·82 [1·18–3·17], p=0·029; appendix p 21). A hierarchical model based on hospital was considered; however, a significant number of hospitals did not contribute sufficient patient numbers to make such modelling feasible.

Independent data validation was performed at 16 hospitals, across all HDI tertiles. Overall data accuracy from the validated dataset was 98·8% and case ascertainment was 100%, with no eligible patients reported missed from the data collection periods in these select centres (appendix p 16).

Discussion

In this international, prospective, observational cohort study of patients undergoing trauma laparotomy, patients from upper-HDI countries were more severely injured but were more likely to survive to discharge than patients from middle-HDI and lower-HDI countries. We observed significant variation in the care received across the patient pathway, in particular with blood product usage, administration of tranexamic acid, and use of CT imaging. Our findings further suggest that there is an underappreciated burden of morbidity for patients undergoing a trauma laparotomy, with only half of these patients returning home with the same care requirements within 30 days. With significant global variations in care processes observed from across the trauma care pathway, this study highlights the need for a coordinated approach to trauma system design, development, and optimisation.

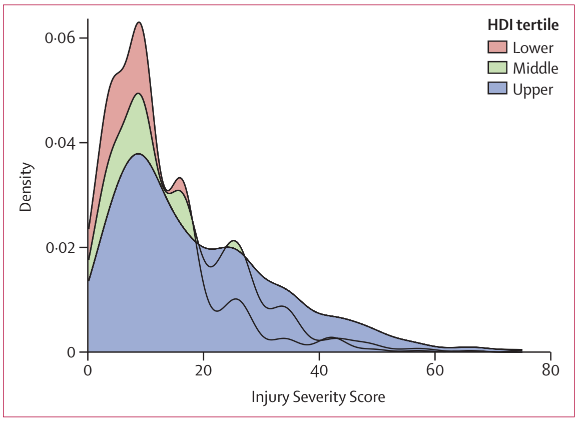

Figure 3: **Density chart showing Injury Severity Scores across each HDI tertile**
HDI=Human Development Index.

Ensuring patients receive the correct care in a timely manner is a cornerstone of trauma management,[31] but the temporal optimisation of acute care is often a particular challenge in fragile health systems.[32] We observed significant variation between HDI settings in the care received in the preoperative phase for those who underwent a trauma laparotomy, including a higher proportion of patients in the upper HDI tertile receiving blood products or undergoing preoperative CT imaging compared with the lower HDI tertile. Global variation in treatments across both maternal health[33,34] and infectious disease[35] have previously been described, and similar disparities have been demonstrated in the provision of neurosurgery and orthopaedic surgery.[36,37] In this study, significant differences in the preoperative phase of trauma care were further illustrated in the methods of transport patients used to attend hospital, with higher proportions in the lower-HDI settings attending hospital via private vehicle and in the higher-HDI settings via land or air ambulance; moreover, we noted around one in four patients attended another hospital before presenting at the hospital where the index procedure was eventually performed. It is well recognised that suboptimal management and excess delay in trauma care can significantly affect clinical outcomes, with inappropriate triaging associated with up to 15% of known deaths.[38] Indeed, time to laparotomy in abdominal trauma patients with haemodynamic instability has been strongly associated with mortality, with an approximate 1% increase for every 3-min delay observed.[39] We observed longer average times to presentation and to operation in the lower-HDI settings (albeit statistically non-significant, due to a high sample variance) and understanding this variability in the preoperative phase is key if outcomes in this patient cohort are to be improved. The majority of current trauma systems in

	Lower HDI tertile (n=563)	Middle HDI tertile (n=714)	Upper HDI tertile (n=492)	Total (n=1769)	p value
Tranexamic acid received preoperatively	144 (25·6%)	133 (18·6%)	252/491 (51·3%)	529/1768 (29·9%)	<0·0001
Blood products received preoperatively	195 (34·6%)	266 (37·3%)	264 (53·7%)	725 (41·0%)	<0·0001
Antibiotics received preoperatively	468 (83·1%)	585 (81·9%)	399 (81·1%)	1452 (82·1%)	0·69
Time to operation from injury, h; median (IQR)	6·8 (3·0–17·3) (n=556)	8·2 (4·3–18·0) (n=707)	3·7 (2·0–8·8) (n=489)	6·3 (2·9–15·2) (n=1752)	0·30
Procedure(s) performed*					
Small bowel procedure	181 (32·1%)	218 (30·5%)	138 (28·0%)	537 (30·4%)	··
Lower gastrointestinal procedure	112 (19·9%)	142 (19·9%)	124 (25·2%)	378 (21·4%)	··
Splenectomy	78 (13·9%)	127 (17·8%)	125 (25·4%)	330 (18·7%)	··
Upper gastrointestinal procedure	74 (13·1%)	101 (14·1%)	56 (11·4%)	231 (13·1%)	··
Primary vascular procedure	32 (5·7%)	82 (11·5%)	64 (13·0%)	178 (10·1%)	··
Hepatorrhaphy or hepatectomy	29 (5·2%)	36 (5·0%)	2 (0·4%)	67 (3·8%)	··
Nephrectomy	17 (3·0%)	31 (4·3%)	11 (2·2%)	59 (3·3%)	··
Diaphragmatic repair	15 (2·7%)	27 (3·8%)	16 (3·3%)	58 (3·3%)	··
Bladder repair	18 (3·2%)	18 (2·5%)	6 (1·2%)	42 (2·4%)	··
Pancreatectomy	4 (0·7%)	16 (2·2%)	10 (2·0%)	30 (1·7%)	··
Negative laparotomy	55 (9·8%)	46 (6·4%)	27 (5·5%)	128 (7·2%)	··
Non-therapeutic laparotomy	19 (3·4%)	33 (4·6%)	24 (4·9%)	76 (4·3%)	··
Blood loss, mL; mean (SD)	766 (734) (n=543)	1016 (1210) (n=696)	1363 (2549) (n=452)	1028 (1600) (n=1691)	<0·0001
Open abdomen†	51/557 (9·2%)	67/703 (9·5%)	112/477 (23·5%)	230/1737 (13·2%)	<0·0001
Most senior surgeon present					
Consultant or attending general surgeon	294 (52·2%)	532 (74·5%)	480 (97·6%)	1306 (73·8%)	··
Registrar or resident general surgeon	266 (47·2%)	172 (24·1%)	12 (2·4%)	450 (25·4%)	··
Other surgeon	3 (0·5%)	4 (0·6%)	0	7 (0·4%)	··
Medically qualified but not in surgical training	0	5 (0·7%)	0	5 (0·3%)	··
Not medically qualified surgical provider	0	1 (0·1%)	0	1 (0·1%)	··
Most senior anaesthetic provider present					
Consultant or attending anaesthetist	186 (33·0%)	369 (51·7%)	449 (91·3%)	1004 (56·8%)	··
Registrar or resident anaesthetist	308 (54·7%)	327 (45·8%)	43 (8·7%)	678 (38·3%)	··
Not medically qualified anaesthesia provider	69 (12·3%)	11 (1·5%)	0	80 (4·5%)	··
Anaesthetic administered by the surgeon	0	7 (1·0%)	0	7 (0·4%)	··

Data are n (%) or n/N (%) unless otherwise indicated. Data are recorded for all patients unless n specified. HDI=Human Development Index. *Most commonly performed procedures reported. †Of patients who survived the index operation.

Table 3: **Intraoperative factors**

higher-resource settings have developed organically,[40–42] using pre-existing hospital infrastructure to ensure optimised trauma care and overcoming limitations in geospatial spread. However, currently the majority of countries globally lack a formalised trauma system, leading to an often uncoordinated and variable response to trauma; for example, previous work has shown that around 30% of the entire African population is located more than 2 h from their nearest hospital, equating to approximately 340 million people with suboptimal trauma care.[43] Improvement of global trauma care does not just require financial and resource investment, but ensuring the appropriate design of a coordinated trauma response.[44,45]

This is the largest prospective global dataset recorded on trauma laparotomy patients. Our data have demonstrated that the in-hospital 30-day postoperative crude mortality rate of those patients presenting to hospital and undergoing a trauma laparotomy was around 11%, similar to reported rates from the wider literature,[23,27,46–48] and comparable across all HDI tertiles. However, there was significant variation in both the overall injury severity and abdominal-specific injury severity scores recorded, with more severely injured patients who underwent a trauma laparotomy presenting to hospitals in the upper-HDI settings. This is alongside a higher proportion of patients in the upper HDI tertile undergoing concurrent non-abdominal procedures during the same period of anaesthesia. As trauma intervention is often time-critical, this observation could potentially indicate that more grievously injured patients in lower-resource settings succumb to their injuries before hospital arrival, or this finding might arise through variation globally in the investigations or management that trauma patients receive. While initial work by our group has suggested potential reasons for this variation,[49] studies using a mixed-methods approach are essential to explore this further. Variation in health outcomes globally has been well described[50] and previous observational work in all-cause emergency abdominal surgery has shown mortality is three times higher in low-HDI countries than in high-HDI countries.[14] This is similarly demonstrated in our regression analysis, demonstrating that patients presenting in lower-HDI regions had an adjusted in-hospital mortality risk approximately three times that of those in higher-HDI regions.

The African Surgical Outcomes Study previously demonstrated high rates of "failure to rescue" postoperatively across Africa,[51] with these patients being twice as likely to die following surgery. Their work suggested that many lives could be saved in lower-HDI settings through improved postoperative surveillance for physiological deterioration, coupled with concomitant rescue strategies. This was reflected in our dataset through the relatively low intraoperative mortality rate compared with the overall postoperative mortality rate, and an adjusted mortality risk lowest in upper-HDI settings, despite their higher rates of severe postoperative complications. A need for improved system strengthening in the postoperative setting can be further demonstrated through the variation in rates of open abdomen and relook operations observed. Managing an open abdomen requires a well functioning inpatient surgical system,[52–54] and so rates of planned relook operations provide a useful and nuanced metric to assess trauma system functioning. Our results suggest that facilities in lower-HDI settings might not have the system ability or capacity currently to deliver such a service reliably, but further work is required to better explore this observation.

The impact of traumatic injuries goes beyond mortality. Despite being highlighted as a research priority in trauma care,[55] the majority of studies on trauma systems have focused on purely medical outcomes, with relatively few reporting functional outcomes or patient-reported outcomes.[56] Our study has shown that only around half of the patients who underwent a trauma laparotomy were discharged home within 30 days of the procedure to the same level of care they had before admission. This implies a significant rehabilitation burden, with knock-on effects to both health economics and quality of life metrics, especially as the average patient suffering traumatic injury is of working age and economically active. In this study, we have only focused on trauma laparotomy patients and therefore these results do not reflect the full burden of non-abdominal traumatic disease that occurs globally, along with its associated disability and morbidity. Our findings support the growing call to focus not solely on mortality rates as outcomes, or on inpatient facilities as the key locus of investment, but to champion investment in rehabilitation

	Lower HDI tertile (n=563)	Middle HDI tertile (n=714)	Upper HDI tertile (n=492)	Total (n=1769)	p value
In-hospital 30-day mortality	60 (10·7%)	82 (11·5%)	53 (10·8%)	195 (11·0%)	0·88
ACDiT score	..	..	..	..	<0·0001
0	162/503 (32·2%)	169/630 (26·8%)	147/368 (39·9%)	478/1501 (31·8%)	..
1	157/503 (31·2%)	208/630 (33·0%)	67/368 (18·2%)	432/1501 (28·8%)	..
2	113/503 (22·5%)	147/630 (23·3%)	81/368 (22·0%)	341/1501 (22·7%)	..
3	55/503 (10·9%)	76/630 (12·1%)	52/368 (14·1%)	183/1501 (12·2%)	..
4	16/503 (3·2%)	30/630 (4·8%)	21/368 (5·7%)	67/1501 (4·5%)	..
Return to theatre*	52/557 (9·3%)	103/703 (14·7%)	134/477 (28·1%)	289/1737 (16·6%)	<0·0001
Discharge destination					
Usual place of residence	457 (81·2%)	507 (71·0%)	283 (57·5%)	1247 (70·5%)	..
Transfer to another hospital	10 (1·8%)	38 (5·3%)	26 (5·3%)	74 (4·2%)	..
Transfer to rehabilitation unit	2 (0·4%)	18 (2·5%)	50 (10·2%)	70 (4·0%)	..
Remains in hospital	30 (5·3%)	67 (9·4%)	76 (15·4%)	173 (9·8%)	..
Absconded	4 (0·7%)	2 (0·3%)	4 (0·8%)	10 (0·6%)	..
Discharged to usual place of residence with same level of care†	310/457 (67·8%)	402/503 (79·9%)	216/279 (77·4%)	928/1239 (74·9%)	<0·0001

Data are n (%) or n/N (%) unless otherwise indicated. Data are recorded for all patients unless n specified. ACDiT=Adapted Clavien–Dindo in Trauma. HDI=Human Development Index. *Of patients who survived the index operation. †Of patients who were discharged to their usual place of residence for whom the level of care was reported.

Table 4: **30-day in-hospital postoperative outcomes**

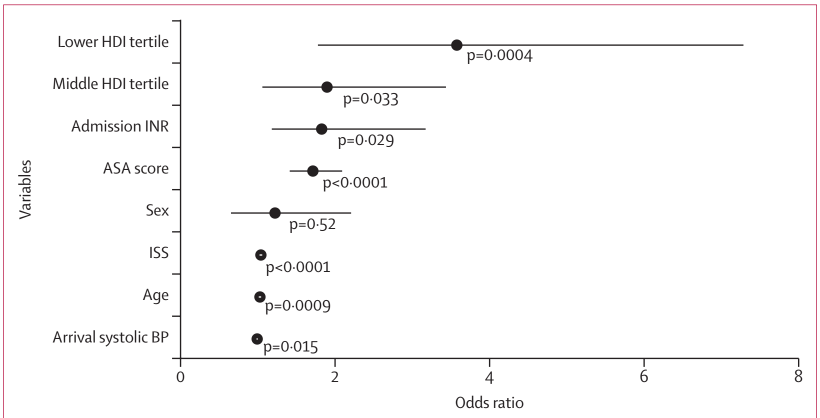

Figure 4: **Forest plot of odds ratios from Lasso regression**
ASA=American Society of Anesthesiologists. BP=blood pressure. HDI=Human Development Index. INR=international normalised ratio. ISS=Injury Severity Score.

services and social support to improve recovery from injury.[57–59]

The 76th World Health Assembly stated that emergency, critical, and operative care services are an integral part of a comprehensive health system.[60] However, the disparity we report across all aspects of the trauma pathway suggests that improvements to one domain might overload another, resulting in a zero-sum investment of time and resource. As an example, improving the transport of critically injured patients to hospital in resource-poor settings might overwhelm surgical services which already struggle to meet the standards of their resource-rich neighbours, not only resulting in no improvement, but potentially even a worsening of health outcomes. No single successful one-size-fits-all model for trauma systems exists, as they must be adapted to meet specific contextual needs, which results in wide heterogeneity across countries.[61] Poor-quality health systems result in more than 8 million deaths per year in low-income and middle-income countries[62] and economic welfare losses of around $6 trillion,[63] yet currently only 16% of development assistance for health has been provided strictly for the strengthening of health systems.[64,65] To improve trauma care, targeted action across the patient pathway is essential, ensuring the design is focused across need, access, and quality.[6,65,66]

We propose that trauma laparotomy could be used as a signal pathology for trauma system assessment globally, a concept that has been suggested across other surgical systems.[67,68] From the access to preoperative care, the interventions received, and a wide range of outcome measures, including overall mortality, relook rates, and functional consequences, trauma laparotomy can provide nuanced metrics at both the system level and hospital level. Mortality outcomes alone will not capture the full burden of system-level care quality in trauma, but trauma laparotomy can provide an opportunity to map a vast array of metrics across the patient pathway and provide nuanced insights into trauma system functioning.

We have surveyed a wide array of hospitals from across the world, with high rates of data accuracy and case ascertainment reported, and a balanced split across HDI tertiles. However, this study does come with a number of limitations. A high proportion of our centres were both tertiary hospitals and located in urban areas, a common issue with global observational studies on emergency care,[69] and limits the applicability of these study findings in more rural settings. With our data collection predominantly occurring from the in-hospital setting, any mortality event that occurred post-discharge will therefore not have been recorded, leading to a potential underestimation of true 30-day mortality rates. As with all observational studies, unmeasured confounding factors remain a concern; indeed, differences in the populations undergoing trauma laparotomy across HDI settings might have influenced outcome comparisons, despite statistical adjustment. There is also likely a sizeable selection bias from the global variation in health-care access, meaning not all individuals who required a laparotomy would have survived to have the operation. This extends further to missing data, with certain datapoints being more unavailable in certain settings, introducing further bias. Furthermore, the most injured and unstable patients might not have been offered an operation, and in this regard we have been cautious not to overstate the study's findings. As participation in this study by hospitals was voluntary, self-selection for study involvement introduces an additional potential selection bias; similarly, sites self-selected for data validation, which introduces further biasing into the validation of the study. Finally, longer-term outcomes or economic metrics were not recorded, which must be a focus of future research in the field.

In conclusion, the GOAL-Trauma study provides key insights into current trauma laparotomy standards from across the patient trauma pathway. While crude mortality rates of those reaching hospital and undergoing a procedure were equivalent, there were significant variations in patient presentation and injury severity across HDI settings, suggesting a potentially missed cohort of injured patients that needs further exploration, as well as higher adjusted mortality rates in the lower-HDI and middle-HDI settings. The study highlights several important areas for further research and emphasises the need for a systems approach if global trauma care standards are to be improved.

Contributors

MFB, KK, and TB: study design, data collection, data analysis, data interpretation, and writing. JA, MM, ZBP, and TCH: study design, data collection, data interpretation, and writing. LH, BGS, PH, and TGW: study design, data analysis, data interpretation, and writing. TE: data collection, data analysis, data interpretation, and writing. CH: data analysis, data interpretation, and writing. ASH, ZZ, DUB, EC, CMNG, LC, MK, RS: data collection, data interpretation, and writing. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication. MB, KK, TE, CH, and TB accessed and verified the data.

Declaration of interests

We declare no competing interests.

Data sharing

After publication, data will be available to any researcher who provides a methodologically sound study proposal that is approved by the GOAL-Trauma steering committee. Proposals may be submitted to the International Health Systems Group at the University of Cambridge. Individual patients or hospitals will not be identifiable in any released data and all appropriate information governance protocols will be followed.

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Editorial note: The Lancet Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

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