Mortality of emergency abdominal surgery in high, middle and lowincome countries

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Mortality of emergency abdominal surgery in high, middle and low income countries

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Abstract

Background: Surgical mortality data are routinely collected in high income countries, yet virtually no low or middle income countries have outcome surveillance in place. We aimed to prospectively collect worldwide mortality data following emergency abdominal surgery, comparing findings across low, middle and high Human Development Index (HDI) countries.

Methods: A prospective, multicentre, cohort study. Self-selected hospitals performing emergency surgery submitted pre-specified data for consecutive patients from at least one two-week period July-December 2014. Postoperative mortality was analysed by hierarchical multivariable logistic regression.

Results: Data were obtained for 10,745 patients from 357 centres in 58 countries; 6538 were from high, 2889 from middle and 1318 from low HDI settings. Overall mortality was 1.6% at 24 hours (high 1.1%, middle 1.9%, low 3.4%, p<0.001), increasing to 5.3% by 30 days (high 4.5%, middle 6.0%, low 8.7%, p<0.001). Of the 578 patients who died, 69.9% (n=404) did so between 24 hours and 30 days following surgery (high 74.2%, middle 68.8%, low 60.5%). After adjustment, 30-day mortality remained higher in middle (OR 2.78, 95% CI 1.84-4.20) and low-income countries (OR 2.97, 1.84-4.81). Surgical safety checklist use was lower in LMICs, but when used was associated with reduced mortality at both 24 hours and 30 days.

Conclusions: Mortality is three times higher in low compared with high HDI countries even when adjusted for prognostic factors. Patient safety factors may have an important role and require further investigation. This study strongly supports 30 day mortality as an international benchmark. (ClinicalTrials.gov: NCT02179112).

Introduction

Global health priorities are typically assessed by measuring the burden of various diseases, including human immunodeficiency virus (HIV), tuberculosis, malaria and trauma. Surgery, however, contributes to the treatment of a very wide range of conditions and its significance may have been obscured by a disease based approach to international health[1]. This is changing and the importance of surgery to human health and welfare has been highlighted by several recent studies[2-4]. For instance, 17 of the 51 million people who died across the world in 2012 suffered from diseases needing surgical care[1, 2]. Access to surgical care varies widely[3, 4]. It has been estimated that less than a third of the world's population have access to safe, timely and affordable surgery and only 6% of the 300 million surgical procedures performed each year take place in a low or middle income country (LMIC) despite one third of people living there[2]. There are firm moves, supported by the World Health Organisation, to improve access to surgical care[3, 5]. However safe surgery requires considerable infrastructure and improving coverage should go hand in hand with quality assurance[3]. Surgical mortality data are collected routinely in high income health systems but 70% of countries lack routine surgical surveillance systems[4, 6].

In this study we take the first step towards remedying the undesirable lack of information by creating an international network of surgeons across all continents to measure mortality rates following emergency abdominal surgery. This represents a common operation type that is carried out with life-saving intent but which nevertheless carries substantial mortality. This makes it an important topic in its own right and a potential proxy for surgical care generally. The aim of this study was to collect postoperative mortality data and analyse variation in factors that might affect mortality. In this first report we describe the feasibility of collecting 'bedside' patient level data across low, middle and high income settings using a new collaborative network. We specifically compared the performance and practicality of using 24 hour or 30 day postoperative mortality as the primary outcome measure in a wide variety of clinical settings. Additionally, we test variation in mortality attributed to markers of prognosis (including operation type) and service (marked by availability and use of safety checklists).

Methods

Study design

An international, multicentre, prospective, observational cohort study was conducted according to a pre-specified, registered and published protocol (ClinicalTrials.gov identifier: NCT02179112)[7]. A UK National Health Service Research Ethics review considered this study exempt from formal research registration (South East Scotland Research Ethics Service, reference: NR/1404AB12); individual centres obtained their own audit, ethical or institutional approval. Results are reported according to STROBE guidelines[8].

Study period

Investigators from self-selected surgical units identified consecutive patients within two-week time periods between 1st July 2014 and 31st December 2014. An open invitation for participation was disseminated through social media, personal contacts, email to authors of published emergency surgery studies, and national/international surgical organisations. Short intensive data collection periods allowed surgical teams within these units to contribute meaningful numbers of patients without requiring additional resources. The study period covered an extended time period to accommodate the availability of local investigators and variable holiday periods, while helping to smooth seasonal variation that can affect surgical pathology. An institution could collect over as many two week periods as desired within the study period.

Patients and procedures

Consecutive patients undergoing emergency intraperitoneal surgery during the chosen two-week period were included. There were no age restrictions. Emergency surgery was defined as any unplanned, non-elective operation, including re-operation after a previous procedure. Intraperitoneal surgery was defined as any open, laparoscopic or laparoscopic-converted procedure that entered the peritoneal cavity. Elective (planned) or semi-elective procedures (where a patient initially admitted as an emergency was then discharged from hospital and re-admitted at later time for surgery) were excluded. Additionally, patients undergoing caesarean section were excluded as they represent a separate operative group with different management needs that have been studied elsewhere [9].

Data

Included patients were followed to day 30 after surgery or for the length of their inpatient stay where follow-up was not feasible. Records were uploaded by local investigators to a secure online website, provided using the Research Electronic Data Capture (REDCap) system [10]. The lead investigator at each site checked the accuracy of all cases prior to data submission. The submitted data were then checked centrally and where missing data were identified, the local lead investigator was contacted and asked to make good the record. Once vetted, the record was accepted into the dataset for analysis.

Outcome measures

The primary outcome measure was the 24 hour postoperative mortality rate. This is the number of deaths during the operation or within 24 hours of the operation's conclusion, divided by the number of eligible operations performed.[11] The main secondary outcome measure was the 30 day postoperative mortality rate. Where 30 day follow-up was unavailable, alive-dead status at the point of discharge from hospital was recorded. Other secondary outcome measures included postoperative complication and reintervention rates. For the purposes of clarity, these will be described in subsequent reports where sufficient detail can be included.

Independent (exploratory) variables

We collected the following patient level factors in order to adjust outcome:

- Patient factors: age, gender, diabetes, smoking status, American Society of Anaesthesiologists (ASA) physical status classification system.
- Disease factors: seven major diagnostic groups were included, representing the spectrum of disease encountered. Additionally, the presence of a perforated abdominal viscus found at operation was included.
- Hospital safety: availability and use of a surgical safety checklist for each patient.

Power considerations

The sample size was limited by practical factors and estimation of power by uncertainty over critical quantities such as clustering and variation in mortality by diagnosis. An indicative power calculation is given in the protocol.

Statistical Analysis

Variation across different international health settings was assessed by stratifying participating centres by country into three tertiles according to Human Development Index rank (HDI). This is a composite statistic of life expectancy, education, and income indices published by the United Nations (http://hdr.undp.org/en/statistics). This aggregate measure of country development that keeps individual countries anonymous, especially since single unit participation was expected from some nations; this would make country level statistical analysis less useful and potential patient identification possible. Differences between HDI tertiles were tested with the Pearson chi-squared test and Kruskal-Wallis test for categorical and continuous variables respectively.

Hierarchical multivariable logistic regression models (random intercept) were constructed with three levels: patients nested within hospitals, nested within countries. HDI tertile and other explanatory variables were included as fixed effects. Other than HDI tertile, all fixed effects were considered at the level of the patient. Coefficients are expressed as odds ratios (OR) with confidence intervals and p values derived from percentiles of 10,000 bootstrap replications. Model residuals were checked at all three levels and first-order interactions explored. Goodness of model fit is reported with the Hosmer and Lemeshow (H&L) test and predictive ability described by area under the receiver operator curve (c-statistic).

To help visualise the relationship of outcomes with a continuous representation of the human development index (HDI rank), the final fixed effect regression models were used with a restricted cubic spline for HDI rank (three knots distributed equally across the range of HDI rank) to allow for potential non-linear relationships. Predictions were made for specified covariate levels and bootstrapped confidence intervals generated.

A pre-specified sensitivity analysis was performed. We predicted that some patients will be discharged alive but not followed-up at 30 days. For the main analysis, we coded these patients as alive. To test the validity of this approach, we excluded these 'discharged alive; not followed-up' patients and re-ran the 30 day mortality analysis.

All analyses were undertaken using the R Foundation Statistical Program (R 3.1.1), using packages plyr, stringr, ggplot2, reshape2, jsonlite, RCurl, httr, Hmisc, rms, lme4 and knitr.

Results

Patients

A total of 10,906 patient records were submitted and 10,745 records were formally accepted for analysis following the quality control algorithm described above. These patients came from 357 centres across 58 countries (figure 1), with 6538 (60.8%) from high, 2889 (26.9%) from middle and 1318 (12.3%) from low HDI settings. A complete record with no missing data was achieved in 99.1% of patients (10,644/10,745); 24 hour outcome data were available in 99.9% (13 missing) and 30 day mortality in 99.8% (24 missing) patients.

Demographics

Differences in demographics across HDI groups are shown in Table 1. Appendicectomy was the most commonly performed operation across all HDI settings (high 38.2%, middle 53.3%, low 38.5%; Fig 2, Table S1). Trauma was the indication for surgery in a higher proportion of cases in middle and low HDI countries (10.0% and 12.1% respectively) compared with high HDI countries (2.2%). Use of a midline laparotomy for intraperitoneal access increased across development index (high 27.1%, middle 27.5%, low 40.9%). Use of a surgical safety checklist occurred in 74.4% of cases, varying significantly across HDI groups (91.2% high, 55.7% middle, 32.1% low, $p<0.001$).

Crude mortality across HDI groups

Crude 24 hour mortality was 1.6% and 30 day mortality was 5.3%. Twenty four hour mortality increased three fold across HDI groups (high 1.1%, middle 1.9%, low 3.4%, $p<0.001$). Likewise there was an inverse relationship between 30 day mortality and HDI (high 4.5%, middle 6.0%, low 8.7%, $p<0.001$).

Mortality varied across HDI group for some operations, but not others. Following appendicectomy, overall 24 hour mortality (0.02%) and 30 day mortality (0.2%) were low and did not vary significantly between HDI groups (30 day mortality high 0.1%, middle 0.1%, low 0.6%). However, mortality following midline laparotomy was higher (4.7% at 24 hours and 14.6% at 30 days) and varied across HDI groups (30 day mortality high 13.0%, middle 17.5%, low 17.3%, $p<0.001$, Fig 3).

Trauma was the indication with the highest 24 hour mortality at 8.4% (high 8.4%, middle 6.6%, low 11.9%, $p=0.144$) rising to 13.9% at 30 days (high 13.3%, middle 11.7%, low 18.2%, $p=0.157$).

Mortality increased from high to low HDI at ASA levels 1-4, but at ASA 5 mortality reduced by half in the lower income groups (30 day mortality high 55.9%, middle 27.7%, low 24.6%, p<0.001, Table 2).

24 hour versus 30 day mortality

Of the 578 patients who died, 69.9% (n=404) did so between 24 hours and 30 days following surgery (high 74.2%, middle 68.8%, low 60.5%). Most of the deaths in this time period related to patients with non-traumatic indications for index surgery (92.1% non-trauma, 7.9% trauma, Table 3).

Mortality adjusted for case-mix

Models of mortality accounted for the clustering of patients within hospitals and patients/hospitals within countries. The effects of prognostic factors on 24 hour mortality are shown in Table S2, and on 30 day mortality in Table 4. After adjusting for case-mix (including age, gender, history of diabetes, smoking history, ASA grade and diagnostic group, presence of a perforated viscus, checklist use), independent correlation between increased mortality in LMICs at 24 hours and 30 days remained. Across the entire dataset, use of a surgical safety checklist was associated with lower hospital mortality rates at both 24 hours and 30 days. Having a checklist available but not using it was associated with reduced mortality at 24 hours but not at 30 days.

Mortality analyses were repeated using non-linear models (Fig 4). These showed that 30 day mortality was a better discriminator of HDI than 24 hour mortality.

Sensitivity analyses

Some 17.7% of patients were discharged alive and assumed to still be alive at 30 days. Excluding these patients from analysis of main outcomes did not affect the size or direction of effects across HDI groups (Table S3).

Discussion

This study is the first to measure mortality following emergency abdominal surgery systematically at a worldwide level, thereby enabling comparisons to be made across low, middle and high HDI countries. It shows that our collaborative ‘bedside’ network can collect mortality statistics following surgery on a large scale, even in low HDI countries, and that follow-up to discharge or 30 days is achievable in the majority of survivors. Mortality after emergency abdominal surgery is two-to-three times higher in low compared with high HDI countries. More than half the patients who die within 30 days did so after 24 hours, strongly supporting 30 day perioperative mortality rate as an international benchmark. This study supports its inclusion in the 2014 World Health Organisation (WHO) Global Reference List of 100 Core Health indicators[5]. It also identifies appendicectomy as the most common emergency general surgical operation performed around the world and in all development tertiles.

The trend towards higher mortality (24 hour and 30 days) in low income countries remained after adjusting for observable prognostic factors. The association between increasing mortality and lower HDI may be explained by unobserved differences in prognosis in different HDI countries, differences in treatment, or both. Higher mortality was seen specifically in trauma cases, and in patients undergoing midline laparotomy. When patients were classified into appendicectomy and non-appendicectomy, those in low income countries had higher mortality rates although the result was not significant among the cases who had had an appendicectomy, arguably because the death rate is low with this operation. Mortality was also higher in LMIC countries for each ASA grade up to level 5, where the trend reverses, perhaps because of reluctance to operate on those moribund patients in resource poor settings.

Surgical safety checklists were included in this study as a marker of hospital safety. Use declined markedly across high to low HDI settings and their use was associated with reduced mortality at both 24 hours and 30 days even after adjustment. When a checklist was available but not used, this was associated with higher mortality at 24 hours but not 30 days, compared to hospitals systems without one at all. This may be a reflection of the urgency of surgery in these cases. However this study cannot definitively determine whether the checklist itself is responsible for improved outcomes, or whether the checklist is merely a marker of safer hospital systems[12, 13]. That said, the fact that risk adjustment for trauma did not affect the mortality gradient across HDI tertiles and that checklist use was associated with reduced mortality, does provide a hint that not all the difference in outcome in LMIC was the result of prognostic factors alone.

An important strategy in our collaborator recruitment was to invert the traditional research model. Rather than department heads, junior clinicians were often the contact point by which a hospital became involved. Social media and technology played an important role in the recruitment and running of the study[14]. Collaborators, particularly in LMICs, were clear in their view that those providing the clinical care can generate high quality data and lead international clinical research. By providing clear protocols, administrative support, secure web-based data collection, and continued direct access to collected data, the collaborative continues to be met with a striking enthusiasm across a diverse range of settings. This collaboration has proved that large studies crossing cultures and levels of socioeconomic development are feasible without extensive resources when data collection is performed during a short but intensive time period[15]. This international surgical network includes strong LMIC partners and has established the feasibility of a common data-sharing platform that is accessible on computers and mobile phones.

The strengths of this study lie in the scale of the network, range of countries included, duration of follow-up, low rates of missing data, and clinical and service detail obtained. Nevertheless, a study of this scale has some inevitable limitations.

We were not able to independently audit entered cases against operative logbooks. However case sheets were signed off by the head at each centre and the dataset was not accepted centrally until remediable deficiencies had been corrected. The data is likely to be more accurate than local administrative data because it was collected by enthusiastic clinicians who understood its purpose. It also contains more clinical detail than can be found in routinely collected data.

It was not possible to capture all salient risk factors. Our risk adjustment strategy purposely used a limited number of variables to facilitate future comparisons, both locally and in other research studies. A balance must be struck between a desire to collect ever more variables and the practical delivery of a study. However other strategies utilising additional predictive variables should be explored in the future. As stated in the introduction, access to surgery is poor in many LMICs with the consequence that patients may present late[2]. The effect of late presentation may not be fully captured in variables such as the ASA score which we were able to collect[18, 19]. The proportion of cases undergoing different types of operation varied by HDI tertile, but we compared outcomes by operation type and ASA score as well as overall. The short timeframes for data capture by local collaborators are tangible and realistic, but do risk selection bias, such as seasonal variation in local presentations. Longer enrolment strategies will help quantify this potential bias.

Use of HDI allowed a comparison between countries by an accepted classification, although other classifications exist, comprised of different measures and cut-offs. By grouping countries, between-country variation will not be detected but is likely to be significant. There is likely to be a selection bias towards better-resourced institutions taking part in this study, even in low income settings. An indication that this was the case is provided by the observation that pulse oximetry was used in a very high proportion of cases despite known shortages in low income settings[20]. Furthermore, a high proportion of senior anaesthetists were present, which may not be expected outside of better funded centres. This selection bias may mean data are not typical of some district or rural hospitals, in terms of distribution of pathology or outcomes. It is therefore likely that this study underestimates mortality in these specific settings. This paper cannot reflect the millions of people without access to essential surgery, for whom investment in infrastructure, training and financial strategies of inpatient care are needed in addition to safety measures alone.

This network can now work together to develop quality improvement collaboratives of the sort that have driven improved standards in high income countries[16]. A second cohort study allows us to increase participation (registration available at http://globalsurg.org/) with surgeons able to re-audit their practice. It will also allow us to test the impact of new risk factors, including HIV status and the impact of pre-hospital delays. From this platform, we are trying to establish a consortium of representative centres to deliver large scale trials with global reach[17]. A fundamental objective moving forward is the evidence-based identification of cost-effective interventions to reduce disparities in outcomes after surgery between countries.

Table 1. Patient factors by human development index (HDI) tertile

		HDI tertile			
		High, n=6538	Middle, n=2889	Low, n=1318	P value
Age (completed years)	Mean (SD)	3162 (48.4)	1600 (55.4)	808 (61.3)	<0.001
Gender	Male	3373 (51.6)	1289 (44.6)	510 (38.7)	<0.001*
	Female	3 (0)	0 (0)	0 (0)	
	Missing	2701 (41.3)	1648 (57)	613 (46.5)	
ASA	1	2004 (30.7)	728 (25.2)	352 (26.7)	<0.001
	2	1134 (17.3)	283 (9.8)	162 (12.3)	
	3	411 (6.3)	98 (3.4)	43 (3.3)	
	4	102 (1.6)	65 (2.2)	69 (5.2)	
	5	183 (2.8)	66 (2.3)	76 (5.8)	
	Unknown	3 (0)	1 (0)	3 (0.2)	
	Missing	6044 (92.4)	2686 (93)	1226 (93)	
Diabetes history	No	491 (7.5)	203 (7)	92 (7)	0.622
	Yes	3 (0)	0 (0)	0 (0)	
	Missing	4633 (70.9)	2247 (77.8)	1100 (83.5)	
Smoking currently	No	1901 (29.1)	640 (22.2)	217 (16.5)	<0.001
	Yes	4 (0.1)	2 (0.1)	1 (0.1)	
	Missing	5522 (84.5)	2416 (83.6)	1049 (79.6)	
Diagnosis type	Non trauma / non cancer	407 (6.2)	80 (2.8)	57 (4.3)	<0.001
	Neoplasm	143 (2.2)	290 (10)	159 (12.1)	
	Trauma	181 (2.8)	48 (1.7)	14 (1.1)	
	No disease identified	285 (4.4)	55 (1.9)	39 (3)	<0.001
	Complication of previous procedure	3883 (59.4)	2354 (81.5)	1173 (89)	
CT performed	No	2652 (40.6)	535 (18.5)	145 (11)	<0.001
	Yes	3 (0)	0 (0)	0 (0)	
	Missing	3966 (60.7)	1230 (42.6)	586 (44.5)	
Procedure start time	0800-1800 (daytime)	1401 (21.4)	755 (26.1)	367 (27.8)	
	1800-2200 (evening)	1167 (17.8)	901 (31.2)	365 (27.7)	
	2200-0800 (night-time)	4 (0.1)	3 (0.1)	0 (0)	<0.001
	Missing	1382 (21.1)	1324 (45.8)	607 (46.1)	
Admission to procedure time	< 6 hours	1192 (18.2)	723 (25)	287 (21.8)	
	6-11 hours	1510 (23.1)	462 (16)	189 (14.3)	<0.001
	12-23 hour	1031 (15.8)	171 (5.9)	94 (7.1)	
	24-47 hours	1415 (21.6)	204 (7.1)	139 (10.5)	
	48+ hours	8 (0.1)	5 (0.2)	2 (0.2)	
	Missing	422 (6.5)	1029 (35.6)	474 (36)	<0.001
Surgical safety checklist used	No, not available in this hospital	146 (2.2)	248 (8.6)	421 (31.9)	
	No, but available in this hospital	5967 (91.3)	1608 (55.7)	423 (32.1)	
	Yes	3 (0)	4 (0.1)	0 (0)	
	Missing	182 (2.8)	1208 (41.8)	384 (29.1)	
Senior surgeon >5 years training	No	6353 (97.2)	1676 (58)	934 (70.9)	
	Yes	3 (0)	5 (0.2)	0 (0)	
	Missing	262 (4)	1395 (48.3)	524 (39.8)	<0.001
Senior anaesthetist >5 years training	No	6273 (95.9)	1490 (51.6)	794 (60.2)	
	Yes	3 (0)	4 (0.1)	0 (0)	
	Missing	6438 (98.5)	2213 (76.6)	1219 (92.5)	<0.001
Anaesthetic type	General	97 (1.5)	673 (23.3)	98 (7.4)	
	Spinal or sedation	3 (0)	3 (0.1)	1 (0.1)	
	Missing	3369 (51.5)	2622 (90.8)	1238 (93.9)	<0.001
Laparoscopic approach	No	3169 (48.5)	267 (9.2)	80 (6.1)	
	Yes	5454 (83.4)	2608 (90.3)	1112 (84.4)	
Bowel resection	No	1077 (16.5)	276 (9.6)	205 (15.6)	<0.001
	Yes	7 (0.1)	5 (0.2)	1 (0.1)	
	Missing	5860 (89.6)	2732 (94.6)	1195 (90.7)	
Stoma formed	No	674 (10.3)	152 (5.3)	123 (9.3)	<0.001
	Yes	4 (0.1)	5 (0.2)	0 (0)	
	Missing	5475 (83.7)	2406 (83.3)	913 (69.3)	
Perforated viscus	No	1059 (16.2)	476 (16.5)	377 (28.6)	<0.001
	Yes	4 (0.1)	7 (0.2)	28 (2.1)	
	Missing	239 (3.7)	515 (17.8)	101 (7.7)	
Supplementary oxygen	No	6296 (96.3)	2370 (82)	1187 (90.1)	<0.001
	Yes	3 (0)	4 (0.1)	30 (2.3)	
	Missing	39 (0.6)	129 (4.5)	15 (1.1)	
Pulse oximetry	No	6496 (99.4)	2756 (95.4)	1303 (98.9)	<0.001
	Yes	3 (0)	4 (0.1)	0 (0)	
	Missing	824 (12.6)	370 (12.8)	177 (13.4)	
Prophylactic antibiotics	No	5709 (87.3)	2514 (87)	1140 (86.5)	0.710
	Yes	5 (0.1)	5 (0.2)	1 (0.1)	
	Missing	3162 (48.4)	1600 (55.4)	808 (61.3)	

Data are n (% by column) unless otherwise indicated. ASA-American Society of Anaesthesiologists physical status classification system. CT-computed tomography. *P value is for Kruskal-Wallis test, otherwise Pearson χ^2 test.

Table 2. Outcomes by HDI tertile and ASA

ASA	24h mortality			30 day mortality		
	High	Middle	Low	High	Middle	Low
1	1/2701 (0.0)	8/1648 (0.5)	3/613 (0.5)	5/2701 (0.2)	25/1648 (1.5)	13/613 (2.1)
2	4/2004 (0.2)	8/728 (1.1)	11/352 (3.1)	23/2004 (1.1)	31/728 (4.3)	27/352 (7.7)
3	14/1134 (1.2)	15/283 (5.3)	9/162 (5.6)	82/1134 (7.2)	50/283 (17.7)	31/162 (19.1)
4	18/411 (4.4)	12/98 (12.2)	6/43 (14.0)	110/411 (26.8)	43/98 (43.9)	15/43 (34.9)
5	31/102 (30.4)	9/65 (13.8)	11/69 (15.9)	57/102 (55.9)	18/65 (27.7)	17/69 (24.6)
Unknown	7/183 (3.8)	2/66 (3.0)	5/76 (6.6)	14/183 (7.7)	6/66 (9.1)	11/76 (14.5)
Missing	0/3 (0.0)	0/1 (0.0)	0/3 (0.0)	0/3 (0.0)	0/1 (0.0)	0/3 (0.0)

Data are n (%).

Table 3. Mortality between 24 hours and 30 days. Percentages are presented split by row, indicating the distribution of those that died in 24 hours versus subsequent deaths for each group.

		Total Died (n=578)	Died within 24 h (n=174)	Died after 24 h within 30 days (n=404)	P value
HDI tertile	High	291	75/291 (25.8)	216/291 (74.2)	0.024
	Middle	173	54/173 (31.3)	119/173 (68.8)	
	Low	114	45/114 (39.5)	69/114 (60.5)	
Diagnosis	Appendicitis	8	2/8 (25.0)	6/8 (75.0)	*
	No disease identified	17	3/17 (17.6)	14/17 (82.4)	
	Other abdominal	339	90/339 (26.5)	249/339 (73.5)	
	Neoplasm	78	16/78 (20.5)	62/78 (79.5)	
	Gallstones	10	1/10 (10.0)	9/10 (90.0)	
	Complication of previous procedure	44	12/44 (27.3)	32/44 (72.7)	
	Trauma	82	50/82 (61.0)	32/82 (39.0)	

Data are n (%, by row). P values χ^2 test. *categories presented for information, no statistical comparisons performed.

Table 4. Factors associated with 30 day mortality. More detailed diagnosis information is shown in supplemental table S1.

		Alive	Died	Univariable OR (95% CI, P value)	Multilevel OR (95% CI, P value)
HDI tertile	High	6240 (61.5)	291 (50.3)		
	Middle	2701 (26.6)	173 (29.9)	1.37 (1.13-1.66, p=0.001)	2.78 (1.84-4.20) p=0.000
	Low	1202 (11.9)	114 (19.7)	2.03 (1.62-2.54, p=0.000)	2.97 (1.84-4.81) p=0.000
Age (years; standardised)	Mean (SD)	38.7 (22.3)	58.5 (24.3)	2.36 (2.16-2.58, p=0.000)	1.68 (1.48-1.91) p=0.000
Gender	Male	5229 (51.6)	333 (57.6)		
	Female	4914 (48.4)	245 (42.4)	0.78 (0.66-0.93, p=0.005)	1.14 (0.92-1.41) p=0.240
Diabetes history	No	9467 (93.3)	469 (81.1)		
	Yes	676 (6.7)	109 (18.9)	3.25 (2.59-4.05, p=0.000)	1.21 (0.92-1.58) p=0.174
Smoking currently	No	7569 (74.6)	395 (68.3)		
	Yes	2571 (25.4)	183 (31.7)	1.36 (1.14-1.63, p=0.001)	0.86 (0.69-1.08) p=0.195
ASA	1	4910 (48.4)	43 (7.4)		
	2	2997 (29.6)	81 (14.0)	3.09 (2.14-4.52, p=0.000)	1.64 (1.10-2.45) p=0.016
	3	1415 (14.0)	163 (28.2)	13.15 (9.44-18.72, p=0.000)	4.69 (3.15-6.99) p=0.000
	4	382 (3.8)	168 (29.1)	50.22 (35.70-72.11, p=0.000)	18.21 (11.95-27.74) p=0.000
	5	144 (1.4)	92 (15.9)	72.95 (49.31-109.52, p=0.000)	30.23 (18.60-49.14) p=0.000
	Unknown	292 (2.9)	31 (5.4)	12.12 (7.47-19.46, p=0.000)	6.95 (3.90-12.38) p=0.000
Diagnosis	Appendicitis	4532 (44.7)	8 (1.4)		
	No disease identified	222 (2.2)	17 (2.9)	43.38 (19.08-107.33, p=0.000)	32.52 (13.01-81.32) p=0.000
	Other abdominal	3147 (31.0)	339 (58.7)	61.02 (32.40-134.55, p=0.000)	20.09 (9.85-40.99) p=0.000
	Neoplasm	464 (4.6)	78 (13.5)	95.23 (48.63-215.20, p=0.000)	27.47 (12.88-58.58) p=0.000
	Gallstones	937 (9.2)	10 (1.7)	6.05 (2.38-15.88, p=0.000)	3.37 (1.31-8.69) p=0.012
	Complication of previous procedure	331 (3.3)	44 (7.6)	75.30 (37.15-173.90, p=0.000)	18.91 (8.58-41.67) p=0.000
	Trauma	510 (5.0)	82 (14.2)	91.08 (46.64-205.48, p=0.000)	23.04 (10.80-49.12) p=0.000
Perforated viscus	No	8424 (83.3)	356 (61.9)		
	Yes	1687 (16.7)	219 (38.1)	3.07 (2.57-3.66, p=0.000)	1.82 (1.46-2.27) p=0.000
Surgical safety checklist used	No, not available in this hospital	1793 (17.7)	128 (22.1)		
	No, but available in this hospital	719 (7.1)	95 (16.4)	1.85 (1.40-2.44, p=0.000)	1.28 (0.81-2.03) p=0.294
	Yes	7628 (75.2)	355 (61.4)	0.65 (0.53-0.81, p=0.000)	0.62 (0.42-0.92) p=0.016

Data are n (% by column) unless otherwise indicated. Confidence intervals and p values derived from percentiles of 10000 bootstrap predictions. Total N=10690. AIC=2974. c-statistic=0.93. H&L GOF test $\chi 2$ = 13.3, df = 8, P value = 0.102. ASA-American Society of Anaesthesiologists physical status classification system. OR-odds ratio. CI-confidence interval.

Figure legends

Fig 1: Collaborating centres and proportion of enrolled patients with trauma diagnosis, by contributing country.

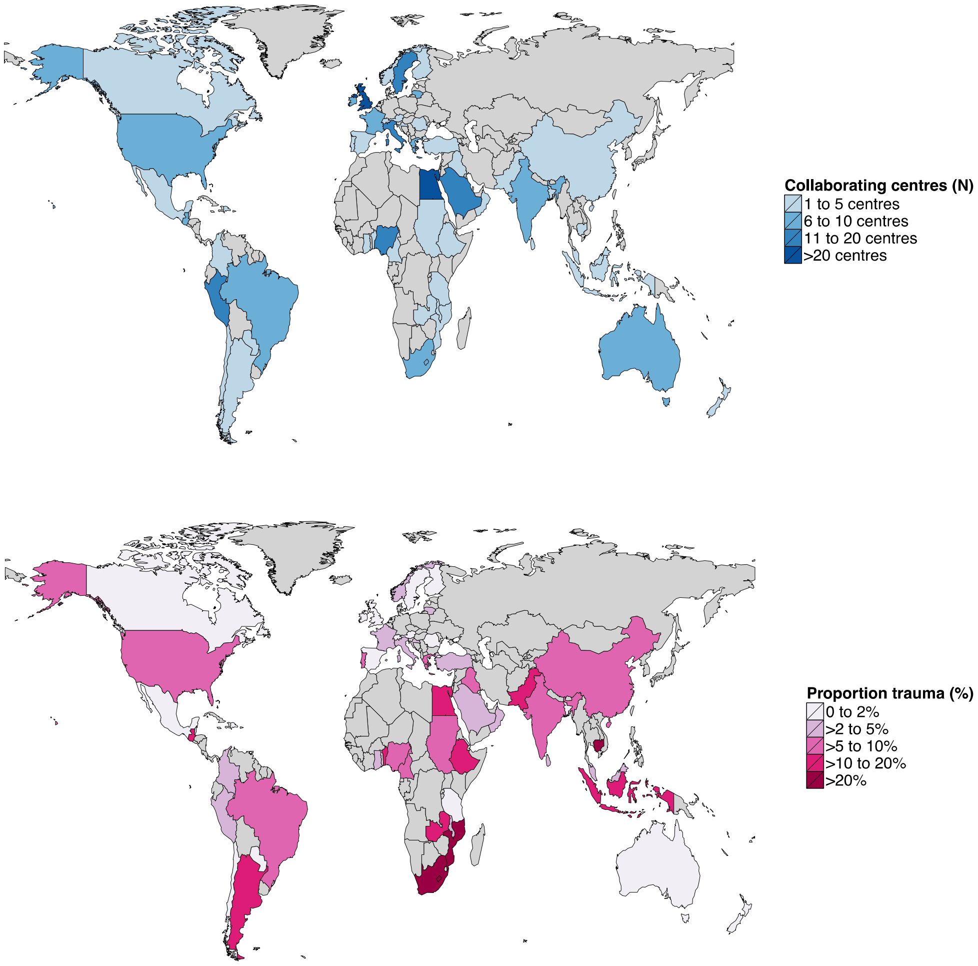

Fig 2: summary diagnostic groups. The coloured bars show the proportional diagnostic groups spread from low to high HDI decile.

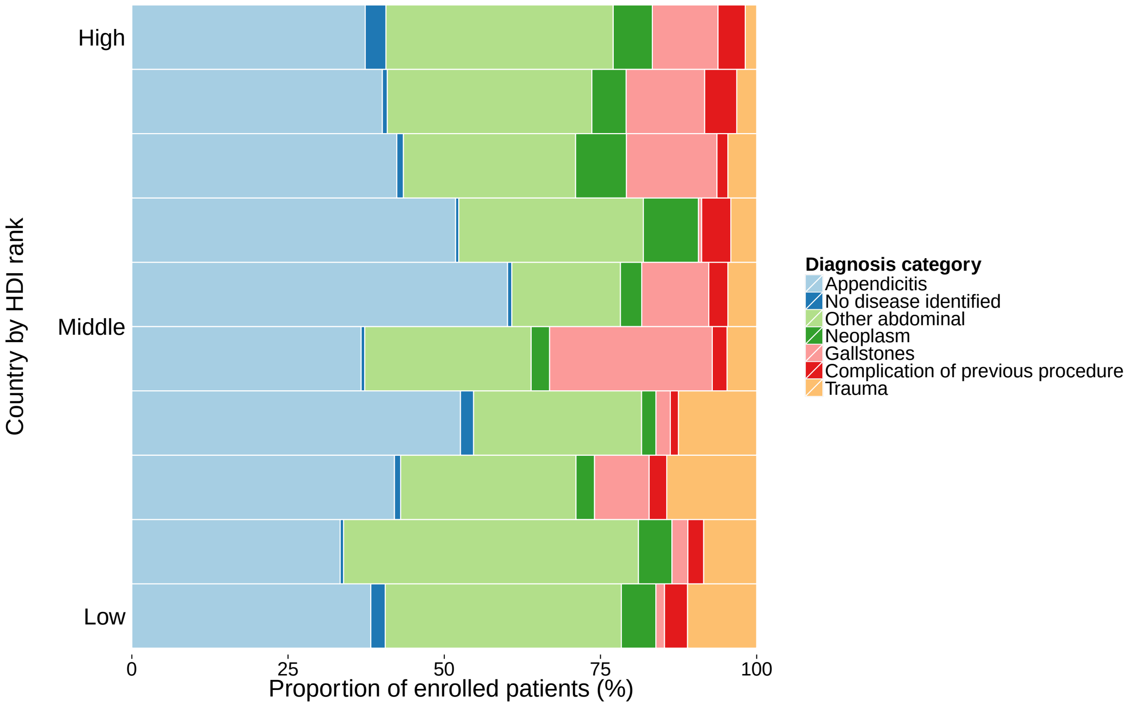

Fig 3: Study process flowchart and key outcomes by Human Development Index.

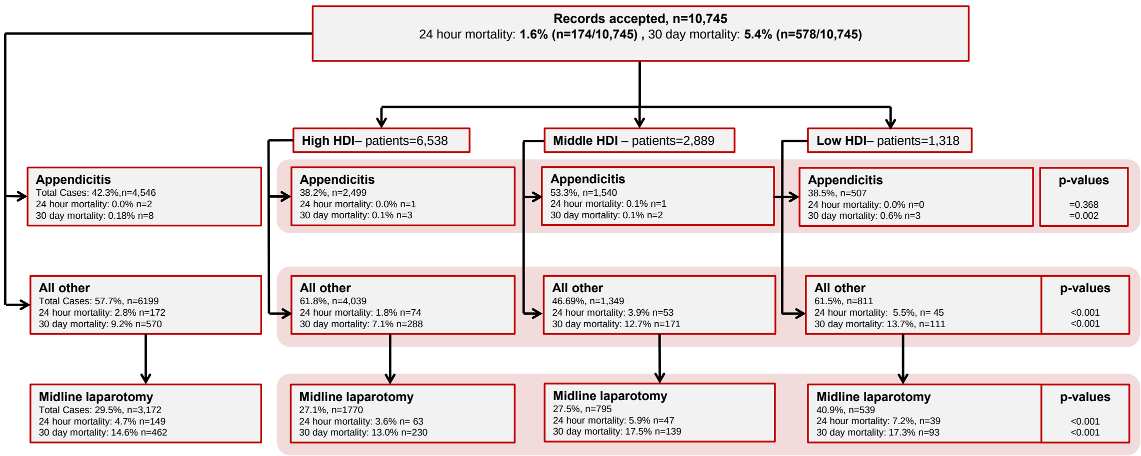

Fig 4: Adjusted associations between human developmental index (HDI) rank and mortality. Multivariable logistic regression models were repeated but using a continuous variable of HDI rank. A restricted cubic spline with three knots distributed equally across the range was applied to HDI rank. Predictions were made on the models and 95% confidence intervals determined (shaded area). Covariate levels, age=35, diabetes=no, gender=male, smoking=no, ASA=1, diagnosis=trauma, checklist=no, not available.

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