Global disease burden of conditions requiring emergency surgery

B. Stewart[1], P. Khanduri[2], C. McCord[3], M. Ohene-Yeboah[4], S. Uranues[5], F. Vega Rivera[6] and C. Mock[1]

[1]Department of Surgery, University of Washington, Seattle, Washington, USA, [2]Department of Hepatobiliary and Pancreatic Surgery and Liver Transplantation, St Stephen's Hospital, Delhi, India, [3]Department of Surgery, Columbia University College of Physicians and Surgeons, New York, USA, [4]Department of Surgery, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, [5]Department of Surgery, Medical University of Graz, Graz, Austria, and [6]Department of Surgery, Hospital Angeles Lomas, Mexico City, Mexico

Correspondence to: Dr B. Stewart, Department of Surgery, University of Washington, 1959 NE Pacific Street, Suite BB-487, PO Box 356410, Seattle, Washington 98195-6410, USA (e-mail: stewarb@uw.edu)

Background: Surgical disease is inadequately addressed globally, and emergency conditions requiring surgery contribute substantially to the global disease burden.

Methods: This was a review of studies that contributed to define the population-based health burden of emergency surgical conditions (excluding trauma and obstetrics) and the status of available capacity to address this burden. Further data were retrieved from the Global Burden of Disease Study 2010 and the University of Washington's Institute for Health Metrics and Evaluation online data.

Results: In the index year of 2010, there were 896 000 deaths, 20 million years of life lost and 25 million disability-adjusted life-years from 11 emergency general surgical conditions reported individually in the Global Burden of Disease Study. The most common cause of death was complicated peptic ulcer disease, followed by aortic aneurysm, bowel obstruction, biliary disease, mesenteric ischaemia, peripheral vascular disease, abscess and soft tissue infections, and appendicitis. The mortality rate was higher in high-income countries (HICs) than in low- and middle-income countries (LMICs) (24·3 *versus* 10·6 deaths per 100 000 inhabitants respectively), primarily owing to a higher rate of vascular disease in HICs. However, because of the much larger population, 70 per cent of deaths occurred in LMICs. Deaths from vascular disease rose from 15 to 25 per cent of surgical emergency-related deaths in LMICs (from 1990 to 2010). Surgical capacity to address this burden is suboptimal in LMICs, with fewer than one operating theatre per 100 000 inhabitants in many LMICs, whereas some HICs have more than 14 per 100 000 inhabitants.

Conclusion: The global burden of surgical emergencies is described insufficiently. The bare estimates indicate a tremendous health burden. LMICs carry the majority of emergency conditions; in these countries the pattern of surgical disease is changing and capacity to deal with the problem is inadequate. The data presented in this study will be useful for both the surgical and public health communities to plan a more adequate response.

Introduction

Conditions that can be treated by surgery pose a considerable health burden[1,2]; many are attributable to immediately life- or limb-threatening conditions that necessitate emergency surgery. Although surgery has long been considered an essential component of health systems and is practised universally, it has been a neglected part of global health initiatives. Nearly a decade ago, 234 million major operations were performed annually worldwide[3]. This equalled the incidence of malaria, was double the volume of childbirths, and dwarfed new cases of tuberculosis, human immunodeficiency virus and malignant neoplasms combined[3]. Despite the burden of disease, two billion people, namely those living below the poverty line in low- and middle-income countries (LMICs), continue to lack access to surgical care[4]. This is particularly important to people requiring emergency surgery, because minutes or hours of delay before treatment have a profound impact on potential disability and chance of survival.

In addition, the global population is ageing and many LMICs are facing rapidly growing and urbanizing societies[5]. This epidemiological transition has resulted in an increasing frequency of many afflictions, particularly the advanced sequelae of cardiovascular disease and neoplasia[6]. This changing pattern requires the general surgeon and health system to adapt in approach and resource allocation to meet the needs of people requiring emergency surgery.

Obviously, an increased knowledge about disease burden for surgical emergencies may be useful for both the surgical and public health communities in planning a more adequate response. Thus, to define better the health burden from, and global pattern of conditions requiring emergency surgery, the currently available literature was explored.

Methods

In this review, a list of the most common indications for emergency surgery often treated by the general surgeon were considered (*Table 1*). Common paediatric surgical emergencies that might fall into a broader LMIC surgical practice are also included, as are several gynaecological conditions that are often entertained in the differential diagnosis of an acute abdomen. In order to focus on the general surgical emergencies that are the theme of the rest of this issue, the review did not encompass trauma, burns, obstetrics, neurosurgery, orthopaedics, complex congenital surgery or cardiothoracic surgery. It is acknowledged that, especially in rural areas of LMICs, general surgeons care for patients with many of these other conditions, especially trauma and obstetrical emergencies.

A literature review was conducted on three related topics: emergency surgical conditions for which it is possible to derive population-based estimates of global burden; emergency surgical conditions for which population-based estimates of global burden are not available; and response to the burden of emergency surgical conditions, including measures of capacity. Studies were selected based on their contribution to defining the burden of emergency surgical conditions and the status of capacity to address this burden. For burden, studies that provided estimates of rates of death and disability from conditions that usually mandate emergency surgical care were sought especially.

Emergency surgical conditions for which there are population-based estimates of the global burden

The main source of data providing population-based estimates of the global burden of death and disability for emergency surgical conditions was the Global Burden of Disease Study 2010 (GBDS). GBDS is a rigorous study estimating deaths and disability from a number of

Table 1 Selected indications for emergency surgery reviewed in this study

Indications requiring emergency surgery
General surgery
Peritonsillar and retropharyngeal abscess
Acute airway obstruction
Oesophageal perforation
Gastrointestinal haemorrhage
Complicated peptic ulcer*
Acute cholecystitis*
Intestinal obstruction or volvulus*
Appendicitis*
Complicated diverticulitis
Toxic megacolon
Incarcerated or strangulated hernia*
Acute abdomen
Abscess and soft tissue infections*
Anorectal sepsis
Gynaecological surgery
Ovarian torsion
Tubo-ovarian abscess
Ectopic pregnancy
Paediatric surgery
Typhoid ileal perforation
Pyloric stenosis
Intussusception
Intestinal atresia
Imperforate anus
Urological surgery
Ureteral obstruction*
Acute urinary retention*
Testicular torsion
Paraphimosis
Priapism
Vascular surgery
Acute aorta*
Acute limb ischaemia
Critical limb ischaemia and wet gangrene*
Acute mesenteric ischaemia*

*Data available directly or derived from the Global Burden of Disease Study 2010 or the University of Washington's Institute for Health Metrics and Evaluation Data visualization database[7–9].

conditions in 1990 and 2010[7,8]. To describe the burden and epidemiology of surgical emergencies, the review focused on 11 conditions reported in the GBDS (*Table 1*) for which deaths would most often arise from complications for which emergency surgery would be indicated. For example, deaths from hernia would almost always be due to complications such as obstruction or strangulation. Data for these 11 conditions as presented in the GBDS were evaluated. More granular data not immediately available from previous GBDS publications were extracted from the University of Washington's Institute for Health Metrics and Evaluation (IHME) online data visualizations[9]. Incumbent in the use of IHME data are the methods described previously by those researchers for estimating morbidity and mortality associated with the selected diseases[10].

Estimates made from the GBDS data are presented under two assumptions. The first was that deaths and years of life lost (YLL) from the 11 selected GBDS conditions are primarily the result of complications that are surgical emergencies. The second was that the additional burden of disabilities (as reflected in disability-adjusted life-years, DALYs) derived from the selected GBDS conditions represent three groups of people of unknown proportions: individuals with a condition who are symptomatic but who do not require emergency surgery (reducible hernia, uncomplicated peptic ulcer, claudication, non-obstructing urolithiasis, etc.); those who survived an indication for emergency surgery without intervention and with some impact on their quality of life, which may have been alleviated by an operation; and those who underwent emergency surgery and survived but are left with some disability.

Data on deaths and YLL were obtained directly from the IHME website. Data on DALYs for ten of the conditions were obtained directly from the IHME data. Data on DALYs owing to acute urinary retention required further calculation, based on the DALYs associated with benign prostatic hypertrophy (BPH, obtained directly from the IHME data) and the percentage of people with BPH who develop acute urinary retention by age group, explained further in *Appendix S1* (supporting information).

Emergency surgical conditions with no population-based estimates of global burden

A number of indications for emergency surgery are not reported individually in the GBDS. To describe these indications, a predefined, systematic search strategy was used (*Appendix S2*, supporting information), built to retrieve reports presenting the incidence, morbidity and mortality of each indication listed in *Table 1*. In addition, references within retrieved reports were searched for manuscripts providing epidemiological data. All estimates of the incidence are subject to variability based on certain assumptions, particularly the estimated populations at risk of each condition within each report. A few reports published only the number of surgical emergencies or deaths in a region or country. To report incidence rates consistently, population estimates from the United Nations[11] and Central Intelligence Agency World Factbook[12] were used to derive the population at risk for reports that gave the number of emergencies in a defined geographical area. These publications tend to report the incidence of hospital admissions or operations. Hence, calculations for population-based mortality rates, YLL and DALYs are not possible.

Finally, the search strategy was also built to retrieve reports describing the response to the burden of emergency surgery, including capacity, cost-effectiveness and clinical effectiveness (*Appendix S2*, supporting information). In addition to the qualitative data presented, an estimate of the number of emergency operations per year was made based on the data published by Weiser and colleagues[3]. Using their data on the number of major operations in aseptic theatres by national income, the proportion of major operations performed by general surgeons and published ratios of emergency to elective surgery by national income, estimates of the number of major emergency general surgical procedures performed globally were calculated.

Results

Global burden and distribution of conditions requiring emergency surgery

In 2010, there were 896 000 deaths, 20 million YLL and 25 million DALYs attributable to the 11 conditions requiring emergency surgery presented in the GBDS. Population rates of this burden overall, by economic category and by condition, are shown in *Table 2*. The most common cause of death was complicated peptic ulcer disease (PUD; 3·5 deaths per 100 000 population per year), followed by aortic aneurysm (2·7), bowel obstruction (2·1), biliary disease (1·3), mesenteric ischaemia (1·0), peripheral vascular disease (0·7), abscess and soft tissue infections (0·6), and appendicitis (0·5). YLL and DALYs followed a similar pattern.

Burden per population was higher in high-income countries (HICs) than in LMICs. This was due almost totally to the higher burden for vascular-related emergencies. However, owing to the higher population in LMICs, 70 per cent of all deaths from the 11 conditions were in LMICs. From 1990 to 2010, the percentage of all surgical emergencies accounted for by the three vascular conditions (peripheral arterial disease, aortic aneurysm and mesenteric ischaemia) rose from 47 to 55 per cent in HICs, but by more (from 15 to 25 per cent) in LMICs. *Fig. 1* shows the change in percentage of all deaths from emergency surgical conditions owing to vascular disease by world region from 1990 to 2010 (details in *Appendix S1*, supporting information).

Surgical emergencies with population-based global estimates for separate conditions

Peptic ulcer disease
The burden of deaths, YLL and DALYs from PUD halved during the 20-year study period. This was the result of awareness and treatment of *Helicobacter pylori*, and

Table 2 Annual rates of deaths, years of life lost and disability-adjusted life-years per 100 000 population for surgical emergencies by national income and year

| | Rate per 100 000 population | | | | | |
| | 1990 | | | 2010 | | |
	Deaths	YLL	DALYs	Deaths	YLL	DALYs
High-income countries						
Hernia	0·8	13	21	0·5	7	15
Ileus and obstruction	3·4	55	56	3·5	44	50
Peptic ulcer disease	5·9	104	124	3·3	53	67
Biliary disease	3·1	44	60	2·5	29	43
Appendicitis	0·6	14	17	0·5	8	11
Soft tissue infections	0·5	9	22	0·4	5	17
Peripheral arterial disease*	1·3	16	28	2·5	26	39
Aortic aneurysm	7·6	122	124	7·0	96	106
Mesenteric ischaemia	3·9	57	60	3·8	47	53
Urolithiasis	0·5	8	24	0·3	4	20
Acute urinary retention†	0·0	0	17	0·0	0	21
Total	27·5	442	552	24·3	319	444
Low- and middle-income countries						
Hernia	0·4	13	18	0·2	5	11
Ileus and obstruction	2·1	78	78	1·8	54	54
Peptic ulcer disease	6·0	200	204	3·5	100	104
Biliary disease	1·0	34	38	1·0	25	30
Appendicitis	0·8	38	40	0·5	21	23
Soft tissue infections	0·9	47	68	0·6	26	47
Peripheral arterial disease*	0·2	2	13	0·3	–	10
Aortic aneurysm	1·4	30	29	1·8	33	34
Mesenteric ischaemia	0·4	82	8	0·5	9	9
Urolithiasis	0·3	8	16	0·3	6	15
Acute urinary retention†	0·0	0	5	0·0	0	7
Total	13·4	533	517	10·6	277	343
All countries						
Hernia	0·4	13	19	0·2	5	11
Ileus and obstruction	2·3	74	71	2·1	54	54
Peptic ulcer disease	6·0	185	190	3·5	90	96
Biliary disease	1·4	36	41	1·3	24	32
Appendicitis	0·7	34	36	0·5	19	21
Soft tissue infections	0·8	41	62	0·6	22	43
Peripheral arterial disease*	0·3	0	10	0·7	8	14
Aortic aneurysm	2·4	45	45	2·7	44	46
Mesenteric ischaemia	1·0	17	17	1·0	15	16
Urolithiasis	0·3	7	17	0·3	6	16
Acute urinary retention†	0·0	0	10	0·0	0	7
Total	15·8	451	517	12·9	287	358

Source of data: http://www.healthmetricsandevaluation.org/gbd/visualizations/country. *The Institute for Health Metrics and Evaluation (IHME) online database does not provide an estimate for years of life lost (YLL) owing to peripheral vascular disease in low- and middle-income countries in 2010. †Acute urinary retention data derived from IHME online database (for details see *Appendix S1*, supporting information). DALY, disability-adjusted life-year.

improved hygiene and minimally invasive diagnostic and treatment techniques[13–15]. However, PUD still remains the leading cause of disability and death among the emergency indications studied in the GBDS, accounting for around 27 per cent of the total DALYs and deaths from the 11 conditions combined. There remains an enormous disparity in incidence of complicated PUD between developed and developing countries. LMICs harbour 90 per cent of PUD DALYs and 85 per cent of PUD-related deaths.

Bowel obstruction

Bowel obstructions contribute to significant morbidity and mortality in both HICs and LMICs, and this has not changed significantly across the 20-year interval. These figures do not account for obstructions related to hernias, which account for the majority of bowel obstructions in LMICs[16–18]. Abdominal adhesive disease accounts for the majority of obstructions in HICs[19]. Bowel obstructions in LMICs are more likely to be a result of external hernias, intussusception or volvulus, tuberculosis and intestinal
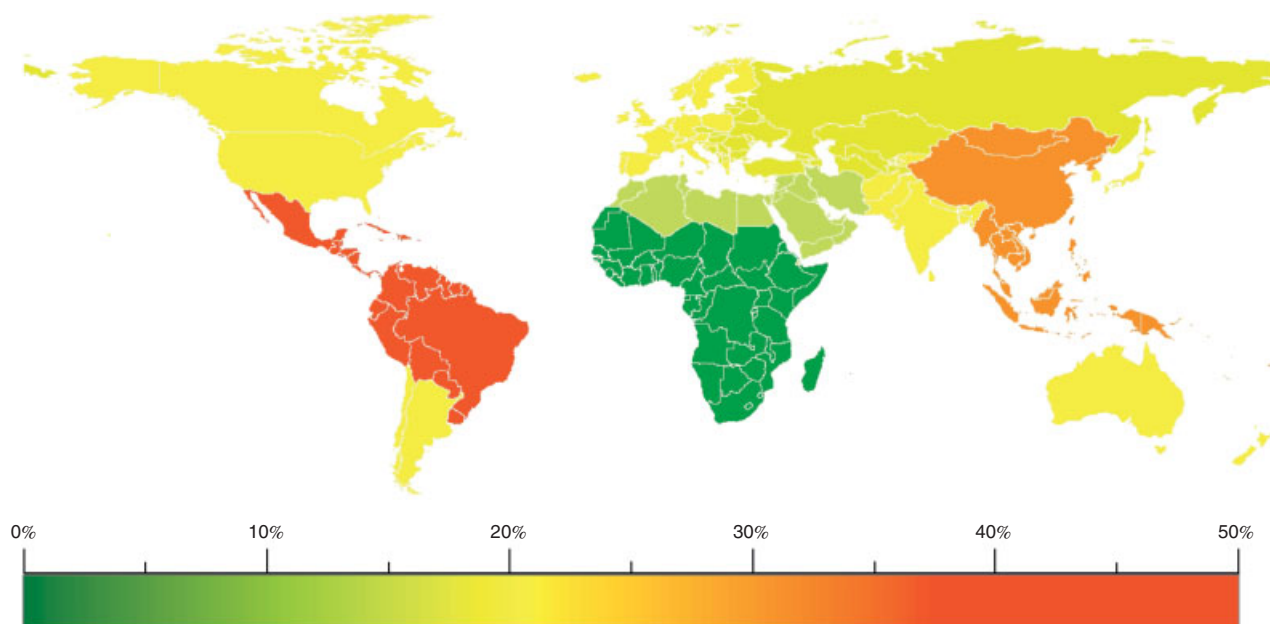
Fig. 1 Change in percentage of all deaths from emergency surgical conditions due to vascular disease (peripheral arterial disease, aortic aneurysm, mesenteric ischaemia) by world region from 1990 to 2010 (details in *Appendix S1*, supporting information)

helminthiasis[20–22]. However, this has been changing, with an increase in bowel obstructions from postsurgical adhesions and colorectal cancer[23–25].

Biliary disease

Both developed and developing countries had a decrease in overall burden from biliary disease. However, LMICs had no change in mortality during the interval (1·0 per 100 000 in both 1990 and 2010). The decreasing mortality from biliary sepsis is thought to be related to early treatment with percutaneous, endoscopic and minimally invasive techniques, all of which are still not widely accessible in LMICs[26,27].

Hernia

Despite being very prevalent, hernias account for only 3 per cent of the DALYs and 2 per cent of the deaths from emergency surgical conditions reported in the GBDS. Several groups in LMICs have reported the prevalence of hernias, incidence of emergency surgical indications related to complicated hernias, and health effectiveness of elective hernia surgery. A significant study[28] of hernia epidemiology has been done in Ghana, where an estimated 3·5 per cent of people have inguinal hernias; given a repair rate of 30 per 100 000 per year and an incidence of symptomatic hernia of 210 per 100 000 per year, a backlog of one million hernias will develop over the next 10 years. This equates to potentially five million DALYs averted by upscaling hernia

repairs in Ghana alone[28]. Other LMICs have also reported significant opportunities to reduce the burden of hernia by avoiding the nearly 20 per cent of hernias that present as emergencies and the associated 5–10 per cent mortality rate[29–31]. As elective hernia repair costs only €4–10 (US $6–13; exchange rate 27 September 2013) per DALY averted, comparable with, or more affordable than, the provision of insecticide-treated bed nets, oral rehydration salts or antiretroviral therapy, it should be considered a fundamental component of public health systems[32–35].

Vascular disease

Perhaps the most surprising finding in this review is the higher burden per population of emergency surgical conditions in HICs compared with LMICs, due almost exclusively to a higher burden of vascular-related conditions. However, LMICs had a significant increase in the burden from these conditions, as noted above. The trend mirrors that of the risk factors for vascular disease in LMICs, namely advanced age, tobacco use, diabetes mellitus and hypertension. Perhaps of equal importance is the lack of public health infrastructure and primary care systems to promote primary and secondary prevention of these non-communicable disease epidemics in most LMICs[36–38].

Urological emergencies

Common urological emergencies, urolithiasis and acute urinary retention, changed minimally in absolute terms,

but increased slightly as a proportion of all surgical emergencies. This increase was most likely due to an ageing population and thus a global increase in benign prostatic hyperplasia[39]. Benign prostatic hyperplasia carries a 75 per cent 10-year risk of acute urinary retention without treatment, common to ageing men in LMICs.

Conditions for which population-based estimates of global burden are not available

The incidence of emergency surgical conditions not reported individually in the GBDS and extracted from reports retrieved with the predefined search strategy (references listed in *Appendix S3*, supporting information) is summarized in *Table 3*. Data from these studies vary in region, size, rigour and population at risk. They also vary in whether the articles report admissions or number of persons with a given condition (especially for congenital conditions). Subsequently, wide ranges of disease burden are given. These burdens are usually specific to a given locality or nation and it is not possible to derive population-based estimates of global burden. Nonetheless, these studies provide a sense of the frequency of each disease and are useful for planning emergency surgical services. There are some interesting differences over time, and

Table 3 Summary of published rates of surgical emergencies for which population-based estimates of global burden are not available

	All reports	HIC	LMIC
General surgery			
Peritonsillar abscess	28 (6–37)	29 (10–37)	6 (6)
Gastrointestinal haemorrhage	94 (20–222)	94 (20–222)	–
Diverticulitis*	45 (4–80)	45 (4–80)	–
Paediatric surgery			
Pyloric stenosis†	189 (11–510)	175 (11–510)	200 (54–470)
Intussusception‡	71 (4–302)	93 (8–236)	35 (4–302)
Intestinal atresia†	25 (13–190)	43 (14–190)	22 (13–31)
Imperforate anus†	41 (30–77)	41 (30–77)	–
Urological surgery			
Testicular torsion§	7 (5–8)	7 (5–8)	–
Priapism	2 (1–2)	2 (1–2)	–
Gynaecological surgery			
Ectopic pregnancy¶	1990 (29–3950)	825 (29–1620)	2305 (660–3950)

Values are median (range). Unless specified otherwise, the values presented are annual incidence rates per 100 000 of the general population. Estimates for urological surgery pertain only to males. Estimates for gynaecological surgery pertain only to females. *Estimates vary by study according to age of patients (over 30 years to over 60 years). †Estimates per 100 000 live births. ‡Estimates vary by study according to age of patients (less than 1 year to less than 5 years). §One study reported incidence per age 1–25 years; one study reported incidence for all ages. ¶Estimates per 100 000 deliveries. HIC, high-income country; LMIC, low- and middle-income country. References for these estimates are listed in *Appendix S3* (supporting information).

between HICs and LMICs. Some of the major points are summarized below.

Gastrointestinal bleeding

The majority of significant gastrointestinal haemorrhage worldwide is the result of complicated PUD, and so these data are partially reflected in the GBDS estimates presented above. HICs have between 20 and 222 new cases per 100 000 persons annually; of these, 5–14 per cent died from the sequelae of uncontrollable haemorrhage. Population studies of gastrointestinal haemorrhage from LMICs are not present in the literature. However, given the large burden of PUD in LMICs, and evidence that bleeding and perforations are twice as common in the poor of HICs than in the wealthy, the incidence and associated mortality of gastrointestinal haemorrhage is probably much higher in LMICs[40]. Lower gastrointestinal haemorrhage appears much less common (20–27 per 100 000 persons) than upper gastrointestinal haemorrhage, although increases more than 200-fold from the third to the ninth decade of life because the preponderance of lower gastrointestinal haemorrhage is the result of diverticulosis, colorectal malignancies, angiodysplasia and ischaemic colitis[41,42].

Diverticulitis

Complicated diverticulitis (for example perforation, abscess, fistula, stricture, bleeding or obstruction) ranges from four to 80 per 100 000 in studies from HICs. A Finnish study[43] reported a 58 per cent increase in the incidence of diverticular perforations from 1986 to 2000. Similar trends have been reported from the USA and the UK, namely related to ageing populations and Western diets[44,45].

Typhoid perforation

Typhoid ileal perforation is most frequently a disease of children living in LMICs and has a high mortality rate. However, several African studies[46–48] have demonstrated a decrease in mortality by nearly half from 1985 to 2005. Large population-based studies have not been reported.

Emergencies in children

Pyloric stenosis remains one of the most common paediatric surgical emergencies worldwide (11–510 per 100 000 infants per year). Data on pyloric stenosis are sparse from LMICs, although case series incidence estimates are similar (54–470 per 100 000 infants per year). Infants born to younger mothers who have a low birth weight and are bottle-fed are at higher risk of pyloric stenosis[49]. All of these are common in LMICs. Intestinal atresia is also common worldwide (13–190 per 100 000 infants per year), but under-represented in the literature from LMICs.

However, series from Kenya and Nigeria report mortality rates of 40 per cent, markedly higher than the rate from HICs, which is consistently reported as less than 8 per cent[50,51].

The incidence of intussusception has been well documented because it has been a component of many rotavirus vaccine safety studies. HICs report a wide range, from eight to 236 cases per 100 000 children per year. Most of these children undergo radiological reduction, but 25 per cent still require operative intervention[52,53]. In LMICs, the incidence is similar (4–302 per 100 000 children per year), but radiological reduction is less available and operative intervention more common. A study[54] of ten African countries showed that 90 per cent of infant intussusceptions required surgery. Operative proportions were similarly high in studies from other LMICs[55–57]. Death from intussusception is rare in HICs, usually less than 1 per cent[58]. In LMICs, between 6 and 25 per cent of children who reach surgical care die[54,59,60].

Ectopic pregnancy
There were 21 studies from HICs and 27 from LMICs reporting the incidence of ectopic pregnancy (*Appendix S3*, supporting information). These studies present incidence rates from different populations at risk (per 100 000 deliveries, per 100 000 pregnancies, per 100 000 women of reproductive age), so they are not directly comparable. The incidence of ectopic pregnancy ranges between 29 and 3950 per 100 000 deliveries per year. However, the mortality rate is less than 1 per cent in HICs, and between 0·5 and 8·6 per cent in LMICs.

Other emergency surgical conditions
Studies providing population-based rates of rarer emergencies, such as retropharyngeal abscess, airway obstruction, oesophageal perforation, toxic megacolon, anorectal sepsis, paraphimosis, ovarian torsion and tubo-ovarian abscess, have not been reported in the literature.

Acute abdomen

Given that an acute abdomen is one of the major indications for emergency surgery, the differing presentation and aetiologies of acute abdomen globally were examined in more detail. The systematic search for the aetiology and epidemiology of the acute abdomen retrieved 28 reports (*Appendix S4*, supporting information) from 26 countries on 46 303 patients. Worldwide, appendicitis, bowel obstructions, incarcerated or strangulated hernias, volvulus and acute biliary pathology remain the most common causes of the acute abdomen in adults. Complicated

PUD, typhoid perforations and tuberculous peritonitis also remain common in LMICs[61–64]. Malignant perforations and complicated diverticulitis are becoming more common globally. Mortality rates for all adults with an acute abdomen range from 2 to 14 per cent, and depend on the indication for surgery and age, being higher for vascular emergencies and the elderly.

The ageing population has changed the epidemiology of acute abdomen. In individuals aged over 50 years, appendicitis is less common (15 *versus* 30 per cent of acute abdomens), whereas cholecystitis (21 *versus* 6 per cent), bowel obstruction (12 *versus* 2 per cent), perforated malignancies, strangulated hernias and acute mesenteric ischaemia (2–4 *versus* less than 1 per cent) are more common than in younger people. In addition, the outcome of surgery for acute abdomen is worse in the elderly[65,66]. Mortality among individuals presenting with an acute abdomen doubles each decade after the age of 30 years. Adults aged less than 30 years have a mortality risk of 0·2 per cent, compared with 7–22 per cent in octogenarians. In addition, physicians' diagnostic accuracy at the time of admission to hospital worsens with patient age. In the first three decades of life 60 per cent of patients with an acute abdomen are diagnosed correctly, in comparison with less than 30 per cent beyond the age of 80 years[67–70]. These facts, at least in part, explain the surprising finding in this study of the higher burden of emergency surgical conditions in HICs compared with LMICs.

Region-specific causes of acute abdomen should be considered and are of relevance to the general surgeon considering a differential diagnosis before surgery. Asia sees a large proportion of perforated gastric cancers at exploration for an acute abdomen, particularly in the elderly[70]. Typhoid fever with ileal perforation, tuberculous peritonitis, obstructive biliary and enteric ascariasis, amoebic liver abscess and other less common abdominal parasitoses are endemic in tropical and subtropical LMICs[71,72]. HICs, with an older population and high-fat low-fibre diet, have a higher incidence of complicated diverticulitis and colorectal malignancies[43,73].

Addressing the burden of emergency surgery

Caseload of emergency surgery
The rates of major surgical operations from countries with published data range from 148 to 23 369 per 100 000 persons per year[3]. The wide range is a result of a lack of access to surgical facilities, not a lack of pathology. The global volume of surgery was estimated at 234 million operations in 2004, with only 41 per cent of these being outside of HICs. General surgical procedures account for

Table 4 Health expenditure and surgical capacity in selected countries

	Total health expenditure per capita (% GDP)[4]	General surgeons per 100 000 population	Physician anaesthetists per 100 000 population	Emergency cases (%)
High-income country				
USA	17·6	9·0	11·4	11
Low- and middle-income countries				
Sierra Leone	13·9	0·2	0·02	–
Liberia	12·2	0·1–1·0	0	57
Rwanda	10·1	0·16–0·49	0·08–0·13	40
Uganda	8·5	0·14–0·32	0–0·05	73
Gambia	6·1	0·84	0·24	–
Tanzania	5·5	0·34	0·06	–
Ethiopia	4·4	0·02–0·13	0·02	54
Bangladesh	3·4	1·6	0·5	46–52

Data for this table were extracted from several sources: USA[4,75,80–82], Sierra Leone[78], Liberia[83,84], Rwanda[85,86], Uganda[74,79,87,88], Gambia[89], Tanzania[90], Ethiopia[91–93], Bangladesh[94]. GDP, gross domestic product.

46–61 per cent of operations in HICs and 37–86 per cent in LMICs[74,75]. Around 10 per cent of operations in HICs and between 21 and 90 per cent in LMICs are general surgical emergencies[76,77]. Therefore, it can be estimated that around 49 million general surgical emergency operations are performed annually (14·5–83·7 million cases), 80 per cent in LMICs.

Capacity for emergency surgery

Despite a pervasive need for emergency surgery services globally, there is wide variability in the human and physical resources available to care appropriately for those in need. In many areas of the world, people in need of emergency surgery are cared for in facilities without running water, electricity, radiography, oxygen, pulse oximeters or standard anaesthetics[4,78,79]. In addition, the number of surgeons, anaesthetists and operating theatres varies significantly by national income (*Table 4*). The USA, the world's biggest spender on healthcare per capita, has 9·0 general surgeons per 100 000 persons, compared with 1·6 per 100 000 in Bangladesh and less than 1 per 100 000 in many African countries. Similarly, the numbers of physician anaesthetists and functional, aseptic operating theatres are widely discrepant. Funk and colleagues[4] reported an average of 6·2 operating theatres per 100 000 globally, with wide ranges per region: 25 per 100 000 in Eastern Europe, 14–15 in North America and Western Europe, 4–14 in Latin America, 4·7 in East Asia, 1·3 in South Asia and 1–1·2 in sub-Saharan Africa[4].

Discussion

Despite numerous challenges, there have been notable successes in increasing the capacity to deal with surgical emergencies. In Mozambique, 92 per cent of the major obstetric and gynaecological operations at the district level were performed by non-physicians. Over a 7-year period, 88 per cent of these surgical care providers remained working at district level, compared with none of the physicians performing the same tasks who were there at the beginning of the study. In addition, non-physicians performed the same work at 27 per cent of the cost of their physician counterparts and without a significant difference in postoperative mortality[95,96]. Similar results from non-physician surgical training programmes in Zambia, Malawi, Uganda, Ethiopia and Tanzania have been reported[97–101]. On-the-job training of dedicated, local personnel in South Sudan, Senegal, Somalia, Thailand, Bangladesh and India has shown impressive results for general surgical emergencies, including strangulated hernias[87,101–103].

This review did not encompass trauma. Nonetheless, the field of trauma care provides some lessons that are applicable to other surgical emergencies[104–106]. In Khon Kaen, Thailand, a quality improvement programme identified a high rate of preventable deaths among injured patients owing to variety of problems, such as prolonged time to the operating room for head injuries and delayed resuscitation in the emergency department, among others[106]. Low-cost corrective measures targeting these problems included increased senior staffing in the emergency department at peak times and improved communications within the hospital, as well as improved monitoring of care through the quality improvement programme. This resulted in a sustained decrease in mortality (from 8·0 to 4·6 per cent among all admitted injured patients). The mortality benefit was the result of faster and more complete resuscitation, and shorter time to emergency surgery, all capabilities important to non-trauma surgical emergencies.

System-wide improvements in emergency capabilities often simultaneously benefit both trauma and other emergency surgical conditions. For example, mortality from severe injury in Quebec, Canada decreased from 43 to 8 per cent over 10 years as a result of progressive improvements to the trauma system, such as designation of trauma centres, reducing prehospital times, and system-wide triage and transfer protocols[107,108]. Many of the resources required in trauma systems are the same as those used in the care of general surgical emergencies. Consequently, it has been observed that improved capabilities for trauma care have resulted in improved care for surgical emergencies, both overall and for certain categories, such as ruptured aortic aneurysms[109]. For example, in Tennessee, USA, a mature regional emergency surgery service lowered mortality rates among non-traumatic surgical emergencies by nearly 75 per cent in 5 years[110,111].

Difficulty meeting the demands of emergency surgery is not unique to LMICs. Exhaustive work hours and less remunerative procedures has led to a decrease in the consistent availability of surgeons to care for surgical emergencies in HICs[112,113]. This has led to the growth of acute-care surgery (ACS) specialists who are dedicated to the care of surgical emergencies. Hospital systems that have developed ACS programmes have decreased surgical waiting times, number of procedures performed at night, elective case cancellations, hospital stay, total costs and preventable deaths. In addition, surgeons who operate within ACS models improve hospital revenue, are more consistently delivering standards of care and have greater job satisfaction[114–119]. These models show consistent improvements in emergency surgical care in HICs, where the majority of procedures performed are elective and many surgeons are specialists of a single discipline. In LMICs where general surgeons are able to perform a breadth of procedures and the majority of their practice is emergency care, the value of the ACS model is uncertain but it is being trialled[120,121].

System- or surgeon specialty-based investments in surgical care have been shown to be cost-effective, despite the perception that surgery is too expensive for global health initiatives. The World Health Organization has recommended that a threshold of €111 (US $150), or three times the per capita gross national income per DALY saved, be used as a decision rule for affordable programme implementation[122]. The cost per DALY averted for essential surgery (such as caesarean section, basic trauma care, and many of the emergency general surgery procedures covered in this article) provided at district-level hospitals has been estimated at €24 (US $33), which is similar to the cost of oral rehydration solution, and cheaper than Bacillus Calmette–Guérin (BCG) and hepatitis B vaccines and antiretroviral and tuberculosis therapy[35,123,124]. Emergency surgery, particularly when performed late in the disease course, is often fraught with complications related to severe physiological derangements. These result in long intensive care and hospital stays, reoperations and prolonged rehabilitation, all of which come at great cost to patients, their families and health systems. Therefore, scaling up elective surgical services to prevent the sequelae of more complicated disease (for example operating when hernias are reducible) proves more cost-effective than simply responding to surgical emergencies as they present.

Some limitations to this review should be mentioned. First, data from the GBDS were relied on for quantitative estimates. This is indeed the most exhaustive source of data for global burden for all health conditions. Nonetheless, for many conditions in LMICs, estimates are based on extrapolations from small data sets. Of approximately 52 million deaths globally, cause of death is available in death registries for only 19 million, mostly from HICs[7]. Hence, the estimates presented in the GBDS and in the present review must be interpreted with appropriate caution. This is especially the case for LMICs, where the precision of estimates is likely to be less than for the corresponding estimates from HICs. Second, a set of 11 conditions were considered for which deaths would most often arise from situations in which emergency surgery would be indicated. Some of the deaths, YLL and especially DALYs for these conditions might not be related to emergency complications. For example, some of the DALYs for hernia or PUD might be due to chronic pain. Third, evaluating the burden of conditions not covered in the GBDS has even more limitations and global estimates for these conditions are not possible. Likewise, a variety of studies were used to estimate health expenditure and surgical capacity in selected countries. These studies used differing methods and data sources. Some provided nationwide estimates, others estimates for specific, smaller (often more rural) catchment areas. There were also differences in how categories of providers were defined. For example, for anaesthesia providers, some reports counted only physician anaesthetists, whereas others included all anaesthetists. It is not possible meaningfully to compare individual countries of similar economic status with one another. However, the logarithmic differences in surgical capacity between countries in different economic strata are glaring. Furthermore, the finding of a higher burden per population in HICs is somewhat surprising. This is, in part, an artefact of the definition of general surgical emergency used for this study. Trauma and obstetrics were not included, both

of which have a higher health burden per population in LMICs. Finally, the rates and burden estimates in this study refer to people who die or are disabled despite having received appropriate surgical care, and people who die or are disabled without having received adequate or any surgical care. It is not possible to estimate the relative proportions of these two categories and thus to estimate the unmet need for emergency surgical care. Despite these limitations, the estimates presented in this article allow reasonable conclusions to be drawn about the burden of conditions requiring emergency surgery.

There is a tremendous burden of death and disability from conditions that require emergency general surgical care. The burden is considerably higher than that for other global health conditions which receive considerable attention and investment. For example, the annual number of deaths from emergency surgical conditions (nearly 1 million) is considerably higher than the number of maternal deaths globally (250 000). The burden of emergency surgical conditions affects both HICs and LMICs, although the sheer number is much higher (70 per cent of deaths) in LMICs. A change in pattern in LMICs is occurring, with an increase in the proportion of deaths related to vascular disease. There has been some progress, with a decrease in the global burden of deaths associated with surgical emergencies from 15·8 per 100 000 in 1990 to 12·9 per 100 000 in 2010. However, the response has been suboptimal in HICs and especially in LMICs. Capacity to address surgical conditions in LMICs remains very low compared with the burden. This is true for human resources (skills, training, staffing), physical resources (equipment, supplies, infrastructure) and the processes through which they are used.

The burden and capacity data reviewed in this paper will be useful for both the surgical and public health communities to plan a more adequate response. Part of this response will need to encompass better training as emergency surgical decision-making and procedural techniques are different from those of elective surgery. In addition, the response will need to involve better organization and planning for service delivery because consistent and swift care greatly affects morbidity and mortality. Finally, the response will need to involve more extensive research on a range of topics, including the epidemiology of surgical conditions and cost-effectiveness of potential measures, to improve the current scenario of care.

Acknowledgements

References

1 Farmer PE, Kim JY. Surgery and global health a view from beyond the OR. *World J Surg* 2008; **32**: 533–536.

2 Debas HT, Gosselin R, McCord C, Thind A. *Disease Control Priorities in Developing Countries*. World Bank: Washington, DC, 2006.

3 Weiser TG, Regenbogen SE, Thompson KD, Haynes AB, Lipsitz SR, Berry WR *et al.* An estimation of the global volume of surgery: a modelling strategy based on available data. *Lancet* 2008; **372**: 139–144.

4 Funk LM, Weiser TG, Berry WR, Lipsitz SR, Merry AF, Enright AC *et al.* Global operating theatre distribution and pulse oximetry supply: an estimation from reported data. *Lancet* 2010; **376**: 1055–1061.

5 Lopez AD, Mathers CD. Measuring the global burden of disease and epidemiological transitions: 2002–2030. *Ann Trop Med Parasitol* 2006; **100**: 481–499.

6 Omran AR. The epidemiologic transition: a theory of the epidemiology of population change. 1971. *Milbank Q* 2005; **83**: 731–757.

7 Lozano R, Naghavi M, Foreman K, Lim S, Shibuya K, Aboyans V *et al.* Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012; **380**: 2095–2128.

8 Murray CJ, Vos T, Lozano R, Naghavi M, Flaxman AD, Michaud C *et al.* Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012; **380**: 2197–2223.

9 Institute for Health Metrics and Evaluation (IHME). *Data Visualization*. http://www.healthmetricsandevaluation.org/tools/data-visualizations [accessed 17 June 2013].

10 Murray CJ, Ezzati M, Flaxman AD, Lim S, Lozano R, Michaud C *et al.* GBD 2010: design, definitions, and metrics. *Lancet* 2012; **380**: 2063–2066.

11 United Nations. *World Population Prospects*. United Nations, Department of Economic and Social Affairs: Geneva, 2012.

12 Central Intelligence Agency (CIA). *The World Factbook*. https://www.cia.gov/library/publications/the-world-factbook/ [accessed 28 June 2013].

13 Dutta AK, Chacko A, Balekuduru A, Sahu MK, Gangadharan SK. Time trends in epidemiology of peptic ulcer disease in India over two decades. *Indian J Gastroenterol* 2012; **31**: 111–115.

14 Wong SN, Sollano JD, Chan MM, Carpio RE, Tady CS, Ismael AE *et al.* Changing trends in peptic ulcer prevalence in a tertiary care setting in the Philippines: a seven-year study. *J Gastroenterol Hepatol* 2005; **20**: 628–632.

15 Lanas A, García-Rodríguez LA, Polo-Tomás M, Ponce M, Alonso-Abreu I, Perez-Aisa MA *et al.* Time trends and impact of upper and lower gastrointestinal bleeding and

perforation in clinical practice. *Am J Gastroenterol* 2009; **104**: 1633–1641.

16 Ohene-Yeboah M, Abantanga FA. Inguinal hernia disease in Africa: a common but neglected surgical condition. *West Afr J Med* 2011; **30**: 77–83.

17 Ohene-Yeboah M, Adippah E, Gyasi-Sarpong K. Acute intestinal obstruction in adults in Kumasi, Ghana. *Ghana Med J* 2006; **40**: 50–54.

18 Adesunkanmi AR, Agbakwuru EA. Changing pattern of acute intestinal obstruction in a tropical African population. *East Afr Med J* 1996; **73**: 727–731.

19 Scott FI, Osterman MT, Mahmoud NN, Lewis JD. Secular trends in small-bowel obstruction and adhesiolysis in the United States: 1988–2007. *Am J Surg* 2012; **204**: 315–320.

20 Madziga AG, Nuhu AI. Causes and treatment outcome of mechanical bowel obstruction in north eastern Nigeria. *West Afr J Med* 2008; **27**: 101–105.

21 Shiekh KA, Baba AA, Ahmad SM, Shera AH, Patnaik R, Sherwani AY. Mechanical small bowel obstruction in children at a tertiary care centre in Kashmir. *Afr J Paediatr Surg* 2010; **7**: 81–85.

22 Archampong EQ, Naaeder SB, Darko R. Changing pattern of intestinal obstruction in Accra, Ghana. *Hepatogastroenterology* 2000; **47**: 185–193.

23 Sourkati EO, Fahal AH, Suliman SH, el Razig SA, Arabi YE. Intestinal obstruction in Khartoum. *East Afr Med J* 1996; **73**: 316–319.

24 Stanciu D, Menzies D. The magnitude of adhesion-related problems. *Colorectal Dis* 2007; **9**(Suppl 2): 35–38.

25 Naaeder SB, Archampong EQ. Changing pattern of acute intestinal obstruction in Accra. *West Afr J Med* 1993; **12**: 82–88.

26 Himal HS, Lindsay T. Ascending cholangitis: surgery *versus* endoscopic or percutaneous drainage. *Surgery* 1990; **108**: 629–633.

27 Lai EC, Mok FP, Tan ES, Lo CM, Fan ST, You KT *et al.* Endoscopic biliary drainage for severe acute cholangitis. *N Engl J Med* 1992; **326**: 1582–1586.

28 Beard JH, Oresanya LB, Ohene-Yeboah M, Dicker RA, Harris HW. Characterizing the global burden of surgical disease: a method to estimate inguinal hernia epidemiology in Ghana. *World J Surg* 2013; **37**: 498–503.

29 Bandré E, Kaboré RA, Sanou A, Ouédraogo I, Soré O, Tapsoba T *et al.* [Strangulated umbilical hernia in children (Burkina Faso): differences with developed countries.] *Bull Soc Pathol Exot* 2010; **103**: 100–103.

30 Lebeau R, Kassi FB, Yénon SK, Diané CB, Kouassi JC. [Strangulated groin hernia still frequent in tropical milieu.] *Rev Med Brux* 2011; **32**: 133–138.

31 Ohene-Yeboah M. Strangulated external hernias in Kumasi. *West Afr J Med* 2003; **22**: 310–313.

32 Shillcutt SD, Clarke MG, Kingsnorth AN. Cost-effectiveness of groin hernia surgery in the Western Region of Ghana. *Arch Surg* 2010; **145**: 954–961.

33 Shillcutt SD, Sanders DL, Teresa Butrón-Vila M, Kingsnorth AN. Cost-effectiveness of inguinal hernia surgery in northwestern Ecuador. *World J Surg* 2013; **37**: 32–41.

34 Shillcutt SD, Walker DG, Goodman CA, Mills AJ. Cost effectiveness in low- and middle-income countries: a review of the debates surrounding decision rules. *Pharmacoeconomics* 2009; **27**: 903–917.

35 Jamison D, Breman J, Measham A, Alleyne G, Claeson M, Evans D *et al. Disease Control Priorities in Developing Countries* (2nd edn), Laxminarayan R, Chow J, Shahid-Salles S (eds). Oxford University Press: Washington, DC, 2006.

36 Mufunda J, Chatora R, Ndambakuwa Y, Nyarango P, Kosia A, Chifamba J *et al.* Emerging non-communicable disease epidemic in Africa: preventive measures from the WHO Regional Office for Africa. *Ethn Dis* 2006; **16**: 521–526.

37 Unwin N, Mugusi F, Aspray T, Whiting D, Edwards R, Mbanya JC *et al.* Tackling the emerging pandemic of non-communicable diseases in sub-Saharan Africa: the essential NCD health intervention project. *Public Health* 1999; **113**: 141–146.

38 Coleman R, Gill G, Wilkinson D. Noncommunicable disease management in resource-poor settings: a primary care model from rural South Africa. *Bull World Health Organ* 1998; **76**: 633–640.

39 Seligman BJ, Cullen MR, Horwitz RI. Aging, transition, and estimating the global burden of disease. *PLoS One* 2011; **6**: e20264.

40 Crooks CJ, West J, Card TR. Upper gastrointestinal haemorrhage and deprivation: a nationwide cohort study of health inequality in hospital admissions. *Gut* 2012; **61**: 514–520.

41 Longstreth GF. Epidemiology and outcome of patients hospitalized with acute lower gastrointestinal hemorrhage: a population-based study. *Am J Gastroenterol* 1997; **92**: 419–424.

42 Ghassemi KA, Jensen DM. Lower GI bleeding: epidemiology and management. *Curr Gastroenterol Rep* 2013; **15**: 333.

43 Mäkelä J, Kiviniemi H, Laitinen S. Prevalence of perforated sigmoid diverticulitis is increasing. *Dis Colon Rectum* 2002; **45**: 955–961.

44 Morris CR, Harvey IM, Stebbings WS, Hart AR. Incidence of perforated diverticulitis and risk factors for death in a UK population. *Br J Surg* 2008; **95**: 876–881.

45 Livingston EH, Fomby TB, Woodward WA, Haley RW. Epidemiological similarities between appendicitis and diverticulitis suggesting a common underlying pathogenesis. *Arch Surg* 2011; **146**: 308–314.

46 Clegg-Lamptey JN, Hodasi WM, Dakubo JC. Typhoid ileal perforation in Ghana: a five-year retrospective study. *Trop Doct* 2007; **37**: 231–233.

47 Osifo OD, Ogiemwonyi SO. Typhoid ileal perforation in children in Benin city. *Afr J Paediatr Surg* 2010; **7**: 96–100.

48 Ameh EA. Typhoid ileal perforation in children: a scourge in developing countries. *Ann Trop Paediatr* 1999; **19**: 267–272.

49 MacMahon B. The continuing enigma of pyloric stenosis of infancy: a review. *Epidemiology* 2006; **17**: 195–201.

50 Walker K, Badawi N, Hamid CH, Vora A, Halliday R, Taylor C *et al.* A population-based study of the outcome after small bowel atresia/stenosis in New South Wales and the Australian Capital Territory, Australia, 1992–2003. *J Pediatr Surg* 2008; **43**: 484–488.

51 Escobar MA, Ladd AP, Grosfeld JL, West KW, Rescorla FJ, Scherer LR III *et al.* Duodenal atresia and stenosis: long-term follow-up over 30 years. *J Pediatr Surg* 2004; **39**: 867–871.

52 Lloyd-Johnsen C, Justice F, Donath S, Bines JE. Retrospective hospital based surveillance of intussusception in children in a sentinel paediatric hospital: benefits and pitfalls for use in post-marketing surveillance of rotavirus vaccines. *Vaccine* 2012; **30**(Suppl 1): A190–A195.

53 Jo DS, Nyambat B, Kim JS, Jang YT, Ng TL, Bock HL *et al.* Population-based incidence and burden of childhood intussusception in Jeonbuk Province, South Korea. *Int J Infect Dis* 2009; **13**: e383–e388.

54 Steele AD, Patel M, Cunliffe NA, Bresee JS, Borgstein E, Parashar UD. Workshop on intussusception in African countries – meeting report. *Vaccine* 2012; **30**(Suppl 1): A185–A189.

55 Lucero Y, Valenzuela MT, O'Ryan M. [Clinical and epidemiological profile of intestinal intussusception among infants of Metropolitan Santiago.] *Rev Med Chil* 2004; **132**: 565–572.

56 Latipov R, Khudoyorov R, Flem E. Childhood intussusception in Uzbekistan: analysis of retrospective surveillance data. *BMC Pediatr* 2011; **11**: 22.

57 Khumjui C, Doung-ngern P, Sermgew T, Smitsuwan P, Jiraphongsa C. Incidence of intussusception among children 0–5 years of age in Thailand, 2001–2006. *Vaccine* 2009; **27**(Suppl 5): F116–F119.

58 Takeuchi M, Osamura T, Yasunaga H, Horiguchi H, Hashimoto H, Matsuda S. Intussusception among Japanese children: an epidemiologic study using an administrative database. *BMC Pediatr* 2012; **12**: 36.

59 Carneiro PM, Kisusi DM. Intussusception in children seen at Muhimbili National Hospital, Dar es Salaam. *East Afr Med J* 2004; **81**: 439–442.

60 Edino ST, Ochicha O, Mohammed AZ, Anumah M. Intussusception in Kano: a 5-year analysis of pattern, morbidity and mortality. *Niger J Med* 2003; **12**: 221–224.

61 Awori MN, Jani PG. Surgical implications of abdominal pain in patients presenting to the Kenyatta National Hospital casualty department with abdominal pain. *East Afr Med J* 2005; **82**: 307–310.

62 Asefa Z. Pattern of acute abdomen in Yirgalem Hospital, southern Ethiopia. *Ethiop Med J* 2000; **38**: 227–235.

63 Ohene-Yeboah M. Causes of acute peritonitis in 1188 consecutive adult patients in Ghana. *Trop Doct* 2005; **35**: 84–85.

64 Ohene-Yeboah M. Acute surgical admissions for abdominal pain in adults in Kumasi, Ghana. *ANZ J Surg* 2006; **76**: 898–903.

65 Espinoza R, Balbontin P, Feuerhake S, Pinera C. [Acute abdomen in the elderly.] *Rev Med Chil* 2004; **132**: 1505–1512.

66 Gürleyik G, Gürleyik E, Unalmişer S. Abdominal surgical emergency in the elderly. *Turk J Gastroenterol* 2002; **13**: 47–52.

67 de Dombal FT. Acute abdominal pain in the elderly. *J Clin Gastroenterol* 1994; **19**: 331–335.

68 Kizer KW, Vassar MJ. Emergency department diagnosis of abdominal disorders in the elderly. *Am J Emerg Med* 1998; **16**: 357–362.

69 Kettunen J, Paajanen H, Kostiainen S. Emergency abdominal surgery in the elderly. *Hepatogastroenterology* 1995; **42**: 106–108.

70 Kim JP, Kim SJ, Lee JH, Kim SW, Choi MG, Yu HJ. Surgery in the aged in Korea. *Arch Surg* 1998; **133**: 18–23.

71 Essomba A, Chichom Mefire A, Fokou M, Ouassouo P, Masso Misse P, Esiene A *et al.* [Acute abdomens of parasitic origin: retrospective analysis of 135 cases.] *Ann Chir* 2006; **131**: 194–197.

72 Montavo-Jave E, Bernes L, Mondragon C, Gutierrez C. Frecuencia de apendiciti relacionada a parasitos, tuberculosis y salmonelosis en la Hospital General de Mexico de 1975–1990. Analisis de 4679 casos. *Cirujano General* 2008; **30**: 136–140.

73 Ferlay J, Shin HR, Bray F, Forman D, Mathers C, Parkin DM. Estimates of worldwide burden of cancer in 2008: GLOBOCAN 2008. *Int J Cancer* 2010; **127**: 2893–2917.

74 Galukande M, von Schreeb J, Wladis A, Mbembati N, de Miranda H, Kruk ME *et al.* Essential surgery at the district hospital: a retrospective descriptive analysis in three African countries. *PLoS Med* 2010; **7**: e1000243.

75 VanBibber M, Zuckerman RS, Finlayson SR. Rural *versus* urban inpatient case-mix differences in the US. *J Am Coll Surg* 2006; **203**: 812–816.

76 Smith M, Hussain A, Xiao J, Scheidler W, Reddy H, Olugbade K Jr *et al.* The importance of improving the quality of emergency surgery for a regional quality collaborative. *Ann Surg* 2013; **257**: 596–602.

77 Shafi S, Aboutanos MB, Agarwal S Jr, Brown CV, Crandall M, Feliciano DV *et al.* Emergency general surgery: definition and estimated burden of disease. *J Trauma Acute Care Surg* 2013; **74**: 1092–1097.

78 Crompton J, Kingham TP, Kamara TB, Brennan MF, Kushner AL. Comparison of surgical care deficiencies between US civil war hospitals and present-day hospitals in Sierra Leone. *World J Surg* 2010; **34**: 1743–1747.

79 Ozgediz D, Galukande M, Mabweijano J, Kijjambu S, Mijumbi C, Dubowitz G *et al.* The neglect of the global surgical workforce: experience and evidence from Uganda. *World J Surg* 2008; **32**: 1208–1215.

80 Belsky D, Ricketts T, Poley S, Gaul K, Fraher E, Sheldon G. *Surgical Deserts in the US: Places Without Surgeons.*

American College of Surgeons Health Policy Research Institute: Chapel Hill, 2009.

81 Schubert A, Eckhout GV, Ngo AL, Tremper KK, Peterson MD. Status of the anesthesia workforce in 2011: evolution during the last decade and future outlook. *Anesth Analg* 2012; **115**: 407–427.

82 Poley S, Belsky D, Gaul K, Ricketts T, Fraher E, Sheldon G. Longitudinal trends in the U.S. surgical workforce, 1981–2006. *Bull Am Coll Surg* 2009; **94**: 27–31.

83 Knowlton LM, Chackungal S, Dahn B, LeBrun D, Nickerson J, McQueen K. Liberian surgical and anesthesia infrastructure: a survey of county hospitals. *World J Surg* 2013; **37**: 721–729.

84 Sherman L, Clement PT, Cherian MN, Ndayimirije N, Noel L, Dahn B *et al.* Implementing Liberia's poverty reduction strategy: an assessment of emergency and essential surgical care. *Arch Surg* 2011; **146**: 35–39.

85 Notrica MR, Evans FM, Knowlton LM, Kelly McQueen KA. Rwandan surgical and anesthesia infrastructure: a survey of district hospitals. *World J Surg* 2011; **35**: 1770–1780.

86 Petroze RT, Nzayisenga A, Rusanganwa V, Ntakiyiruta G, Calland JF. Comprehensive national analysis of emergency and essential surgical capacity in Rwanda. *Br J Surg* 2012; **99**: 436–443.

87 Kruk ME, Wladis A, Mbembati N, Ndao-Brumblay SK, Hsia RY, Galukande M *et al.* Human resource and funding constraints for essential surgery in district hospitals in Africa: a retrospective cross-sectional survey. *PLoS Med* 2010; **7**: e1000242.

88 Linden AF, Sekidde FS, Galukande M, Knowlton LM, Chackungal S, McQueen KA. Challenges of surgery in developing countries: a survey of surgical and anesthesia capacity in Uganda's public hospitals. *World J Surg* 2012; **36**: 1056–1065.

89 Iddriss A, Shivute N, Bickler S, Cole-Ceesay R, Jargo B, Abdullah F *et al.* Emergency, anaesthetic and essential surgical capacity in the Gambia. *Bull World Health Organ* 2011; **89**: 565–572.

90 Penoyar T, Cohen H, Kibatala P, Magoda A, Saguti G, Noel L *et al.* Emergency and surgery services of primary hospitals in the United Republic of Tanzania. *BMJ Open* 2012; **2**: e000369.

91 Chao TE, Burdic M, Ganjawalla K, Derbew M, Keshian C, Meara J *et al.* Survey of surgery and anesthesia infrastructure in Ethiopia. *World J Surg* 2012; **36**: 2545–2553.

92 Rennie JA, Janka A. Emergency surgery in Ethiopia. *Ann R Coll Surg Engl* 1997; **79**(Suppl): 254–256.

93 Reshamwalla S, Gobeze AA, Ghosh S, Grimes C, Lavy C. Snapshot of surgical activity in rural Ethiopia: is enough being done? *World J Surg* 2012; **36**: 1049–1055.

94 Lebrun DG, Dhar D, Sarkar MI, Imran TM, Kazi SN, McQueen KA. Measuring global surgical disparities: a survey of surgical and anesthesia infrastructure in Bangladesh. *World J Surg* 2013; **37**: 24–31.

95 Kruk ME, Pereira C, Vaz F, Bergström S, Galea S. Economic evaluation of surgically trained assistant medical officers in performing major obstetric surgery in Mozambique. *BJOG* 2007; **114**: 1253–1260.

96 Pereira C, Cumbi A, Malalane R, Vaz F, McCord C, Bacci A *et al.* Meeting the need for emergency obstetric care in Mozambique: work performance and histories of medical doctors and assistant medical officers trained for surgery. *BJOG* 2007; **114**: 1530–1533.

97 Bewes P. Learning from low income countries: what are the lessons? Trained medical assistants can successfully do work of doctors. *BMJ* 2004; **329**: 1184.

98 Mkandawire N, Ngulube C, Lavy C. Orthopaedic clinical officer program in Malawi: a model for providing orthopaedic care. *Clin Orthop Relat Res* 2008; **466**: 2385–2391.

99 Saswata B, Omar F, Aubery RJ, Jaffer B, Michael W. Bridging the health gap in Uganda: the surgical role of the clinical officer. *Afr Health Sci* 2005; **5**: 86–89.

100 Gessessew A, Barnabas GA, Prata N, Weidert K. Task shifting and sharing in Tigray, Ethiopia, to achieve comprehensive emergency obstetric care. *Int J Gynaecol Obstet* 2011; **113**: 28–31.

101 Meo G, Andreone D, De Bonis U, Cometto G, Enrico S, Giustetto G *et al.* Rural surgery in southern Sudan. *World J Surg* 2006; **30**: 495–504.

102 Chu KM, Ford NP, Trelles M. Providing surgical care in Somalia: a model of task shifting. *Confl Health* 2011; **5**: 12.

103 Chu K, Rosseel P, Gielis P, Ford N. Surgical task shifting in Sub-Saharan Africa. *PLoS Med* 2009; **6**: e1000078.

104 Mock C, Juillard C, Joshipura M, Goosen J. *Strengthening Care for the Injured: Success Stories and Lessons Learned from Around the World*. World Health Organization: Geneva, 2010.

105 Husum H, Gilbert M, Wisborg T, Van Heng Y, Murad M. Rural prehospital trauma systems improve trauma outcome in low-income countries: a prospective study from North Iraq and Cambodia. *J Trauma* 2003; **54**: 1188–1196.

106 Chadbunchachai W, Saranrittichai S, Sriwiwat S, Chumsri J, Kulleab S, Jaikwang P. Study on performance following Key Performance Indicators for trauma care: Khon Kaen Hospital 2000. *J Med Assoc Thai* 2003; **86**: 1–7.

107 Liberman M, Mulder DS, Lavoie A, Sampalis JS. Implementation of a trauma care system: evolution through evaluation. *J Trauma* 2004; **56**: 1330–1335.

108 Sampalis JS, Denis R, Lavoie A, Fréchette P, Boukas S, Nikolis A *et al.* Trauma care regionalization: a process–outcome evaluation. *J Trauma* 1999; **46**: 565–579.

109 Utter GH, Maier RV, Rivara FP, Nathens AB. Outcomes after ruptured abdominal aortic aneurysms: the 'halo effect' of trauma center designation. *J Am Coll Surg* 2006; **203**: 498–505.

110 Diaz JJ Jr, Norris PR, Gunter OL, Collier BR, Riordan WP, Morris JA Jr. Does regionalization of acute care surgery decrease mortality? *J Trauma* 2011; **71**: 442–446.

111 Diaz JJ Jr, Norris P, Gunter O, Collier B, Riordan W, Morris JA Jr. Triaging to a regional acute care surgery center: distance is critical. *J Trauma* 2011; **70**: 116–119.

112 Uranues S, Lamont E. Acute care surgery: the European model. *World J Surg* 2008; **32**: 1605–1612.

113 Jurkovich GJ. Acute care surgery: the trauma surgeon's perspective. *Surgery* 2007; **141**: 293–296.

114 Heng M, Wright JG. Dedicated operating room for emergency surgery improves access and efficiency. *Can J Surg* 2013; **56**: 167–174.

115 Roehr B. Restructuring emergency surgery staffing improves outcomes and reduces costs. *BMJ* 2012; **345**: e7753.

116 Cubas RF, Gómez NR, Rodriguez S, Wanis M, Sivanandam A, Garberoglio CA. Outcomes in the management of appendicitis and cholecystitis in the setting of a new acute care surgery service model: impact on timing and cost. *J Am Coll Surg* 2012; **215**: 715–721.

117 Miller PR, Wildman EA, Chang MC, Meredith JW. Acute care surgery: impact on practice and economics of elective surgeons. *J Am Coll Surg* 2012; **214**: 531–535.

118 Barnes SL, Cooper CJ, Coughenour JP, MacIntyre AD, Kessel JW. Impact of acute care surgery to departmental productivity. *J Trauma* 2011; **71**: 1027–1032.

119 Wood L, Buczkowski A, Panton OM, Sidhu RS, Hameed SM. Effects of implementation of an urgent surgical care service on subspecialty general surgery training. *Can J Surg* 2010; **53**: 119–125.

120 Goosen J, Veller M. Trauma and emergency surgery: South African model. *World J Surg* 2008; **32**: 1622–1625.

121 Poggetti R, Leppanemi A, Ferrada P, Puyana JC, Peitzman AB, Ansaloni L *et al.* WSES SM (World Society of Emergency Surgery Summer Meeting) highlights: emergency surgery around the world (Brazil, Finland, USA). *World J Emerg Surg* 2009; **4**: 11.

122 World Health Organization (WHO). *WHO Guide to Cost-Effectiveness Analysis*. WHO: Geneva, 2003.

123 Gosselin RA, Heitto M. Cost-effectiveness of a district trauma hospital in Battambang, Cambodia. *World J Surg* 2008; **32**: 2450–2453.

124 Gosselin RA, Thind A, Bellardinelli A. Cost/DALY averted in a small hospital in Sierra Leone: what is the relative contribution of different services? *World J Surg* 2006; **30**: 505–511.

Supporting information

Additional supporting information may be found in the online version of this article:

Appendix S1 Additional methodological details (Word document)

Appendix S2 Systematic search strategy for articles on emergency surgical capacity, cost-effectiveness and conditions requiring emergency surgery that were not reported individually in the Global Burden of Disease Study (Word document)

Appendix S3 Bibliography of articles retrieved from the search describing the incidence, morbidity and mortality from emergency surgical indications not described in the Global Burden of Disease Study and from which data were obtained for *Table 3* (Word document)

Appendix S4 Bibliography of articles retrieved from the search describing the epidemiology of the acute abdomen and abdominal emergencies (Word document)