Original article

BJS Open Open Access

Global variation in anastomosis and end colostomy formation following left-sided colorectal resection

GlobalSurg Collaborative*

Correspondence to: Mr A. Bhangu, National Institute for Health Research Unit on Global Surgery, University of Birmingham, 2nd Floor, Institute of Translational Medicine, Heritage Building, Mindelsohn Way, Birmingham B15 2TH, UK (e-mail: a.a.bhangu@bham.ac.uk)

Background: **End colostomy rates following colorectal resection vary across institutions in high-income settings, being influenced by patient, disease, surgeon and system factors. This study aimed to assess global variation in end colostomy rates after left-sided colorectal resection.**

Methods: **This study comprised an analysis of GlobalSurg-1 and -2 international, prospective, observational cohort studies (2014, 2016), including consecutive adult patients undergoing elective or emergency left-sided colorectal resection within discrete 2-week windows. Countries were grouped into high-, middle- and low-income tertiles according to the United Nations Human Development Index (HDI). Factors associated with colostomy formation *versus* primary anastomosis were explored using a multilevel, multivariable logistic regression model.**

Results: **In total, 1635 patients from 242 hospitals in 57 countries undergoing left-sided colorectal resection were included: 113 (6·9 per cent) from low-HDI, 254 (15·5 per cent) from middle-HDI and 1268 (77·6 per cent) from high-HDI countries. There was a higher proportion of patients with perforated disease (57·5, 40·9 and 35·4 per cent; $P < 0·001$) and subsequent use of end colostomy (52·2, 24·8 and 18·9 per cent; $P < 0·001$) in low- compared with middle- and high-HDI settings. The association with colostomy use in low-HDI settings persisted (odds ratio (OR) 3·20, 95 per cent c.i. 1·35 to 7·57; $P = 0·008$) after risk adjustment for malignant disease (OR 2·34, 1·65 to 3·32; $P < 0·001$), emergency surgery (OR 4·08, 2·73 to 6·10; $P < 0·001$), time to operation at least 48 h (OR 1·99, 1·28 to 3·09; $P = 0·002$) and disease perforation (OR 4·00, 2·81 to 5·69; $P < 0·001$).**

Conclusion: **Global differences existed in the proportion of patients receiving end stomas after left-sided colorectal resection based on income, which went beyond case mix alone.**

*Members of the GlobalSurg Collaborative are collaborators in this study and are listed in *Appendix S1* (supporting information)

Funding information
Medical Research Council, MR/N022114/1
National Institute for Health Research, 16/136/79

Paper accepted 27 November 2018
Published online 28 February 2019 in Wiley Online Library (www.bjsopen.com). **DOI:** 10.1002/bjs5.50138

Introduction

In 2015, the Lancet Commission on Global Surgery highlighted a substantial gap in access to safe and affordable surgical care across low- and middle-income countries (LMICs), raising the priority of surgery on the global health agenda[1]. Despite this, reporting of outcomes following abdominal surgery from many LMICs remains unstandardized and of mixed quality. Where high-quality evidence is available, a threefold higher risk of death in low- *versus* high-income settings has been observed[2]. However, other key outcomes from the surgical management of colorectal cancer or benign colorectal disease in LMICs have been particularly poorly profiled to date[3].

End colostomy rates following colorectal cancer resection vary substantially between centres in high-income countries, ranging from 15 to 70 per cent[4]. This may reflect variations in case mix, as the decision to create an end colostomy rather than a primary restorative anastomosis is influenced by the urgency of presentation, the presence of operative field contamination, disease severity and stage, as well as functional status of the pelvic floor. For patients, quality of life with an end colostomy is influenced by multiple factors, including functional

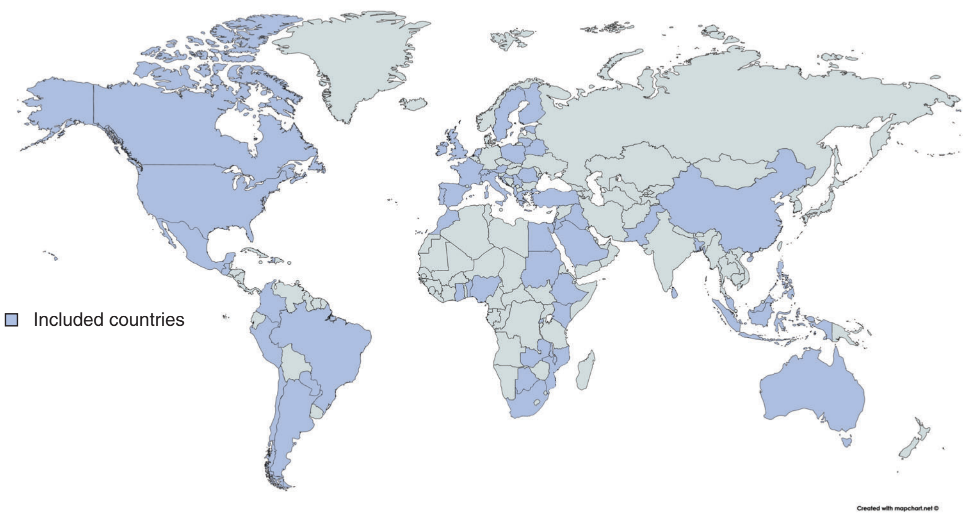

Fig. 1 Map of included countries

status, social support, income level, education and availability of specialist services[5]. The care requirements of a stoma may present a different psychosocial and physiological burden for patients in LMICs compared with those in high-income settings. For example, geographical barriers and limited health resources are likely to raise treatment costs and reduce access to specialist equipment and services[6], increasing the risk of catastrophic expenditure following colorectal surgery[7]. Examining international practice in stoma formation is therefore important in seeking to identify areas of variation and improve outcomes.

The primary aim of this study was to determine variation in rates of end colostomy formation following colorectal resection between low-, middle- and high-Human Development Index (HDI) strata, after adjusting for patient, disease and operative factors. Secondary aims were to report the mode of presentation, rate of laparoscopic surgery, and to determine any relationship between stoma formation and postoperative mortality in patients undergoing resections.

Methods

Protocol and network

This study was an exploratory subgroup analysis from two international, multicentre, prospective cohort studies conducted according to previously published protocols (NCT02179112, NCT02662231)[2,8]. These protocols were disseminated through social media, and national and international surgical and anaesthetic associations. Briefly, the model required small teams of local investigators to collect data on prospectively determined items, coordinated by regional and national lead investigators, across short time windows, with pooled analysis by a central steering committee.

Patients and settings

Any hospital providing both emergency surgery and elective colorectal surgical services was eligible to contribute patients to this study. Patients were included during at least one discrete 2-week period between 1 July 2014 and 31 December 2014 (GlobalSurg-1) and 4 January 2016 and 31 July 2016 (GlobalSurg-2). To maximize inclusiveness and minimize burden on resource-constrained clinicians, collaborators were permitted to collect data within any 2-week interval across this time window, so long as data collection was consecutive and case ascertainment was complete. Adult patients (aged over 16 years) undergoing elective (GlobalSurg-2) or emergency (GlobalSurg-1 and -2) left hemicolectomy, sigmoid colectomy or rectal resection were included. Emergency procedures were defined as unplanned operations occurring within 2 weeks of hospital admission, and included procedures for trauma and reoperation following surgical complications. Open, laparoscopic and laparoscopic converted to open procedures were all eligible. To reduce risk of bias based on case mix, only colorectal resections for a primary gastrointestinal indication were included. Patients were excluded if the primary indication for surgery was vascular, gynaecological, obstetric, urological or

Table 1 Baseline demographics of patients undergoing left-sided colorectal resection, grouped by Human Development Index tertile

	High HDI (*n* = 1268)	Middle HDI (*n* = 254)	Low HDI (*n* = 113)	*P*§
Age (years)*	65·9(13·8)	53·3(16·6)	51·4(16·9)	< 0·001¶
Sex				0·169
M	694 (54·7)	137 (53·9)	75 (66·4)	
F	533 (42·0)	107 (42·1)	36 (31·9)	
Missing	41 (3·2)	10 (3·9)	2 (1·8)	
ASA fitness grade				0·003
< III	706 (55·7)	170 (66·9)	70 (61·9)	
≥ III	553 (43·6)	80 (31·5)	41 (36·3)	
Missing	9 (0·7)	4 (1·6)	2 (1·8)	
Diabetes				0·133
No	1070 (84·4)	219 (86·2)	103 (91·2)	
Yes	198 (15·6)	35 (13·8)	10 (8·8)	
Smoking				0·026
No	884 (69·7)	181 (71·3)	94 (83·2)	
Yes	271 (21·4)	52 (20·5)	17 (15·0)	
Missing	113 (8·9)	21 (8·3)	2 (1·8)	
Malignancy				0·001
No	453 (35·7)	106 (41·7)	59 (52·2)	
Yes	815 (64·3)	148 (58·3)	54 (47·8)	
Urgency				< 0·001
Elective	691 (54·5)	140 (55·1)	28 (24·8)	
Emergency	577 (45·5)	114 (44·9)	85 (75·2)	
Time to operation (h)†				0·001
< 6	233 (18·4)	37 (14·6)	21 (18·6)	
6–11	89 (7·0)	22 (8·7)	16 (14·2)	
12–23	273 (21·5)	42 (16·5)	17 (15·0)	
24–47	272 (21·5)	39 (15·4)	19 (16·8)	
≥ 48	368 (29·0)	107 (42·1)	38 (33·6)	
Missing	33 (2·6)	7 (2·8)	2 (1·8)	
Laparoscopic				< 0·001
No	892 (70·3)	215 (84·6)	112 (99·1)	
Yes	376 (29·7)	39 (15·4)	1 (0·9)	
Perforated disease				< 0·001
No	813 (64·1)	147 (57·9)	47 (41·6)	
Yes	449 (35·4)	104 (40·9)	65 (57·5)	
Missing	6 (0·5)	3 (1·2)	1 (0·9)	
Checklist‡				< 0·001
No, not available	157 (12·4)	40 (15·7)	23 (20·4)	
No, but available	37 (2·9)	27 (10·6)	44 (38·9)	
Yes	1066 (84·1)	184 (72·4)	46 (40·7)	
Missing	8 (0·6)	3 (1·2)	0 (0)	

Values in parentheses are percentages by column, unless indicated otherwise; *values are mean(s.d.). †Time from presentation to index procedure. ‡WHO Surgical Safety Checklist. HDI, Human Development Index. §Pearson χ^2 test, except ¶Kruskal–Wallis test.

transplantation, or if they were undergoing multivisceral resection.

Ethics and reporting

A UK National Health Service (NHS) Research Ethics review considered both studies exempt from formal research registration (South East Scotland Research Ethics Service, references NR/1404AB12 and NR/1510AB5). Individual centres were responsible for audit or institutional review board or ethical approval if required by local regulations. This study is reported according to the STROBE guidelines[9].

Outcome measures

The primary outcome measure was the end colostomy formation rate, defined as formation of an end colostomy during the index procedure without restorative anastomosis. The secondary outcome measure was the postoperative mortality rate (death within 30 days of the index procedure).

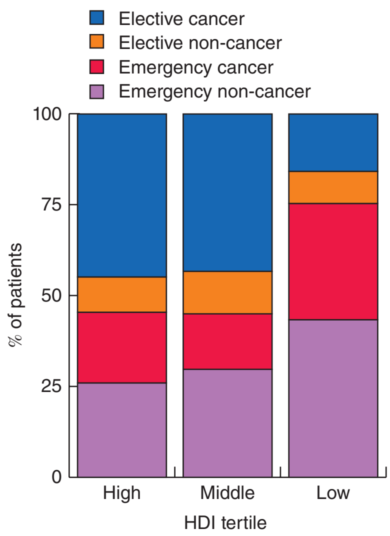

Fig. 2 Presentation of patients undergoing left-sided colorectal resection by Human Development Index tertile. HDI, Human Development Index

Other included explanatory variables

Data variables were designed to be assessed objectively, standardizable and internationally relevant. Variables deemed candidates in the causal pathway for stoma formation were indication for surgery, urgency of surgery (elective/planned or emergency/unplanned (within 2 weeks of hospital admission)) and colonic or rectal perforation noted at the time of surgery. Variables deemed to be confounders associated with both the causal pathway and outcome measures included age, sex, ASA fitness classification, smoking status, use of the WHO Surgical Safety checklist[10], and use of laparoscopic surgery.

Data capture and validation

Study data were collected and managed using REDCap (Research Electronic Data Capture) tools hosted at the University of Edinburgh (https://www.project-redcap.org/). REDCap is a secure, web-based application designed to support data capture for research studies, providing: an intuitive interface for validated data entry; audit trails for tracking data manipulation and export procedures; automated export procedures for seamless data

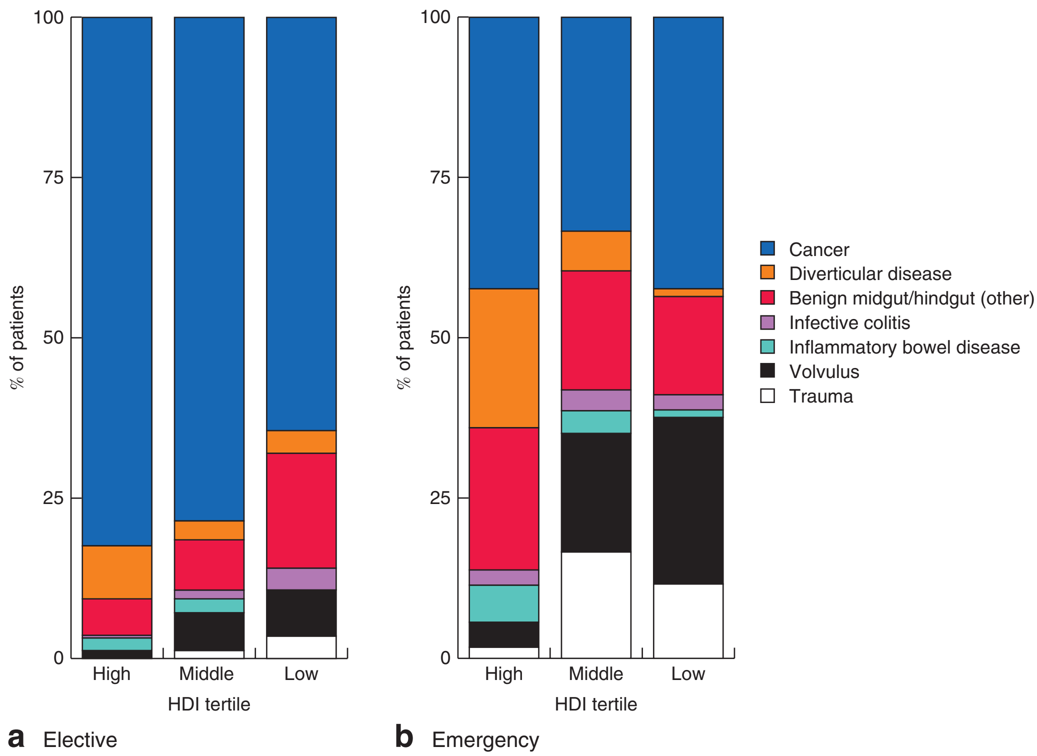

Fig. 3 Indications for left-sided colorectal resection by Human Development Index tertile and urgency of surgery. **a** Elective and **b** emergency. HDI, Human Development Index

Table 2 Baseline demographics of patients undergoing left-sided colorectal resection, grouped by whether they underwent end colostomy formation or primary restorative anastomosis

	Anastomosis ($n = 1273$)	End colostomy ($n = 362$)	P§
HDI tertile			< 0·001
High	1028 (81·1)	240 (18·9)	
Middle	191 (75·2)	63 (24·8)	
Low	54 (47·8)	59 (52·2)	
Age (years)*	63·6(14·5)	60·5(18·4)	0·025¶
Sex			0·108
M	714 (78·8)	192 (21·2)	
F	513 (75·9)	163 (24·1)	
Missing	46 (87)	7 (13)	
ASA grade			0·004
< III	764 (80·8)	182 (19·2)	
≥ III	497 (73·7)	177 (26·3)	
Missing	12 (80)	3 (20)	
Diabetes			0·524
No	1080 (77·6)	312 (22·4)	
Yes	193 (79·4)	50 (20·6)	
Smoking			0·122
No	918 (79·2)	241 (20·8)	
Yes	253 (74·4)	87 (25·6)	
Missing	102 (75·0)	34 (25·0)	
Malignancy			0·006
No	459 (74·3)	159 (25·7)	
Yes	814 (80·0)	203 (20·0)	
Urgency			< 0·001
Elective	776 (90·3)	83 (9·7)	
Emergency	497 (64·0)	279 (36·0)	
Time to operation (h)†			< 0·001
< 6	230 (79·0)	61 (21·0)	
6–11	101 (79·5)	26 (20·5)	
12–23	283 (85·2)	49 (14·8)	
24–47	268 (81·2)	62 (18·8)	
≥ 48	356 (69·4)	157 (30·6)	
Missing	35 (83)	7 (17)	
Laparoscopic			< 0·001
No	908 (74·5)	311 (25·5)	
Yes	365 (87·7)	51 (12·3)	
Perforated disease			< 0·001
No	887 (88·1)	120 (11·9)	
Yes	377 (61·0)	241 (39·0)	
Missing	9 (90)	1 (10)	
Checklist‡			0·047
No, not available	178 (80·9)	42 (19·1)	
No, but available	73 (67·6)	35 (32·4)	
Yes	1013 (78·2)	283 (21·8)	
Missing	9 (82)	2 (18)	

Values in parentheses are percentages by row, unless indicated otherwise; *values are mean(s.d.). †Time from presentation to index procedure. ‡WHO Surgical Safety Checklist. HDI, Human Development Index. §Pearson χ^2 test, except ¶Kruskal–Wallis test.

downloads to common statistical packages; and procedures for importing data from external sources. In both studies, a local lead investigator was responsible for overall quality assurance, case ascertainment and data accuracy at each centre. Where missing data were identified, the lead investigator was contacted and asked to ensure completeness. Records from centres that had an overall data completion rate of less than 95 per cent were removed from this analysis.

Statistical analysis

Variation across different international health settings was assessed by stratifying participating centres by country into tertiles according to HDI. This is a composite statistic of life expectancy, education and income indices published by the United Nations (http://hdr.undp.org/en/content/human-development-index-hdi). Differences between HDI tertiles were tested with the Pearson χ^2 test and Kruskal–Wallis test for categorical and continuous variables respectively. Descriptive percentages are listed as low HDI *versus* middle HDI *versus* high HDI throughout for consistency. To account for case mix, mixed-effects, hierarchical multilevel logistic regression models were constructed. Patients nested within countries were considered by a random-effects model. Patient-, disease- and operation-specific variables considered *a priori* to be candidates in the causal pathway, or confounders to the included outcomes, were included and treated as fixed effects. Model residuals were checked at both levels, checking for first-order interactions; these were included in final models if found to be influential. Final model selection was by minimizing the widely applicable information criterion (variables considered to be marginal candidates in the causal pathway, and that reduced the goodness of the model fit were removed). Any variables with an incident rate below 1 per cent were not taken forwards into the multivariable models. Model discriminative ability was determined using the C-statistic (area under the receiver operator curve, AUC). Coefficients generated were presented as odds ratios (ORs) with 95 per cent confidence intervals. All analyses were performed using the R version 3.1.1 (R Foundation for Statistical Computing, Vienna, Austria) with packages forcats, tidyverse, Hmisc, ggplot2, scales, RColorBrewer, lme4, gmodels, pglm, summariser and pROC.

Results

In total, 1635 patients from 242 hospitals in 57 countries (including 30 LMICs) undergoing left-sided colorectal

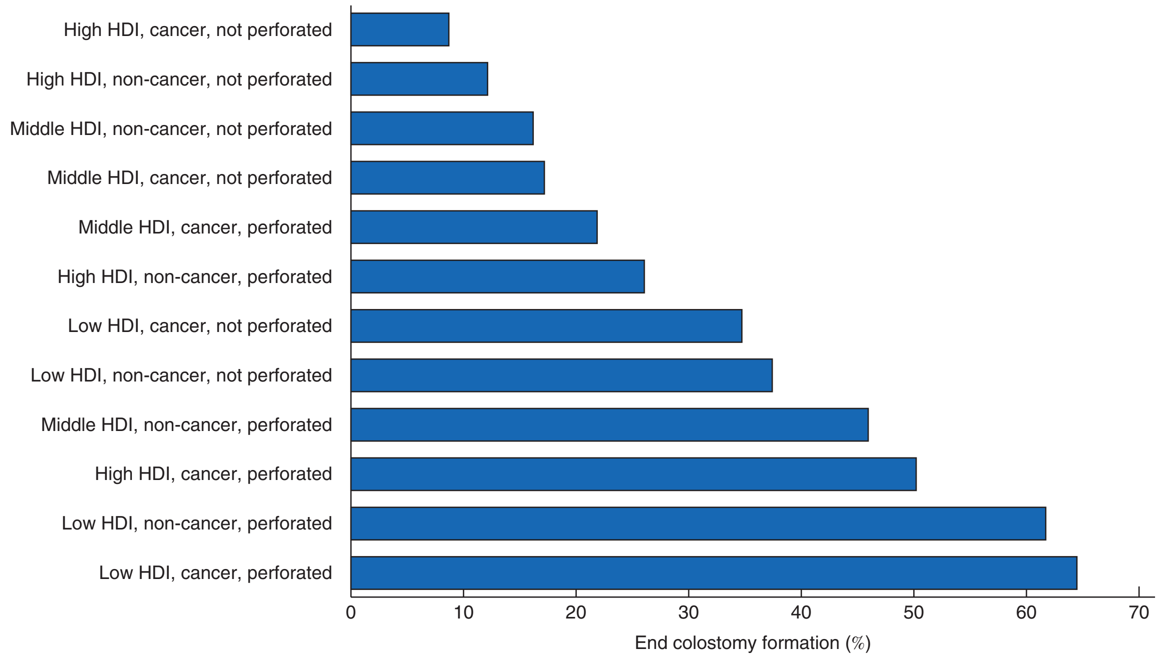

Fig. 4 End colostomy formation rates by Human Development Index tertile, indication for surgery and presence of perforated disease. HDI, Human Development Index

resection were included in this study (*Fig. 1*); 113 patients (6·9 per cent) were from low-HDI, 254 (15·5 per cent) from middle-HDI and 1268 (77·6 per cent) from high-HDI countries. Patients from low- and middle-HDI settings were significantly younger, more frequently men, lower risk (ASA grade below III) and less likely to smoke than those in high-HDI settings (*Table 1*). Patients were more likely to present as an emergency in low-HDI settings (low, 75·2 per cent; middle, 44·9 per cent; high, 45·5 per cent; $P < 0·001$) (*Fig. 2*) and more likely to have perforated disease at presentation (57·5, 40·9 and 35·4 per cent respectively; $P < 0·001$).

Disease profiles in patients from low-HDI settings were different from those in middle- and high-HDI settings (*Fig. 3*). Fewer procedures were performed for malignancy (47·8, 58·3 and 64·3 per cent respectively; $P = 0·001$), diverticulitis (1·7, 4·3 and 14·2 per cent; $P < 0·001$) and inflammatory bowel disease (0, 1·6 and 1·4 per cent; $P = 0·007$), but a greater proportion of procedures were for volvulus (21·2, 7·5 and 2·4 per cent; $P < 0·001$) and trauma (9·7, 8·3 and 0·8 per cent respectively; $P < 0·001$). An overall delay from presentation to surgery of at least 48 h was more common in both low- and middle-HDI than high-HDI countries (33·6, 42·1 and 29·0 per cent; $P < 0·001$). A WHO checklist was used in only 40·7 per cent of operations in low-HDI countries compared with 72·4 and 84·1 per cent in middle- and high-HDI countries respectively. Half as many patients in middle-HDI countries had a planned laparoscopic operation than in high-HDI countries (15·4 *versus* 29·7 per cent; $P < 0·001$). Only one patient from a low-HDI country had laparoscopic surgery (this was subsequently excluded from the mixed-effects models).

Variation in rates of end colostomy formation

Some 362 patients received an end colostomy (22·1 per cent) and 1273 a primary anastomosis (77·9 per cent) (*Table 2*). Of patients with an anastomosis, 211 (16·6 per cent) underwent left hemicolectomy, 40 (3·1 per cent) transverse or extended left hemicolectomy, 611 (48·0 per cent) sigmoid colectomy and 411 (32·3 per cent) rectal resection. Patients who received an end colostomy were more commonly high risk (ASA at least grade III: 48·9 *versus* 39·0 per cent; $P = 0·004$), had a benign indication (including trauma: 43·9 *versus* 36·1 per cent; $P = 0·006$) and perforated disease (66·6 *versus* 29·6 per cent; $P < 0·001$). Emergency surgery (77·1 *versus* 39·0 per cent; $P < 0·001$), open surgery (85·9 *versus* 71·3 per cent; $P < 0·001$) and a delay to surgery of 48 h or more (43·4 *versus* 28·0 per cent; $P < 0·001$) were also more common in the end colostomy group. Patients underwent formation of an end colostomy twice as frequently in low- compared with middle- or high-HDI countries (52·2, 24·8 and 18·9 per cent; $P < 0·001$). *Fig. 4* shows end colostomy formation

Table 3 Factors associated with end colostomy formation in univariable and multilevel mixed-effects logistic regression models

	Anastomosis	End colostomy	Univariable analysis		Multilevel analysis	
			Odds ratio*	P	Odds ratio*	P
HDI tertile						
High	1028 (80·8)	240 (66·3)	1·00 (reference)		1·00 (reference)	
Middle	191 (15·0)	63 (17·4)	1·41 (1·02, 1·93)	0·033	1·11 (0·53, 2·32)	0·777
Low	54 (4·2)	59 (16·3)	4·68 (3·15, 6·96)	< 0·001	3·20 (1·35, 7·57)	0·008
Age (years)	63·6(14·5)†	60·5(18·4)†	0·99 (0·98, 0·99)	0·001	0·99 (0·98, 1·00)	0·061
Sex						
M	714 (58·2)	192 (54·1)	1·00 (reference)		1·00 (reference)	
F	513 (41·8)	163 (45·9)	1·18 (0·93, 1·50)	0·169	1·17 (0·85, 1·59)	0·338
ASA fitness grade						
< III	764 (60·6)	182 (50·7)	1·00 (reference)		1·00 (reference)	
≥ III	497 (39·4)	177 (49·3)	1·49 (1·18, 1·89)	0·001	1·22 (0·87, 1·71)	0·256
Diabetes						
No	1080 (84·8)	312 (86·2)	1·00 (reference)		1·00 (reference)	
Yes	193 (15·2)	50 (13·8)	0·90 (0·64, 1·25)	0·525	1·08 (0·69, 1·68)	0·744
Smoking						
No	918 (78·4)	241 (73·5)	1·00 (reference)		1·00 (reference)	
Yes	253 (21·6)	87 (26·5)	1·31 (0·98, 1·73)	0·061	0·97 (0·68, 1·39)	0·889
Malignancy						
No	459 (36·1)	159 (43·9)	1·00 (reference)		1·00 (reference)	
Yes	814 (63·9)	203 (56·1)	0·72 (0·57, 0·91)	0·007	2·34 (1·65, 3·32)	< 0·001
Urgency						
Elective	776 (61·0)	83 (22·9)	1·00 (reference)		1·00 (reference)	
Emergency	497 (39·0)	279 (77·1)	5·25 (4·03, 6·91)	< 0·001	4·08 (2·73, 6·10)	< 0·001
Time to operation (h)‡						
< 6	230 (18·6)	61 (17·2)	1·00 (reference)		1·00 (reference)	
6–11	101 (8·2)	26 (7·3)	0·97 (0·57, 1·61)	0·910	0·65 (0·34, 1·23)	0·184
12–23	283 (22·9)	49 (13·8)	0·65 (0·43, 0·99)	0·044	0·76 (0·44, 1·29)	0·308
24–47	268 (21·6)	62 (17·5)	0·87 (0·59, 1·30)	0·498	1·24 (0·73, 2·11)	0·424
≥ 48	356 (28·8)	157 (44·2)	1·66 (1·19, 2·35)	0·003	1·99 (1·28, 3·09)	0·002
Laparoscopic§						
No	908 (71·3)	311 (85·9)	1·00 (reference)		–	
Yes	365 (28·7)	51 (14·1)	0·41 (0·29, 0·56)	< 0·001	–	
Perforated disease						
No	887 (70·2)	120 (33·2)	1·00 (reference)		1·00 (reference)	
Yes	377 (29·8)	241 (66·8)	4·73 (3·69, 6·08)	< 0·001	4·00 (2·81, 5·69)	< 0·001
Checklist¶						
No, not available	178 (14·1)	42 (11·7)	1·00 (reference)		1·00 (reference)	
No, but available	73 (5·8)	35 (9·7)	2·03 (1·20, 3·44)	0·008	1·10 (0·50, 2·41)	0·813
Yes	1013 (80·1)	283 (78·6)	1·18 (0·83, 1·72)	0·359	0·83 (0·44, 1·58)	0·576

Values in parentheses are percentages by column unless indicated otherwise; *values in parentheses are 95 per cent confidence intervals and †values are mean(s.d.). ‡Time from presentation to index procedure. §Not included in multilevel model owing to low event rate in low-Human Development Index (HDI) tertile (less than 1 per cent). ¶WHO Surgical Safety Checklist.

rates across HDI strata, indications for surgery and the presence or absence of perforated disease.

In univariable analysis, middle-HDI (OR 1·41, 95 per cent c.i. 1·02 to 1·93; $P = 0·033$) and low-HDI (OR 4·68, 3·15 to 6·96; $P < 0·001$) tertile were both strongly associated with end colostomy formation, as were ASA grade III or higher, malignancy, emergency surgery, a time to operation of 12–23 h or 48 h and over, perforated disease and absence of checklist use where it was available (*Table 3*). In the multilevel model, low-HDI tertile retained an association with colostomy formation (OR 3·20, 1·35 to 7·57; $P = 0·008$), despite adjustment for malignant disease (OR 2·34, 1·65 to 3·32; $P < 0·001$), emergency surgery (OR 4·08, 2·73 to 6·10; $P < 0·001$), a time to operation of 48 h or longer (OR 1·99, 1·28 to 3·09; $P = 0·002$) and perforation (OR 4·00, 2·81 to 5·69; $P < 0·001$). The model demonstrated excellent discrimination (AUC 0·85) (*Table 3*).

Variation in mortality

The unadjusted 30-day postoperative mortality rates were three times higher in low-HDI countries than in middle-

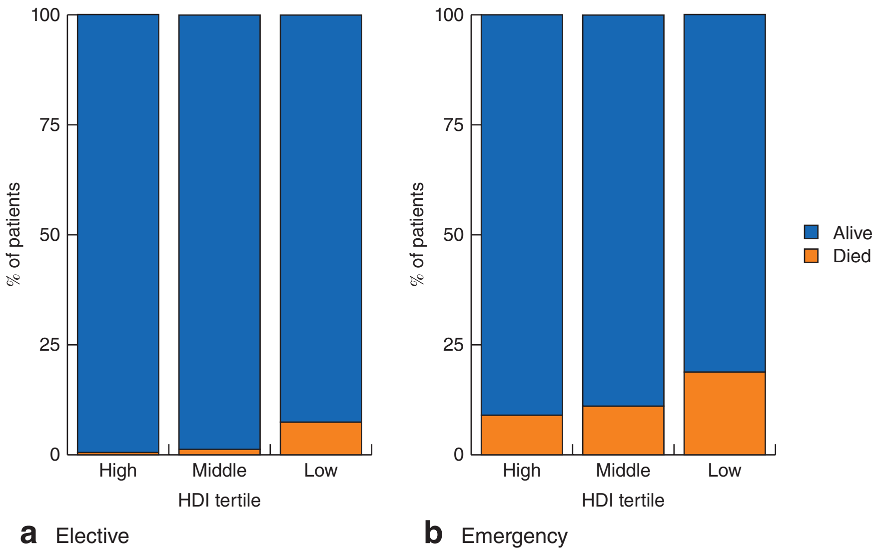

Fig. 5 Percentage of patients who died within 30 days after left-sided colorectal resection by Human Development Index tertile and urgency of surgery. **a** Elective and **b** emergency. HDI, Human Development Index

and high-HDI settings (15·9, 5·5 and 4·6 per cent respectively) (*Fig. 5*). Patients with an end colostomy had a significantly higher risk of death (adjusted OR 2·18, 95 per cent 1·23 to 3·85; $P = 0{\cdot}007$), as did those from a low-HDI tertile (OR 2·80, 1·00 to 7·82; $P = 0{\cdot}050$), older patients, those with an ASA grade of at least III, patients having emergency surgery, and those with a delay to surgery of 24–47 h (*Table 4*). The benefit of use of the WHO Checklist in theatre reached borderline significance (OR 0·50, 0·22 to 1·13; $P = 0{\cdot}094$). The model demonstrated excellent discrimination (AUC 0·89).

Discussion

This study demonstrated that end stoma rates in low-HDI countries were twice those in middle- and three times those in high-HDI countries. As each of the HDI strata included multiple hospitals of different size and nature, it suggests that variation based on income per capita may be more important than variation within countries. The difference between groups is partly explained by differences in case mix, with greater emergency presentation of both malignant and non-malignant conditions in low-HDI settings. This association persisted despite adjustment, suggesting that other factors may contribute to this variation.

Patients in LMICs were more likely to present as emergencies and to have perforated disease than patients in high-HDI settings. In part, this reflects differences in the overall disease burden, with trauma and volvulus being more common in LMICs. However, the increased frequency of emergency procedures for malignancy in LMICs may reflect barriers to accessing care and treatment for non-communicable disease in LMICs[1,3]. These may include limited implementation of screening programmes, inefficient referral pathways, the relatively high cost of investigations such as endoscopy[3,11,12], as well as some patients having limited access to health education or a preference to seek care from traditional healers[13–16]. The greater burden of emergency surgery suggests that patients in LMICs may be more likely to delay a decision to seek healthcare until they have deteriorated with complicated, advanced disease. Because significant populations live more than a 2-h drive from the nearest hospital[17,18], patients' conditions may deteriorate further owing to delays while identifying affordable and efficient means of transport[19,20]. In LMICs, once patients reach hospital, delayed and lack of appropriate investigations, staff shortages, erratic electric and water supplies, and insufficient funds to pay for care can limit and further delay surgery[21]. In the present study, patients in LMICs were more likely to experience significant in-hospital delays. Consistent with previous studies[22,23], this was associated with end stoma formation. It should be noted in the present data, however, that in-hospital delay (48 h or more) was not associated with an increased risk of death in the mixed-effects model. This may reflect appropriate delay of surgical intervention (such as for preoperative optimization of an obstructing cancer) and appropriate rationalization of resources (the most unwell patients were prioritized for early access to

Table 4 Factors associated with mortality in patients undergoing left-sided colorectal resection in univariable and multilevel, multivariable logistic regression models

			Univariable analysis		Multilevel analysis	
	Alive	Died	Odds ratio*	P	Odds ratio*	P
HDI tertile						
High	1200 (78·8)	58 (64)	1·00 (reference)		1·00 (reference)	
Middle	229 (15·0)	14 (16)	1·26 (0·67, 2·24)	0·443	1·60 (0·64, 3·97)	0·313
Low	93 (6·1)	18 (20)	4·00 (2·21, 6·95)	< 0·001	2·80 (1·00, 7·82)	0·050
Age (years)	62·7(15·3)†	69·1(15·9)†	1·03 (1·02, 1·05)		1·03 (1·01, 1·05)	0·001
Sex						
M	847 (57·5)	44 (51)	1·00 (reference)		1·00 (reference)	
F	625 (42·5)	43 (49)	1·32 (0·86, 2·04)	0·203	1·40 (0·82, 2·39)	0·214
ASA fitness grade						
< III	921 (61·0)	16 (18)	1·00 (reference)		1·00 (reference)	
≥ III	589 (39·0)	74 (82)	7·23 (4·29, 12·97)	< 0·001	6·16 (3·12, 12·19)	< 0·001
Diabetes						
No	1296 (85·2)	75 (83)	1·00 (reference)		1·00 (reference)	
Yes	226 (14·8)	15 (17)	1·15 (0·62, 1·98)	0·639	0·86 (0·43, 1·73)	0·681
Smoking						
No	1077 (77·3)	68 (78)	1·00 (reference)		1·00 (reference)	
Yes	316 (22·7)	19 (22)	0·95 (0·55, 1·58)	0·855	0·73 (0·39, 1·39)	0·345
Malignancy						
No	558 (36·7)	50 (56)	1·00 (reference)		1·00 (reference)	
Yes	964 (63·3)	40 (44)	0·46 (0·30, 0·71)	< 0·001	0·83 (0·48, 1·44)	0·503
Urgency						
Elective	837 (55·0)	9 (10)	1·00 (reference)		1·00 (reference)	
Emergency	685 (45·0)	81 (90)	11·00 (5·79, 23·68)	< 0·001	4·92 (2·18, 11·13)	< 0·001
Time to operation (h)‡						
< 6	267 (18·0)	18 (21)	1·00 (reference)		1·00 (reference)	
6–11	111 (7·5)	15 (17)	2·00 (0·96, 4·12)	0·058	1·12 (0·46, 2·72)	0·800
12–23	314 (21·2)	17 (19)	0·80 (0·40, 1·60)	0·529	0·98 (0·43, 2·19)	0·952
24–47	320 (21·6)	5 (6)	0·23 (0·08, 0·59)	0·004	0·21 (0·06, 0·70)	0·011
≥ 48	470 (31·7)	33 (38)	1·04 (0·58, 1·92)	0·893	0·78 (0·39, 1·59)	0·497
Laparoscopic§						
No	1115 (73·3)	85 (94)	1·00 (reference)		–	
Yes	407 (26·7)	5 (6)	0·16 (0·06, 0·36)	< 0·001	–	
Perforated disease						
No	961 (63·5)	32 (36)	1·00 (reference)		1·00 (reference)	
Yes	552 (36·5)	57 (64)	3·10 (2·00, 4·89)	< 0·001	1·07 (0·59, 1·92)	0·833
Checklist¶						
No, not available	197 (13·0)	17 (19)	1·00 (reference)		1·00 (reference)	
No, but available	92 (6·1)	12 (13)	1·51 (0·68, 3·27)	0·299	1·38 (0·46, 4·11)	0·564
Yes	1223 (80·9)	61 (68)	0·58 (0·34, 1·04)	0·054	0·50 (0·22, 1·13)	0·094
Anastomosis/colostomy						
Anastomosis	1208 (79·4)	48 (53)	1·00 (reference)		1·00 (reference)	
End colostomy	314 (20·6)	42 (47)	3·37 (2·18, 5·19)	< 0·001	2·18 (1·23, 3·85)	0·007

Values in parentheses are percentages by column unless indicated otherwise; *values in parentheses are 95 per cent confidence intervals and †values are mean(s.d.). ‡Time from presentation to index procedure. §Not included in multilevel model owing to low event rate in low Human Development Index (HDI) tertile (less than 1 per cent). ¶WHO Surgical Safety Checklist.

theatre resources) across included hospitals. The three stages of delay in accessing acute care, in making a decision to travel to hospital, in travelling to hospital, and in hospital[24], all contribute to patients in LMICs being more likely to present acutely unwell with complicated disease that makes primary restorative surgery challenging, and influencing the decision whether primary anastomosis or end colostomy is appropriate[25].

Differences in training and provision of specialist colorectal surgery, and lack of available or affordable equipment for technically difficult anastomoses, could also affect stoma rates. With fewer patients presenting with operable colorectal cancer in many low-HDI countries[3,12] and fewer formal training opportunities, access to subspecialist colorectal services is limited[3,26,27]. High baseline mortality rates[2], inadequate provision of critical care support[28,29] and insufficient medicolegal protection[30] may also promote risk-averse practices. Stapling devices may be unaffordable for both patient and provider in many LMICs, meaning that only selected patients have access to these techniques[31]. Similarly, although laparoscopic colorectal resection was performed in middle-HDI settings, it was uncommon. Lack of affordable laparoscopic equipment, variable provision of training and hospital-level difficulties, such as a reliable electrical supply, remain barriers to minimal access surgery in LMIC settings[32], despite potential for patient benefit[33,34].

The high mortality rate for both elective and emergency surgery reported in this study supports previous findings that patients have a higher risk of death following surgery in low-HDI settings which cannot be accounted for by case mix alone[2,35]. The present analysis showed that patients undergoing end stoma formation were at increased risk of death. Despite adjustment, this finding could represent a surrogate marker of disease severity where the highest-risk patients are being selected to receive a stoma. In the present study, it was not possible to measure physiological markers of disease severity beyond ASA classification (such as hypotension, tachycardia, high lactate level or an end-organ perfusion deficit) that could influence surgical decision-making and outcomes.

This study has important limitations that could affect its generalizability. As it included a relatively low mean number of patients per centre in a 'snapshot' methodology, no analysis was performed at a per-centre or per-country level. Although only one-quarter of patients in the data set were from LMICs, sites across 30 countries contributed data, bolstering external generalizability across LMIC settings. Data were collected across all HDI tertiles in both emergency (GlobalSurg-1 and -2) and elective (GlobalSurg-2) settings, and are relevant to both planned and unplanned left-sided colorectal resections, but numbers in some groups (such as elective operations for cancer in low-HDI settings) were small. Further validation of these findings is therefore required in future work. Although there were no centre-level exclusion criteria for case volume or infrastructure, a sampling bias is likely to exist, wherein the best resourced and/or academically affiliated centres within LMICs were more likely to access the study protocol and provide patient data than those in remote and rural settings. This may have led to an underestimate of the true rate of end stoma formation within LMICs.

Reported end colostomy rates have varied from 0 to as high as 74 per cent[25,36–39] in groups including emergency surgery[39], late presentations of cancer[25], complications of infectious disease[38] and traumatic injury[36]. The collaborative methodology in the present study enabled clinicians to enter data into a secure online platform contemporaneously alongside their clinical practice, in accordance with a prespecified protocol. This led to high levels of data accuracy and completeness[40] and has provided the basis on which further studies can be developed to examine other factors that influence outcomes in different settings.

Acknowledgements

This paper reports the results of two preregistered studies (ClinicalTrials.gov; NCT02179112 and NCT02662231). To minimize the possibility of unintentionally sharing information that can be used to reidentify private information, a subset of the summary data generated for this study are available in an online visualization application that can be accessed at http://ssi.globalsurg.org [40].

Organizations assisting in dissemination and/or translation: Asian Medical Students' Association; Association of Surgeons in Training; College of Surgeons of East, Central and Southern Africa; Cutting Edge Manipal; Egyptian Medical Student Research Association; International Collaboration for Essential Surgery; International Federation of Medical Student Associations; Italian Society of Colorectal Surgery; Lifebox Foundation; School of Surgery; Student Audit and Research in Surgery; The Electives Network; United Kingdom National Research Collaborative; World Society of Emergency Surgery; and World Surgical Association.

This study was funded by Department For International Development–Medical Research Council–Wellcome Trust Joint Global Health Trial Development grant (MR/N022114/1) and a National Institute of Health Research (NIHR) Global Health Research Unit Grant (NIHR 16/136/79). The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the UK Department of Health.

References

1 Sullivan R, Alatise OI, Anderson BO, Audisio R, Autier P, Aggarwal A *et al.* Global cancer surgery: delivering safe, affordable, and timely cancer surgery. *Lancet Oncol* 2015; **16**: 1193–1224.
2 GlobalSurg Collaborative. Mortality of emergency abdominal surgery in high-, middle- and low-income countries. *Br J Surg* 2016; **103**: 971–988.
3 Arnold M, Sierra MS, Laversanne M, Soerjomataram I, Jemal A, Bray F. Global patterns and trends in colorectal cancer incidence and mortality. *Gut* 2017; **66**: 683–691.

4 Morris E, Quirke P, Thomas JD, Fairley L, Cottier B, Forman D. Unacceptable variation in abdominoperineal excision rates for rectal cancer: time to intervene? *Gut* 2008; **57**: 1690–1697.
5 Thyø A, Emmertsen KJ, Pinkney TD, Christensen P, Laurberg S. The colostomy impact score: development and validation of a patient reported outcome measure for rectal cancer patients with a permanent colostomy. A population-based study. *Colorectal Dis* 2017; **19**: O25–O33.
6 Ameh EA, Mshelbwala PM, Sabiu L, Chirdan LB. Colostomy in children – an evaluation of acceptance among mothers and caregivers in a developing country. *S Afr J Surg* 2006; **44**: 138–139.
7 Shrime MG, Dare AJ, Alkire BC, O'Neill K, Meara JG. Catastrophic expenditure to pay for surgery worldwide: a modelling study. *Lancet Glob Health* 2015; **3**(Suppl 2): S38–S44.
8 GlobalSurg Collaborative. Determining the worldwide epidemiology of surgical site infections after gastrointestinal resection surgery: protocol for a multicentre, international, prospective cohort study (GlobalSurg 2). *BMJ Open* 2017; **7**: e012150.
9 von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *PLoS Med* 2007; **4**: e296.
10 Haynes AB, Weiser TG, Berry WR, Lipsitz SR, Breizat AH, Dellinger EP *et al.*; Safe Surgery Saves Lives Study Group. A surgical safety checklist to reduce morbidity and mortality in a global population. *N Engl J Med* 2009; **360**: 491–499.
11 Ahmed F. Barriers to colorectal cancer screening in the developing world: the view from Pakistan. *World J Gastrointest Pharmacol Ther* 2013; **4**: 83–85.
12 Lambert R, Sauvaget C, Sankaranarayanan R. Mass screening for colorectal cancer is not justified in most developing countries. *Int J Cancer* 2009; **125**: 253–256.
13 Langenbach MR, Schmidt J, Neumann J, Zirngibl H. Delay in treatment of colorectal cancer: multifactorial problem. *World J Surg* 2003; **27**: 304–308.
14 Irfan FB, Irfan BB, Spiegel DA. Barriers to accessing surgical care in Pakistan: healthcare barrier model and quantitative systematic review. *J Surg Res* 2012; **176**: 84–94.
15 Barker RD, Millard FJ, Malatsi J, Mkoana L, Ngoatwana T, Agarawal S *et al.* Traditional healers, treatment delay, performance status and death from TB in rural South Africa. *Int J Tuberc Lung Dis* 2006; **10**: 670–675.
16 Okeke TA, Okafor HU, Uzochukwu BS. Traditional healers in Nigeria: perception of cause, treatment and referral practices for severe malaria. *J Biosoc Sci* 2006; **38**: 491–500.
17 Raykar NP, Bowder AN, Liu C, Vega M, Kim JH, Boye G *et al.* Geospatial mapping to estimate timely access to surgical care in nine low-income and middle-income countries. *Lancet* 2015; **385**(Suppl 2): S16.
18 Ouma PO, Maina J, Thuranira PN, Macharia PM, Alegana VA, English M *et al.* Access to emergency hospital care provided by the public sector in sub-Saharan Africa in 2015: a geocoded inventory and spatial analysis. *Lancet Glob Health* 2018; **6**: e342–e350.
19 Grimes CE, Bowman KG, Dodgion CM, Lavy CB. Systematic review of barriers to surgical care in low-income and middle-income countries. *World J Surg* 2011; **35**: 941–950.
20 Wilson A, Hillman S, Rosato M, Skelton J, Costello A, Hussein J *et al.* A systematic review and thematic synthesis of qualitative studies on maternal emergency transport in low- and middle-income countries. *Int J Gynaecol Obstet* 2013; **122**: 192–201.
21 Adamu A, Maigatari M, Lawal K, Iliyasu M. Waiting time for emergency abdominal surgery in Zaria, Nigeria. *Afr Health Sci* 2010; **10**: 46–53.
22 Ong M, Guang TY, Yang TK. Impact of surgical delay on outcomes in elderly patients undergoing emergency surgery: a single center experience. *World J Gastrointest Surg* 2015; **7**: 208–213.
23 Khan S, Zafar H, Zafar SN, Haroon N. Inter-facility transfer of surgical emergencies in a developing country: effects on management and surgical outcomes. *World J Surg* 2014; **38**: 281–286.
24 Thaddeus S, Maine D. Too far to walk: maternal mortality in context. *Soc Sci Med* 1994; **38**: 1091–1110.
25 Saidi H, Nyaim EO, Githaiga JW, Karuri D. CRC surgery trends in Kenya, 1993-2005. *World J Surg* 2008; **32**: 217–223.
26 Hoyler M, Hagander L, Gillies R, Riviello R, Chu K, Bergström S *et al.* Surgical care by non-surgeons in low-income and middle-income countries: a systematic review. *Lancet* 2015; **385**(Suppl 2): S42.
27 Federspiel F, Mukhopadhyay S, Milsom P, Scott JW, Riesel JN, Meara JG. Global surgical and anaesthetic task shifting: a systematic literature review and survey. *Lancet* 2015; **385**(Suppl 2): S46.
28 Firth P, Ttendo S. Intensive care in low-income countries – a critical need. *N Engl J Med* 2012; **367**: 1974–1976.
29 Adhikari NK, Fowler RA, Bhagwanjee S, Rubenfeld GD. Critical care and the global burden of critical illness in adults. *Lancet* 2010; **376**: 1339–1346.
30 Gordhan CG, Anandalwar SP, Son J, Ninan GK, Chokshi RJ. Malpractice in colorectal surgery: a review of 122 medicolegal cases. *J Surg Res* 2015; **199**: 351–356.
31 Adisa AO, Olasehinde O, Arowolo OA, Alatise OI, Agbakwuru EA. Early experience with stapled gastrointestinal anastomoses in a Nigerian hospital. *Niger J Surg* 2015; **21**: 140–142.
32 Ismaila BO, Shuaibu SI, Ale AA. Laparoscopic surgery in a Nigerian teaching hospital for 1 year: challenges and effect on outcomes. *Niger J Med* 2013; **22**: 134–137.
33 van der Pas MH, Haglind E, Cuesta MA, Fürst A, Lacy AM, Hop WC *et al.*; COlorectal cancer Laparoscopic or Open Resection II (COLOR II) Study Group. Laparoscopic *versus*

open surgery for rectal cancer (COLOR II): short-term outcomes of a randomised, phase 3 trial. *Lancet Oncol* 2013; **14**: 210–218.
34 COLOR Study Group. COLOR: a randomized clinical trial comparing laparoscopic and open resection for colon cancer. *Dig Surg* 2000; **17**: 617–622.
35 Biccard BM, Madiba TE, Kluyts HL, Munlemvo DM, Madzimbamuto FD, Basenero A *et al.*; African Surgical Outcomes Study (ASOS) investigators. Perioperative patient outcomes in the African Surgical Outcomes Study: a 7-day prospective observational cohort study. *Lancet* 2018; **391**: 1589–1598.
36 Angelici AM, Montesano G, Nasti AG, Palumbo P, Vietri F. Treatment of gunshot wounds to the colon: experience in a rural hospital during the civil war in Somalia. *Ann Ital Chir* 2004; **75**: 461–464.
37 Asuquo ME, Bassey OO, Etiuma AU, Ugare G, Ngim O. A prospective study of penetrating abdominal trauma at the University of Calabar Teaching Hospital, Calabar, Southern Nigeria. *Eur J Trauma Emerg Surg* 2009; **35**: 277, 280.
38 Athié-Gutiérrez C, Rodea-Rosas H, Guízar-Bermúdez C, Alcántara A, Montalvo-Javé EE. Evolution of surgical treatment of amebiasis-associated colon perforation. *J Gastrointest Surg* 2010; **14**: 82–87.
39 Chalya PL, Mabula JB. Sigmoid volvulus and ileo-sigmoid knotting: a five-year experience at a tertiary care hospital in Tanzania. *World J Emerg Surg* 2015; **10**: 10.
40 GlobalSurg Collaborative. Surgical site infection after gastrointestinal surgery in high-income, middle-income, and low-income countries: a prospective, international, multicentre cohort study. *Lancet Infect Dis* 2018; **18**: 516–525.

Supporting information

Additional supporting information can be found online in the Supporting Information section at the end of the article.

Patient viewpoint

This study reveals global variation in end colostomy rates after left-sided colorectal resection; stoma rates in low-HDI countries were twice those in middle- and three times those in high-HDI countries.

Awakening after surgery with a colostomy will have been a traumatic experience for all 362 patients. I wish we could ask everyone who still survives today some honest questions about their quality of life since. I imagine those in high-HDI countries will have adapted better to their changed bodies and altered selves than their low-HDI counterparts.

In high-HDI England my own stoma is easy to accommodate thanks to freely accessible healthcare, uninterrupted supplies of decent ileostomy bags, sanitation, plentiful water, an angel of a specialist stoma nurse, and legal protection from societal or workplace discrimination: I am fortunate to enjoy a lovely life as a 'Bag Lady'.

The absence of such enabling factors can, however, make having a stoma far more burdensome in low-HDI countries. Financial ruin, inability to resume usual daily activities, societal rejection, family/community shame, and becoming unemployable and unmarriageable are, sadly, common sequelae. Indeed, my East African-born parents insist that had I not been 'Made in Britain' long after they relocated to England, I would have suffered 'intolerable strife or loss of life'.

There is a real need to reduce avoidable stoma formation globally. This need is most pressing in low-HDI countries where physical, psychological, economic, educational and social challenges are magnified. The insurmountable obstacles they may face in low-HDI settings can lead patients to question whether surviving surgery is in fact the superior of the two possible outcomes. Thus, although surgeons in restricted-resource settings may have good reason to fear the consequences of anastomotic leaks, patients may have greater reason to fear the lifelong consequences of a stoma.

Ms Azmina Verjee
GlobalSurg UK Patient Representative