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

GlobalSurg Collaborative*

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 percent) from low-HDI, 254 (15.3 percent) from middle-HDI and 1268 (77.6 percent) from high-HDI countries. There was a higher proportion of patients with perforated disease (57.5, 40.9 and 35.4 percent; $P<0.001$) and subsequent use of end colostomy (52.2, 24.8 and 18.9 percent; $P<0.001$) 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 percent 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)

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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 agenda¹. 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 observed². However, other key outcomes from the surgical management of colorectal cancer or benign colorectal disease in LMICs have been particularly poorly profiled to date³.

End colostomy rates following colorectal cancer resection vary substantially between centres in high-income countries, ranging from 15 to 70 per cent⁴. 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...
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...
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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              |                     |                      |                   |     |
| 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|                     |                      |                   |     |
| < 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         |                     |                      |                   |     |
| No               | 1070 (84.4)         | 219 (86.2)           | 103 (91.2)        |     |
| Yes              | 198 (15.6)          | 35 (13.8)            | 10 (8.8)          |     |
| Smoking          |                     |                      |                   |     |
| 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       |                     |                      |                   |     |
| No               | 453 (35.7)          | 106 (41.7)           | 59 (52.2)         |     |
| Yes              | 815 (64.3)          | 148 (58.3)           | 54 (47.8)         |     |
| Urgency          |                     |                      |                   |     |
| Elective         | 691 (54.5)          | 140 (55.1)           | 28 (24.8)         |     |
| Emergency        | 577 (45.5)          | 114 (44.9)           | 85 (75.2)         |     |
| Time to operation (h)† |                 |                      |                   |     |
| < 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     |                     |                      |                   |     |
| No               | 892 (70.3)          | 215 (84.6)           | 112 (99.1)        | < 0.001 |
| Yes              | 376 (29.7)          | 39 (15.4)            | 1 (0.9)           |     |
| Perforated disease|                    |                      |                   |     |
| No               | 813 (64.1)          | 147 (57.9)           | 47 (41.6)         | < 0.001 |
| 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 χ² 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 guidelines9.

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

| HDI tertile | Anastomosis (n = 1273) | End colostomy (n = 362) | P§ |
|-------------|------------------------|-------------------------|----|
| High        | 1028 (81.1)            | 240 (18.9)              | < 0.001 |
| Middle      | 191 (75.2)             | 63 (24.8)               | 0.025§ |
| Low         | 54 (47.8)              | 59 (52.2)               | 0.108 |
| Age (years)*| 63.6 (14.5)            | 60.5 (18.4)             | 0.0524 |
| Sex         |                        |                         | 0.122 |
| M           | 714 (78.8)             | 192 (21.2)              | 0.004 |
| F           | 513 (75.9)             | 163 (24.1)              | 0.006 |
| Missing     | 46 (87)                | 7 (13)                  | < 0.001 |
| ASA grade   |                        |                         | < 0.001 |
| < III       | 764 (80.8)             | 182 (19.2)              | 0.006 |
| ≥ III       | 497 (73.7)             | 177 (26.3)              | 0.001 |
| Diabetes    |                        |                         | 0.001 |
| No          | 1080 (77.6)            | 312 (22.4)              | 0.052 |
| Yes         | 193 (79.4)             | 50 (20.6)               | 0.012 |
| Smoking     |                        |                         | 0.006 |
| No          | 918 (79.2)             | 241 (20.8)              | 0.001 |
| Yes         | 253 (74.4)             | 87 (25.6)               | 0.001 |
| Malignancy  |                        |                         | 0.001 |
| No          | 459 (74.3)             | 159 (25.7)              | 0.006 |
| Yes         | 814 (80.0)             | 203 (19.9)              | 0.001 |
| Urgency     |                        |                         | 0.001 |
| Elective    | 776 (90.3)             | 83 (9.7)                | 0.001 |
| Emergency   | 497 (64.0)             | 279 (36.0)              | 0.001 |
| Time to operation (h) |        |                         | 0.001 |
| < 6         | 230 (79.0)             | 61 (21.0)               | 0.001 |
| 6–11        | 101 (79.5)             | 26 (20.5)               | 0.001 |
| 12–23       | 283 (85.2)             | 48 (14.8)               | 0.001 |
| 24–47       | 268 (81.2)             | 62 (18.8)               | 0.001 |
| ≥ 48        | 356 (69.4)             | 157 (30.6)              | 0.001 |
| Missing     | 35 (83)                | 7 (17)                  | 0.001 |
| Laporascopic|                        |                         | 0.001 |
| No          | 908 (74.5)             | 311 (25.5)              | 0.001 |
| Yes         | 365 (87.7)             | 51 (12.3)               | 0.001 |
| Perforated disease |       |                         | 0.001 |
| No          | 887 (88.1)             | 120 (11.9)              | 0.001 |
| Yes         | 377 (76.0)             | 99 (24.0)               | 0.001 |
| Missing     | 9 (90)                 | 1 (10)                  | 0.001 |
| Checklist   |                        |                         | 0.047 |
| No, not available | 178 (80.9) | 42 (19.1) | 0.047 |
| No, but available | 73 (67.6) | 35 (32.4) | 0.047 |
| Yes         | 1013 (78.2)            | 283 (21.8)              | 0.047 |
| Missing     | 9 (82)                 | 2 (18)                  | 0.047 |

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 χ² 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 χ² 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...
End colostomy formation rates by Human Development Index tertile, indication for surgery and presence of perforated disease. HDI, Human Development Index

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 hemicolecotomy, 40 (3.1 per cent) transverse or extended left hemicolecotomy, 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...
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

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. These may include limited implementation of screening programmes, inefficient referral pathways, the relatively high cost of investigations such as endoscopy, as well as some patients having limited access to health education or a preference to seek care from traditional healers. 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, patients’ conditions may deteriorate further owing to delays while identifying affordable and efficient means of transport. 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. In the present study, patients in LMICs were more likely to experience significant in-hospital delays. Consistent with previous studies, 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

|                        | Alive | Died | Univariable analysis | Multilevel analysis |
|------------------------|-------|------|----------------------|---------------------|
|                        |       |      | 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, 2.44)    | 0.443               |
| Low                    | 93 (6.1)  | 18 (20) | 4.00 (2.21, 6.95)    | < 0.001             |
| **Age (years)**        | 62.7 (15.3) | 69.1 (15.9) | 1.03 (1.02, 1.05) | 1.03 (1.01, 1.05) |
| **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               |
| **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             |
| **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               |
| **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               |
| **Malignancy**         |       |      |                      |                     |
| No                     | 558 (36.7) | 50 (66) | 1.00 (reference)     | 1.00 (reference)    |
| Yes                    | 964 (63.3) | 40 (44) | 0.46 (0.30, 0.71)    | < 0.001             |
| **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             |
| **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               |
| 12–23                  | 314 (21.2) | 17 (19) | 0.80 (0.40, 1.60)    | 0.529               |
| 24–47                  | 320 (21.6) | 5 (6)   | 0.23 (0.08, 0.59)    | 0.004               |
| ≥ 48                   | 470 (31.7) | 33 (38) | 1.04 (0.58, 1.92)    | 0.893               |
| **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)     |                     |
| Yes                    | 552 (36.5) | 57 (64) | 3.10 (2.00, 4.89)    | < 0.001             |
| **Checklist:**         |       |      |                      |                     |
| No, not available      | 197 (13.0) | 17 (19) | 1.00 (reference)     | 1.00 (reference)    |
| Yes                    | 92 (6.1)  | 12 (13) | 1.51 (0.68, 3.27)    | 0.299               |
| No, but available      | 1223 (80.9) | 61 (68) | 0.58 (0.34, 1.04)    | 0.054               |
| Yes                    | 1208 (79.4) | 48 (53) | 3.37 (2.18, 5.19)    | < 0.001             |
| **Anastomosis/colostomy** |     |      |                      |                     |
| Anastomosis            | 1208 (79.4) | 48 (53) | 3.37 (2.18, 5.19)    | < 0.001             |
| End colostomy          | 314 (20.6) | 42 (47) | 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 means(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 (including hospitals) 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 hospital12, 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 appropriate25.

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 countries22,12 and fewer formal training opportunities, access to subspecialist colorectal services is limited12,26,27. High baseline mortality rates2, inadequate provision of critical care support28,29 and

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insufficient medicolegal protection 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. 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, despite potential for patient benefit.

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. 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 territories 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 in groups including emergency surgery, late presentations of cancer, complications of infectious disease and traumatic injury. 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 and has provided the basis on which further studies can be developed to examine other factors that influence outcomes in different settings.

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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.

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**Supporting information**

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

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**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 unmarrigeable 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*