Variation in the rates of emergency surgery amongst emergency admissions to hospital for common acute conditions

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Abstract

Background: There is a lack of rigorous evidence on variation across hospitals in receipt of Emergency Surgery (ES). This paper assesses variation in ES receipt amongst emergency admissions to hospital with acute appendicitis, cholelithiasis, diverticular disease, abdominal wall hernia or intestinal obstruction.

Methods: Records of emergency admissions between 1/4/2010 and 31/12/2019 for the five conditions were extracted from Hospital Episode Statistics for 136 acute NHS trusts in England. Patients having ES were identified using OPCS procedure codes, selected by consensus of a clinical panel. The differences in ES according to patient characteristics, and unexplained variations across NHS trusts were estimated by multilevel logistic regression.

Results: The cohort sizes ranged from 107,325 (hernia) to 268,253 (appendicitis) patients, and the proportion receiving ES from 11.0% (diverticular disease) to 92.3% (appendicitis). Older patients were generally less likely to receive ES, with adjusted odds ratios (OR) of ES for those aged 75-79 vs 45-49 of: 0.34 (appendicitis), 0.49 (cholelithiasis), 0.87 (hernia) and 0.91 (intestinal obstruction). Patients with diverticular disease aged 75-79 were more likely to receive ES than those aged 45-49 (OR 1.40). Variation in ES rates across NHS trusts remained after case-mix adjustment and was greatest for cholelithiasis; trusts' median 18%, 10th to 90th centile 7%-35%.

Conclusions: For patients presenting as emergency hospital admissions with common acute conditions, variation in ES rates between NHS trusts remained after adjustment for demographic and clinical characteristics. Age was strongly associated with the likelihood of ES for some procedures.

Introduction

Emergency surgery (ES) poses a considerable global burden to publicly funded health systems,[1] and is responsible for approximately 750,000 admissions per year in England alone,[2] with surgical procedures accounting for approximately 10% of the annual NHS budget.[3] In the United States (US), there are around three million hospital admissions presenting for ES, at an estimated cost of $28 billion, projected to rise to about $41 billion in 2060.[4] For common acute conditions (e.g. acute diverticular disease) that present as emergency admissions, an area of ongoing concern is which patients should receive emergency surgery (ES) versus non-emergency surgery (NES) strategies, that include medical management, non-surgical procedures (e.g. drainage of abscess), or surgery deferred to the elective (planned) setting.

For patients with acute conditions, ES rates have declined over the last two decades,[5] which may reflect changes in the characteristics of those presenting as emergency admissions and improved diagnostics. In addition, protocols for NES strategies have been implemented as part of randomised controlled trials (RCTs), and for some acute conditions these have resulted in similar outcomes to ES.[6,7] Following the onset of the COVID-19 pandemic, international guidelines have encouraged further reductions in ES rates for acute conditions.[1] However, delaying or avoiding surgical strategies may have unintended consequences.[8,9] Patients with acute conditions, such as acute cholelithiasis or inguinal hernia, who do not have ES, can develop severe complications such as acute pancreatitis or strangulated bowel, or have recurrent symptoms leading to delayed surgery and further pressure on surgical waiting lists.[8,10] Despite initiatives to standardise the clinical management of these acute conditions,[11-13] clinical uncertainty and difference in the availability of surgical facilities and specialists, may lead to wide variations in ES for patients with common acute conditions. However, previous evidence about variation in ES across NHS trusts in England has been limited to a single condition or short time-period,[14] or has not recognised the role of patient factors such as frailty or number of co-morbidities.[11-13]

The aim of this paper is to investigate variation in ES in adults across NHS hospital trusts in England from 2010-2019, for emergency hospital admissions with common acute conditions.

Methods

This NIHR funded study, Emergency Surgery or Not (ESORT) uses national Hospital Episodes Statistics (HES) data for England to define patient cohorts admitted as emergencies to NHS acute hospital trusts for five common acute conditions: appendicitis, cholelithiasis, intestinal obstruction (small or large bowel), (symptomatic) diverticular disease, and abdominal wall hernia.[15] These acute conditions were defined according to the International Classification of Diseases, tenth revision (ICD-10) diagnosis codes corresponding to each condition.

The research was approved by the London School of Hygiene and Tropical Medicine ethics committee (Ethics Reference no: **21687)**. The study involved the secondary analyses of existing pseudo anonymised data and did not require UK National Ethics Committee approval. The study drew from the findings of two workshops with patients and the public, held in July 2020, that reported it was of potential benefit to patients and the public to examine why access to ES might vary according to different patient groups.[16]

Study Population

An admission can contain several finished consultant episodes, and patients aged 18 or over were eligible for a cohort if a finished consultant episode met the following criteria: (i) occurred between 1/4/2010 and 31/12/2019; (ii) included a main diagnosis with an ICD-10 diagnosis code (see supplementary tables S1 and S2) that was judged relevant according to the consensus of a clinical panel; (iii) was within an emergency admission through the Emergency Department, or from a primary care referral; (iv) was under a consultant general surgeon, sub-speciality general surgeon, or surgeon working in the general surgery specialty; and (v) was the first or second episode within the admission. For the intestinal obstruction cohort, a relevant diagnosis could appear in the second diagnosis field if the main diagnosis was colorectal cancer. An admission was excluded if there had been a prior emergency admission with a relevant diagnosis in the previous 12 months, or further diagnostic exclusion criteria were met according to the consensus of a clinical panel (see Table S2).

Definition of Emergency Surgery (ES)

The final list of procedures defined according to Office of Population Censuses and Surveys (OPCS) codes, and the maximum number of days within which the surgery had to occur to constitute ES, was defined from the consensus of the study's clinical panel (for full details see supplement, Table S3, and weblink[17]). In brief, the qualifying surgical procedure had to be within three days (hernia), seven days (appendicitis, cholelithiasis, intestinal obstruction), or any time within the emergency admission (diverticular disease).

Patient Characteristics and definition of NHS Trusts

The following patient characteristics were available from HES data at admission and were considered to potentially influence the treatment decision: age (years), gender, ethnicity, Index of Multiple Deprivation (IMD), diagnostic subcategories, number of comorbidities and frailty. The Charlson comorbidity index,[18] and SCARF frailty index,[19] were derived for all patients. Those patients with missing ethnicity data were designated a missing data category. The proportion of qualifying admissions who had ES were derived for 136 general acute NHS Trusts in existence on 31/3/2016. Organisational changes during the study period such as trust mergers, were addressed by mapping 175 hospitals to their 2016 NHS Trust status. The total volume of emergency admissions that met the inclusion criteria for each trust was calculated over the time-period.

Statistical Analysis

Summary statistics were used to describe the patients' demographic and clinical characteristics. Age was categorised into five-year age bands. The proportions of eligible emergency admissions were calculated for each cohort overall, and according to pre-specified subgroups of interest. For each condition, multilevel logistic models were developed which included year of emergency admission, age, gender, ethnicity, diagnostic subcategories, IMD (quintiles), number of Charlson comorbidities, and SCARF frailty index as independent variables, and whether the patient received ES or not as the dependent variable. The multilevel model included random intercepts for each NHS trust to allow for clustering, and to report the level of unexplained Trust-level variation in ES, after allowing for patient factors and the time-period. The model was used to predict the case-mix adjusted odds ratios (95% CI) of ES associated with patient factors, and the levels of unexplained variation attributable to NHS Trusts. Funnel plots were used to display the variation in the case-mix adjusted proportions receiving ES, versus the volume of emergency admissions within NHS trusts.

Results

Patient characteristics

The number of patients who were eligible emergency admissions were: 107,325 (hernia), 137,744 (intestinal obstruction), 139,090 (diverticular disease), 241,626 (cholelithiasis) and 268,253 (appendicitis) (Table S4). Table 1 presents the patient characteristics for each cohort of emergency admissions who met the study's inclusion criteria. The numbers (proportions) of patients in each diagnostic subcategory are listed in Table S5.

Receipt of ES

The proportion of emergency admissions in the cohort that met the criteria for ES was highest for acute appendicitis (92.3%), lower for hernia (57.9%), intestinal obstruction (29.9%) and cholelithiasis (21.5%), and lowest for diverticular disease (11.0%) (Table S4). The most common ES procedures are listed in Table S6. The proportion of patients who received ES was generally lower for patients in older age groups (Table 2). Women were more likely than men to receive ES for cholelithiasis, hernia and intestinal obstruction. For all five conditions, patients with comorbidities were less likely to receive ES than those without comorbidities. The proportion of patients who had ES increased with frailty for patients with diverticular disease and intestinal obstruction, but decreased for appendicitis and hernia.

Patient factors associated with ES receipt

Table 3 presents the association of each factor with ES, after adjustment for other patient-level variables, hospital trust, and time-period. For all conditions apart from diverticular disease, after adjustment, ES declined for those patients in older age groups, with adjusted odds ratios for patients aged 85-89 versus 45-49 ranging from 0.2 (appendicitis) to 0.68 (hernia). The decline in ES with increasing age was steepest for appendicitis and cholelithiasis. For patients with diverticular disease, ES was higher for patients aged 60-80 (Figure 1). After adjusting for frailty and other factors, patients for all five conditions were less likely to have ES if they had any comorbidities. The association of frailty with ES differed by condition. There was a consistent decline in the rate of ES as the number of Charlson comorbidities increased, but the association between frailty and ES was less consistent. The relationship was strongest for patients with acute appendicitis or hernia; the patients with more severe frailty were less likely to receive ES. For patients with cholelithiasis, diverticular disease or intestinal obstruction, patients with all levels of frailty were more likely to receive ES (Table 3). Investigation of interactions between comorbidity and frailty showed that in diverticular disease and intestinal obstruction, the effect of frailty was strongest in patients with no Charlson comorbidities (Table S7).

Variation in ES rates across NHS trusts

Before case-mix adjustment, the overall variation in ES rates across NHS trusts was greatest for cholelithiasis (median of 18.9%, 10^{th} to 90^{th} centile 7.1%-35.4%), and hernia (59.0%, 49.9%-69.6%), followed by intestinal obstruction (29.9%, 24.3%-35.6%), appendicitis (93.0%, 88.5%-96.1%), and diverticular disease (10.9%, 7.9%-15.0%) (Figure 2). Figure 3 shows that variation in ES across NHS trusts remained after case-mix adjustment. Rates of ES between trusts were positively correlated for all conditions and highest between appendicitis and cholelithiasis (r=0.33). The level of unexplained variation did not appear related to the volume of emergency admissions for the respective condition within each trust. The estimated proportion of the unexplained variation that was at the level of the NHS trust rather than the patient, was highest for cholelithiasis, with intraclass correlation (95% confidence interval) of 0.169 (0.137 to 0.205), followed by appendicitis (0.053, 0.042 to 0.067), hernia (0.027, 0.021 to 0.035), diverticular disease (0.022, 0.016 to 0.029), and intestinal obstruction 0.014, 0.010 to 0.018).

Discussion

This paper reports variation in rates of ES across NHS trusts for patients presenting as emergency admissions to hospital with acute appendicitis, cholelithiasis, diverticular disease, abdominal wall hernia or intestinal obstruction. This variation remained after adjustment for differences in patient-level characteristics and the time-period of the emergency admission, and was greatest for patients admitted as an emergency with diagnoses of acute cholelithiasis. The study also reported wide differences in ES according to age-group. Older patients were less likely to receive ES, after allowing for differences in other patient characteristics, including number of Charlson comorbidities, level of frailty, and diagnostic subcategory. The decline in the rate of ES with increasing age, was greatest for patients with appendicitis and cholelithiasis.

The study finds differences amongst the five conditions in the levels of unexplained variation across NHS trusts in ES rates. The largest level of unexplained variation in ES is for patients presenting with acute cholelithiasis, which suggests that in some trusts, NICE guidelines that recommend laparoscopic cholecystectomy within seven days of diagnosis, are not being followed.[20] These guidelines are informed by evidence from meta-analysis that reported improved outcomes for ES versus delayed cholecystectomy for patients with biliary colic, acute cholecystitis or gallstone pancreatitis.[21] Despite these recommendations, related research has also reported large levels of unexplained variation across NHS trusts in ES over a two-month time period.[14] The present study adds to these previous findings in reporting these levels of unexplained variation across a large number of NHS trusts (136), over a ten-year time period.

The unexplained variation in ES for patients with acute cholelithiasis, is after adjusting for the annual volume of ES procedures performed in each trust, and may reflect differences in the levels of surgical expertise and resource availability across NHS trusts. Previous research on trust-level variation for patients with benign gallbladder diseases, reported higher ES in those centres with a specialist hepato-biliary (HPB) centre available, which may reflect better availability of operating theatre space, clearer understanding of the evidence comparing emergency and delayed cholecystectomy, or the enthusiasm to deliver an emergency cholecystectomy service.[14] This previous study found that other trust-level factors, such as the availability of ES operating lists specific to the condition, or the number of consultants with expertise in the specific forms of ES, were not associated with ES rates for patients with benign gall bladder diseases. [14] Surgeon-lead quality Improvement initiatives such as the Cholecystectomy Quality Improvement Collaborative (Chole-QuIC), have the potential to increase the uptake of ES.[22] Lessons from these initiatives, which warrant consideration more widely, include the importance of ensuring that all stakeholders (surgeons, senior service managers and staff gatekeeping emergency theatre lists) agree on the purpose and benefits of rapid surgical intervention.[22]

For acute appendicitis and abdominal wall hernia, the unexplained variation in ES across trusts was moderately large, and may reflect the lack of evidence about which patients benefit from ES versus NES for these conditions, that there are less well-defined care pathways, and a lack of clinical guidelines in the UK to inform the choice of whether or not the patient has ES.[23,24] It is also notable that in this study, abdominal wall hernia covered heterogenous groups of patients with inguinal, femoral, umbilical and ventral hernias and also included bilateral hernias. The unexplained variation across trusts remains after adjusting for these diagnostic subcategories. It is also important to recognise that, over the study time-period, emergency admissions with abdominal wall hernia were not managed by a distinct surgical subspeciality in the UK, which may have hindered attempts to standardise practice,[24] and that different local policies on restricting elective hernia surgery affected emergency provision.[25,26] For patients with uncomplicated acute appendicitis the emerging evidence for antibiotics as an alternative to ES may explain variability.[6,7]

For patients with intestinal obstruction and diverticular disease, the variation in ES rates across trusts was relatively low, which for diverticular disease may reflect increased standardisation in the clinical management of the condition over the study's time-period, that RCTs were undertaken, and these required clinical pathways to be developed.[27-29] For diverticular disease, there is consensus in the UK about the surgical speciality (colorectal surgery) that manages patients. For patients with acute diverticular disease, ES has declined over time,[30] and the low ES rate reflects current NICE recommendations that encourages NES strategies, and the lack of high-quality evidence on the effectiveness of ES for patients with acute diverticular disease.[31] Indeed, for both these conditions, the unexplained variations in ES across trusts while low compared to the other three conditions, is still of sufficient magnitude to raise concerns that for some underlying patient subgroups, similar patients received ES in some trusts and NES in others.

This research extends previous studies which have generally found lower rates of ES for specific subgroups of older patients presenting with acute conditions within the UK.[12-14] Reports by the Royal College of Surgeons of England have generally found lower levels of ES for patients aged over 75 versus those aged 65-74, notably for patients with acute cholelithiasis.[13,14] These previous national recommendations have discouraged ES rationing by biological age,[13,14] and called for further research on ES by age to also consider co-morbidities and frailty. A previous study of five common surgical emergencies including appendicitis, and incarcerated or strangulated hernia, found that rates of ES were lower in the UK than for comparable patients in the US, and that within the UK in-hospital mortality was lower for patients who had ES versus those who did not, after adjustment for some case-measures.[32] Our study finds that, even after adjusting for a wider range of case-mix measures including frailty, ES generally decreases with age. For patients with acute cholelithiasis and appendicitis this age-gradient is especially steep and goes across the age distribution. For patients presenting with hernia, previous studies reported higher ES rates for patients aged over 75, versus patients aged 65-74.[12,13]

Previous reports comparing ES across age groups,[12,13] did not adjust for differences in levels of frailty, number of co-morbidities or diagnostic subcategories. Our finding that in diverticular disease and intestinal obstruction patients with no Charlson comorbidities, there is a strong association between increasing frailty and ES receipt might appear counterintuitive. However, a previous study in perforated diverticular disease found that while comorbidity was associated with higher mortality, the relative risk of mortality compared to the general population, was highest for patients without comorbidity.[33] The present study emphasises the importance of allowing for other case-mix differences, when trying to understand reasons for different levels of ES across patient groups.

This study has several strengths. First, the study considered all eligible emergency admissions from 136 acute hospital trusts across a 10-year time-period. By adopting these broad inclusion criteria, the study had a representative sample of emergency admissions that was sufficiently large to draw inferences about the association of a multitude of routinely measured patient factors with receipt of ES. Second, unlike previous comparisons of ES rates across areas, and patient demographics,[11-13] the study was able to adjust for differences in other routinely available measures of patient case-mix, in particular patient frailty and the number of co-morbidities. Third, the study used clinically-relevant definitions of ES that could be applied to large-scale administrative datasets.

The limitations of this paper are: detailed information on patients' acute condition, for example their physiology at admission were not available, and for some conditions (e.g. acute appendicitis, diverticular disease) the absence of information from imaging could mean that differences in the true diagnosis or severity of the condition may explain some of the variations in ES across NHS trusts or patient subgroups. Other unmeasured variables which could be important in helping understand these variations include: patient preferences, and lack of emergency theatre capacity for these conditions within the local health care systems. A further challenge is that the categorisation of ES versus NES assumes accurate coding of OPCS procedures and episode dates. It is conceivable that there were coding differences across NHS trusts, for example, some trusts could code patients with umbilical hernia as ventral hernia and vice-versa. However, this would seem unlikely to explain differences in ES rates of the magnitude reported. Third, this paper does not seek to define the optimum level of ES versus NES for each condition.

This paper therefore provokes important areas for further research. In particular, given the wide variations in ES rates reported, there is a clear requirement for evidence about the effectiveness of ES versus NES strategies for subgroups of patients presenting as emergency admissions with acute conditions. The ESORT study, will use the variation across NHS trusts and hospitals in ES rates to assess the effectiveness and cost-effectiveness of ES for each of these five conditions.[15] This can provide complementary evidence to that available from recent RCTs,[6] and ongoing observational studies.[24,34]

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Tables and Figures

Table 1: Patient characteristics of the five cohorts

	Appendicitis (n=268,253)	**Cholelithiasis (n=241,626)**	**Diverticular disease (n=139,090)**	**Hernia (n=107,325)**	**Intestinal obstruction (n=137,744)**
Age category: n (%)					
Under 25	63,405 (23.6)	12,137 (5.0)	310 (0.2)	2,282 (2.1)	2,251 (1.6)
25-29	37,585 (14.0)	15,339 (6.4)	1,077 (0.8)	3,159 (2.9)	2,352 (1.7)
30-34	31,391 (11.7)	16,480 (6.8)	2,471 (1.8)	4,021 (3.8)	2,807 (2.0)
35-39	25,494 (9.5)	16,121 (6.7)	4,659 (3.4)	4,760 (4.4)	3,520 (2.6)
40-44	21,668 (8.1)	17,783 (7.4)	7,595 (5.5)	6,137 (5.7)	4,770 (3.5)
45-49	19,799 (7.4)	20,627 (8.5)	11,482 (8.3)	7,832 (7.3)	6,850 (5.0)
50-54	17,431 (6.5)	21,133 (8.8)	14,021 (10.1)	8,295 (7.7)	8,578 (6.2)
55-59	13,844 (5.2)	19,783 (8.2)	14,077 (10.1)	8,014 (7.5)	9,724 (7.1)
60-64	11,158 (4.2)	18,907 (7.8)	13,681 (9.8)	8,406 (7.8)	11,612 (8.4)
65-69	9,464 (3.5)	19,799 (8.2)	14,339 (10.3)	9,241 (8.6)	14,462 (10.5)
70-74	6,992 (2.6)	18,969 (7.9)	14,677 (10.6)	10,414 (9.7)	16,425 (11.9)
75-79	4,729 (1.8)	16,863 (7.0)	14,106 (10.1)	10,859 (10.1)	17,330 (12.6)
80-84	3,019 (1.1)	14,179 (5.9)	12,893 (9.3)	10,881 (10.1)	16,686 (12.1)
85-89	1,606 (0.6)	9,061 (3.8)	9,149 (6.6)	8,276 (7.7)	12,697 (9.2)
90 and over	668 (0.3)	4,445 (1.8)	4,553 (3.3)	4,748 (4.4)	7,680 (5.6)
Sex: n (%)					
Female	123,520 (46.1)	163,219 (67.6)	81,994 (59.0)	37,776 (35.2)	72,237 (52.4)
Male	144,720 (54.0)	78,398 (32.5)	57,093 (41.1)	69,545 (64.8)	65,504 (47.6)
Missing	13	9	3	4	3
Ethnicity: n (%)					
Black/Black mixed	6,401 (2.7)	4,761 (2.1)	2,132 (1.6)	2,647 (2.7)	3,433 (2.6)
Asian/Asian mixed	12,721 (5.3)	11,359 (5.0)	2,421 (1.8)	3,621 (3.6)	4,462 (3.4)
White	211,433 (88.0)	207,696 (90.7)	126,246 (95.2)	91,651 (91.7)	122,152 (92.3)
Chinese and other	9,764 (3.6)	5,105 (2.2)	1,876 (1.4)	1,989 (2.0)	2,361 (1.8)
Missing	27,934	12,705	6,415	7,417	5,336
Deprivation quintile:					
Most deprived	53,835 (20.4)	56,610 (23.7)	25,024 (18.1)	23,033 (21.7)	24,167 (17.7)
2	54,385 (20.6)	50,779 (21.2)	27,325 (19.8)	22,094 (20.8)	26,253 (19.3)
3	53,351 (20.2)	48,313 (20.2)	29,119 (21.1)	21,908 (20.6)	28,914 (21.2)
4	51,739 (19.6)	44,492 (18.6)	29,270 (21.2)	20,646 (19.4)	28,796 (21.1)
Least deprived	50,564 (19.2)	39,067 (16.3)	27,180 (19.7)	18,614 (17.5)	28,092 (20.6)
Missing	4,379	2,365	1,172	1,030	1,522
Comorbidity: n (%)					
None	222,935 (83.1)	157,866 (65.3)	83,367 (59.9)	66,156 (61.6)	72,308 (52.5)
1	39,727 (14.8)	62,343 (25.8)	39,661 (28.5)	29,847 (27.8)	43,582 (31.6)
2	4,753 (1.8)	17,108 (7.1)	12,697 (9.1)	9,013 (8.4)	17,129 (12.4)
3 or more	838 (0.3)	4,309 (1.8)	3,365 (2.4)	2,309 (2.2)	4,725 (3.4)
Frailty index: n (%)					
Fit	221,900 (82.7)	157,866 (65.3)	72,225 (51.9)	57,435 (53.5)	62,989 (45.7)
Mild frailty	38,612 (14.4)	62,343 (25.8)	44,551 (32.0)	32,973 (30.7)	45,428 (33.0)
Moderate frailty	6,200 (2.3)	17,108 (7.1)	16,163 (11.6)	12,416 (11.6)	20,497 (14.9)
Severe frailty	1,541 (0.6)	4,309 (1.8)	6,151 (4.4)	4,501 (4.2)	8,830 (6.4)

Table 2: Percentage of emergency admissions receiving ES according to patient characteristics

	Appendicitis (n=268,253)	Cholelithiasis (n=241,626)	Diverticular disease (n=139,090)	Hernia (n=107,325)	Intestinal obstruction (n=137,744)
Age category:					
Under 25	99.0	26.4	14.5	50.2	32.5
25-29	94.5	27.4	13.0	51.9	27.3
30-34	94.0	26.3	11.5	53.7	27.8
35-39	93.8	25.6	10.9	53.6	29.4
40-44	93.1	25.0	10.9	55.6	30.9
45-49	92.0	24.8	9.9	57.2	31.4
50-54	91.3	24.1	9.6	58.4	30.2
55-59	89.9	23.0	9.7	58.5	31.1
60-64	88.4	20.7	11.4	59.4	31.2
65-69	86.7	19.9	13.1	61.4	31.7
70-74	85.3	18.2	13.5	60.6	31.8
75-79	80.5	15.8	12.9	60.0	30.9
80-84	75.5	12.4	11.3	59.2	30.5
85-89	67.3	9.8	8.1	57.8	26.3
90 and over	50.8	6.8	4.2	53.0	19.6
Sex:					
Female	91.7	22.6	10.3	65.5	32.6
Male	92.8	19.3	12.0	53.8	26.8
Comorbidity index:					
None	93.1	23.3	11.4	59.1	31.6
1	89.9	19.7	10.9	58.0	29.9
2	78.1	14.9	9.2	52.6	24.8
3 or more	65.0	10.1	8.1	45.2	21.0
Frailty index:					
Fit	93.2	22.8	8.3	57.2	28.2
Mild frailty	89.4	20.5	12.2	59.1	30.6
Moderate frailty	81.3	17.3	16.2	58.5	32.2
Severe frailty	73.0	15.6	19.4	56.5	32.5

Table 3: Emergency admissions receiving ES according to patient characteristics, with adjusted odds ratios

	Appendicitis (n=268,253)	Cholelithiasis (n=241,626)	Diverticular disease (n=139,090)	Hernia (n=107,325)	Intestinal obstruction (n=137,744)
Age category:					
Under 25	2.00 (1.87, 2.13)	1.33 (1.25, 1.40)	1.76 (1.20, 2.60)	0.93 (0.84, 1.04)	1.11 (1.00, 1.25)
25-29	1.79 (1.67, 1.92)	1.30 (1.24, 1.37)	1.33 (1.06, 1.66)	0.99 (0.90, 1.09)	0.86 (0.77, 0.96)
30-34	1.54 (1.43, 1.66)	1.22 (1.15, 1.28)	1.14 (0.97, 1.34)	1.03 (0.94, 1.12)	0.91 (0.82, 1.01)
35-39	1.44 (1.34, 1.56)	1.12 (1.06, 1.18)	1.09 (0.96, 1.24)	0.98 (0.90, 1.06)	0.91 (0.82, 1.00)
40-44	1.23 (1.14, 1.32)	1.03 (0.98, 1.09)	1.08 (0.97, 1.21)	0.97 (0.90, 1.05)	0.99 (0.91, 1.08)
45-49	reference	reference	reference	reference	reference
50-54	0.87 (0.80, 0.94)	0.92 (0.87, 0.96)	1.04 (0.94, 1.14)	1.01 (0.94, 1.08)	0.94 (0.87, 1.01)
55-59	0.73 (0.68, 0.79)	0.84 (0.80, 0.89)	1.05 (0.96, 1.16)	0.97 (0.90, 1.04)	0.98 (0.91, 1.06)
60-64	0.62 (0.57, 0.68)	0.71 (0.67, 0.74)	1.25 (1.13, 1.37)	0.97 (0.90, 1.04)	0.97 (0.91, 1.04)
65-69	0.52 (0.48, 0.57)	0.66 (0.63, 0.70)	1.48 (1.34, 1.62)	0.96 (0.89, 1.03)	1.01 (0.95, 1.08)
70-74	0.47 (0.43, 0.51)	0.59 (0.56, 0.62)	1.45 (1.32, 1.60)	0.94 (0.87, 1.01)	0.96 (0.90, 1.03)
75-79	0.34 (0.31, 0.38)	0.49 (0.46, 0.52)	1.40 (1.27, 1.54)	0.87 (0.81, 0.93)	0.91 (0.85, 0.97)
80-84	0.26 (0.24, 0.29)	0.36 (0.34, 0.39)	1.05 (0.94, 1.16)	0.78 (0.72, 0.84)	0.84 (0.79, 0.90)
85-89	0.17 (0.15, 0.19)	0.27 (0.25, 0.29)	0.67 (0.59, 0.75)	0.70 (0.64, 0.75)	0.66 (0.61, 0.71)
90 and over	0.09 (0.07, 0.10)	0.17 (0.15, 0.19)	0.29 (0.24, 0.35)	0.47 (0.43, 0.52)	0.44 (0.40, 0.48)
Sex:					
Female	0.95 (0.93-0.98)	1.18 (1.15-1.21)	0.97 (0.93, 1.02)	0.98 (0.95-1.02)	1.27 (1.24, 1.30)
Male	reference	reference	reference	reference	reference
Comorbidity:					
None	reference	reference	reference	reference	reference
1	0.86 (0.82, 0.90)	0.87 (0.84, 0.89)	0.71 (0.68, 0.75)	0.88 (0.85, 0.91)	0.77 (0.75, 0.80)
2	0.54 (0.50, 0.59)	0.67 (0.64, 0.71)	0.44 (0.41, 0.48)	0.71 (0.66, 0.75)	0.56 (0.54, 0.59)
3 or more	0.37 (0.31, 0.43)	0.44 (0.39, 0.49)	0.33 (0.28, 0.38)	0.57 (0.51, 0.63)	0.42 (0.39, 0.46)
Frailty index:					
Fit	reference	reference	reference	reference	reference
Mild	0.99 (0.94, 1.03)	1.11 (1.08, 1.15)	2.00 (1.90, 2.11)	1.01 (0.97, 1.05)	1.42 (1.38, 1.47)
Moderate	0.89 (0.81, 0.97)	1.22 (1.16, 1.28)	3.29 (3.06, 3.54)	0.93 (0.88, 0.99)	1.84 (1.77, 1.92)
Severe	0.80 (0.70, 0.92)	1.34 (1.23, 1.45)	3.84 (3.48, 4.24)	0.72 (0.66, 0.78)	1.98 (1.87, 2.10)

Figure 1: Association between age group and receiving ES, with adjusted odds ratios (95% CIs) in comparison with 45-49 year olds.

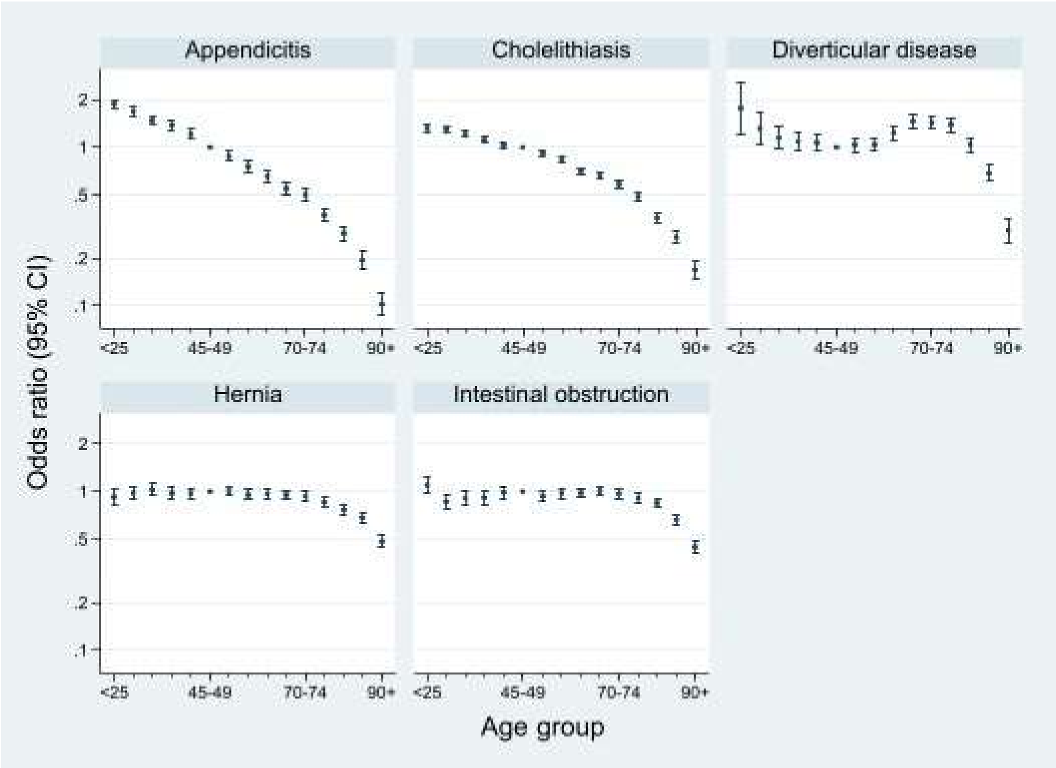


Figure 2: Variation in rates of emergency surgery in emergency admissions to 136 acute NHS Trusts in England April 2010-December 2019

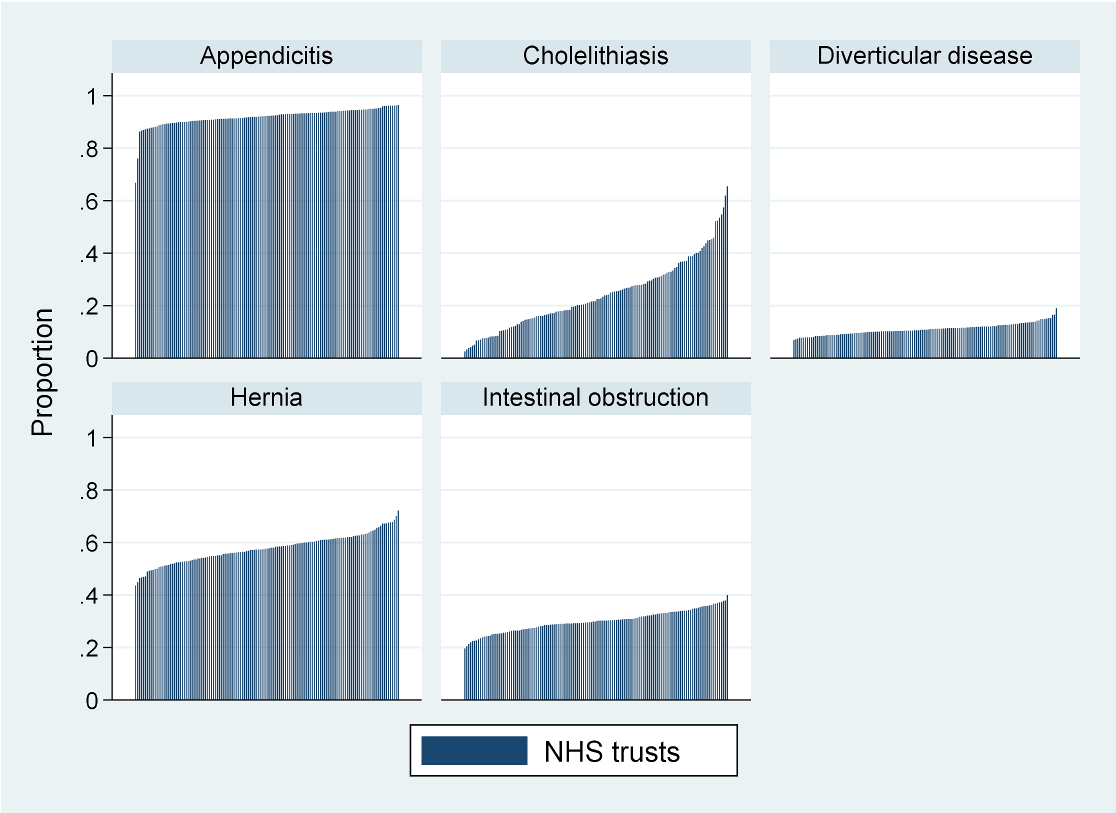
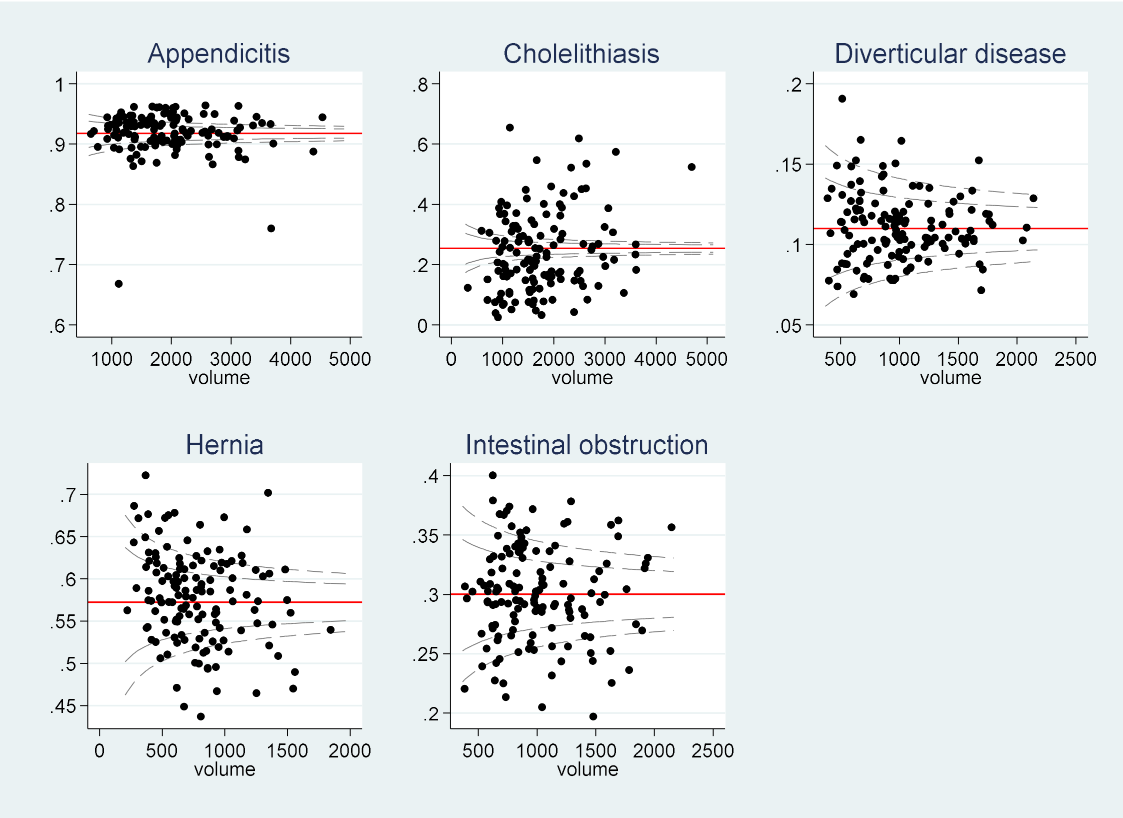


Figure 3: Funnel plots of variation in rates of emergency surgery in 136 acute NHS Trusts in England April 2010-December 2019



Control limits are at 95% (long dash) and 99.8% (short dash).

Supplementary tables (provided separately)

Supplementary Table S1: List of ICD-10 codes considered for inclusion criteria

Supplementary Table S2: Clinical panel-derived diagnostic inclusion and exclusion criteria

Supplementary Table S3: Clinical panel-derived definitions of emergency surgery for each condition

Supplementary Table S4: Inclusion and exclusion criteria for emergency admissions to 136 acute NHS Trusts in England April 2010-December 2019

Supplementary Table S5: Frequency of diagnostic subcategories for each condition

Supplementary Table S6: Characteristics of emergency surgery for each condition

Supplementary Table S7: Adjusted odds ratios for association between SCARF frailty index and receipt of ES for diverticular disease and intestinal obstruction at each level of the Charlson comorbidity index