Emergency general surgery: Impact of hospital and surgeon admission case volume on mortality

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BACKGROUND: Emergency general surgery (EGS) is a high-volume and high-risk surgical service. Interhospital variation in EGS outcomes exists, but there is disagreement in the literature as to whether hospital admission volume affects in-hospital mortality. Scotland collects high-quality data on all admitted patients, whether managed operatively or nonoperatively. Our aim was to determine the relationship between hospital admission volume and in-hospital mortality of EGS patients in Scotland. Second, to investigate whether surgeon admission volume affects mortality.

METHODS: This national population-level cohort study included EGS patients aged 16 years and older, who were admitted to a Scottish hospital between 2014 and 2018 (inclusive). A logistic regression model was created, with in-hospital mortality as the dependent variable, and admission volume of hospital per year as a continuous covariate of interest, adjusted for age, sex, comorbidity, deprivation, surgeon admission volume, surgeon operative rate, transfer status, diagnosis, and operation category.

RESULTS: There were 376,076 admissions to 25 hospitals, which met our inclusion criteria. The EGS hospital admission rate per year had no effect on in-hospital mortality (odds ratio [OR], 1.000; 95% confidence interval [CI], 1.000–1.000). Higher average surgeon monthly admission volume increased the odds of in-hospital mortality (>35 admissions: OR, 1.139; 95% CI, 1.038–1.250; 25–35 admissions: OR, 1.091; 95% CI, 1.004–1.185; <25 admissions was the referent).

CONCLUSION: In Scotland, in contrast to other settings, EGS hospital admission volume did not influence in-hospital mortality. The finding of an association between individual surgeons' case volume and in-hospital mortality warrants further investigation. (*J Trauma Acute Care Surg.* 2021;90: 996–1002. Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Care management, Level IV.

KEY WORDS: Emergency general surgery; hospital admission volume; surgeon admission volume; mortality; epidemiology.

Emergency general surgery (EGS) is a high-volume and high-risk surgical service. Morbidity and mortality are particularly high in the elderly, who form a large proportion of those using EGS services.[1–4] Emergency general surgery admissions are increasing annually, associated with an aging demographic,[1,2,5] and there is variation in EGS outcomes between hospitals.[6,7] There has been an increasing trend in multiple medical and surgical specialties to centralize services, to concentrate patients in centers of excellence, which has led to improved outcomes and less variation in care.[8–15] For example, trauma services have been regionalized in many countries, including the United States and United Kingdom, based on evidence that higher hospital volumes of trauma lead to better outcomes for high-risk patients, although the effect is not as pronounced for low-risk patients.[16,17] Along with concentrating complex care, smaller hospitals must be incorporated in the overall network, because inclusive systems are more effective than exclusive networks.[17,18] However, trauma and EGS are different conditions, and further centralization of EGS services may not lead to improved outcomes.

There is disagreement in the literature as to whether EGS outcomes are affected by hospital volumes. While some studies have demonstrated a clear relationship, suggesting patients treated at hospitals with larger volumes have improved survival,[19,20] others did not find a clear relationship between hospital volumes and patient outcome.[21–24] Several analyses have demonstrated that higher hospital operative volume was of limited benefit, while high surgeon operative volume and specialization improved outcome.[25–27] Given the ongoing uncertainty regarding whether outcomes for EGS are affected by case load, a comprehensive evaluation is warranted. Scotland is particularly well suited as a research site to answer this question because of the quality and breadth of routine administrative data collected by the Information Services Division (ISD) of the Scottish Government.[28] Most of the existing studies report only on patients who have undergone an operation, but our previous work has demonstrated that only 25% of patients who are admitted to an EGS service have operations,[3] and that this proportion has been decreasing over time.[1] Furthermore, even nonoperatively managed patients admitted to EGS services have high mortality.[1–4] Therefore, it is prudent to capture all admitted patients for analysis, as opposed to only those who underwent an operation.

The primary aim of this study was to determine the relationship between EGS hospital admission volume and outcome of EGS patients in Scotland. The secondary aim was to investigate whether the admission volume load of individual surgeons affects mortality. Our hypothesis is that, as hospital admission volume and surgeon admission volume increased, mortality decreased.

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METHODS

Data Source

Our study data comprised routinely collected administrative data from the ISD of the Scottish Government,[28] which has been described in detail in our previous works.[1–4] The data comprised a national database, using the entire adult population of EGS patients during the study period, thus a sample size calculation was not applicable as there was no sample. Any study period beyond ours (5 years) contains a risk of chronological bias. Nevertheless, our data represent a larger study size than cohort studies focusing on a similar research question.[24,27]

Case Definition and Data Selection

We included all patients in the calendar years 2014 to 2018 (5-year period), 16 years and older, who were admitted under the care of a consultant (attending) general surgeon in Scotland, as an emergency. We excluded those who were 15 years and younger (5,528 admissions), those for whom sex was unknown (10 admissions), those hospitals which had less than one EGS admission per week (56 admissions in 14 hospitals), and those hospitals which either opened or closed during the study period (29,207 admissions in five hospitals), to avoid the potential confounding factor of major organizational change. Patients were followed up until date of discharge.

Data obtained from ISD included age; sex; Charlson Comorbidity Index (CCI, 10-year look-backs)[29]; Scottish Index of Multiple Deprivation (SIMD) (2016 quintiles), a measure of social deprivation[30]; transfer status (whether patients had been transferred from a domicile environment, hospital or subspecialty, care facility, or other); diagnoses (based on the International Statistical Classification of Diseases and Related Health Problems, 10th Revision [ICD-10])[31]; and operations (based on the Office of Population, Censuses and Surveys classifications of surgical operations and procedures, fourth revision: OPCS4).[32] There were few missing data: none of the records were missing data for key variables (hospital, inpatient mortality, age, CCI, diagnosis, and operations), SIMD was missing in 2,577 (0.7%) records, and transfer status was missing in 1,449 (0.4%) records. We, therefore, determined that replacement of missing data (for example, using multiple imputation) was not required.

Hospital category (teaching hospital, large district general hospital [DGH], small DGH) is determined by the Scottish Government, based on published criteria.[7] Teaching hospitals cover a full range of services and with special units; large DGHs are general hospitals with some teaching units, and usually have more than 250 staffed beds; and small DGHs usually have less than 250 staffed beds.

Risk Adjustment

The authors used a theoretical, *a priori* approach to choose predictors for the risk adjustment model, based on previous research showing possible association with the chosen outcome.[1–4,9,20,21,24–27,33–38] Analyses were adjusted for demographics including age, sex, comorbidity (CCI), deprivation (SIMD quintiles), as well as surgeon admission volume, surgeon operative rate, transfer status, diagnosis, and operation categories. Age was divided into the following categories: 16–30, 31–45, 46–60, 61–75, >75, according to our previous work.[1–4] Age was evaluated as a categorical variable, rather than continuous variable, because our previous work has shown that the relationship between outcome and age in EGS is not linear,[1–4] with sharp increases in risk of mortality and morbidity with increasing age, thus treating age as a continuous variable would be inaccurate at the extremes of its estimation. Charlson Comorbidity Index was coded as 0 (no comorbidity), 1–2 (mild comorbidity), 3–4 (moderate comorbidity), and >4 (severe comorbidity). Deprivation is represented by SIMD, which is a comprehensive socio-economic ranking of small geostatistical areas. The results are often presented as quintiles (1, most deprived; 5, least deprived), which were evaluated as categorical variables in our risk adjustment.[30] Surgeon admission volume was classified by average monthly admissions and divided into three similar-sized bins: <25, 25–35, and >35 average monthly admissions, comprising 33.8% (127,255), 36.7% (138,131), 29.4% (110,655) of admissions, respectively. These broad categories were a pragmatic approach to provide more meaning than a continuous variable would in practice. Surgeon operative rate was calculated as the number of admissions that resulted in patients having an operation divided by the total number of admissions under the care of the surgeon over the time period of the study. We included surgeon operative rate because, given the assumption that EGS would present reasonably similar pathology, and risk and need

TABLE 1. Demographics of Scottish EGS by Inpatient Mortality, 2014–2018

Variables	Category	Inpatient Mortality: Alive	Inpatient Mortality: Died
Categorical		n (%)	n (%)
No. admissions		372,194 (99.0)	3882 (1.0)
Diagnosis	Low-risk diagnoses	349,176 (93.8)	2823 (72.7)
	High-risk diagnoses	23,018 (6.2)	1059 (27.3)
Operations	No operation	269,250 (72.3)	3228 (83.2)
	Operation	102,944 (27.7)	654 (16.8)
Operation category	Gastrointestinal	64,666 (17.4)	362 (9.3)
	Skin/soft tissue	21,194 (5.7)	116 (3.0)
	Other	17,070 (4.6)	176 (4.5)
Age, y	16–30	67,954(18.3)	6 (0.2)
	31–45	72,576 (19.5)	56 (1.4)
	46–60	89,331 (24.0)	281 (7.2)
	61–75	81,063 (21.8)	1036 (26.7)
	>75	61,270 (16.5)	2503 (64.5)
Sex	Male	165,147 (44.4)	1736 (44.7)
	Female	207,047 (55.6)	2146 (55.3)
Comorbidities	CCI = 0 (none)	207,247 (55.7)	323 (8.3)
	CCI = 1–2 (mild)	101,653 (27.3)	1135 (29.2)
	CCI = 3–4 (moderate)	32,443 (8.7)	935 (24.1)
	CCI > 4 (severe)	30,851 (8.3)	1489 (38.4)
Deprivation	SIMD 1 (most deprived)	104,005 (28.1)	1048 (27.1)
	SIMD 2	84,754 (22.9)	905 (23.4)
	SIMD 3	70,456 (19.1)	754 (19.5)
	SIMD 4	61,295 (16.6)	674 (17.4)
	SIMD 5 (least deprived)	49,115 (13.3)	493 (12.7)
Transfers	Domicile	324,456 (87.5)	3130 (81.0)
	Hospital	38,303 (10.3)	560 (14.5)
	Care facility	2032 (0.5)	128 (3.3)
	Other	5971 (1.6)	47 (1.2)
Hospital type	Teaching	164,190 (44.1)	1533 (39.5)
	Large DGH	184,085 (49.5)	2036 (52.4)
	Small DGH	23,919 (6.4)	313 (8.1)

		Alive: Mean	Alive: Median (IQR)	Died: Mean	Died: Median (IQR)
Continuous					
Age	Years	53	53 (36–69)	78	80 (71–86)
LOS	Days	3	1 (0–3)	7	3 (1–9)

n, number; IQR, interquartile range; LOS, length of hospital stay.

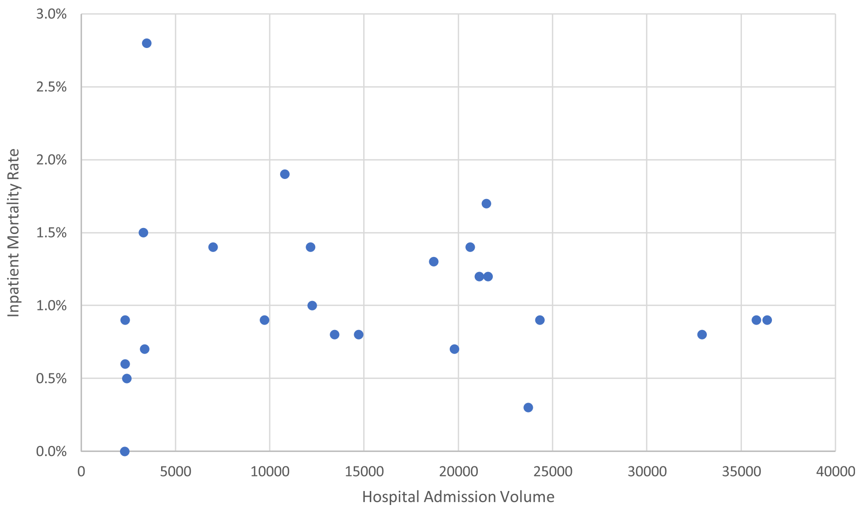

Figure 1. Unstandardized inpatient mortality rate by hospital admission volume.

for intervention regardless of who is on-call and at which hospital, the operative rate may be a surrogate of a surgeon's tendency towards intervention. Some surgeons are more risk averse in their decision-making, while others tend to accept risk when faced with similar situations. Transfer status was coded as those who were admitted from a domicile environment, transferred from another hospital or subspecialty, transferred from a care facility, or other (including those with no fixed abode, and those not resident in Scotland). Diagnoses were categorized into high risk EGS diagnoses, and all other diagnoses, based on the classification by Symons et al.,[33] using four-character ICD-10 diagnostic codes, details of which are available in Supplementary Table S1 (http://links.lww.com/TA/B925).[33] Operative categories were classified based on groupings of OPSC4 large letter categories and frequency in the data: nonoperative management (73.5%), gastrointestinal surgery (17.3%; G, H, J), skin and soft tissue (5.7%; S, T), and other (3.5%; A, B, C, D, E, F, K, L, M, N, P, Q, R, U, V, W, X).

Regression Analysis

A logistic regression model was created, with in-hospital mortality as the dependent variable, and admission volume of hospital per day as a continuous covariate of interest. This analysis was adjusted in the model for age, sex, CCI, SIMD, surgeon admission volume, surgeon operative rate, transfer status, diagnosis, and operation category. Values reported are significance (*p* value), odds ratio (OR) and its 95% confidence interval (CI). Statistical analysis was performed using SPSS (International Business Machines Corporation, Armonk, New York, USA).

Sensitivity Analyses

Two sensitivity analyses were performed. The first repeated the regression analysis and risk adjustment as before, but excluding any patient who had been transferred between hospitals, or from a different subspecialty (Supplementary Table S2, http://links.lww.com/TA/B926). The second repeated the regression analysis and risk adjustment as before, but excluding all admissions to small DGHs (Supplementary Table S3, http://links.lww.com/TA/B927).

Ethics Approval

This study was approved via the Public Benefit and Privacy Panel for Health and Social care (PBPP 1819–0340), and did not require research ethics approval.

RESULTS

Demographics

There were 410,877 EGS admissions during our study period. After excluding those patients who were 15 years and younger, those for whom sex was unknown, those hospitals which had less than one admission per week, and those hospitals which experienced major organizational change, a final number of 376,076 admissions to 25 hospitals were included for analysis.

Table 1 describes the demographics of Scottish EGS by inpatient mortality, including admissions, diagnostic category, operations, operation category, age, (categorical and continuous) sex, comorbidity, deprivation, transfer status, hospital type, and length of hospital stay (Table 1). There was considerable variation between those episodes where patients survived to discharge (99.0%) and those who died in hospital (1.0%), including the proportion of high-risk diagnoses (93.8% versus 72.7%, respectively), operation rate (27.7% versus 6.8%, respectively), median age (53 versus 80 years, respectively), severe comorbidities (8.3% versus 38.4%, respectively), transfers from a care facility (0.5% versus 3.3%, respectively), and length of hospital stay (3 days versus 7, respectively) (Table 1). More admissions who survived had gastrointestinal operations (17.4%) than those who died (9.3%). The male/female ratio, deprivation levels, and hospital classification were similar between those who survived and those who died (Table 1).

Figure 1 shows the unstandardized mortality rate of all included hospitals. There does not appear to be a relationship between the crude mortality rate and the hospital admission volume, although, as is to be expected, there is greater variability for hospitals with smaller admission volumes.

TABLE 2. Binary Logistic Regression Analysis, With In-Hospital Mortality as the Dependent Variable, for All Hospitals

Predictor	Category	OR 95% CI	p
Hospital admission rate per year		1.000 (1.000–1000)	0.778
Surgeon volume (average monthly admissions)	<25*	1.000	
	25–35	1.091 (1.004–1.185)	0.039
	>35	1.139 (1.038–1.250)	0.006
Surgeon operative rate	Admissions with operation/all admissions under surgeon	1.003 (0.999–1.008)	0.108
Age, y	16–30*	1.000	
	31–45	6.363 (2.740–14.776)	<0.001
	46–60	16.564 (7.366–37.244)	<0.001
	61–75	44.898 (20.068–100.446)	<0.001
	>75	119.421 (53.43–266.921)	<0.001
Sex	Male*	1.000	
	Female	1.112 (1.041–1.188)	0.002
Comorbidity (CCI)	CCI = 0 (none)*	1.000	
	CCI = 1–2 (mild)	3.179 (2.799–3.611)	<0.001
	CCI = 3–4 (moderate)	5.364 (4.698–6.125)	<0.001
	CCI > 4 (severe)	10.791 (9.514–12.239)	<0.001
Deprivation	SIMD 5 (least deprived)*	1.000	
	SIMD 4	1.093 (0.968–1.233)	0.15
	SIMD 3	1.052 (0.934–1.184)	0.404
	SIMD 2	1.125 (1.004–1.260)	0.043
	SIMD 1 (most deprived)	1.250 (1.118–1.397)	<0.001
Transfer status	Domicile*	1.000	
	Hospital	1.495 (1.356–1.649)	<0.001
	Care Facility	1.899 (1.568–2.299)	<0.001
	Other	0.893 (0.664–1.202)	0.457
High-risk diagnosis	Low risk*	1.000	
	High risk	3.828 (3.546–4.133)	<0.001
Operation classification	Nonoperative*	1.000	
	Gastrointestinal	0.404 (0.361–0.452)	<0.001
	Other	0.677 (0.579–0.792)	<0.001
	Skin/soft tissue	0.453 (0.374–0.548)	<0.001

Goodness of Fit: Cox & Snell R Square was 0.025; Nagelkerke R Square was 0.232.

*Referrent covariate category.

Inpatient mortality was the dependent variable, and independent variables included hospital admission rate per year, average monthly surgeon admission volume, surgeon operative rate, age, sex, comorbidity, deprivation, transfer status, high-risk diagnosis, and operative classification.

Regression Analysis

The results of the logistic binary regression analysis are shown in Table 2. The EGS hospital admission rate per day had no statistically significant effect on mortality (OR, 1.000; 95% CI, 1.000–1.000). Similarly, there was no significantly increased mortality depending on surgeon operative rate (OR, 1.003; 95% CI, 0.999–1.008).

Covariates associated with an increased risk of mortality included higher surgeon admission volume (>35 average monthly admissions: OR, 1.139; 95% CI, 1.038–1.250; 25–35 average monthly admissions: OR, 1.091; 95% CI, 1.004–1.185; <25 average monthly admissions is the referent), increasing age (age >75 years: OR, 119.421; 95% CI, 53.430–266.921; age 16–30 years is the referent), female sex (OR, 1.112; 95% CI, 1.041–1.188), increasing comorbidity (CCI > 4: OR, 10.791; 95% CI, 9.514–12.239; CCI = 0 is the referent), increased deprivation (SIMD 1—most deprived: OR, 1.250; 95% CI, 1.118–1.397; SIMD 5—least deprived—is the referent), requiring transfer from another hospital or subspecialty (OR, 1.495; 95% CI, 1.356–1.649) or care facility (OR, 1.899; 95% CI, 1.568–2.299), and high risk diagnosis (OR, 3.828; 95% CI, 3.546–4.133). Compared with those not having an operation, patients who underwent gastro-intestinal surgery (OR, 0.404; 95% CI, 0.361–0.452), skin/soft tissue surgery (OR, 0.453; 95% CI, 0.374–0.548), and other surgery (OR, 0.677; 95% CI, 0.579–0.792), all had lower mortality.

Sensitivity Analyses

The analysis was repeated after excluding those patients who had been transferred from another hospital or subspecialty (n = 335,764 admissions included). Mortality remained similar for the covariate of interest (hospital admission rate per year) (OR, 1.000; 95% CI, 1.000–1.000), and all covariates (Supplementary Table S2, http://links.lww.com/TA/B926).

The analysis was repeated after excluding all those admitted to a small DGH (n = 351,844 included). Mortality remained similar for the covariate of interest (hospital admission rate per year) (OR, 1.000; 95% CI, 1.000–1.000), and all covariates (Supplementary Table S3, http://links.lww.com/TA/B927).

DISCUSSION

Our results demonstrate that, in Scotland, EGS hospital admission volume does not influence inpatient mortality nor surgeon operative rate. Higher individual surgeon EGS admission volume adversely influences mortality. Many of the other covariates, which were controlled for, were also associated with increased mortality, including increasing age, female sex, increased morbidity, increased deprivation, requiring transfer from another hospital or subspecialty, and high-risk diagnosis. Interestingly, having an operation is associated with decreased mortality.

These data add to the debate about the impact of hospital volumes in the context of EGS care. Several recent large US-based studies have shown that higher EGS volume is associated with decreased mortality.[19,20] However, there are important differences between these analyses and our study, in terms of the patients included. There are also important differences between the US health care system, and the National Health Service. Furthermore, the findings of the US analyses must be viewed in the context of other literature, which shows less clear relationships between volume and mortality.[21–24,27] It is conceivable that these divergent results are not artefactual, and that there are genuine differences between settings.

A novel and unexpected finding was that, as the admission volume of individual surgeons increases, mortality increases. The reasons for this are unclear. On call surgeons in Scotland are generally free of elective surgical commitments. Nevertheless, the number of EGS patients looked after by some general surgeons in Scotland can be high, which could lead to cognitive overload, competing time pressures and poorer decision making, with resulting impact on outcomes. It is also possible that there are more delays to obtaining imaging, or operative treatment, in busier centers. Our finding, therefore, requires further study.

Methods for risk adjustment to statistically compare hospitals' mortality include hierarchical logistic regression modeling,[34] multivariable beta regression modeling,[35] and Bayesian modeling,[36] which can all evaluate patient-level and hospital-level effects. We chose logistic regression modeling as it was the most appropriate model to use to answer the research question we posed, using the data available. Becher et al.[36] suggested that socioeconomic deprivation should not be used in risk adjustment because it may mask disparity of care. However, in the context of Scotland where National Health Service hospital care is free from point of access, this is not considered to be an issue of disparity of care, and SIMD is a powerful description of regional deprivation, which will help the risk adjustment of patients.

Our data also confirm what other studies have found that mortality increases with age, comorbidity, deprivation, and high-risk diagnosis.[1–4,25,33,37] Having an operation is associated with a lower risk of mortality, however this most likely represents case selection, a tenet of operative principles: "choose well, cut well, get well."[38] Study patients not having an operation may be too frail to survive operative intervention—thus this could represent active decisions for palliation or symptom control rather than operative intervention. This reiterates the importance of including nonoperative patients in these hospital-wide analyses, as we have done.

Patients who are transferred from another hospital or subspecialty are at an increased risk of inpatient death in our study (OR, 1.495; 95% CI, 1.356–1.649). This is not surprising given common indications for transfer are to access specialist services or personnel, which are not available at the referring hospital, or patients initially admitted to medicine given their underlying comorbidity or frailty but found to have a surgical diagnosis of insidious onset.

The finding of female sex being associated with increased risk is also unexpected and unexplained. Although higher volumes of elderly females are admitted to EGS,[39] with associated comorbidity,[1] these variables have been adjusted for in the model. This also warrants further investigation.

The main strength of this study is that it used national data, accounting for all operative and nonoperative EGS patients admitted to Scottish hospitals over a 5-year period, which provided comprehensive evaluation of the research question. The main limitation is the possibility of insufficient data for risk adjustment: because this was an administrative data set, there was no information about patient's physiology, biochemistry, complexity of imaging, individual components of comorbidity, or granularity about diagnoses or operations performed. Second, the data did not allow quantification of the experience of the admitting surgeon, which may have an influence on decisions and outcomes, including operative rate and mortality. In other words, our analysis did not account for "learning curve" effects.

In Scotland, in contrast to other settings, emergency general surgery hospital admission volume does not influence inpatient mortality. Scottish hospitals provide a consistent level of EGS care, regardless of size.

The finding of an association between individual surgeon's case volume and mortality warrants further investigation.

AUTHORSHIP

J.M.W., G.R., M.B., N.S., A.J.M.W., and J.O.J. designed the study. J.M.W. performed the literature search. J.M.W., G.R., and J.O.J. arranged for data collection. J.M.W. and N.S. performed the data analysis. J.M.W. wrote the article. J.M.W., G.R., M.B., N.S., A.J.M.W., and J.O.J. interpreted the results, and provided critical revisions to the article.

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DISCLOSURE

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