World J Surg (2018) 42:2329–2338
https://doi.org/10.1007/s00268-018-4465-5

ORIGINAL SCIENTIFIC REPORT

Post-operative Complications Following Emergency Operations Performed by Trainee Surgeons: A Retrospective Analysis of Surgical Deaths

Noha Ferrah[1] · **Karen Stephan**[1] · **Janaka Lovell**[1] · **Joseph Ibrahim**[1] · **Barry Beiles**[2]

Published online: 23 January 2018

Abstract

Background Adequate surgical care of patients and concurrent training of residents is achieved in elective procedures through careful case selection and adequate supervision. Whether this applies when trainees are involved in emergency operations remains equivocal. The aim of this study was therefore to compare the risk of post-operative complications following emergency procedures performed by senior operators compared with supervised trainees.

Methods This is a retrospective cohort study examining in-hospital deaths of patients across all surgical specialties who underwent emergency surgery in Australian public hospitals reported to the national surgical mortality audit between 2009 and 2015. Multivariable logistic regression was used to explore whether there was an association between the level of operator experience (senior operator vs trainee) and the occurrence of post-operative surgical complications following an emergency procedure.

Results Our population consisted of 6920 patients. There were notable differences between the trainees and senior operator groups; trainees more often operated on patients aged over 80 years, with cardiovascular and neurological risk factors. Senior operators more often operated on very young and obese patients with advanced malignancy and hepatic disease. Supervised trainees had a lower rate of post-operative complications compared with senior operators; 18% ($n = 396$) and 25% ($n = 1210$), respectively ($p < 0.05$). Operations performed by trainees were associated with an 18% decrease (95% CI 5–29%; $p < 0.05$) in odds of post-operative complications compared with senior operators, adjusting for potential confounders.

Conclusions Contrary to popular belief, our results suggest that supervised trainees safely perform emergency operations, provided that cases are judiciously selected.

Introduction

Factors contributing to the mortality of patients undergoing surgery are the subject of considerable research. This has intensified since the publication of surgical mortality rates and the media attention to variations in the reported rates between individual surgeons and units [1, 2].

A phenomenon given much attention is the "resident effect" [3], whereby operations performed by surgical trainees are associated with greater mortality owing to their relative inexperience. This popular belief is contradicted by research evidence that there is no difference in patient

✉ Noha Ferrah
noha.ferrah@monash.edu

1 Department of Forensic Medicine, Monash University, 65 Kavanagh Street, Southbank, VIC 3006, Australia

2 Royal Australasian College of Surgeons, College of Surgeons' Gardens, 250-290 Spring Street, East Melbourne, VIC 3002, Australia

mortality between trainees and senior operators (consultants and fellows), if cases are judiciously selected (i.e. with a lower baseline risk, and appropriate level of complexity), and sufficient training and supervision is provided [4]. However, the evidence so far is limited to elective procedures [5, 6]. Whether mortality and morbidity in emergency procedures differ between trainees and senior operators remains uncertain.

Patients undergoing emergency surgery have significantly greater mortality compared to elective surgery, allegedly due to the severely deranged physiology, and the absence of peri-operative assessment or optimization in the former [3, 7]. The mortality rate is almost fourfold (13 vs 3%) in emergency surgery compared with non-emergency general surgery and the rate of major complications two-and-a-half-fold (33 vs 13%) [7].

A recent study highlighted an association between trainee involvement and increased rate of complications in emergency surgery, including rates of transfusions, unplanned return to theatre, post-operative wound complications and venous thromboembolic events, irrespective of operation time [6, 8].

This provoked controversy as the risk of post-operative complications following emergency operations among trainees compared with senior operators remains equivocal, being greater in some studies [6, 8, 9] and equivalent in others [5, 10, 11]. A caveat in many studies is that emergency procedures were not specifically isolated or only pertained to one surgical specialty [12].

Exposure of trainees to the operating theatre is essential to achieve satisfactory technical skills and judgment [5]. This is particularly problematic in emergency surgery, with the numbers of procedures having significantly decreased over the past few decades [13]. Trainees may therefore fail to acquire sufficient experience and competency, which may undermine the safety of future patients [14]. Determining whether involvement of trainees may affect outcomes of emergency procedures is therefore essential to ensure patient safety whilst providing adequate training and support [4]. The aim of this study was to compare the risk of post-operative complications following emergency procedures performed by senior operators compared with supervised trainees.

Methods

Study design and population

This is a retrospective cohort study examining in-hospital deaths of patients who underwent surgery in Australian public hospitals reported to the Australian and New Zealand Audit of Surgical Mortality (ANZASM) between 2009 and 2015. Data from New South Wales were not available for this analysis. Private hospitals were excluded from the analysis as their patients are not treated by trainees.

In 2012, the Royal Australasian College of Surgeons (RACS) mandated treating surgeons to complete a standard surgical case form for all in-hospital deaths of patients under the care of surgeon or where a surgeon was significantly involved, whether an operation occurred or not. Deaths are notified to the audit directly by hospitals and since 2011; 100% of public hospitals participated. All de-identified cases undergo a first-line review by a surgeon from the same specialty but from a different hospital, and approximately 12% of these have a detailed second-line review where a different surgeon has access to the original hospital records [15]. Feedback is then provided to the treating surgeon with the aim of educating and improving patient care.

Supervision was defined according to regulations and practices implemented in Australia [16]. Trainees receive on-site supervision by consultants and fellows who are scrubbed or non-scrubbed. Selection of cases where trainees are the primary surgeons is based upon the decision of the supervising surgeon. Trainees are required to perform a significant proportion of cases as primary surgeon and a certain proportion of cases of minor and major complexity.

The eligibility criteria for inclusion in this study were (Fig. 2):

- Emergency admissions to public hospitals
- Timing of operation was (1) immediate (<2 h post-admission); (2) emergency (<24 h); and (3) scheduled emergency (>24 h).
- Experience of operating surgeon and occurrence of post-operative complications were known.

Exclusion criteria were:

- American Society of Anaesthesiologists (ASA) grade 6, as these are “declared brain dead patients whose organs are being removed for donor purposes” [17].
- Patients who had more than one operation (because the complications in the database could refer to any of the operations performed during the admission)
- Operations performed by general practitioners (GP) and international medical graduates (IMG) as their competencies and training may differ from that of Australian consultants/fellows and trainees.

Data extraction

In order to adjust the analysis for confounders, information on age, sex and co-existing risk factors for death such as obesity, ASA grade (assigned by the surgeon), timing of operation, experience of operator, surgical diagnosis, type of operation and cause of death was extracted.

Surgical and education training (SET) is the programme responsible for the training and assessment of surgical trainees in Australia [18]. Service registrars are house officers within a surgical unit who may or may not have been selected into a SET programme. Experience of the most senior operating surgeon was thus stratified into two groups:

1. Consultants or fellows,
2. SET trainees or service registrars supervised by a consultant or fellow.

Although the level of experience varies considerably in the first group, a minimum standard of skills and autonomy is expected from all consultants.

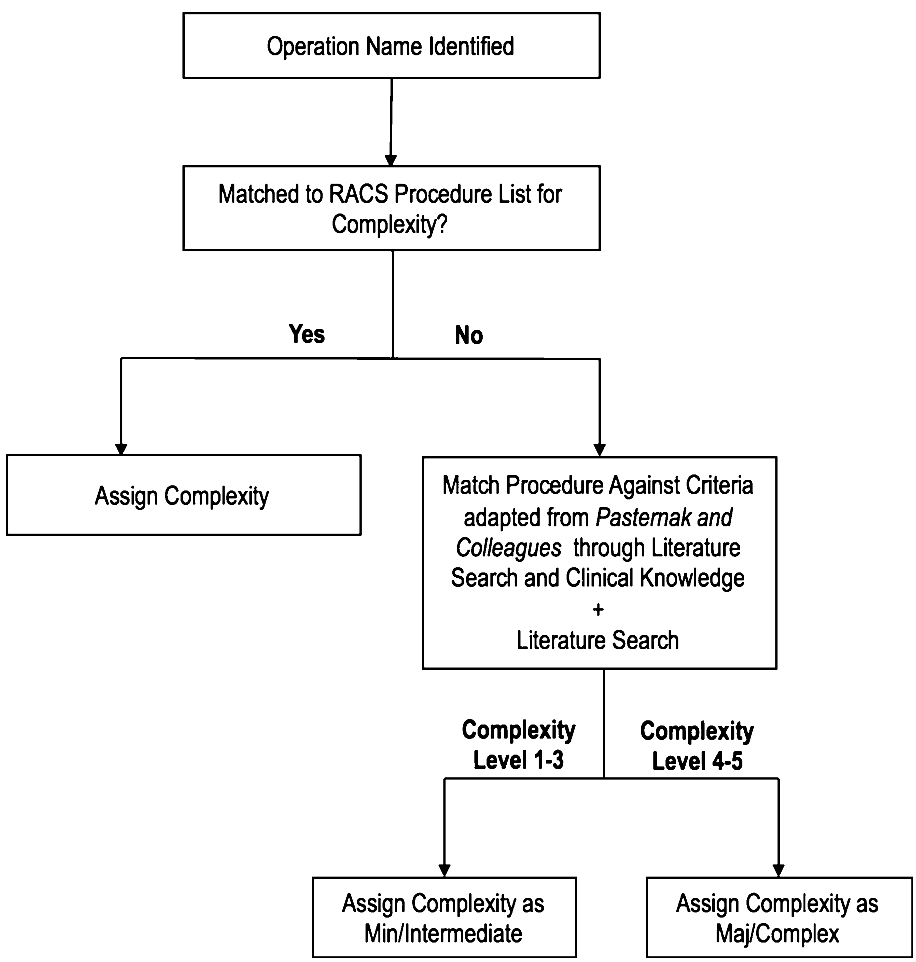
Operation type was classified according to the level of complexity based on recommendations from the RACS procedure list [19], developed for the purpose of SET training and assessment. If operations were not classifiable by this method, they were matched against Pasternak and colleagues' criteria and categorized as minor/intermediate for level 1–3 complexity or major/complex for level 4–5 (Fig. 1) [20]. The primary outcome was the occurrence of post-operative complications, which comprised surgical and general complications.

Statistical methods

Multivariable logistic regression was used to estimate the association between experience of operating surgeon in emergency procedures and the occurrence of post-operative complications.

Emergency cases assigned to less experienced operators may differ from those not involving trainees; these patients may be younger and have less co-morbidity, and operations may be less complex. The factors related to patient assignment may also be associated with post-operative complications and are therefore potential confounders to the relationship between the experience of the surgeon and post-operative complications. We used univariate logistic regression to investigate the relationship between several factors that may influence case assignment (age, sex, risk factors for death, ASA grade, timing of the operation and operation complexity) and the experience of the surgeon.

Fig. 1 Assignment of operation complexity



Variables that were significantly associated ($p < 0.05$) with surgeon experience in the univariate analyses were included as potential confounders in the multivariable model used to estimate the relationship between surgeon experience and post-operative complications. Surgical diagnoses were not included in the multivariable model, as a substantial proportion of patients had more than one diagnosis, and diagnosis did not provide any additional information on the complexity of the procedure or patient health status that were not already included. Cases with missing data for any of the variables in the multivariable model were excluded. Statistical analyses were performed using Stata Version 14.1 [21]. Model specification and goodness of fit were assessed using the link test [22], and the Pearson and Hosmer–Lemeshow goodness-of-fit tests, whilst the discriminative ability of the model was assessed by the area under the receiver operating characteristic (ROC) curve [23].

Ethics approval

The Monash University Human Research Ethics Committee (MUHREC) granted approval for this study on 4 August 2017 (10,514).

Results

Population

The final cohort consisted of 6920 patients who died following an emergency operation (Fig. 2). Almost half of patients were aged above 80 years (3285, 47.5%). Most had at least one risk factor for mortality, most commonly cardiovascular disease, followed by respiratory and renal disease, and displayed deranged physiology at presentation (Table 1).

Supervised trainees were the main operators for 2158 patients (31%). Notably, patient populations differed between senior operator and trainee groups, with a greater proportion of individuals aged over 80 years with cardiovascular and neurological risk factors in the trainee group. In contrast, senior operators operated more often on patients aged less than 80 years and most significantly those under 16 years, patients who were obese, had advanced malignancy, hepatic disease and other risk factors. Furthermore, senior operators performed procedures on proportionally more patients presenting with neoplasms, circulatory diseases such as ruptured abdominal aortic aneurysms, perinatal diseases, infection, gastrointestinal, respiratory and other diagnoses. In contrast, trainees performed proportionally more operations on patients with orthopaedic injury, neurological and dermatological disorders (Table 1).

The majority of patients were acutely ill at presentation, with almost half having an ASA grade of four (3273, 47%), corresponding to severe disease posing a constant threat to life. Individuals with ASA grade 1–3 were significantly more likely to be operated on by trainees (Table 1).

The most common diagnoses were injury and gastrointestinal diseases with 36.2 and 22.1% of diagnoses, respectively, whilst the most common causes of death were circulatory diseases and others, which included a large proportion of acute myocardial infarct and multiorgan failure, respectively.

Operations

Most operations were classified as emergency or scheduled emergency, occurring two or more hours after admission (5317, 77%). Senior operators performed a greater proportion of immediate operations (within 2 h of presentation) and in general, vascular and cardiothoracic surgery, whilst trainees performed proportionally more procedures in orthopaedics, neurosurgery and urology (Table 1).

Most operations were classified as major/complex (5800, 84%). Notably, there was no significant difference in the proportion of major and complex operations between the senior operator and trainee groups (Table 1).

Post-operative complications

Post-operative complications were reported for 1606 patients, representing 23% of the population. In other words, 23% of patients who died experienced a post-operative complication, whilst 77% of patients who died did not experience a post-operative complication. Supervised trainees had a lower rate of post-operative complications compared with senior operators; 18% ($n = 396$) and 25% ($n = 1210$), respectively ($p < 0.05$) (Table 1). Operations performed by supervised trainees were associated with an 18% decrease in adjusted odds of post-operative complications relative to senior operators, controlling for potential confounders (Table 2).

Multivariable logistic regression showed that compared with general surgery, the odds of post-operative complications were significantly higher in cardiothoracic and vascular cases and significantly lower in orthopaedic and neurosurgery cases (Table 2). The majority of post-operative complications were reported as “others”, as they were not deemed specific surgical complications, and these included acute myocardial event, pneumonia, acute kidney injury and pulmonary embolism. Within specific surgical post-operative complications, bleeding, procedure-related

Fig. 2 PRISMA flow chart of patient selection

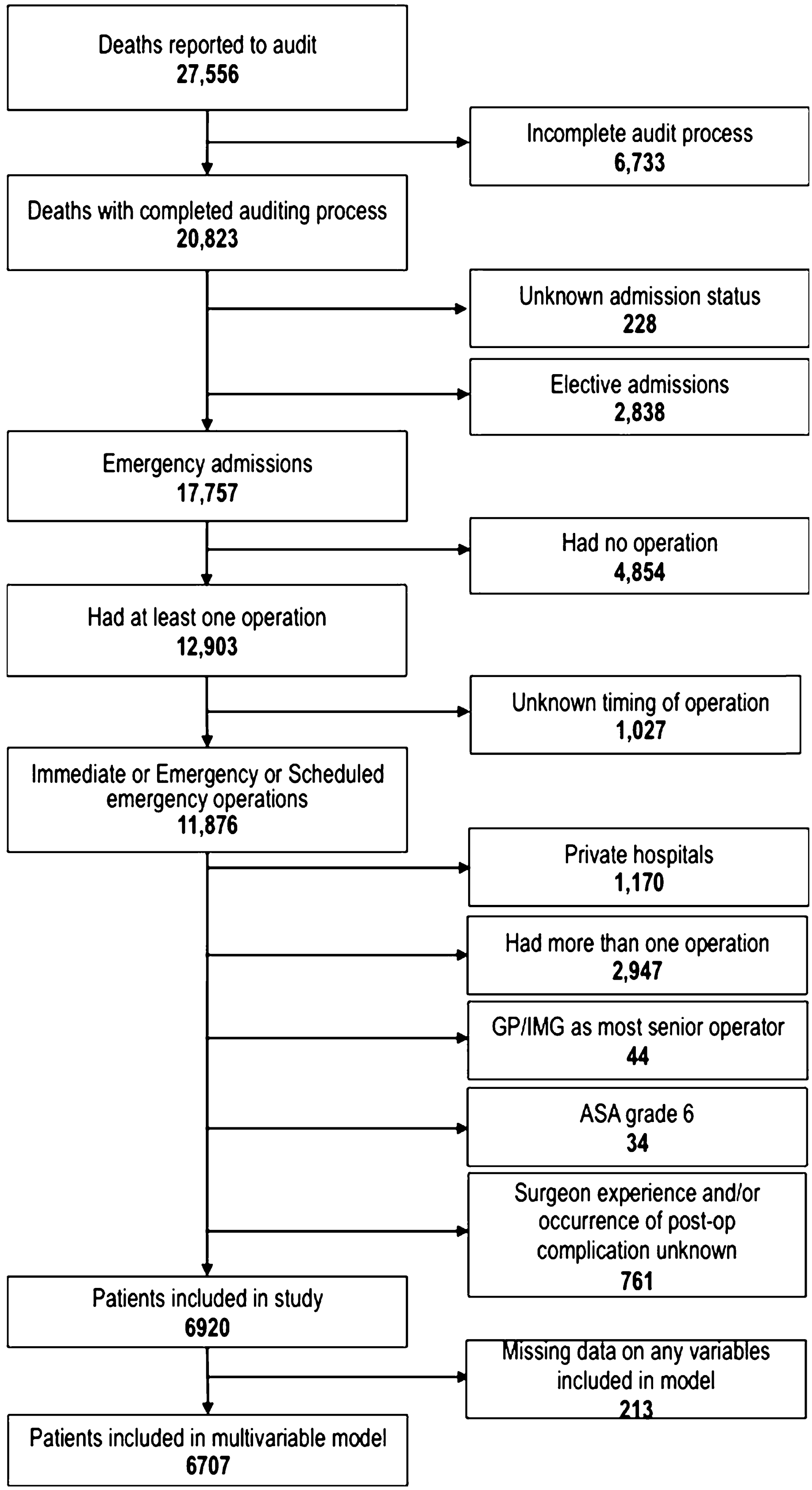


Table 1 Demographic and clinical characteristics of patients operated on by senior operators and trainees (univariate logistic regression)

Variables—frequencies	Senior operators ($N = 4762$)	Trainees ($N = 2158$)	Odds ratio (95% CI)	p value
Age group (years) n (%)				
0–15	95 (2.0)	11 (0.5)	**0.20 (0.10–0.37)**	**<0.0005**
16–45	329 (6.9)	119 (5.5)	**0.62 (0.49–0.77)**	**<0.0005**
46–65	770 (16.2)	294 (13.6)	**0.65 (0.56–0.76)**	**<0.0005**
66–80	1497 (31.4)	520 (24.1)	**0.59 (0.52–0.67)**	**<0.0005**
>80	2071 (43.5)	1214 (56.3)	1.0	
Gender n (%)				
Male*	2608 (54.8)	1092 (50.6)	**0.84 (0.76–0.94)**	**0.001**
Female	2148 (45.1)	1065 (49.4)	1.0	
Mortality risk factors n (%)	4265 (89.6)	1958 (90.7)	1.14 (0.96–1.36)	0.135
Advanced malignancy	621 (13.0)	225 (10.4)	**0.78 (0.66–0.91)**	**0.002**
Cardiovascular disease	2923 (61.4)	1436 (66.5)	**1.25 (1.12–1.39)**	**<0.0005**
Diabetes	856 (18.0)	374 (17.3)	0.96 (0.84–1.09)	0.516
Obesity	399 (8.4)	95 (4.4)	**0.50 (0.40–0.63)**	**<0.0005**
Renal disease	1262 (26.5)	575 (26.7)	1.01 (0.90–1.13)	0.900
Hepatic disease	387 (8.1)	128 (5.9)	**0.71 (0.58–0.88)**	**0.001**
Neurological disease	919 (19.3)	613 (28.4)	**1.66 (1.47–1.87)**	**<0.0005**
Respiratory disease	1656 (34.8)	796 (36.9)	1.10 (0.99–1.22)	0.089
Other	1176 (24.7)	475 (22.0)	**0.86 (0.76–0.97)**	**0.015**
ASA grade n (%)				
1 or 2	315 (6.6)	165 (7.7)	1.0	
3	1218 (25.6)	738 (34.2)	1.16 (0.94–1.43)	0.173
4	2279 (47.9)	994 (46.1)	0.83 (0.68–1.02)	0.076
5	804 (16.9)	194 (9.0)	**0.46 (0.36–0.59)**	**<0.0005**
Missing	146 (3.1)	67 (3.1)		
Surgical diagnosis n (%)				
Infection	111 (2.3)	29 (1.3)	**0.57 (0.38–0.86)**	**0.008**
Neoplasm	418 (8.8)	90 (4.2)	**0.45 (0.36–0.57)**	**<0.0005**
Injury	1238 (26.0)	1270 (58.9)	**4.07 (3.66–4.53)**	**<0.0005**
Gastrointestinal	1351 (28.4)	181 (8.4)	**0.23 (0.20–0.27)**	**<0.0005**
Musculoskeletal	57 (1.2)	33 (1.5)	1.28 (0.83–1.97)	0.260
Circulatory	999 (21.0)	371 (17.2)	**0.78 (0.69–0.89)**	**<0.0005**
CNS	29 (0.6)	24 (1.1)	**1.84 (1.07–3.16)**	**0.028**
Skin	47 (1.0)	42 (2.0)	**1.99 (1.31–3.03)**	**0.001**
Respiratory	47 (1.0)	8 (0.4)	**0.37 (0.18–0.79)**	**0.010**
Genitourinary	44 (0.9)	21 (1.0)	1.05 (0.62–1.78)	0.844
Pre/perinatal	81 (1.7)	2 (0.1)	**0.05 (0.01–0.22)**	**<0.0005**
Other[2]	97 (2.0)	23 (1.0)	**0.52 (0.33–0.82)**	**0.005**
Timing post-admission *n* (%)				
<2 h	1251 (26.3)	352 (16.3)	**1.0**	
<2–24 h	1978 (41.5)	861 (39.9)	**1.55 (1.34–1.78)**	**<0.0005**
<24 h	1533 (32.2)	945 (43.8)	**2.19 (1.90–2.53)**	**<0.0005**
Case specialty n (%)				
General	2154 (45.2)	297 (13.8)	**1.0**	
Orthopaedics	984 (20.7)	1135 (52.6)	**8.37 (7.21–9.70)**	**<0.0005**
Neurosurgery	566 (11.9)	509 (23.6)	**6.52 (5.50–7.73)**	**<0.0005**
Vascular	467 (9.8)	106 (4.9)	**1.65 (1.29–2.10)**	**<0.0005**
Cardiothoracic	371 (7.8)	8 (0.4)	**0.16 (0.08–0.32)**	**<0.0005**

Table 1 continued

Variables—frequencies	Senior operators ($N = 4762$)	Trainees ($N = 2158$)	Odds ratio (95% CI)	p value
Urology	76 (1.6)	51 (2.4)	**4.87 (3.35–7.08)**	**<0.0005**
Plastics	48 (1.0)	31 (1.4)	**4.68 (2.93–7.48)**	**<0.0005**
Other[1]	96 (2.0)	21 (1.0)	1.59 (0.97–2.58)	0.064
Operation complexity n (%)				
Minor/intermediate	754 (15.8)	332 (15.4)	1.0	0.598
Major/complex	3980 (83.6)	1820 (84.3)	1.04 (0.90–1.20)	
Missing	28 (0.6)	6 (0.3)		
Post-op complications n (%)	1210 (25.4)	396 (18.4)	**0.66 (0.58–0.75)**	**<0.0005**
Anastomotic leak	51 (1.1)	9 (0.4)	**0.39 (0.19–0.79)**	**0.009**
Bleeding	112 (2.4)	22 (1.0)	**0.43 (0.27–0.68)**	**<0.0005**
Tissue ischaemia	112 (2.4)	14 (0.7)	**0.27 (0.16–0.47)**	**<0.0005**
Endoscopic perforation	11 (0.2)	2 (0.1)	0.40 (0.09–1.81)	0.234
Infection	100 (2.1)	13 (0.6)	**0.28 (0.16–0.50)**	**<0.0005**
Other	907 (19.1)	322 (14.9)	**0.75 (0.65–0.86)**	**<0.0005**

$p < 0.05$ indicated in bold type

Asterisk indicates that the gender of 7 patients had not been reported

[1]ENT, paediatrics, obstetrics/gynaecology, maxillo-facial, ophthalmology

[2]Endocrine, metabolic, haematological, psychiatric, congenital, symptom, unspecified

infection and ischaemia were the most common complications (Table 1).

Overall, when adjusting for other variables, an ASA grade of three, and other mortality risk factors such as haematological disturbances, frailty, heavy smoking or immunosuppression were associated with a significant increase in the odds of post-operative complications. (Table 2).

Operations classified as major or complex, or performed more than 2 h following presentation were associated with a 69 and 52% increased odds of post-operative complications, respectively (Table 2).

The final analytic model included 6707 (97%) cases. The link test and the Hosmer–Lemeshow goodness-of-fit test were not statistically significant ($p = 0.207$ and $p = 0.20$, respectively) which indicates that the model was correctly specified, no relevant variables were omitted, and model fit was good. The area under the ROC curve was 0.67.

Discussion

This study found that across all surgical specialties, supervised trainees are safely performing emergency operations, indicated by the outcome measure of post-operative complications. This is consistent with evidence pertaining to elective procedures, as highlighted in a recent meta-analysis reporting lower mortality rates and shorter length of stay with operations performed by trainees [4]. Akin to elective procedures, the observed statistically significant reduction in odds of post-operative complications for trainees relative to consultants may be due to the selection of cases with a lower baseline risk, and with a complexity appropriate for their level of training and supervision. Supporting this were significant differences found between trainees and senior operators in patient and operation characteristics. Potential confounders available in the dataset were controlled for in the multivariable analysis. However, other factors not measured pertaining to patients, surgeons and institutions may have also contributed to the lower risk of complications in the trainee group. Comorbidities not recorded, high injury severity score among trauma patients or tumour stage in malignancy may have been more prevalent in the senior operator group, making operations higher-risk [11]. Individual differences in surgeons' technical skills, experience in operating and supervising, case-volume and surgical techniques employed were also unknown [24]. Evidence shows that experience measured either as years of practice or case-volume positively correlates with patient outcome, at least in the initial years of surgical practice [25]. Hospital characteristics such as size, case-volume, local policies and the presence of an intensive care unit may too have contributed to the observed difference [26].

Table 2 Adjusted and unadjusted associations with post-operative complications

	Post-op complications—*n* (%)	No post-op complications—*n* (%)	Unadjusted OR (95% CI)	Adjusted OR[2] (95% CI)	*p* value
Main operator					
Senior operators	1176 (75.1)	3440 (66.9)	1.00	1.00	
Trainees	389 (24.9)	1702 (33.1)	**0.66 (0.58–0.75)**	**0.82 (0.71–0.95)**	**0.008**
Age group (years)					
0–15	8 (0.5)	85 (1.7)	**0.28 (0.14–0.56)**	**0.34 (0.15–0.75)**	**0.007**
16–45	58 (3.7)	376 (7.3)	**0.48 (0.37–0.64)**	**0.53 (0.38–0.72)**	**<0.0005**
46–65	171 (10.9)	866 (16.8)	**0.59 (0.49–0.70)**	**0.52 (0.42–0.64)**	**<0.0005**
66–80	527 (33.7)	1427 (27.8)	1.11 (0.98–1.26)	0.96 (0.84–1.11)	0.611
>80	801 (51.2)	2388 (46.4)	1.00	1.00	
ASA grade					
1 or 2	90 (5.8)	390 (7.6)	1.00	1.00	
3	548 (35.0)	1408 (27.4)	**1.69 (1.31–2.16)**	**1.33 (1.02–1.74)**	**0.038**
4	775 (49.5)	2498 (48.6)	**1.34 (1.05–1.71)**	0.93 (0.72–1.21)	0.587
5	152 (9,7)	846 (16.5)	0.78 (0.58–1.04)	**0.54 (0.40–0.73)**	**<0.0005**
Other mortality risk factor					
No	1122 (71.7)	3990 (77.6)	1.00	1.00	
Yes	443 (28.3)	1152 (22.4)	**1.35 (1.19–1.53)**	**1.45 (1.27–1.66)**	**<0.0005**
Case specialty					
General	608 (38.9)	1776 (34.5)	1.00	1.00	
Orthopaedics	416 (26.6)	1635 (31.8)	**0.75 (0.65–0.86)**	**0.54 (0.46–0.64)**	**<0.0005**
Neurosurgery	144 (9.2)	901 (17.5)	**0.46 (0.37–0.56)**	**0.65 (0.52–0.81)**	**<0.0005**
Vascular	185 (11.8)	378 (7.4)	**1.42 (1.16–1.73)**	**1.54 (1.25–1.89)**	**<0.0005**
Cardiothoracic	167 (10.7)	202 (3.9)	**2.38 (1.91–2.97)**	**3.00 (2.35–3.83)**	**<0.0005**
Urology	20 (1.3)	981 (1.9)	**0.55 (0.34–0.89)**	0.73 (0.44–1.22)	0.228
Plastics	12 (0.8)	61 (1.2)	0.63 (0.35–1.13)	0.80 (0.42–1.54)	0.511
Other[1]	13 (0.8)	91 (1.8)	**0.37 (0.20–0.66)**	0.65 (0.34–1.23)	0.187
Timing of operation					
<2 h	264 (16.9)	1292 (25.1)	1.00	1.00	
≥2 h[3]	1301 (83.1)	3850 (74.9)	**1.66 (1.43–1.91)**	**1.52 (1.28–1.80)**	**<0.0005**
Operation complexity					
Minor/intermediate	198 (12.0)	856 (16.7)	1.00	1.00	
Major/complex	1367 (88.0)	4263 (83.3)	**1.49 (1.26–1.76)**	**1.69 (1.40–2.04)**	**<0.0005**

$p < 0.05$ indicated in bold type

[1]ENT, paediatrics, obstetrics/gynaecology, maxillo-facial, ophthalmology

[2]Model including age, ASA grade, other mortality risk factors, operation timing, surgical specialties, operation complexity and level of experience

[3]Emergency (2–24 h) and scheduled emergency were pooled as they had the same odds ratio

Level of operation complexity was reported as equivalent in both groups. Yet, operation complexity was a crude measure solely based on the nature of the procedure, not taking into account patients' individual characteristics, which may have an impact on the operation complexity.

Future directions

The ability to proficiently perform emergency procedures is a fundamental component of surgical training. Yet, concerns have been expressed regarding the operative skills of surgical trainees in the context of declining exposure to emergency operations [14]. To provide clear and reliable guidelines, future studies ought to determine how much, to whom and in what form supervision is most beneficial [27]. For instance, a study comparing surgical outcomes of colorectal cancer resection according to level of experience and supervision found senior trainees could provide effective supervision [28].

Here, level of supervision could not be ascertained with precision. Therefore, insofar as many confounders may affect the relationship between level of experience and post-operative complications, the next step is a prospective cohort or planned case–control study taking into consideration surgeon and hospital case-volume, level of experience among senior operators and trainees, and type and extent of supervision. This would enable the measurement of both mortality and complications, and any relation with either outcome. Further, analysis at the level of specific emergency procedures could be undertaken to better evaluate the effect of operation complexity.

Strengths and limitations

This study is the first to examine the effect of surgeon experience on post-operative complications in emergency procedures across all surgical specialties in a mortality audit. Other strengths include a large nationwide population from rural and urban centres, reliable and accurate clinical data derived from first accounts of the peri-operative events, having demonstrated external validity [29].

Limitations include the data being derived from evaluation of care by the surgeons in charge of the patient, which may be susceptible to reporting bias. Mandatory reporting of surgical deaths was only implemented in 2012; therefore, there is the potential for a bias in data collection between 2009 and 2011, during which time the number of post-operative complications may be underestimated. Emergency operations not followed by death are not included owing to the nature of the data source, and follow-up time was limited as only in-hospital deaths were examined. Our findings may therefore not be generalizable to all emergency operations.

Upholding the quality of training in surgery is a fundamental part of ensuring patient safety [30]. Adequate exposure to emergency operations must therefore remain a core component of surgical training. This study demonstrates that contrary to popular belief, trainees can safely perform emergency procedures provided that cases are judiciously selected and adequate supervision is provided.

Funding The project was funded with existing departmental resources provided by the Department of Forensic Medicine, Monash University.

Compliance with ethical standards

Conflict of interest There are no financial or other relationships that may lead to a conflict of interest, or influence the content of the manuscript.

References

1. E. Cohen JB (2015) Secret deaths: CNN finds high surgical death rate for children at a Florida hospital. CNN. http://edition.cnn.com/2015/06/01/health/st-marys-medical-center/
2. Boseley S (2016) Leading hospital under CQC scrutiny over high heart surgery death rate. The Guardian https://www.theguardian.com/society/2016/mar/03/queen-elizabeth-hospital-birmingham-cqc-heart-surgery-high-death-rate
3. Holena DN, Hadler R, Wirtalla C, Carr B, Morris JB, Kelz RR (2011) Teaching status: the impact on emergency and elective surgical care in the US. Ann Surg 253(5):1017–1023
4. D'Souza N, Hashimoto DA, Gurusamy K, Aggarwal R (2016) Comparative outcomes of resident vs attending performed surgery: a systematic review and meta-analysis. J Surg Educ 73(3):391–399
5. Kazaure HS, Roman SA, Sosa JA (2012) The resident as surgeon: an analysis of ACS-NSQIP. J Surg Res 178(1):126–132
6. Kiran RP, Ahmed Ali U, Coffey JC, Vogel JD, Pokala N, Fazio VW (2012) Impact of resident participation in surgical operations on postoperative outcomes: national surgical quality improvement program. Ann Surg 256(3):469–475
7. Havens JM, Peetz AB, Do WS, Cooper Z, Kelly E, Askari R et al (2015) The excess morbidity and mortality of emergency general surgery. J Trauma Acute Care Surg 78(2):306–311
8. Kasotakis G, Lakha A, Sarkar B, Kunitake H, Kissane-Lee N, Dechert T et al (2014) Trainee participation is associated with adverse outcomes in emergency general surgery: an analysis of the national surgical quality improvement program database. Ann Surg 260(3):483–493
9. Advani V, Ahad S, Gonczy C, Markwell S, Hassan I (2012) Does resident involvement effect surgical times and complication rates during laparoscopic appendectomy for uncomplicated appendicitis? an analysis of 16,849 cases from the ACS-NSQIP. Am J Surg 203(3):347–352
10. Mizrahi I, Mazeh H, Levy Y, Karavani G, Ghanem M, Armon Y et al (2013) Comparison of pediatric appendectomy outcomes between pediatric surgeons and general surgery residents. J Surg Res 180(2):185–190
11. de Santibañes M, Alvarez FA, Sieling E, Vaccarezza H, de Santibañes E, Vaccaro CA (2015) Postoperative complications at a university hospital: is there a difference between patients operated by supervised residents vs. trained surgeons? Langenbeck's Arch Surg 400(1):77–82
12. McLoughlin V, Millar J, Mattke S, Franca M, Jonsson PM, Somekh D et al (2006) Selecting indicators for patient safety at the health system level in OECD countries. Int J Qual Health Care J Int Soc Qual Health Care Isqua 18(Suppl 1):14–20
13. Kelly E, Rogers SO (2012) Graduate medical education in trauma/critical care and acute care surgery. defining goals for a new workforce. Surg Clin N Am 92(4):1055–1064
14. Bell RH, Biester TW, Tabuenca A, Rhodes RS, Cofer JB, Britt LD et al (2009) Operative experience of residents in US general surgery programs: a gap between expectation and experience. Ann Surg 249(5):719–724

15. Raju RS, Guy GS, Majid AJ, Babidge W, Maddern GJ (2015) The Australian and New Zealand audit of surgical mortality-birth, deaths, and carriage. Ann Surg 261(2):304–308
16. RACS Council (2017) RACS accreditation application. In: Royal Australasian Council of Surgeons (ed) Accreditation of hospitals and posts for surgical education and training booklet
17. Owens WD, Felts JA, Spitznagel EL Jr (1978) ASA physical status classifications: a study of consistency of ratings. Anesthesiology 49(4):239–243
18. RACS (2017) Surgical education and training (SET). Royal Australasian College of Surgeons, Melbourne (cited 2017 2 May). http://www.surgeons.org/becoming-a-surgeon/surgical-education-training/
19. RACS (2017) Procedure list for SET and IMG general surgery. Royal Australian College of Surgeons, Melbourne (cited 2017 2 May). https://www.surgeons.org/media/21713569/2015-05-14_doc_malt_general_surgery_procedure_list.pdf
20. Pasternak LR (1995) Screening patients: strategies and studies. Ambulatory anesthesiology: a problem-oriented approach. Williams & Wilkins, Baltimore, pp 2–19
21. Stata statistical software: release 14. StataCorpLP 2017, College Station, Texas
22. Pregibon (1979) Cited in Stata 13 Base Reference Manual. StataCorp 2013, College Station, Texas
23. Hosmer DW Jr, Lemeshow S, Sturdivant RX (2013) Applied logistic regression. Wiley, New York
24. Chowdhury MM, Dagash H, Pierro A (2007) A systematic review of the impact of volume of surgery and specialization on patient outcome. Br J Surg 94(2):145–161
25. Maruthappu M, Gilbert BJ, El-Harasis MA, Nagendran M, McCulloch P, Duclos A et al (2015) The influence of volume and experience on individual surgical performance: a systematic review. Ann Surg 261(4):642–647
26. McCrum ML, Lipsitz SR, Berry WR, Jha AK, Gawande AA (2014) Beyond volume: does hospital complexity matter?: an analysis of inpatient surgical mortality in the United States. Med Care 52:235–242
27. van der Leeuw RM, Lombarts KMJMH, Arah OA, Heineman MJ (2012) A systematic review of the effects of residency training on patient outcomes. BMC Med 10:65
28. Khan OA, Lin PF, Chaudhuri J, Nelson M, Elsmore S, Walsh T (2008) Training outcomes in colorectal cancer surgery in a district general hospital. Acta Chir Belg 108(5):503–507
29. Rey-Conde T, Shakya R, Allen J, Clarke E, North JB, Wysocki AP et al (2016) Surgical mortality audit data validity. ANZ J Surg 9:644
30. Aitken RJ (2012) Lost opportunity cost of surgical training in the Australian private sector. ANZ J Surg 3:145