



Prolonged operating room time in emergency general surgery is associated with venous thromboembolic complications



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ABSTRACT

Background: We evaluated the association between operating room time and developing a deep vein thrombosis (DVT) or pulmonary embolus (PE) after emergency general surgery (EGS).

Methods: We reviewed six common EGS procedures in the 2013–2015 NSQIP dataset. After tabulating their incidence of postoperative VTE events, we calculated predictors of developing a VTE using adjusted multivariate logistic regressions.

Results: Of 108,954 EGS patients, 1,366 patients (1.3%) developed a VTE postoperatively. The median time to diagnosis was 9 days [5–16] for DVTs and 8 days [5–16] for PEs. Operating room time of 100 min or more was associated with increased risk of developing a DVT (OR 1.30 [1.12–2.21]) and PE (OR:1.25 [1.11–2.43]) with a 7% and 5% respective increase for every 10 min increase after the 100 min. Other independent predictors of VTE complications were older age, and history of cancer, and emergent colectomies on procedure-level analysis.

Conclusion: Prolonged operating room time is independently associated with increased risk of developing VTE complications after an EGS procedure. Most of the VTE complications were delayed in presentation.

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Introduction

Venous thromboembolism (VTE) is the most preventable cause of morbidity and mortality in hospitalized patients in the United States¹ and is particularly common following surgery. Emergency general surgery admissions have been increasing in recent years, comprising 7% of all hospital admissions in the United States^{2,3}, of which 29% required urgent surgery.³ Emergency general surgery (EGS) patients represent an especially diverse and challenging population carrying a high risk of developing venous thromboembolic events with a reported rate of 2.5%.⁴ This risk is present during their hospitalization and persists afterwards; up to 35% of

the VTEs occurring post-discharge.^{5,6,7} The high rate of VTE complications in the EGS population leads to higher readmission rates, 30-day mortality rates, and consequently poses a large cost burden on the health care system.

Almost 70% of those patients who develop post-discharge VTE require readmission.⁵ In addition, the 30 day postoperative mortality in patients with VTE is higher, reaching 11.9%, in comparison to patients without VTE.⁸ With a total estimated cost of \$5 billion for deep venous thrombosis (DVT) alone and up to \$10 billion for DVT and pulmonary embolus (PE) per year in the U.S.⁹, reporting and measuring VTE outcomes has become a priority for Centers for Medicare, Medicaid, the Joint Commission, and the Agency for Healthcare Research and Quality.¹⁰ The Agency for Healthcare Research and Quality placed VTE prophylaxis on the list of the most strongly encouraged patient safety practices.¹¹ These organizations' aim is to reduce the incidence of VTE and avoid its preventable harm.

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Reported risk factors for the development of VTE following EGS include increased age, prior VTE, presence of malignancy or inflammatory bowel disease, sepsis, increased American Society of Anesthesiologists (ASA) class, longer length of stay, and obesity.² In addition, a multicenter large cohort study by Kim et al. found a stepwise increase in VTE risk with increasing operative times¹²; the longest procedures experiencing up to 1.27 fold increase in the odds of developing a VTE within 30 days of an index operation in comparison to an average length procedure. Interestingly, in their study they defined total surgical duration as the duration of general anesthesia time and the procedures were divided into quintiles by length of procedure, as opposed to type and approach. However, there still exists limited data to what extent longer operative time increases a patient's risk of a VTE event. Using the American College of Surgeons, National Surgical Quality Improvement Program (ACS-NSQIP) dataset, we evaluated the impact of operative time on developing DVT and/or PE after an emergency general surgery in this special population. We hypothesize that longer operating room time for emergency general surgery results in substantially increased rate of VTE complications.

Methods

Data source

The ACS-NSQIP is a large prospective surgical database representing a national validated program that provides risk-adjusted information on short-term surgical outcomes (30-days) and their predictors for the purpose of improving hospital surgical quality. ACS-NSQIP collects data from around 570 institutions across the United States and Canada and cases are collected based on current procedural terminology (CPT) codes using a random sampling of procedures per institution. We followed the suggested recommendations for best practices for using NSQIP data in health services and outcomes research.^{13,14} The Institutional Review Board determined that this analysis does not involve human participants and contains no identified patient's data, thus it was exempted from formal approval.

Patient selection

We examined data retrospectively for all patients who underwent six common emergency general surgery procedures from 2013 to 2015 from the ACS-NSQIP database. "Emergency surgery" is a variable defined in the ACS-NSQIP database dictionary as "An emergency case performed within a short interval of time from patient diagnosis or the onset of related preoperative symptomatology. It is implied that the patient's wellbeing and outcome is potentially threatened by unnecessary delay and the patient's status could deteriorate unpredictably and rapidly." The six procedures included appendectomy, cholecystectomy, colectomy, perforated peptic ulcer repair, ischemic bowel resection, and incarcerated hernia repair which were identified using their respective CPT codes and represent 75% of all EGS cases in the NSQIP database. Patients who underwent elective procedures were excluded from the analysis.

Dataset, predictor and outcome variables

We examined the following data points: age, gender, body mass index, race, comorbidities (including diabetes mellitus, smoking, hypertension, disseminated cancer, history of chronic obstructive pulmonary disease, and history of a cerebrovascular accident), American Society of Anesthesiologists (ASA) class, pre-operative International Normalized Ratio (INR), thromboembolic

complications, operative time, days to complication (DVT and/or PE), type (i.e. appendectomy, cholecystectomy, etc.) and approach (open vs. laparoscopic) of the procedure. Patients were stratified into two groups based on the primary independent variable of interest, total operation time, reported as < 100 min and \geq 100 min. Using the receiver operator characteristic curve analysis, all possible operative time thresholds were considered in terms of sensitivity and specificity for predicting the study outcome. The sensitivity and specificity were both optimized at a threshold of 100 min (Highest Youden's Index). Using this cutoff, we stratified our sample into two groups (<100 min and \geq 100 min). Our primary outcome variables were the incidence of DVT and/or PE within 30 days after the principal operative procedure.

Statistical analyses

We performed a descriptive statistical analysis and reported continuous data as mean \pm standard deviation (SD), ordinal variables as median [Interquartile Range (IQR)], and categorical variables as proportions. A multivariate logistic regression was performed to control for confounding variables such as age, gender, body mass index, history of cancer, other comorbidities, pre-admission international normalized ratio (INR), ASA class, the diagnosis, and the type and approach of procedure. Additionally, we adjusted for the presence of sepsis, functional dependence, and pre-operative lab results including: sodium, blood urea nitrogen, serum creatinine, serum albumin, total bilirubin, serum glutamic oxaloacetic transaminase (SGOT), alkaline phosphatase (ALK-p), white blood cell count (WBC), hematocrit (HCT), and platelet count. Because the incidence of VTE increases with age in a nonlinear fashion, we chose to classify age into two discrete ranges (age \leq 65 and age \geq 65)^{15,16}. The Hosmer-Lemeshow test was used to test for goodness of fit for our regression model. For this study, we considered a p-value < 5% as statistically significant. All the statistical analyses in this study were executed through The Statistical Package for Social Sciences (SPSS, Version 23; SPSS, Inc. Armonk, NY).

Since it has been shown that VTE rates vary significantly by surgery type¹⁷, we performed a stratified analysis, looking separately within each of the six different groups of emergency procedures at the incidence of thromboembolic events, days to VTE events, and the association with prolonged operative times.

Results

We analyzed a total of 108,954 EGS patients. Mean age was 50.4 \pm 17 years, 51.4% were female and the two most common procedures were appendectomies (65.4%) followed by cholecystectomies (11.6%).

Patients were stratified into two groups based on the total operation time; < 100 min (n = 89,342) vs \geq 100 min (n = 19,612). [Table 1](#) summarizes the patient characteristics of both groups. Patients in the \geq 100 min group were more likely to be older (age: 57 \pm 18 vs. 49 \pm 17, $p < 0.001$), obese (body mass index: 28 \pm 8 vs. 27.9 \pm 12, $p < 0.001$), and have an ASA class \geq 3 (31.9% vs. 25.1%, $p < 0.001$) compared to the <100 min group. The \geq 100 min surgical duration group was also significantly more likely to have all the comorbidities collected in [Table 1](#), in addition to higher likelihood of having \geq 3 comorbidities. Pre-operative labs such as serum creatinine and serum international normalized ratio (INR) and hospital length of stay were also significantly higher in that group. Hospital length of stay was 6^{3–11} days in the \geq 100 min vs. 2^{1–6} days in the <100 min group. The most common procedure performed in the <100 min group was appendectomy, otherwise all remaining procedures were more likely to be longer than 100 min. The most

Table 1
Demographic characteristics.

Variable	<100 Minutes (n = 89,342)	≥100 Minutes (n = 19,612)	P- Value
Age, mean ± SD	49 ± 17	57 ± 18	<0.001
Female, n (%)	46011 (51.5)	10021 (51.1)	0.34
White, n (%)	62271 (69.7)	13512 (68.9)	0.03
BMI, mean ± SD	27.9 ± 12	28 ± 8	<0.001
Independent functional status, n (%)	86751 (97.1)	83088 (93)	<0.001
ASA Class ≥ 3, n (%)	22424 (25.1)	6256 (31.9)	<0.001
Comorbidities, n (%)			
Diabetes Mellitus	7147 (7.9)	2981 (15.2)	<0.001
Hypertension	20727 (23.2)	9218 (47.0)	<0.001
Smoking	17153 (19.2)	4117 (21.3)	<0.001
CHF within 30 days before surgery	1072 (1.2)	431 (2.2)	<0.001
History of COPD	2412 (2.7)	1549 (7.9)	<0.001
Disseminated Cancer	893 (1.0)	1000 (5.1)	<0.001
History of Stroke or TIA	4467 (4.9)	1196 (6.1)	<0.001
Chronic corticosteroid use	2144 (2.4)	1490 (7.6)	<0.001
Ascites	893 (1)	510 (2.6)	<0.001
Hemodialysis dependent	625 (0.7)	431 (2.2)	<0.001
Dyspnea	2144 (2.4)	1353 (6.9)	<0.001
≥ 3 comorbidities	3037 (3.4)	2059 (10.5)	<0.001
Presence of sepsis, n (%)			
SIRS	16082 (18)	11614 (13)	<0.001
Sepsis	10989 (12.3)	23497 (26.3)	<0.001
Septic shock	536 (0.6)	2591 (2.9)	<0.001
Ventilator dependence, n (%)	1429 (1.6)	3842 (4.3)	<0.001
Pre-operative labs, mean ± SD			
Sodium, meq/L	137.92 ± 3.26	137.36 ± 4.08	<0.001
Blood urea nitrogen, meq/l	14.76 ± 10.38	20.11 ± 16.52	<0.001
Serum Creatinine, mg/dl	0.95 ± 0.7	1.17 ± 1.05	<0.001
Serum albumin, g/dl	4.02 ± 0.64	3.49 ± 0.8	<0.001
Total bilirubin, mg/dl	0.86 ± 0.72	0.93 ± 0.92	<0.001
SGOT, units/l	30 ± 43.69	34.6 ± 54.89	<0.001
ALK-p, units/l	81.97 ± 42.48	94.05 ± 60.82	<0.001
WBC, cells per mm ³	12.77 ± 5.11	12.65 ± 6.47	<0.001
HCT, %	40.69 ± 5.2	38.2 ± 6.7	<0.001
Platelet count, 1000 cells per mm ³	240.88 ± 73.9	259.32 ± 106.77	<0.001
International normalized ratio,	1.14 ± 0.36	1.25 ± 0.48	<0.001
Procedure, n (%)			
Appendectomy	66649 (74.6)	3726 (19.0)	<0.001
Cholecystectomy	9828 (11.0)	3157 (16.1)	<0.001
Emergent Colectomy	3931 (4.4)	6375 (32.5)	<0.001
Perforated Peptic Ulcer Repair	1786 (2.0)	1059 (5.4)	<0.001
Ischemic Bowel Resection	3574 (4.0)	3726 (19.0)	<0.001
Incarcerated Hernia Repair	3574 (4.0)	1569 (8.0)	<0.001
Hospital Length of Stay, d, median [IQR]	2 [1–6]	6 [3–11]	<0.001

BMI; body mass index, SD; standard deviation, ASA; American society of anesthesiologists, IQR; interquartile range, CHF; congestive heart failure, COPD; chronic obstructive pulmonary disease, TIA; transient ischemic attacks; SGOT=Serum glutamic oxaloacetic transaminase; ALK-p = alkaline phosphatase; WBC = white blood cell count; HCT = hematocrit.

common surgery requiring ≥100 min was emergent colectomy.

Overall, 1,366 (1.3%) patients developed VTE complications postoperatively, specifically 65% had DVT, 28% had PE and 7% developed combined DVT and PE. The median time to diagnose DVT was 9 days [5–16] and to diagnose PE was 8 days [5–16]. [Table 2](#) summarizes the incidence of thromboembolic complications, median time to develop thromboembolic complications postoperatively, and the median operation time across the six different EGS procedures and their different approaches (open vs. laparoscopic). Although the procedures consisted of 71% laparoscopic and 29% open, apart from appendectomies and cholecystectomies, the remaining procedures were mostly or entirely done through open approach. The incidence of thromboembolic complications was the highest in the emergent colectomy procedure (6.8%) followed by perforated peptic ulcer repair (4.1%) and ischemic bowel resection (3.1%). The longest operation time was noticed in the emergent colectomy group (minutes, [IQR]; 113 min, [82–154]) which had the highest percentage of ≥100 min operations (60.9%) followed by ischemic bowel resection (minutes, [IQR]; 89 min, [64–128]).

On regression analysis, we found that operation time of 100 min or more was independently associated with increased risk of developing DVT (OR: 1.73 [1.50–2.01]) and PE (OR: 2.02 [1.62–2.52]). For every 10 min increase after the 100 min, the risk of developing DVT increased by 7% and the risk of PE increased by 5%. Other independent predictors of VTE complications (both DVT and PE) were history of disseminated cancer (DVT: OR 1.92 [1.49–2.47] and PE: OR 2.53 [1.78–3.59]), ASA Class ≥ 3 (DVT: OR 2.76 [2.21–3.44] and PE: OR 1.80 [1.34–2.43]), and longer hospital length of stay (DVT: OR 1.36 [1.03–2.64] and PE: OR 1.31 [1.02–2.16]). Age ≥65 (OR 1.20 [1.08–1.34]), open surgical approach (OR 1.34 [1.12–2.39]), and ≥3 comorbidities (OR 1.26 [1.09–5.21]) were also independent predictors of developing DVT. Patients with BMI ≥30 had significantly increased likelihood of developing PE (OR 1.31 [1.06–1.63]) ([Table 3](#)).

On stratified analysis based on type of procedure, the relationship between longer operating room time (≥100 min) and VTE held true for all the EGS procedure types. While this finding was statistically significant in most operations, a few did not reach statistical significance, in particular cholecystectomy and appendectomy.

Table 2
Outcomes.

	Appendectomy (n = 71,309)	Cholecystectomy (n = 12,673)	Emergency Colectomy (n = 10,210)	Perforated Peptic Ulcer Repair (n = 2,694)	Mesenteric Ischemia Bowel Resection (n = 6,855)	Incarcerated Hernia Repair (n = 5,213)	All Procedures (108,954)	P- Value
Laparoscopic, n (%)	65,017 (91%)	11,226 (88%)	388 (4%)	–	–	405 (8%)	77,036 (71%)	<0.01
Open, n (%)	6,292 (9%)	1,447 (12%)	9,822 (96%)	2,694 (100%)	6,855 (100%)	4,808 (92%)	31,918 (29%)	<0.01
Thromboembolic Events, n (%)	181 (0.25%)	63 (0.49%)	701 (6.8)	112 (4.1%)	218 (3.1%)	91 (1.7%)	1366 (1.3%)	<0.001
DVT ^a	108 (60%)	41 (65%)	461 (66)	75 (67%)	148 (68%)	55 (60%)	888 (65%)	
Lap ^b	83 (77%)	25 (61%)	10 (3%)	–	–	4 (8%)	–	
Open ^b	25 (23%)	16 (39%)	451 (97%)	75 (100%)	148 (100%)	51 (92%)	–	
PE ^a	59 (32%)	18 (29%)	190 (27%)	27 (24%)	60 (27%)	27 (30%)	381 (28%)	
Lap ^c	40 (67%)	14 (77%)	7 (4%)	–	–	1 (4%)	–	
Open ^c	19 (33%)	4 (23%)	183 (96%)	27 (100%)	60 (100%)	26 (96%)	–	
DVT & PE ^a	14 (8.0%)	4 (6.0%)	50 (7.0%)	10 (9.0%)	10 (5.0%)	9 (10%)	97 (7%)	
Days to TE Events, median [IQR]								
Days to DVT	10 [6–17]	10 [4–16]	9 [5–15]	10 [5–15]	8 [5–15]	11 [7–19]	9 [5–16]	0.03
Days to PE	7 [4–13]	13 [8–24]	8 [5–15]	9 [5–16]	10 [5–16]	7 [2–15]	8 [5–16]	0.02
Operation Time, median [IQR]	43[31–60]	68[49–96]	113[82–154]	69[49–99]	89[64–128]	63[41–97]	53 [36–84]	<0.001
Operation Time ≥ 100 Minutes, n (%)	3494 (4.9)	2902 (22.9)	6218 (60.9)	671 (24.9)	2872 (41.9)	1235 (23.7)	17392 (16)	<0.001

^a n(%) of the total thromboembolic events.
^b n(%) of the total DVT.
^c n(%) of the total PE.

Importantly, none showed a higher VTE rate in the shorter operations. Emergency colectomy was associated with the highest odds of developing both DVT and PE (DVT: OR: 1.91 [1.42–2.23] and PE: OR 1.82 [1.44–2.31]), followed by perforated peptic ulcer repair (DVT: OR 1.60 [1.24–2.01] and PE: OR: 1.53 [1.04–2.31]), and ischemic bowel resection (DVT: OR 1.23 [1.01–1.52] and PE: OR 1.12 [1.02–1.30]) (Table 4).

Discussion

Using the ACS-NSQIP database, we found that an operation time of 100 min or more was independently associated with increased risk of developing DVT and PE. For every 10 min increase after the 100 min, the risk of developing DVT increases by 7% and the risk of PE increases by 5%. The incidence of thromboembolic complications was highest for emergent colectomies (6.8%) followed by perforated peptic ulcer repairs (4.1%) and ischemic bowel resections (3.1%). Our work builds upon previous studies that have established a relationship between VTE and increased surgical duration across subspecialties¹², and stands out as we have

quantified the surgical duration at which the risk of VTE increases in different EGS procedures.

The physiology of venous thromboembolism (VTE) is well known and has been developed since Virchow's initial description in 1856 describing three contributing factors: thrombus formation caused by stasis or turbulence of blood flow, damage to the vessel wall, and hypercoagulability.¹⁸ Understanding this principle makes it easier to understand why surgical patients are at particularly high-risk of developing VTE. During surgery, stasis occurs in the veins secondary to both prolonged immobility and anesthesia effect.¹⁹

We found a VTE rate of 1.3% in patients undergoing the most common EGS procedures, where median time to diagnosis was 9 days for DVT and 8 days for PE. The reported rate of VTE among patients undergoing EGS, in a recent review of the literature, is approximately 2.5%.² This rate is higher than our reported 1.3%, however it includes all studies from 1990 to 2017.² Current VTE prophylaxis practices could potentially influence our current lower reported rate. In Addition, our findings suggest that many of these VTE events are delayed in nature and likely occur after discharge, as

Table 3
Multivariate Logistic Regression Analysis for VTE Risk in EGS patients.

Variable	DVT		PE	
	OR [95% CI]	p-value	OR [95% CI]	p-value
Operation Time ≥ 100 min ^{a,c}	1.73 [1.50–2.01]	<0.001	2.02 [1.62–2.52]	<0.001
Age ≥ 65	1.20 [1.08–1.34]	<0.001	0.91 [0.64–1.30]	0.62
Disseminated Cancer	1.92 [1.49–2.47]	<0.001	2.53 [1.78–3.59]	<0.001
Female Gender	0.92 [0.80–1.06]	0.92	0.87 [0.71–1.08]	0.62
BMI ≥ 30	1.13 [0.98–1.31]	0.08	1.31 [1.06–1.63]	0.01
ASA Class ≥ 3	2.76 [2.21–3.44]	<0.001	1.80 [1.34–2.43]	<0.001
Open Surgery (Lap Ref.) ^b	1.34 [1.12–2.39]	0.02	1.21 [0.94–1.21]	0.16
≥3 comorbidities	1.26 [1.09–5.21]	0.04	0.85 [0.61–1.78]	0.33
Hospital LOS	1.36 [1.03–2.64]	0.03	1.31 [1.02–2.16]	0.01

BMI; body mass index, ASA; American Society of Anesthesiologists.

^a Adjusting for age ≥ 65, disseminated cancer, female gender, BMI ≥ 30, ASA Class ≥ 3, Open Surgery, type of surgery, presence of sepsis, functional dependence, Sodium, meq/L, Blood urea nitrogen, meq/l, Serum Creatinine, mg/dl, Serum albumin, g/dl, Total bilirubin, mg/dl, SGOT, units/l, ALK-p, units/l, WBC, cells per mm³, HCT, %, Platelet count, 1000 cells per mm³, International normalized ratio.

^b Laparoscopic Surgery is the Reference.

^c For every 1 min increase in operative time the odds of VTE are multiplied by 1.007. Therefore, for every 10 min the odds of DVT are multiplied by (1.007)¹⁰ = 1.07 (odds of DVT increase by 7%) and for every 10 min the odds for PE are multiplied by (1.005)¹⁰ = 1.05 (odds of PE increase by 5%).

Table 4
Odds of VTE for short (<100 min) vs. long (\geq 100 min) operative times for patients undergoing specific EGS procedures.

Variable	DVT		PE	
	OR ^a [95% CI]	p-value	OR ^a [95% CI]	p-value
Appendectomy	1.13 [0.94–1.32]	0.07	1.11 [0.89–1.20]	0.06
Cholecystectomy	1.23 [0.92–1.43]	0.09	1.21 [0.95–1.35]	0.10
Emergency Colectomy	1.91 [1.42–2.23]	<0.001	1.82 [1.44–2.31]	<0.001
Perforated Peptic Ulcer Repair	1.60 [1.24–2.01]	<0.001	1.53 [1.04–2.31]	<0.001
Ischemia Bowel Resection	1.23 [1.01–1.52]	<0.001	1.12 [1.02–1.30]	<0.001
Incarcerated Hernia Repair	1.11 [1.09–1.41]	<0.001	1.09 [0.91–1.21]	0.07

^a Multivariate logistic regression for operation Time \geq 100 min.

reported in previous literature. Specifically, prior literature has documented that more than 30% of VTEs occur after discharge in the EGS population⁵, the increased risk persisting for as long as 12 weeks after surgery.²⁰ This reported increased risk in surgical patients, even after surgery, is explained by the prolonged immobility and continued inflammation brought about by the surgery.

Among the most common EGS procedures, emergent colectomy, ischemic bowel resection and perforated peptic ulcer repair had the highest incidence of VTE complications. The reason for this finding is likely multifactorial. These procedures correlate with the longest median operative times, 113 min for emergent colectomy, 89 min for ischemic bowel resection and 69 min for perforated peptic ulcer repair. 96% of emergent colectomies and 100% of perforated peptic ulcers and ischemic bowel resections were open surgeries which was found to be an independent risk factor for DVTs. In a study comparing the incidence of VTE following laparoscopic versus open surgery in 138,595 patients, there was a statistically significant reduction in risk of VTE after laparoscopic surgery compared to open surgery, even after stratification by severity of illness.²¹ The longer operative time might be explained by the generally sicker patient population, more acute presentation among EGS patients, and inherently by the need for a more complex and intensive operation. These procedures are also occurring in patients who likely have more systemic inflammation related to the underlying pathology requiring operation, creating a nidus for VTE formation. In a qualitative study characterizing providers' impressions of patient-variability and system-variability contributing to the disproportionate rates of morbidity and mortality in emergency general surgery (in comparison to elective general surgery), EGS patient-variability was attributed to their acute physiology and chronic comorbidities.²² Participants reported that the emergent nature of EGS was characterized by patients' propensity toward advanced disease, progressive inflammation, and septic physiology, culminating in more technically difficult operations as well as their aptitude to carry with them comorbidities that may not be well understood at the time of EGS presentation.²²

Our patient demographic characteristics reveal that patient's whose operation took longer than 100 min were older, with higher body mass index, higher ASA class, higher rates across all complications and longer hospital length of stay. This is understandable because the sicker and more morbid the patient is pre-operatively, the more likelihood, potentially, of an intraoperative complicated course and subsequently longer operative times.

Upon stratification by procedure type, the relationship between longer operating times (\geq 100 min) and VTE was still found to be statistically significant across the different operations with the exception of appendectomies and cholecystectomies. This may be due to lack of power from small sample sizes and/or low event rates. However, this stratified analysis is critical because different procedures have different expected average operative durations and potentially different expected rates of VTE. This is better answered by stratification as seen in Table 4 than by regression

alone.

While the proportion of emergency surgeries is relatively small (11% of total surgeries), their postoperative morbidity and mortality (28% and 47% respectively of total postoperative complications and deaths) is noted to be much higher.⁴ This makes EGS a ripe field for quality initiatives and better understanding of its potentially preventable postoperative complications and their risk factors, especially because preoperative optimization and risk factor modification is difficult and sometimes not possible in this population.⁴ Towards this, recognition of the dramatic effect of operative duration on VTE formation in EGS patients, should play a role in surgeons' operative planning. While shortening the length of the operation might be impractical, our findings can change practice in other ways. They should heighten awareness in this high-risk population to ensure VTE prophylaxis is prescribed and administered to provide ideal prophylaxis.^{23,24,25} This is especially important in a time when VTE has been targeted as a priority for quality improvement.¹⁰ The documented higher rates of overall morbidity and mortality in emergency general surgery patients in comparison to elective general surgery could be partly attributed to the higher rates of VTE complications.²⁶ VTEs are independent risk factors for increased mortality and up to 4-fold increased health care costs.⁵ After infectious complications, VTE complications were found to be the second most common reason for readmissions in EGS patients, specifically postoperative pulmonary embolism (77%).⁵ Readmission rates are strong contributors to cost and are considered hospital quality of care markers by the Affordable Care Act.²⁷

There are several limitations in our study mainly due to its retrospective nature. First, the ACS-NSQIP only tracks patients for 30-days, and the risk of VTE remains elevated for 90-days²⁰, allowing the possibility that patients who developed DVT/PE after 30-days may not be included in our analysis. Second, NSQIP does not include data on VTE prophylaxis medications prescribed or administered, another important driver of, or protector from, VTE.^{10,28–30} Third, the characteristics of each event are not recorded. It is therefore unknown if the patient was asymptomatic with an incidental finding of VTE, or if they were symptomatic and the degree of those symptoms. Fourth, NSQIP also does not track personal or family history of VTE, which is an important risk factor for development of VTE postoperatively. Given that this is not common, it is unlikely that the lack of this information would have a significant impact on our results. Fifth, physiologic parameters (i.e. blood pressure, heart rate) are not available and may serve as residual confounders influencing VTE occurrence. There is also the possibility of surveillance bias, the "more you look, the more you find" phenomenon which is well known to impact VTE event rates^{31,32,33} Sixth, NSQIP does not track the nature and characteristics of the institutions and their specific chemo prophylaxis measures and protocols, and the inability to control for differences among these possible confounders across different hospitals remains a limitation. Finally, the dataset does not provide specific information regarding the severity of comorbidities, indications for

surgery, or specific outcomes related to a given procedure. Despite these limitations, a major advantage of NSQIP is that it remains to be a wealth of data prospectively collected from various clinicians across the country with a low rate of inter-observer disagreement.³⁴

Conclusion

This analysis looked at 114,034 EGS patients undergoing 6 common EGS procedures over 3 years to evaluate the impact of time in the operating room on developing DVT and/or PE after emergency general surgical procedures.

Prolonged operative time, specifically more than 100 min, was found to be an independent risk factor for developing VTE after an EGS procedure. For every 10 min increase after the 100 min, the risk of developing DVT increases by 7% and the risk of PE increases by 5%. These findings should guide surgeons with operative planning aimed at decreasing the incidence of post-operative VTE, with the goal of decreasing the increased rate of morbidity and mortality associated with EGS.

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Disclosures

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.amjsurg.2019.04.022>.

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