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Incidence and Cost of Deep Vein Thrombosis in Emergency General Surgery Over 15 Years

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ABSTRACT

Background: Deep vein thromboses (DVTs) are a significant sequela of surgery and are associated with significant of morbidity and mortality in the United States. Operative emergency general surgery (EGS) cases have been demonstrated to have a greater burden of DVT than other types of surgery.

Materials and methods: DVT in EGS cases were identified from the National Inpatient Sample–Healthcare Cost and Utilization Project database from 2001 to 2015 Q3 based on ICD-9 code specification. National incidence of DVT in EGS was calculated using the National Inpatient Sample–Healthcare Cost and Utilization Project sampling methodology, and propensity score matching was used to assess costs associated with DVT.

Results: Among 15,148,352 sample-weighted hospitalizations, 0.623% (94,392) experienced DVT. Incidence of DVT was greatest in GI ulcer surgery (1.705%) and lowest in appendectomy (0.095%). Patients with a perioperative DVT incurred $22,301 more in hospital-related costs than their counterparts who did not have a DVT. Although rates of DVT remained stable over the period analyzed, DVT-associated costs increased at a 2.09% annual rate in excess of inflation during the period analyzed. This increase in costs was most significant for laparotomy, which increased at a rate of 8.09% annually.

Conclusions: DVT continues to be a significant burden on resources in EGS in spite of efforts with DVT prophylaxis. Considering the increase in costs and little change in incidence, further research on cost-effective management of DVT in EGS is warranted.

Introduction

Surgery is a well-established risk factor for the development of deep vein thrombosis (DVT).[1] In 2004, the rate of DVTs was approximately 15% to 30% in patients undergoing general surgery without DVT prophylaxis.[2] That same year, the American College of Chest Physicians released several grade 1 recommendations regarding the use of venous thromboembolism (VTE) prophylaxis based on risk stratification of surgical patients.[3] The ENDORSE study published in 2008, however, found that only 58.5% of surgical patients had received appropriate VTE prophylaxis,[4] and rates were as low as 12.7% in general surgery patients.[5] Despite public health efforts to raise awareness and adherence to guidelines, development of DVT remains a common risk factor for increased length of stay (LOS) and hospital readmission.[6] Current CDC data report more than $10 billion dollars are spent annually on VTE-associated costs and approximately 50% of VTEs are health care associated.[7,8]

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Operative emergency general surgery (EGS) cases have been shown to have higher rates of DVT when compared with non-EGS cases. A 2015 study found that 15.6% of EGS patients experienced a postoperative DVT requiring treatment, whereas only 9.1% of non-EGS patients similarly experienced a postoperative DVT.[9] Furthermore, up to 35% of EGS patients developed a VTE after discharge, and undergoing an EGS procedure was found to be a significant risk factor for readmission because of VTE.[10,11] The cost of DVTs increases further with readmission, approximating an additional $9782 because of any cause.[12,13] Based on validated risk assessment scores, most EGS patients are at moderate to high risk for VTE.[14] EGS is an emerging field of general surgery whose nationwide annual incidence now accounts for approximately $28 billion dollars annually in the United States.[15] EGS is associated with a higher rate of morbidity and mortality as well as mean cost per admission at $13,241.[16-18] There is a large gap, however, as to how the EGS population contributes to the significant VTE-associated costs in our health care system, especially given the variability between operative *versus* nonoperative EGS.

Despite publication of American College of Chest Physicians guidelines on VTE prophylaxis approximately 15 y ago, the ongoing rates and costs of DVT continue to remain high. Patients undergoing EGS are an important population to evaluate for VTE incidence as the burden of EGS continues to expand and contribute to health care costs. One study reported that only 41% of surgical patients received appropriate VTE prophylaxis, but that surgical patients admitted from the emergency department with higher acuity were found to have higher rates of adherence.[19] Thus, the actual contribution of DVT-associated costs in EGS patients to the national costs spent on VTE-associated expenditures remains unknown. Furthermore, the impact of ongoing public health efforts to lower the rates of DVTs over time has yet to be determined, particularly within a growing EGS population.

The aim of this study is to identify whether trends of DVT-associated costs have changed within the EGS population and which procedures are contributing most to these costs. As the scope of EGS is highly varied, identifying which cases contribute most to DVT-related expenditures can provide a practical target for quality improvement interventions. In addition, this study aims to identify the differences in cost between operative and nonoperative EGS patients, as nonoperative EGS patients can represent a substantial proportion of an EGS service caseload and may even contribute to higher rates of complications.[20]

Material and methods

Study data

Hospital discharge data for the years 2001-2015 Q3 was sourced from the National Inpatient Sample (NIS) and Healthcare Cost and Utilization Project (HCUP) Agency for Healthcare Research and Quality.[21] This is the largest publicly available all-payer inpatient database, covering approximately 20% of hospital discharges in the United States. The NIS database provides a sufficiently large sample size for the robust analysis of relatively infrequent events, such as rates of DVT. Each record in the NIS represents a single hospital discharge and provides demographic data for the patient, diagnoses, and procedures furnished through the course of the hospitalization, LOS for the patient, and total charges billed.

Inclusion criteria for emergency general surgery cases

Surgical admissions were selected for inclusion on the basis of the primary procedure code specified in each discharge record and a nonelective admission type. These were matched against a list of relevant ICD-9 codes for EGS (Table 1). NIS migrated specification of procedures and diagnoses to ICD-10 after the third quarter of 2015; therefore, we limited our analysis to the time period specified by ICD-9 codes to ensure consistent coding across the period analyzed.

Comorbidity derivation and identification of DVT cases

Data analysis was performed using the R statistical computing environment version 3.6.0 (Planting of a Tree).[22] Comorbidities were abstracted from discharge records using the "icd9_comorbid_ahrq" function from the ICD package, which is based on mapping logic from the Elixhauser Comorbidity Software Tool version 3.7.[23,24] Perioperative DVT was identified via relevant ICD-9 codes (Table 1). DVT rates for each procedure over time were then calculated using the trend weights provided by HCUP and then dividing the number of discharges with DVT by the total number of discharges for each procedure under consideration.[25]

Propensity score matching and cost analysis

The cost of each admission was calculated by adjusting total billed charges using the appropriate charge-to-cost ratio for each hospital and year, supplied by the HCUP-NIS database. In situations where hospital-specific ratios were unavailable, a ratio was imputed by using the mean ratio for hospitals in the same census bureau region with a similar number of beds and academic/community hospital status. Nominal costs were adjusted for inflation by converting them to 2016 dollars based on the mean Consumer Price Index for that year.[26]

To control for the effects of comorbid conditions on DVT incidence and the effect of DVT on total cost and LOS, a propensity score matching technique was implemented using the R package MatchIt.[27,28] Using this method, patients who develop a DVT are matched on a 1:1 basis to the other patient in the database from the same hospital and discharge year who were undergoing the same EGS procedure with the most similar likelihood of developing a DVT but did not (Table 2). Exact matching by hospital, discharge year, and EGS procedure type was performed to account for baseline differences in the DVT rate by institution, year, and procedure type and to provide the most robust comparison possible within the constraints of the data available.

Each patient that had a DVT was matched to a non-DVT control from the same hospital and year undergoing the same type of EGS with a similar profile of comorbidities. Matching was accomplished by first calculating a binary logistic propensity score and then performing 1:1 nearest-neighbor matching. The R package "svymeans" as used to calculate mean LOS and total

Table 1 – ICD-9 inclusion criteria.

ICD-9 code	ICD-9 short description	EGS categorization
453.4	Acute venous embolism and thrombosis of deep vessels of lower extremity	DVT
453.41	Acute DVT/embolism of the proximal lower extremity	
453.42	Acute DVT/embolism of the distal lower extremity	
453.50	Embolism of superficial vessels of the lower extremity	
453.51	Acute venous embolism and thrombosis of other specified veins	
453.52	Acute embolism of other specified veins	
453.6	Other venous embolism and thrombosis of unspecified site	
45.76	Open and other sigmoidectomy	Colectomy
45.73	Open and other right hemicolectomy	
45.75	Open and other left hemicolectomy	
45.72	Open and other cecectomy	
45.79	Other and unspecified partial excision of large intestine	
45.74	Open and other resection of transverse colon	
45.71	Open and other multiple segmental resection of large intestine	
45.62	Other partial resection of small intestine	Bowel resection
45.61	Multiple segmental resection of small intestine	
45.63	Total removal of small intestine	
51.23	Laparoscopic cholecystectomy	Cholecystectomy
51.22	Cholecystectomy	
51.21	Other partial cholecystectomy	
51.24	Laparoscopic partial cholecystectomy	
44.42	Suture of duodenal ulcer site	Gastroduodenal ulcer surgery
44.41	Suture of gastric ulcer site	
44.4	Suture of peptic ulcer, not otherwise specified	
44.49	Other control of hemorrhage of stomach or duodenum	
54.59	Other lysis of peritoneal adhesions	Adhesiolysis
54.51	Laparoscopic lysis of peritoneal adhesions	
47.01	Laparoscopic appendectomy	Appendectomy
47.09	Other appendectomy	
54.11	Exploratory laparotomy	Laparotomy
54.19	Other laparotomy	
54.12	Reopening of recent laparotomy site	

cost in patients with and without DVT for each of the procedure types analyzed.[29] Cost burden was calculated as the difference between total cost for patients undergoing a particular procedure who had a DVT and that of those who did not. A logistic regression model was applied to identify annual trends of DVT incidence and DVT cost burden. Results were considered statistically significant at a P value < 0.05.

The use of HCUP databases meets the criteria for being exempt from IRB review by the Committee for the Protection of Human Subjects at Rutgers New Jersey Medical School.

Results

Demographics

EGS procedures comprised a total of 15,148,352 hospitalizations from 2001 to 2015. The average age of these patients was 50.23 y and 56.8% were female.

DVT incidence

From 2001 to 2015 Q3, 0.623% (94,392) perioperative DVTs were identified. DVTs occurred most frequently subsequent to GI ulcer surgery at a rate of 1.705% (4018) and least frequently after appendectomy at a rate of 0.095% (3698). On average, hospitalization of patients who experienced a DVT subsequent to EGS cost $22,301 more than counterparts who did not have a DVT. This cost burden was most pronounced in laparotomy, where the additional cost associated with experiencing a DVT was $34,975. Hospitalization associated with DVT was least expensive for patients undergoing cholecystectomy which was associated with an increase of $13,856 in total cost of hospitalization. Annual trends in incidence of DVT from 2001 to 2016 are presented in Table 3.

Trend analysis: incidence

For the period analyzed from 2001 to 2015 Q3, there was no statistically significant trend in the incidence of DVT with

Table 2 – Balance statistics for propensity score matching.

Demographics and comorbidities	DVT	No DVT	P-value
Mean age	65.6	67.0	<0.001
Female, %	54.9	55.6	0.174
Selected ccomorbidities*, %			
Pulmonary hypertension	13.8	11.4	<0.001
Metastatic disease	15.8	16.3	0.159
Weight loss	22.6	23	0.508
Coagulopathy	10.9	10.6	0.299
Hypertension	43	44.4	0.007
Hypothyroidism	7.5	7.3	0.381
Valvular disease	4.8	5.1	0.260

* Additional comorbidities included in the model: HIV, peptic ulcer disease, lymphoma, fluid/electrolyte imbalance, tumor, paralysis, rheumatic disease, renal disease, anemia, neurologic disease, drug/substance abuse, congestive heart failure, psychoses, peripheral vascular disease, diabetes mellitus, alcohol use, obesity, pulmonary disease, depression, liver disease. These are not listed here because of low prevalence or small effect size in the propensity score matching model.

incidence ranging from 0.490% in 2011 to 0.701% in 2004. This reflects no distinct temporal association and therefore a stable trend. Subgroup analysis by procedure type demonstrated a statistically significant (1.83%, $P < 0.05$) annual decrease in rates for adhesiolysis surgery (CI [3.19%, −0.45%], $P = 0.035$) and 2.33% decrease annually for bowel resection (CI [−3.98%, −0.65%], $P = 0.029$). Other surgeries demonstrated no significant trend (Table 3).

Trend analysis: cost

Inflation-adjusted costs associated with DVT in EGS overall demonstrated a 2.09% increase annually in the period from 2001 to 2015 Q3 (CI [1.34%, 2.86%], $P < 0.001$). This increase was most prominent in laparotomy, which demonstrated an 8.09% annual increase (CI [3.89%, 12.45%], $P = 0.004$). Cholecystectomy, surgery for acute gastroduodenal ulcer, and appendectomy showed no statistically significant change in costs associated with DVT for the period analyzed (Table 4).

Discussion

Health care–associated VTE events remain an important preventable complication for surgical patients. In this study, we found that from 2001 to 2015 Q3, the overall incidence of DVTs in EGS did not change, although there was a statistically significant decrease in DVTs after adhesiolysis surgery and bowel resection. Furthermore, the costs associated with DVTs in EGS were found to have increased significantly overall by 2.09% and are greatest in laparotomy, where costs increased by 8.09%. This observation suggests that there are still gaps in DVT prevention and more is being spent on DVT-associated complications.

Previous reports have cited the growing burden of VTE, with one report estimating more than 1.82 million cases by 2050.[7,30] Trends of VTE rates are seen to be declining in high-risk populations such as those undergoing major operative procedures, however.[31] This is consistent with the decreasing rates of DVT after adhesiolysis and bowel resection found in this study. However, the two most common operative cases of EGS are cholecystectomy and appendectomy,[14] which were not found to have a change in DVT rates and may consequently account for why there is no overall decrease in DVT incidence for EGS patients.

From 2001 to 2010, approximately 7.1% of all hospital admissions in the United States were EGS admissions.[32] The increasing costs of hospitalization associated with DVT may be related to an increased LOS in a growing EGS population. Excess LOS after abdominal surgery is 10.88 d longer in patients with VTE compared with those without VTE using multivariate analysis.[33] This study found that the average cost of hospitalization for EGS patients who experienced DVT is $22,301 more than EGS patients without DVT.

The cost burden of EGS patients with DVTs is highest in patients undergoing laparotomy and lowest for patients undergoing gallbladder surgery. The median LOS for laparotomy is 17 d, which is 8 d longer than the average LOS for all operative EGS cases.[9,34] Furthermore, the mean cost of laparotomy is $21,962 over a 4-year study period (2008-2011) compared with a mean cost of $10,579 for cholecystectomy.[14] This study found that the additional cost for laparotomy associated with DVT is $34,975 while there is an additional $13,856 cost for gallbladder surgery associated with DVT.

The scope of EGS varies widely in both clinical practice and systemic delivery of care, impacting the excess burden of disease seen in EGS. A recent study showed how the variation of LOS in EGS patients is likely related to nonclinical factors.[35] There is a lack of standardization for implementing EGS among hospitals (e.g., lack of formal sign out, data collection, and call duties), although dedicated acute care surgery models have been shown to improve clinical and financial outcomes for EGS.[36,37] By creating a standardized approach to EGS patients, a decrease in LOS—and consequently DVT costs—may result. Furthermore, implementation of standardized protocols, such as order sets and dedicated multidisciplinary teams, has been shown to improve adherence to VTE prophylaxis and prevention of health care–associated VTE.[38,39]

Limitations

This study has several limitations. The HCUP-NIS database provides a large, nationally representative sample size that has inherent limitations that stem from inconsistencies observed in coding and payment incentives. These challenges may encourage or oppose the use of certain codes and lead to a potential statistical bias in the analysis and impact the interpretation of the findings. Different approaches in the inclusion and exclusion criteria have been widely described in the literature and have the potential to result in over- or underreporting of certain diagnoses. This could occur because of the differences in coding standards specific to the U.S. institutions and result in a limited number of diagnoses which could be listed per patient. These differences have the potential to be particularly challenging for any scientific study because of the Center for Medicare and Medicaid Services-imposed

Table 3 – Trends in DVT incidence by procedure.

Year	EGS overall, %	Adhesiolysis, %	Appendectomy, %	Bowel resection, %	Colectomy, %	Cholecystectomy, %	Laparotomy, %	Ulcer surgery, %
2001	0.54	0.9	0.07	1.56	1.1	0.26	1.49	1.46
2002	0.59	1.08	0.08	1.7	1.13	0.32	1.58	1.42
2003	0.68	1.01	0.12	2.01	1.26	0.39	1.77	1.97
2004	0.7	0.99	0.12	1.81	1.42	0.4	1.67	1.33
2005	0.58	1.01	0.11	1.63	1.11	0.27	1.58	1.69
2006	0.64	0.94	0.1	1.9	1.24	0.3	1.69	1.53
2007	0.64	0.95	0.1	1.94	1.19	0.33	1.67	2.07
2008	0.69	0.99	0.1	2.16	1.34	0.35	1.85	1.95
2009	0.64	0.93	0.08	2.04	1.49	0.3	1.88	2.23
2010	0.51	0.77	0.06	1.48	1.19	0.25	1.42	1.64
2011	0.49	0.68	0.08	1.26	1.03	0.28	1.46	1.55
2012	0.51	0.69	0.06	1.23	1.18	0.25	1.76	1.77
2013	0.52	0.8	0.08	1.28	1.29	0.25	1.35	1.14
2014	0.57	0.76	0.09	1.35	1.33	0.28	1.6	1.33
2015	0.69	1.06	0.14	1.5	1.55	0.31	1.85	2.28
Annual growth rate, %	−0.68	−1.83	−0.78	−2.33	0.96	−1.40	−0.040	0.40
95% confidence interval	−1.99, 0.65	−3.19, −0.45	−3.56, 2.09	−3.98, −0.65	−0.23, 2.16	−2.88, 0.10	−1.15, 1.09	−1.84, 2.68
P-value	0.384	0.035	0.635	0.029	0.176	0.121	0.954	0.760

Table 4 – Trends in inflation-adjusted cost associated with DVT by procedure.

Year	EGS overall, $	Adhesiolysis, $	Appendectomy, $	Bowel resection, $	Colectomy, $	Cholecystectomy, $	Laparotomy, $	Ulcer surgery, $
2001	18,090	13,221	6992	19,816	12,095	8409	14,782	34,358
2002	19,653	9865	12,639	17,020	14,783	11,741	21,553	32,866
2003	20,569	19,419	15,667	17,305	15,894	11,300	20,334	14,924
2004	20,044	15,719	14,830	9400	16,708	13,275	29,960	24,608
2005	21,205	18,827	16,899	19,028	18,812	13,322	13,938	9739
2006	20,146	9482	13,180	18,892	15,415	15,949	32,868	35,852
2007	23,711	22,341	30,872	20,263	19,039	17,682	27,257	22,353
2008	23,160	21,989	19,063	21,220	20,242	18,343	30,009	18,792
2009	22,815	17,665	13,747	25,701	20,023	15,908	28,909	17,994
2010	25,179	26,335	9829	26,710	23,001	12,225	43,705	16,084
2011	21,341	21,098	18,483	21,069	16,209	13,032	59,362	18,512
2012	27,895	30,258	18,713	31,674	25,856	14,159	35,010	45,855
2013	24,203	24,964	18,735	35,080	21,463	4912	50,233	51,081
2014	24,960	33,211	16,556	27,720	25,702	16,957	19,684	30,068
2015	23,415	15,373	15,002	34,385	17,476	9833	84,384	27,895
Annual growth rate, %	2.09	5.26	2.77	6.04	3.47	−0.47	8.09	2.44
95% confidence interval	1.34, 2.86	1.99, 8.65	−0.67, 6.33	3.62, 8.51	1.82, 5.14	−4.09, 3.30	3.89, 12.45	−2.38, 7.50
P-value	<0.001	0.013	0.178	<0.001	0.002	0.827	0.004	0.392

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financial penalties for hospital-acquired conditions that rely on the diagnosis codes and, therefore, may incentivize under-reporting of ICD-9 codes associated with DVT. In addition, the HCUP-NIS database cannot capture all details of a patient's hospital course and may therefore be deficient in reporting certain comorbidities or complications that meaningfully contribute to patient costs or LOS. The mapping logic used for comorbidity identification, while validated by the organization that administers the HCUP-NIS database, may also not include all possible cost-modifying comorbidities and may therefore contribute to inaccuracies in our calculations because of biases that may not be accounted for properly in our matching.

This study is limited by its evaluation of DVT during the index admission. This group of patients may contribute significantly to the total cost of health care–associated DVT. In addition, this study does not evaluate pulmonary embolisms, despite pulmonary embolism being a major contributor to the mortality rate and cost of VTE.

Conclusions

The incidence of DVT in EGS is an area for improvement regarding patient safety and nationwide health care costs. A propensity score matching analysis was implemented to investigate DVTs in EGS procedures, resulting in no significant decrease of DVTs overall but higher associated costs. Higher costs can be related to increased LOS. Further studies identifying gaps in patient care and implementing interventions may help address this problem.

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Disclosure

The authors report no conflict of interest.

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