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# Prevalence of Risk Factors for Hospital-Acquired Venous Thromboembolism in Neurosurgery and Orthopedic Spine Surgery Patients

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## ABSTRACT

**Background:** Hospital-acquired venous thromboembolisms (HA-VTE) are a significant source of morbidity and mortality in spine surgery patients. The purpose of this study was to review HA-VTE rates at our institution and evaluate the prevalence of known risk factors in patients who developed HA-VTE among both neurosurgical and orthopedic spine surgeries.

**Methods:** Retrospective chart reviews were conducted of all spine surgery patients from January 1, 2013, to July 31, 2017, to evaluate rates of HA-VTE and prevalence of known HA-VTE risk factors among these patients. Univariate and multivariate logistic regression analysis for categorical variables and independent Student *t* test for continuous variables were utilized with significance set at  $P < .05$ .

**Results:** The overall HA-VTE rate was 0.94% (0.61% orthopedic, 1.87% neurosurgery). Patients with VTEs had higher rates of thoracic procedure ( $P = .002$ ), posterior approach ( $P = .001$ ), diagnosis of fracture ( $P = .013$ ) or flatback syndrome ( $P = .028$ ), neurosurgery division ( $P < .001$ ), and diagnosis-related group (DRG) of noncervical malignancy ( $P = .001$ ). Patients with VTEs had lower rates of cervical procedure ( $P < .001$ ), diagnosis of herniated nucleus pulposus ( $P = .006$ ) and degenerative disc disease ( $P = .001$ ), and DRG of cervical spine fusion ( $P < .001$ ). In the patients who sustained VTE, the neurosurgical patients had higher rates of active cancer (22.86% vs 0%,  $P = .004$ ) and age  $>60$  (80% vs 50%,  $P < .001$ ), and orthopedic patients had higher estimated blood loss (EBL) (2436 ml vs 1176 mL,  $P = .006$ ) and rates of anterior-posterior surgery (22.58% vs 0%,  $P = .003$ ). Neurosurgery department, diagnosis of fracture, and DRG of noncervical malignancy were found to be significant independent risks for developing HA-VTE. Cervical procedures were independently associated with significantly lower risk. Postoperative anticoagulation initiated sooner in neurosurgery patients (postoperative day 1.26 vs 3.19,  $P < .001$ ).

**Conclusions:** The overall HA-VTE rate at our institution was 0.94% (0.61% orthopedic, 1.87% neurosurgery). In patients who sustained VTE, neurosurgical patients had higher rates of active cancer and age  $>60$  years, and orthopedic patients had higher EBL and rates of anterior-posterior surgery. This highlights the different patient populations between the 2 departments and the need for individualized thromboprophylaxis regimens.

**Level of Evidence:** 4.

Complications

Keywords: hospital acquired, venous thromboembolism, prevention

## INTRODUCTION

Venous thromboembolism (VTE) is the number 1 preventable hospital-acquired cause of morbidity and mortality in the United States.<sup>1</sup> In 2003, over 12 million patients, comprising 31% of U.S. hospital discharges, were at risk of VTE.<sup>2</sup> It is estimated that there are nearly 300,000 VTE-related deaths annually in the United States, and approximately two-thirds of symptomatic VTE events are hospital acquired.<sup>3</sup> A 2015 study found that 72% of VTE

patients had emboli that were potentially preventable with prophylaxis.<sup>4</sup> At the same time, poor adherence to thromboprophylaxis, whether pharmacologic or mechanic, correlates with increased VTE events. Previous studies have reported adherence rates between 38% and 60% with American College of Chest Physicians guidelines.<sup>5–8</sup> Even after a successfully treated episode, subsequent complications affecting the pulmonary, renal, cardiac, and nervous systems may persist for years.<sup>9</sup> Up to half of lower-extremity deep vein thrombosis (DVT)

patients develop postthrombotic syndrome and chronic venous insufficiency, struggling with pain, swelling, skin necrosis, and ulceration.<sup>10,11</sup> Even after a standard course of anticoagulant therapy, one-third of VTE patients experience a recurrence within 10 years of the initial event.<sup>10</sup> While the highest risk occurs within the first year, patients with a previous VTE remain at increased risk for life. Thus, many VTE patients require long-term anticoagulation to prevent additional clots, and this treatment itself decreases quality of life and increases risk for bleeding episodes.<sup>10</sup>

Another significant challenge presented by VTEs is a resulting increase in health care spending. It is estimated that the total annual health care cost attributable to VTE ranges from \$7594 to \$16,644 per patient, up to \$10 billion annually. These costs are often driven significantly by increased lengths of stay; reoperations and unplanned patient readmissions are generally even more costly.<sup>9,11,12</sup> There are known risk factors for hospital-acquired VTEs (HA-VTE), but the prevalence of these risk factors is not always reviewed in patients who have sustained DVT or pulmonary embolism (PE). Such factors include genetic (family history, thrombophilic diseases), acquired (age, cancer, obesity, chronic diseases), and transiently acquired (pregnancy, oral contraceptives, trauma, immobilization) variables.<sup>10</sup>

Several studies exist evaluating the prevalence of DVT and PE following orthopedic surgery.<sup>13–15</sup> Rates of venographic DVT and proximal DVT 1–2 weeks following major orthopedic surgery in patients receiving no prophylaxis are between 40% and 60% and 10% and 30%, respectively.<sup>12</sup> However, most existing research pertaining to VTEs and orthopedic procedures has explored total hip and knee arthroplasties and hip fractures, and limited data are available on spine surgeries. While there is strong evidence for recommendations on prophylaxis in spine procedures, little information addresses more nuanced details regarding risk factors.<sup>12</sup> Furthermore, analyses associating categories of diagnoses and procedures in spine surgery with VTE development are lacking. Therefore, this study aimed to review HA-VTE rates at our institution and evaluate the prevalence of known risk factors in patients who developed HA-VTE among both neurosurgical and orthopedic spine surgery patients.

## MATERIALS AND METHODS

### Data Source and Inclusion Criteria

This is a retrospective review of all patients who presented at a large single academic spine center for spinal surgery from January 1, 2013, to July 31, 2017. All patients were included for analysis excluding those with lengths of stay <1 day or newborns. Prior approval was obtained from the institutional review board for retrospective patient chart review. Patients were evaluated for rates of HA-VTE as well as prevalence of known HA-VTE risk factors.

### Data Collection and Outcome Measures

Patients were assessed for development of HA-VTE. This was defined as an inpatient discharge that was diagnosed with DVT or PE not present on admission or a discharge that was readmitted within 30 days of index discharge with a principal diagnosis of DVT or PE. Patient demographics and risk factors were studied for patients with HA-VTE to compare differences in their prevalence between the orthopedic surgery and neurosurgery divisions. Demographic data collected included gender, age, ethnicity, body mass index (BMI), length of hospital stay, and number of spinal levels involved in surgery. Risk factors evaluated included estimated blood loss, anterior-posterior surgery, active cancer, age >60, BMI >40, prior VTE, congestive heart failure with ejection fraction <40%, thrombophilic disease, pulmonary hypertension, restrictive lung disease, smoking history, preoperative neurologic deficit, and intraoperative durotomy. Surgical factors analyzed included procedure level, procedure type, preoperative diagnosis, facility where surgery was performed, surgery department, and diagnosis-related group (DRG). Procedure levels used were thoracic, cervical, and lumbar. Procedure types assessed were fusion, discectomy, posterior approach, and interbody performed. Preoperative diagnoses and surgical DRGs were also evaluated. The prevalence of these factors was compared between patients with and without HA-VTE, between patients undergoing procedures with orthopedic surgery and neurosurgery, and also between patients at different hospital facilities at our institution.

### Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences, version 23

(SPSS Inc, Chicago, Illinois). Univariate analysis and multivariate logistic regression analysis for categorical variables and independent Student *t* test for continuous variables were utilized to evaluate characteristics in association with either development or no development of HA-VTE with a significance set at  $P < .05$ .

## RESULTS

### Study Sample

A total of 7156 patients undergoing spine surgery at our institution from January 1, 2013, to July 31, 2017, were studied.

### VTE vs Non-VTE: Patient Factors

The overall HA-VTE rate was 0.94% ( $n = 67$ ). The HA-VTE rate was 0.61% (32/5283) in orthopedic patients and 1.87% (35/1873) in neurosurgery patients. Patients with VTEs had a significantly higher percentage of individuals with the following factors: thoracic procedure ( $P = .002$ ), posterior approach ( $P = .001$ ), diagnosis types of fracture ( $P = .013$ ) and flatback syndrome ( $P = .028$ ), surgery performed at Hospital C ( $P < .001$ ), neurosurgery division ( $P < .001$ ), and DRG of noncervical malignancy ( $P = .001$ ) (Table 1). Patients with VTEs had a significantly lower percentage of individuals with cervical procedures ( $P < .001$ ), diagnosis types of herniated nucleus pulposus ( $P = .006$ ) and degenerative disc disease ( $P = .001$ ), and DRG of cervical spine fusion ( $P < .001$ ).

Multivariate logistic regression analysis was used to assess for independence of VTE risk factors, controlling for age and gender. The following factors were significant independent risks for developing VTE (Table 2): neurosurgery department (odds ratio [OR] 3.521 [95% confidence interval (CI) 2.110–5.882],  $P < .001$ ), diagnosis of fracture (OR 8.25 [95% CI 1.471–46.260],  $P = .016$ ), and DRG of noncervical malignancy (OR 4.798 [95% CI 2.845–8.090],  $P < .001$ ). Cervical procedure (OR 0.343 [95% CI 0.134–0.879],  $P = .026$ ) was independently associated with significantly lower risk of VTE development.

### Orthopedic Surgery vs Neurosurgery: Patient Factors

Comparing patient factors between departments, orthopedic surgery patients had a significantly

**Table 1.** Patient factor comparisons for venous thromboembolism (VTE) and non-VTE.

Factor	With VTE (n = 67), %	Without VTE (n = 7089), %	P-Value
Procedure level			
Thoracic	11.9	3.2	.002
Cervical	7.5	28.1	<.001
Lumbar	46.3	52.4	.328
Procedure type			
Fusion	46.3	35.1	.071
Discectomy	1.5	3.2	.726
Posterior approach	71.6	51.0	.001
Interbody performed	16.4	18.3	.874
Diagnosis			
Degenerative spondylolisthesis	11.9	9.3	.403
Fracture	3.0	0.2	.013
Acquired spondylolisthesis	10.4	8.0	.492
Adolescent idiopathic scoliosis	4.5	5.0	1.000
Herniated nucleus pulposus	6.0	18.4	.006
Hardware failure	1.5	0.2	.107
Myelopathy	10.4	14.0	.482
Radiculopathy	1.5	6.4	.128
Degenerative disc disease	17.9	37.2	.001
Adjacent segment disease	1.5	1.2	.569
Flatback syndrome	1.5	0.0	.028
Kyphosis	7.5	5.7	.431
Degenerative scoliosis	7.5	5.9	.596
Stenosis	14.9	18.2	.632
Facility			
Hospital A	41.8	68.2	<.001
Hospital B	1.5	1.1	
Hospital C	56.7	30.7	
Gender			
Male	35.8	47.7	.064
Female	64.2	52.3	
Department			
Neurosurgery	52.2	25.9	<.001
Orthopedic surgery	47.8	74.1	
DRG			
Cervical spine fusion	4.5	26.8	<.001
Noncervical malignancy	38.8	9.9	<.001
Noncervical fusion	32.8	39.2	.316
Combined anterior-posterior	14.9	15.2	1.000
Fusion			
Back and neck procedure without fusion	9.0	8.9	1.000

higher percentage of individuals with the following factors: lumbar procedure ( $P < .001$ ); fusion ( $P < .001$ ) and interbody ( $P = .005$ ) procedures; diagnosis types of degenerative spondylolisthesis ( $P < .001$ ), acquired spondylolisthesis ( $P < .001$ ), adolescent idiopathic scoliosis ( $P < .001$ ), radicu-

**Table 2.** Significant independent patient risk factors for venous thromboembolism.

Factor	Odds Ratio	95% Confidence Interval	P-Value
Neurosurgery department	3.521	2.110–5.882	<.001
Cervical procedure level	0.343	0.134–0.879	.026
Fracture diagnosis	8.250	1.471–46.260	.016
Noncervical malignancy (diagnosis-related group)	4.798	2.845–8.090	<.001



**Table 3.** Patient factor comparisons between orthopedic surgery and neurosurgery.

Factor	Orthopedic Surgery (n = 5283), %	Neurosurgery (n = 1873), %	P-Value
Procedure level			
Thoracic	3.3	3.0	.822
Cervical	26.2	33.7	<.001
Lumbar	55.4	43.7	<.001
Procedure type			
Fusion	37.0	29.8	<.001
Discectomy	1.9	7.0	<.001
Posterior approach	49.8	54.1	.001
Interbody performed	19.1	16.2	.005
Diagnosis			
Degenerative spondylolisthesis	11.0	4.6	<.001
Fracture	0.2	0.5	.003
Acquired spondylolisthesis	9.2	4.4	<.001
Adolescent idiopathic scoliosis	6.4	0.8	<.001
Herniated nucleus pulposus	18.8	17.5	.165
Hardware failure	0.2	0.2	.525
Myelopathy	8.9	28.5	<.001
Radiculopathy	7.2	4.0	<.001
Degenerative disc disease	31.4	53.8	<.001
Adjacent segment disease	1.3	1.0	.333
Flatback syndrome	0.0	0.1	1.000
Kyphosis	7.0	2.0	<.001
Degenerative scoliosis	7.2	2.1	<.001
Stenosis	18.6	16.8	.075
Facility			
Hospital A	87.6	12.7	<.001
Hospital B	0.9	1.6	
Hospital C	11.5	85.7	
Gender			
Male	46.6	52.1	.001
Female	53.4	47.9	
Diagnosis-related group			
Cervical spine fusion	24.6	33.1	<.001
Noncervical malignancy	10.7	7.8	.002
Noncervical fusion	37.4	44.1	<.001
Combined anterior-posterior fusion	19.3	3.5	<.001
Back and neck procedure without fusion	8.0	11.5	<.001

lopathy ( $P < .001$ ), kyphosis ( $P < .001$ ), and degenerative scoliosis ( $P < .001$ ); surgery performed at Hospital A ( $P < .001$ ); female gender ( $P = .001$ ); and DRGs of noncervical malignancy ( $P = .002$ ) and combined anterior-posterior fusion ( $P < .001$ ) (Table 3). Neurosurgery patients had a significantly higher percentage of individuals with the following factors: cervical procedure ( $P < .001$ ); discectomy ( $P < .001$ ) and posterior approach ( $P < .001$ ) performed; diagnosis types of fracture ( $P = .003$ ), myelopathy ( $P < .001$ ), and degenerative disc disease ( $P < .001$ ); surgery performed at Hospital C ( $P < .001$ ); male gender ( $P < .001$ ); and DRGs of cervical spine fusion ( $P < .001$ ), noncervical fusion ( $P < .001$ ), and back and neck procedure without fusion ( $P < .001$ ).

**Table 4.** Patient factor comparisons between hospital facilities.

Factor	Hospital A (n = 4863), %	Hospital C (n = 2215), %	P-Value
Procedure level			
Thoracic	2.5	5.1	<.001
Cervical	26.7	29.6	.013
Lumbar	57.2	42.2	<.001
Procedure type			
Fusion	36.7	29.8	<.001
Discectomy	1.7	6.5	<.001
Posterior approach	48.8	56.5	<.001
Interbody performed	19.6	13.7	<.001
Diagnosis			
Degenerative spondylolisthesis	11.2	5.4	<.001
Fracture	0.1	0.5	.001
Acquired spondylolisthesis	9.8	4.2	<.001
Adolescent idiopathic scoliosis	4.4	6.5	<.001
Herniated nucleus pulposus	19.1	15.7	<.001
Hardware failure	0.1	0.2	.749
Myelopathy	9.6	22.7	<.001
Radiculopathy	7.3	3.7	<.001
Degenerative disc disease	32.9	45.5	<.001
Adjacent segment disease	1.2	1.2	1.000
Flatback syndrome	0.0	0.0	1.000
Kyphosis	5.4	6.5	.069
Degenerative scoliosis	5.7	6.6	.116
Stenosis	19.6	15.5	<.001
Gender			
Male	47.0	49.2	.120
Female	53.0	50.8	
Department			
Neurosurgery	4.9	72.5	<.001
Orthopedic surgery	95.1	27.5	
Diagnosis-related group			
Cervical spine fusion	24.9	29.3	<.001
Noncervical malignancy	8.5	14.1	<.001
Noncervical fusion	38.3	40.9	.038
Combined anterior-posterior fusion	20.3	4.3	<.001
Back and neck procedure without fusion	7.9	11.4	<.001

### Facility Comparison: Patient Factors

Patient factors were compared between Hospital A (n = 4863) and Hospital C (n = 2215), excluding Hospital B (n = 78) due to a lack of patient volume, which could skew analyses. Patients at Hospital A had a significantly higher percentage of the following factors: lumbar procedure ( $P < .001$ ); fusion ( $P < .001$ ) and interbody ( $P < .001$ ) procedures; diagnosis types of degenerative spondylolisthesis ( $P < .001$ ), acquired spondylolisthesis ( $P < .001$ ), herniated nucleus pulposus ( $P < .001$ ), radiculopathy ( $P < .001$ ), and stenosis ( $P < .001$ ); orthopedic surgery division ( $P < .001$ ); and DRG of combined anterior-posterior fusion ( $P < .001$ ) (Table 4). Patients at Hospital C had a significantly higher percentage of the following factors: thoracic ( $P < .001$ ) and cervical ( $P = .013$ ) procedures; discectomy ( $P < .001$ ) and posterior approach ( $P < .001$ ) performed; diagnosis types of fracture ( $P = .001$ ),

**Table 5.** Characteristics of patients with venous thromboembolism (VTE) in orthopedic surgery and neurosurgery.

Factor	Orthopedic Surgery	Neurosurgery	P-Value
Demographics, %			
Gender (F)	68.75	60	.611
Average age	64.80	60.59	.117
Ethnicity, %			.059
White	65.63	70.59	
Black	18.75	23.53	
Hispanic	15.63	0	
Asian	0	5.88	
Average body mass index (BMI)	31.32	28.99	.112
Average length of stay	9.66	10.74	.400
No. of surgery levels	6.56	5.68	.442
VTE risk factors			
Estimated blood loss, mL	2436	1176	.005
Anterior-posterior surgery, %	22.58	0	.003
Active cancer, %	0	22.86	.005
Age >60, %	50	80	.001
BMI >40, %	6.25	2.86	.603
Prior VTE, %	25	11.76	.210
Congestive heart failure with ejection fraction <40%, %	3.13	0	.478
Thrombophilic disease, %	3.13	0	.478
Pulmonary hypertension, %	3.13	0	.478
Restrictive lung disease, %	9.68	0	.335
Smoking history, %	51.72	51.43	1.000
Preoperative neurodeficit, %	46.90	62.90	.225
Durotomy, %	6.30	17.10	.170
First day of mobilization (postoperative)	1.56	2.09	.176
Invasiveness index score	19.09	15.74	.196

adolescent idiopathic scoliosis ( $P < .001$ ), myelopathy ( $P < .001$ ), and degenerative disc disease ( $P < .001$ ); neurosurgery division ( $P < .001$ ); and DRGs of cervical spine fusion ( $P < .001$ ), noncervical malignancy ( $P < .001$ ), noncervical fusion ( $P = .038$ ), and back and neck procedure without fusion ( $P < .001$ ).

#### Orthopedic Surgery vs Neurosurgery: Characteristics of Patients With VTE

Among patients with VTE, there was no difference between orthopedic and neurosurgery patients in terms of patient age, ethnicity, gender, BMI, length of stay, and number of surgical levels (Table 5). When evaluating the prevalence of known risk factors among patients who sustained HA-VTE, orthopedic patients had a higher estimated blood loss (EBL) (2436 mL vs 1176 mL,  $P = .005$ ) and percentage undergoing anterior-posterior surgery (22.58% vs 0%,  $P = .003$ ). Neurosurgery patients

had higher rates of active cancer (22.86% vs 0%,  $P = .004$ ) and more patients over the age of 60 (80% vs 50%,  $P < .001$ ). Other known risk factors of BMI >40, prior VTE, congestive heart failure with ejection fraction <40%, thrombophilic disorder, pulmonary hypertension, restrictive lung disease, smoking history, durotomy, preoperative neurologic deficit, first day of mobilization, and invasiveness index score were not significantly different between orthopedic and neurosurgery patients who sustained HA-VTE. The neurosurgery and orthopedic surgery patients who developed VTE had an average number of risk factors of 1.74 and 1.85 ( $P = .759$ ), respectively.

When comparing the cohort of patients with HA-VTE for differences between the neurosurgery and orthopedic surgery divisions, there were a few differences in practice patterns between the divisions, but these differences were not associated with HA-VTE (Table 6). Orthopedic patients had lower rates of inferior vena cava filter placement (28.13% vs 62.86%,  $P = .004$ ). All patients of both departments received postoperative anticoagulation, but it was initiated sooner in neurosurgery patients (postoperative day 1.26 vs 3.19,  $P < .001$ ).

## DISCUSSION

Costs for the management of VTE, the most common preventable, hospital-acquired cause of morbidity and mortality in the United States, are substantial and have increased over time.<sup>1,11</sup> VTE is estimated to be the second most common cause of excess length of hospital stay and the third most common cause of excess mortality, and readmissions may be up to 48% more costly than the initial event.<sup>11,12</sup> Given the economic burden of VTEs and their negative impact on patient quality of life, further exploration on the prevalence of patient risk factors for HA-VTE could improve preventive efforts. Twenty-four percent of VTEs are attributable to hospitalizations following surgery, of which orthopedic procedures make up a significant portion.<sup>16</sup> Spine surgery in particular lacks analyses associating categories of diagnoses and procedures with VTE development. This retrospective analysis

**Table 6.** Practice pattern differences between orthopedic surgery and neurosurgery in patients with venous thromboembolism.

Factor	Orthopedic Surgery	Neurosurgery	P-Value
Prophylaxis and treatment factors			
Rate of inferior vena cava filter placement	28.13%	62.86%	.007
Time of anticoagulation initiation (postoperative day)	3.19	1.26	<.001

aimed to review HA-VTE rates at our institution and evaluate the prevalence of known risk factors in patients who developed HA-VTE among both neurosurgical and orthopedic spine surgery patients. A total of 7156 patients undergoing spine surgery at our institution were included in this study.

We report an overall HA-VTE rate of 0.94%. In the current literature, spine fracture patients have been found to experience VTE at 4 times the rate of other spine surgery patients despite being more likely to receive chemoprophylaxis.<sup>17</sup> Although our sample size of VTE patients was small, diagnosis of fracture was found to be an independent risk factor for VTE development. While several studies have found a higher VTE risk in anterior approaches, our study did not find anterior approach to be an independent risk for HA-VTE.<sup>18,19</sup> It is not surprising that patients with malignancy would have a higher HA-VTE risk and that a DRG of noncervical malignancy was a significant independent risk factor for VTE.<sup>19,20</sup> Cervical procedure levels were associated with significantly lower risk of HA-VTE, likely because of the lower metabolic burden of such operations, allowing patients to mobilize and be discharged more quickly than in thoracolumbar cases. Operation by the neurosurgery department was also an independent HA-VTE risk factor, though this is likely attributable to the significantly higher rates of fracture patients and patients with malignancy seen in the neurosurgery patient population as demonstrated by Table 3.

Comparing such factors among all patients, between the orthopedic surgery and neurosurgery divisions and also between Hospital A and Hospital C allowed us to further characterize our findings. There were significant differences in most procedure types, diagnoses, and DRGs. Hospital A and the orthopedic surgery division generally followed similar trends, while Hospital C and the neurosurgery division followed similar trends. This is likely because the majority of the spine cases performed by the orthopedic surgery division occurred at Hospital A, while those performed by neurosurgery occurred at Hospital C. Overall, comparison between facilities and also between departments generally showed significant differences in the procedures and diagnoses represented by their respective patient populations. These results are consistent with the overall trend that VTEs developed in a higher percentage of neurosurgery patients and in a higher percentage of patients at Hospital C.

Among patients who developed VTEs, orthopedic patients had a higher EBL and percentage of patients undergoing anterior-posterior surgery. Higher intraoperative blood loss is associated with higher rates of VTE in previous studies.<sup>17</sup> However, EBL was not found to be an independent risk factor in our analysis, and the higher EBL noted in the orthopedic department more likely reflects a higher volume and percentage of deformity procedures performed. We found a higher rate of anterior-posterior surgery in orthopedic surgery patients. Neurosurgery patients had higher rates of active cancer and more patients over the age of 60. While having a lower average patient age, it is possible that the neurosurgery patients who were over 60 years had more complicated conditions, such as malignancy and trauma, that made them more predisposed to developing VTE compared to the orthopedics patients. There was also no significant difference in first day to mobilization between orthopedic surgery and neurosurgery patients, so patients of both departments were generally mobilized at the same time postoperatively. In addition, there was no significant difference in invasiveness index scores between departments. While the overall average index score for procedures conducted by neurosurgery would likely be higher than that of orthopedics, many of the orthopedic VTE patients underwent extensive adult deformity surgeries involving arthrodesis and instrumentation of numerous levels as opposed to more common procedures that were less invasive, such as laminectomy and discectomy.

We found no significant difference between orthopedic and neurosurgery patients with regard to risk factors for VTE such as BMI >40, prior VTE, congestive heart failure with ejection fraction <40%, thrombophilic disorder, pulmonary hypertension, restrictive lung disease, smoking history, durotomy, or preoperative neurologic deficit. More surgical levels are associated with increased VTE risk, and cardiac risk factors predict increased readmission rates.<sup>17</sup> The neurosurgery and orthopedic surgery patients who developed VTE had an average number of risk factors of 1.74 and 1.85, respectively, which reflects the overall low rate of operation on patients with a high risk for VTE.

There were a few notable practice differences between the neurosurgery and orthopedic surgery departments. Orthopedic patients had lower rates of inferior vena cava filter placement, while postoper-

ative anticoagulation was initiated sooner in neurosurgery patients. These differences most likely highlight differing philosophies between departments about approaching postprocedure anticoagulation as well as timing. While earlier use of VTE prophylaxis has been proposed to better prevent thromboembolic events without a significantly increased risk of bleeding complications, there is no clear consensus on the most effective timing of initiation.<sup>21</sup> The neurosurgical patients were started on anticoagulation on postoperative day 1, which demonstrates a routine use for starting shortly after surgery. Orthopedic surgery patients were started on postoperative day 3, which suggests a “wait and see” approach to drain removal and patient mobility. Yet, while neurosurgical patients were started on anticoagulation earlier, there was a higher rate of VTE in their group overall. It may be prudent to further explore prophylaxis regimens in future studies, as these results suggest that expanding on standard prophylaxis for patients at increased risk of VTE, such as trauma and cancer patients, may potentially be beneficial.

Our study had several limitations, mainly its retrospective design with a risk of selection bias and the relatively small sample size for patients who developed HA-VTEs, which may lead to an underestimation of significance for some of the parameters studied. It is also important to recognize that the true incidence of VTE may be higher, with some readmissions for VTE going to outside institutions and also the possibility of asymptomatic VTE. Existing literature suggests that VTEs may be underrecognized following spine surgery and may be as high as 15.5% in patients without prophylaxis.<sup>22</sup> This study demonstrates that, at our institution, the true VTE rate is unlikely to be that high. As this analysis focused on a single institution, it also reflects the clinical and operative decision making of our own surgeons with regard to patient selection, surgical procedures, and management. The difference between neurosurgery and orthopedic surgery may additionally be due to practice patterns related to diagnosing VTE. The difference noted may be due simply to a higher likelihood to order ultrasounds on neurosurgery postoperative patients. Our study adds to existing literature pertaining to postoperative VTE in spine surgery by exploring the prevalence of risk factors in greater detail and examining differences between spine disciplines as well as categories of diagnoses and procedures.

Future studies may expand on this work, and a multicenter study may further elucidate the reasons why certain procedures and diagnoses are more associated with HA-VTEs as well as differences between spine disciplines.

## CONCLUSIONS

The overall rate of HA-VTE is 0.94% for all spine surgery patients at our institution. The HA-VTE rate was 0.61% in orthopedic patients and 1.87% in neurosurgery patients. In the patients who sustained VTE, the neurosurgical patients had higher rates of active cancer and age >60, and orthopedic patients had higher EBL and rates of anterior-posterior surgery. This highlights the different patient populations between the 2 departments and the need for individualized thromboprophylaxis regimens.

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