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ORIGINAL ARTICLE

Venous thromboembolism after nephrectomy: incidence, timing and associated risk factors from a national multi-institutional database

Brian J. Jordan[1] · Richard S. Matulewicz[1] · Brian Trihn[1] · Shilajit Kundu[1]

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Abstract
Purpose To evaluate the rate of venous thromboembolism (VTE) after nephrectomy with specific focus on event timing and location (before or after hospital discharge) in order to identify modifiable risk factors and establish benchmarks for preventive interventions.
Methods Using the ACS-NSQIP database, we identified patients undergoing nephrectomy from 2006 to 2012. Patients were analyzed in two cohorts: collectively and by surgical approach [open vs. lap/robotic (MIS)]. Rates of deep vein thrombosis (DVT) and pulmonary embolus (PE) were assessed and time to each event was established in relation to discharge status. Logistic regression analysis was performed to assess association between preoperative risk factors, surgical variables, and VTE.
Results In total, 13,208 patients met inclusion criteria. The overall rate of VTE was 1.2% (PE = 0.5% and DVT = 0.8, 0.1% DVT and PE). Using regression analysis, diabetes, dependent functional status, and longer operative time were associated with higher odds of DVT. For PE, dyspnea, disseminated cancer, and longer operative time were significant associations. The rate of VTE was higher in open surgery compared to MIS (2 vs. 0.8%, $p < 0.001$). Median times to DVT and PE were 8.5 and 6 days, respectively, with 53.3% of DVTs and 63.1% of PEs occurring prior to discharge.
Conclusions The overall rate of VTE after nephrectomy is low, occurs roughly one week after surgery, and is associated with longer hospital stays. Certain patient factors, open surgical approach, and longer operative times were associated with higher odds of post-operative VTE; these patients may benefit from more aggressive prophylaxis.

Keywords Venous thromboembolism · Radical nephrectomy · Partial nephrectomy · Risk factors

✉ Brian J. Jordan
brian.jordan@northwestern.edu

[1] Department of Urology, Northwestern Feinberg School of Medicine, 303 E Chicago Ave, Tarry 16-703, Chicago, IL 60611, USA

Introduction

Venous thromboembolism (VTE) is a potentially devastating post-operative complication that includes both deep venous thrombosis (DVT) and pulmonary embolism (PE). VTE is known to be significantly associated with higher readmission rates and is the most common cause of death within 30 days after cancer surgery [1]. Estimates suggest that 60,000–100,000 Americans die of VTE annually. Approximately 10–30% of people will die within one month of diagnosis, and sudden death is the first event in about one-quarter (25%) of people who have a PE [2]. Major surgery is a well-known risk factor for VTE and those who develop VTE in the post-operative period have a higher mortality rate (adjusted proportionate mortality ratio 1.85) [3].

Of the many urological surgeries performed, cystectomy (2.9%), prostatectomy (1.0%) and nephrectomy (1.0%) have the highest post-operative VTE rates [4]. Studies have identified risk factors associated with VTE following cystectomy [5] and prostatectomy [6]. However, there is minimal data regarding the risk factors associated with VTE following nephrectomy.

In this study, we seek to define the rate of VTE and factors associated with an increased risk for VTE in the

30 days following nephrectomy, partial nephrectomy, or nephroureterectomy. Additionally, we sought to assess the time to VTE events and it's relation to discharge status. The identification of modifiable risk factors associated with VTE and the time to VTE event following these surgeries could potentially have significant clinical impact for prevention strategies and quality improvement initiatives.

Methods

Data source

Data for this study was obtained through the American College of Surgeons-National Surgical Quality Improvement Program (ACS-NSQIP) Participant Use Data File (PUF). NSQIP collects data on over 135 variables, including preoperative risk factors, intraoperative variables, and 30-day postoperative morbidity and mortality for patients undergoing major surgical procedures throughout the United States [7]. The information is collected prospectively by a site's surgical clinical nurse reviewer. An Inter-Rater Reliability Audit is performed to validate the data, with an approximate disagreement rate of 2.5%.

Study population

For study years 2006–2012, we identified patients using Current Procedural Terminology (CPT) codes who underwent radical or simple nephrectomy (CPT codes: 50220, 50225, 50230, 50545, and 50546,), partial nephrectomy (CPT codes: 50240 and 50543), or nephroureterectomy (CPT codes: 50234, and 50236, and 50548).

Variables

For each patient, preoperative characteristics including age, gender, BMI, smoking status, alcohol use, chronic obstructive sleep apnea (COPD), dyspnea (at rest and with moderate exertion), diabetes, hypertension, bleeding disorder, American Society of Anesthesiologists (ASA) score, disseminated cancer, and dependent functional status were reported. Additionally, information regarding the use of dialysis, current steroid use, chemotherapy use, or prior surgery was reported. Operative time, readmission, death within 30 days, and length of stay was recorded. The cases were also stratified by surgical approach: laparoscopic (LAP/MIS) (CPT Codes: 50543, 50545, 50546, and 50548) and open (CPT codes: 50220, 50225, 50230, 50234, 50236, and 50240).

Outcomes

The primary outcome was the rate of DVT, PE, and collectively, VTE within the 30-day postoperative period. NSQIP defines DVT as a deep venous clot confirmed by standard imaging and also treated with anticoagulation therapy or a caval filter. PE is defined as an embolism in the pulmonary artery or visible segmental arteries confirmed by standard imaging studies and treated with anticoagulation or a filter [7]. The time to DVT and PE were measured. Length of stay was used to determine inpatient vs. outpatient status at the time of VTE event. The relationship between VTE and length of stay was assessed.

Statistical analysis

Categorical variables were summarized as frequencies and percentages and compared between DVT and PE groups using Fisher's exact test. Continuous variables were summarized by means and standard deviations and compared between DVT and PE groups using the Wilcoxon rank-sum test. Logistic regression analysis was used to examine factors associated with DVT and PE using the bivariate screen method. Cases were analyzed together as a group and then sub-stratified by open and laparoscopic/minimally (MIS) operative approach. Length of stay (LOS) was summarized by medians and inter-quartile ranges (IQR). Time to event was compared to the LOS to determine inpatient or post-discharge status. All analyses were conducted in STATA v13.1 (College Park, TX) or SAS 9.4 (Cary, NC). Institutional IRB exemption was granted due to de-identified data.

Results

Our complete cohort was comprised of 13,208 patients who underwent nephrectomy (54.5%), partial nephrectomy (36.9%), or nephroureterectomy (8.6%). Among these patients, 107 (0.8%) developed DVT and 65 (0.5%) developed PE within 30 days of surgery. Twelve patients (0.1%) developed both a DVT and PE. The rates of VTE for nephrectomy, partial nephrectomy, and nephroureterectomy were 1.11, 1.18, and 1.85%, respectively, and were not significantly different ($p = 0.116$).The presence of DVT and PE were significantly associated with higher readmission rates; 12.5 and 7.7%, respectively, compared to a 2% readmission rate for patients without a DVT or PE ($p < 0.0001$ and $p = 0.001$). There was also a significantly higher 30-day mortality rate in the DVT (5.6%) and PE groups (7.7%) compared to those without postoperative VTE (0.7%, $p = 0.0002$ and $p = 0.0001$).

Demographics and clinical characteristics were compared among cohorts who did and did not experience a

DVT or PE following surgery (Table 1). Specifically, the patients who developed DVT had a mean age of 62.2 years, and 59.8% of them were male. On bivariate analysis, postoperative DVT was significantly associated with dyspnea (16.8 vs. 9.2%, $p = 0.009$), diabetes (29.9 vs. 18.8%, $p = 0.013$), an ASA score of 3 or 4 (73.8% vs. 60.4, $p = 0.005$), dependent functional status (7.5 vs. 2.1%, $p = 0.002$), and longer operative time (249.4 vs. 187.1 min $p < 0.0001$) (Table 1). Using logistic regression, open surgical approach (OR 2.45, 95% CI 1.64–3.67, $p < 0.001$), diabetes (OR 1.61, 95% CI 1.05–2.48, $p = 0.03$), dependent functional status (OR 2.84, 95% CI 1.34–6.03, $p = 0.006$), and increasing operating time (OR 1.07, 95% CI 1.05–1.10, $p < 0.001$) remained significantly associated with higher rates of DVT (Table 2).

The 65 patients who developed PE had a mean age of 64.8 years, and 64.6% of them were male. On bivariate analysis, postoperative PE was significantly associated with increasing age (mean age 64.8 vs. 60.7, $p = 0.03$), chronic obstructive pulmonary disease (COPD) 13.9 vs. 5.3%, $p = 0.008$), dyspnea (23.1 vs. 9.2%, $p < 0.0001$), disseminated cancer (10.8 vs. 3.9%, $p = 0.01$), and longer operative time (236.1 vs. 187.4 min, $p = 0.005$) (Table 1). On multivariate analysis, factors associated with an increased odds ratio for PE included: open surgical approach (OR 2.29, 95% CI 1.38–3.82, $p = 0.001$), presence of dyspnea (OR 2.27, 95% CI 1.21–4.24, $p = 0.011$), and disseminated cancer (OR 2.46, 95% CI 1.1–5.48, $p = 0.028$). Each additional 15 min of operative time carried an increased risk for PE (OR 1.06, 95% CI 1.03–1.09, $p < 0.001$) (Table 2).

The incidence of DVT was more common in open surgery than in LAP/MIS (1.2 vs. 0.5%, $p < 0.001$). As seen in Table 3, in patients who underwent open surgery, postoperative DVT was significantly associated with diabetes (33.3 vs. 18.9%, $p = 0.005$), poor functional status (7.3 vs. 2.7%, $p = 0.04$), and increased operative time (249.5 vs. 186 min, $p < 0.0001$). In patients undergoing LAP/MIS, postoperative DVT was significantly associated with dyspnea (23.7 vs. 18.4%, $p = 0.004$), ASA 3 or 4 (76.3 vs. 58.5%, $p = 0.03$), dependent functional status (7.9 vs. 1.7, $p = 0.03$), increased operative time (249.3 vs. 188 min, $p = 0.002$), and male gender (81.6 vs. 57.9%, $p = 0.003$).

Similarly, PE was more likely to occur in patients after open surgery than after LAP/MIS (0.8 vs. 0.3%, $p < 0.001$). Of those who underwent open surgery, postoperative PE was significantly associated with increased age (mean

Table 1 Baseline demographics and clinical characteristics for patients who did and did not have a VTE (DVT or PE) event

	Presence of DVT % ($n = 107$)	No DVT % ($n = 13{,}101$)	p value	Presence of PE % ($n = 65$)	No PE % ($n = 13{,}143$)	p value
Male	59.8 (64)	58.4 (7654)	0.84	64.6 (42)	58.4 (7676)	0.32
Age (years), mean ± SD	62.2 ± 13.8	60.7 ± 13.7	0.19	64.8 ± 13.1	60.7 ± 13.7	0.03
BMI, mean ± SD	30.4 ± 7.1	29.9 ± 6.9	0.52	29.3 ± 5.6	29.9 ± 6.9	0.68
Alcohol use	2.8 (3)	1.8 (232)	0.56	0 (0)	1.8 (235)	0.65
COPD	6.5 (7)	5.4 (703)	0.52	13.9 (9)	5.3 (701)	0.008
Dyspnea*	16.8 (18)	9.2 (1205)	0.009	23.1 (15)	9.2 (1208)	<0.0001
At rest	1.9 (2)	0.4 (53)	–	4.6 (3)	0.4 (52)	–
Moderate exertion	15.0 (16)	8.8 (1152)	–	18.5 (12)	8.8 (1156)	–
Diabetes*	29.9 (32)	18.8 (2461)	0.013	24.6 (16)	18.9 (2477)	0.26
Hypertension	61.7 (66)	63.0 (8248)	0.84	70.8 (46)	62.9 (8268)	0.2
Bleeding disorders	4.7 (5)	3.0 (388)	0.25	4.6 (3)	3.0 (390)	0.45
Wound infection	1.9 (2)	1.1 (141)	0.32	1.5 (1)	1.1 (142)	0.51
Disseminated cancer*	5.6 (6)	3.9 (515)	0.32	10.8 (7)	3.9 (514)	0.01
Dialysis	4.7 (5)	4.3 (558)	0.81	3.1 (2)	4.3 (561)	0.99
Steroid use	7.5 (8)	4.3 (559)	0.14	3.1 (2)	4.3 (565)	0.99
Chemotherapy	0 (0)	0.8 (100)	0.93	1.5 (1)	0.8 (99)	0.43
ASA 3 or 4*	73.8 (79)	60.4 (7915)	0.005	72.3 (47)	60.5 (7947)	0.056
Dependent functional status*	7.5 (8)	2.1 (278)	0.002	0 (0)	2.2 (286)	0.41
Operation time (m), mean ± SD*	249.4 ± 140.2	187.1 ± 88.0	<0.0001	236.1 ± 147.2	187.4 ± 88.3	0.005
Readmission	12.5 (13)	2.0 (260)	<0.0001	7.7 (5)	2.0 (268)	0.001
Death <30 days	5.6 (6)	0.7 (96)	0.0002	7.7 (5)	0.7 (97)	0.0001

DVT deep venous thrombosis, *PE* pulmonary embolism, *BMI* body mass index, *COPD* chronic obstructive pulmonary disease, *ASA* American Society of Anesthesiologists

* Statistically significant characteristics selected for multivariate analysis

Table 2 Multivariable logistic regression analysis examining factors associated with an increased odds of DVT and PE

Risk factor	Odds ratio estimates for DVT	
	OR [95% CI]	*p* value
Open surgical approach	2.45 (1.64–3.67)	<0.001
Diabetes	1.61 (1.05–2.48)	0.03
Dependent functional status	2.84 (1.34–6.04)	0.007
Operative time (15 min inc)	1.07 (1.05–1.10)	<0.001
	Odds ratio estimates for PE	
	OR [95% CI]	*p* value
Open surgical approach	2.29 (1.38–3.82)	0.001
Dyspnea	2.27 (1.21–4.2)	0.011
Disseminated cancer	2.46 (1.10–5.4)	0.028
Operative time (15 min inc)	1.06 (1.03–1.0)	<0.001

age 65.5 vs. 60.1, $p = 0.017$) and dyspnea (22 vs. 9.4%, $p = 0.005$). Of those who underwent LAP/MIS, postoperative PE was significantly associated with COPD (16.7 vs. 5.3%, $p = 0.04$), dyspnea (25 vs. 9%, $p = 0.005$), and increased operative time (262.4 vs. 188 min, $p = 0.0005$) (Table 3).

The timing of post-operative VTE was assessed and compared to the time to discharge. Median time to DVT was 8.5 days (IQR 4–15), and time to PE was 6 days (IQR 3–13). The overall median length of stay (LOS) for patients who did not experience a DVT or PE was 4 days (IQR 2–4). For MIS the median LOS was 3 days, compared to 5 days for open surgery ($p < 0.001$). 53.3% of DVTs and 63.1% of PEs occurred in inpatients (Fig. 1). Median length of stay was 8 days for those that developed a DVT (IQR 5–13) or PE (IQR 5–11).

Discussion

Venous thromboembolism (VTE) is associated with significant morbidity and mortality. The rate of VTE is higher in the post-operative period, particularly among those patients undergoing a major abdominal or pelvic surgery. Additionally, patients with an active malignancy have higher rates of VTE. Previous studies have evaluated the rates of VTE after various urologic surgeries, most commonly prostatectomy and cystectomy. We found that for patients undergoing nephrectomy, partial nephrectomy, or nephroureterectomy, the combined rate of VTE was 1.2%. Certain factors were associated with higher rates of DVT and PE after nephrectomy, including longer operative time, open surgical approach, and patients with preoperative dyspnea. Patients who developed a VTE post-operatively had longer lengths of stay, with approximately half of VTE events occurring prior to discharge.

Previous studies have reported variable rates of VTE after nephrectomy, but early studies may have had a selection bias towards those with advanced renal cell carcinoma [8]. Pettus et al. reported a 1.5% rate of VTE after renal surgery [9]. The Hospital Episode Statistics database from the United Kingdom evaluated 6230 patients undergoing nephrectomy and found a VTE rate of 1.01% [10]. We demonstrated amongst approximately 13,000 cases a combined VTE rate of 1.2%. The rate of DVT was 0.8% and PE was 0.5%. In contrast to other major urologic procedures, the rates of DVT and PE were comparable to prostatectomy and less frequent than cystectomy [11].

The etiology of any VTE event is multifactorial: patient characteristics, operative variables, and postoperative factors. Malignancy is a well-described risk factor for the development of VTE. One study demonstrated a sevenfold increase in VTE risk in patients with a malignancy compared to those without, and a 19.8% adjusted OR for those with distant metastases [12]. In another retrospective review of patients undergoing robotic assisted radical prostatectomy, an increase in operative time of 30 or 60 min was associated with 1.6 and 2.8 times increased VTE rates [13]. We identified a number of factors that increased the risk of developing a post-operative PE. Older patients and those with dyspnea at baseline or disseminated cancer had higher rates. Additionally, the length of surgery was associated with an increased risk of PE. We found that each additional 15 min of operative time carried an increased risk for PE (OR 1.06, 95% CI 1.03–1.09, $p < 0.001$). When comparing surgical approach, the open surgery group had higher rates of both DVT and PE. In an analysis of the US Surveillance, Epidemiology, and End Results-Medicare data for patients undergoing treatment for T1 renal cell carcinoma, patients undergoing partial nephrectomy, either open or laparoscopic, had higher rates of surgical complications compared to laparoscopic radical nephrectomy. However, medical complications including VTE rates were similar across all groups with a VTE rate of approximately 1% [14]. Another single institution study comparing open and laparoscopic partial nephrectomy for predominantly T1a renal cell carcinoma found no difference in 30-day complication rates when stratified by surgical approach. However, patients with higher Charlson Comorbidity Index scores and larger tumors had higher complication rates post-operatively [15]. The mean OR times recorded were similar to the no VTE group in our study, which were significantly shorter than those who developed a DVT or PE. These findings may be due in part to differences in tumor stage that is likely to affect the difficulty of the operation, operative time and in some cases the determination of operative approach. Unfortunately, we could not evaluate

Table 3 Unadjusted rates of DVT and PE stratified by surgical approach (open vs. Lap/MIS) for various demographics and clinical characteristics

	Open surgery						LAP/MIS					
	Presence of DVT	No DVT	*p* value	Presence of PE	No PE	*p* value	Presence of DVT	No DVT	*p* value	Presence of PE	No PE	*p* value
	n = 69 (%)	*n* = 5500 (%)		*n* = 41 (%)	*n* = 5528 (%)		*n* = 38 (%)	*n* = 7601 (%)		*n* = 24 (%)	*n* = 7615 (%)	
Male	33 (48.8)	3251 (59.1)	0.06	25 (61.0)	3259 (59.0)	0.87	31 (81.6)	4403 (57.9)	0.003	17 (70.8)	4417 (58.0)	0.22
Age (years), mean ± SD	61.1 ± 14.2	60.1 ± 13.4	0.46	65.5 ± 13.8	60.1 ± 13.4	0.017	64.3 ± 13.1	61.1 ± 13.8	0.13	63.7 ± 12.1	61.1 ± 13.8	0.56
BMI, mean ± SD	30.4 ± 7.3	29.9 ± 7.0	0.72	28.5 ± 5.0	29.9 ± 7.1	0.29	30.4 ± 6.7	29.9 ± 6.9	0.54	30.7 ± 6.3	29.9 ± 6.9	0.52
Alcohol use	2 (2.9)	107 (2.0)	0.39	0 (0)	109 (2.0)	0.89	1 (2.6)	125 (1.6)	0.56	0 (0)	126 (1.7)	0.89
COPD	3 (4.4)	299 (5.4)	0.99	5 (12.2)	297 (5.4)	0.07	4 (10.5)	404 (5.3)	0.14	4 (16.7)	404 (5.3)	0.04
Dyspnea*	9 (13.0)	522 (9.5)	0.27	9 (22.0)	522 (9.4)	0.005	9 (23.7)	683 (9.0)	0.004	6 (25.0)	686 (9.0)	0.005
At rest	1 (1.5)	34 (0.6)	–	2 (4.9)	489 (8.9)	–	1 (2.6)	19 (0.3)	–	1 (4.2)	19 (0.2)	–
Mod. exertion	8 (11.6)	488 (8.9)	–	7 (17.1)	33 (0.06)	–	8 (21.1)	664 (8.8)	–	5 (20.8)	667 (8.8)	–
Diabetes*	23 (33.3)	1040 (18.9)	0.005	10 (24.4)	1053 (19.0)	0.38	9 (23.7)	1402 (18.4)	0.18	6 (25.0)	1424 (18.7)	0.6
Hypertension	41 (59.4)	3432 (62.4)	0.62	28 (68.3)	3445 (62.3)	0.52	25 (65.8)	4816 (63.4)	0.87	18 (75.0)	4823 (63.3)	0.29
Bleeding disorders	5 (7.3)	189 (3.4)	0.09	2 (4.9)	192 (3.5)	0.65	0 (0)	199 (2.6)	0.63	1 (4.2)	198 (2.6)	0.47
Wound infection	1 (1.5)	75 (1.4)	0.61	1 (2.4)	75 (1.4)	0.43	1 (2.6)	66 (0.9)	0.29	0 (0)	67 (0.9)	0.99
Disseminated cancer	5 (7.3)	290 (5.3)	0.41	5 (12.2)	290 (5.3)	0.06	1 (2.6)	225 (3.0)	0.99	2 (8.3)	224 (2.9)	0.16
Dialysis	3 (4.4)	254 (4.6)	0.99	1 (2.4)	256 (4.6)	0.99	2 (5.3)	304 (4.0)	0.66	1 (4.2)	305 (4.0)	0.99
Steroid use	6 (8.7)	262 (4.8)	0.15	1 (2.4)	267 (4.8)	0.72	2 (5.3)	297 (3.9)	0.66	1 (4.2)	298 (3.9)	0.62
Chemotherapy	0 (0)	72 (1.3)	0.64	1 (2.4)	71 (1.3)	0.45	0 (0)	28 (0.4)	0.78	0 (0)	28 (0.4)	0.72
ASA 3 or 4*	50 (72.5)	3447 (62.7)	0.1	29 (70.7)	3468 (62.7)	0.33	29 (76.3)	4468 (58.8)	0.03	18 (75.0)	4479 (58.8)	0.15
Dependent functional status*	5 (7.3)	147 (2.7)	0.04	0 (0)	152 (2.8)	0.63	3 (7.9)	131 (1.7)	0.03	0 (0)	134 (1.8)	0.99
Operation time (m), mean ± SD*	249.5 ± 140.9	186.0 ± 97.1	<0.0001	220.7 ± 160.7	186.6 ± 97.3	0.31	249.3 ± 140.8	187.9 ± 80.8	0.002	262.4 ± 119.2	188.0 ± 81.1	0.0005
Readmission	9 (13.0)	113 (2.1)	<0.0001	3 (7.3)	119 (2.2)	0.06	4 (10.5)	147 (1.9)	0.002	2 (8.3)	149 (2.0)	0.08
Death <30 days	2 (2.9)	63 (1.2)	0.19	4 (9.8)	61 (1.1)	0.001	4 (10.5)	33 (0.4)	<0.0001	1 (4.2)	36 (0.5)	0.11

Mod. Exertion moderate exertion

* Statistically significant characteristics selected for multivariate analysis

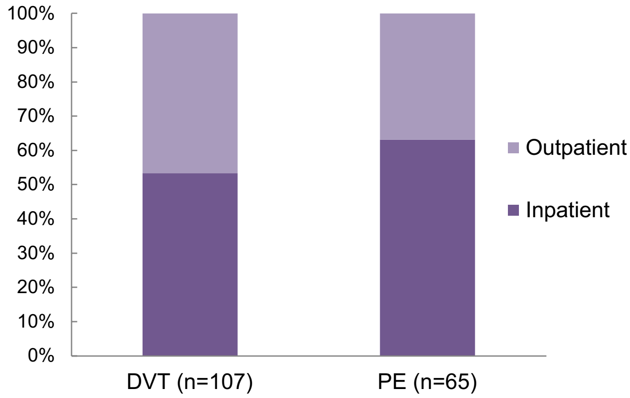

Fig. 1 Inpatient vs. outpatient status at time of DVT and PE

this effect due to the lack of pathologic information in the database.

Certain patient factors, including dyspnea, diabetes, ASA class 3 or 4, and poor functional status were associated with an increased rate of post-operative DVT. While these comorbidities are not modifiable, attention to the perioperative VTE prophylaxis management of these patients is important. Pre- and/or post-operative chemoprophylaxis may be warranted in patients with one or more risk factors. ACS-NSQIP has created a surgical risk calculator that is accessible online and our findings were consistent with the currently available risk calculator [16].

The ideal duration of postoperative anticoagulation prophylaxis has not been clearly defined. Patients undergoing radical cystectomy are now commonly given a four-week course of continued chemoprophylaxis due to high rates of post-operative VTE [17]. In a multicenter randomized study, a four-week vs. one-week administration of anticoagulation prophylaxis significantly reduced the risk of VTE after major abdominal surgery without increasing the risk of bleeding [18]. A recent study examined the use of preoperative chemoprophylaxis in patients undergoing major cancer surgery, including radical nephrectomy, and demonstrated that a single preoperative dose did not increase bleeding or transfusion rates while significantly decreasing VTE rates [19]. Another study demonstrated 30-day readmission rates for VTE at 2.9% for radical nephrectomy and 5.9% for partial nephrectomy [20].

We sought to determine the necessary duration of anticoagulation after nephrectomy by evaluating the rate of VTE, time to event, and in-hospital versus post-discharge status. The median LOS was 4 days (IQR 2–5), while the median times to DVT and PE were 8.5 and 6 days, respectively. While this initially might suggest the need for post-discharge VTE prophylaxis, less than half of all VTE occurred after discharge; 53.3% of DVT and 63.1% of PE occurred during an inpatient stay. VTE after nephrectomy occurs over a week after surgery on average and appears to be predominantly driven by patients with an extended hospital course. The length of stay for those who developed a VTE was twice that of those without (8 vs. 4 days). When comparing MIS to open surgery, LOS was longer for open surgery, and had an associated increased rate of VTE over the MIS group. We found that 75% of DVTs occurred within 15 days post-operatively, while 75% of PEs occurred at a slightly shorter interval of 13 days after surgery. Given these findings, a four-week course of prophylaxis after surgery would provide coverage during the time when most patients are vulnerable to thrombotic events.

There are several limitations to our study. NSQIP does not capture preventive measures, namely the use of chemo or mechanical prophylaxis, which undoubtedly influences the rate of VTE. Additionally, pathology data is not available for review. However, as the majority of renal surgery is performed for malignancy and final pathology results are often not available in the immediate post-operative period, all patients undergoing renal surgery should be assumed to have a malignancy when risk stratifying for VTE risk. The patient and disease characteristics influencing the decision to perform an open vs. MIS nephrectomy are unavailable. We also did not sub-stratify by type of operation, including nephroureterectomy, radical nephrectomy, and partial nephrectomy. The underlying differences in disease processes that result in each of the above surgeries may influence the rate of VTE. Despite these limitations, we feel that the data provide a comprehensive assessment of the risks of VTE after nephrectomy for hypothesis generation and quality improvement.

While the overall rate of VTE is low, it is a potentially devastating and life-threatening complication. On average, VTE tends to occur around one week after surgery. While the majority of patients are discharged after four days, only 46.7% of DVTs and 36.9% of PEs occur after discharge. Routine VTE prophylaxis should be employed whenever possible, and while the data does not clearly support a need for all patients, there is likely a high-risk population that may benefit from extended VTE prophylaxis after discharge.

Conclusions

Using a national database, we determined the rate of DVT and PE after nephrectomy to be 0.8 and 0.5%, respectively. VTE typically occurs around one week post-operatively, and despite the median LOS of four days, over half of events occurred prior to discharge. Certain patient factors, open surgical approach (vs. LAP/MIS) and longer operative times are associated with an increased risk of post-operative VTE. Understanding these factors may allow clinicians to identify high-risk patients who may benefit from more aggressive VTE prophylaxis.

Author's contribution BJ Jordan: Data analysis, manuscript writing/editing. RS Matulewicz: Project development, data analysis, manuscript writing/editing. B Trihn: Data analysis. S Kundu: Project development, manuscript writing/editing.

Compliance with ethical standards

In the NSQIP database all patient information is completely de-identified. For this type of study formal consent is not required

Conflict of interest All authors declare that they have no conflict of interest.

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