Exploring the Risk Factors for Deep Vein Thrombosis after Percutaneous Nephrolithotomy

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Background: Deep vein thrombosis (DVT), a frequent complication following percutaneous nephrolithotomy (PCNL), may lead to severe conditions like pulmonary embolism. Current knowledge on postoperative DVT risk factors is, however, limited. The aim of our study was to investigate the risk of DVT after PCNL.
Methods: A retrospective study was conducted on patients who underwent PCNL from March 2020 to March 2023 at our institution. Patient demographics and clinical data, including, DVT-specific information, preoperative labs, and surgical details, was evaluated.
Results: One hundred patients were included. Thirty-two (20 males, 12 females, mean age 52.5 $\pm$ 7.4 years) developed lower limb DVT post-surgery, while the remaining 68 (48 males, 20 females, mean age 51.1 $\pm$ 5.5 years) had no DVT symptoms. Analysis revealed significant correlations between hyperlipidemia, operating time, postoperative bed rest duration, D-dimer level on the first day after surgery, Caprini risk assessment model (RAM) score, and DVT risk. D-dimer on the first day after percutaneous nephrolithotomy, postoperative bed rest time and Caprini RAM scores were independent risk factors for DVT after PCNL. Sex, age, hypertension status, diabetes status and smoking and drinking habits were not significantly associated with DVT risk.
Conclusions: D-dimer on the first day after PCNL, postoperative bed rest time and Caprini RAM scores were independent risk factors for DVT after PCNL.

Keywords: deep vein thrombosis; percutaneous nephrolithotomy; risk factors; hyperlipidemia; operating time

Introduction

Deep vein thrombosis (DVT) is a condition characterized by the formation of blood clots in deep veins and often occurs in the lower limbs [1]. It is a significant vascular disease and ranks as the third most common after acute myocardial infarction and stroke [2]. While extensive research has been conducted on conditions such as myocardial infarction and stroke, understanding of DVT in the general population is still limited.

Postoperative complications such as DVT are not uncommon in routine urological surgeries such as percutaneous nephrolithotomy (PCNL) compared to procedures such as prostatectomy. However, little research has been conducted to identify the risk factors associated with DVT, specifically after PCNL surgery [3]. Therefore, a comprehensive retrospective analysis to determine the incidence and risk factors contributing to DVT after PCNL surgery is needed. This analysis will help guide diagnosis and treatment strategies for patients undergoing PCNL [4].

DVT occurs when blood clots form within deep veins, obstructing blood flow [5]. Prolonged immobility, bed rest, surgery, fractures, tumours, pregnancy, and hormone therapy are common factors contributing to the formation of blood clots [6]. When these clots dislodge and travel through the bloodstream to the lungs, they can result in a life-threatening condition known as acute pulmonary embolism [7].

PCNL, a routine urological surgical procedure employed for the treatment of kidney stones, may involve some degree of bleeding during kidney puncture to create a channel and perform lithotripsy [8]. Postoperative rest is typically necessary, and in certain cases, prolonged bed rest may be required due to bleeding [9]. This restriction of mobility can significantly increase the risk of postoperative DVT. It is important to be aware of this potential complication associated with PCNL.

There is currently only limited data available about risk factors for DVT after PCNL surgery [10]. Surgical trauma itself and patient-specific characteristics (including age, sex, and medical history) may lead to an increased risk of DVT

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after PCNL. Therefore, we conducted a retrospective analysis of patients undergoing PCNL surgery to determine the factors related to the occurrence of DVT and to develop strengthened prevention and treatment strategies to benefit patients [11].

Materials and Methods

Patient Population and Data Collection

This study retrospectively analyzed data from patients who underwent PCNL from March 2020 to March 2023 at our hospital. Patients who developed DVT post-PCNL, the DVT group, were compared to patients who did not develop DVT, despite undergoing the same procedure, the control group (No DVT group). Patient demographics and comprehensive clinical data, including DVT-specific information, preoperative labs, and surgical details, were gathered.

Inclusion and Exclusion Criteria for the DVT Group

Patients with complete and traceable records, from basic demographics to DVT prevention measures, and undiagnosed DVT confirmed by bilateral lower limb venous ultrasound both pre- and post-surgery. The DVT patients were matched in a 1:2 ratio with the No DVT patients by disease and surgery type. Incomplete clinical records were grounds for exclusion.

Diagnostic Criteria for Postoperative DVT

The diagnosis of DVT includes medical history, clinical manifestations, physical examination, and auxiliary examinations. In terms of medical history, attention should be given to potential risk factors that may trigger DVT, such as surgery, trauma, prolonged bed rest, pregnancy, and the use of oral contraceptives or hormone replacement therapy. Patients diagnosed with DVT may experience symptoms that are not limited to swelling, pain, redness, fever, or lower limb tenderness. Possible physical examination results may include, but are not limited to, swelling, skin redness, increased tension, limb tenderness (mostly located in the calf, thigh, and groin areas), and a positive Homans sign on the affected side of the lower limb. D-dimer levels below 200 μg/L in auxiliary examinations are generally considered to exclude acute DVT. Doppler ultrasound, as the preferred diagnostic method for DVT, was used for all our research subjects, and further improvements have been made in computed tomography (CT) scan, magnetic resonance imaging (MRI), or magnetic resonance venography (MRV) for complex cases or those requiring clear thrombus extent and location.

Statistical Analysis

Statistical analysis was conducted using SPSS22.0 (IBM Corp, Chicago, IL, USA), with continuous data expressed as means ± standard deviations and categorical data as frequencies and percentages. Area under the curve and logistic regression analyses were utilized for continuous and binary data, respectively. p-values < 0.05 were considered statistically significant. In order to more accurately evaluate the relationship between risk factors for deep vein thrombosis after percutaneous nephrolithotomy, control the influence of confounding factors, and improve the accuracy and reliability of conclusions, we first identified possible risk factors through univariate analysis, and then analyzed independent risk factors among multivariate analysis.

Results

There were 100 PCNL patients, 32 patients (20 males, 12 females, mean age 52.5 ± 7.4 years) who developed lower limb DVT post-surgery and 68 patients (48 males, 20 females, mean age 51.1 ± 5.5 years) who had no DVT symptoms.

Univariate analysis, conducted to identify potential risk factors for DVT post-PCNL, showed no direct link between DVT occurrence and age, sex, hypertension, diabetes, or past smoking and drinking habits. However, significant correlations were found with hyperlipidemia, surgical duration, postoperative bed rest, first-day post-surgery D-dimer levels, and Caprini risk assessment model (RAM) scores (Table 1).

Based on the comparison of data between the DVT group and the No DVT group, the occurrence rate of DVT in male patients was 62.5 % (20 out of 32), whereas the occurrence rate of DVT in female patients was 37.5% (12 out of 32). Despite the high incidence rate of DVT among female patients, there was no significant association between sex and the incidence of DVT ($p = 0.419$).

There was no significant difference in age between the two groups ($p = 0.289$).

There was no significant correlation between hypertension, diabetes, smoking, or drinking history and the incidence of DVT ($p = 0.059$, $p = 0.391$, $p = 0.852$, $p = 0.749$).

Hyperlipidemia was a significant risk factor for DVT ($p = 0.004$) hyperlipidemia Seventy-five percent (24/32) of patients in the DVT group had a previous history of hyperlipidemia, whereas in the No DVT group, only 44.1% (30/68) had a history of hyperlipidemia.

Patients who underwent surgery for more than 60 minutes and who had a postoperative bed rest time exceeding 10 days were more likely to develop DVT.

There was a significant correlation between D-dimer, Caprini RAM score, and the incidence of DVT on the first day after surgery.

The important risk factors for DVT included hyperlipidemia, operating time, postoperative bed rest time, and D-dimer level and Caprini RAM score on the first day after surgery. On the other hand, there was no significant correlation between DVT and sex, age, history of hypertension, history of diabetes, or history of smoking or alcohol consumption. In medical practice, more attention should be given to patients who exhibit the significant risk factors mentioned above, and active measures must be taken to reduce the incidence of DVT (Fig. 1).

Table 1. Univariate analysis of postoperative DVT in PCNL patients [Mean ± SD, n (%)].

Risk factors	DVT group (n = 32)	No DVT group (n = 68)	*p*-value	OR (95% CI)
Sex [n (%)]			0.419	1.44 (0.59–3.49)
Male	20 (62.5)	48 (70.6)		
Female	12 (37.5)	20 (29.4)		
Age, years (Mean ± SD)	52.53 ± 7.40	51.12 ± 5.54	0.289	1.04 (0.97–1.12)
Hypertension [n (%)]			0.059	1.11 (0.48–2.6)
Yes	14 (43.8)	28 (41.2)		
No	18 (56.2)	40 (58.8)		
Diabetes [n (%)]			0.391	1.56 (0.56–4.29)
Yes	8 (25.0)	12 (17.6)		
No	24 (75.0)	56 (82.4)		
Hyperlipidemia [n (%)]			0.004	3.8 (1.5–9.65)
Yes	24 (75.0)	30 (44.1)		
No	8 (25.0)	38 (55.9)		
Smoking [n (%)]			0.852	1.09 (0.44–2.71)
Yes	10 (31.3)	20 (29.4)		
No	22 (68.7)	48 (70.6)		
Alcohol consumption [n (%)]			0.749	1.19 (0.42–3.33)
Yes	7 (21.9)	13 (19.1)		
No	25 (78.1)	55 (80.9)		
Operating time (minutes) [n (%)]			1.000	1 (0.43–2.32)
Operating time ≥60 minutes	16 (50.0)	34 (50.0)	<0.05	
Operating time <60 minutes	16 (50.0)	34 (50.0)	>0.05	
Postoperative bed rest time (days) [n (%)]			0.045	2.40 (1.01–5.71)
Postoperative bed rest time ≥10	16 (50.0)	20 (29.4)	<0.05	
Postoperative bed rest time <10	16 (50.0)	48 (70.6)	>0.05	
D-dimer (μg/L) (Mean ± SD)	319.2 ± 83.5	190.6 ± 60.7	<0.001	1.03 (1.02–1.04)
Caprini RAM (Mean ± SD)	6.3 ± 1.6	4.5 ± 1.7	<0.001	1.92 (1.38–2.68)

DVT, deep vein thrombosis; PCNL, percutaneous nephrolithotomy; RAM, risk assessment model.

Multivariate Analysis of DVT in the Lower Limbs after PCNL

To provide additional clarification on the factors that are significantly linked to the risk of postoperative DVT, a multivariate logistic regression analysis was performed (Table 2).

An analysis was conducted to further examine the three identified risk factors for DVT in the lower limbs after PCNL. The results of the multivariate logistic regression analysis indicated that postoperative bed rest time, D-dimer level, and Caprini RAM score were significantly associated with the risk of postoperative DVT.

First, the analysis revealed that an increase in postoperative bed rest time was significantly linked to a greater risk of DVT. Specifically, for every unit increase in postoperative bed rest time (measured in days), the odds of developing DVT increased by a factor of 4.8. This finding suggested that prolonged bed rest may lead to venous stasis and increase the likelihood of DVT.

Second, the analysis showed that elevated D-dimer levels were significantly associated with an increased risk of DVT. For every unit increase in D-dimer level (measured in ng/mL), the odds of DVT increased by a factor of 1.03. This indicates that higher D-dimer levels may reflect increased activation of coagulation and fibrinolysis, which potentially increases the risk of DVT.

Last, the analysis demonstrated that a higher Caprini RAM score was significantly correlated with an increased risk of DVT. For every unit increase in the Caprini RAM score, the odds of developing DVT increased by a factor of 1.73. The Caprini RAM is a validated risk assessment tool for thromboembolism, and this finding suggests that patients with a higher overall risk score are more likely to experience DVT after PCNL.

Discussion

According to existing research findings, there is a certain relationship between D-dimer levels and the postoperative complications of DVT. D-dimer is a blood test indicator used to evaluate the activity levels of platelets and coagulation systems in the body [12]. During the postoperative period, an increase in D-dimer levels is associated with an increased risk of DVT. This is because the damage and inflammatory reactions during the surgical process can activate the coagulation system, thereby releasing more D-dimers [13]. High D-dimer levels suggest the possibility

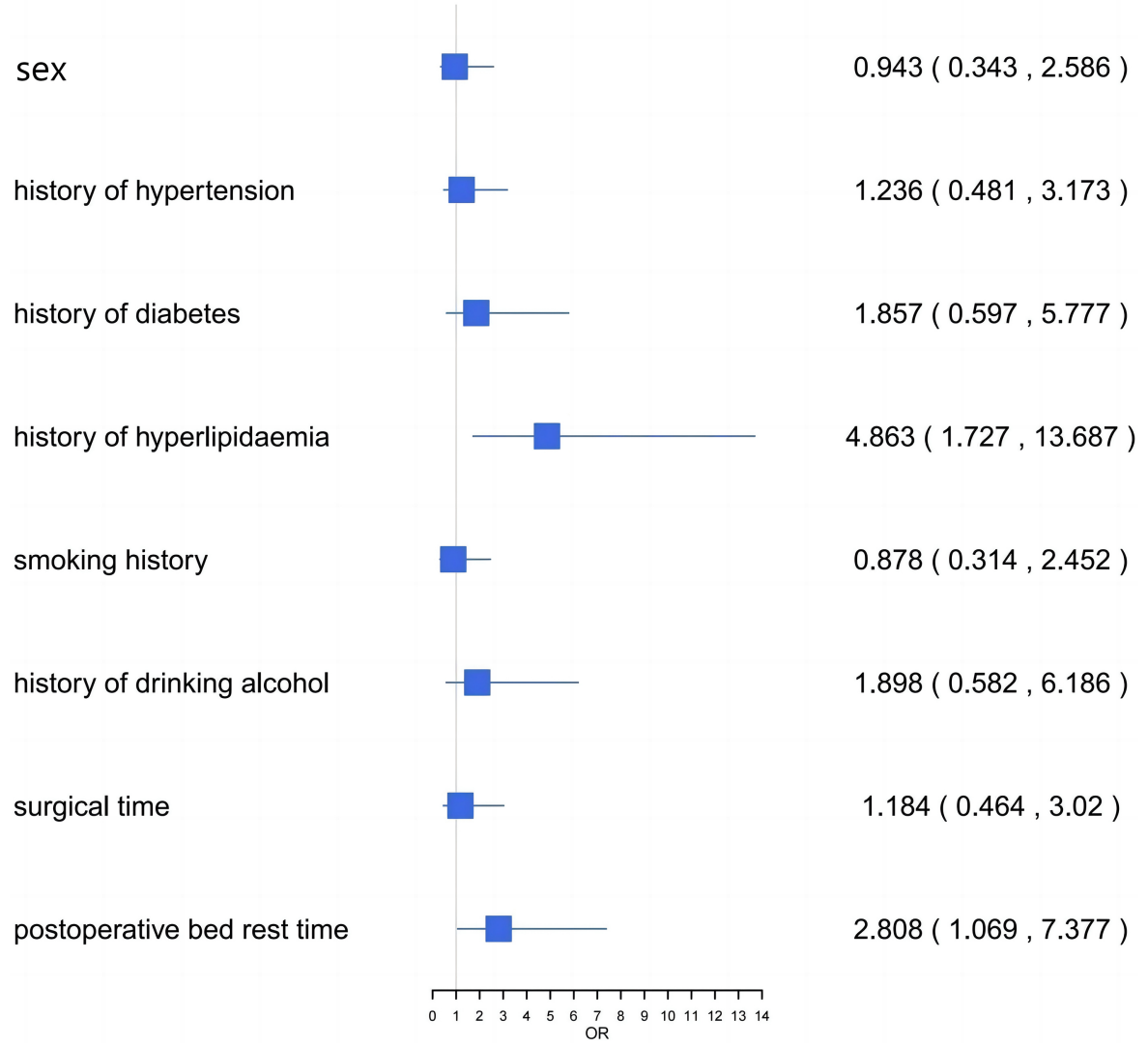

Fig. 1. Area under curve analysis compares continuous data.

of thrombosis and can be used as an early screening tool for postoperative DVT. However, D-dimer levels are influenced by various factors, such as age, obesity, infection, and other inflammatory states [14]. Therefore, using D-dimer levels alone to assess the risk of postoperative DVT is not accurate enough. Further research is still needed to determine under what circumstances and how to combine other clinical indicators to better utilize the D-dimer level in predicting and diagnosing postoperative DVT [15].

According to the literature, there is a certain correlation between the Caprini RAM score and postoperative complications of DVT [16]. This scoring system considers multiple risk factors, including age, body mass index (BMI), surgical duration, previous DVT history, bleeding tendency, other comorbidities and activity level [17]. According to current research findings, high Caprini RAM scores are significantly associated with an increased incidence of postoperative DVT. In particularly, for patients who undergo high-risk surgeries, such as PCNL and prostatectomy, and who require long-term bed rest for recovery after surgery, their Caprini RAM score is higher, and the risk of DVT may be greater [18]. However, it should be noted that not all studies have reached consistent conclusions [19]. Therefore, further large-scale clinical studies are still needed to verify the exact relationship between the Caprini RAM score and postoperative DVT and to determine its clinical application value in predicting and intervening in postoperative DVT [20].

According to the latest research findings, there is a close relationship between postoperative bed rest days and postoperative complications of DVT. Long postoperative bed rest may lead to slowed blood circulation, blood retention in the veins, and an increased risk of thrombosis. Especially in urological surgery, such as PCNL, postoperative patients usually need to rest in bed to promote postoperative recovery [21]. However, long-term bed rest may lead to reduced muscle activity in the lower limbs, obstructed venous return, and thus the occurrence of DVT [22]. Al-

Table 2. Multivariate analysis of DVT after PCNL.

Independent risk factors	Regression coefficient	Standard error	Wald χ^2	*p*-value	OR (95% CI)
Postoperative bed rest time	1.568	0.709	4.89	0.027	4.8 (1.2–19.27)
D-dimer (ng/mL)	0.025	0.006	18.694	<0.001	1.03 (1.01–1.04)
Caprini RAM	0.548	0.202	7.379	0.007	1.73 (1.17–2.57)
Constant	–10.7	2.097	26.04	<0.001	

DVT, deep vein thrombosis; PCNL, percutaneous nephrolithotomy; RAM, risk assessment model.

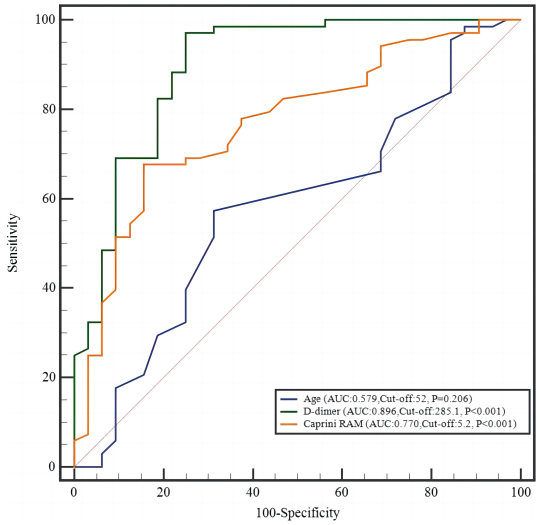

Fig. 2. Logistic analysis compares binary variables. AUC, area under the curve; RAM, risk assessment model.

though limited research has shown a correlation between postoperative bed rest time and DVT, there is currently a lack of large-scale, randomized, controlled clinical studies to further validate this relationship [23]. Therefore, in-depth research on the correlation between postoperative bed rest days and DVT will help guide postoperative rehabilitation management strategies, reduce the incidence of DVT, and optimize patient prognosis.

Our study found that in patients with DVT after PCNL, hyperlipidemia, operation duration, postoperative bed rest time, D-dimer level on the first day after operation and Caprini RAM score were significantly correlated with the risk of DVT. These findings are consistent with previous study to some extent [24]. Previous studies mainly focused on the comparison of the predictive ability of the Padua Prediction Score and Caprini RAM score for postoperative DVT. The Padua score is a DVT risk assessment tool based on clinical characteristics, while the Caprini RAM score is a DVT risk assessment tool based on individual characteristics of the patients and surgical process. Our study further analyzed the independent risk factors, and found that D-dimer level, postoperative bed rest time and Caprini RAM score were the independent factors influencing the risk of DVT after PCNL. This is consistent with the results of previous studies, emphasizing the importance of monitoring D-dimer levels and implementing appropriate postoperative bed rest programs to reduce the risk of DVT. The difference is that our study further investigated the impact of hyperlipidemia and operating time on the risk of DVT. These factors may not have received sufficient attention in previous study [25]. Our results show that hyperlipidemia and operating time are closely related to the risk of DVT after PCNL, which provides clinicians with more information to assess the risk and take preventive measures. The contribution of these findings to the existing knowledge is that we provide a more comprehensive analysis of the risk factors of DVT after PCNL, emphasizing the important roles of hyperlipidemia, operating time, postoperative bed rest time, D-dimer level and Caprini RAM score on the risk of DVT. Early mobilization, close monitoring of D-dimer levels, and appropriate prophylactic measures based on the Caprini RAM score may help reduce the incidence of DVT and improve patient outcomes after PCNL procedures (Fig. 2).

This study has certain limitations. First of all, it is a retrospective single-center study, with the risk of selection bias and information bias, which may affect the accuracy and reliability of the results [26]. Second, the sample size is relatively small, so it may be difficult to comprehensively evaluate the relationship between different factors and DVT. Although there are potential deviations and relatively small sample size limitations in the retrospective study design, the study can still obtain reliable and generalizable research results through appropriate statistical analysis methods such as confidence interval to correct the impact of selection bias on the results and increase the reliability of the results. Future studies should adopt a large sample, multicenter, prospective design, comprehensively consider the impact of a variety of potential factors, and comprehensively evaluate the occurrence and prevention of postoperative DVT [27]. In addition, the combination of clinical practice and scientific research can further improve the postoperative rehabilitation management strategy, reduce the incidence of postoperative DVT and improve the prognosis of patients [28, 29].

Conclusions

Based on the findings of this study, it can be concluded that the incidence of DVT after PCNL is considerable, reaching 32%. The analysis revealed several factors significantly associated with an increased risk of DVT, including hyperlipidemia, operating time, postoperative bed rest time, D-dimer levels on the first day after surgery, and the Caprini

RAM score. Notably, both D-dimer levels and the Caprini RAM score on the first day after PCNL were identified as independent risk factors for DVT.

Availability of Data and Materials

Upon reasonable request, the corresponding authors will provide access to the datasets and materials utilized or analyzed in the current study.

Author Contributions

Conception and design: JWH, ZPZ, XYC; Provision of study materials or patients: JWH, ZPZ, XYC; Collection and assembly of data: JWH, ZPZ, XYC; Data analysis and interpretation: PZL, YFS; Manuscript writing: JWH. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The Ethics Committee of Dongguan Songshan Lake Central Hospital (Grant No. 2022-KYSB-032) granted approval for all experimental procedures. The study is in accordance with the Declaration of Helsinki. Informed consent was obtained from all patients.

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Conflict of Interest

The authors declare no conflict of interest.

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