Evaluation and Analysis of Incidence and Risk Factors of Lower Extremity Venous Thrombosis After Urologic Surgeries: A Prospective Two-Center Study Using LASSO-Logistics Regression.

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Research

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Abstract

Purpose: To analyze the incidence and risk factors of lower extremity venous thrombosis after urologic surgeries.

Methods: A prospective two-center study was conducted from August 2019 to January 2020. 1122 consecutive patients who underwent urologic procedures were enrolled. The study primary end point was the detection of asymptomatic or symptomatic deep vein thrombosis (DVT) of lower extremity within 7 days after the surgeries. Univariate and LASSO-logistics regression analysis were performed.

Results: We excluded 111 patients who met exclusion criteria. Totally, 56 (5.54%) out of 1011 patients had developed DVT. In the univariate analysis, Barthel Index ≤40, D-dimer levels ≥0.5mg/L and age≥ 60 yrs ($p < 0.001$) were the most significant risk factors. The LASSO-logistics regression model identified 9 factors including age, history of DVT, lymph nodes dissection, perioperative steroid use, Caprini Score, Barthel Index, D-dimer levels, cystectomy and prostatectomy.

Conclusion: Our study used the LASSO-logistic regression model to provide reliable data on risk factors of DVT after comprehensive urologic surgeries. It might facilitate individualized anticoagulant management of patients undergoing urologic procedures.

Trial registration: ChiCTR1900024784

Introduction

Deep vein thrombosis (DVT) is known as one of the most frequent complications of surgery. It may cause mortality or long-term unfavorable health outcomes, which requires extensive treatment and follow up(1).

The risks of DVT after surgery include the type of disease, age, body mass index (BMI), personal or family history of DVT and the approach of surgery, etc.(2, 3). Until now, a large proportion of urologic surgeries are endoscopic and the risks of DVT are lower compared with conventional open surgeries. The overall DVT incidence of laparoscopic surgeries for urologic cancers is between 0.7% and 10.3%(2, 3). A systematic review pointed out that pharmacological anticoagulation prophylaxis decreases the risk of DVT in surgical patients by approximately 50%(4). However anticoagulation has side effects, especially the increased bleeding tendency(5). It is necessary to find out the patients who actually need the perioperative pharmacological anticoagulation. A recent retrospective study demonstrates that age greater than 60 years, condition of disseminated cancer, congestive heart failure (CHF) and anesthesia time greater than 120 minutes are independently associated with DVT formation after common urologic procedures.(6) Another Australian cohort study assessed risk factors among patients undergoing major pelvic urologic surgery and revealed that the risk factors for DVT included long operative time of greater than 4 hours, lymph node dissection (LND) and blood transfusion(7).

In 2017, European Association of Urology (EAU) published its first guideline for DVT prophylaxis(8). However, the risk classifications were too simple, which only included age, BMI and the history of DVT. This guideline needs more convincing prospective evidence-based data.

Least absolute shrinkage and selection operator method (LASSO) is a popular and robust method for regression with high dimensional predictors(9–11). In this prospective two-center study, we estimated the incidence of DVT and constructed a LASSO-logistics regression model to evaluate risk factors for the development of DVT among patients undergoing urologic surgeries.

Materials And Methods

Patients

We prospectively collected the data of patients who received urologic procedures between August 2019 and January 2020 in Xiangya Hospital and Hunan Cancer Hospital. The exclusion criteria were as follows: (1) age < 18 years old; (2) using anticoagulant or antiplatelet therapy before or after surgery; (3) patients underwent day-time surgeries (ureteroscopy, ureteral stent placed or removed, cystoscopy, transperineal prostate biopsy, etc.) (4) patients found with DVT before surgery.

DVT risk factors

We assessed the following parameters to screen the possible risk factors on DVT development: (1) basic and demographic characteristics: age, gender, BMI, history of smoking, history of DVT, history of any diseases or surgeries; (2) information about surgical procedures: methods of surgery, operative time, intraoperative blood loss; (3) postoperative information: complications (infection, hemorrhage and etc.), D-dimer levels (on the first postoperative day), immediate postoperative Caprini Score(a predictive risk assessment tool), Barthel Index (BI) (to evaluate patients' functional status)(12, 13), absolute bed rest time, platelet count and mean corpusular hemoglobin concentration (MCHC) (on the first postoperative day)(11, 12).

Diagnosis of DVT

All patients underwent a physical examination and venous ultrasound of the lower extremity at the day of admission. The patients were performed with ultrasound when they were suspected of clinical DVT. All patients received a second venous ultrasound 7 days after surgery to detect those asymptomatic DVT. A standardized complete compression ultrasound protocol was utilized by experienced sonographers.

Ethics

Written informed consent was obtained preoperatively from all patients. All surgery procedures were performed by experienced surgeons. The study was approved by Hospitals Ethic Committee (IRB number: 201906142) and has been registered in the Chinese clinical trial registry (ChiCTR1900024784).

Statistics

We compared two groups using the t-test for continuous variables and χ^2 test for categorical variables by using SPSS (IBM Corp. Released 2017. IBM SPSS Statistics for Macintosh, Version 25.0. Armonk, NY: IBM Corp.). We used the LASSO-logistics regression model to select the most useful prognostic risk factors of lower extremity DVT after urology surgery. All types of operations were identified with a dummy variable. We used the R software version 3.6.1 and the “glmnet” package (R Foundation for Statistical Computing, Vienna, Austria) to do the LASSO-logistics regression analysis. All statistic evaluations were performed by the Department of Statistics, School of Mathematics and Statistics, Beijing Technology and Business University, China.

Results

A total of 1122 patients underwent regular urologic procedures between August 2019 and July 2020 in two hospitals. One hundred and eleven patients were excluded since they met exclusion criteria. The final number of eligible participants included in the analysis was 1011 (Fig. 1). Among these patients, DVT developed in 56 (5.54%) and PE developed in 2(0.2%) within 7 days after surgery. The in-hospital mortality rate was zero. Table 1 summarized the incidence of DVT by surgical types. Patients performed with radical prostatectomy had the highest incidence (23.3%) of DVT after the surgery, whereas transurethral resection of bladder tumor (TURBT) had the lowest risk of DVT (0.0%).

Table 1
The urologic procedures and incidence of DVT in present study

Procedure	DVT (%)	Total
Partial nephrectomy, laparoscopic/open	5 (5.9)	85
Radical nephrectomy, laparoscopic/open	2 (2.1)	95
Renal cyst unroofing, laparoscopic	1 (2.8)	36
Adrenalectomy, laparoscopic/open	3 (3.6)	83
Radical nephroureterectomy, laparoscopic	1 (3.7)	27
TURBt	0 (0)	85
Cystectomy, laparoscopic	5 (16.1)	31
Prostatectomy, laparoscopic	7 (23.3)	30
spermatic vein ligation, laparoscopic	0 (0)	10
Pyeloplasty, laparoscopic + ureteroscopic	0 (0)	14
TURP	7 (14.6)	48
Percutaneous nephrolithotomy	18 (8.8)	205
Ureteroscopic lithotripsy	6 (4.4)	137
Others	1 (0.8)	125

Table 2 listed the possible risk factors on DVT development, including age, sex, BMI, preoperative assessment, intraoperative parameters and postoperative information. In the univariate analysis, sex, BMI, current smoker, history of Ca, history of DVT, history of COPD, history of atrial fibrillation, history of CHF, surgery (emergency vs selective) and MCHC were not significantly associated with DVT ($P > 0.05$). The strongest risk factors were Barthel Index ≤ 40 (HR 10.269, 95% CI 2.715–18.454, $p < 0.001$), D-dimer ≥ 0.5 mg/L (HR 7.937, 95% CI 3.845–16.384, $p < 0.001$), and age ≥ 60 yrs (HR 3.801, 95% CI 2.136–6.764, $p < 0.001$).

Table 2
Univariate analysis of DVT risk factors

Risk factors	No. of patients(955)	No. of DVT (56)	Univariate HR(95%CI)	P Value
Sex (male vs female)	623/332	36/20	0.959(0.546–1.684)	0.886
Age (≥ 60 yrs vs <60 yrs)	341/614	38/18	**3.801(2.136–6.764)**	**<0.001**
BMI (≥ 24 vs <24)	352/603	18/38	0.811(0.456–1.444)	0.476
Current smoker (yes vs no)	290/665	13/43	0.693(0.367–1.309)	0.295
History of Ca (yes vs no)	224/731	16/40	1.305(0.717–2.376)	0.419
History of DVT (yes vs no)	26/929	4/52	2.749(0.925–8.167)	0.079
History of COPD (yes vs no)	25/930	4/52	2.862(0.960–8.526)	0.071
History of Atrial fibrillation (yes vs no)	6/949	1/55	2.876(0.340-24.305)	0.330
History of CHF (yes vs no)	278/677	18/38	1.154(0.647–2.056)	0.651
Surgery (emergency vs selective)	4/951	0/56	0.944(0.930–0.959)	1
Lymph nodes dissection (yes vs no)	66/889	12/44	**3.674(1.851–7.291)**	**<0.001**
Blood loss after surgery (yes vs no)	21/934	5/51	**4.360(1.580-12.035)**	**0.012**
blood transfusion (≥ 2U vs<2U)	14/941	4/52	**5.170(1.664–16.259)**	**0.014**
perioperative steroid use (yes vs no)	4/951	3/53	**13.458(2.937–61.672)**	**0.005**
postoperative infection (yes vs no)	95/860	12/44	**2.469(1.260–4.837)**	**0.011**
Caprini Score(≥ 5 vs <5)	312/643	36/20	**3.710(2.112–6.514)**	**<0.001**
Barthel Index (≤ 40 vs >40)	65/890	24/32	**10.269(5.715–18.454)**	**<0.001**

Risk factors	No. of patients(955)	No. of DVT (56)	Univariate	
			HR(95%CI)	P Value
Anesthesia time (≥ 120 min vs <120 min)	610/345	48/8	**3.393(1.587–7.256)**	**<0.001**
D-Dimer (≥ 0.5 mg/L vs <0.5 mg/L)	379/576	47/9	**7.937(3.845–16.384)**	**<0.001**
Absolute bed rest time (≥ 48 h vs <48 h)	247/708	26/30	**2.484(1.441–4.283)**	**0.0061**
Platelet count (≥ $300*10^9$/L vs <$300*10^9$/L)	56/899	10/46	**3.490(1.673–7.280)**	**<0.001**
MCHC* (≥ $370*10^9$/L vs <$370*10^9$/L)	306/649	19/37	1.089(0.616–1.925)	0.769

The LASSO-logistics model went through generalized cross-validation. With the change of the log (λ) value of harmonic parameter, the area under the curve (AUC) value of the ordinate model changed as well. Table 3 showed all the assignments of variables associated with DVT. The numbers of corresponding variables screened out by the model were listed in Fig. 2A. We used a LASSO-logistics regression model to build a risk factors classifier (Fig. 2B). After LASSO-logistic analysis, 9 risk factors were selected including age, history of DVT, LND, perioperative steroid use, Caprini score, BI, D-dimer levels, cystectomy, prostatectomy (Table 4).

Table 3
Variable assignments

Variables	Risk Factors	Assignment
X_1	Age	continuous variable
X_2	Gender	female = 0, male = 1
X_3	Current smoker	yes = 1, no = 0
X_4	History of Ca	yes = 1, no = 0
X_5	History of DVT	yes = 1, no = 0
X_6	History of COPD	yes = 1, no = 0
X_7	History of Atrial fibrillation	yes = 1, no = 0
X_8	History of CHF	yes = 1, no = 0
X_9	Surgery	emergency = 1, selective = 0
X_{10}	Cystectomy, laparoscopic	yes = 1, no = 0
X_{11}	Percutaneous nephrolithotomy	yes = 1, no = 0
X_{12}	spermatic vein ligation, laparoscopic	yes = 1, no = 0
X_{13}	TURBt	yes = 1, no = 0
X_{14}	Prostatectomy, laparoscopic	yes = 1, no = 0
X_{15}	TURP	yes = 1, no = 0
X_{16}	Partial nephrectomy	yes = 1, no = 0
X_{17}	Radical nephrectomy	yes = 1, no = 0
X_{18}	Renal cyst unroofing, laparoscopic	yes = 1, no = 0
X_{19}	Adrenalectomy	yes = 1, no = 0
X_{20}	Ureteroscopic lithotripsy	yes = 1, no = 0
X_{21}	Pyeloplasty	yes = 1, no = 0
X_{22}	Anesthesia $\geq$ 120 min	yes = 1, no = 0
X_{23}	blood loss intraoperative	continuous variable

Variables	Risk Factors	Assignment
X_{24}	Anesthesia ≥ 120 min	yes = 1, no = 0
X_{25}	LND	yes = 1, no = 0
X_{26}	blood transfusion ≥ 2U	yes = 1, no = 0
X_{27}	perioperative steroid use	yes = 1, no = 0
X_{28}	postoperative infection	yes = 1, no = 0
X_{29}	D-dimer levels	continuous variable
X_{30}	BMI	continuous variable
X_{31}	BI	100 = 0, 61–99 = 1, 41–60 = 2, less than 40 = 3
X_{32}	Caprini Score	1–2 = 1, 3–4 = 2, more than 4 = 3
X_{33}	absolute bed time	continuous variable
X_{34}	platelet count	continuous variable
X_{35}	MCHC	continuous variable

Table 4
Risk factors selected by LASSO-logistic regression model

Variables	Risk factors	Coefficient
X_{1}	Age	0.0126
X_{24}	LND	0.0578
X_{5}	History of DVT	0.0862
X_{11}	Cystectomy, laparoscopic	0.1911
X_{32}	Caprini Score	0.2305
X_{29}	D-dimer levels	0.4184
X_{31}	BI	0.6258
X_{14}	Prostatectomy, laparoscopic	0.6924
X_{27}	Perioperative steroid use	1.2959

Discussion

DVT events might be a serious complication of common urologic procedures(14). Understanding the risk factors for DVT is of importance in detecting DVT high risk group and decreasing morbidity and mortality after urologic surgeries. This study collected the most comprehensive risk factors of DVT after urologic surgeries in the prospective two-center cohort. With great help of LASSO-logistics regression analysis, 9 risk factors were demonstrated as the most meaningful factors to select high-risk group of DVT. The overall incidence of DVT after surgeries was 5.54% in this study. It could be seen that the incidence of DVT was not low after urologic surgery. This was in agreement with other studies describing the incidence of DVT after urologic surgery(15, 16).

Previous studies have identified multiple risk factors related to DVT(17–19). In particular, radical cystectomy, personal history of DVT and LND have been shown to be associated with the occurrence and development of DVT. However, these studies have been limited by a small number of risk factors screened, small sample sizes, retrospective nature and the inappropriate statistical methods. The LASSO-logistics regression allowed us to integrate multiple possible risk factors into one tool, which has significantly greater prognostic accuracy than that of the single-factor and multi-factor logistic regression analysis.

This study firstly included the Caprini Score, BI, absolute bed time, platelet count, MCHC and non-cancer urologic surgeries as potential risk factors. The Caprini Score is one widely accepted model with an established history and utilization as a reliable predictive DVT risk assessment tool. Based on the scores, it can be divided into low, moderate and high-risk subtypes. This rating scale can be used in numerous surgical fields, but not for urologic surgeries specifically(20–22). In our univariate analysis, high-risk subtype categorized by Caprini score represented a risk factor (HR 3.710, 95%CI 2.112–6.514, $p < 0.001$). LASSO-logistics regression model had also selected this rating scale. Thus, it is necessary to include the Caprini Score in the routine preoperative evaluation.

BI is a 10-item measure of activities of daily living originally described in 1965 (13). BI has been used in clinical practice to assess baseline abilities and quantify functional changes. In our study, we firstly assessed the relationship between BI and DVT. Our data suggested that patients whose BI was less than 40 may need more thromboprophylaxis measures after surgeries.

In the univariate analysis, absolute bed rest time ≥ 48 h was associated with a 2.484-fold increase in risk for DVT and platelet count ≥ $300*10^9$/L was associated with a 3.49-fold increase. This result indicated that when absolute bed rest time and platelet count exceeded a certain threshold, the DVT incidence would increase. The pathophysiological mechanism of absolute bed rest time may be the blood stasis in the lower extremity venous (23).

The kind of operations was found an important aspect the of our research. LASSO-logistics regression model also selected these two operation as important risk factors of DVT. Prostatectomy was associated with the highest rate of DVT (23.3%) and cystectomy had the second-highest rate (16.1%). Prostatectomy and cystectomy are the most complicated regular pelvic surgeries in urology. Except the common factors, patients who undergoing these two surgeries should be alert to any sign of DVT. It should be noted that TURP and percutaneous nephrolithotomy had 14.6% had 8.8% rate to develop DVT, respectively. Our data suggested that these two procedures should deserve attention, although the final model did not select. Data of these two surgeries should be further validated by large sample prospective study.

In addition to the factors screened above, the LASSO model and univariate analysis founded that the infusion of red blood cells (≥ 2U) and perioperative steroid use increased the risk of thrombosis. This result supports the findings of Beyer et al.(19), which proves that there is a statistical significance between blood transfusion greater than 2U and thrombosis. Many studies also considered blood transfusions as a risk factor for DVT(24–26). Steroid use was first considered as meaningful in a retrospective analysis by Tyson et al.(6) Using prospective two-center data, we demonstrated perioperative steroid use is a significant risk factor of DVT.

D-dimer levels were increased in almost all cases of DVT in our study. Any process that increases fibrin production or breakdown will increase D-dimer levels. Shi et al. confirmed that elevated D-dimer early after operation is an independent predictor of DVT in patients undergoing urologic tumor surgery(27). According to the LASSO model, D-dimer levels could also apply to the non-cancer urologic surgeries. However, a single D-dimer assay should not be used to diagnose DVT. Our result showed that among the negative patients, 379 (39.7%) patients were found with D-dimer levels higher than 0.5 mg/L. Therefore, patients suspected to have DVT should be performed with ultrasound to confirm.

It is additionally notable that history of DVT had no significance with DVT on univariate analysis, but the LASSO-logistic regression model screened it out as a risk factor. The result further illustrated the LASSO-logistic regression model is superior to multivariate regression analysis with high dimensional data. To obtain relatively important variables as much as possible, the model chooses the ideal value of λ to maximize the AUC and obtain the optimal number of compression variables.

There are some limitations of this study. Ultrasound was performed within 7 days after the operations, and no further screening was carried out beyond that duration. Therefore, some patients might develop DVT after discharge would be overlooked. Another limitation was the lack of consistency amongst sonographers performing ultrasound examinations due to nature of two-center study. In addition, exclusion of anticoagulation patients after surgery may also affect the incidence rate. Thus, the finding of DVT may be affected by detection bias.

Conclusions

It is the first prospective study in analyzing risk factors of DVT development in urologic surgeries for cancer or non-cancer. The results suggested that in addition to the traditional risk factors (age, history of DVT, LND, prostatectomy, cystectomy), D-dimer levels, BI, Caprini Score and perioperative steroid use are significant risk factors for DVT development in clinical practice of urology. The patients found with these risk factors might consider the use of anticoagulation therapy.

List Of Abbreviation

Deep vein thrombosis (DVT)

Body mass index (BMI)

Congestive heart failure (CHF)

Lymph node dissection (LND)

European Association of Urology (EAU)

Least absolute shrinkage and selection operator method (LASSO)

Barthel Index (BI)

Mean corpusular hemoglobin concentration (MCHC)

Transurethral resection of bladder tumor (TURBT)

Declarations

Ethics approval

The study was approved by Hospitals Ethic Committee (IRB number: 201906142) and has been registered in the Chinese clinical trial registry (ChiCTR1900024784).

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Consent for publication

The authors all made a significant contribution to this manuscript and agreed to publish.

Availability of data and material

Contacting the corresponding author by email to get the data and meterial.

Code availability

Contacting the corresponding author by email to get the code.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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Author Contributions

Guyu Tang: Project development, data collection, and manuscript writing

Zepeng Sun: Data analysis

Jing Liu: Data collection

Shuai Zhu: Data collection

Lingxiao Chen: Data collection

Bin Huang: Data collection

Zhengtong Lv: Data collection

Yao Liu: Data collection

Yuan Li: project development

Lin Qi: project development

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Figures

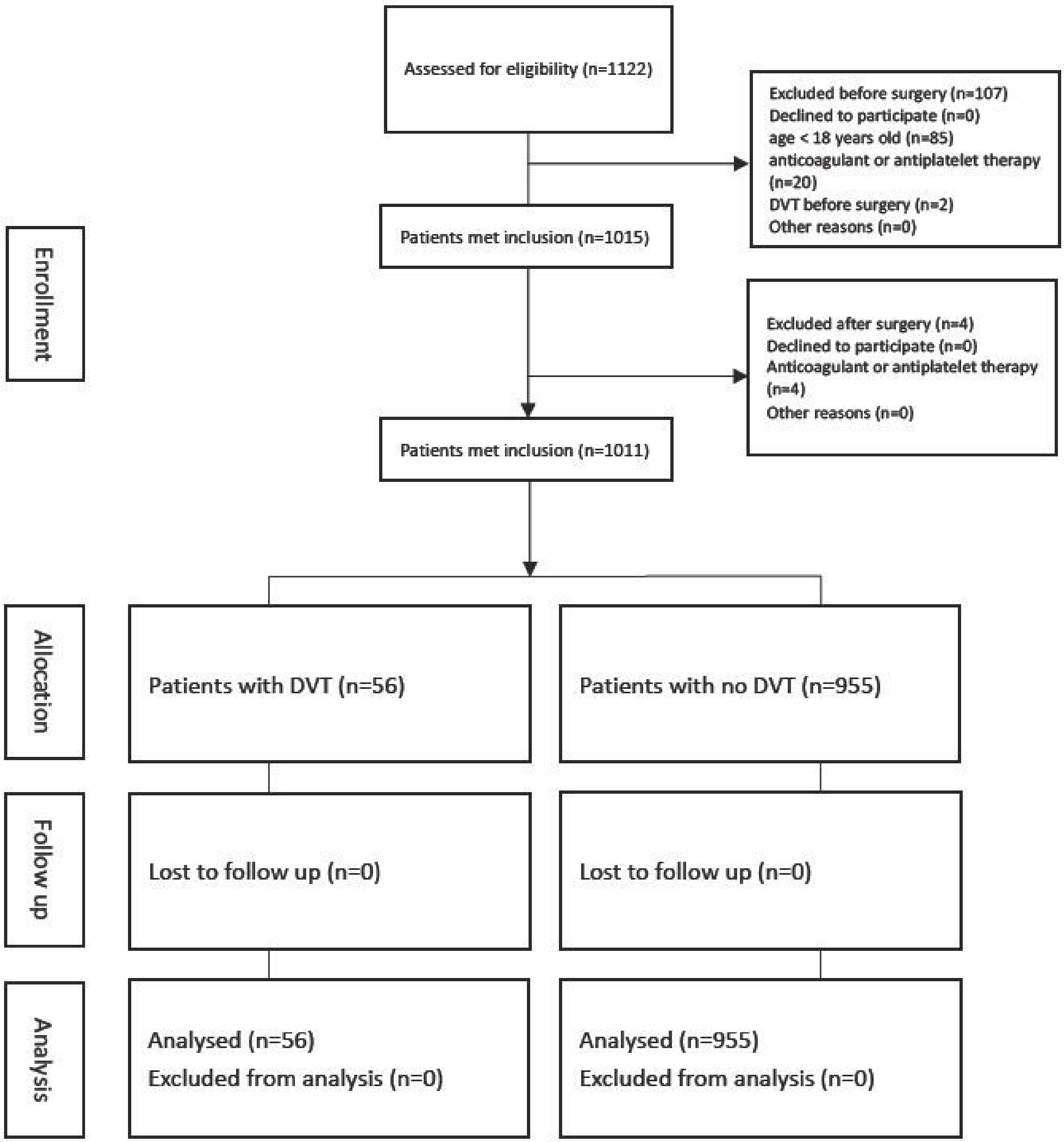

Figure 1

Patients' cohort.

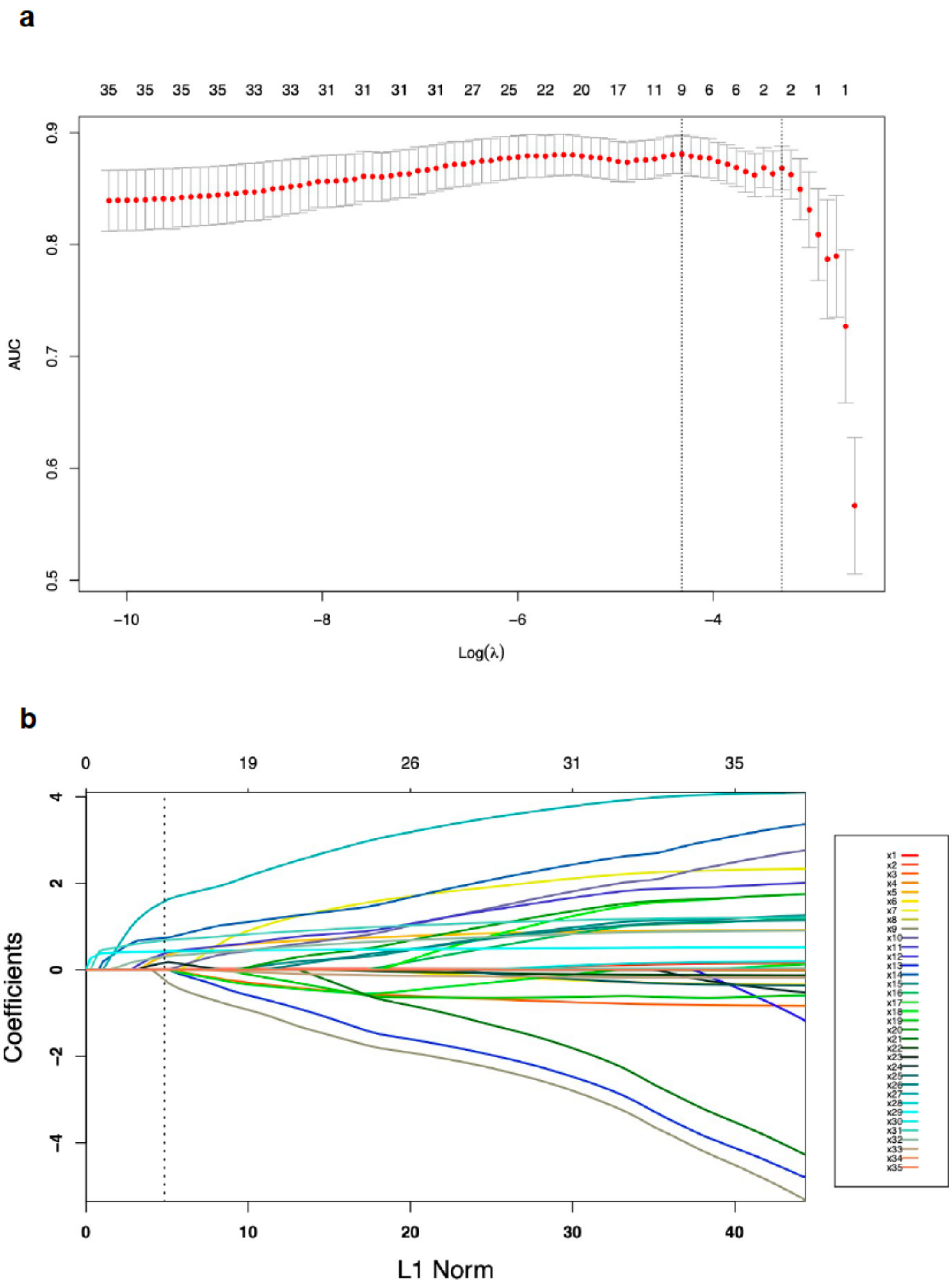

Figure 2

LASSO-Logistics regression a. The cross-validation results. The value in the middle of the two dotted lines is the range of the positive and negative standard deviations of log(λ). The dotted line on the left indicated the value of the harmonic parameter log(λ) when the error of the model is minimized. Nine variables were selected when log(λ)=-4.32. b. LASSO coefficient profiles of the 35 variables. A vertical line was drawn at the value chosen by 10-fold cross-validation. As the value of λ decreased, the degree of model compression increased and the function of the model to select important variables increased.