scientific reports

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Risk factors for postoperative surgical complications after inguinal lymph node dissection in penile cancer patients

Yilong Gao[1,2], Yanxiang Shao[1,2], Xu Hu[1], Linghao Meng[1] & Xiang Li[1]✉

Wound related and lymphatic reflow-related complications are commonly seen in penile cancer patients after inguinal lymph node dissection (ILND). However, the risk factors for them remain unclear. The objective of this study is to identify surgical-related risk factors for complications after ILND in penile squamous cell carcinoma (PSCC) patients. In this study, 192 PSCC patients aged 23–88 were enrolled between October 2008 and October 2023. Univariate analysis and logistic regression were performed to identify risk factors. Receiver operating characteristic (ROC) curves were used to analyze the relationship between certain risk factors and postoperative complications and find cut-off points for certain risk factors. Postoperative complications were observed in 87.5% of patients, with lymphatic fistula being the most common (50.0%) and wound dehiscence the least common (1.1%). Different factors were associated with each complication. Additionally, we found that the retention time of the drainage tube correlates with both lymphocele and wound infection, emphasizing the importance of optimizing drainage tube management to reduce lymphatic and wound-related complications. In conclusion, this study identified specific risk factors for complications after ILND in PSCC patients, particularly the shorter and longer retention times of the drainage tube for lymphocele and wound infection as determined by our multivariate analysis, and proposed new strategies to not only reduce the occurrence of these complications but also accelerate the postoperative healing process.

Keywords Penile cancer, Inguinal lymph nodes dissection, Risk factors, Postoperative complications

Penile cancer is a rare genital cancer whose incidence rates are 0.94/100,000 among males in Europe and 0.5/100,000 among males in the United States[1]. However, in regions with poor sanitation, such as South America, South East Asia, and Africa, the incidence rates of penile cancer are much higher, accounting for up to 1–2% of malignant tumors in males[1]. It is common to observe patients with inguinal metastases, which are indicative of poor prognosis[2].

Inguinal lymph nodes (ILNs) are the most common site for initial metastasis in penile cancer[3]. The presence and extent of nodal metastases is the most important prognostic factor for survival of penile cancer[4,5]. Inguinal lymph node dissection (ILND) is the standard therapy for penile squamous cell carcinoma (PSCC) patients with enlarged palpable inguinal lymph nodes or pathologically confirmed metastasis to ILNs[6,7]. ILND is not only helpful for treating potentially metastatic PSCC, but also for staging[8]. However, patients who undergo ILND frequently suffer high rates of postoperative complications—even as high as 70%[9]. According to existing research, most common postoperative complications are wound-related (such as wound infection, delayed wound healing, and skin necrosis) and lymphatic-related issues (such as lymphocele, lymphatic fistula, and lower limb edema)[10,11]. The primary mechanism of lymphatic dysfunction after ILND involves the disruption of lymphatic vessels and nodes responsible for draining lymph fluid from the lower extremities and genital regions. Additionally, a patient's overall preoperative condition and the extent of the surgical area may contribute to postoperative infection susceptibility. But currently, not only do the risk factors for these surgical complications remain unclear, but effective solutions for both prevention and accelerated healing are also greatly needed. The number of patients enrolled in related research were usually small, leading to less persuasive conclusions. Our study aims to analyze the incidence and identify key risk factors for postoperative surgical complications after

[1]Department of Urology, West China Hospital, Sichuan University, 37 Guoxue Lane, Chengdu 610041, China. [2]Yilong Gao, and Yanxiang Shao contributed equally to this work. ✉email: xiangli87@hotmail.com

ILND in a larger cohort of enrolled PSCC patients to provide actionable insights for complication prevention, reduction, and improved perioperative management.

Materials and methods

Population

This is a retrospective study. Our inclusion criteria involved pathologically confirmed PSCC patients that received ILND at our hospital from October 2008 to October 2023 and exclusion criteria involved patients that were unwilling to participate in our study. By following these criteria, 192 patients were included and 370 surgeries were conducted based on sides. Among them, 14 patients received unilateral ILND with conventional way of surgery, 12 patients received minimally invasive and conventional ILND for different sides, 35 patients received minimally invasive dissection for both sides of inguinal lymph nodes, and the rest received conventional ILND for both sides. The study adhered to STROCSS criteria for reporting observational studies in surgical research to ensure methodological rigor[12].

ILND indications

Regardless of the surgery (partial or complete penectomy) that patients underwent previously, bilateral ILND was recommended for patients with pathological results of pT2–4 or moderate- to poor-differentiation tumors and/or palpable inguinal masses on examination. Enlargement or metastasis of lymph nodes was determined by physical examination, ultrasound, or Computed Tomography (CT) scans.

Surgical techniques for ILND

All of the operations, namely, 82 minimally invasive surgeries and 288 conventional (open) surgeries, were conducted by experienced urological surgeons. The boundaries of dissection can be summarized as follows: pectineus muscle as lateral margin, adductor longus muscle as medial margin, 2 cm above the inguinal ligament as upper margin, and inferior margin of the femoral triangle as lower margin. En-bloc dissections of fat and lymphatic tissues were performed from top to bottom and from periphery to center. Both the superficial and deep inguinal lymph nodes were dissected. The great saphenous vein was preserved if its anatomical structure was clear and no enlarged peripheral lymph nodes were found. After the dissection, a silicon drainage tube connected to a negative pressure suction bottle was placed at the surgical site and the incision was closed with sutures or staples.

Postoperative therapies

Negative pressure suction bottles were placed to maintain continuous negative pressure drainage in the surgical area and monitor the drainage volume on each side after dissection. The drainage tube was removed if the drainage volume on one side was less than 50 ml for three consecutive days and the skin flaps adhered well to the surgical area. The dressing was changed every 2–3 days and decisions on whether to remove the sutures or staples were made according to the wound recovery status two weeks after surgery. Sutures or staples were not removed if the wound was not healed completely. Antibiotic prophylaxis was not used in most cases after surgery, which meant that antibiotics were only administered in case of confirmed wound infection.

Postoperative surgical complications

Postoperative complications were divided into two major types, namely, wound-related and lymphatic reflow-related. The severity of same kinds of postoperative surgical complication varies among patients, so we adopted the Clavien-Dindo classification[13] for grading complications. Wound-related issues included wound infection, poor wound healing, and wound dehiscence. Lymphatic reflow-related issues included lymphatic fistulas, lymphocele, and lower limb edema. Data on postoperative complications for both sides were collected. The definitions and classifications of severity of postoperative complications were shown in Table 1. Complications were counted based on sides.

	Definition	Grade I	Grade II	Grade III	Grade IV	Grade V
Wound infection	The positive result of secretion culture from the wound	39	17	0	0	0
Poor wound healing	The wound had not healed completely for more than 14 days after surgery	23	67	0	0	0
Wound dehiscence	Partial or complete separation of the edges of the surgical incision	0	0	4	0	0
Lymphatic fistula	It took more than 10 days to remove the drainage tube	161	7	0	0	0
Lymphocele	A palpable, fluctuant cyst that appeared near the wound after surgery	51	17	31	0	0
Lower limb edema	Apparent larger lower limb after surgery	84	3	0	0	0

Table 1. The definitions and classifications of severity of postoperative complications.

Data collection

We collected data on a series of risk factors that might be related to postoperative complications, including the age of the patient when receiving ILND, duration of surgery, history of smoking, maximum diameter of excised lymph nodes (cm), preoperative skin condition of the inguinal area (including no local ulceration or necrosis, local skin adhered to lymph nodes, and skin and lymph node ulceration), ILND approach on each side (minimally invasive or open), whether the great saphenous vein was preserved, duration of drainage tube retention in the surgical area, number of lymph nodes removed during surgery, number of pathologically confirmed positive lymph nodes, time between PSCC surgery and ILND, and preoperative inguinal lymph node status (including no enlarged lymph nodes, single enlarged lymph node, multiple enlarged lymph nodes, lymph nodes fused into clusters, and enlarged or fused lymph nodes breaking through the capsule).

Statistical analysis

Statistical analysis was performed using SPSS 29 (Chicago, USA) and GraphPad Prism 9 (SanDiego, USA). Univariate analysis was conducted using t-tests, rank-sum analysis, Fisher's exact test, and chi-square test. Results were presented as Mean ± Standard Deviation (SD) accompanied by 95% Confidence Interval (CI), and Median (P25, P75). T-tests and rank-sum analysis were employed to evaluate differences in continuous variables among patient groups, Fisher's exact test and chi-square test were used to assess differences in categorical variables among patient groups. Multivariate logistic regression model was used to find out risk factors associated with postoperative complications, presenting results as odds ratios (OR). Receiver operating characteristic (ROC) curves were employed to analyze the relationship between certain risk factors and postoperative complications and find out cut-off points for certain risk factors. Values of $p < 0.05$ were considered to indicate statistical significance.

Ethical approval

The approval of study was obtained from the Institutional Review Board of West China Hospital, Sichuan University (2024 – 675). All methods were performed in accordance with relevant guidelines and regulations including the Declaration of Helsinki. Informed consent was obtained from all participants and their authorized family members, and consent for publication was obtained from all participants.

Results

Population characteristics

Risk factors related to postoperative complications and the details of these postoperative complications are presented in Tables 2, 3 and 4.

Among the patients, 87.5% of patients suffered at least one of the postoperative complications listed above, with lymphatic fistula being the most common (50.0% of patients) and wound dehiscence being the least common (four patients, 2.1%).

Univariate or multivariate analyses both indicated that history of smoking was not associated with the occurrence of postoperative complications.

T staging: 71 patients had undergone penile surgery at other hospitals, making it difficult to acquire their pathology reports, according to the pathological reports of 121 patients that received penectomy at our hospital, 70 (57.85%) were classified as T3, and 51 (42.15%) were classified as T2.

1. Wound infection.

Univariate analysis revealed that patients suffered from wound infections had a longer time interval (days) between penile surgery and ILND (82.00 (38.00, 206.00) vs. 53.00 (27.75, 107.00), $p = 0.014$), worse preoperative inguinal lymph nodes condition, poorer preoperative skin condition, longer surgical duration (minutes) (70.50 (61.00, 92.50) vs. 62.50 (50.00, 80.00), $p = 0.004$) and longer duration of drainage tube retention (days) (12.5 (7.0, 22.0) vs. 8 (6, 14), $p < 0.001$). Fewer of them received minimally invasive surgeries (3.6% vs. 25.5%, $p < 0.001$) or preserved the great saphenous vein (25.0% vs. 42.7%, $p = 0.013$).

Multivariate analysis indicated that minimally invasive surgery ($p = 0.014$, OR = 0.157) and the longer duration of drainage tube retention ($p < 0.001$) were associated with postoperative wound infection. ROC curves generated for the duration of drainage tube retention and occurrence of wound infection revealed a significant increase in the wound infection occurrence rate when the drainage tube was retained for more than 10.5 days (23.75% vs. 9.05%) (Fig. 1a).

2. Poor wound healing.

Univariate analysis showed that patients suffered from poor wound healing had longer duration (minutes) of surgery (75.00 (57.50, 92.50) vs. 61.75 (50.00, 79.00), $p = 0.001$), worse preoperative inguinal lymph nodes condition, poorer preoperative skin condition, longer duration (days) of drainage tube retention (11.00 (7.00, 21.25) vs. 8 (6, 14), $p = 0.011$). Fewer of them received minimally invasive surgeries (12.2% vs. 25.4%, $p = 0.009$) or preserved the great saphenous vein (17.8% vs. 47.1%, $p < 0.001$).

Multivariate analysis indicated that the longer duration of surgery ($p = 0.035$), whether the great saphenous vein was preserved ($p < 0.001$, OR = 0.25), and the longer duration of drainage tube retention ($p = 0.003$) were associated with poor postoperative wound healing. ROC curves generated for the duration of drainage tube retention and occurrence of poor wound healing revealed a significant increase in the occurrence of poor wound healing when the drainage tube was retained for more than 10.5 days (30% vs. 20%) (Fig. 1b).

Continuous variables			Median (P25, P75)	
Duration of surgery (minutes)			64.25 (50.00, 85.00)	
Age at the time of ILND (years)			51.64 (43.05, 62.89)	
Maximum diameter (cm) of excised lymph nodes			1.85 (1.00, 3.00)	
Duration of drainage tube retention (days)			9.00 (6.00, 15.00)	
Number of lymph nodes removed during surgery			9.00 (5.75, 12.00)	
Number of lymph nodes with positive pathological results			0.00 (0.00, 1.00)	
Time interval between penile surgery and ILND (days)			55.00 (31.75, 120.75)	
Categorical variables			**Negative**	**Positive**
History of smoking			91, 47.4%	101, 52.6%
Whether minimally invasive surgery was performed			288, 77.8%	82, 22.2%
Whether the great saphenous vein was preserved			222, 60.0%	148, 40.0%
Wound infection			314, 84.9%	56, 15.1%
Poor wound healing			280, 75.7%	90, 24.3%
Wound dehiscence			366, 98.9%	4, 1.1%
Lymphatic fistula			202, 54.6%	168, 45.4%
Lymphocele			271, 73.2%	99, 26.8%
Lower limb edema			283, 76.5%	87, 23.5%
Preoperative skin condition of the inguinal area				
No local ulceration, necrosis			271, 73.2%	
Local skin adhered to lymph nodes			72, 19.5%	
Skin and lymph node ulceration			27, 7.3%	
Preoperative inguinal lymph node status				
No enlarged lymph nodes			167, 45.1%	
Single enlarged lymph node			77, 20.8%	
Multiple enlarged lymph nodes			82, 22.2%	
Lymph nodes fused into clusters			35, 9.5%	
Enlarged lymph nodes breaking through the capsule			9, 2.4%	
pN	**0**	**1**	**2**	**3**
	76, 39.6%	36, 18.8%	48, 25.0%	32, 16.7%

Table 2. Demographic, clinical, and pathological features of 192 patients and 370 surgeries. ILND: inguinal lymph nodes dissection.

3. Lymphatic fistula.

Univariate analysis demonstrated that those suffered from lymphatic fistula were older overall (55.48 (46.17, 66.00) vs. 48.33 (41.00, 59.59), $p < 0.001$) and had more lymph nodes removed during surgery (11 (9, 15) vs. 7 (5, 9), $p < 0.001$).

Multivariate analysis indicated that the interval between penile surgery and ILND ($p = 0.001$), the number of lymph nodes removed during surgery ($p < 0.001$), and the number of positive lymph nodes according to the final pathological results ($p = 0.029$) were associated with the occurrence of postoperative lymphatic fistula. ROC curves generated for the number of lymph nodes removed during surgery and the occurrence of postoperative lymphatic fistula revealed a significant increase in the lymphatic fistula occurrence rate when more than 9.5 lymph nodes were removed (72.22% vs. 24.52%) (Fig. 1c).

4. Lymphocele.

Univariate analysis demonstrated that those suffered lymphocele had a shorter duration of drainage tube retention (days) (5 (4, 6) vs. 11 (7, 17), $p < 0.001$). Also, 18 patients whose drainage tubes accidentally detached from the wound before meeting our criteria for removing them all subsequently developed lymphocele on the same side.

Multivariate analysis indicated that the only factor related to lymphocele occurrence was the duration of drainage tube retention. ROC curves generated for the duration of drainage tube retention and the occurrence of lymphocele revealed a significantly higher rate of lymphocele occurrence in patients for whom the duration of drainage tube retention was less than 6.5 days (72.07% vs. 7.34%) (Fig. 1d).

5. Lower limb edema.

Univariate analysis demonstrated that compared with patients without lower limb edema, those suffered from lower limb edema had lower rate of no preoperative lymph node enlargement (34.5% vs. 48.4%), higher rate of

		Wound infection			Poor wound healing		
		No	Yes	*p* Value	No	Yes	*p* Value
Duration of surgery (minutes), Median (P25, P75)		62.50 (50.00, 80.00)	70.50 (61.00, 92.50)	0.004	61.75 (50.00, 79.00)	75.00 (57.50, 92.50)	0.001
Age at the time of ILND, Median (P25, P75)		50.93 (43.01, 62.30)	54.00 (45.65, 65.50)	0.294	52.25 (44.02, 63.17)	50.11 (42.13, 60.62)	0.381
Maximum diameter (cm) of lymph nodes removed during surgery, Median (P25, P75)		1.5 (0.9, 2.5)	3.500 (1.625, 5.000)	< 0.001	1.7 (0.9, 2.6)	2.2 (1.0, 4.0)	0.002
Preoperative skin condition of the inguinal area (%)	1. No local ulceration or necrosis	77.1	51.8	< 0.001	78.2	57.8	<0.001
	2. Abnormal skin condition	22.9	48.2		21.8	42.2	
Surgery type (%)	1. Conventional	74.5	96.4	< 0.001	74.6	87.8	0.009
	2. Minimally invasive	25.5	3.6		25.4	12.2	
Preservation of the great saphenous vein (%)		42.7	25.0	0.013	47.1	17.8	< 0.001
The duration of drainage tube retention (days), Median (P25, P75)		8 (6, 14)	12.5 (7.0, 22.0)	< 0.001	8 (6, 14)	11.00 (7.00, 21.25)	0.011
The number of lymph nodes removed during surgery, Median (P25, P75)		9 (6, 11)	10.00 (5.00, 14.75)	0.340	8 (6, 11)	10 (5, 14)	0.029
The number of lymph nodes with positive pathological results, Median (P25, P75)		0 (0, 1)	1 (0, 1)	0.002	0 (0, 1)	1 (0, 1)	0.004
The time interval between penile surgery and ILND (days), Median (P25, P75)		53.00 (27.75, 107.00)	82.00 (38.00, 206.00)	0.014	55.00 (32.00, 110.75)	66.00 (24.00, 164.00)	0.416
Preoperative inguinal lymph node status (%)	1. No enlarged lymph nodes	48.4	26.8	< 0.001	48.9	33.3	0.003
	2. Abnormal inguinal lymph node status	51.6	73.2		51.1	66.7	

Table 3. Univariate analysis of possible risk factors for wound-related complications after inguinal lymph nodes dissection in penile squamous cell cancer patients. ILND: inguinal lymph nodes dissection.

lymph nodes fused into clusters (16.1% vs. 7.4%), and longer duration of surgery (69.0 (60.0, 92.5) vs. 61 (49, 80), $p < 0.001$).

Multivariate analysis indicated that the duration of surgery ($p = 0.003$), whether the great saphenous vein was preserved ($p = 0.001$, OR = 2.57), and preoperative lymph node conditions ($p < 0.001$, OR = 1.859) were associated with the occurrence of postoperative lower limb edema.

In regard to the relationships between various postoperative complications, chi-square analysis suggested that poor wound healing ($p < 0.001$, OR = 18.791), lymphatic fistula ($p < 0.001$, OR = 2.720), and lower limb edema ($p < 0.001$, OR = 2.723) were associated with wound infection, lymphatic fistula ($p = 0.048$, OR = 1.617) was associated with poor wound healing, lymphocele ($p < 0.001$, OR = 0.113) was associated with lymphatic fistula, and lower limb edema ($p = 0.032$, OR = 1.750) was associated with lymphocele.

Discussion

How to prevent surgical complications and accelerate healing after ILND have always been problems for urological surgeons. In our study, we found that the duration of ILND, preoperative skin condition of the inguinal area and whether minimally invasive surgeries were performed were significantly correlated with wound-related complications. And the duration of drainage tube retention, the number of lymph nodes removed during surgery showed a distinct relationship with lymph-related complications. What's more, in our study, we found the optimal timing for removing the drainage tube was between 6.5 and 10.5 days as to both reduce the incidence of lymphocele and wound-related issues. Currently, there are relatively few studies on risk factors for each type of postoperative complication after ILND and analyzing the mechanisms behind these complications. Moreover, the sample size in these studies was small. In our study, we examined five postoperative complications and 12 potential risk factors, and also made further investigation on the mechanism of formation of these complications to both prevent them from happening and seek solutions to accelerate healing after ILND.

Extant studies had found the incidence of postoperative wound infections to be in the range of 0.5–3%[15,16]. Postoperative wound infection might be related to factors such as diabetes, immunosuppressive status, malnutrition, obesity, preoperative infection, smoking history, age, skin infection history, history of radiation therapy, duration of surgery, perioperative hypothermia, operating room air contamination, postoperative hyperglycemia, the surgeon's proficiency in conducting ILND, and postoperative wound care[17]. Additionally, Seidelman et al.[17] suggested that the risk of postoperative wound infection could be reduced by avoiding shaving with razors, disinfecting with intranasal antimicrobial and skin antiseptic agents, using chlorhexidine gluconate and alcohol-based skin preparations, maintaining perioperative body temperature above 36 °C, controlling blood sugar levels during perioperative period, and using negative pressure wound therapy. In our study, we additionally found that specifically for ILND, whether the procedure was performed minimally invasively and the duration of drainage tube retention were independently correlated with wound infection. Previous studies had shown that the use of laparoscopy can reduce the risk of postoperative wound infection[18,19]—the reason might be that conventional (open) surgery could induce a more apparent inflammatory response than laparoscopic

		Lymphatic fistula			Lymphocele			Lower limb edema		
		No	Yes	*p* Value	No	Yes	*p* Value	No	Yes	*p* Value
Duration of surgery (minutes), Median (P25, P75)		62.500 (51.125, 87.500)	65.000 (47.875, 79.000)	0.382	62.5 (50.0, 82.5)	67.5 (52.5, 87.5)	0.339	61 (49, 80)	69.0 (60.0, 92.5)	< 0.001
Age at the time of ILND, Median (P25, P75)		48.33 (41.00, 59.59)	55.48 (46.17, 66.00)	< 0.001	52.25 (44.14, 63.20)	48.67 (40.86, 59.00)	0.062	50.93 (42.61, 62.61)	56.63 (45.17, 65.00)	0.112
Maximum diameter (cm) of lymph nodes removed during surgery, Median (P25, P75)		1.5 (1.0, 3.0)	2.00 (1.00, 3.15)	0.171	1.8 (1.0, 3.0)	2.0 (1.0, 4.0)	0.361	1.8 (1.0, 3.0)	2.0 (1.0, 3.5)	0.233
Preoperative skin condition of the inguinal area (%)	1. No local ulceration, necrosis	72.3	74.4	0.419	72.3	75.8	0.061	72.4	75.9	0.537
	2. Abnormal skin condition	27.7	25.6		27.7	24.2		27.6	24.1	
Surgery type (%)	1.Conventional	78.2	77.4	0.847	78.6	75.8	0.560	76.3	82.8	0.206
	2.Minimally invasive	21.8	22.6		21.4	24.2		23.7	17.2	
Preservation of the great saphenous vein (%)		37.6	42.9	0.306	39.9	40.4	0.924	36.0	52.9	0.005
The duration of drainage tube retention (days), Median (P25, P75)		6 (4, 7)	15.00 (12.00, 22.75)	< 0.001	11.00 (7.00, 17.00)	5.00 (4.00, 6.00)	< 0.001	9 (6, 14)	11 (6, 15)	0.255
The number of lymph nodes removed during surgery, Median (P25, P75)		7 (5, 9)	11 (9, 15)	< 0.001	9 (6, 12)	7 (5, 10)	< 0.001	9 (6, 11)	9 (5, 15)	0.210
The number of lymph nodes with positive pathological results, Median (P25, P75)		0 (0, 1)	0 (0, 1)	0.648	0 (0, 1)	0 (0, 1)	0.472	0 (0, 1)	1 (0, 1)	0.128
The time interval between penile surgery and ILND (days), Median (P25, P75)		50.50 (25.00, 123.25)	65.00 (36.00, 118.00)	0.433	55.00 (32.00, 120.00)	56.00 (21.00, 138.00)	0.779	53 (24, 115)	71 (35, 156)	0.063
Preoperative inguinal lymph node status (%)	1. No enlarged lymph nodes	43.1	47.6	0.507	46.1%	42.4%	0.141	48.4	34.5	0.044
	2. Abnormal inguinal lymph node status	56.9	52.4		53.9	57.6		51.6	65.5	

Table 4. Univariate analysis of possible risk factors for lymph-related complications after inguinal lymph nodes dissection in penile squamous cell cancer patients. ILND: inguinal lymph nodes dissection.

surgery, and laparoscopic surgery may therefore better preserve the patient's systemic immune function[20]. Furthermore, there is a lack of sufficient studies analyzing the relationship between the duration of drainage tube retention and wound infection. We speculate that this relationship may be attributable to several reasons: (1) Retention of the drainage tube increases the chances of contact between the surgical site and the external environment, therefore increasing the risk of wound infection. (2) Patients with long duration of drainage tube retention often have lymphatic fistula, creating a moist environment around the surgical site that is conducive to the growth of bacteria. Therefore, based on our findings, we believe it is important to minimize contact between the incision and the external environment, keep the wound dry and clean, change dressings regularly, enhance nutritional support and provide appropriate antibiotic therapy if necessary to both prevent postoperative wound infection from happening and accelerate its healing process if it happens. After taking these measures, we indeed observed an accelerated healing process for patients with wound infection. It could also be helpful to reduce the risk of postoperative wound infection by shortening the duration of drainage by avoiding lymphatic fistula.

There is currently no unified definition of poor wound healing. Some studies described complete wound healing as "100% epithelialization without drainage or dressing requirements confirmed at two consecutive study visits two weeks apart"[21]. According to our clinical experience, we consider wounds that have not completely healed 14 days after surgery as indicating poor wound healing. Studies had shown that the risk factors for postoperative poor wound healing included diabetes, postoperative wound infection, chronic kidney failure, chronic obstructive pulmonary disease (COPD), malnutrition, obesity, smoking, alcohol consumption, drug abuse, postoperative chemotherapy or radiotherapy, and the use of corticosteroids[22]. In our study, we additionally found that risk factors for poor wound healing after ILND included operation time, duration of drainage retention tube. And poor wound healing is strongly associated with wound infection. However, we did not find a history of smoking to be a risk factor for any wound-related complication after ILND. Additionally, we found that the incidence of poor wound healing increased significantly (30% vs. 20%) when the drainage tube was retained for more than 10.5 days. In all, based on our findings, we believe that it is vital to reduce the risk of postoperative poor wound healing by preventing wound infection from happening in the first place, improving patients' preoperative overall condition both preoperatively and postoperatively, shortening the duration of surgery if the condition of inguinal area allows, and reducing the duration of drainage if possible. It would be better to have further research validating our effective measures.

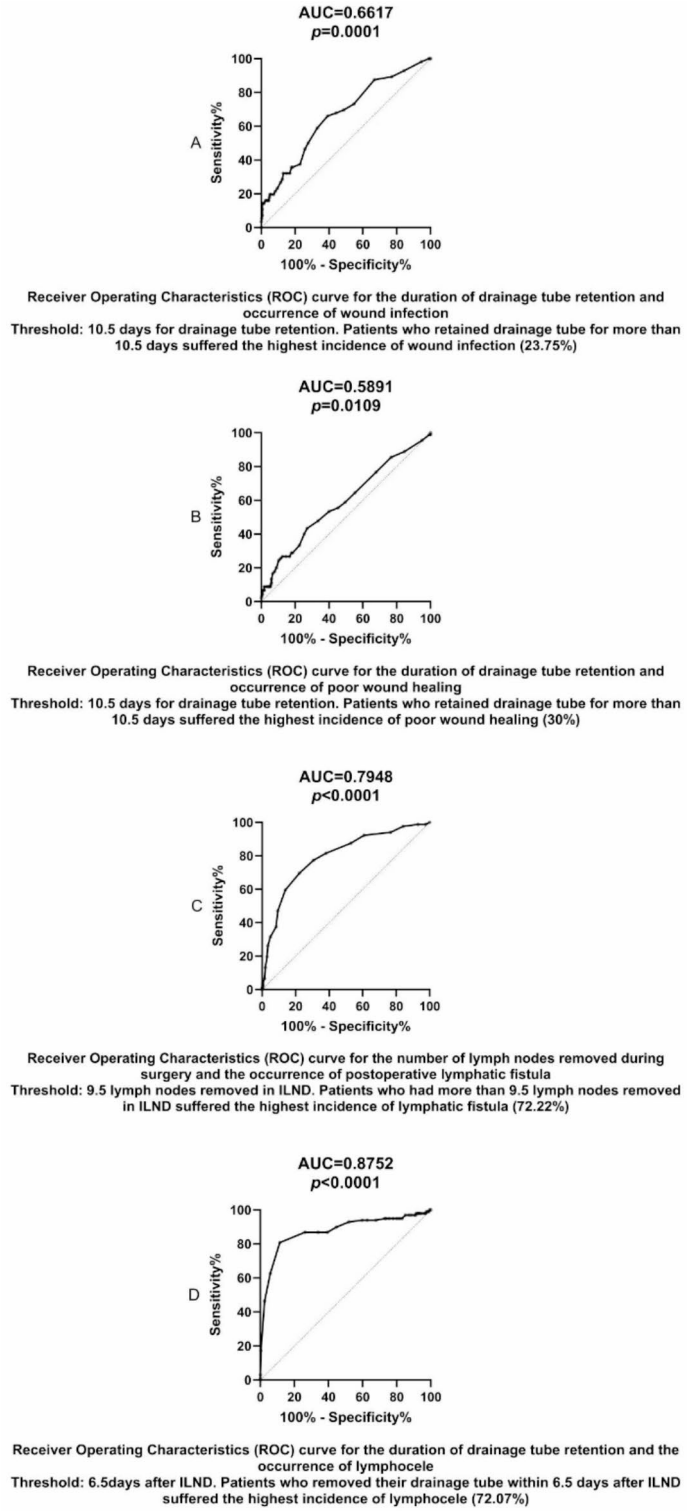

Fig. 1. Receiver operating characteristics (ROC) curves for the relationship between certain risk factors and postoperative complications with cut-off values. ILND: inguinal lymph nodes dissection. No patients required readmission, and all except those with lower limb edema experienced prolonged hospitalization.

In our study, we found the incidence of wound dehiscence to be 1.1%. A previous study had reported the incidence of wound dehiscence to be 1.3–9.3% after ILND[23]. They divided potential risk factors into three categories: (1) preoperative: high body mass index (BMI), smoking, diabetes, COPD, peripheral vascular disease. (2) intraoperative: risk factors vary in different surgeries, for example, operative time, emergency procedure, and clean wound classification in abdominal surgeries. (3) postoperative: hypoxemia or prolonged ventilation,

length of ICU stays, blood transfusion, and hypotension. However, we were unable to further analyze these risk factors because of the lack of patients with postoperative wound dehiscence in our study. But additionally, the four patients which suffered postoperative wound dehiscence in our study exhibited preoperative skin and lymph node ulceration and malnutrition. Taken together, we strongly believe we can lower the risk of wound dehiscence after ILND by improving patients' preoperative overall conditions, paying more attention to wound status, and preventing wound infection.

One study revealed that the incidence of postoperative wound infection, poor wound healing, and wound dehiscence vary in regard to different kinds of incisions[24], although another study from our hospital showed no significant differences between them[14].

In this study, we examined lymphatic fistula, lymphocele, and lower limb edema as lymph-related postoperative complications. Currently, there are few studies on the preoperative and intraoperative risk factors for lymphatic fistula. Our study found that the number of lymph nodes removed during surgery, the number of lymph nodes pathologically confirmed to be positive may be independent risk factors. Based on our clinical experience and the findings of this study, we believe that it is inevitable for patients to experience some extent of lymphatic fistula after standard ILND due to the surgery's nature. Because ILND inevitably causes damage to patient's inguinal lymph system and it takes time for the severed end of lymphatic vessel to seal itself. But we discovered the risk of postoperative lymphatic fistula can be minimized by avoiding using blunt instruments such as forceps or fingers to create gap in interstitial space too frequently, and by using energy instruments such as electrosurgical knives and ultrasonic scalpels to seal invisible lymph channels. In our study, we found that the incidence of postoperative lymphatic fistula was lower in patients who underwent ILND with energy instruments compared to those who had the procedure with blunt instruments. Further studies are needed to determine whether specific choice of surgical technique will influence the occurrence of lymphatic fistula. Several other studies had reported their methods to lower the incidence of postoperative lymphatic fistula, for instance, Hautmann et al.[25] reported that postoperative radiotherapy could reduce lymph fluid secretion and Jazmati et al.[26] reported it may eliminate the risk of lymphatic fistula. Spiess et al.[24] and Crawford et al.[27] reported that using a negative pressure suction device in the surgical area after surgery could prevent the occurrence of lymphatic fistula while Jain et al.[28] claimed that negative pressure drainage devices not only failed to prevent the occurrence of lymphatic fistula, but also increased pain and were associated with prolonged hospital stays. Another study reported the necessity of postoperative drainage without specifying the optimal duration for drainage[29]. Heyns et al.[30] claimed that drainage could be stopped once the drainage volume had decreased to 30–50 ml in 24 h. More multi-center research and studies with larger patient samples are needed to verify our new findings and proposal.

There is limited research on the occurrence of lymphocele after ILND. Jansen et al.[31] included the surgery type (open vs. laparoscopy), whether adjuvant radiotherapy was performed, the number of lymph nodes removed during surgery, and condition of pelvic lymph nodes as risk factors for pelvic lymph node dissection (PLND). However, their study did not find a correlation between the mentioned factors and the formation of symptomatic lymphocele. Although our study found similar results, a notable difference was that we found that shorter duration of drainage retention (less than 6.5days) was associated with postoperative lymphocele as mentioned above. The mechanism behind this phenomenon has barely been discussed in other studies and we speculate that it is because although some patients' drainage volume is small enough to remove the drainage tube, there is still an invisible accumulation of lymph fluid occurring together with fat liquefaction, leading to more obvious lymphocele. In regard to existing lymphocele, a study claimed that despite conventional treatments such as repeated aspirations and pressure bandaging, recurrence rate remained high[32]. Giacalone et al.[32] and Boccardo et al.[33] reported resolution of lymphocele through a minimally invasive approach, namely, anastomosing non-closed lymphatic channels with nearby veins. It should be noted that lymphocele is often caused by localized lymphatic fistula. Premature interventions for lymphocele cannot stop lymphatic fluid leaking from non-closed lymphatic channels, but instead may increase the risk of postoperative wound infection. In our clinical practice, drainage tubes are placed or needle aspiration is performed after the fibrosis and closure of non-closed lymphatic channels and establishment of collateral circulation, which is usually 4–6 weeks after the formation of lymphocele. Among the 99 cases of lymphocele, 31 cases still caused discomfort to patients after 4–6 weeks. Using our timing for aspiration, only two cases reappeared but with significantly smaller diameters than the initial ones and barely affected patients' quality of life.

In regard to lower limb edema, some studies reported that whether the great saphenous vein was preserved[34,35] and the number of lymph nodes removed during surgery[36] were associated with limb edema. Our study found that duration of surgery, the number of lymph nodes removed during surgery, and the preoperative condition of the inguinal lymph nodes are potential risk factors, while the preservation of great saphenous vein was not related with lower limb edema. A previous study[36] claimed that reverse mapping and constructing lymphatic-venous anastomoses may prevent postoperative limb edema. We believe that lower limb edema is related to a temporary impairment of lymphatic flow and will mostly disappear gradually with the establishment of compensatory lymphatic flow. In clinical practice, we strongly suggest that patients avoid sitting and standing for long periods after ILND and elevate the limb when lying down, which may help to accelerate the disappearance of lower limb edema. In our study, lower limb edema in most affected patients was transient, lasting 7 to 30 days after implementing the mentioned measures. And it would be better if more studies could support our treatment approach.

The limitations of this study are as follows: (1) As a retrospective study, our research has a lower level of evidence and weaker control over potential confounders and biases compared to prospective studies, including the risk of selection bias. (2) Some of the patients had undergone penile surgery elsewhere, making it difficult to acquire data on their pT grade. (3) Our study is single-centered, and lack of external validation. Future

multicenter studies with prospective designs are warranted to validate our findings and explore additional preventive and protective strategies.

Conclusions

Our study provides evidence-based recommendations for optimizing drainage tube management and minimizing ILND-related complications in PSCC patients. In particular, the relationship we observed between drainage tube duration and lymphocele highlights the importance of determining the optimal timing for drainage tube removal to reduce the risks of both lymphocele and wound infection. New and effective measures should be taken to reduce the occurrence of postoperative complications and accelerate postoperative healing process. Further prospective, multi-center studies are needed to support and validate our noteworthy discoveries.

Data availability

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Received: 3 December 2024; Accepted: 11 March 2025
Published online: 20 March 2025

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Acknowledgements
We would also like to thank all of our colleagues who helped us collect data.

Author contributions
X.L. managed the study. Y.G. and Y.S. designed the study. Y.G., Y.S., X.H. and L.M. collected the data. Y.G. and L.M. controlled the quality of data and algorithms. Y.G. and Y.S. analyzed and interpreted the data. All authors contributed to the manuscript writing and final approval of manuscript.

Funding
Supported by Sichuan Science and Technology Program (2022YFS0133).

Competing interests
The authors declare no competing interests.

Additional information
Correspondence and requests for materials should be addressed to X.L.

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