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Review

Robot-assisted endoscopic inguinal lymphadenectomy: A review of current outcomes



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Abstract *Objective:* To review the role of robot-assisted endoscopic inguinal lymphadenectomy (RAIL) in the management of penile cancer.

Methods: A PubMed search for all relevant publications regarding RAIL series up until August 2019 was performed using the keyword “robotic”, “inguinal lymph node dissection”, and “penile cancer”. Weighted mean was calculated in the largest series for all outcomes using the number of patients included in each study as the weighting factor.

Results: We identified 23 articles, of note the three largest series that included 102, 27, and 20 RAIL in 51, 14, and 10 patients, respectively. Saphenous vein was spared in 88.93% of RAIL cases in these series and node yield was 11.42 per groin; 35.28% of patients had positive pathological nodes. The weighted mean of operative time was 87.98 min per RAIL and the estimated blood loss was 37.08 mL per patient. The mean length of hospital stay was 1.29 days and the drain was kept in place for 17.02 days; the major complication rate was only 5.31% in these series. The mean follow-up was 33.46 months with a recurrence-free survival of 96.33%.

Conclusion: The literature regarding RAIL describes promising results, although it has shorter follow-up and higher costs when compared to historically series from the open approach. Initial series reported lower cutaneous complications compared to conventional approach, without compromising oncological outcomes. However, long-term results and larger trials are crucial to validate those findings.

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1. Introduction

Invasive penile squamous cell carcinoma (PSCC) has an incidence smaller than 1% of all malignant neoplasms in men from the United States and Europe. However, in developing nations of Asia, Africa, and South America, it reaches up to 10% [1]. Besides the penectomy, assessment of the inguinal lymph nodes is of utmost importance, because nodal metastasis follows a predictable spreading pattern. Initially, it starts from the penis to the inguinal sentinel node, then to other superficial and deep inguinal nodes, the node of Cloquet, and finally to pelvic nodes, where the odds to progress with distant metastasis rise substantially [2–4].

Current guidelines recommend to perform bilateral modified inguinal lymphadenectomy (ILND) in patients with no palpable inguinal nodes presenting with intermediate (T1b and G1-2) or any high-risk features (T1G3 or higher, >50% poor differentiated, lymphovascular invasion) and radical ILND in patients with palpable inguinal nodes (cN1/cN2) [5,6].

Catalona [7] was the first author, in 1988, to propose a modified template compared to the radical dissection by Daseler and associates [8]. He found the innovative technique as being less morbid than the classical ILND [7]. Despite that, perioperative complications such as wound infection, flap necrosis and lymphedema can affect as many as two-thirds of patients even with modified templates [9]. Modifications such as thicker skin flaps and smaller fields dissection have successfully decreased these rates to almost a quarter of patients [10]. Nevertheless, due to its morbidity, ILND is still reported as underperformed in the United States, and even when this procedure is performed, node yield is often unsatisfactory [11].

Other possibility trying to reduce morbidity for intermediate or high-risk disease is dynamic sentinel guided biopsy with reliability to properly identify rates in more than 90% when done combining techniques of radioisotope and patent blue by experienced centers [12–15].

As in the other fields in urology, minimally invasive approaches to ILND have been described in an attempt to reduce morbidity and optimize convalescence [16]. The first endoscopic technique of ILND performed on two human cadavers was described by Bishoff and associates in 2003 [17], and subsequently in a living patient. Then, the first successfully videoendoscopic radical inguinal lymphadenectomy (VEIL) report in the clinical urology scenario was performed by Machado et al. [18] in 2005.

In the following years, Machado et al. [3] compared the morbidity of open ILND (OILND) with VEIL. They described 50% more complications in the open procedure. Despite the longer operative time (OT) in the VEIL group, the mean number of retrieved and positive nodes was similar, while

length of stay (LOS) and time to resumption of daily activities were shorter with VEIL.

Due to penile cancer rarity and the steep learning curve of pure laparoscopy, a robotic-assisted endoscopic inguinal lymphadenectomy (RAIL) was first described by Josephson and colleagues [19] in 2009, intending to surpass the limitations of lap surgery. The possibility to follow the surgical principles of OILND associated with the benefits of the robotic platform, including the increased magnification, 3-dimensional clarity, and dexterity optimization given by additional degrees of freedom, could decrease the morbidity while preserving the oncologic outcomes of ILND [19–23].

This article aims to review the outcomes of RAIL currently described in the literature.

2. Methods

We performed an electronic PubMed search for all relevant publications regarding outcomes and techniques of the RAIL up to August 2019, which resulted in a total of 23 papers. We used the keywords “robotic”, “inguinal lymph node dissection”, and “penile cancer”. One of them was regarding the role of robot-assisted inguinal lymph node dissection for vulvar carcinoma and it was excluded from this analysis.

Since PSCC is a rare disease and RAIL was first described only 10 years ago, we selected the three largest reports that included ten or more patients and calculated the weighted means for perioperative and oncologic outcomes.

3. Results

Since the first RAIL described in 2009 and the relative rarity of this disease, small reports have been published suggesting feasibility, acceptable OT, low estimated blood loss (EBL), short LOS, proper amount of lymph nodes retrieved and promising postoperative outcomes, especially regarding few rates of complications [21,22,24–28]. Of note, two from this previously reports described also initial experience with the use of near-infrared fluorescence imaging (NIRF) using indocyanine green (ICG) to facilitate lymph node identification during robotic groin dissection for PSCC [26,28].

Hereafter, results from the three largest series are presented and their weighted means are evaluated. Patients' characteristics are described in Table 1. In total, 75 patients and 149 groin dissection were analyzed combining the three series. The clinical nodal staging was described as follows: Seventy-three point three two percent of patients without palpable nodes (cN0), 14.72% cN1, and 10.64% cN2 (Table 1).

Table 1 Characteristics of patients from the three largest RAIL series, according to number of patients, procedures, age and clinical stage.

Characteristic	Singh et al., 2018 [31]	Russell et al., 2017 [30]	Matin et al., 2013 [29]	Weighted mean
Number of patients	51	14	10	38.63
Number of RAIL	102	27	20	77.40
Age in years ^a	58 (50–68)	72 (62–76)	62 (58–69)	52.75
cTNM Stage, <i>n</i> (%)				
cN0	34 (67)	14 (88) ^b	20 (100)	75.32
cN1	10 (20)	2 (6) ^b	None	14.72
cN2	7 (14)	2 (6) ^b	None	10.64

cTNM Stage, clinical tumoral, node and metastasis classification; RAIL, robotic-assisted endoscopic inguinal lymphadenectomy; VEIL, videoendoscopic radical inguinal lymphadenectomy.

^a Median and interquartile range.

^b Whole series (VEIL and RAIL).

The weighted means of operative outcomes are described in Table 2. Of note, 63.19% of patients underwent superficial ILND only. The saphenous vein was spared in 88.93%, node yield per groin was 11.42, and OT per limb was 87.98 min, with EBL of 37.08 mL, and LOS of 1.29 day. Drainage was kept in place for 17.02 days.

Table 3 describes the oncologic outcomes. Combining the data of these three series, the rate of positive pathological nodes (pN+) was 35.28%, and the recurrence-free survival rate was 96.34%, with a mean follow-up of 33.46 months.

Finally, complications are summarized in Table 4. The major complication rates (Clavien III and IV) in these series were 5.31%; only three flap necroses were recorded in a total of 149 procedures (1.34%). The lower rates of cutaneous complications seem to be the greatest advantage of RAIL compared to OILND, which has classically been correlated with flap necrosis rate as high as 15%–20% [5].

In 2013, Matin and colleagues [29] reported a prospective phase 1 study of 10 patients who underwent

superficial RAIL with a median age of 62 years; all patients were cN0. The primary endpoint of this trial was to ensure the adequacy of RAIL by an independent open surgeon that verified the surgical field with an open incision after the RAIL procedure. The open surgeon confirmed that 18 of 19 inguinal areas (94.7% in nine patients) had an adequate dissection, all the positive nodes were properly retrieved by RAIL, and only two benign nodes could be found just beneath Scarpa's fascia above the inguinal dissection field. As part of the study design, making an open incision to verify the surgical field limited the evaluation of complications. The median EBL was 100 mL (range from 10 mL to 200 mL), while the OT range per groin was from 90 min to 120 min (Table 2). There were no intraoperative complications. The median superficial and deep pN+ were 2 and 1, respectively (Table 3). Recurrence and follow-up were not recorded—One RAIL procedure needed conversion due to poor visualization after a wrong plane dissection (Table 4). Despite the study design limitation to access the

Table 2 Operative outcomes from the three largest RAIL series, according to node dissection, saphenous vein sparing and perioperative findings.

Characteristic	Singh et al., 2018 [31]	Russell et al., 2017 [30]	Matin et al., 2013 [29]	Weighted mean
Depth of dissection of each RAIL, <i>n</i> (%)				
superficial only	62 (61)	16 (59)	16 (80)	63.19%
superficial and deep	40 (39)	11 (41)	4 (20) ^c	36.81%
Saphenous vein sparing, <i>n</i> (%)	88 (86)	27 (100)	Preserved when possible	88.93%
Node yield/groin ^a	13 (11–15)	8 (6–12)	8 (6–12)	11.42
Superficial	NM	8 (5–11)	8 (6–13)	NA
Deep	NM	2 (1–2)	2 (2–2)	NA
Operative time per limb ^a , min	75 (70–85)	137 (123–153)	(90–120) ^d	87.98
Estimated blood loss ^a , mL	75 (65–80)	50 (15–50)	100 (10–200) ^b	37.08
Length of stay ^a , day	3 (3–4)	1 (1–2) ^b	NM	1.29
Duration of drainage ^a , day	12 (10–15)	36 (25–49)	NM	17.02

NA, not applicable (not calculated due to missing data from at least one study); NM, not mentioned; RAIL, robotic-assisted endoscopic inguinal lymphadenectomy.

^a Median and interquartile range.

^b Range.

^c Deep dissection was completed by open approach due to study design.

^d Only range reported.

Table 3 Oncological outcomes from the three largest RAIL series, according to pathological grade, tumoral and nodal staging and recurrence status.

Characteristic	Singh et al., 2018 [31]	Russell et al., 2017 [30]	Matin et al., 2013 [29]	Weighted mean
Grade, <i>n</i> (%)				
1	5 (9.8)	NM	NM	NA
2	39 (76.5)	NM	NM	NA
3	7 (13.7)	NM	NM	NA
pT, <i>n</i> (%)				
pT1	14 (27.5)	NM	3 (30)	NA
pT2	26 (51.0)	NM	4 (40)	NA
pT3	11 (21.6)	NM	3 (30)	NA
pN+				
Patients with pN+, <i>n</i> (%)	20 (40)	4 (29)	2 (20)	35.28%
No. superficial nodes ^a	NM	1 (1–2)	2 (1–4)	NA
No. deep nodes ^a	NM	2 (1–2)	1 (1–1)	NA
Recurrence				
In-field recurrence, <i>n</i> (%)	None	2 (11) ^b	NM	NA
RFS, <i>n</i> (%)	51 (100)	15 (83) ^b	NM	96.34%
Follow-up, month ^a	41 (28–57)	6 (3–11)	NM	33.46

NA, not applicable (not calculated due to missing data from at least one study); NM, not mentioned (data not shown by the authors); pN+, pathologic positive nodes; RAIL, robotic-assisted endoscopic inguinal lymphadenectomy; RFS, recurrence free survival; VEIL, videoendoscopic radical inguinal lymphadenectomy.

^a Median and interquartile range.

^b Whole series (VEIL and RAIL).

complications, two patients required re-admission to the hospital within 60 days for wound infection treatment. One of them underwent incision and drainage of an abscess. Two other patients were treated as outpatients, one for wound breakdown (over the verification site) and the other for skin necrosis (overlying the dissected field).

Then in 2017 Russell et al. [30] reported 14 patients submitted to RAIL and four patients submitted to VEIL. The patients were mainly cN0; however, there were two patients clinical N1 (palpable mobile unilateral inguinal lymph node) and N2 (palpable mobile multiple or bilateral inguinal lymph nodes), Table 1. They found similar results between

the groups with higher ratios of saphenous vein sparing favoring RAIL with a significant difference. Additionally, there were lower reports in overall complications (11% vs. 43%) supporting RAIL. From 27 RAIL procedures, 16 were only superficial, and 11 also included dissection of the deep lymph nodes (Table 2). The median nodal yield, OT, EBL and LOS were 8 nodes, 137 min, 50 mL and 1 day, respectively. The median time to drain removal was 36 days. The median pN+ of inguinal superficial and deep were 1 and 2, respectively (Table 3). In a median follow-up of 6 months, all three patients who developed recurrence had pN+ that occurred in a median time of 2 months. There were no

Table 4 Complications from the three largest RAIL series, according to trans-operative and postoperative period.

Characteristic	Singh et al., 2018 [31]	Russell et al., 2017 [30]	Matin et al., 2013 [29]	Weighted mean
Trans-operative issues per procedure, <i>n</i> (%)	None	None	1 (5)	0.67%
Injury, no conversion	None	None	None	none
Conversion, <i>n</i> (%)	None	None	1 (5)	0.67%
Reason	None	None	Wrong plane with visualization issues	NA
Postoperative complications, patients, <i>n</i> (%)	50 (98)	3 (21)	4 (40)	75.89%
Clavien-Dindo I and II	49 (96), distributed in 35 Grade I 14 Grade II	1 (7) lymphocele	1 (10) cellulitis 1 (10) wound break-down 1 (10) skin necrosis	66.99%
Clavien-Dindo III and IV	1 (2) flap necrosis patient, with episodes: 2 Grade 3a 1 Grade 3b	1 (7) wound infection 1 (7) flap necrosis	1 (10) cellulitis with abscess	5.31%

NA, not applicable; NM, not mentioned; RAIL, robotic-assisted endoscopic inguinal lymphadenectomy.

conversions to open ILND (Table 4). Three patients developed complications, one minor (lymphocele) and two others that required intervention, such as wound infection and flap necrosis.

Finally, recently, Singh et al. [31] described the largest series up to date from India. They compared retrospectively 51 patients submitted to RAIL to 100 patients treated with OILND. The authors found a significant difference between the groups in terms of OT, LOS, days with drain, major complication, complication, edge necrosis, flap necrosis, and severe limb edema favoring RAIL. The median age of the robotic group was 58 years; 34 patients had no palpable inguinal nodes, ten patients were cN1, and seven were cN2 (Table 1). In the robotic arm, there were 62 procedures with only superficial ILDN and 40 that required both superficial and deep dissection; in this group, the saphenous vein sparing could be performed in 88 of the 102 procedures and the median lymph node yield per groin was 13 with an OT of 75 min. Finally, regarding the robotic arm, the median EBL and LOS were 75 mL and 3 days, respectively. They recorded a total of 20/51 (40%) patients from the RAIL group with pN+ (Table 3). After a median follow-up of 41 months, no recurrence was observed, with a recurrence-free survival of 100%. Moreover, none of the RAIL procedures needed conversion. Of the 51 patients in the RAIL, 40 (79%) had postoperative complications. However, most of them were Clavien Grade I or II, and only 1 (2%) had a major complication.

4. Discussion

Penile cancer is an aggressive disease that can present fast progression and lead to death if not appropriately treated [32]. The optimal surgical procedure to increase survival in this group of patients must be performed with free margins resection of the primary PSCC and ILND in those with high-risk features or patients with positive clinical nodes. The most important prognostic factors impacting survival in patients with invasive PSCC are the inguinal and pelvic lymph node status and the extent of metastasis. The number of pN+, the presence of extranodal extension, and the involvement of pelvic nodes are highly associated with the worst cancer-specific survival. That's why it's of utmost importance to manage this disease as soon as possible [4].

Efforts have been made for more than 30 years to reduce the significant ratios of morbidity of the OILND whereas almost 2/3 of patients present minor complications, such as superficial wound infections, wound dehiscence, mild edema, and seroma. The 1/3 remaining have major complications such as flap necrosis, deep vein thrombosis, and lymphocele requiring drainage [33,34]. Modifications of OILND with smaller fields of dissections, saphenous vein sparing, and thicker skin flaps have been described, even though high rates of complications were maintained [7,35]. Still, attempts of template modification also presented false-negative results with insufficient nodes retrieved, while the high incidence of false positive nodes could indicate unnecessary surgery [36].

In this background, dynamic senile biopsy improved over time and recently series reported false-negative rates

around 5% with low complication rates lower than 10% without long term sequelae [37–40].

The introduction of minimally invasive approaches showing less postoperative pain, blood loss, and faster postoperative recovery in other pathologies appeared attractive and promising also in the ILND scenario [41–43]. Initially, with VEIL and more recently with RAIL, better outcomes in terms of EBL, unintentionally trans-operative injuries, LOS, and postoperative complications have been recorded [19,44,45]. In fact, it seems that one of the major advantages of RAIL series is the lower rates of skin necrosis, severe lymphedema, and wound infection requiring surgical intervention compared to OILND [31].

Even when comparing VEIL to RAIL, Russell et al. [30] showed that this evolution occurred due to surgeons' preferences over time. The advantages of three-dimensional magnification, and degrees of freedom with increased manual dexterity provided more precise dissection and allowed to accomplish all surgeries without conversion, beyond to preserve saphenous vein in all their patients. However, in the VEIL arm the saphenous vein could not be spared in 9% and there was one patient that presented a major bleeding requiring conversion. They also reported major rates of complications in patients that saphenous vein was not spared, which favors better outcomes with the RAIL technique.

As an inherent part of a rare pathology, the current literature has few reports since the introduction of RAIL. The eight case-report regarding this procedure could describe the feasibility of the first RAIL technique reported with minimal modifications when compared to the open surgery [19,26,30]. They also assumed that the increased freedom of movements and better images provided by the robotic system could properly replicate the open technique, maintaining the oncologic principles [19].

According to the three most recent publications, the number of patients submitted to RAIL increased from 20 to up to 102 cases. Also, these series reported low rates of major complications and better outcomes when compared to OILND. Moreover, RAIL revealed to be an acceptable method in all the three series in terms of lymph node yield, where a median number of nodes retrieved were comparable to OILND reports [46,47]. Initially, only patients with unpalpable nodes were included in the studies; however, in the latest two series, even patients with positive nodes underwent surgery with satisfactory outcomes.

Singh et al. [31] compared OILND to RAIL in a head-to-head study and described that the pathological nodal stage and the OILND were independent risk factors associated with an increased risk of major complications. Therefore, the authors reinforced the importance of not delaying the diagnosis and suggested the migration to minimally invasive treatment.

The two most considerable limitations of RAIL are the costs related to the robotic system and long-term follow-up to evaluate the oncologic outcomes. As reported by Chang et al. [48], costs are significantly higher in patients with melanoma who were submitted to ILDN and developed postoperative complications. However, until now, the literature lack studies to evaluate and compare costs in patients with PSCC submitted to ILND. Finally, as the

technology continues to spread to developing countries, where the incidence of this disease is higher, the understanding regarding the long-term oncological outcomes of this minimally invasive procedure tends to increase [49,50].

5. Conclusion

Historically, the ILND technique underwent different attempts of modifications to reduce the morbidity related to the procedure. The minimally invasive approach, specially RAIL, is feasible at centers experienced in managing this disease and appears to be promising by decreasing the complication rates, especially the major cutaneous issues. Also, the replication of the open templates with similar lymph node yield retrieved was achieved in the recent series. It's important to properly identify and select patients more likely to benefit from RAIL, mainly patients with less volume of disease. Still, long-term follow-up and further trials comparing the classical OILND and VEIL with RAIL are expected to ensure long-term oncologic outcomes.

Author contributions

Study concept and design: Gilberto José Rodrigues, Giuliano Betoni Guglielmetti, Marcelo Orvieto, Rafael Ferreira Coelho.

Data acquisition: Gilberto José Rodrigues.

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Conflicts of interest

The authors declare no conflict of interest.

References

- [1] Pow-Sang MR, Ferreira U, Pow-Sang JM, Nardi AC, Destefano V. Epidemiology and natural history of penile cancer. *Urology* 2010; 76:S2–6. <https://doi.org/10.1016/j.urology.2010.03.003>.
- [2] Nabavizadeh R, Master V. Minimally invasive approaches to the inguinal nodes in cN0 patients. *Curr Opin Urol* 2019;29: 165–72.
- [3] Machado MT, Tavares A, Ornellas AA, Molina WR, Juliano RV, Wroclawski ER. Video endoscopic inguinal lymphadenectomy: a new minimally invasive procedure for radical management of inguinal nodes in patients with penile squamous cell carcinoma. *J Urol* 2007;177:953–8.
- [4] Djajadiningrat RS, Graafland NM, van Werkhoven E, Meinhardt W, Bex A, van der Poel HG, et al. Contemporary management of regional nodes in penile cancer-improvement of survival? *J Urol* 2014;191:68–73.
- [5] Hakenberg OW, Compérat E, Minhas S, Necchi A, Protzel C, Watkin N. EAU Guidelines: Penile Cancer. *Uroweb* n.d. <https://uroweb.org/guideline/penile-cancer/>. [Accessed 11 September 2019].
- [6] Flaig TW, Spiess PE, Agarwal N, Bangs R, Buyyounouski MK, Chang S, et al. National comprehensive cancer network practice guidelines in oncology (NCCN Guidelines®). Penile cancer 2019. Version 2.2019. https://www.nccn.org/professionals/physician_gls/pdf/penile.pdf. [Accessed 13 May 2019].
- [7] Catalona WJ. Modified inguinal lymphadenectomy for carcinoma of the penis with preservation of saphenous veins: technique and preliminary results. *J Urol* 1988;140:306–10.
- [8] Daseler EH, Anson BJ, Reimann AF. Radical excision of the inguinal and iliac lymph glands; a study based upon 450 anatomical dissections and upon supportive clinical observations. *Surg Gynecol Obstet* 1948;87:679–94.
- [9] Ravi R. Morbidity following groin dissection for penile carcinoma. *Br J Urol* 1993;72:941–5.
- [10] Spiess PE, Hernandez MS, Pettaway CA. Contemporary inguinal lymph node dissection: minimizing complications. *World J Urol* 2009;27:205–12.
- [11] Elsamra SE, Poch MA. Robotic inguinal lymphadenectomy for penile cancer: the why, how, and what. *Transl Androl Urol* 2017;6:826–32.
- [12] Ramos JG, Jaramillo DC, Sandoval D, Gallego LJ, Riveros C, Sierra JA, et al. Diagnostic precision of sentinel lymph node biopsy in penile cancer. *Indian J Urol* 2019;35:282–6.
- [13] Kamel MH, Khalil MI, Davis R, Spiess PE. Management of the clinically negative (cN0) groin penile cancer patient: a Review. *Urology* 2019;131:5–13.
- [14] Mehralivand S, van der Poel H, Winter A, Choyke PL, Pinto PA, Turkbey B. Sentinel lymph node imaging in urologic oncology. *Transl Androl Urol* 2018;7:887–902.
- [15] Sadeghi R, Gholami H, Zakavi SR, Kakhki VRD, Tabasi KT, Horenblas S. Accuracy of sentinel lymph node biopsy for inguinal lymph node staging of penile squamous cell carcinoma: systematic review and meta-analysis of the literature. *J Urol* 2012;187:25–31.
- [16] Rassweiler JJ, Teber D. Advances in laparoscopic surgery in urology. *Nat Rev Urol* 2016;13:387–99.
- [17] Bishoff JA, Du K. Endoscopy subcutaneous modified inguinal lymph node dissection for squamous cell carcinoma of the penis. In: Smith AD, Priminger GM, Kavoussi LR, Badlani GH, Rastinehad DO AR, editors. *Smith's textbook of endourology*. 4th ed. John Wiley & Sons Ltd; 2018. pp.1060–5.
- [18] Machado MT, Tavares A, Molina WR, Zambon JP, Forsetto P, Juliano RV, et al. Comparative study between video-endoscopic radical inguinal lymphadenectomy (veil) and standard open lymphadenectomy for penile cancer: preliminary surgical and oncologic results. *J Urol* 2005;173:226. [https://doi.org/10.1016/S0022-5347\(18\)35003-1](https://doi.org/10.1016/S0022-5347(18)35003-1).
- [19] Josephson DY, Jacobsohn KM, Link BA, Wilson TG. Robotic-assisted endoscopic inguinal lymphadenectomy. *Urology* 2009; 73:167–70.
- [20] Pini G, Matin SF, Suardi N, Desai M, Gill I, Porter J, et al. Robot assisted lymphadenectomy in urology: pelvic, retroperitoneal and inguinal. *Minerva Urol Nefrol* 2017;69:38–55.
- [21] Dogra PN, Saini AK, Singh P. Robotic-assisted inguinal lymph node dissection: a preliminary report. *Indian J Urol* 2011;27: 424. <https://doi.org/10.4103/0970-1591.85458>.
- [22] Sotelo R, Cabrera M, Carmona O, de Andrade R, Martin O, Fernandez G. Robotic bilateral inguinal lymphadenectomy in penile cancer, development of a technique without robot repositioning: a case report. *E Cancer Med Sci* 2013;7:356. <https://doi.org/10.3332/ecancer.2013.356>.
- [23] Corona-Montes VE, Moyo-Martínez E, Almazán-Treviño L, Ríos-Dávila V, Santiago-Hernández Y, Mendoza-Rojas EE. [Linfadenectomía inguinal robot asistida (LIRA) para cáncer de pene]. *Revista Mexicana De Urología* 2015;75:292–6. [Article in Spanish].

- [24] Andreou A, Bekos A. [Curage ganglionnaire inguinal robot-assisté dans le cancer du pénis. Description de technique]. *Prog Urol* 2014;24:897. <https://doi.org/10.1016/j.purol.2014.09.021> [Article in French].
- [25] Ahlawat R, Khera R, Gautam G, Kumar A. Robot-assisted simultaneous bilateral radical inguinal lymphadenectomy along with robotic bilateral pelvic lymphadenectomy: a feasibility study. *J Laparoendosc Adv Surg Tech* 2016;26:845–9.
- [26] Bjurlin MA, Zhao LC, Kenigsberg AP, Mass AY, Taneja SS, Huang WC. Novel use of fluorescence lymphangiography during robotic groin dissection for penile cancer. *Urology* 2017;107:267. <https://doi.org/10.1016/j.urology.2017.05.026>.
- [27] Ogrich LM, Stigall LE, Tyler WB, Hossler EW. Invasive penile squamous cell carcinoma. *Cutis* 2018;101:224–7.
- [28] Sávio LF, Barboza MP, Alameddine M, Ahdoot M, Alonzo D, Ritch CR. Combined partial penectomy with bilateral robotic inguinal lymphadenectomy using near-infrared fluorescence guidance. *Urology* 2018;113:251. <https://doi.org/10.1016/j.urology.2017.11.021>.
- [29] Matin SF, Cormier JN, Ward JF, Pisters LL, Wood CG, Dinney CPN, et al. Phase 1 prospective evaluation of the oncological adequacy of robotic assisted video-endoscopic inguinal lymphadenectomy in patients with penile carcinoma. *BJU Int* 2013;111:1068–74.
- [30] Russell CM, Salami SS, Niemann A, Weizer AZ, Tomlins SA, Morgan TM, et al. Minimally invasive inguinal lymphadenectomy in the management of penile carcinoma. *Urology* 2017;106:113–8.
- [31] Singh A, Jaipuria J, Goel A, Shah S, Bhardwaj R, Baidya S, et al. Comparing outcomes of robotic and open inguinal lymph node dissection in patients with carcinoma of the penis. *J Urol* 2018;199:1518–25.
- [32] Leone A, Diorio GJ, Pettaway C, Master V, Spiess PE. Contemporary management of patients with penile cancer and lymph node metastasis. *Nat Rev Urol* 2017;14:335–47.
- [33] Protzel C, Alcaraz A, Horenblas S, Pizzocaro G, Zlotta A, Hakenberg OW. Lymphadenectomy in the surgical management of penile cancer. *Eur Urol* 2009;55:1075–88.
- [34] Bouchot O, Rigaud J, Maillet F, Hetet JF, Karam G. Morbidity of inguinal lymphadenectomy for invasive penile carcinoma. *Eur Urol* 2004;45:761–6.
- [35] Bevan-Thomas R, Slaton JW, Pettaway CA. Contemporary morbidity from lymphadenectomy for penile squamous cell carcinoma: the M.D. Anderson Cancer Center Experience. *J Urol* 2002;167:1638–42.
- [36] Lopes A, Hidalgo GS, Kowalski LP, Tortoni H, Rossi BM, Fonseca FP. Prognostic factors in carcinoma of the penis: multivariate analysis of 145 patients treated with amputation and lymphadenectomy. *J Urol* 1996;156:1637–42.
- [37] Kroon BK, Horenblas S, Meinhardt W, van der Poel HG, Bex A, van Tinteren H, et al. Dynamic sentinel node biopsy in penile carcinoma: evaluation of 10 years experience. *Eur Urol* 2005;47:601–6.
- [38] Kroon BK, Lont AP, Valdés Olmos RA, Nieweg OE, Horenblas S. Morbidity of dynamic sentinel node biopsy in penile carcinoma. *J Urol* 2005;173:813–5.
- [39] Lam W, Alnajjar HM, La-Touche S, Perry M, Sharma D, Corbishley C, et al. Dynamic sentinel lymph node biopsy in patients with invasive squamous cell carcinoma of the penis: a prospective study of the long-term outcome of 500 inguinal basins assessed at a single institution. *Eur Urol* 2013;63:657–63.
- [40] Fuchs J, Hamann MF, Schulenburg F, Knüpfer S, Osmonov D, Lützen U, et al. Sentinel lymph node biopsy for penile carcinoma: assessment of reliability. *Urologe* 2013;52:1447–50 [Article in German].
- [41] Andersen MH, Mathisen L, Oyen O, Edwin B, Digernes R, Kvarstein G, et al. Postoperative pain and convalescence in living kidney donors-laparoscopic versus open donor nephrectomy: a randomized study. *Am J Transplant* 2006;6:1438–43.
- [42] Hager B, Herzog SA, Hager B, Sandner-Kiesling A, Zigeuner R, Pummer K. Comparison of early postoperative pain after partial tumour nephrectomy by flank, transabdominal or laparoscopic access. *Br J Pain* 2019;13:177–84.
- [43] Porpiglia F, Renard J, Billia M, Scoffone C, Cracco C, Terrone C, et al. Open versus laparoscopy-assisted radical cystectomy: results of a prospective study. *J Endourol* 2007;21:325–9.
- [44] Machado MT, Tavares A, Molina Jr WR, Forseto Jr PH, Juliano RV, Wroclawski ER. Video endoscopic inguinal lymphadenectomy (VEIL): minimally invasive resection of inguinal lymph nodes. *Int Braz J Urol* 2006;32:316–21.
- [45] Machado MT, Correa WF, Reis LO, Starling ES, de Castro Neves O, Juliano RV, et al. Single-site video endoscopic inguinal lymphadenectomy: initial report. *J Endourol* 2011;25:607–10.
- [46] Stuiver MM, Djajadiningrat RS, Graafland NM, Vincent AD, Lucas C, Horenblas S. Early wound complications after inguinal lymphadenectomy in penile cancer: a historical cohort study and risk-factor analysis. *Eur Urol* 2013;64:486–92.
- [47] Machado MT, Tavares A, Silva MNR, Molina WR, Forseto PH, Juliano RV, et al. Can video endoscopic inguinal lymphadenectomy achieve a lower morbidity than open lymph node dissection in penile cancer patients? *J Endourol* 2008;22:1687–91.
- [48] Chang SB, Askew RL, Xing Y, Weaver S, Gershenwald JE, Lee JE, et al. Prospective assessment of postoperative complications and associated costs following inguinal lymph node dissection (ILND) in melanoma patients. *Ann Surg Oncol* 2010;17:2764–72.
- [49] Iavazzo C, Papadopoulou EK, Gkegkes ID. Cost assessment of robotics in gynecologic surgery: a systematic review. *J Obstet Gynaecol Res* 2014;40:2125–34.
- [50] Hoekstra HJ, Wobbles T, Heineman E, Haryono S, Aryandono T, Balch CM. Fighting global disparities in cancer care: a surgical oncology view. *Ann Surg Oncol* 2016;23:2131–6.