Chapter

Robotic-Assisted Inguinal Lymphadenectomy (RAIL)

Victor Enrique Corona-Montes, Eduardo Gonzalez-Cuenca and Marcos Tobias-Machado

Abstract

The objective of the following chapter is to describe thoroughly the surgical technique for a robotic-assisted inguinal lymphadenectomy for penile cancer, and the surgery has been through modifications from its creation to "the Robotic Era." Penile cancer is a rare neoplasm, with an estimated 1570 cases in the United States. The spread is predictable to the inguinal lymph nodes, where 1–2% of patients will present distant metastases. The first draining lymph area is found in the inguinal region and the secondary spread in the pelvic region, main reason for the inguinal part of the treatment of penile cancer under different indications. Radical resection of inguinal metastases of penile cancer is the standard treatment for this technique, which has been adapted to become a minimally invasive surgery compared to an open inguinal lymphadenectomy, which entails a high incidence of morbidity that stands at 50–90%. A robotic-assisted inguinal lymphadenectomy, despite its high cost, is a feasible technique when carried out in specialized centers that can reduce morbidity rates and offer good oncological results, less blood loss, and shorter hospital stay.

Keywords: inguinal dissection, penile cancer, robotic surgery

1. Introduction

In 2002, Ian M. Thompson and Jay T. Bishop conceived the idea of an endoscopic and subcutaneous approach for inguinal lymph node dissection applying laparoscopic techniques. The endoscopic subcutaneous approach for a modified inguinal lymphadenectomy (ESMIL) procedure was described in a cadaveric model and performed in 2003 on a patient with T3N1M0 squamous cell carcinoma of the penis with an adequate identification of anatomical landmarks and overall feasibility [1]. In 2007, Tobias-Machado et al. reported reduced complications (20% vs 70%), shorter hospitalization times, more favorable cosmetic outcomes, and optimal oncologic outcomes regarding a refined technique coined as "video-endoscopic inguinal lymphadenectomy" (VEIL), in contrast with more traditional open procedures [2, 3].

International literature proclaimed the benefits and fewer complications that minimally invasive lymph node resection implied, such as skin necrosis without compromising oncologic control. These facts paved the way for new technological advances to be employed, as in the case for the "robotic-assisted inguinal lymphadenectomy" (RAIL). This robotic technology allows for a three-dimensional operative field, tremor filter, and articulated instruments, which grant the surgeon improved visibility, identification of anatomical landmarks, dexterity, and improved ergonomics, thus overcoming the limitations of VEIL. Josephson and associates were the first to describe the feasibility of a nonsimultaneous bilateral RAIL using the da Vinci S robotic system [4].

In 2013, Matin et al. published a prospective study where the oncologic efficacy of RAIL to adequately stage the disease was confirmed, with an independent surgeon assessment by a direct visual evaluation of the dissection field through a small inguinal incision [5]. Russell also described a lower complication rate of the RAIL approach in comparison with VEIL technique (10% vs. 40%), although the group of VEIL patients was smaller [6]. Sotelo et al. and Ahlawat et al. have described different techniques that allows for a simultaneous bilateral RAIL to be performed without moving the robotic system across the operating room and maintaining an adequate reproducibility as well as allowing a bilateral staging procedure in the same surgical time [7, 8].

The author of the chapter described the first RAIL carried out in Mexico in the year 2015. It was performed on a 73-year-old patient with squamous cell carcinoma of the penis (T3N0M0G1), and he underwent a radical penectomy 4 weeks earlier the lymphadenectomy. The bilateral RAIL using the da Vinci Si HD surgical system was performed, and both saphenous veins were successfully preserved [9].

New technological advances, refinements, and modifications in the minimally invasive lymph node dissection technique will continue to reduce the morbidity and complications and improve the quality of life of the penile cancer patient.

2. Epidemiology of penile cancer

Penile cancer is a rare neoplasm, making up for less than an estimated 1% of all types of cancer in the United States, translating to an approximate amount of 2100 new cases and 400 deaths annually [9]. According to the Global Cancer Observatory, the estimated number of incident cases is 34,475 and a mortality of 15,138 cases in all ages [10]. This type of cancer is more common in less developed areas of the world (i.e., Africa, Asia, and South America), where it accounts up to 10–20% of all malignancies in men. Penile cancer is considered a disease that typically affects older men, where males between ages 55 and 58 are more prone to be affected.

This tumor is unusual in younger patients (<40 years old), although cases have been reported [11]. The ethnicity has been demonstrated to have no impact in the incidence, but it does play a role as a risk factor regarding survival outcomes (it is worse for African-American ethnicities).

Multiple factors are associated with a risk of developing penile cancer, such as suffering from genital warts (OR 7.6), penile tears (OR 5.2), chronic penile rash (OR 3.2), penile injuries (OR 3.5), phimosis (seven times higher risk), human papilloma virus (DNA identified >30%), human immunodeficiency virus (4–8 times higher risk), tobacco exposure (3 times more likely), and lichen sclerosis (balanitis xerotica obliterans) [12].

The spread is predictable to the inguinal lymph nodes, where only 1–2% of patients will present distant metastases. Approximately 20% of patients with clinically nonpalpable inguinal nodes harbor occult metastases. The first draining lymph node group is found both in the superficial and in the deep inguinal region (superomedial zone), whereas the second lymph node group spread lies in the ipsilateral pelvic region and, lastly, in the retroperitoneum (para-caval/para-aortic lymph nodes) [13].

Penile cancer patients in the low-risk group (Tis, Ta, T1G1, No LVI) have a <16% metastatic rate to the lymph nodes, intermediate risk (T1G2) have 17–50%, and high risk (T1G3, >T2, LVI) have 68–73% metastatic rate [14].

Radical resection of inguinal metastases of penile cancer is the standard treatment, and the greatest single predictor of survival in squamous cell carcinoma of the penis is the incidence and extent of lymph node involvement [11, 14]. The objective of the lymph node resection is providing accurate pathology staging and if disease exists in the nodes alter its natural history and pattern of metastasis. Men found to have a single node involved (N1) had a 100% 3-year disease-specific survival. The presence of 1–3 involved nodes predicts a 5-year overall survival rate of 75.6%, whereas for 4 or 5 nodes involved the rate is at 8.4 and 0% for patients with more than 5 positive nodes [14].

This technique has been adapted as a minimally invasive surgery, and in comparison with the open inguinal lymphadenectomy, it preferred because of the latter's high incidence of morbidity that stands a 50–90% rate regarding an open approach [2]. Robotic-assisted inguinal lymphadenectomy, aside from its high cost, is a feasible technique when carried out in specialized centers reduces morbidity and provides adequate oncological results, less blood loss, and shorter hospital stay.

3. Anatomical aspects

The femoral vessels are found in the femoral triangle and formed laterally by the sartorius muscle laterally, superiorly by the inguinal ligament superiorly, and medially by the long adductor medially. The junction between the saphenous and femoral vessels is located approximately two fingerbreadths lateral and two fingerbreadths inferior to the pubic tubercle. The saphenous vein passes anteriorly through the fossa ovalis and elapses with the superficial inguinal region. The structures that will be found in the femoral triangle are (from lateral to medial) femoral nerve, the femoral artery, the femoral vein, and the deep inguinal lymph nodes. These last three are located inside the femoral sheath [13] **Figure 1**.

The fascia lata separates the inguinal lymph nodes into superficial and deep groups. The superficial inguinal lymph nodes are situated in the deep membranous layer of the superficial fascia of the thigh (Camper's fascia), approximately composed by 4 or up to 25 nodes. The superficial inguinal nodes have been divided into 5 anatomic groups by Daseler in 1948 [13, 15] (**Figure 2**).

1. Superomedial nodes (I) around the superficial external pudendal and superficial epigastric veins.

2. Superolateral nodes (II) around the superficial circumflex vein.

3. Inferolateral nodes (III) around the lateral femoral cutaneous and superficial circumflex veins.

4. Inferomedial nodes (IV) around the greater saphenous vein.

5. Central nodes (V) around the saphenofemoral junction.

The superficial external pudendal vein, superficial circumflex vein, and the lateral femoral cutaneous vein are branches of the greater saphenous vein (**Figure 3**).

The deep inguinal nodes are located deep into the fascia lata and lie medial to the femoral vein in the femoral triangle. The node of Cloquet is the most cephalad node in the deep inguinal region, located between the femoral vein and the lacunar ligament.

The standard or full template for the inguinal lymph node dissection includes Daseler's 5 group nodes in the superficial dissection and the deep

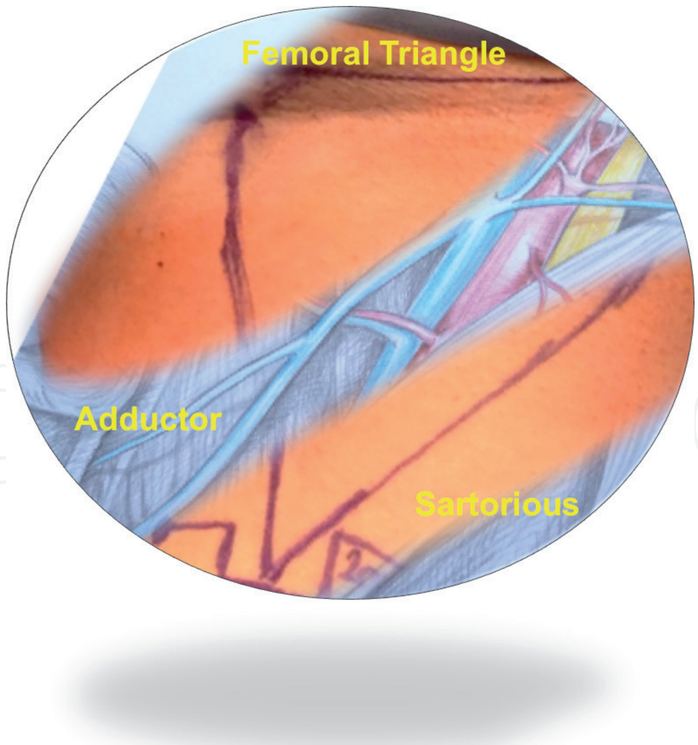

Figure 1.
Femoral triangle (left limb).

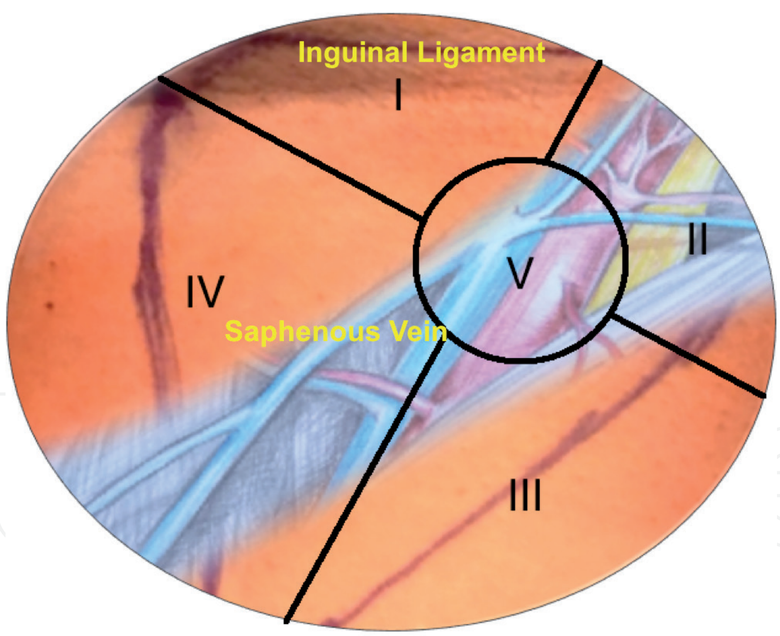

Figure 2.
Schematics of Daseler zones (left limb).

inguinal nodes from the femoral triangle, limiting the dissection lateral to the femoral artery, which eliminates the risk of injury to the femoral nerve. This template includes the ligation of the saphenous vein as it emerges from the femoral vein. The template requires the superficial dissection of the first group lymph nodes entirely, as well as a portion of the second and fifth group lymph nodes, the inferior group nodes are not dissected, the deep dissection remains the same. The modified template was described to reduce the complication rate, which can be also accomplished by the minimally invasive approach.

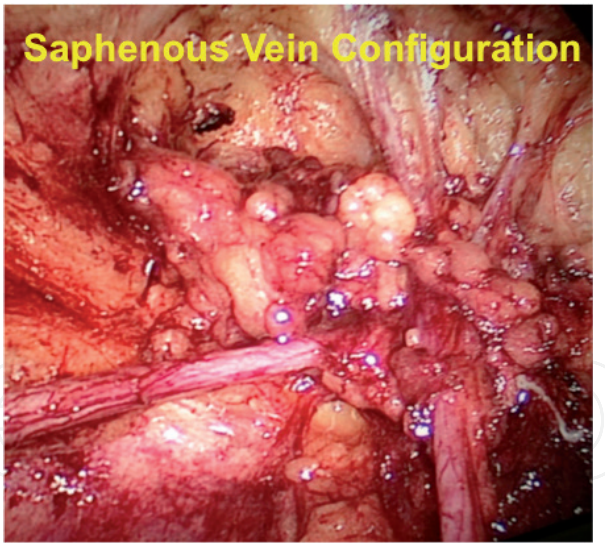

Figure 3.
Saphenous vein configuration.

4. Surgical indications for RAIL

The treatment of regional lymph nodes is decisive for patient survival. A cure for the disease confined to regional nodes can be achieved and a radical lymphadenectomy is the treatment of choice. For this section, a description of the actual surgical indications for inguinal lymphadenectomy in the different group risks and clinical stages will be presented [16, 17].

4.1 Patients with clinically normal inguinal lymph nodes (cN0)

Micrometastatic disease occurs in up to 25% of the patients and invasive lymph node staging is necessary. The indication for an inguinal lymphadenectomy is for intermediate (T1b, Grade 1 or 2) and high-risk tumors (T1b, Grade 3 or 4; any T2 or greater), which are considered to have an elevated risk of lymphatic spread. The superficial inguinal lymphadenectomy is an option that can be completed (radical) if one pathological lymph node is found without extranodal extension. If extranodal extension is present or ≥2 lymph nodes are positive, inguinal and pelvic lymphadenectomy should be considered.

4.2 Patients with palpable uni- or bilateral inguinal nodes (cN1/cN2)

Metastatic disease is very likely and lymph node surgery (radical inguinal lymphadenectomy) with histopathology is necessary. Treatment in these patients should not be delayed given that the metastatic spread continues. If a high-risk primary lesion was identified, a complete inguinal lymphadenectomy + contralateral superficial lymphadenectomy should be performed. If ≥2 inguinal nodes are positive or ≥1 inguinal node is positive with extranodal extension, an ipsilateral pelvic lymph node dissection is recommended to be performed.

4.3 Patients with bulky inguinal nodes

In this scenario, the patients will require multimodal treatment consisting of chemotherapy and surgery. The radical inguinal lymphadenectomy will be indicated after a positive metastatic (fine needle aspiration) disease in unilateral mobile ≥4 cm lymph node. If ≥2 nodes are positive or have extranodal extension, a pelvic lymphadenectomy should be performed and adjuvant chemotherapy considered. In the scenario where the lymph node is ≥4 cm and fixed or mobile bilateral, neoadjuvant chemotherapy should be administrated after the positive finding in the fine needle aspiration, followed by inguinal and pelvic lymphadenectomy if an adequate response to chemotherapy was documented.

In others of RAIL, descriptions the patients staging where up to cN2 and less than 3 cm in size lymph nodes, as equal for VEIL studies (**Figure 4**).

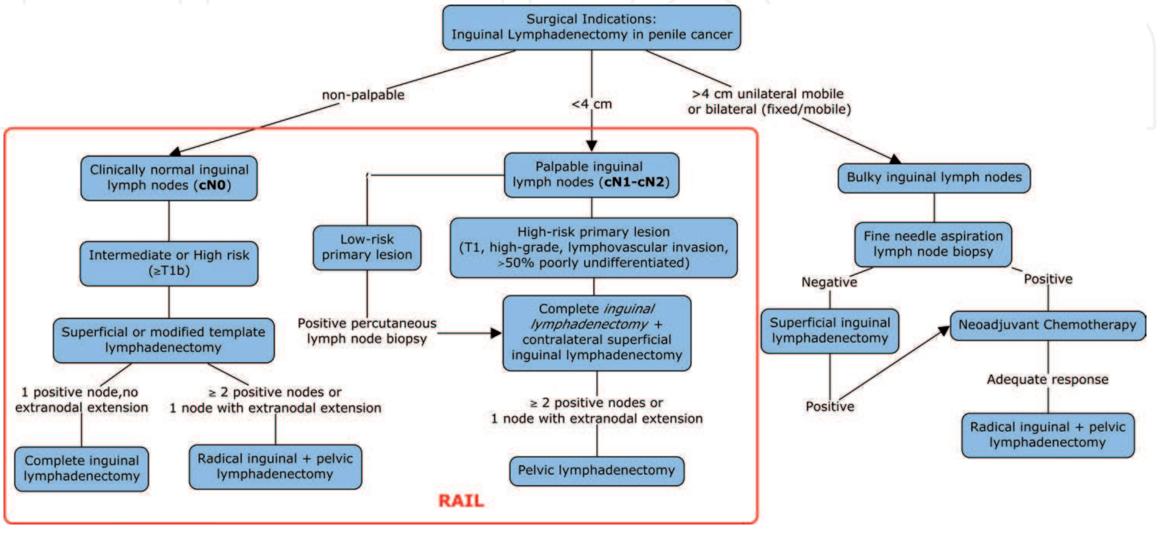

Figure 4.
Surgical indications for inguinal lymphadenectomy in penile cancer.

4.4 Patient preparation and position

An initial challenge presents itself at the beginning of the procedure: the positioning of the da Vinci robot and the operation table. Initially, the robot was placed on the right side of the table, considering it was an SI system that did not require repositioning but simply redocking of the instruments. As a first step, the operating field is prepared and readied by having the patients lie in the dorsal decubitus position with abduction of both legs dressed since the beginning of the procedure to avoid time loss.

The preparation is then followed by realizing a medial incision localized in the femoral triangle, inside the Sartorius muscle and joint with the adductor longus. A 3 cm incision is realized 5 cm over the knee, under protection of the skin and small fatty tissue from the leg, we follow a digital dissection in direction of the inguinal ligament. This blunt finger dissection is accompanied with movements to the left and right sides of the thigh and heading also as upper as possible. The previous dissection is realized for the superficial plane of the lymph's (**Figure 5**).

4.5 Surgical technique

4.5.1 Trocar placement: anterior, lateral, and posterior boundaries

Once we have created this space manually, three more incisions will be performed. The first, a 5 mm one that will serve as a laparoscopic port, is placed 2 cm medial and below the initial incision of the left leg, while replicating this incision on the right leg (on its lateral side) and at the same distance, also 2 cm, so that the assistant port is external to the position of both legs. Right away, one of the robotic ports is placed 2 cm higher on the external side of the left leg, and one more robotic

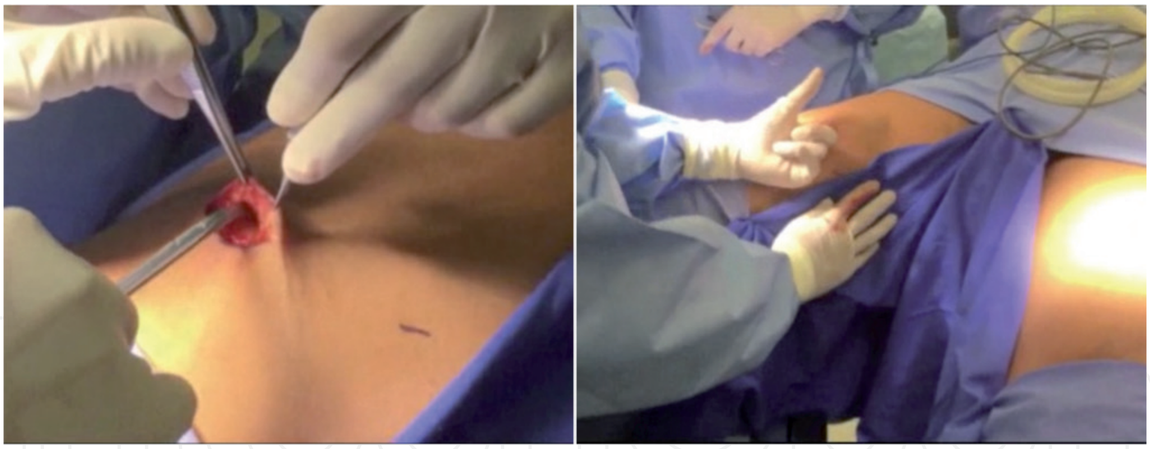

Figure 5.
Skin incision and finger dissection.

port is situated 3 cm to the left of the initial incision, on the same leg. This is where the camera port will be placed.

For the right leg, the first robotic port is placed 2 cm higher on the leg's external side, and the second robotic port is located 3 cm to the right of the initial incision on this leg. This description is done simultaneously so that both legs are ready to dock the robot.

In the case of da Vinci X or Xi, right-side placement is also performed simply with a redocking of the arms, which allow for smaller incisions and for the camera to be changed to another robotic port, as well as the advantage of an easier, faster, and better position in the middle of the abducted legs of the patient. For every kind of model of the da Vinci systems, we use 0° lens, and once the ports are installed, the CO_2 insufflation is managed at 10 mmHg (**Figure 6**).

Once the docking is done, under the da Vinci system's 0° lens, the anatomical references of the femoral triangle and the packet of superficial nodes are located over the fascia lata. When performing a deep node dissection, we transected the fascia lata with each trocar staying laterally to the adductor longus and sartorius muscles doing a work below the fascia. The CO_2 insufflation creates a working space, so we follow the middle of the muscles to find femoral nerve and vessels removing the femoral nodes (**Figure 7**).

After this, the trocars are slightly pulled up (without redocking) hence staying only on the superficial level. We lift up the superficial packet and follow the packet to the inguinal ligament, lateral to the saphenous vein, which is not always respect but transected, going higher to the saphenofemoral junction, an reaching the superficial nodes packet **Figure 8.**

Figure 6.
Trocars' position and docking.

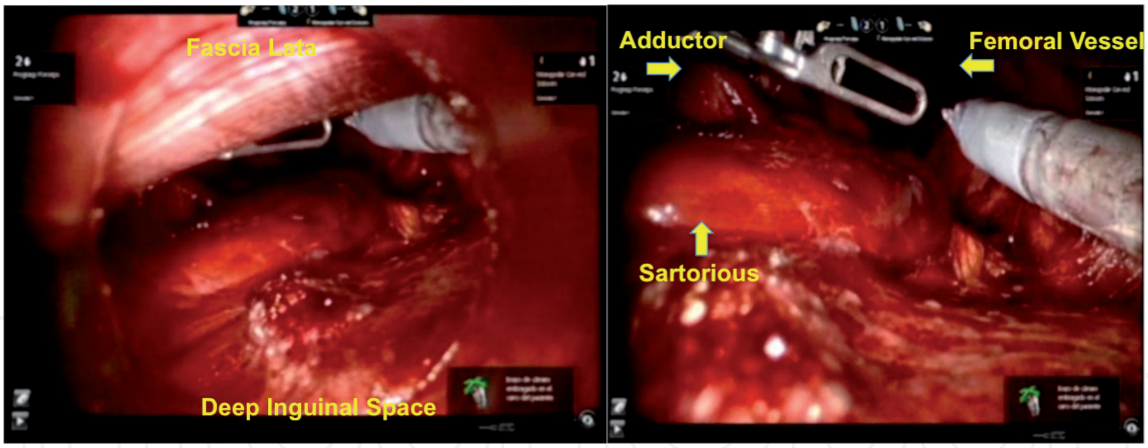

Figure 7.
Deep inguinal space.

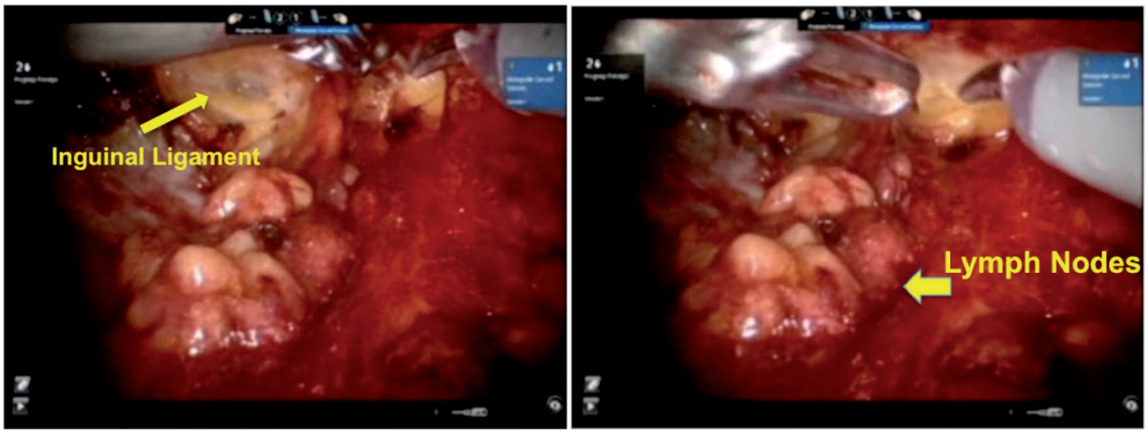

Figure 8.
Inguinal ligament and superficial nodes.

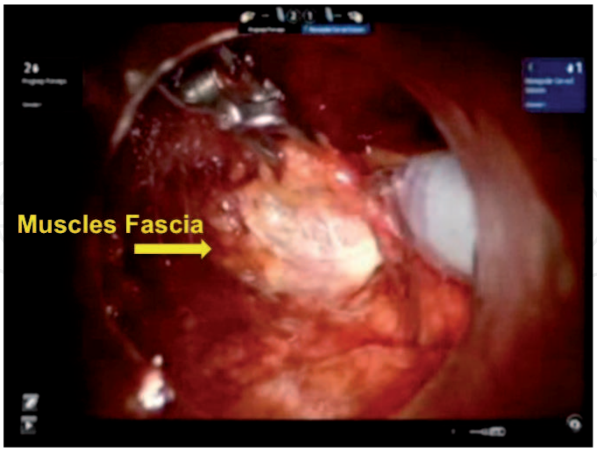

Figure 9.
Muscles fascia.

The control of the saphenofemoral junction can be performed with either metallic clips or 10 mm hem-o-lok; this junction is found over the muscles fascia in the interior side of the leg (**Figure 9**).

The packet is placed in an endobag and removed via the initial incision or the camera's main port. A drain is placed in each leg through the 5-mm incision trocar. See **Figure 10**.

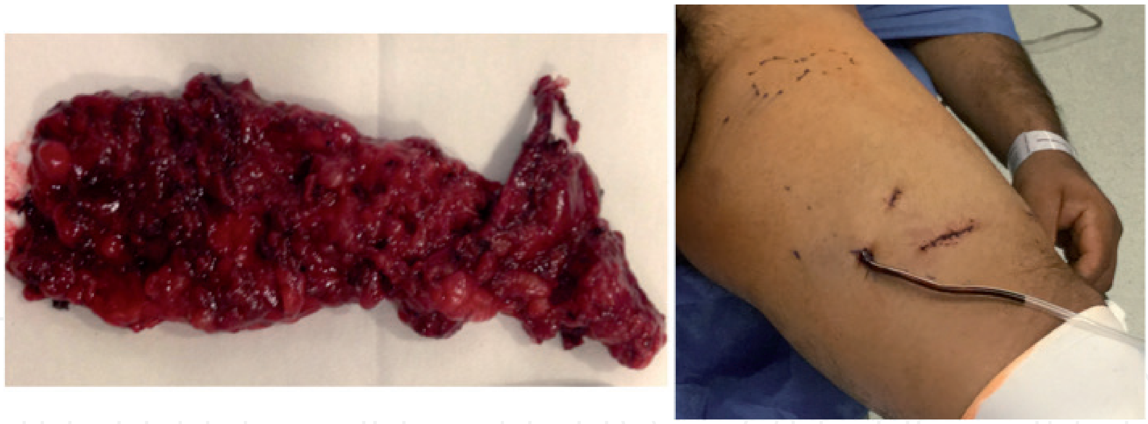

Figure 10.
Nodes packet and drain.

5. Our experience

Between 2015 and 2018, we have performed 12 cases (24 limbs) of robotic inguinal lymph node dissection, where the patient's median age was 58 years old. A 100% of the patients had been diagnosed with penile squamous cell carcinoma, confirmed by biopsy, and had previously experienced a partial or total penectomy. The TNM for the patients was T2–3, cN1–2, M0, G1–3. Operative room mean time was 110 min (range 90–230 min). The mean blood loss was 59 ml (35–85). None of the surgeries were converted to an open approach. The total mean number of dissected lymph was 148 and mean lymph nodes per case were 12, and from those, 1.8 were positive for SCC per limb (n = 22 positive lymph nodes). Hospitalization median stay was 2.5 days (range 2–4 days), and the duration of the drainage on overage 16 days (range 10–21 days). Complications were classified as Clavien-Dindo III (lymphocele: 2/24) whom needed single percutaneous drainage and 10 days of antibiotic treatment, however, did not require any hospital stay (**Tables 1** and **2**).

No. of patients (limbs)	12 (24)
Age (range)	58 years old (41–73)
Histological type	Penile SCC
Operative time (range)	110 min (90–230)
Blood loss (range)	59 ml (35–85)
Conversion to open surgery	None
Total of dissected lymph nodes (mean per patient)	148 (12)
No. of total positive nodes (mean per patient)	22 (1.8)
Hospital stay (range)	2.5 days (2–4)
Duration of drainage (range)	16 days (10–21)
Postoperative complications (n)	Lymphocele (2/12)

Table 1.
Description group.

Author	Year	Case report/ case series	Number of patients (# limbs)	Age (mean -years)	Penile cancer (histologic)	T stage	Pre-LND cN stage	Lymph nodes dissected (n) - mean	Operative time (min)	Blood loss (mL)	Complications
Josephson et al. [4]	2009	Case report	1 (2)	37	SCC♦	T3	cN2	10/9*	120/130*	100/50*	None
Matin et al. [5]	2013	Case series	10 (20)	62	SCC♦	T1–3	cN0-cN1	Left: 9, Right: 9	180–240	100 (mean)	Cellulitis (2/10), wound breakdown (2/10), skin necrosis (1/10)
Sotelo et al. [6]	2013	Case report	1 (2)	64	SCC♦	T3	cN0	33	360	100	Lymphocele
Corona-Montes et al. [9]	2015	Case report	1 (2)	73	SCC♦	T3	cN0	NA	230	50	None
Ahlawat et al. [7]	2016	Case series	3 (6)	56	SCC♦	T2-T3	cN1-cN2	Left: 18, Right: 14	453	147 (mean)	Lymphocele (1/3)
Our experience	2018	Case series	12 (24)	58	SCC♦	T2-T3	cN1-cN2	12	110	59 (mean)	Lymphocele (2/12)

**RAIL performed in two separate procedures (one OR time per limb).*
♦Squamous cell carcinoma of the penis.

Table 2.
RAIL comparative reports.

6. Conclusions

The robotic inguinal lymphadenectomy for penile cancer is still a novel technique that requires further studies to thoroughly demonstrate its utility. The open approach has shown an increased morbidity and rate of complications, primary producing flap skin necrosis, longer hospitalization stays, and infections. On the contrary, RAIL provides a three-dimensional vision and improved dexterity thanks to the articulated instruments that allow surgeons to work in a very reduced workspace, produce less surgical trauma to the skin, reduce operative time (while winning experience in anatomy field and in the docking of the robot), and perform both superficial and deep lymphadenectomy in both legs as previous approaches. The challenges for the aforementioned robotic approach are not only the high costs implied but also the learning curve for the femoral triangle anatomy and anatomical variations. There is not enough prospective evidence about robotic inguinal approach for penile cancer, but what can be affirmed is that the previously presented evidence report not only less morbidity with minimally invasive techniques (VEIL, RAIL) and equal oncologic results.

Conflict of interest

The authors declare no conflict of interest.

Notes/Thanks/Other declarations

Thanks to collaborative group.

Nomenclature

ESMIL	endoscopic subcutaneous modified inguinal lymphadenectomy
VEIL	video-endoscopic inguinal lymphadenectomy
RAIL	robotic-assisted inguinal lymphadenectomy

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References

[1] Bishoff JT, Lackland AFB, Basler JW, Teichman JM, Thompson IM. Endoscopic subcutaneous modified inguinal lymph node dissection (ESMIL) for squamous cell carcinoma of the penis. Journal of Urology. 2003;**169**(suppl):78. abstract 301

[2] Tobias-Machado M, 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. Juro. 2007;**177**:953-7–discussion958. DOI: 10.1016/j.juro.2006.10.075

[3] Tobias-Machado M, 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? Journal of Endourology. 2008;**22**:1687-1691. DOI: 10.1089/end.2007.0386

[4] Josephson DY, Jacobsohn KM, Link BA, Wilson TG. Robotic-assisted endoscopic inguinal lymphadenectomy. 2009;73:167-170. doi:10.1016/j.urology.2008.05.060

[5] 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 International. 2013;**111**:1068-1074. DOI: 10.1111/j.1464-410X.2012.11729.x

[6] 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. Ecancermedicalscience. 2013;**7**:356. DOI: 10.3332/ecancer.2013.356

[7] Ahlawat R, Khera R, Gautam G, Kumar A. Robot-assisted simultaneous bilateral radical inguinal lymphadenectomy along with robotic bilateral pelvic lymphadenectomy: A feasibility study. Journal of Laparoendoscopic & Advanced Surgical Techniques. Part A. 2016;**26**:845-849. DOI: 10.1089/lap.2015.0611

[8] Siegel RL, Miller KD, Jemal A. Cancer statistics, 2019. CA: A Cancer Journal for Clinicians. 2019;**69**:7-34. DOI: 10.3322/caac.21551

[9] 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**:292-296. DOI: 10.1016/j.uromx.2015.06.006

[10] Global Cancer Observatory. Cancer Today [Internet]. 2018. Available from: https://gco.iarc.fr

[11] Pettaway CA, Crook J, Pagliaro L. Tumor of the penis. In: Wein A, Kavoussi L, Partin A, editors. Campbell-Walsh Urology. 11th ed. Philadelphia: Elsevier; 2016. pp. 846-878

[12] Daling JR, Madeleine MM, Johnson LG, Schwartz SM, Shera KA, Wurscher MA, et al. Penile cancer: Importance of circumcision, human papillomavirus and smoking in in situ and invasive disease. International Journal of Cancer. 2005;**116**:606-616. DOI: 10.1002/ijc.21009

[13] Angermeier K, Sotelo R, Sharp D. Inguinal node dissection. In: Wein A, Kavoussi L, Partin A, editors. Campbell-Walsh Urology. 11th ed. Philadelphia: Elsevier; 2016. pp. 846-878

[14] Hegarty PK, Dinney CP, Pettaway CA. Controversies in ilioinguinal lymphadenectomy. The Urologic Clinics of North America. 2010;**37**:421-434. DOI: 10.1016/j.ucl.2010.04.005

[15] Daseler EH, Anson BJ, Reinmann AF. Radical excision of the inguinal and iliac lymph glands; a study based upon 450 anatomical dissections and upon supportive clinical observations. Surgery, Gynecology & Obstetrics. 1948;**87**(6):679-694

[16] Hakenberg OW. Penile Cancer. European Association of Urology Guidelines [Internet]. 2018. Available from: https://uroweb.org/guideline/penile-cancer/ [Accessed: 2019-08-08]

[17] Flaig TM. Penile Cancer. NCCN Clinical Practice Guidelines in Oncology [Internet]. 2018. Available from: https://www.nccn.org/professionals/physician_gls/default.aspx#penile [Accessed: 2019-08-08]