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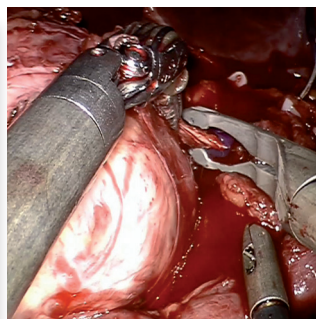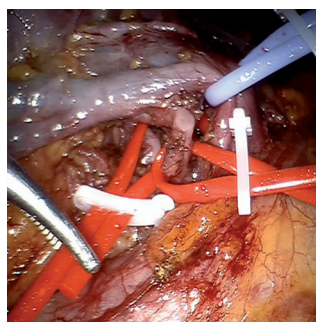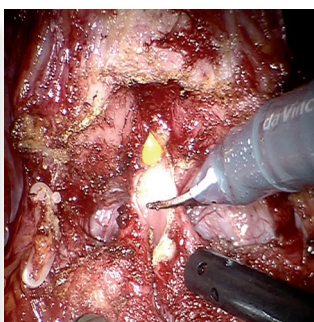
Robot assisted lymphadenectomy in urology: pelvic, retroperitoneal and inguinal

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A B S T R A C T

Lymph node dissection represents an essential surgical step in the treatment of the most commonly treated urological cancers. The introduction of robotic surgery has lead to the possibility of treating these diseases with a minimally invasive surgical approach, but the surgical principles of open surgery need to be carefully respected in order to achieve comparable oncological results. Therefore, the robotic approach to urological cancers must include a carefully performed lymph node dissection when indicated.

In the current manuscript we reviewed the current indications and extensions of lymph node dissection in prostate, bladder, testicular, upper urinary tract, renal and penile cancers respectively, with a special focus on the state of the art surgical technique for each procedure.

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Lymph node dissection (LND) can play different potential roles in uro-oncology: reduce or eliminate the risk of regional recurrence, improve cancer specific survival, improve staging, and anticipate the identification of a metastatic disease in patients who may therefore benefit from adjuvant therapy.

The advent of minimally invasive surgery has revolutionized the field of urologic oncology over the past 25 years, and robotic-assisted technique offers potential perioperative advantages and equivalent oncological outcomes when compared to standard open techniques in many cases. Similar considerations cannot be yet addressed with regard to LND. The only available data consist mainly of retrospective and few prospective studies and furthermore, the level of knowledge achieved, concerning indications and anatomical maps, is not uniform for all malignancies.

Facing the lack of well-designed randomized phase III trials, herein, we provide a systematic review and critical analysis of the current evidence of LND performed for prostate, bladder, kidney, upper tract urothelial, testicular, and penile cancer.

Methods

A systematic literature review was performed in July 2016 using PubMed and Scopus to identify relevant studies. A comprehensive electronic English literature search was conducted from January 2001 to July 2016 by applying a free-text protocol combining surgical subject heading (MeSH) search terms and related articles function. Keyword searches included: "Lymph Node Dissection" OR "Lymphadenectomy" AND "Robotic-assisted" AND "inguinal penis/penile" OR "prostate/prostatic" OR "bladder", "retroperitoneal kidney" OR "retroperitoneal transitional cell carcinoma" OR "retroperitoneal upper tract urothelial carcinoma" OR " retroperitoneal testis / testicular". Since data on LND in case of UTUC and renal cell carcinoma (RCC) are very scarce we search for robotic nephroureterectomy, radical nephrectomy and partial nephrectomy. Only studies describing LND performed during urologic robot-assisted laparoscopic procedures were included for further screening. Other publications on laparoscopic technique were taken in account since considered milestones in the transition to robotic surgery. In addition, references from the selected articles retrieved in the search were assessed. Conference abstracts and single case reports were not included.

Results

After the very first clinical experience of Robotic-assisted LND performed in human for urologic disease, published in 2001,[1] we were able to find another 259 articles. The anatomical region more often explored was the pelvis, prostate and bladder cancer, with 202 articles, 105 and 98 articles, respectively; others were retroperitoneal LND (RPLND) with 50 publications, testis 38, kidney 12, and penile 12 articles.

Pelvic lymph node dissection

Robot-assisted pelvic lymph node dissection for prostate cancer

Pelvic lymph node dissection (PLND) represents the most accurate and reliable staging procedure for patients diagnosed with organ-confined prostate cancer (PCa) who undergo radical prostatectomy (RP) and may also represent an effective treatment for high-risk and locally advanced patient.[2] Although standard imaging tools have very limited ability (35% sensitivity)[3] in predicting lymph node invasion (LNI) for lymph node (LN) ≤1cm, to date the risk can be assessed relying on predicting nomograms and international guidelines strongly suggest their use. The European Association of Urology (EAU) recommends performing an extended template (ePLND) in intermediate and high risk whenever the LNI risk is >5% based on updated Briganti's nomogram, while they do recommend omitting PLND in low risk.[4] The National Comprehensive Cancer Network (NCCN) recommends ePLND when the risk, based on a separate nomogram, is greater than 2%.[5]

To date, the number of nodes removed still represents the most reliable measure of the accuracy of PLND, and the most meticulous studies show that the mean number of nodes removed with an extended template may be ≥20.[6] Prostate has a very complex lymphatic pathway that varies widely among men and is characterized by typical crossover and proper anatomical templates have been so far standardized (Figure 1). However, early results of minimally invasive surgery dramatically brought down the rate of PLNDs performed at the time of RP when compared to open radical prostatectomy (ORP), and this was clearly a surgeon's bias as a consequence of a new learning curve process and time savings. More recently, standardization of the technique has increased compliance, with most recent series showing an adherence to guidelines, with LN yield, complication rates and oncologic outcomes comparable to open surgery.[2] Figure 2 shows the steps of rPLND dissection in PCa.

The role played by the learning curve in robot assisted radical prostatectomy (RARP) was accurately shown by Van der Poel *et al.* who observed advancement of the PLND technique after 150 cases for operative time (108min *vs.* 49min), 250 for nodal yield (10 *vs.* 18), 300 for node positivity rate (4 *vs.* 23%),
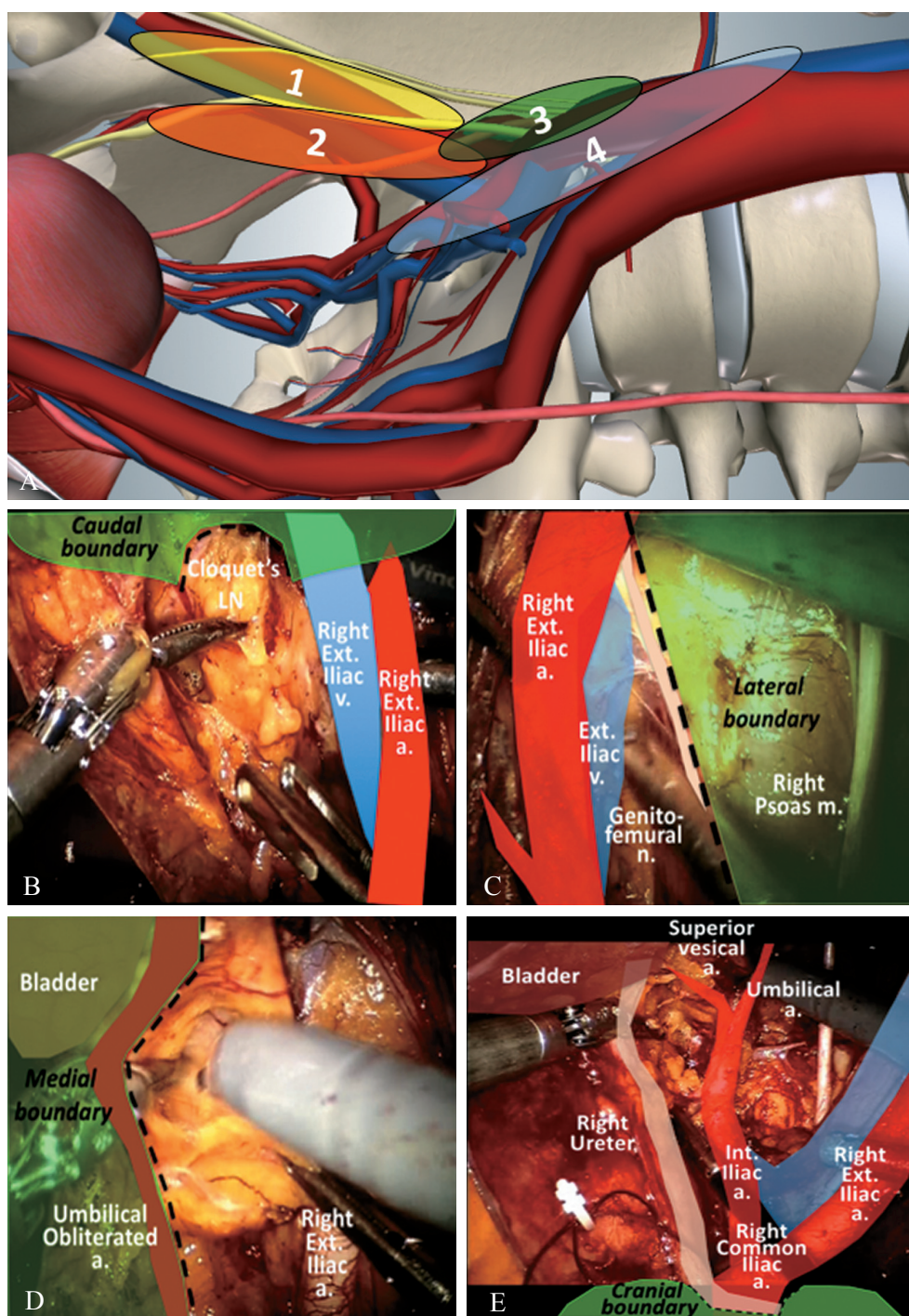
Figure 1.—Template in PLND dissection in prostate cancer. A) Lymph node dissection templates in prostate cancer (courtesy of F. Gaboardi); B-E) boundaries of extended PLND. Caudally Cloquet's lymph node, laterally genitofemoral nerve, medially umbilical obliterated artery, peritoneal sheet and bladder; cranially ureter crossing at level of common iliac artery.
1: Limited - External iliac above the obturator nerve; 2: standard - external iliac, obturator, hypogastric (pelvic sidewall laterally, the bladder wall medially, the floor of the pelvis posteriorly, Cooper's ligament distally and the internal iliac artery proximally); 3: extended - previous template and common iliac vessels at level of ureter crossing; 4: super-extended - previous template and presacral, aortic bifurcation, eventually preaortic and precaval.
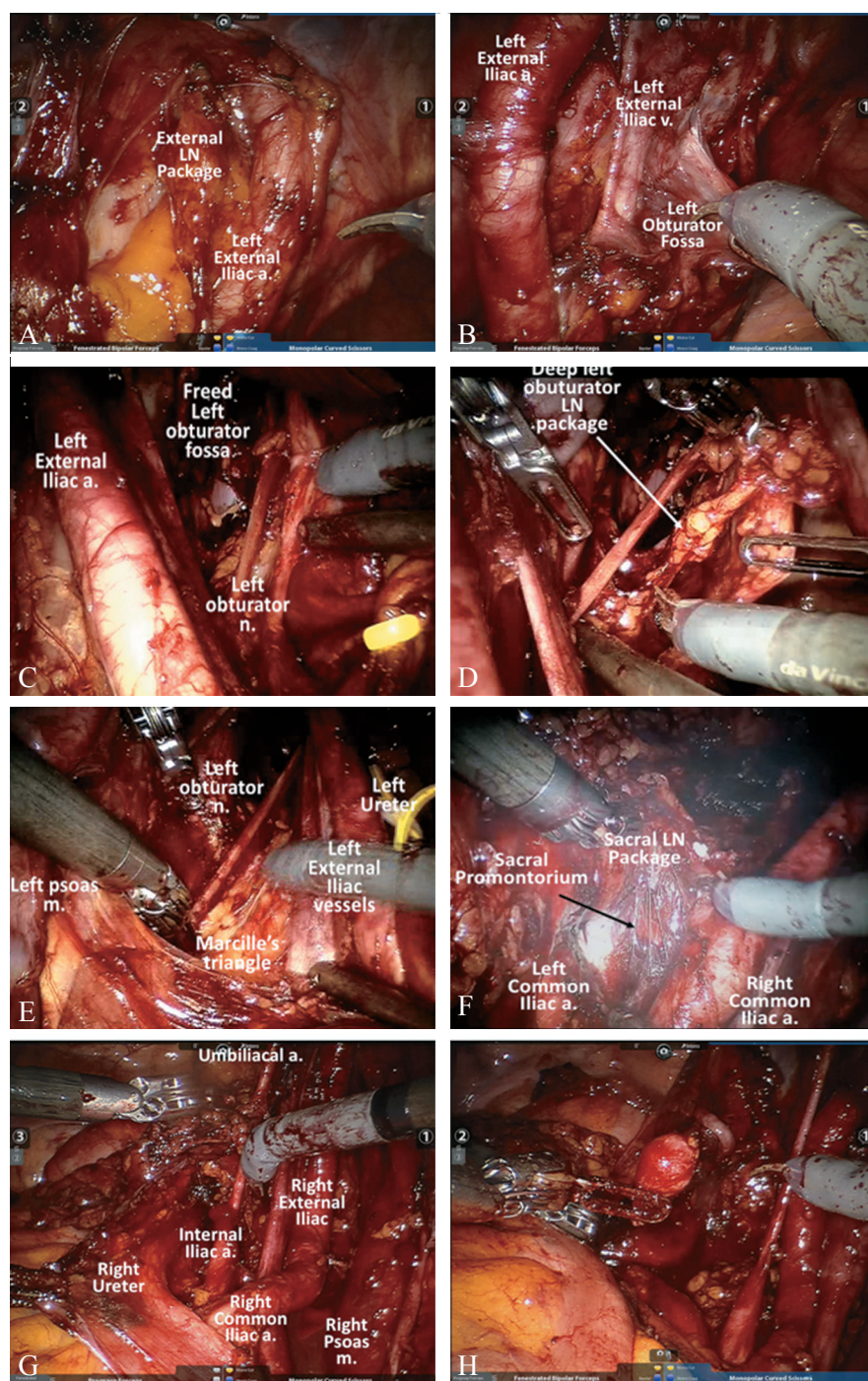
Figure 2.—Steps in robot-assisted PLND dissection in prostate cancer. A) lateral lymph node package dissection (left sided) at level of external iliac artery (Courtesy of G. Pini); B) external iliac vein dissection (left sided) and approaching the obturator fossa; C) superficial obturator nerve lymph nodes package (left sided); D) deep obturator nerve lymph nodes package (left sided); E) Marcille's triangle/fossa exposition (left sided): after detaching left external iliac vessels from psoas muscle the procedure allows for a safer dissection of obturator nerve emergency from lateral wall of pelvic floor. Vessel loop secures ureter; F) sacral lymphnode dissection follows a proper dissection of bilateral common iliac artery; G) final result of an extended-PLND (right sided); H) salvage lymph node dissection (right sided) following biochemical relapse and positive single node at c-11 choline PET-CT scan.

and 400 for complication rate (Clavien grade I and II complications).[7] Similarly, the LAP-PRO study (multicenter prospective control trial robotic *vs.* open prostatectomy, 3544 patients) [8] showed RARP offering an increased LN yield in ePLND template (21.5 *vs.* 18.3) compared do ORP. Concerning complications, the same study showed that PLND increased the absolute incidence of thromboembolic event sevenfold and particularly, ORP amplified the risk threefold compared to RARP, data corroborated by other retrospective and populations-based studies. Possible mechanisms that might clarify protection of RARP against thromboembolic event must be seen in the context of the Virchows triad (hypercoagulability, endothelial lesions and blood stasis): fewer estimated blood losses and transfusion-rates, hematomas and lymphorrhea not constrained into a limited extraperitoneal space, Trendelenburg position which facilitates blood flow from the leg, no need of self-retaining retractors that leading to prolonged tissues compression.[9]

A sentinel lymph node (SLN) biopsy might be a safe and efficient way to reduce PLND extension and related complication, but its role remains to be determined in minimally invasive surgery. Recently, near-infrared fluorescence (NIRF) imaging has been applied to RARP. Transrectal ultrasound- or percutaneous robot guided prostatic injection of indocyanine green (ICG) allows with fluorescence visualization of LN using the FIREFLY-system (Novadaq Technologies Inc, Mississauga, Canada) integrated in the da Vinci robot (Intuitive Surgical, Sunnyvale, CA, USA). Potential benefits of such modifications include identification of relevant primary lymph nodes, avoidance of overdissection, and enabling lymphangiography without the need for ionizing radiation.[10]

New imaging tools [PSMA or 11C-choline PET fused with CT or MRI, and diffusion-weighted MRI imaging (DWI)], seem to significantly improve restaging of LN in case of biochemical PCa relapse.[3] From the perspective that salvage-LND can delay clinical progression and postpone hormonal therapy in almost one-third of the patients (Figure 2H),[4]

few case reports on robotic-assisted LND show the ability to perform this surgery robotically.[11]

Robot-assisted PLND for bladder cancer

Standard treatment of muscle invasive bladder cancer (BC) is radical cystectomy (RC) and PLND.[12, 13] Although open radical cystectomy (ORC) still remains the most common approach (up tp 80% in USA in 2014), robot-assisted RC (RARC) is gradually gaining popularity worldwide due to the ability to duplicate ORC and showing promising short- and intermediate term results.[14] Historical issues concerning laparoscopic treatment of urothelial cancer (namely spreading of tumor, peritoneal seeding, port site recurrence) and technically ability to offer same PLND as ORC have been demystified.[15]

It is well known that LNI is a well know poor prognostic indicator in BC, leading to a 5 years overall survival less than 15-30%,[13] and the extent of PLND, reflection of LN yield, has been shown to play an important role in cancer control. In their systematic review (19793 pt undergoing RC, 23 studies), Bruins *et al*. concluded that any kind of PLND is advantageous over no PLND, although in the presence of a poor data quality (22/23 retrospective data). Furthermore, ePLND appears to be superior to lesser degrees of dissection, while super-extended PLND offered no additional benefits.[16] Table I describes PLND in BC. These factors show that the degree of extension and the ideal proximal limit of PLND remains still controversial, even if at least 10-14 nodes

TABLE I.—*Lymph node dissection templates in bladder tumor.*

LND template	
Standard	External iliac, internal iliac, obturator
Extended	External iliac, internal iliac, obturator, common iliac (presacral, presciatic – debated inclusion as ePLND)
Super-extended or high-extended	External iliac, internal iliac, obturator, common iliac, presacral, presciatic; preaortic, interaortocaval, paracaval inferior to inferior mesenteric artery takeoff

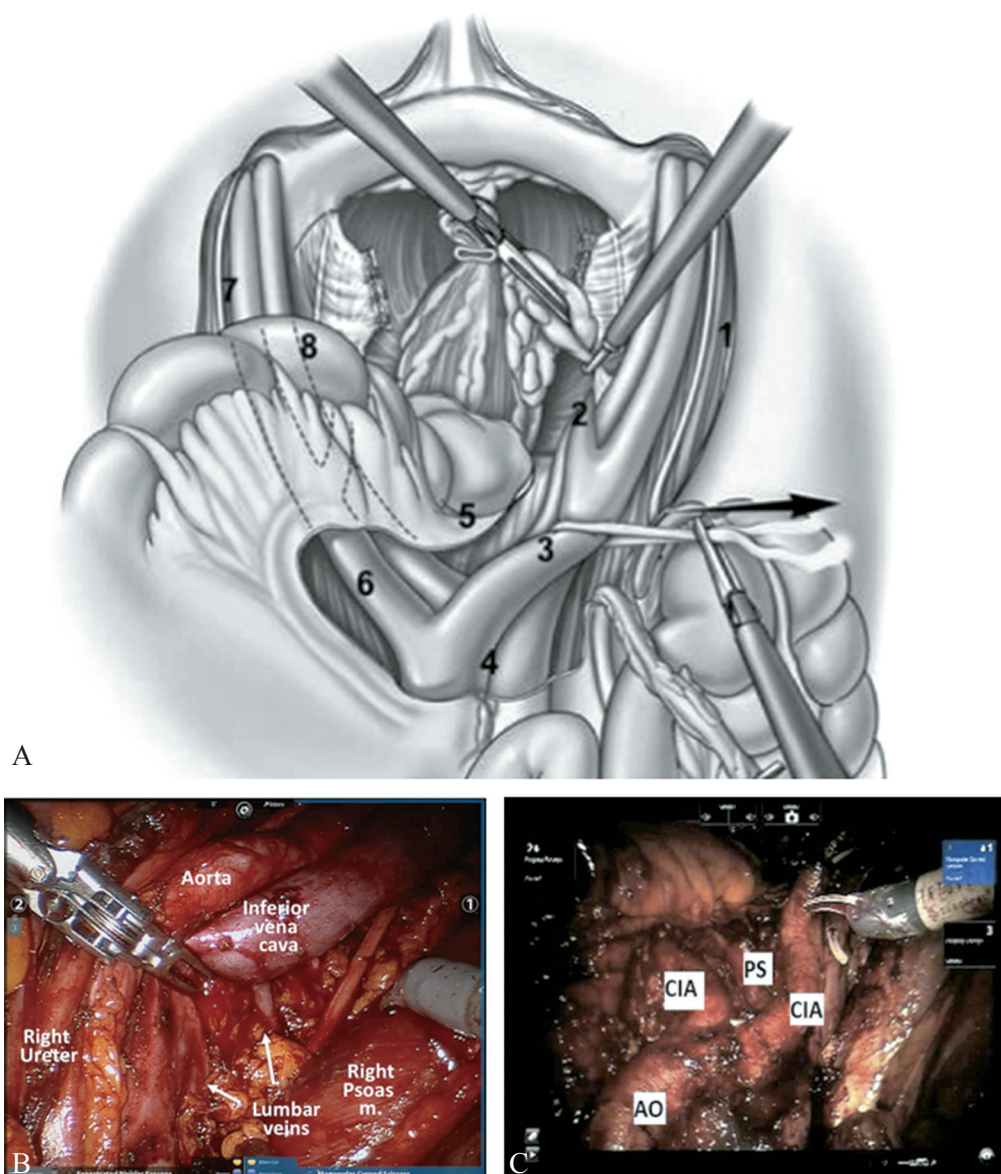LND: Lymph node dissection; ePLND: extended pelvic lymph node dissection.

Figure 3.—Robot-assisted PLND dissection in bladder cancer. A) High extended pelvic lymph node dissection (courtesy of M. Desai); B) final view following a high extended pelvic lymph node dissection (courtesy of M. Desai). The distal aorta, common iliac arteries (CIAs), and presacral (PS) regions are completely dissected off lymphatic tissue; C) Pre- and paracaval lymph node dissection dissection (courtesy of G. Pini), lumbar vein are easily visible.
1: right external iliac; 2) right internal iliac/ obturator; 3) right common iliac; 4) preparacaval and preparaaortic; 5) presacral (PS); 6) left common iliac; 7) left external iliac; and 8) left internal iliac/obturator.

should be removed to offer an oncologic benefit.[13]

Nevertheless, robot-assisted surgery has been able to show abilities to replicate open PLND and even offering a better LN sampling. The International Radical Cystectomy Consortium (IRCC, 800 patients undergone RARC, multi institutions, prospective database) reports an increasing number of LN yield when compared to ORC (18 *vs.* 19), although highlighting the role of surgeons volume and center case-load (>100cases/y, 18 *vs.* 23 LN yield) and

importance of learning curve (30 cases to reach 20 LN yield).[15] Similarly, Tang *et al.* report in their metanalysis the ability of robot-assistance to increase node count of 2.18 nodes than open approach.[14] Recently, Desai *et al* report the capabilities to perform an high-extended (super extended) technique (Figure 3) defined as extending proximally up to the inferior mesenteric artery (IMA) and including external iliac, obturator, presciatic, hypogastric, common iliac, presacral, preaorticortic, pre-, para-caval, and interaortocaval nodes.[17] Although the extent of PLND (extended *vs.* super-extended) does not seem to increase the relative-risk of complications,[12] it exponentially rises operative time and costs. With the aim of reducing the unnecessary extension of the dissection, preliminary sentinel node biopsy studies (tracer injected peritumorally via cystoscope before surgery) showed feasibility, a detection rate of 87% and ability to find micrometastasis (<2mm).[18] However, as in the case of RARP, near-infrared fluorescence (NIRF) imaging [transuretral peritumoral injection of indocyanine green (ICG)] is rapidly taking over in RARC, showing feasibility and identification of sentinel drainage in 90% of 10 patients with a median of 30 minutes after the injection.[19]

PLND performed in BC reproduces the same technique followed in PCa, first type of surgery in which the surgeon engages in its own learning curve. Only greater attention must be taken into account to eliminate risk of local spillage of malignant urothelial cells, well known source of early local recurrence and peritoneal seeding: following a split-and-roll technique, the direct incision of LNs should be avoided, while the retrieval of LN package within a specimen bag should take place as soon as possible, included each single piece of lymphoid tissue still present in operative filed.

Retroperitoneal lymph node dissection

Robot-assisted retroperitoneal lymph node dissection (RPLND) for testicular cancer

Testicular cancer is commonly known to be the most frequent malignancy in young men (age 30-40 yr). Inguinal orchiectomy, ultimately followed by active surveillance or adjuvant chemiotherapy, is the gold standard and offers excellent cure rates.[20] However, up to 35% of patients could present metastatic LNI despite negative imaging at clinical staging (CS).[21] Primary RPLND has the ability to precisely detect LN micrometastasis, staging the extent of disease and hence identify patients who may benefit from adjuvant treatment. Grounded on solid long-term oncologic results, open RPLND is endorsed by international guidelines as a valid alternative to chemotherapy in patients with low-clinical stage (CS 1) nonseminomatous germ cell tumor (NSGCT), low-volume CS IIa disease, and residual disease after chemotherapy.[22] However, while 3-4 cycles of adjuvant platinum-based chemotherapy is strongly linked to long-term risks of cardiovascular toxicity, secondary malignancy, and infertility,[23] oRPLND requires invasive and debilitating skin incisions. Laparoscopic RPLND, made his debut in 1992 showing in experienced hand not only comparable staging precision and intermediate-oncologic results as oRPLND, but also potential lower morbidity, namely shorter hospital stays, quicker return of bowel function, and faster convalescence, central condition to allow appropriate candidates to receive chemotherapy sooner.[24] However, the widespread of the technique has been hampered by classic limitation of laparoscopy, steep learning curve, and technical challenges. Table II reports the few retrospective single-center and one recent multi-institutional series that followed the first rRPLND, described in 2006.[20, 22, 25-27] In case of unilateral template dissection, the historical approach, followed a transperitoneal 4-robotic-arms with patient in a lateral flank position and robot docked posterior to the patient.[28] However, this method did not allow a full bilateral dissection without the need to un-dock and reposition the patient and makes otherwise impossible to access the contralateral field in case of bilateral disease or accorded to intraoperative frozen section results. To overcome these issue, a supine approach with patient in Trendelenburg position has been described

TABLE II.—*Robotic assisted retroperitoneal lymph node dissection (RPLND) in testicular cancer.*

Autor (yr)	Pearce SM (2016)[20]	Stepanian S (2016)[22]	Harris (2015)[25]	Cheney (2015)[26]	Williams (2011)[27]
Study	Multicentric (4 centers), retrospective (LE3)	Single center, retrospective, (LE3)	Single center, retrospectove (LE3) Comparative, laparoscopic vs robotic	Single center, retrospectove (LE3)	Single center,
Cases (n)	47	20	16	18	3
Age (Yr)	30	31.2	29.8	32.2	31
BMI (Kg/m2)	28	25.6	28.9	27.3	ND
OT(min)	235	293	271	329	187
EBL (mL)	50	50	75	103	167
LOS (d)	1	1	ND	2.4	2
Transfusion cases (n)	ND	0	ND	1	0
Post-chemotherapy cases, n (%)		4 (20)	0	8 (44)	0
Bilateral cases, n (%)	0	5 (25)	0	11(61)	0
Lymph node yeld, (n)	26	19.5	30	20	25
Patient with positive nodes, n (%)	8 (17)	8 (42)	2 (12.5)	8 (44)	0
Follow-up (mo)	16	49	13.5	22	ND
RPD Recurrence (cases, n)	1	0	0	0	ND
Clavien III-IV complication (n)	2	1	1	0	0

BMI: Body Mass Index; ND: no data; OT: operating time; EBL: estimated blood loss; LOS: length of hospital stay; RPD: retroperitoneal disease, NSGCTS: nonseminomatous germ cell testicular cancer.

(2011, Dr. James L'Esperance of the US Naval Hospital in San Diego - personal communication). Figure 3 shows robot docking and ports configurations. While Da Vinci Si is docked over the left shoulder, the daVinci Xi adopts a four-port linear configuration with docking alongside the patient. Adopted in case of CS I NSGCT, unilateral templates retrace the classic template of oRPLND.[22] On the left side it includes the removal of gonadal vein, nodal tissue surrounding left common iliac, pre-, para-, retro-aortic, interaortocaval and inferior mesenteric artery. On the right side, it includes nodal tissues close to gonadal vein, proximate to right common iliac, para-, pre and retro-caval, interaortocaval, and preaortic to the level of the inferior mesenteric artery. For both sides, the superior and lateral borders of dissection are the renal hilum and the ureter respectively. Due to lymphatic cross-over, a frozen section is suggested and in case of invasion it is recommended the extend of the RPLND contralaterally. Bilateral rPLND refers to the excision of all nodal tissue between the ureters from the renal hilum to the inferior mesenteric artery in addition to the ipsilateral iliac nodes and gonadal vein. Within the limits of a proper oncologic respect, a nerve sparing approach can be attempt to maintain antegrade ejaculation[26] by preservation of sympathetic chain and lumbar splanchnic nerves within inteartocaval and pre- and paraortic nodal tissue.[29]

Up to date due to limited caseload and only short/intermediate follow-up, no formal indications can be drawn, except that R-RPLND it is a safe technique, able to postpone possible further chemo-therapy and seems to be on the right pathway to retrace oncologic results of oRPLND.[20] Small laparoscopic feasibility studies on sentinel nodes detection at time of orchiectomy has been motivated to define which patients could benefit from adjuvant therapy and potentially reduce radiation exposure (CT scans) and follow up schedule for large part of patients with stage 1 cancer.[21]

RPLND for upper tract urinary cancer

A different embryological origin and expansive geographical range marks the nature of LND of upper tract urothelial carcinoma

(UTUC), slightly dissimilar from bladder urothelial carcinoma (BC). Definitely rarer, UTUC are more commonly invasive at the time of initial diagnosis in approximately 60% of cases, compared to 15-25% of bladder cancers.[30] Furthermore, about 30% of patients with muscle-invasive UTUC present with LNI at surgery a well know independent prognostic factor in UTUC [31]. Diversely from BC,[12] the benefit of RPLND performed at time of radical nephroureterectomy (NU) and "en-bloc" bladder cuff excision (BCE) remains unclear.[32] Based on retrospective evaluation, high-risk patients would benefit from a NU-RPLND, with evidence of higher CSS (89.8% vs. 51.7%)[33] and reduction of loco-regional re-currence.[34] RPLND is strongly recommended when clinically indicated and, while not fully proven, in presence of high risk features such as high grade on biopsy or sessile tumors. PLND (and possibly a higher RPLND according to limited data)[32, 49] should be considered in high-grade UTUC of the lower third of the ureter. Evidence of clinical local or lymph node invasion, indicated chemotherapy as primary option; salvage surgery can be considered in case of clinical relapse.

Because of this ambiguity, literature and guidelines are far from exhaustive, but can be inferred indirectly by analyzing case studies on NU. This multiquadrant, multiorgan surgery has historically required a

TABLE III.—*Robotic assisted nephroureterectomy (RNU) series including Retroperitoneal Lymph Node Dissection (RPLND).*

Autor (yr)	Melquist JJ (2016)[35]		Ambani SN (2014)[41]		Hemal (2011)[38]	Aboumohamed (2015)[42]
Study (Level of evidence)	RNU+RPLND, Single center, retrospective (LE3)		RNU+RPLND, Single center, retrospective (LE 3), RPLND performed in high risk tumor		RNU + RPLND, Single center, retrospective (LE 3), RPLND performed in high risk tumor	RNU+RPLND, single-center prospective (LE 3)
	Pure Robot single docking	Lap + Gibson*	Robot, redocking[a]	Lap, hand assisted	Robot, single redocking[a]	Pure Robot single docking[a,b]
Cases (n)	37	63	22	22	15	60
RPLND performed, n (%)	37 (100)	63 (100)	13 (59)	6 (27)	ND	32 (53)
Age (Yr)	68	72.6	70.1	70.8	63	69
BMI (Kg/m2)	28	28	ND	ND	30.4	27.3
Tumor location						
Pelvicalyceal only	21 (57)	29 (46)	14 (64)	14 (64)	12 (80)	22 (36.7)
Ureter only	9 (24)	23 (37)	6 (28)	6 (28)	2 (13.3)	23 (38.3)
Pelvicalyceal and ureter	7 (19)	11 (17)	2 (9)	2 (9)	1 (6.7)	15 (25)
Neoadjuvant chemoterapy	19 (51)	34 (54)	3 (14)	0 (0)	ND	ND
Histology Urothelial carcinoma	30 (81)	44 (70)	ND	ND	15 (100)	ND
Carcinoma in situ	8 (22)	20 (32)	ND	ND		8 (13.3)
OT (h)	5.1	3.9	5.0	4.2	3.1	ND
EBL (mL)	150	200	380	233	103	ND
Transfusion cases, n (5)	3 (8)	19 (30)	2 (9)	0 (0)	ND	ND
LOS (d)	5	3	3.1	3.1	2.73	ND
Clavien II-V	5 (14)	15 (24)	ND	ND	0	4 (6.7)
Clavien III-V	4 (11)	3 (5)	ND	ND	0	2 (3.4)
Lymph node yeld (n)	21	11	5.5	1.0	4-9	5.3
Positive pathologic lymph nodes (pN+), n (%)	2 (5)	13 (21)	2 (17)	2 (29)	ND	7 (21.9)
Follow-up (mo)	8.5	30.9	ND	ND	ND	25.1

RPLND: retrotperitoneal lymoh Node dissection, BMI: Body Mass Index; ND: no data; OT: operating time; EBL: estimated blood loss; LOS: length of hospital stay.
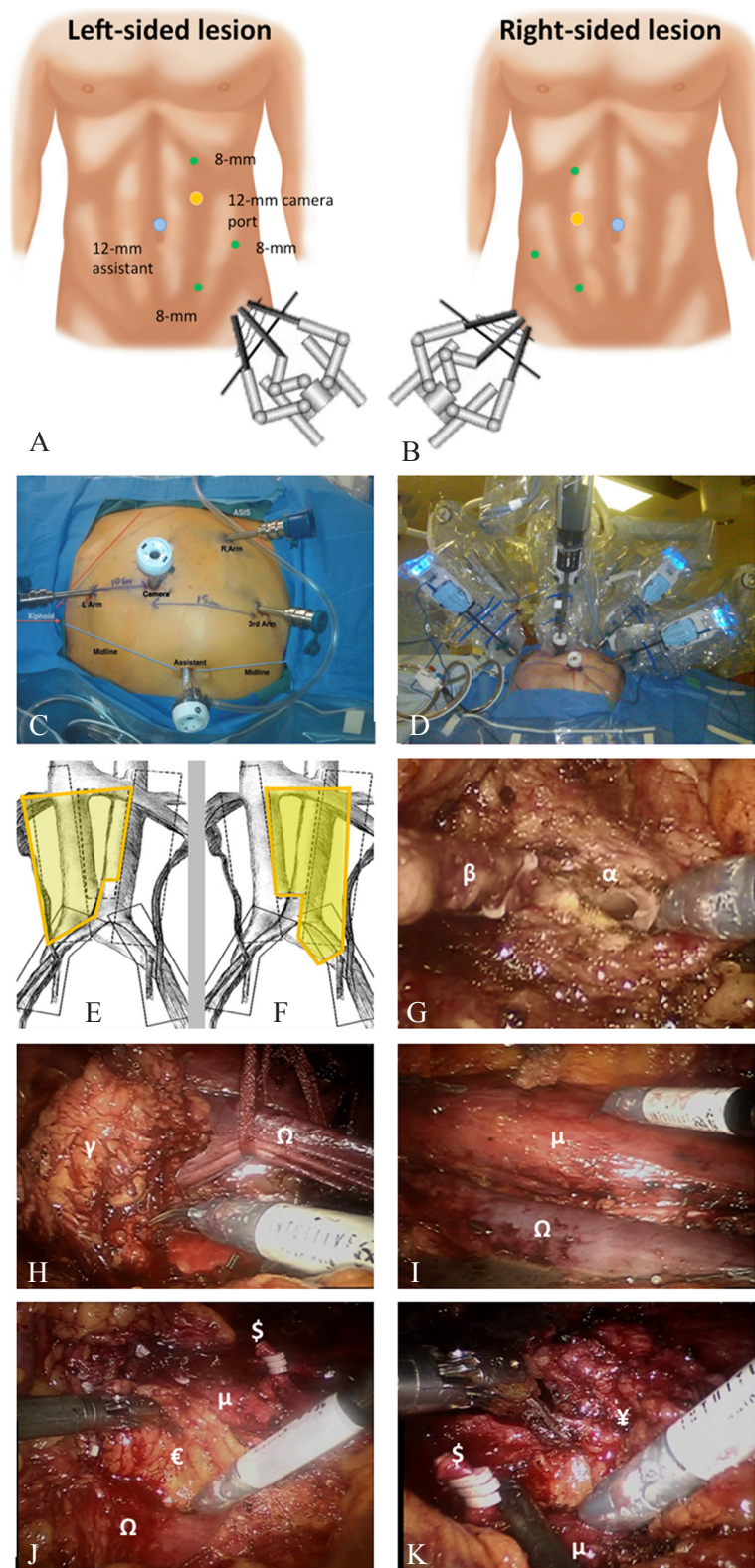
Figure 4.—Robotic-assisted nephro-ureterectomy, bladder cuff excision and RPLND in upper tract urothelial carcinoma (courtesy of SF Matin). A-D) Port placement and robot docking for a single-docking approach with the da Vinci Si. The robotic cart is placed over the patient's hip at a 45° angle, facing the contralateral shoulder. The patient is positioned in a modified flank position (45-60°) with the disease side up, in a slight Trendelenburg position (15°) and table flexed; E, F) modified template suggested in right- and left-sided UTUC; G) bladder cuff excision. The single-docking approach allows for an easy ureteral dissection. Before excision of the bladder cuff, the ureter is secured with clips to prevent tumor migration. Cystostomy is then closed with running suture. α. Cystostomy β. Pelvic ureter; H) peri, pre- and interaorto-caval RPLND in right sided tumor. Following circumferential cava dissection, a vessel loop helps for retrocaval RPLND. Ω. Cava; γ. Peri-, pre- and interaorto-caval LN package; I) aorta and cava completely skeletonized. Ω. Cava; μ: Aorta; J) interaortocaval RPLND in left sided tumor. Ω. Cava; μ: Aorta; €: Interaortocaval LN package; $: clipped left renal artery; K) para- and peri-aortic RPLND from left side. μ: aorta; ¥: LN package, $: clipped left renal artery.

TABLE IV.—*Minimally invasive primary radical of partial nephrectomy performed with Lymph Node Dissection (LND) in renal solid cancer.*

	Laparoscopy			Robot-assisted
Autor (yr)	Simmons (2007) [47]	Chapman (2008) [49]	Rosoff (2009) [48]	Abaza (2011) [50]
Study, level of evidence	Single center, retrospective, case report, (LE 3) RPLND in advanced Renal Cancer & cN+1-2, Hilar LND	Single center, retrospective, case report, (LE 3) RPLND in cN0,	Single center, retrospective, case report, (LE 3) RPLND in cN+,	Single center, retrospective, case report, (LE 3) RPLND in cN0 (6/36) and cN+ (30/36),
Procedures, n	14	50	6	36
OT (h)	199 (152-260)	210 (LRN); 217 (LPN)	175.7	
EBL (mL)	250 (100-2100)	140 (LRN); 150 (LPN)	275.5	
Number of nodes (range)	2.7 (1-9)	7.8 (0-25) (overall) 12.1 (last 10 patient of the series	5 (2-10)	13.9 (4-36)
Positive nodes %	57	10	17	2.8
LOS (d)	2.5 (2-5)	1.9 (LRN); 1.7 (LPN)	2.4	1.03
LND related complication, (%)	1 (7.4)	4 (8)	2 (32)	2 (5.6)
Complication by type, n (%)	generalized ileus	2 (4) Chylous ascites 1 (2) Ileus 1 (2) IVC tear	1 (16) Ileus 1 (16) Postoperative Bleeding	1 (2.3) Asymptomatic lymphocele 1 Intraoperative small bowel injury

OT: operating time; EBL: estimated blood loss; LOS: length of hospital stay; LND: lymph node dissection.

TABLE V.—*Series of robotic robot assisted video endoscopic inguinal lymphadenectomy (RAVEIL) and most prominent video endoscopic inguinal lymphadenectomy (VEIL) and open inguinal lymph node dissection (ILND).*

	RAVEIL				
Autor (yr)	Josephson [56] (2009)	Dogra [57] (2011)	Matin [60] (2013)	Thyavihally [58] (2013)	Sotelo [59] (2013)
Study, Level of Evidence	RAVEIL, Single center, retrospective, case report, (LE 3)	RAVEIL, Single center, retrospective, case report, (LE 3)	RAVEIL, Single center, prospective (LE1b)	RAVEIL, Single center, retrospective, case report, (LE 3)	RAVEIL, Single center, retrospective, case report, (LE 3)
Procedures, n	2	4	15	5	2
OT (h)	125	90-110	90-120	140 (120-190)	360 (both)
EBL (mL)	75	50-100	10-200	30-100	100 (50-150)
Number of nodes (range)	5.5 superficial 4 deep	ND	9.5 (5-21)	ND	14-19
LOS (d)	1	2	ND	ND	3
Duration of drainage, in days	12	8.5	ND	14	21
Overall postoperative complications, n (%)	0	0	3 (20)	0	0
Complication by type, n (%)	0	0	2 (13.3) Cellulitis 1 (6.7%) Wound necrosis	0	0

RAVEIL: robot assisted video endoscopic inguinal lymphadenectomy; VEIL: robot assisted video endoscopic inguinal lymphadenectomy; ILND: inguinal lymph node dissection; BMI: Body Mass Index; ND: no data; OT: operating time; EBL: estimated blood loss; LOS: length of hospital stay.

single large or 2 separate incisions in order to approach the retroperitoneal and pelvic regions.[35] Laparoscopic technique, while improving morbidity and showing similar oncologic results, showed difficulty in the step of BCE and required often combined technique (open, laparoscopic or endoscopic) to complete the procedure.[36] Robotic-NU (RNU) series, described first in 2006,[37] required often a redocking in order to complete the pelvic dissection, but allowed an easier complete laparoscopic procedure. Recently a single-docking technique has simplified the operation [38-40] albeit very few data on concurrent RPLND are available. Table III shows the most significant case series of unified RNU-RPLND-BCE.[35, 38, 41, 42] Among those, Melquist *et al*. described a simplified single-docking technique and first emphasizes the RPLND.[35] Figure 4A-D shows ports configuration and docking. Recently, Patel *et al* described benefit of the newest robotic plat-

forms (da Vinci Si and Xi) with elimination of arm collisions.[43] RNU is first performed and until the pedicle is sectioned and the ureter clipped, the kidney should not be manipulated to prevent migration of tumor cell into the bladder during mobilization. Before further dissection of the distal ureter and BCE (Figure 4G), robotic RPLND is undertaken using a conventional split and-roll technique. Extensive use of bipolar and metal or locking clips is done to minimize lymphatic leakage (Figure 4H-K), or alternatively, the vessel sealer can be used in lieu of bipolar and clipping. On the right side for renal pelvis and proximal ureter tumors, RPLND includes the hilar, pre-, para-, retro-caval, and interaortocaval regions (Figure 5E); while for left-sided disease, hilar, retro-, peri-, para-aortic tissues (Figure 5F); interaortocaval dissection for left sided disease does not seem necessary and its incremental yield for detection of LNI is minimal.[32] Patients with distal ure-

VEIL			ILND	
Tobias-Machado (2008) [53]	Sotelo (2007) [54]	Canter (2012) [55]	Koifman (2013) [61]	Stuiver (2013) [62]
VEIL, Single center, retrospective, case report, (LE 3)	VEIL, Single center, retrospective, case report, (LE 3)	VEIL, Single center, retrospective, case report, (LE 3)	ILND, Single center, retrospective, case report, (LE 3)	ILND, Single center, retrospective, case report, (LE 3)
20	14	19	340	237
120 (90-160	91 (50-150)	177.5 (132-140)	94	ND
			ND	ND
10.8 (7-16)	9 (4-15)	11 (3-26)	10.9 (6-19)	9 (1-25)
1	NA	1 (1-12)	6.4 (4-27)	9 (1-62)
4.9 (3-12)	NA	25 (8-101)	NA	11 (1-57)
4 (20)	3 (21)	7 (36.8)	35 (10.3)	137 (58)
1 (5) lymphorrhea 1 (5) skin necrosis 1 (5) hematoma 1 (5) lymphocele	3 (21) lymphocele	3 (15.8) seroma 1 (5.3) wound infection 1 (5.3) pneumomediastinum 1 (5.3) lymphedema 1 (5.3) cellulitis	14 (4.1) lymphedema 4 (1.2) seroma 3 (0.9) scrotal edema 3 (0.9) skin necrosis 3 (0.9) lymphocele 2 (0.6) wound infection 2 (0.6) flap necrosis 2 (0.6) wound abscess 2 (0.6) DVT	102 (43) wound infection 57 (24) seroma 38 (16) skin-flap

teric tumors are subjected to at least ipsilateral PLND, and possibly paracaval (right) or paraaortic (left) dissection owing to potential upward migration, but these templates require further validation.

RPLND for renal cell carcinoma

The value of LND in the management of renal cell carcinoma (RCC) is still controversial and to date, no data have clearly proven benefit in terms of cancer control, which patients should undergo LND and moreover which template should be used.

While AUA does not argue the subject and the NCCN considers LND only to help in staging the disease, EAU strongly suggest an extended LND in case of clinical enlarged LN.[44]

Among other causes, current imaging techniques do not allow for detection of small metastases in normal-sized LNs and high false-positive rates, with only 40% of LNI, have been shown in case of clinically enlarged nodes.[45] The existing evidence suggests that only primary tumor size seems to be the best predictor of LNI and therefore an extended pattern may be beneficial with a 15% overall survival benefit at 5 years in candidates with locally advanced disease (T3-T4). Protective role was shown as well in unfavorable clinical and pathologic characteristics (high Fuhrman grade, larger tumors, presence of sarcomatoid features, and/or coagulative tumor necrosis).[44] Regional LND in the remaining cases (T1-2N0M0) can offers limited staging information and no benefit in terms of oncologic benefit.[45] Minimum number of LN to achieve a 90% chance of finding a positive LN is 15, with more required in the presence of unfavorable tumor features.[46]

However, lacking of an established indication, the widespread increase of minimally invasive procedure (which makes LND a challenging procedure), and the stage migration (increased detection of incidental small renal masses) made urologist avoid performing LND at time of nephrectomy with a drop rate below 5% of all surgery for RCC.[44]

Table IV shows few minimally invasive feasibility case series available.[47-50] Node yields with standard laparoscopy do not exceed a mean of 7.8, though Chapman and associates could extended their LND template to mean of 12.1 nodes in the last part of their series (50 patients).[49] The first robot assisted series, reported by Abaza and Lowe with 36 cases, showed the ability to increase LND yield from 13.9 to 16.8 LN in the second half of the series, witnessing the possible standardization of the technique and the role of the learning curve.[50]

Despite a wide variation in the anatomical localization of lymph node metastases from RCC, possible LND template encompasses for the left kidney the para- and pre-aortic and interaortocaval LN, between the crus of the diaphragm and the inferior mesenteric artery; for the right kidney the para-, retro-, and pre-caval and interaortocaval LN, between adrenal vein to inferior mesenteric artery.

Robot-assisted video endoscopic inguinal lymphadenectomy

Radical inguinal lymph node dissection (ILND) is strongly supported in patient affected by penile cancer presenting palpable enlarged inguinal nodes. Similarly, patients with clinical normal nodes could harbor a 25% risk of micro-metastases.[51] Given the fact that current imaging techniques are not trustworthy in identifying micro-metastases, ILND gained also a role in intermediate and high risk patients (≥pTaG2) showing the best overall survival when compared to other modalities (surgery *vs.* radiotherapy *vs.* surveillance, 74% *vs.* 66% *vs.* 63%).[52]

Considering that lymphatic spread from any primary penile cancer follows a cross-over pathway and the superficial and deep inguinal lymph nodes are the first nodes reached, a bilateral ILND is the standard of care. Unfortunately, this procedure is anything but non-invasive, associated with 10 to 46% rate of complications in contemporary series even in the most experienced hands, primarily wound dehiscence, cellulitis, skin necrosis, leg edema and deep vein thrombosis.[51]
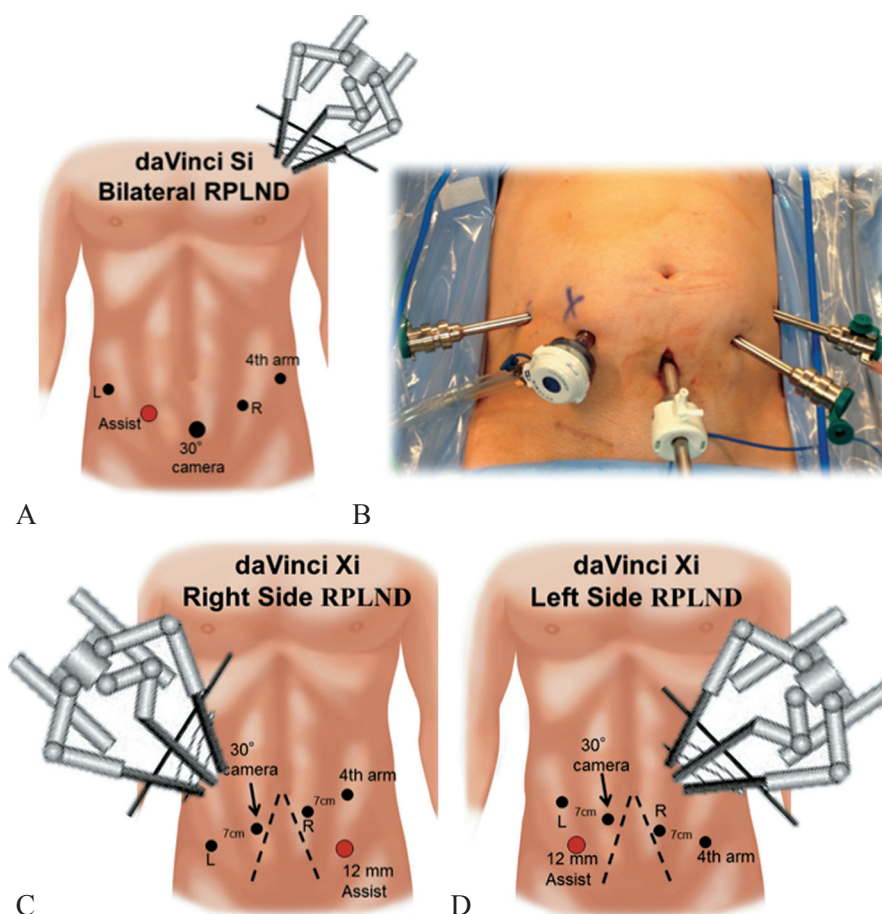
Figure 5.—Robot-assisted RPLND in testicular cancer. A, B) Port placement for a supine approach with the da Vinci Si for right, left, and bilateral templates (courtesy of J. Porter). Four arms approach and inverted U-shaped configuration. Two 8-mm robotic ports are placed in the left lower quadrant, while an 8-mm robotic port and a 12-mm assistant port are placed in the right lower quadrant; C, D) port placement for a supine approach with the da Vinci Xi (courtesy of Porter J). Four arms approach with a linear port configuration. The assistant port placed in the lower quadrant opposite the side of the template.

With the aim of reducing the morbidity without compromising oncologic results, endoscopic ILND has been first described in a cadaveric model by Bishoff *et al*. (2003), and subsequently refined by Tobias-Machado (2006),[53] who baptized the technique video-endoscopic inguinal lymphadenectomy (VEIL), Sotelo in 2007 [54] and Canter.[55] These feasibility cases report were marked by an absence or limited intraoperative or wound related complications (Table V).[53-62]

In 2009, Josephson [56] described the very first robot assisted VEIL (RAVEIL). To date a total of 28 procedures were described and collected in 5 case-reports and mainly focused on feasibility and technical aspect.[56-60] Figure 4 shows

ports placement, robot docking and dissection templates. Matin *et al*. [60] offered the only prospective study (15 cases) and included an independent surgeon's assessment of the procedure's oncologic adequacy, by direct visual evaluation of the dissection field through a small inguinal incision. A first cadaveric experience is as well reported on single site RAVEIL.[63]

With the exception of the high-risk cases, authors suggest frozen section in order to determine whether deep ipsilateral dissection will be required. The down time will be used to create the working space in the other leg while waiting for the results.

Oncologically, limited but promising data
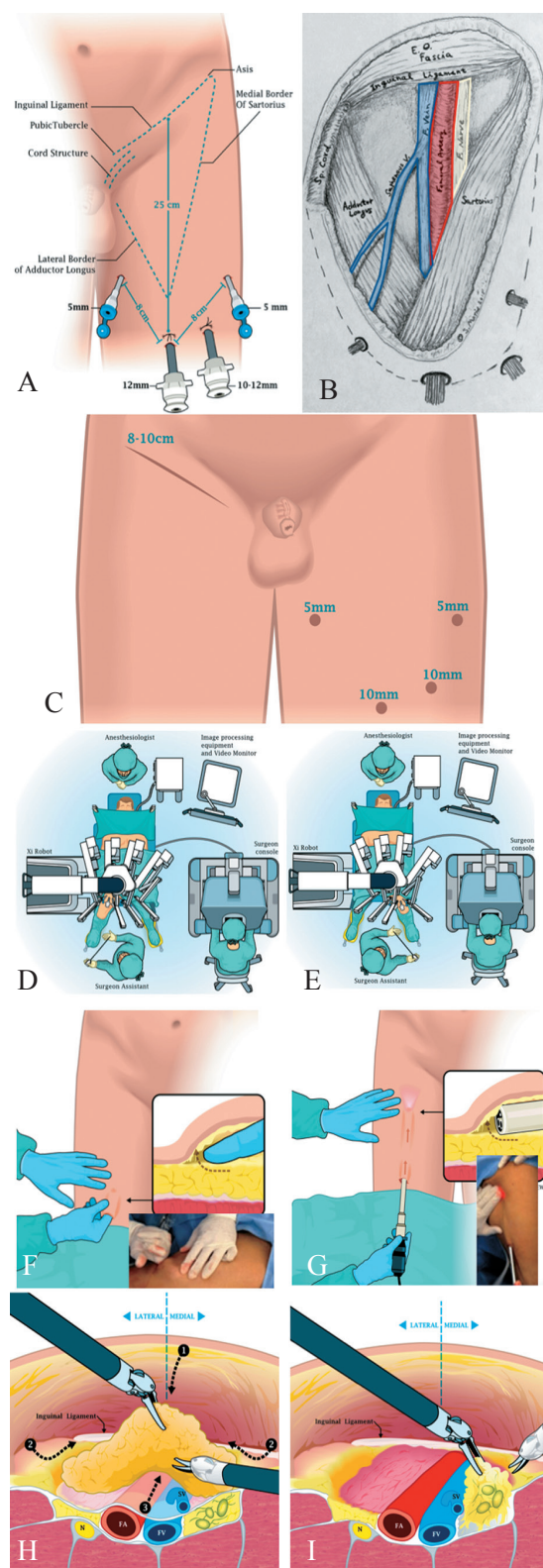
show that RAVEIL appears to be effective and safe when performed with careful quality control. In the absence of an intermediate and long term follow-up data, both RAVEIL and especially the more substantial VEIL series are capable for LN yield similar to the standard ILND, with a potentially lower morbidity rate than that of open surgery. More prospective studies, especially focused on peri- and postoperative parameters, (*e.g.* intermediate and long term complications rate) and with longer follow-up will be critical to assess 5-year cancer specific survival and recurrence rates in these relatively new procedures (Figure 6).

Conclusions

The rapid expansion of robotic-assisted laparoscopic technique in the treatment of urological cancer showed excellent ability to reproduce the open approaches. Nevertheless, facing very few well designed large clinical trials, we must carefully evaluate the oncologic efficacy of the LND. Well known benefits of robotic surgery, greater visualiza-

Figure 6.—RAVEIL in penile cancer. A) Left surgical procedures template (courtesy of R. Sotelo). The femoral (inverted) triangle delineate port positioning and dissection template; B) schematic view of a deep dissection results on left side (courtesy of S. F. Matin); C) comparison of standard open incision and RAVEIL (courtesy of R. Sotelo); D, E) patient position, robot docking and assistant position (courtesy of R. Sotelo). Split-leg and low lithotomy position (Allen-Stirrups) allows bilateral dissection without repositioning the robot. For the right RAVEIL, the robot is located at 45° contralateral to procedure and bed-side assistant and the right side. For the left RAVEIL cart is parallel to the table and assistant between the patient's leg; F, G) schematic and intraoperative blunt subcutaneous dissection (courtesy of R. Sotelo). A 2-cm incision is made 3 cm below the apex of femoral triangle, (25 cm below the inguinal ligament). Scarpa's fascia is identified and finger dissection or balloon dissection allow to to develop the potential space to insert two additional robotic (8-mm) ports. Further subcutaneous workspace is obtained under vision by sweeping the endoscope cranially; H) dissection of the superficial LND package (courtesy of R. Sotelo). With blunt dissection, the node packet can be rolled inwards on both sides. This manoeuvre is continued inferiorly as much as possible from both sides to define inferior apex of the nodal packet. The saphenous vein will be identified, section when necessary, even if its preservation reduce the risk of postoperative lymphedema; I) dissection of the deep LND package (courtesy of R. Sotelo). Fascia lata is opened medial to the saphenous arch and the saphenofemoral junction isexposed. Deep inguinal nodes dissection should be continued to the level of the femoral canal and until the pectineus muscle is seen to insure complete nodal retrieval.

tion through three dimensional high definition source and enhanced dexterity given by endowrist-technology, incorporate the ability of safely dissect around vessels and providing enhanced dexterity in case of unpleasant vascular damages. These facts are guaranteed even in extreme dissection surgery by permitting access to nodal tissue located posteriorly to the great vessels, which can be challenging with conventional laparoscopy. The newborn daVinci XI could help increase these skills in difficult case scenarios by easily reassigning camera port in order to get better view angulation without the need to change in port's placement or patient re-positioning.

Robotic assisted surgery can properly replace open RP in nomograms based ePLND both with a staging and curative purpose, while conferring a protective role in thromboembolic event. A similar ePLND can be beneficial in patients with bladder cancer and robot assisted surgery showed comparable abilities in LN yield as open surgery, without compromising oncologic safety in intermediate term follow-up.

Use of robot-assistance in RPLND for testicular cancer may reduce morbidity, but represent still a complex surgery and performed only at expert centers. Reproducing the experience covered in testicular cancer, template-based robotic RPLND performed at time of RNU for high risk UTUC and radical nephrectomy for high burden, locally advanced or high risk RCC is gaining support, but still requires higher level studies to identifies proper dissection templates and whether a therapeutic role can rely besides staging. Routine LND does not appear to yield benefit in RCC, especially in small renal masses when metastatic risk is really limited. Minimally invasive inguinal LND is still at its infancy even if has shown high potentiality to reduce wound complication rate.

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