Review

Robot-assisted retroperitoneal lymphadenectomy: The state of art

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Abstract *Objective:* To perform a narrative review about the role of robot-assisted retroperitoneal lymphadenectomy (R-RPLND) in the management of testicular cancer.
Methods: A PubMed search for all relevant publications regarding the R-RPLND series up until August 2019 was performed. The largest series were identified, and weighted means calculated for outcomes using the number of patients included in each study as the weighting factor.
Results: Fifty-six articles of R-RPLND were identified and eight series with more than 10 patients in each were included. The weighted mean age was 31.12 years; primary and post chemotherapy R-RPLND were performed in 50.59% and 49.41% of patients. The clinical stage was I, II and III in 47.20%, 39.57% and 13.23% of patients. A modified R-RPLND template was used in 78.02% of patients, while 21.98% underwent bilateral full template. The weighted mean node yield, operative time and estimated blood loss were, respectively, 22.15 nodes, 277.35 min and 131.94 mL. The weighted mean length of hospital stay was 2 days and antegrade ejaculation was preserved in 92.12% of patients. Major post-operative complications (Clavien III or IV) occurred in 5.34%. Positive pathological nodes were detected in 24.54%, while the recurrence free survival was 95.77% with a follow-up of 21.81 months.
Conclusion: R-RPLND has proven to be a reproducible and safe approach in experienced centers; short-term oncologic outcomes are similar to the open approach with less morbidity and shorter convalescence related to its minimal invasiveness. However, longer follow-up and new trials comparing head-to-head both techniques are expected.
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1. Introduction

Testicular germ-cell tumor (GCT) is the most common solid neoplasms in young male adults between 20 and 44 years old [1]. Although sometimes only the orchiectomy itself is sufficient for cure when there are risk factors associated with occult metastatic disease in clinical stage (CS) I, possible subsequent treatments may be required [2].

After the properly evolution of multimodal treatments, the overall survival rate achieved 98% [1]. Therefore, efforts have to be made in reducing morbidity and long-term toxicity for testicular cancer survivors [3].

Retroperitoneal lymph node dissection (RPLND) remains a complex and potentially morbid treatment option in the primary setting for low-stage (CS I and II) diseases and especially in residual masses after chemotherapy [2]. Open RPLND (O-RPLND) has been considered classically the gold standard for surgical management of the retroperitoneum, however, as in the other fields in urology, recently minimally invasive approaches have been described aiming to decrease the morbidity related to the procedure, especially in high experienced centers [4,5].

The first laparoscopic RPLND (L-RPLND) was performed in 1992, by Rukstalis and Chodak [6], and advantages in terms of peri-operative outcomes were described. Nevertheless, an extended learning curve and technically challenging procedure resulted in the limited adoption of L-RPLND worldwide [6,7]. Since the development of the robotic platform in the early 2000s and the improvement in movement freedom owing to the flexibility of the wristed instruments, in 2006, the first robot-assisted RPLND (R-RPLND) was described by Davol et al. at Geisinger Medical Center, Pennsylvania [8].

The rationale for a robotic-assisted approach to RPLND was the shortening of the learning curve, improvement in safety and reproducibility for this challenging procedure in high volume centers with experienced surgeons [8–10]. After this first description, both series of R-RPLND even in the primary R-RPLND (pR-RPLND) or post-chemotherapy setting (PC-R-RPLND) have already been published from experienced groups, showing its feasibility and safety by high volume and well-trained robotic surgeons [7,11–13].

A narrative review of R-RPLND outcomes is described next, focusing on the largest reports published so far.

2. Methods

We performed an electronic PubMed search for all relevant publications regarding outcomes and techniques of the R-RPLND up to August 2019. We used the keywords "robotic", "retroperitoneal lymph node dissection", and "testicular cancer". All single and multi-institutional R-RPLND studies in adults with testicular cancer were included and reviewed in addition to studies comparing outcomes from O-RPLND and L-RPLND. Eleven articles were excluded, as illustrated below in the diagram (Fig. 1).

After properly identification of the eight largest series reported up to date, which included more than 10 patients in each, the weighted means were calculated. Series from non-adult patients, R-RPLND from primary sites other than GCT were excluded. Although collaborative efforts between institutions may have occurred in different papers analyzed herein, we couldn't find out and split exactly the number of patients possible mixed in each series, which may represent a limitation of this review.

3. Results

3.1. Characteristics of patients, scenario and operative outcomes

We identified 56 articles regarding R-RPLND; detailed perioperative outcomes from the eight largest series (>10 patients) are described next and are summarized in Tables 1 and 2. Of note, the weighted means age was 31.12 years; primary and post-chemotherapy RPLNDs were performed in 50.59%, and 49.41% of patients analyzed in this review. The clinical stage was I, II, and III in 47.20%, 39.57%, and 13.23% of patients. A modified RPLND template was used in 78.02% of patients, while 21.98% underwent a full bilateral template. The weighted mean node yield, operative time (OT), and estimated blood loss (EBL) were, respectively, 22.15 nodes, 277.35 min, and 131.94 mL.

In the exclusively pR-RPLND setting, there were only two series that fulfilled the criteria inclusions. Pearce et al. [13] reported 47 patients submitted to pR-RPLND, while Harris et al. [14] described 16 consecutive pR-RPLND patients. Most of them were CS I and were mainly positioned in the flank; the robot was docked laterally during surgery; a modified template was performed in most pR-RPLND cases, even though achieving a median node yield of 26 and 30, respectively in these two series. Bleeding was minimal, median OT was 235 min, and 271 min; Pearce et al. [13] reported a median length of stay (LOS) of 1 day.

Mixed series by Stepanian et al. [10] and Cheney et al. [15] reported 16 (75%) and 11 (36%) from their patients submitted to pR-RPLND. While the first author changed patient position during surgery throughout the learning curve (resulting in more than half of his patients performing surgery in flank position), the second author carried out all procedures in the supine position with robot docked cranially. Stepanian et al. [10] performed a modified template in 14 (70%) of his patients, achieving a median node yield of 20, and Cheney et al. [15] did it in 7 (39%) of his patients, resulting in a mean node yield of 22. Bleeding was minimal in both series and the median OT reported was 293 min by the first author and 329 min by the last. While the first author presented a median LOS of 1 day, the second refereed a mean of 3 days.

Regarding the PC-R-RPLND scenario, there were four published series included herein, which were described by Overs et al. [16], Kamel et al. [17], Singh et al. [11] and Li et al. [18]. They reported, respectively, 11, 12, 13 and 30 patients in this setting, mainly in CS II (91%), 6 (50%), 13 (100%) and 19 (63%) patients. The remaining patients were all CS III. Patient position adopted was mostly flanked with robot docked laterally. Overs et al. [16] performed a modified template for all the patients, resulting in a
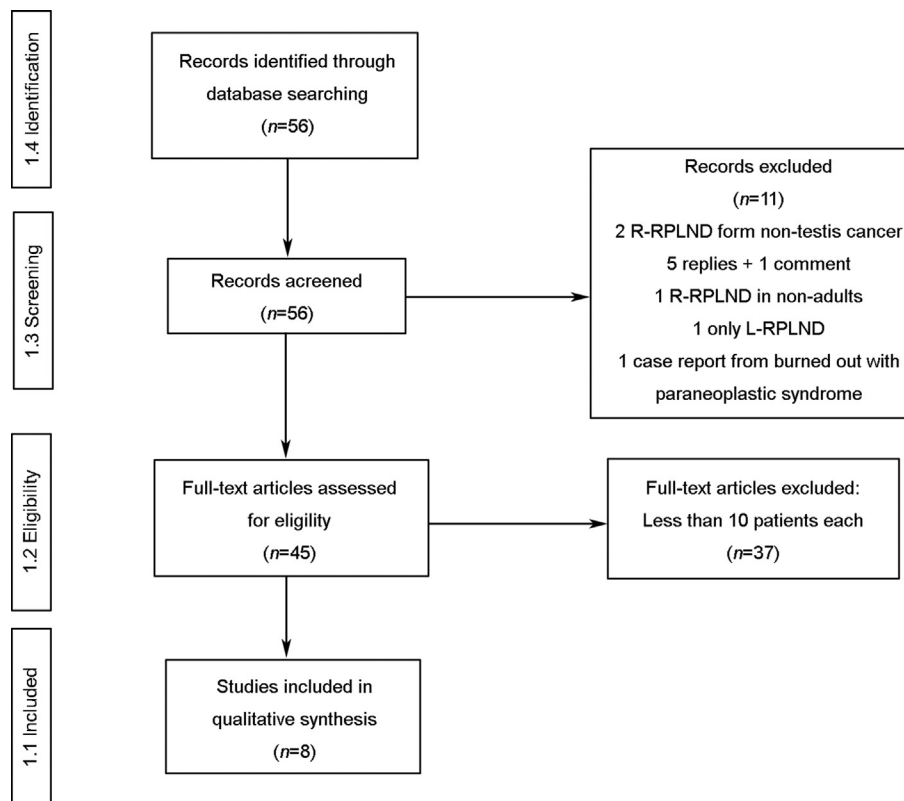
Figure 1   PRISMA 2009 Flow Diagram. R-RPLND, robot-assisted retroperitoneal lymphadenectomy; L-RPLND, laparoscopic retroperitoneal lymph node dissection; PRISMA, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. From: Moher D, Liberati A, Tetzlaff J, Altman DG, the PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6 (7): e1000097. https://doi.org/10.1371/journal.pmed1000097. For more information, visit http://www.prisma-statement.org/.

median node yield of 7; similarly, the remaining three series used a full bilateral template in less than half of patients.

Kamel et al. [17] reported a mean node yield of 12, while Singh et al. [11] and Li et al. [18] reported a median of 20 and 24, respectively. The first author explained that in half of the patients, a lymph node matted $\geq$5 cm was excised, and the pathologist referred difficult on counting, reporting it as lymph node mass. The mean OT reported by Overs et al. [16] and by Kamel et al. [17] was 150 min and 312 min, respectively, while Singh et al. [11] and Li et al. [18] reported median OT of 200 min and 372 min. Kamel et al. [17] recorded mean EBL of 475 mL, while Overs et al. [16], Singh et al. [11] and Li et al. [18] presented median EBL of 120 mL, 120 mL and 235 mL. Kamel et al. [17] reported mean LOS of three days. Overs et al. [16], Singh et al. [11], and Li et al. [18] presented median LOS of three, four and two days, respectively.

3.2. Complications

Combining the data of all eight series included in this review, the overall intra-operative and post-operative complications rates were 23.92%, 8.31%, and 15.19% (Table 3). In general, the most common complications were Clavien I-II, accounting eight cases of ileus, followed by three chylous ascites and two wound infection. From the Clavien III-IV complications, the most prevalent was chylous ascites (five cases).

3.2.1. Intra-operative complications

In the two largest series of pR-RPLND presented in this paper, there was only one patient in each that needed to be converted to open surgery due to aortic injury.

Considering the cohorts in both scenarios, pR-RPLND and PC-R-RPLND, Stepanian et al. [10] reported no conversion to open surgery at all; the authors reported a ureteral transection, which was immediately perceived and repaired robotically with a ureteroureterostomy over a double-J ureteral stent. This patient was properly followed, and a diuretic renogram was obtained at 6 weeks during the post-operative period demonstrated patency, with no evidence of obstruction. Cheney et al. [15] had three conversions. In two of them, the surgery was in the post-chemotherapy scenario, and the one pR-RPLND needed to be converted due to poor visualizations issues.

Finally, in the last four series that included only patients in a more challenging scenario of PC-R-RPLND, only Overs et al. [16] didn't report any intra-operative complication. Li et al. [18] reported one diaphragmatic lesion successfully managed robotically, one conversion to O-RPLND due to vascular injury, and the other two patients due to visualization issues. Singh et al. [11] presented one aortic injury managed with no conversion. Kamel et al. [17] also had one aortic injury fixed robotically, but also had one inferior mesenteric artery injury that required conversion to the open approach.

Table 1 Characteristics of patients and scenario from the largest series of R-RPLND with the weighted means calculated.

Scenario	Pearce et al., 2017 [13]	Harris et al., 2015 [14]	Stepanian et al., 2016 [10]	Cheney et al., 2015 [15]	Li et al., 2019 [18]	Singh et al., 2017 [11]	Kamel et al., 2016 [17]	Overs et al., 2018 [16]	Weighted means
	pR-RPLND		pR-RPLND and PC-R-RPLND		PC-R-RPLND				
Median age, years (IQR)	30 (26—38)	30 (25—38)	31	35 (23—39)	30 (26—36)	26 (21—37)	38 (20—55)	33 (22—49)	31.12
Number of patients	47	16	20	18	30	13	12	11	27.08
pR-RPLND n (%)	47 (100)	16 (100)	16 (75)	11 (36)	0	0	0	0	50.59%
PC-R-RPLND, n (%)	0	0	4 (25)	7 (64)	30 (100)	13 (100)	12 (100)	11 (100)	49.41%
cTNM Stage n (%)									
I	42 (89)	16 (100)	11 (55)	10 (56)	0	0	0	0	47.20%
II	5 (11)	0	6 (30)	7 (39)	19 (63)	13 (100)	6 (50)	10 (91)	39.57%
III	0	0	3 (15)	1 (6)	11 (37)	0	6 (50)	1 (9)	13.23%

IQR, interquartile range; RPLND, retroperitoneal lymph node dissection; PC-R-RPLND, post chemotherapy robotic RPLND; pR-RPLND, primary robotic RPLND; R-RPLND, robot-assisted RPLND.

Table 2 Operative outcomes from the eight largest series of R-RPLND with the weighted means calculated.

Scenario	Pearce et al., 2017 [13]	Harris et al., 2015 [14]	Stepanian et al., 2016 [10]	Cheney et al., 2015 [15]	Li et al., 2019 [18]	Singh et al., 2017 [11]	Kamel et al., 2016 [17]	Overs et al., 2018 [16]	Weighted means
	pR-RPLND		pR-RPLND and PC-R-RPLND		PC-R-RPLND				
Patient positioning-robot docking, n (%)									
Flank-lateral	42 (89)	16 (100)	11 (55)	0	30 (100)	12 (92)	6 (50)	11 (100)	76.52%
Supine-cranial	5 (11)[a]	0	9 (45)	18 (100)	0	1 (8)	6 (50)	0	23.48%
RPLND template, n (%)									
Modified	45 (96)	16 (100)	14 (70)	7 (39)	17 (57)	11 (85)	9 (75)	11 (100)	78.02%
Bilateral	2 (4)	0	6 (30)	11 (61)	13 (43)	2 (15)	3 (25)	0	21.98%
Node yield	26 (18—32)[b]	30 (23—36)[b]	20 (14—27)[b]	22 (10)[c]	24 (17—30)[b]	20[d]	12 (5—21)[e]	7 (1; 24)[f]	22.15
Operative time, min	235 (214—258)[b]	271 (236—299)[b]	293 (258—317)[b]	329 (40)[c]	372 (329—437)[b]	200[d]	312 (205—408)[e]	150 (45—300)[e]	277.35
Estimated blood loss, mL,	50 (50—100)[b]	75 (50—100)[b]	50 (50—100)[b]	103 (78)[c]	235 (160—300)[b]	120[d]	475 (50—1 800)[e]	120 (5—300)[f]	131.94
Length of stay, day	1 (1—1)[b]	NR	1 (1—2)[b]	3 (2.3)[c]	2[d]	4 (3—5)[b]	3 (2—5)[e]	3 (2—4)[f]	2.00

RPLND, retroperitoneal lymph node dissection; PC-R-RPLND, post chemotherapy robotic RPLND; pR-RPLND, primary robotic RPLND; R-RPLND, robot-assisted RPLND; NR, not reported.
[a] Over left shoulder.
[b] Median (interquartile range).
[c] Mean (standard deviation).
[d] Only median reported.
[e] Mean and range.
[f] Median and range.

3.2.2. Post-operative complications

In the pR-RPLND series, Pearce et al. [13] reported 2 (4%) major post-operative complications (Clavien III-IV), one of them with body wall hematoma that required intervention and the other with chylous ascites that needed to be drained by a single paracentesis.

In the PC-R-RPLND series, Li et al. [18] described 3 (10%) patients that required intervention: One case of chylous ascites, one pneumothorax, and another one that evolved with colon ischemia, perforation, and multiple organ failure attributed to the inferior mesenteric artery ligation. No deaths were reported. Singh et al. [11] highlighted their higher incidence of chylous ascites and speculated two possible explanations. First, authors argued that they didn't leave the patients on a low-fat diet in the immediate post-operative period; second, the higher incidence could be because of less use of suture and clip during lymphatic dissection,

Table 3 Complications from the largest series of R-RPLND with the weighted means calculated.

Scenario	Pearce et al., 2017 [13]	Harris et al., 2015 [14]	Stepanian et al., 2016 [10]	Cheney et al., 2015 [15]	Li et al., 2019 [18]	Singh et al., 2017 [11]	Kamel et al., 2016 [17]	Overs et al., 2018 [16]	Weighted means
	pR-RPLND		pR-RPLND and PC-R-RPLND		PC-R-RPLND				
Complications									
Overall, *n* (%)	6 (13)	1 (6)	1 (5)	6 (33)	10 (33)	10 (77)	5 (42)	1 (9)	23.92%
Trans-operative, *n* (%)	2 (4)	1 (6)	1 (5)	3 (17)	4 (13)	1 (8)	2 (17)	0	8.31%
Injury, no conversion	1 pancreatic	0	1 ureter	0	1 diaphragmatic	1 aortic	1 aortic	0	NA
Conversion, *n* (%)	1 (2)	1 (6)	0	3 (17)	3 (10)	0	1 (8)	0	5.34%
Reason	1 aortic injury	1 aortic injury	0	1 robotic malfunction 1 poor exposure 1 risk of bleeding	2 poor visualization 1 vascular injury	0	1 inferior mesenteric artery injury	0	NA
Post-operative, ≤90 day, *n* (%)	4 (9)	0	0	3 (17)	6 (20)	9 (69)	3 (25)	1 (9)	15.19%
Clavien-Dindo I—II	1 chylous ascites 1 ileus	0	0	1 ileus 1 transfusion 1 hyperkalemia	2 wound infection 1 delirium tremens	5 ileus 1 chylous ascites	1 ileus 1 neuropathy in the upper limb	1 chylous ascites	9.80%
Clavien-Dindo III—IV	1 chylous ascites 1 body wall hematoma	0	0	0	1 chylous ascites 1 colon perforation leading to multiple organ failure 1 pneumothorax	3 chylous ascites	1 aortic pseudoaneurysm repaired by endovascular technique	0	5.39%

NA, not applicable; RPLND, retroperitoneal lymph node dissection; PC-R-RPLND, post chemotherapy robotic RPLND; pR-RPLND, primary robotic RPLND; R-RPLND, robot-assisted RPLND.

Table 4 Functional and oncological outcomes from the largest series of R-RPLND with the weighted means calculated.

Scenario	Pearce et al., 2017 [13]	Harris et al., 2015 [14]	Stepanian et al., 2016 [10]	Cheney et al., 2015 [15]	Li et al., 2019 [18]	Singh et al., 2017 [11]	Kamel et al., 2016 [17]	Overs et al., 2018 [16]	Weighted means
	pR-RPLND		pR-RPLND and PC-R-RPLND		PC-R-RPLND				
Antegrade ejaculation, n (%)									
No	0	0	2 (10)	1 (9)[d]	0	2 (15)	1 (10)[f]	1 (11)[f]	NA
Yes	44 (94)	16 (100)	18 (90)	10 (91)[d]	0	11 (85)	9 (90)[f]	8 (89)[f]	92.12%
Unknown	3 (6)	0	0	0	30 (100)	0	2 (17)	2 (18)	NA
Patients pN+[a], n (%)	8 (17)	2 (13)	8 (42)	8 (44)	5 (17)	3 (23)	5 (46)	1 (9)[g]	24.54%
Adjuvant chemotherapy (if pN+), n (%)									
No	3 (38)	NR	18 (90)	16 (89)	3 (17)	13 (100)	0	11 (100)	NA
Yes	5 (62)	NR	2 (10)	2 (11)	2 (7)	0	1 (8)	0	23.96%
Recurrence									
In-field recurrence, n	0	NR	0	0	0	0	0	0	NA
RFS[b], %	97	NR	100	89	90	100	100	100	95.77
Follow-up, month	16 (9—23)[c]	NR	49 (37—71)[c]	22 (1—58)[c]	15 (1—51)[e]	23 (3—58)[e]	31 (5—39)[e]	4 (1—48)[e]	21.81

NA, not applicable; NR, not reported; RPLND, retroperitoneal lymph node dissection; PC-R-RPLND, post chemotherapy robotic RPLND; pR-RPLND, primary robotic RPLND; R-RPLND, robot-assisted RPLND.

[a] Patients with positive nodes in final pathology.
[b] Recurrence free survival.
[c] Median (interquartile range).
[d] There were only 11 patients submitted to nerve sparing.
[e] Median (range).
[f] Rates in the patients whose ejaculation status was assessed.
[g] Authors didn't consider teratoma as pNt in this paper.

besides the difficulties of proper identification of lymphatic channels in the post-chemotherapy scenario. Kamel et al. [17] described a Clavien III in the post-operative period. It was a patient with residual mass from a seminoma that, during the surgery, had an aortic injury. He evolved with an aortic pseudoaneurysm in the post-operative period that needed to be endovascular repaired. Overs et al. [16] reported no major complications.

3.3. Functional and oncological outcomes

Functional and oncological outcomes are illustrated in Table 4. The antegrade ejaculation rates, pathological positive nodes rates (pN+), the performance of adjuvant chemotherapy, recurrence-free survival (RFS), and follow-up were, respectively, 92.12%, 24.54%, 23.96%, 95.77% in 21.81 months. Of note, pN+ detailing between teratoma or other GCT wasn't always recorded specifically by all the authors, whenever described we explained into the text.

In the setting of pR-RPLND, Pearce et al. [13] informed that nerve sparing was based on surgeon preference and achieved antegrade ejaculation in 44 (94%) patients, while the remaining three could not be assessed. Adjuvant chemotherapy was performed in 5 of 8 (62%) patients with pN+; the three other patients were managed with surveillance, and none had recurred up to a median follow-up of 6 months. No great details about the histology of pN+ were recorded, besides that one patient pN2 managed with surveillance had embryonal carcinoma with the largest node 2.1 cm. Only one patient that was receiving adjuvant chemotherapy had a pelvic relapse, outside of the template of dissection, 8 months after the pR-RPLND. It was resected (teratoma), and the patient remained disease-free up to 9 months after the last surgery. Harris et al. [14] employed nerve sparing surgery for all their patients and reached 100% of their patients with no issues regarding ejaculation. Also, they found 2 (13%) with pN+, one embryonal and one teratoma. They didn't report any data regarding adjuvant chemotherapy, neither oncological outcomes.

Mixed series (pR-RPLND and PC RPLND) by Stepanian et al. [10] and Cheney et al. [15] reported nerve sparing surgery in 20 (100%) and 11 (61%) of their patients, achieving antegrade ejaculation, respectively in 18 (90%) and 10 (91%) patients. Both series presented eight patients with pN+; the first author presented three patients with teratoma and five with embryonal carcinoma, while the second author didn't recorded details regarding the histology of the nodes. Only two patients in each series were managed with adjuvant chemotherapy, Stepanian et al. [10] referred one patient due to pathological stage IIC and the other developed lung recurrence at 4 months after surgery. Cheney et al. [15] referred both patients with lung recurrence to four cycles of bleomycin, etoposide and cisplatin, with complete response. The first author reported RFS of 100% in a median follow-up of 49 months, while the second 89% in 22 months.

Regarding the PC-R-RPLND series, Li et al. [18] and Kamel et al. [17] didn't reported the rates from nerve sparing technique, although the last author recorded modified template in 9 (75%) patients and antegrade ejaculation in 9 (90%). Similarly, Overs et al. [16] reported only modified template in their series, achieving antegrade ejaculation in 8 (89%) patients. While Singh et al. [11] performed nerve sparing in all their patients independently of template with antegrade ejaculation in 11 (85%). Patients presenting pN+ by Li et al. [18] were 5 (17%), however no histology details were reported. Singh et al. [11] reported 3 (23%) patients with teratoma. Kamel et al. [17] reported 5 (46%) patients, 4 with teratoma and 1 with viable GCT; and finally Overs et al. [16] reported only 1 (9%) patient with GCT. From the patients presenting pN+—Highlighting that some authors didn't differentiated teratoma from other viable GCT tumor—Only 2 (7%) patients from Li et al. [18] series and 1 (8%) from Kamel et al. [17] required additional cycles of chemotherapy. Li et al. [18] reported two of three patients presenting distant recurrence after a desperation PC-RPLND that revealed viable GCT in the retroperitoneum. The other patient presented pulmonary recurrence despite being submitted initially to lobectomy at the same time as the PC-R-RPLND. Rates from RFS in these series were reported as follows, 90% in a median of 15 months, 100% in 23 months, 100% in 31 months, and 100% in 4 months, respectively.
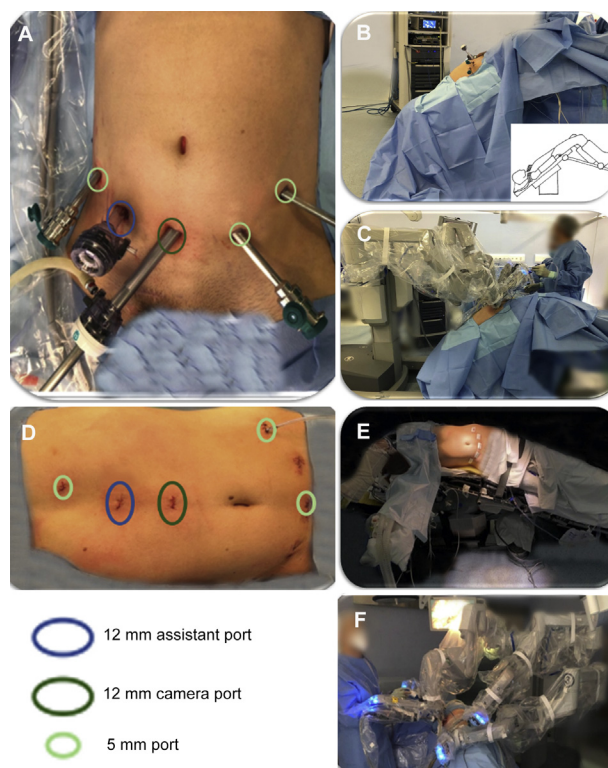

Figure 2 Supine position and docking and flank position and docking. (A) Trocar placement; (B) Patient positioning; (C) Robot docking; (D) Supine; (E) Flank decubitus; (F) The doctors were performing R-RPLND. R-RPLND, robot-assisted retroperitoneal lymphadenectomy.
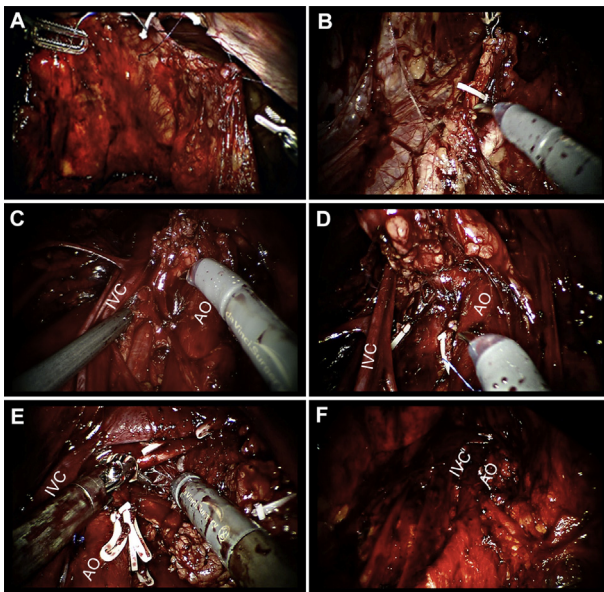
Figure 3 Trans-operative relevant moments of RPLND in supine position. (A) Peritoneum suspension in abdominal wall to begin dissection and access the retroperitoneum; (B) Beginning of paracaval template, above the ureter cross the right iliac artery; (C) Precaval, preaortic, interaortocaval and retrocaval template with identification and sparing of postganglionic sympathetic nerve fibers (crossing between the IVC and AO); (D) Interaortocaval and retrocaval dissection reaching the right superior boundaries of the template (right renal hilum); (E) Preaortic and paraortic superior boundaries reaching the left renal hilum; (F) Final template showing the retroperitoneum vessels. AO, aorta; IVC, inferior vena cava; RPLND, retroperitoneal lymph node dissection.

Besides all these encouraging results presented in this paper, there was one recent report of adverse oncologic outcomes of five patients submitted to R-RPLND. One patient had an in-field recurrence located beside undivided lumber vessel while the four others presented with abnormal patterns such as invading sigmoid colon, peritoneal carcinomatosis with perinephric mass, large-volume liver lesions with suprahilar disease extending into retrocrural space, and lymph nodes in the celiac axis. All of them were managed with different chemotherapy regimens and three of them required additional surgeries. One patient died from the disease progression despite all the efforts [19]. However, we believe that those adverse outcomes are related to poor surgical technique; those procedures were performed by low volume surgeons in low volume centers. If the oncological principles are followed during surgery, including adequate templates and removal of nodal masses without violation, the outcomes of robotic RPLND are similar to the open counterpart, as shown by the series included in this paper.

4. Discussion

The pure laparoscopic approach to RPLND has been correlated, since its first description, with clear benefits in terms of peri-operative recovery. However, widespread adoption of this approach, even in the other fields of urology, has limited due to the technical challenges and the need for extensive training in laparoscopic surgery [19—22].

The robotic approach to RPLND was subsequently described to reach the same oncologic efficacy of O-RPLND while minimizing the morbidity associated with the procedure and decreasing the long learning curve related to the pure laparoscopic technique [6,8—10]. The robotic approach, with better ability from the wristed instruments, facilitates the control and suturing of the great vessels in case of injury, clearly improving the safety of the procedure [1]. As a result, multiple series of R-RPLND have been successfully reported recently in multiple experienced centers around the world, showing the potential of this surgical approach to increase the number of well-trained surgeons performing minimally invasive RPLND [10,11,13—18]. Even challenging cases as bulky CS III disease with concomitant inferior vena cava thrombectomy for metastatic GCT have already been managed successfully with a robotic approach by high-volume surgeons [23—27]. With regards to patient positioning, the initial series described the R-RPLND approach with the patient in flank position and trocar placement and docking similar to a partial nephrectomy [4]. The most important benefit of this position includes the familiarity of most urologists with the retroperitoneal anatomy using this lateral approach. However, in most patients this positioning only allows the performance of modified template which is not adequate especially in the post chemotherapy setting; the patient usually has to be repositioned in order to remove the contralateral nodes while preserving the postganglionic sympathetic fibers.

Stepanian et al. [10] and Cheney et al. [15] described a modification of the technique; in this approach, the patient is placed on a supine position, and trocars are placed in the lower abdomen. A peritoneal incision is performed, and the retroperitoneal space is exposed, similar to an open RPLND. The major advantage of this approach is the possibility to perform a full bilateral dissection with no need to reposition the patient neither redock the robot. However, it is the author's opinion that for masses around the renal hilum, especially in the postchemotherapy setting, a flank approach allows better exposure and control of the renal vessels. Multiple series adopting the supine approach have been recently published with encouraging results [11,13,15,17,28]. Of note, the removal of the ipsilateral spermatic cord can be easily done with the da Vinci Xi using the supine technique without the need of redocking the robot [10,29]. For illustration purpose, we report herein patient position, trocar placement and robot docking from a patient who was submitted to R-RPLND due to a NSGCT (non-seminoma GCT) by the last author from this paper, a very experienced and large volume robotic surgeon. The procedure was initiated in supine position and posteriorly repositioned in right flank decubitus to complete the tumor resection that extended largely to the left supra-hilar region (Fig. 2). Also, trans-operative photos from this surgery are recorded in Fig. 3 and a schematic illustration of the templates are depicted in Fig. 4.

pR-RPLND is an option for patients with a high risk of microscopic metastases or patients who are at risk of
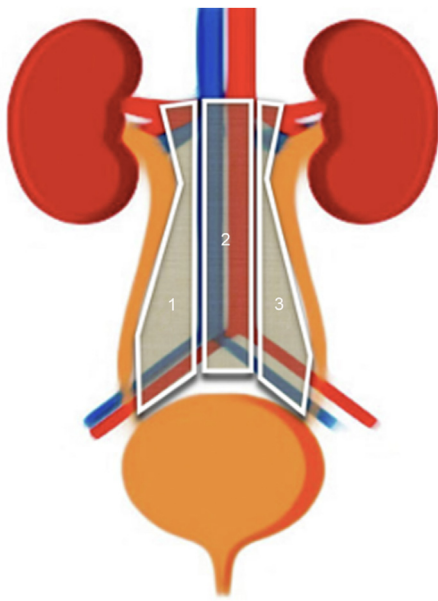
Figure 4 Schematic templates and boundaries for retroperitoneal lymphadenectomy. 1. Boundaries of paracaval template (superior: Right renal hilum including dissection of renal arteries; lateral: Right ureter; medial: Interaortocaval template; inferior: Right ureter crossing the right iliac vessels. 2. Boundaries of interaortocaval, precaval, retrocaval, preaortic and retroaortic templates (superior: Renal vessels; lateral: Paracaval and paraortic templates; inferior: Aorta bifurcation. 3. Boundaries of paraaortic template (superior: Left renal hilum including dissection of renal arteries; lateral: Left ureter; inferior: Left ureter crossing the left iliac vessels [laterally]).

noncompliance with the follow-up [30]. While it can be overtreatment for some patients, around 25%—35% of patients will harbor occult metastatic disease in retroperitoneum without radiographic evidence [31]. However, in many reference centers around the world, RPLND has been replaced by chemotherapy in high-risk NSGCT due to the high morbidity of open RPLND, including blood transfusion, injuries of adjacent organs, ileus, chylous ascites and long convalescence period [32]. Since the randomized phase III trial comparing p-RPLND as the primary treatment versus BEPx1, the role of surgery in this setting has diminished due to better RFS (99.5% *vs.* 91.0%) provided by the clinical treatment with lower rates of complications [33]. Besides that, surgery could avoid the long-term toxicities of chemotherapy such as nephrotoxicity and cardiotoxicity, decrease infertility and even the risk of second malignancies [34—39]. Still, surveillance is another option that prevents adverse effects and can be offered to select patients who are compliant with the treatment, since salvage treatment in those who relapse presents high cancer specific survival [2]. R-RPLND has the potential to rescue the role of surgery in the primary treatment of high-risk NSGCT by minimizing complications and shortening the recovery period, but it should be considered to be done in high-volume centers by experienced surgeons [40,41].

Peri-operative outcomes described in Table 2 showed weighted means regarding EBL and LOS of 131.94 mL and 2

days, respectively, while reports from a contemporary O-RPLND series recorded mean EBL of 294 mL and LOS of 4 days [42]. Those results illustrate perhaps the most notable advantages of R-RPLND, which are the shorter convalescence period, less bleeding, less ileus, and less post-operative pain at higher costs and OT [12,43]. Of note, oncologic outcomes do not seem to be compromised by the minimally invasive technique. Also, the node yield, which usually reflects the effectiveness of oncologic surgery, presented a weighted mean of 22.15 nodes in our review and was comparable with recent publications on the O-RPLND series that reported a median 28 [19—38] nodes removed [41,44].

Complications from RPLND vary according to scenario (primary or post-chemo) and are distributed in Table 3. Surgery in the PC-RPLND setting is far more complex because of the high adhesions of tissues due to desmoplastic reactions induced by chemotherapy, with no clear dissection plan. Generally, bleeding and complications are higher. Therefore, it is not unusual to perform adjunctive procedures in these patients, such as organ (kidney, bowel, and spleen) resections or vascular (inferior vena cava and aorta) reconstructions [16,32,45]. It was observed inadvertent injuries in three from the four largest series included in this setting, although almost all of them were repaired robotically. The conversion was needed only in 4 from these 66 patients (6%), while one of the largest series of L-RPLND in this setting reported a rate of 12% [46]. Of note, complications Clavien III—IV occurred in only 7 (11%) patients in PC-R-RPLND, similarly reported previously in the same laparoscopic series in this context with a rate of 8% and with 6% in an open series [32]. However, high volume centers already reported much lower of complications from RPLND, such as a British multicenter series with 162 patients who underwent mostly to O-RPLND [47]. The highest complication grade reported was IIIb (no patient died within 30 days from surgery) in only 1.5% of patients, while the overall complication rate was 9%. One possible explanation to these better outcomes is that very well-trained surgeons in high volume centers tend to present greater outcomes, independently of the technique employed [48].

As demonstrated in Table 4, antegrade ejaculation with pR-RPLND was preserved in almost all patients (97%) included in this review; in the post-chemotherapy scenario, R-RPLND could preserve rates around 90% also from the series that reported it. Similar results were reported in one extraperitoneal O-RPLND series with more than 90% of patients presenting antegrade ejaculation and in another series through the classical open technique preserving it in 80% of the patients [49,50]. However, in a large recent O-RPLND series, which included near 100 patients in each pre- and post-chemotherapy setting, antegrade ejaculation was preserved in 80% and 41% only, respectively [32]. These findings call attention to better results when the procedure is done by high volume centers with very experienced surgeons. An alternative to achieve even better functional results is to perform modified templates, which also carries out lower complications rates, as showed recently even with O-RPLND in the post-chemotherapy setting, reaching 94% of patients with antegrade ejaculation [51]. Therefore, possibly the

magnification of the robotic approach may facilitate the identification and preservation of the postganglionic sympathetic fibers. Finally, the weighted means of RFS was 95.77% in a short follow-up of 21.81 months. Data from a large series of O-RPLND including more than 700 patients in the post-chemotherapy scenario showed RFS of 87%. Therefore, with short to intermediate follow-up, R-RPLND seems to have similar results to its open counterpart.

The robotic approach should unquestionably mimic the O-RPLND classic steps respecting the oncologic principles. Mainly in the PC-R-RPLND setting, it is crucial to follow the boundaries of dissection. Therefore, this approach should be performed only by well-trained robotic surgeons in this challenging scenario. When done correctly, it's possible to expect such good oncologic outcomes as the open approach with even better results in terms of EBL and LOS [12,43]. Analysis of a more extensive follow-up from these series and head-to-head trials are expected to determine the role of robotic in this pathology.

5. Conclusion

R-RPLND has proven to be a reproducible and safe approach in the treatment of testicular cancer by experienced surgeons; short-term oncologic outcomes are similar to the open counterpart, with less morbidity and shorter convalescence period due to minimally invasiveness, improved tridimensional image and dexterity afforded by the robotic system. However, longer follow-up and new trials comparing head-to-head with O-RPLDN are expected.

Authors contribution

Study design: Giuliano B. Guglielmetti, Rafael F. Coelho, Gilberto J. Rodrigues.
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Data analysis: Marcelo Orvieto, Gilberto J. Rodrigues.
Drafting of manuscript: Gilberto J. Rodrigues, Kulthe Ramesh Seetharam Bhat.
Critical revision of the manuscript: Giuliano B. Guglielmetti, Vipul R. Patel.

Conflicts of interest

The authors declare no conflict of interest.

References

[1] Schwen ZR, Gupta M, Pierorazio PM. A review of outcomes and technique for the robotic-assisted laparoscopic retroperitoneal lymph node dissection for testicular cancer. Adv Urol 2018;2018:2146080. https://doi.org/10.1155/2018/2146080.

[2] Laguna MP, Albers P, Algaba F, Bokemeyer C, Boormans JL, Fischer S, et al. EAU guidelines: testicular cancer. [Accessed 2 September 2019]. https://uroweb.org/guideline/testicular-cancer/.

[3] Ahluwalia P, Gautam G. Current concepts in management of stage I NSGCT. Indian J Surg Oncol 2017;8:51—8.

[4] Williams SB, Lau CS, Josephson DY. Initial series of robot-assisted laparoscopic retroperitoneal lymph node dissection for clinical stage I nonseminomatous germ cell testicular cancer. Eur Urol 2011;60:1299—302.

[5] Rassweiler JJ, Teber D. Advances in laparoscopic surgery in urology. Nat Rev Urol 2016;13:387—99.

[6] Rukstalis DB, Chodak GW. Laparoscopic retroperitoneal lymph node dissection in a patient with stage 1 testicular carcinoma. J Urol 1992;148:1907—10.

[7] İslamoğlu E, Özsoy Ç, Anıl H, Aktaş Y, Ateş M, Savaş M. Post-chemotherapy robot-assisted retroperitoneal lymph node dissection in non-seminomatous germ cell tumor of testis: feasibility and outcomes of initial cases. Turk J Urol 2018;45: 113—7.

[8] Davol P, Sumfest J, Rukstalis D. Robotic-assisted laparoscopic retroperitoneal lymph node dissection. Urology 2006;67:199. https://doi.org/10.1016/j.urology.2005.07.022.

[9] Pugin F, Bucher P, Morel P. History of robotic surgery: from AESOP® and ZEUS® to da Vinci®. J Visc Surg 2011;148(5 Suppl):e3—8. https://doi.org/10.1016/j.jviscsurg.2011.04.007.

[10] Stepanian S, Patel M, Porter J. Robot-assisted laparoscopic retroperitoneal lymph node dissection for testicular cancer: evolution of the technique. Eur Urol 2016;70:661—7.

[11] Singh A, Chatterjee S, Bansal P, Bansal A, Rawal S. Robot-assisted retroperitoneal lymph node dissection: feasibility and outcome in postchemotherapy residual mass in testicular cancer. Indian J Urol 2017;33:304—9.

[12] Mittakanti HR, Porter JR. Robotic retroperitoneal lymph node dissection for testicular cancer: feasibility and latest outcomes. Curr Opin Urol 2019;29:173—9.

[13] Pearce SM, Golan S, Gorin MA, Luckenbaugh AN, Williams SB, Ward JF, et al. Safety and early oncologic effectiveness of primary robotic retroperitoneal lymph node dissection for nonseminomatous germ cell testicular cancer. Eur Urol 2017; 71:476—82.

[14] Harris KT, Gorin MA, Ball MW, Pierorazio PM, Allaf ME. A comparative analysis of robotic *vs.* laparoscopic retroperitoneal lymph node dissection for testicular cancer. BJU Int 2015; 116:920—3.

[15] Cheney SM, Andrews PE, Leibovich BC, Castle EP. Robot-assisted retroperitoneal lymph node dissection: technique and initial case series of 18 patients. BJU Int 2015;115: 114—20.

[16] Overs C, Beauval JB, Mourey L, Rischmann P, Soulié M, Roumiguié M, et al. Robot-assisted post-chemotherapy retroperitoneal lymph node dissection in germ cell tumor: is the single-docking with lateral approach relevant? World J Urol 2018;36:655—61.

[17] Kamel MH, Littlejohn N, Cox M, Eltahawy EA, Davis R. Post-chemotherapy robotic retroperitoneal lymph node dissection: institutional experience. J Endourol 2016;30:510—9.

[18] Li R, Duplisea JJ, Petros FG, González GMN, Tu S-M, Karam JA, et al. Robotic postchemotherapy retroperitoneal lymph node dissection for testicular cancer. Eur Urol Oncol 2019; S2588—9311:30015—X. https://doi.org/10.1016/j.euo.2019.01.014.

[19] Calaway AC, Einhorn LH, Masterson TA, Foster RS, Cary C. Adverse surgical outcomes associated with robotic retroperitoneal lymph node dissection among patients with testicular cancer. Eur Urol 2019;76:607—9.

[20] Bhayani SB, Allaf ME, Kavoussi LR. Laparoscopic RPLND for clinical stage I nonseminomatous germ cell testicular cancer: current status. Urol Oncol 2004;22:145—8.

[21] Schwartz MJ, Kavoussi LR. Controversial technology: the Chunnel and the laparoscopic retroperitoneal lymph node dissection (RPLND). BJU Int 2010;106:950—9.

[22] Abboudi H, Khan MS, Guru KA, Froghi S, de Win G, Van Poppel H, et al. Learning curves for urological procedures: a systematic review. BJU Int 2014;114:617—29.

[23] Torricelli FCM, Jardim D, Guglielmetti GB, Patel V, Coelho RF. Robot-assisted laparoscopic retroperitoneal lymph node dissection in testicular tumor. Int Braz J Urol 2017;43:171. https://doi.org/10.1590/S1677-5538.IBJU.2015.0436.

[24] Lee SH, Kim DS, Chang S-G, Jeon SH. Robot-assisted laparoscopic retroperitoneal lymph node dissection for stage IIIb mixed germ cell testicular cancer after chemotherapy. J Urol 2015;56:540—4.

[25] Zhang K, Zhu G, Liu X, Tian J, Gu Y, Zhai M, et al. Robot-assisted laparoscopic retroperitoneal lymph node dissection with concomitant inferior vena cava thrombectomy for metastatic mixed testicular germ cell cancer: a case report. J Med Case Rep 2019;13:272. https://doi.org/10.1186/s13256-019-2200-y.

[26] Patel HD, Mullins JK, Pierorazio PM, Jayram G, Cohen JE, Matlaga BR, et al. Trends in renal surgery: robotic technology is associated with increased use of partial nephrectomy. J Urol 2013;189:1229—35.

[27] Pierorazio PM, Patel HD, Feng T, Yohannan J, Hyams ES, Allaf ME. Robotic-assisted versus traditional laparoscopic partial nephrectomy: comparison of outcomes and evaluation of learning curve. Urology 2011;78:813—9.

[28] Tamhankar AS, Patil SR, Ojha SP, Ahluwalia P, Gautam G. Therapeutic supine robotic retroperitoneal lymph node dissection for post-chemotherapy residual masses in testicular cancer: technique and outcome analysis of initial experience. J Robot Surg 2019;13:747—56.

[29] Stephenson AJ, Klein EA. Surgical management of low-stage nonseminomatous germ cell testicular cancer. BJU Int 2009; 104:1362—8.

[30] Beck SD, Foster RS, Bihrle R, Ulbright T, Koch MO, Wahle GR, et al. Teratoma in the orchiectomy specimen and volume of metastasis are predictors of retroperitoneal teratoma in post-chemotherapy nonseminomatous testis cancer. J Urol 2002; 168:1402—4.

[31] Fernandez EB, Moul JW, Foley JP, Colon E, McLeod DG. Retroperitoneal imaging with third and fourth generation computed axial tomography in clinical stage I non-seminomatous germ cell tumors. Urology 1994;44:548—52.

[32] Subramanian VS, Nguyen CT, Stephenson AJ, Klein EA. Complications of open primary and post-chemotherapy retroperitoneal lymph node dissection for testicular cancer. Urol Oncol 2010;28:504—9.

[33] Albers P, Siener R, Krege S, Schmelz H-U, Dieckmann K-P, Heidenreich A, et al. Randomized phase III trial comparing retroperitoneal lymph node dissection with one course of bleomycin and etoposide plus cisplatin chemotherapy in the adjuvant treatment of clinical stage I Nonseminomatous testicular germ cell tumors: AUO trial AH 01/94 by the German Testicular Cancer Study Group. J Clin Oncol 2008; 26:2966—72.

[34] Fosså SD, Aass N, Winderen M, Börmer OP, Olsen DR. Long-term renal function after treatment for malignant germ-cell tumours. Ann Oncol 2002;13:222—8.

[35] Meinardi MT, Gietema JA, van der Graaf WT, van Veldhuisen DJ, Runne MA, Sluiter WJ, et al. Cardiovascular morbidity in long-term survivors of metastatic testicular cancer. J Clin Oncol 2000;18:1725—32.

[36] Huddart RA, Norman A, Shahidi M, Horwich A, Coward D, Nicholls J, et al. Cardiovascular disease as a long-term complication of treatment for testicular cancer. J Clin Oncol 2003;21:1513—23.

[37] Nuver J, Smit AJ, van der Meer J, van den Berg MP, van der Graaf WTA, Meinardi MT, et al. Acute chemotherapy-induced cardiovascular changes in patients with testicular cancer. J Clin Oncol 2005;23:9130—7.

[38] van den Belt-Dusebout AW, de Wit R, Gietema JA, Horenblas S, Louwman MWJ, Ribot JG, et al. Treatment-specific risks of second malignancies and cardiovascular disease in 5-year survivors of testicular cancer. J Clin Oncol 2007;25:4370—8.

[39] Brydøy M, Fosså SD, Klepp O, Bremnes RM, Wist EA, Wentzel-Larsen T, et al. Paternity following treatment for testicular cancer. J Natl Cancer Inst 2005;97:1580—8.

[40] Katz MH, Eggener SE. The evolution, controversies, and potential pitfalls of modified retroperitoneal lymph node dissection templates. World J Urol 2009;27:477—83.

[41] Rassweiler JJ, Scheitlin W, Heidenreich A, Laguna MP, Janetschek G. Laparoscopic retroperitoneal lymph node dissection: does it still have a role in the management of clinical stage I nonseminomatous testis cancer? A European perspective. Eur Urol 2008;54:1004—15.

[42] Williams SB, McDermott DW, Winston D, Bahnson E, Berry AM, Steele GS, et al. Morbidity of open retroperitoneal lymph node dissection for testicular cancer: contemporary perioperative data. BJU Int 2010;105:918—21.

[43] Werntz RP, Pearce SM, Eggener SE. Indications, evolving technique, and early outcomes with robotic retroperitoneal lymph node dissection. Curr Opin Urol 2018;28:461—8.

[44] Nayan M, Jewett MAS, Sweet J, Anson-Cartwright L, Bedard PL, Moore M, et al. Lymph node yield in primary retroperitoneal lymph node dissection for nonseminoma germ cell tumors. J Urol 2015;194:386—91.

[45] Macleod LC, Rajanahally S, Nayak JG, Parent BA, Ramos JD, Schade GR, et al. Characterizing the morbidity of postchemotherapy retroperitoneal lymph node dissection for testis cancer in a national cohort of privately insured patients. Urology 2016;91:70—6.

[46] Calestroupat J-P, Sanchez-Salas R, Cathelineau X, Rozet F, Galiano M, Smyth G, et al. Postchemotherapy laparoscopic retroperitoneal lymph node dissection in nonseminomatous germ-cell tumor. J Endourol 2009;23:645—50.

[47] Wells H, Hayes MC, O'Brien T, Fowler S. Contemporary retroperitoneal lymph node dissection (RPLND) for testis cancer in the UK—a national study. BJU Int 2017;119:91—9.

[48] Woldu SL, Matulay JT, Clinton TN, Singla N, Krabbe L-M, Hutchinson RC, et al. Impact of hospital case volume on testicular cancer outcomes and practice patterns. Urol Oncol 2018;36:e7—15. https://doi.org/10.1016/j.urolonc.2017.08.024. 14.

[49] Pettus JA, Carver B, Masterson T, Stasi J, Sheinfeld J. Preservation of ejaculation in patients undergoing nerve-sparing post-chemotherapy retroperitoneal lymph node dissection for metastatic testicular cancer. Urology 2009;73:328—32.

[50] Syan-Bhanvadia S, Bazargani ST, Clifford TG, Cai J, Miranda G, Daneshmand S. Midline extraperitoneal approach to retroperitoneal lymph node dissection in testicular cancer: minimizing surgical morbidity. Eur Urol 2017;72:814—20.

[51] Hiester A, Nini A, Fingerhut A, Große Siemer R, Winter C, Albers P, et al. Preservation of ejaculatory function after postchemotherapy retroperitoneal lymph node dissection (PC-RPLND) in patients with testicular cancer: template vs. bilateral resection. Front Surg 2019;5:80. https://doi.org/10.3389/fsurg.2018.00080.