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Teaching Advanced Surgical Technique Using Peer-Reviewed Multimedia: An Assessment of Technical Competence in Cadaveric-Based Simulation

Pocharapong Jenjitranant, *The University of Western Ontario*

Supervisor: Power, Nicholas E., *The University of Western Ontario*
Co-Supervisor: Beveridge, Tyler S., *The University of Western Ontario*
Co-Supervisor: Huynh, Melissa, *The University of Western Ontario*
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Abstract

Nerve-sparing retroperitoneal lymph node dissection (RPLND) is a rare and complex surgical procedure to which trainees have limited exposure. We created expert-designed and led video learning material to teach RPLND. 10 urology trainees were tasked with performing one-half (unilateral portion) of a nerve-sparing RPLND on human cadavers before and after watching this video. Their surgical performance was quantitatively assessed as well as video-recorded for further qualitative assessment by a blinded expert surgeon.

All measurements showed significant improvement after exposure to a training intervention. This included the percentage of lymph node mass resected, mean total OSATS global rating and procedure-specific scales as well as mean self-assessment scores. The results suggested that a significant amount of possible surgical performance improvement can come from the opportunity to participate in the video learning material and cadaveric simulation. We expect this model can be successfully applied to teaching rare and complex procedures in other fields.

Keywords

Retroperitoneal Lymph Node Dissection, Testicular Cancer, Surgical Education, Technical skills, Cadaver, Simulation, Urology, Residents, Global Rating Scale, Educational Assessment

Summary of Lay Audience

Surgical residency training requires not only theoretical knowledge but also technical skills. Recent global developments have impacted modern surgical residency programs and created new challenges to training highly skilled surgeons the world over. The effect of major events like the COVID-19 pandemic, along with changes in working hours and a reduction in operative exposure, continue to influence the ability of trainees to gain operative experience in many surgical procedures.

Retroperitoneal Lymph Node Dissection (RPLND) is a highly effective surgery to remove testicular cancer metastasis with high cure rates in expert centers. However, RPLND poses the risk of postoperative functional infertility caused by unintentional damage to a complex network of nerves—a preventable complication that is particularly concerning given that testicular cancer primarily affects young males. Nerve-sparing RPLND is an uncommon and complex procedure that surgical trainees may only see a few times during their programs.

In this study, we explored if video learning material combined with human cadaveric training simulation can improve the surgical performance of trainees performing nerve-sparing RPLND. We created an expert-designed and led video demonstrating the procedure. After studying paper-based materials of the procedure, trainees were tasked with performing one-half of the procedure on human cadavers before and the second-half after watching the video. Their surgical performance was then quantitatively assessed. Their surgical procedures were also video-recorded for further qualitative assessment by a blinded expert surgeon. Trainees also qualitatively self-evaluated their own surgical performance.

Significant improvements in performance were seen in the second-half of the procedure, both quantitatively and qualitatively, as evaluated by our expert. The self-assessment score was significantly improved. These results suggested that video learning material combined with human cadaveric simulation can improve the surgical performance of trainees and be used for teaching uncommon and complex procedures. It also has the potential to meet the challenges impacting surgical residency programs today.

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List of Abbreviations

AFP	Alpha-fetoprotein
AJCC	American Joint Committee on Cancer
b-hCG	Beta subunit of human chorionic gonadotropin
BEP	Bleomycin, etoposide and cisplatin
CI	Confidence interval
CS	Clinical stage
CT	Computed tomography
EC	Embryonal carcinoma
FDG	Fluorodeoxyglucose
GCT	Germ cell tumor
GCNIS	Germ cell neoplasia in situ
hCG	Human chorionic gonadotropin
IGCCCG	International Germ Cell Cancer Collaborative Group
IQR	Interquatile range
IU/L	International unit per liter
kDa	Kilodalton
LDH	Lactate dehydrogenase
LH	Luteinizing hormone
LVI	Lymphovascular invasion
M	Mean
MHz	Megahertz
miRNA	Microribonucleic acid
PFS	Progression-free survival
PET	Positron emission tomography
NSGCT	Nonseminoma germ cell tumor
OS	Overall survival
OSATS	Objective Structured Assessment of Technical Skills
OSCE	Objective Structured Clinical Examination
PC	Post-chemotherapy
PGY	Postgraduate year
RPLND	Retroperitoneal lymph node dissection

RR	Relative risk
SD	Standard deviation
STM	Serum tumor marker
TNM	Tumor, node and metastasis
ULN	Upper limit of normal
VIP	Etoposide, ifosfamide and cisplatin

Chapter 1

1 INTRODUCTION AND LITERATURE REVIEW

1.1 Testicular Cancer

1.1.1 Epidemiology and Natural History

In Canada, testicular cancers are the most common cancer recorded among young males aged 15–44 years.(1) An estimated 9,760 cases resulting in 500 deaths will be diagnosed in the United States in 2024, increasing from 9,190 cases and 470 deaths estimated in the previous year.(2, 3) A substantial variation in the incidence of testicular cancers is attributable to geographic region, with the highest average rates recorded in continental Europe (especially in Scandinavia and excluding Great Britain and Ireland); intermediate rates in Australasia, Great Britain and Ireland, and North America; and low rates in Africa, Asia, and Central and South America.(4)

During human embryonic development, the gonads originate in the abdominal cavity before descending into the scrotum. As a result, the blood supply of the testes is connected from the abdomen and the lymphatic channels drain into nodes in the retroperitoneum. Most testicular cancers metastasize via lymphatic drainage. Therefore, the retroperitoneal lymph nodes are the primary metastatic sites for the disease with predictable landing zones for both right- and left-sided tumors.(5, 6)

For right-sided tumors, the inter-aortocaval lymph nodes are the primary metastatic site. For left-sided tumors, it is the para-aortic lymph nodes. Spreading of disease from the right to the left lymph nodes is observed more often than the opposite direction. Spreading from the left to the right is usually associated with bulky disease.(7-9) Testicular cancers that do not metastasize via lymphatic drainage spread through a hematogenous route. Choriocarcinoma, for example, can have distant hematogenous metastatic sites, including the brain, lungs, and liver.(10-12)

1.1.2 Pathogenesis and Histologic Classification

Approximately 90% of all testicular cancers are germ cell tumors (GCTs), which are mainly derived from precursor lesions called germ cell neoplasia in situ (GCNIS).(13) These lesions arise from arrested primordial germ cells that transform into gonocytes during embryonic development, which fail to differentiate as prespermatogonia during fetal development. The malformed germ cells remain dormant in the testes until rising testosterone levels during puberty triggers a transition to GCNIS and proliferation results in progression to an invasive GCT.(14-16, 21)

The sex-determining region Y gene on the short arm of the Y chromosome is fundamental to testis development and is important to germ cell differentiation and spermatogenesis.(14) An abnormal gain in the short arm of chromosome 12 (12p) in this gene is connected to testicular cancers.(16, 17) This isochromosome of 12p has been demonstrated by cytogenetic testing to be present in over 80% of all testicular GCTs.(21, 23) It is generally believed that this cytogenic abnormality is involved with the progression of GCNIS to an invasive GCTs.(16)

Although most testicular cancers are post-pubertal GCNIS-derived GCTs, pre-pubertal GCTs, dermoid cysts, ovarian teratomas, and spermatocytic tumors are not.(13, 17) Therefore, GCTs can be classified more broadly as GCNIS-derived or non-GCNIS-derived. GCNIS-derived GCTs are further subclassified as seminoma or nonseminoma (NSGCT). Seminoma is slightly more common and accounts for 52–56% of all GCTs.(18, 19) NSGCTs can appear in a pure form as one GCT subtype or as a combination, with or without seminoma; however, in most cases, they are mixed tumors of two or more subtypes. NSGCT subtypes are embryonal carcinoma (EC), choriocarcinoma, yolk sac tumor, and teratoma. GCTs that include both seminoma and NSGCT subtypes are also classified as NSGCTs, despite the latter component generally comprising only a small fraction of the tumor.

1.1.3 Risk Factors

The well-established risk factors of testicular cancer are white ancestry, a family or personal history of the disease, GCNIS, and cryptorchidism.(20) An increased risk is also reported in people that are infertile or sub-fertile.(33)

Family history is a significant contributor to the potential development of testicular cancer in a person. The relative risk (RR) for those whose father is affected by the disease is 2–4, while it is 8–12 for those with an affected brother.(26-28) Therefore, risk is considerably increased among those who have an affected first-degree relative, with the median age of diagnosis 2–3 years younger in comparison to the general population.(29)

GCNIS is linked with a 50% risk of developing a GCT within five years.(23) It is detected in the nearby testicular parenchyma of approximately 90% of all patients with GCTs and is also present in the unaffected contralateral testis of 5–9%. Patients with testicular atrophy or cryptorchidism have a higher incidence in the contralateral testis of up to 36%.(22, 24) Thus, the risk of developing a GCT in the contralateral testis is 12 times higher for patients with a history of testicular cancer; however, the cumulative incidence over a 15-year period is only 2%.(25)

Higher incidences of GCNIS are also associated with testicular microlithiasis detected in the contralateral testis of patients with a history of GCTs.(34) However, in a prospective study of 1500 healthy asymptomatic participants by DeCastro et al., in which testicular microlithiasis was detected in 5.6% of participants, only 1.6% developed a GCT during a 5-year follow up interval. Therefore, the association of testicular microlithiasis with testicular cancers remains uncertain among the general population.(35)

In patients with cryptorchidism, testicular cancer is 4–6 times more common in the afflicted testis; however, if orchiopexy is performed prior to puberty, the RR is decreased to 2–3.(30, 31) A meta-analysis by Akre et al. reported a potential increased risk in both testes, even the unilateral undescended testis, with a significantly higher RR in the ipsilateral side at 6.33 (95% confidence interval [CI] 4.30–9.31) when compared with the contralateral side at 1.74 (95% CI 1.01–2.98).(32)

1.1.4 Serum Tumor Markers

Serum tumor markers (STMs) for GCTs, including alpha-fetoprotein (AFP), human chorionic gonadotropin (hCG), and lactate dehydrogenase (LDH), were introduced into clinical practice in the 1970s.(36, 37) They are beneficial in the management of testicular cancers as they may reveal a histology of GCTs. However, they also have limitations due to a low sensitivity for disease.(38) STMs are elevated in approximately 60% of testicular cancer patients.(39) They should be measured at diagnosis, before and after a orchiectomy for staging and prognostic information (with half-life kinetics taken into account), and to monitor for treatment response and relapse in patients both under surveillance and after therapy.(57, 58)

AFP is a single-chain glycoprotein with a molecular weight of 70 kDa and a half-life of 5–7 days. It is secreted by both yolk sac tumor and EC cells.(40) Seminoma and choriocarcinoma do not produce AFP. Therefore, if a pathological analysis of an orchiectomy specimen reveals seminoma, but an elevation in AFP levels is also observed, the patient is considered to have a NSGCT. It is elevated in 50–70% of patients with NSGCTs.(39, 41) Elevation is also observed in patients with hepatocellular carcinoma and pancreatic, colorectal, gastric, and bronchial cancer tumors,(42, 43) as well as non-neoplastic liver diseases, including cirrhosis, viral hepatitis, and liver injury.(44)

hCG is a 38 kDa glycoprotein consisting of an α-subunit and a β-subunit (b-hCG) with a half-life of 24–36 hours. It is secreted by syncytiotrophoblastic cells both in the placenta during pregnancy and in chorionic carcinoma.(45) Elevation in hCG levels is observed in 10–40% of patients with NSGCT and in 15–20% with seminoma. The α-subunit has a strong similarity to pituitary hormones such as luteinizing hormone (LH) and thyroid and follicular stimulating hormones. Whereas the β-subunit has a structure that makes it unique. For this reason, b-hCG is detected and measured in radioimmunoassay for the diagnosis of many conditions.(46, 47) However, false-positive results can occur due to cross-reactivity of the β-subunit with LH and a false elevation in levels has been linked to marijuana use.(48) Elevated hCG and LH is also produced in the pituitary gland by primary hypogonadism;(49) however, a short course of testosterone administration can suppress pituitary hCG and LH secretion and normalize levels in 48–72 hours.(50) hCG can also be elevated in non-trophoblastic tumors, including those in lung, breast, stomach, liver, pancreatic, kidney, and bladder cancers.(51, 52)

LDH is a 134 kDa cytoplasmatic enzyme with a half-life of 24 hours. It is present in all cells of the human body and is released during apoptosis.(53) Its clinical practicality is lower than that of AFP and hCG due to its non-specific origin.(54) It was revealed in a meta-analysis by Gilligan et al. that LDH has a prevalence rate of 40–60% in all cases of GCT.(55) And, in a review of 499 patients with testicular GCTs, Venkitaraman et al. reported that it has a limited sensitivity of 40%, a specificity of 90.5%, and a positive predictive value of 12.8%, when it comes to detecting a relapse of disease. Moreover, they estimated that its false-positive rate is high and that 47% of all patients reviewed with elevated LDH were false-positive results.(56)

There is also growing evidence that microribonucleic acids or microRNAs (miRNAs) may be novel biomarkers for GCTs. A review by Leao et al. found that, when compared to traditional GCT STMs, miRNAs (particularly miR-371a-3p) have better discriminatory accuracy for the diagnosis, treatment monitoring, and residual or ongoing viable disease prediction.(59) However, Lobo et al. has reported that a number of pragmatic concerns, including laboratory standardization, the availability of the test, and prognostic validation, that must be addressed before the standard use of miRNAs in a clinical setting.(60)

1.1.5 Diagnosis

Intensive screening of asymptomatic healthy people for testicular cancers, with both scrotal examination and ultrasound, is not recommended as it would have minimal improvement on outcomes and is not cost-effective. For those at a higher risk of developing the disease, self-examination is still advised.(35, 61) Its common presentation is that of a painless testicular mass which may be discovered during self-examination or a general physical exam. Scrotal ultrasound should be used to assess a hard intratesticular mass, which should be regarded as malignant unless demonstrated otherwise. Patients may occasionally have a concomitant hydrocele, which can make it difficult to palpate a testicular tumor.(20) The misdiagnosis of epididymitis or hydrocele also occurs in approximately a third of tumors.(62) When a tumor is suspected, the first imaging examination to be conducted is a high frequency (>10 MHz) scrotal ultrasound to identify and distinguish any potential intratesticular parenchymal tumor from an extratesticular lesion.(63) A scrotal ultrasound should be evaluated on both sides due to the 2% prevalence of bilateral GCTs.(25)

Contrast-enhanced computed tomography (CT) is recommended for complete staging prior to an orchiectomy; however, this can be postponed until malignancy is confirmed.(64) The retroperitoneum is a challenging location for accurate staging. Normal CT imaging can reveal a 25–35% incidence of pathologically-affected retroperitoneal lymph nodes. A size threshold of 10 mm is used when reporting enlarged lymph nodes for clinical stage (CS) I NSGCT.(65)

The size criteria for diagnosis of retroperitoneal lymph node metastasis on abdominal-pelvic CT imaging with high sensitivity is reduced by the predictable sites for right- and left-sided testicular tumors. According to Leibovitch et al., a size cutoff of 4 mm for the primary landing zone and 10 mm outside the area was associated with a 91% sensitivity and a 50% specificity for pathologic stage II disease.(66) Similarly, Hilton et al. reported a 4 mm cutoff for lymph nodes in the primary landing zone that were anterior to a horizontal line bisecting the aorta, with a sensitivity of 93% and a specificity of 58%.

Any decisions for the treatment of GCTs should be based on CT imaging studies completed within 4 weeks prior to commencement, owing to their rapid growth.(67) Visceral metastasis to the brain and bone is rare in asymptomatic testicular cancer patients. Therefore, brain CT imaging and bone scintigraphy are not recommended for routine testicular cancer staging. However, brain imaging should be considered for patients who are in the International Germ Cell Cancer Cooperative Group (IGCCCG) poor-prognosis group (particularly if b-hCG levels are greater than 5000 IU/L), have numerous lung metastases, or clinical symptoms of brain metastases.(68)

1.1.6 Staging and Prognosis Classification

According to the American Joint Commission on Cancer (AJCC) tumor, node and metastasis (TNM) staging system (tables 1 and 2), histopathological analysis of orchiectomy specimens, contrast-enhanced CT imaging results, and post-orchiectomy STMs, are used to stratify patients.(69-71) Patients with seminoma had a proportion of 85%, 10%, and 5% for CS I, II, and III at diagnosis, whereas the proportion for patients with NSGCT is 33% for all stages. CS I patients with seminoma also had a reduced rate of occult metastasis (10–15%) compared to NSGCT (25–35%). The risk of systemic relapse after treatment is also lower in seminoma (1–4% after radiotherapy) compared to NSGCT (10% after RPLND).(19)

Patients presenting with metastatic disease (CS IIC–III) are further categorized based on the IGCCCG group classification. A recently updated cohort was revalidated by the IGCCCG in 2021 (table 3).(70, 71) For patients with NSGCT, the 5-year progression-free survival (PFS) remains unchanged for the good- and intermediate-prognosis groups, but is significantly improved (from 41–54%) for the poor-prognosis group. The 5-year overall survival (OS) is notably improved for all patient groups, especially for the poor-prognosis group. For patients with seminoma GCTs, the 5-year OS increased to 95% and 88% in the good- and intermediate-prognosis groups respectively, with corresponding 5-year PFS rates of 89% and 79%.(72)

Table 1. **TNM classification for testicular cancer (adapted from the eighth edition of AJCC)**

T	**Primary tumor**
TX	Primary tumor cannot be assessed
T0	No evidence of primary tumor
Tis	Germ cell neoplasia in situ
T1	Tumor limited to testis (including rete testis invasion) without LVI
T1a[a]	Tumor smaller than 3 cm
T1b[a]	Tumor 3 cm or larger
T2	Tumor limited to testis (including rete testis invasion) with LVI, or Tumor invading hilar soft tissue or epididymis or penetrating visceral mesothelial layer covering the external surface of tunica albuginea with or without LVI
T3	Tumor directly invading spermatic cord soft tissue with or without LVI
T4	Tumor invading scrotum with or without LVI
N	**Regional lymph nodes**
NX	Regional lymph nodes cannot be assessed
N0	No regional lymph nodes metastasis
N1	Metastasis with a lymph node mass $\leq$ 2 cm in greatest dimension or multiple lymph nodes ($\leq$5), none >2 cm in greatest dimension
N2	Metastasis with a lymph node mass >2 cm but not >5 cm in greatest dimension or multiple lymph nodes (>5), any one mass >2 cm but not >5 cm in greatest dimension or evidence of extranodal extension
N3	Metastasis with a lymph node mass >5 cm in greatest dimension
M	**Distant metastasis**
M0	No distant metastasis
M1	Distant metastases or discontinuous involvement of spermatic cord soft tissue
M1a	Non-retroperitoneal nodal or pulmonary metastases
M1b	Non-pulmonary visceral metastases

S Serum markers

SX Marker studies not available or nor performed
S0 Markers study levels within normal limits
S1 LDH < 1.5 x N and HCG (mIU/mL) < 5000 and AFP (ng/mL) < 1000
S2 LDH 1.5-10 x N and HCG (mIU/mL) 5000-50 000 or AFP (ng/mL) 1000-10 000
S3 LDH > 10 x N and HCG (mIU/mL) > 50 000 or AFP (ng/mL) > 10 000

Note: N indicates the upper limit of normal for the LDH assay.
Abbreviations: AJCC, American Joint Commission on Cancer; AFP, alpha-fetoprotein; hCG, human chorionic gonadotropin; LVI, lymphovascular invasion; LDH, lactate dehydrogenase.
Subclassification of T1 applies only to pure seminoma.

Table 2. Prognostic groups for testicular cancer

Stage group	T	N	M	S
Stage 0	pTis	N0	M0	S0
Stage I	pT1–T4	N0	M0	SX
Stage IA[a]	pT1	N0	M0	S0
Stage IB[b]	pT2–T4	N0	M0	S0
Stage IS[c]	Any pT/TX	N0	M0	S1-3
Stage II	Any pT/TX	N1-N3	M0	SX
Stage IIA	Any pT/TX	N1	M0	S0
	Any pT/TX	N1	M0	S1
Stage IIB	Any pT/TX	N2	M0	S0
	Any pT/TX	N2	M0	S1
Stage IIC	Any pT/TX	N3	M0	S0
	Any pT/TX	N3	M0	S1
Stage III	Any pT/TX	Any N	M1a	SX
Stage IIIA	Any pT/TX	Any N	M1a	S0
	Any pT/TX	Any N	M1a	S1
Stage IIIB	Any pT/TX	N1-N3	M0	S2
	Any pT/TX	Any N	M1a	S2
Stage IIIC	Any pT/TX	N1-N3	M0	S3
	Any pT/TX	Any N	M1a	S3
	Any pT/TX	Any N	M1b	Any S

Stage IA[a]: patients have primary tumors limited to the testis and epididymis, with no evidence of microscopic vascular or lymphatic invasion by tumor cells on microscopy, no sign of metastases on clinical examination or imaging, and post-orchiectomy STM levels within normal limits. STM decline in patients with clinical stage I disease should be assessed until normalization occurs on two consecutive measurements.
Stage IB[b]: patients have a more locally invasive primary tumor, but no sign of metastatic disease.
Stage IS[c]: patients have persistently elevated (and usually increasing) serum tumor marker levels after orchiectomy, indicating the presence of subclinical metastatic disease or possibly a second GCT in the contralateral testis.

Table 3. Prognostic-based system for staging of metastatic germ cell cancer (International Germ Cell Cancer Collaborative Group)

Good-prognosis group

Nonseminoma	All of the following criteria: 5-yr PFS 90% 5-yr survival 96% Testis/retroperitoneal primary tumour No non-pulmonary visceral metastases AFP <1000 ng/ml hCG <5000 IU/l (1000 ng/ml) LDH <1.5 x ULN
Seminoma	All of the following criteria: 5-yr PFS 89% 5-yr survival 95% Any primary site No non-pulmonary visceral metastases Normal AFP Any hCG Any LDH

Intermediate-prognosis group

Nonseminoma	Any of the following criteria: 5-yr PFS 78% 5-yr survival 89% Testis/retroperitoneal primary tumour No non-pulmonary visceral metastases AFP 1000–10 000 ng/ml or hCG 5000–50 000 IU/l or LDH 1.5–10 x ULN
Seminoma	All of the following criteria: 5-yr PFS 79% 5-yr survival 88% Any primary site Non-pulmonary visceral metastases Normal AFP Any hCG Any LDH

Poor-prognosis group

Nonseminoma	Any of the following criteria: 5-yr PFS 54% 5-yr survival 67% Mediastinal primary tumour Non-pulmonary visceral metastases AFP >10 000 ng/ml or hCG >50 000 IU/L (10 000 ng/ml) or Lactate dehydrogenase >10 x ULN
Seminoma	No patients classified as having poor prognosis

1.1.7 Management

1.1.7.1 Clinical Stages I, IIA, and IIB

For CS I seminoma patients who underwent a radical orchiectomy and had pure seminoma in pathological specimens, no history of elevated AFP, normalized STMs after orchiectomy, and normal imaging, the risk of recurrence is around 15% with the majority of relapses occurring in the retroperitoneum.(73-75) The treatment options after orchiectomy include surveillance, radiation therapy to para-aortic ± pelvic areas, or chemotherapy, along with one or two cycles of carboplatin.(76)

For CS IIA and IIB seminoma patients, depending on the location of lymph nodes and bulk of the disease, treatment options include radiation therapy or chemotherapy.(77) Patients treated with radiation therapy have a relapse-free survival rate of nearly 90%, which can be further cured with salvage chemotherapy. Additionally, patients have very few relapses after primary chemotherapy.(78) For CS IIC seminoma patients, chemotherapy should be considered as the relapse rate after radiation therapy is almost 50%.(77)

For CS I NSCGT patients who underwent a radical orchiectomy, with any component of EC, choriocarcinoma, yolk sac tumor, or teratoma in pathological specimens, or patients with pure seminoma but elevated serum AFP or markedly elevated hCG (>5000 mIU/ml), the rate of relapse without adjuvant treatment is approximately 20–30%.(74, 79) Therefore, treatment

options include surveillance, chemotherapy (typically 1–2 cycles of bleomycin, etoposide and cisplatin [BEP]) or RPLND. The risk of relapses in patients with high-risk characteristics and lympho-vascular invasion (LVI), EC predominance, or both, is approximately 50%; therefore, should be treated with adjuvant therapy rather than surveillance.(79)

For CS IIA and IIB NSGCT patients, treatment options include primary RPLND or primary chemotherapy. If viable germ cell elements are discovered in pathology after primary RPLND, adjuvant chemotherapy can also be offered. Alternatively, some patients may need post-chemotherapy (PC)-RPLND if imaging reveals residual disease of more than 1 cm. The choice of initial therapy is based on the CS and the presence of elevated STMs. For example, RPLND can be considered as an initial therapy for CS IIA patients with negative STMs.(76)

1.1.7.2 Advanced or Metastatic Disease

For CS IS (positive STMs at 4–6 weeks after an orchiectomy with normal imaging), IIC and III patients, chemotherapy should be offered according to the corresponding IGCCCG group for seminoma and NSGCT. For patients in the good-prognosis group, 3 cycles of BEP is recommended. However, 4 cycles of etoposide and cisplatin can be considered in patients with contraindications to bleomycin such as extensive pulmonary disease.(80-82) For patients in the intermediate- or poor-prognosis group, 4 cycles of BEP is considered to be the standard treatment.(83) Etoposide, ifosfamide and cisplatin (VIP) can be the alternative regimen for patients who have contraindications to bleomycin; however, VIP has more myelosuppression and genitourinary toxicity.(84, 85)

Post-chemotherapy residual masses are common in advanced seminoma patients and usually do not require further treatment. If the masses are smaller than 3 cm, surveillance is preferrable without the need of a fluorodeoxyglucose (FDG)-positron emission tomography (PET) scan. If the size of the residual mass is $\geq$ 3 cm a FDG-PET scan can be considered.(86, 87) Surveillance is recommended in patients with negative FDG-PET results as it can help to predict necrosis. Positive predictive value of FDG-PET is 23%.(88) For positive results, close follow up is recommended as masses may decrease in FDG avidity and continue to shrink over time. If FDG-PET results remain strongly positive over time, with the concern of viable cancer, biopsy or complete surgical resection can be considered.(89, 90)

Post-chemotherapy NSGCT patients may have residual masses upon follow up imaging (size ≥ 1 cm) with normal STMs. Pathological analyses of the residual masses in this setting reveal tumor necrosis in 40–50%, teratoma in 35–40%, and viable cancer in 10–15% of patients.(91, 92) A lack of teratoma detection in post-chemotherapy NSGCT limits the clinical practicality of PET scans.(93) In this setting, with residual masses ≥ 1 cm, bilateral nerve-sparing RPLND surgery has been advised.(94) However, surveillance is the recommended treatment option for post-chemotherapy residual masses of < 1 cm, as the relapse rate in this setting is only 6–9%.(95, 96) If histopathology of the residual masses from post-chemotherapy surgery reveals necrosis or teratoma, there is no need for further management. However, post-surgery chemotherapy may be considered if the histopathology shows viable cancer, which may help to improve disease-free survival but not OS.(97, 98)

Brain metastasis is a rare condition that occurs in 2–3% of patients with metastatic GCTs, of which more than 95% are NSGCT. The 3-year OS of patients with synchronous brain metastases at initial diagnosis (48%) is longer than those who develop metachronous metastasis (27%).(68) VIP chemotherapy is preferred because ifosfamide can cross the blood brain barrier. Local treatment with surgery or radiation therapy may also be considered.(68)

1.1.7.3 Relapsed and Refractory Disease

According to the 2022 Canadian Urological Association guidelines for the management of testicular GCTs,(76) the recommendations for relapsed and refractory disease are as below:

- For stage I seminoma patients who are under surveillance and the relapse occurs only in the retroperitoneum, radiation therapy may be considered according to the recommendations for stage II seminoma. In other cases, chemotherapy can be considered.

- For stage I seminoma patients who underwent adjuvant carboplatin and the relapse occurs only in the retroperitoneum, radiation therapy may be considered according to the stage II seminoma recommendations. In other cases, chemotherapy can be considered.

- For stage I or II seminoma patients who underwent radiation therapy, the relapse should be treated with chemotherapy.

- For stage I NSGCT patients who are under surveillance and the relapse occurs only in the retroperitoneum, RPLND may be considered according to the recommendations for stage II NSGCT. In other cases, chemotherapy can be considered.

- For stage I NSGCT patients who underwent adjuvant chemotherapy, RPLND may be considered (if the relapse occurs only in the retroperitoneum) as well as standard first-line chemotherapy, or salvage chemotherapy.

- For stage I or II NSGCT patients who underwent RPLND, relapse should be treated with chemotherapy.

- For stage I both seminoma and NSGCT patients with relapse outside the retroperitoneum, curative-intent chemotherapy should be considered (exception for stage I NSGCT patients who underwent adjuvant BEP).

- For the patients whose relapses occur after initial cisplatin-based chemotherapy, salvage chemotherapy should be considered. If residual disease exists after salvage chemotherapy, surgical resection should be performed.

The recurrence of disease at more than two years after complete response to initial therapy is defined as late relapse, which is observed in 3.2% of NSGCT and 1.4% of seminoma.(99) Multimodal therapy is often required for late relapse due to disease complexity.(100, 101) Surgical resection is essential if the disease has become resistant to chemotherapy. However, pre- and post-operative chemotherapy may still be required.(102, 103)

1.2 Retroperitoneal Lymph Node Dissection

Long-term cure rates are still attainable for testicular cancer, even in the event of metastatic disease.(20) Retroperitoneal lymph node dissection (RPLND) surgery has been performed to treat testicular cancer since the late 1940s, prior to the availability of chemotherapy.(104) After the advent of cisplatinum-based chemotherapy in 1970s, RPLND was used mainly for the purpose of staging, with the histologically-confirmed metastatic disease in the resected retroperitoneal lymph nodes used to guide the administration of adjuvant chemotherapy.(105)

As a consequence of the gonads originating in the abdominal cavity and descending into the scrotum during embryonic development, the lymphatic channels drain into the retroperitoneal nodes located in the abdomen. In addition to this, the patterns of retroperitoneal lymph node metastasis in testicular cancer are predictable depending on the side of the primary tumors.(5, 6) A pathologic mapping study by Donohue et al. demonstrated that the primary lymph node metastatic site for the right-sided testicular tumors are the interaortocaval or paracaval regions. Whereas, for left-sided testicular tumors it is the paraaortic area.(8) Spreading to the contralateral side occurs more commonly from the right to the left retroperitoneal; although spreading in the opposite direction can be observed in bulky disease. Lymph node metastasis to the interiliac region is very rare.(7-9)

Historically, RPLND involved the excision of all the lymphatic tissue in the interiliac region inferiorly to the level of the common iliac arterial bifurcation, which sometimes included the bilateral suprahilar areas, in addition to the contemporary bilateral infrahilar templates—and of which the latter remains the current standard procedure.(6, 8) In the past, due to the large boundary, dissection was frequently performed though a thoracoabdominal incision, which was linked with considerable perioperative morbidity and a high incidence of postoperative ejaculatory dysfunction. Regardless of the significant complications, to offer the patient the best opportunity for a cure, the scale of dissection was thought to be crucial in a time where curative chemotherapy for GCTs was not yet available.(106)

1.2.1 Role of RPLND in Testicular Cancer

RPLND has a primary role in treating CS I NSGCT patients, especially in those who have high-risk characteristics, and CS IIA, and IIB disease. For patients with CS I NSGCT, the standard treatment remains debatable as the patients have a high survival rate from either RPLND, primary chemotherapy, or active surveillance. However, approximately 30% of patients will have occult retroperitoneal lymph node metastasis which may be undetectable by STM levels or imaging. Therefore, RPLND can help to improve the accuracy of disease staging from histopathological analysis. Conversely, approximately 70% of patients may undergo RPLND unnecessarily and 10% will have systemic metastases requiring salvage chemotherapy. About 50–70% of patients receiving primary chemotherapy are overtreated and at risk for unnecessary side-effects of chemotherapy.(107)

RPLND also has a role in treating CS I NSGCT patients who have relapses that occur only in the retroperitoneum after initial surveillance or primary chemotherapy. For patients with CS IIA or IIB NSGCT, depending on the presence of elevated STMs and the CS, the treatment options can be RPLND or primary chemotherapy. If retroperitoneal lymph node metastasis is detected after RPLND, adjuvant chemotherapy may be considered. Or, if post-chemotherapy imaging reveals residual disease, PC-RPLND may be performed.(76)

PC-RPLND has a role in treating NSGCT patients who have remaining retroperitoneal lymph nodes after receiving chemotherapy in order to remove viable disease in 10–20% or teratoma in 30–40% of patients.(108-110) Residual lesions with viable germ cell components indicate chemotherapy resistance and will eventually progress if not removed, despite salvage chemotherapy.(111) Post-chemotherapy residual retroperitoneal disease is defined by lesions of $\geq$ 1 cm. However, if teratoma was present in the initial histology, there is also an increased risk of residual teratoma in patients whose residual masses are < 1 cm, so PC-RPLND should be considered.(112) PC-RPLND also has a role in treating patients who have residual disease after salvage chemotherapy.(76)

The role of RPLND in treating seminoma patients is only considered for post-chemotherapy patients with advanced seminomas whose residual masses are $\geq$ 3 cm and with lesions that appear positive in FDG-PET scans. In other conditions, seminoma lesions should be closely monitored and not necessarily excised.(108) PC-RPLND surgery in seminoma patients is challenging and associated with an increased frequency of additional intraoperative procedures as well as a high rate of post-operative complications.(113) RPLND can also be performed with multimodal therapy in late-relapse patients who have a recurrence of disease at more than two years after the initial complete response.(76)

1.2.2 Terminologies of RPLND

The different terminologies of RPLND are derived from type and timing and of the primary therapy used,(109, 114-116) as listed below:

Primary RPLND: Performed after a radical orchiectomy for CS I or low-volume CS II NSGCT patients who have normal STMs.

Post-chemotherapy (PC)-RPLND: Performed after induction chemotherapy, usually when patients have residual retroperitoneal masses ≥ 1 cm with normal post-chemotherapy STMs.

Salvage PC-RPLND: Performed after patients have received both induction and salvage chemotherapy.

Desperation PC-RPLND: Performed in patients who have persistently elevated or increasing STMs after primary or salvage chemotherapy (indicating chemoresistance).

Reoperative RPLND: Performed in patients who underwent previous RPLND.

Resection of late relapse: RPLND is performed in patients who have a late relapse of the disease (at the period of more than 2 years after a complete response to primary therapy).

1.2.3 Loss of Antegrade Ejaculation

Other than the common complications associated with surgery in general (such as bleeding, infection, bowel ileus, lymphocele, venous thromboembolism, etc.), one of the most concerning long-term complications that is directly related to RPLND is the loss of antegrade ejaculation. Studies have reported that overall complication rates after primary RPLND range from 10.6–-24%.(117-119) However, complication rates from PC-RPLND range from 20–30%,(119, 120) which appears to be higher than in primary RPLND, even though this may occur less frequently in high-volume centers.(121) As it is young males aged 15–44 years that are mostly affected by testicular cancers, the issue of fertility after surgery is problematic and important.

Regular antegrade ejaculation requires a sequence of phases of seminal emission and bladder neck closure, followed by rhythmic contraction of the bulbocavernosus and ischiocavernosus muscles, to cause semen expulsion. In the emission phase, afferent impulses are delivered via the pudendal nerve. These impulses arise in the preganglionic fibers from T10 to L2 spinal

region, then synapse in the sympathetic ganglia, before exiting via the postganglionic fibers, which cross along the aorta to form the hypogastric plexus. Seminal emission is evoked by the terminal nerves from the pelvic plexus that innervate the bladder neck, seminal vesicles, vas deferens, and prostate. The nerve-sparing RPLND surgical technique to preserve antegrade ejaculation requires the surgeon to carefully identify and meticulously preserve the lumbar sympathetic trunks, postganglionic fibers, and nerves of the hypogastric plexus.(105)

In 1992, Dieckmann et al. reported an intraoperative test to identify relevant postganglionic sympathetic nerve fibers using electrostimulation during RPLND. Intraoperative ejaculation without tumescence was observed when electrostimulation was applied to the L1 to L3 sympathetic fibers, with a discharge of semen reproducible upon repeated stimulation.(122) There are four distinct sympathetic ganglia within the aortic plexus, consisting of the left and right spermatic ganglia, supplied by the L1 lumbar splanchnic nerves; the inferior mesenteric ganglion, supplied by the left L2 lumbar splanchnic nerve; and a new previously unidentified ganglion discovered by Beveridge et al. in 2015 named the prehypogastric ganglion, supplied by the right L2 lumbar splanchnic nerve. They also discovered a variation in the aortic plexus in terms of exhibiting accessory splanchnic nerves.(123)

1.2.4 RPLND Templates

Dissections of the retroperitoneal lymph nodes were initially attempted via transabdominal approaches, which were mostly unsuccessful due to bulky tumors and a high risk of serious complications.(124) Bilateral RPLND is considered the traditional template for testicular cancer, which can help to maximize the oncological controls. The boundaries of the traditional bilateral RPLND template consist of the bilateral renal hilar cranially, common iliac regions and proximal external iliac vessels caudally, extending to the bilateral ureters laterally, and usually include the suprahilar areas cranially to the renal hilum.(6) However, the standard for RPLND has evolved to include only the areas inferior to the renal hilum according to the low incidence of suprahilar disease involvement and the high complication rates from suprahilar dissection, including chylous ascites, vascular, bowel, and pancreatic injuries.(125)

To reduce the rate of antegrade ejaculation loss, several modified unilateral templates were proposed.(6, 8, 9) However, many modified templates commonly share general principles, which are the dissection of the ipsilateral lymph node areas from the renal hilum cranially to the bifurcation of common iliac vessels caudally, avoidance of the dissection around the contralateral sympathetic trunk, and discarding contralateral lymph node dissection caudal to the inferior mesenteric artery in order to avoid the injury to the hypogastric plexus and postganglionic fibers.(125) Many centers continue to use these modified RPLND templates for the purpose of minimizing the rates of postoperative ejaculatory dysfunction.(125-127) Nevertheless, viable diseases outside the boundaries of the templates found in some studies have questioned the applicability of the modified templates.(94, 128)

Depending on the modified templates utilized, Carver et al. discovered that at least 7–32% of patients had viable GCTs or teratoma outside the template boundaries in PC-RPLND. They concluded that the full bilateral infrahilar template is the most prudent approach to maximize efficacy, and nerve-sparing techniques be performed where possible to maintain normal ejaculatory function.(94) However, attempts to preserve antegrade ejaculation should not be made at the expense of incomplete tumor resection.(105)

1.2.5 Nerve-sparing RPLND

Nerve-sparing RPLND was first described by Michael Jewett in 1987 to preserve ejaculation function and demonstrated that 90% of patients could ejaculate following the procedure.(129) Very high success rates in ejaculatory preservation from primary nerve-sparing RPLND have since been reported. For example, Donohue et al. reported a 100% preservation of antegrade ejaculation in 75 patients with only one patient with retroperitoneal recurrence.(130) And Heidenreich et al. also reported that antegrade ejaculation was preserved in 93.3% of patients with only a 1.2% retroperitoneal recurrence.(118)

Coogan et al. has also reported nerve-sparing RPLND to be feasible in a post-chemotherapy setting. In a 1996 study of 472 testicular cancer patients who underwent PC-RPLND from 1988–1995, local recurrence rates were found to have not increased despite the indications for nerve-sparing PC-RPLND had expanded. Moreover, the locations of the recurrence in all the patients who underwent the nerve-sparing procedure were outside the retroperitoneal. In

this study, it was reported that 76.5% of patients that underwent the nerve-sparing procedure post-chemotherapeutically could maintain normal ejaculatory function. Therefore, it was concluded that nerve-sparing PC-RPLND could preserve fertility potential without raising the rates of retroperitoneal recurrence.(131)

However, there were a wide variety of the rates of ejaculatory preservation when it comes to nerve-sparing PC-RPLND in post-chemotherapy patients. For example, a review by Pettus et al. in 2009 found that 79% of patients treated with PC-RPLND using a bilateral template maintained antegrade ejaculation.(132) Whereas, in 2012, Heidenreich and Pfister reported 25% of patients who could maintain antegrade ejaculation after bilateral PC-RPLND.(107) The disparity among the rates of ejaculatory preservation reported in the studies may be due to different patient presentations, including the residual tumor size and stage of the disease. The skill-level of the surgeon performing the RPLND procedure may also contribute to this variation, as some may have additional experience from working in higher-volume centers.

Successful nerve-sparing RPLND requires an understanding of retroperitoneal anatomy and complex neurovascular relationships. Beveridge et al investigated the relative anatomy of the infrarenal vasculature, including inferior mesenteric artery, lumbar vessels, and right gonadal vein in human cadavers, and the complex relationships between the sympathetic nerves of the aortic plexus and these vessels were identified. The relative distances from the left renal vein can help to categorize the infrarenal vessels into three groups. The superior vessels include the right gonadal vein, right superior lumbar vein, and second (first infrarenal) pair of lumbar arteries. The middle vessels consist of the common lumbar trunk, inferior mesenteric artery, and the third (second infrarenal) pair of lumbar arteries. The inferior vessels include the left inferior lumbar vein, right inferior lumbar vein, and fourth (third infrarenal) pair of lumbar arteries.

In addition, Beveridge et al. found that lumbar splanchnic nerves (sometimes referred to as post ganglionic nerves/fibers) that supply the aortic plexus most often course anteromedial to the corresponding lumbar vein.(133) They also studied the variation of the infrarenal lumbar splanchnic nerves in 26 human cadavers and discovered that 98% of lumbar splanchnic nerves originated from the lumbar sympathetic trunk cranial to the inferior mesenteric artery before joining the aortic plexus, in which they often course in parallel. Additionally, retroaortic lumbar splanchnic nerves, which are significantly longer and angled more inferior

compared to lumbar splanchnic nerves joining the aortic plexus, were found in up to 85% of cadavers. The retroaortic lumbar splanchnic nerves exhibit a distinct course between the left common iliac vein and common iliac arteries before joining the superior hypogastric plexus caudal to the aortic bifurcation. This important discovery may help to improve nerve-sparing RPLND techniques needed to effectively preserve antegrade ejaculation.(134)

1.3 Surgical Education

It is widely accepted that a repetitive and deliberate practice is a leading method in learning and skills-acquisition.(135) For surgeons, this can involve the opportunity to perform in a high volume of cases, especially in the matter of complicated procedures. However, a limited exposure to many rare procedures in some centers, like RPLND, can impact this opportunity.

Surgical residency requires not only theoretical knowledge but also technical skill.(136, 137) Historically, the cornerstone of surgical training was extensive patient-based exposure in the operating theatre using the apprenticeship model created by Sir William Halsted.(138) The Halstedian apprenticeship-based system, with an emphasis on graded responsibility, was first introduced at Johns Hopkins Hospital in 1889 and has been used for surgical training in North America for more than a century.(139) This model of “see one, do one, teach one” has been shown to be a useful method for teaching new surgical skills; however, it requires close supervision and significant time to be effective.(140)

Competency-based education has become the current model for surgical training, as modern residency programs evolved beyond the traditional 19th century apprenticeship system.(141) However, contemporary challenges in developing competency in surgical skills include restricted working hours and reduction in operative exposure, with the latter also in part due to the effects of the COVID-19 pandemic.(142-144) The combination of these factors has forced an evolution in surgical residency programs to ensure the graduation of well-prepared as well as technically-competent surgeons.

1.3.1 Need for Video Learning Material

Video learning material may be suitable for both current and future generations of residents as they have ready access to video, in the form of online media, as a platform for both entertainment and education. Although online media, like YouTube videos, can be accessed by residents for educational purposes, the quality of content may be inconsistent.(145) In the digital era, online video is easily accessible for educational purposes. For surgical education, trainees can study surgical procedures by watching available online videos of their procedure of interest.

However, the reliability of online sources remains in doubt. Kim et al. reported that YouTube videos regarding the injury of the medial collateral ligament of the knee had poor quality and educational reliability.(146) Nelms et al. found that YouTube videos had poor content quality as an educational resource for studying perioperative anesthesia.(147) Vasan et al. described the usefulness and quality of tonsillectomy videos posted on YouTube were low. Chaudhary et al. concluded that YouTube was not a trustworthy source of information for temporomandibular joint ankylosis videos. Hwang et al. also concluded that YouTube videos of robotic pancreaticoduodenectomy were not only variable in educational quality, but some also missed important safety information.(149) They surmised that the reliability and quality of the videos created by healthcare professionals were significantly higher than those which were not and videos published by authoritative medical sources had better information.(148, 150)

Surgical procedure videos published by authoritative medical sources may be a more reliable source of quality information. However, most of the available videos are of laparoscopic or robotic surgeries, which may be because it is easier to edit the videos from recorded footage of laparoscopic automatically recorded during minimally invasive surgeries. In a review of the published urologic educational videos in the Surgery in Motion section of the European Urology Journal from 2013 to 2023, a total of 161 videos of surgical operations, there were 142 (88.2%) minimally invasive operations (laparoscopic or robotic), with only 19 (11.8%) being open operations.

There only were 3 videos regarding RPLND; two of which were robotic RPLND.(151, 152) The robotic RPLND video from Stepanian et al. demonstrated surgical techniques via lateral and supine approaches, while another robotic RPLND video from Pearce et al. showed the operation without explanation. However, one open RPLND video by Syan-Bhanvadia et al. focused on reporting outcomes rather than on demonstration of detailed technical steps.(153)

1.3.2 Cadavers for Surgical Training

Knowledge of and exposure to anatomy are crucial for both the practice of medicine and in surgical training.(154) However, the time spent on anatomy as a subject and the use of cadaveric models in the first year of medical school is becoming more limited.(155) Hands-on surgical experience involving patients in training programs has also become more limited due to the reduction in working hours, decreased operating times and ethical imperatives to protect patients.(156, 157)

A successful approach to overcoming these obstacles is the use of simulation. A simulation is described as a technique to "replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner."(158) Devices or models that are used for the training of individuals are, by definition, simulators of real-life scenarios through imitation. This training is not achieved by allowing the trainee to practice unsupervised with the simulator. It is outlined in McGaghie et al. that simulations must be integrated into curriculums with the incorporation of education principles including feedback, deliberate practice, mastery learning, outcome measurement, skills acquisition and maintenance.(159)

Many countries currently use animals, such as live porcine models, for surgical training.(160-163) However, there are also legal and ethical challenges to the use of animal models, such as the ability for animals to consents, as well as a move towards the Russel and Burch-initiative of the 3Rs to reduce, replace, and refine procedures to improve conditions for animals used in experimental protocols promoted by the National Center for the Replacement, Reduction, and Refinement of Animals in Research for over 50 years.(164, 165) Another disadvantage to the use of animals in surgical training is the physical and anatomical differences to humans.(166, 167)

The superior simulation for RPLND surgical training is a human cadaveric model, due to the anatomy of the human retroperitoneum not being accurately simulated in animals. RPLND is a complex procedure that require a number of considerations such as the complexities of retroperitoneal masses during bilateral RPLND which make the complete vascular control of the lumbar vessels and nerve sparing difficult to achieve.(105)

Traditionally used in the study of human anatomy, cadaveric models can also be utilized for the simulation of surgical training. In terms of their utilization as simulators, they can be used to improve the technical competencies of trainees through the practice of surgical procedures. Therefore, by extension, they can also be a valuable tool for the evaluation of trainee surgical skills. The use of cadavers also eliminates the risk of evaluating trainees while operating on a patient, which has potential for complications, morbidities, and mortalities.

1.3.3 Surgical Performance Evaluation

One of the main objectives for postgraduate surgical training is the acquisition of technical skills. However, most current surgical licensures require only written and oral examinations without formal evaluation of performance. In some surgical training programs, In-Training Evaluation Reports (ITERs) are used for the assessment of the competency of trainees.(168)

Traditionally, performance of surgical residents is evaluated from the feedback provided by supervisors in the operating rooms.(169) Trainees may have to perform a large number of specific procedures under supervision of surgical consultants, who will establish the point at which a trainee will become technically competent. This evaluation method is considered to be subjective and is increasingly impractical to be applied in modern training programs. The subjective nature of the assessment is also unreliable.

Potential threats to technical skills acquisition in surgical residency programs also include the decreased working hours of residents, greater time pressures in operating rooms and the increasing complexity of cases at teaching centers.(170) Despite this, programs must continue to objectively assess that technical proficiency has been achieved by surgical trainees and that they graduate as well-prepared as well as technically-competent surgeons.

Surgical skill evaluation tools should be valid (measure the intended outcome) and reliable (repeatable). Various objective assessments for evaluating surgical performance have been proposed and reported to have validity and reliability, in contrast to subjective judgements.(169) For example, the following checklists have been used to assess operative skills of residents in a surgical programs:(171) The Objective Structured Clinical Examination (OSCE) model has been proved to be a reliable method for evaluating clinical skills by using a structured score sheets for standardized tasks.(172) The Multiple Objective Measures of Skill (MOMS) examination, which is based on the OSCE format, has been used to assess each basic surgical task, such as knot formation, skin-pad suturing, and excision of skin lesion.(173)

Operative surgical skill exams using bench model simulation have also been used to evaluate trainee performance outside the operating room.(174) Video-recorded assessment of technical skills has been reported to allow multiple assessors to evaluate performance with reliability and shorten assessment times.(175) Motion analysis by electromagnetic tracking devices has also been used to analyze the hand movements of a surgeon and movement data, such as speed of movement, time, distance, number of movements, which is then used to evaluate performance.(176) Other systems have also proven to be capable of objectively evaluating technical skills, however, the feasibility of some remain in doubt as their implementation may be time-consuming and expensive.

A single global rating graded by surgical trainees' preceptors to assess clinical competence may be unreliable in its ability to provide formative feedback and inadequate to assess technical skills.(177) The Objective Structured Assessment of Technical Skills (OSATS) is a model that has been used in surgical residents since the 1990s. With this method, trainees are observed by-experts during the performance of operative tasks. In general, it consists of two components, which are a global rating scale and an operation-specific checklist. The global rating scale usually consists of the evaluation of seven aspects on a 5-point scale that can be used to assess any surgical procedures. Therefore, the total score ranges from 7–35 points. The aspects include respect for tissue, time and motion, instrument handling, knowledge of instruments, flow of operation, use of assistants, and knowledge of specific procedure. If no assistant is included, the total score ranges from 6–30.(178)

OSATS has been proven by various studies to be reliable, valid, and feasible for assessing surgical skills of the trainees in both simulations and operative rooms,(177, 178) and has been modified into many versions according to need. Global Rating Index for Technical Skills (GRITS), for example, was further developed from OSATS to include depth of perception and bimanual dexterity that can be specifically used for laparoscopic procedures, and also for communication skills.(179) The Modified OSATS, which is a condensed version of OSATS with only 4 aspects, including economy of movement (time and motion), confidence of movement (instrument handling), respect for tissue, and precision of operative technique (flow of operation), was designed and used for video-based assessment.(180) The Global Operative Assessment of Laparoscopic Skills (GOALS) was developed by Vassiliou et al. in 2005 to be an evaluating tool for laparoscopic performance. It consists of 5 items in global rating scale (depth perception, bimanual dexterity, efficiency, tissue handling, and autonomy), 10 items in the check list, and 2 visual analog scales (degree of difficulty and overall competence).(181) In 2015, the C-SATS (Crowd-Sourced Assessment of Technical Skills) was published and validated by Deal et al. as a basic tool to standardize laparoscopic performance.(182)

Apart from a global rating scale that can be generally used for the assessment of any surgical procedures, procedure-specific rating scales were also invented to assess particular procedures for specific surgical steps such as laparoscopic cholecystectomy, and laparoscopic hysterectomy.(183, 184) The Global Evaluative Assessment of Robotic Skills (GEARS) was designed by Goh et al. to measure technical skills in robotic surgeries.(185)

1.4 Thesis Rationale

To establish if a facilitator-led video demonstrating RPLND technique and high-fidelity cadaveric simulation can be used as learning material to enhance the surgical skills of trainees, we recruited 10 urology residents and fellows as participants whose RPLND performances were assessed before and after watching the video learning material. The participants were tasked with performing one half (unilateral portion) of a nerve-sparing RPLND on fresh, or soft embalmed, human cadavers before the exposure to the video learning material. After studying the video, they were tasked with performing nerve-sparing

RPLND on the contralateral side. Each participant was evaluated quantitatively for operative time of RPLND and percentage of lymph node mass resected.

Their surgical performance was also video-recorded for further qualitative assessment by a blinded reviewer, who is an expert in RPLND surgery, using the generic Objective Structured Assessment of Technical Skills (OSATS) global rating and procedure-specific rating scales. To account for any order effect or experience bias, the participants were randomized into one of two groups, with one group performing the left-sided RPNLD before studying the video learning material, and another group performing the right-sided RPLND before. The participants were also asked to perform self-assessment for qualitative measures including efficiency, technique, thoroughness (completeness of lymph node resection), quality (viability of nerve), and comfort level while operating. This study was designed to compare the surgical performance of the participants, both quantitatively and qualitatively, before and after the exposure to the cadaveric model and video learning material by eliminating potential biases. Our hypothesis was that the surgical performance of the participants would be significantly improved after the exposure to the intervention.

1.5 Research Question (Hypothesis)

The clinical research question (H_1) was to assess if the surgical performance of the participants would be significantly improved after the exposure to the cadaveric simulation and video learning material. The H_0 hypothesis would be that there is no difference of participants' surgical performance before and after the exposure to the cadaveric simulation and video learning material.

Chapter 2

2 MATERIALS AND METHODS

The purpose of this study was to evaluate if the surgical performance in the nerve-sparing RPLND surgical procedure of each individual participant would be significantly improved after exposure to a high-fidelity surgical simulation utilizing a cadaveric model in combination with facilitator-led video learning material.

2.1 Study Design

A prospective study was conducted following approval from the Western University Research Ethics Board (ID: 11334), Western University Office of Human Research Ethics (OHRE) Cadaveric Research Ethics Board (CREB) Committee (ID: 124130), and Lawson Health Research Institute (ReDA #6201). 10 urology residents and fellows from Western University were invited to participate in this study. An explanation of the study was provided in an oral and written format. If the participant agreed to participate in the study, consent was obtained, and the participant was then enrolled in the study. The choice to participate or not would not affect their education. Each participant was provided with an ID number for identification during data analysis. Their names were stored separately from the ID numbers.

2.2 Sample Size and Randomization

A sample size of n=10 in the present study had sufficient power ($1-\beta = 0.8$) to detect the large effect size (Cohen's $d_Z = 0.996$) between two groups with an α error value of 0.05. Therefore, significance in our study demonstrated a large effect that might be clinically relevant.

The left- and right-sided RPLND surgical procedures have different anatomic considerations which may affect their difficulty. To account for any order effect or experience bias, the participants were randomized into one of two groups, with one group performing the left-sided RPLND before watching the video learning material and another group performing the

right-sided RPLND before. The participants were informed of the orders of sides that they had to perform just before the surgery started.

2.3 Methodology

Before the surgery day, the participants were permitted to spend an unlimited amount of time studying the nerve-sparing RPLND surgical procedure from the four paper-based learning materials provided as well as any other published paper and multimedia that they could find. On the surgery day, they were tasked with performing nerve-sparing RPLND on one half (unilateral portion) of a fresh or soft embalmed human cadaver. Followed by a break, where they watched the facilitator-led video learning material for 9 minutes and 30 seconds, they then performed the second half (contralateral portion). The participants were asked to complete a self-assessment survey to evaluate their own surgical performance after the first and second surgeries respectively. After both surgeries, their performance was then quantitatively assessed for the operative time and percentage of lymph node mass resected by an expert. Their performance was also video recorded for further qualitative assessment by the blinded reviewer who is the expert in the nerve-sparing RPLND surgical procedure.

2.3.1 Before the Surgery Day

Prior to the surgery day, participants were provided with four paper-based learning materials to study the nerve-sparing RPLND surgical procedure. The four provided materials included:

1) Riggs S, Gaston K, Clarke PE. Surgery of testicular tumors. In: Partin AW, et al, editors. Campbell-Walsh-Wein Urology. 12th ed. Philadelphia: Elsevier-Saunders. 2020. p. 1711-37.
2) Cary C, Foster RS. Retroperitoneal lymph node dissection. In: Smith JA, et al, editors. Hinman's Atlas of Urologic Surgery. 4th ed. Philadelphia: Elsevier-Saunders. 2018. p. 831-6.
3) Beveridge TS, Allman BL, Johnson M, Power A, Sheinfeld J, Power NE. Retroperitoneal Lymph Node Dissection: Anatomical and Technical Considerations from a Cadaveric Study. J Urol. 2016;196(6):1764-71.(133);
4) Jewett MA, Groll RJ. Nerve-sparing retroperitoneal lymphadenectomy. Urol Clin North Am. 2007;34(2):149-58; abstract viii.(105).

We believe that these four articles were enough to provide substantial knowledge, including the background, indication, anatomy, technique, and complications of nerve-sparing RPLND so that the participants were well-prepared for the surgery day. The participants were also permitted to spend an unlimited amount of time studying the nerve-sparing RPLND surgical procedure from the provided materials prior to the surgery day. Moreover, if they preferred, they could also study any available paper-based learning materials, including textbooks and literature, as well as any other multimedia that they could find.

2.3.2 On the Surgery Day

On the surgery day, participants had 30 minutes to review the nerve-sparing RPLND surgical procedure from both the provided and their personal learning materials before beginning the surgery. They were asked to complete the demographic and the self-assessment surveys prior to the surgery. They were tasked with performing nerve-sparing RPLND on one half (unilateral portion) of a fresh or soft embalmed human cadaver according to their randomized group. After they had completed the first surgery, they watched the facilitator-led video learning material for 9 minutes and 30 seconds before returning to perform the second half (contralateral portion). They were permitted to spend an unlimited time performing each of the surgeries. They also completed a self-assessment survey to evaluate their own surgical performance, after the first and second surgeries respectively, and their performance was quantitatively assessed for the operative time and percentage of lymph node mass resected by an expert after the completion of both surgeries.

2.3.2.1 Human Cadaveric Model: High-fidelity Simulation

The high-fidelity surgical simulation was created for performing the nerve-sparing RPLND surgical procedure in fresh or soft embalmed human cadaveric models and designed to mimic the actual surgery by setting the operative fields to look as similar as possible to real operating rooms. Participants were providing with surgical gloves, gowns, and real surgical instruments. The participants were tasked with performing the nerve-sparing RPLND surgical procedure by removing the lymph nodes in specific locations. They performed paracaval and interaortocaval lymph node dissections for the right-sided RPLND, and para-aortic lymph node dissection for the left-sided RPLND.

Each participant was provided with one fresh or soft embalmed human cadaver to perform the nerve-sparing RPLND surgical procedure on both sides of (one side before and one side after watching the video learning material). The bowel mobilization and the installation of the self-retaining retractors was done by an expert prior to the surgery. The participants began performing the surgery from the step after the bowel mobilization. They could also ask for an adjustment of the surgical fields and self-retaining retractors to their preference. A photo of a participant performing nerve-sparing RPLND in a soft embalmed cadaver is shown in Figure 1.

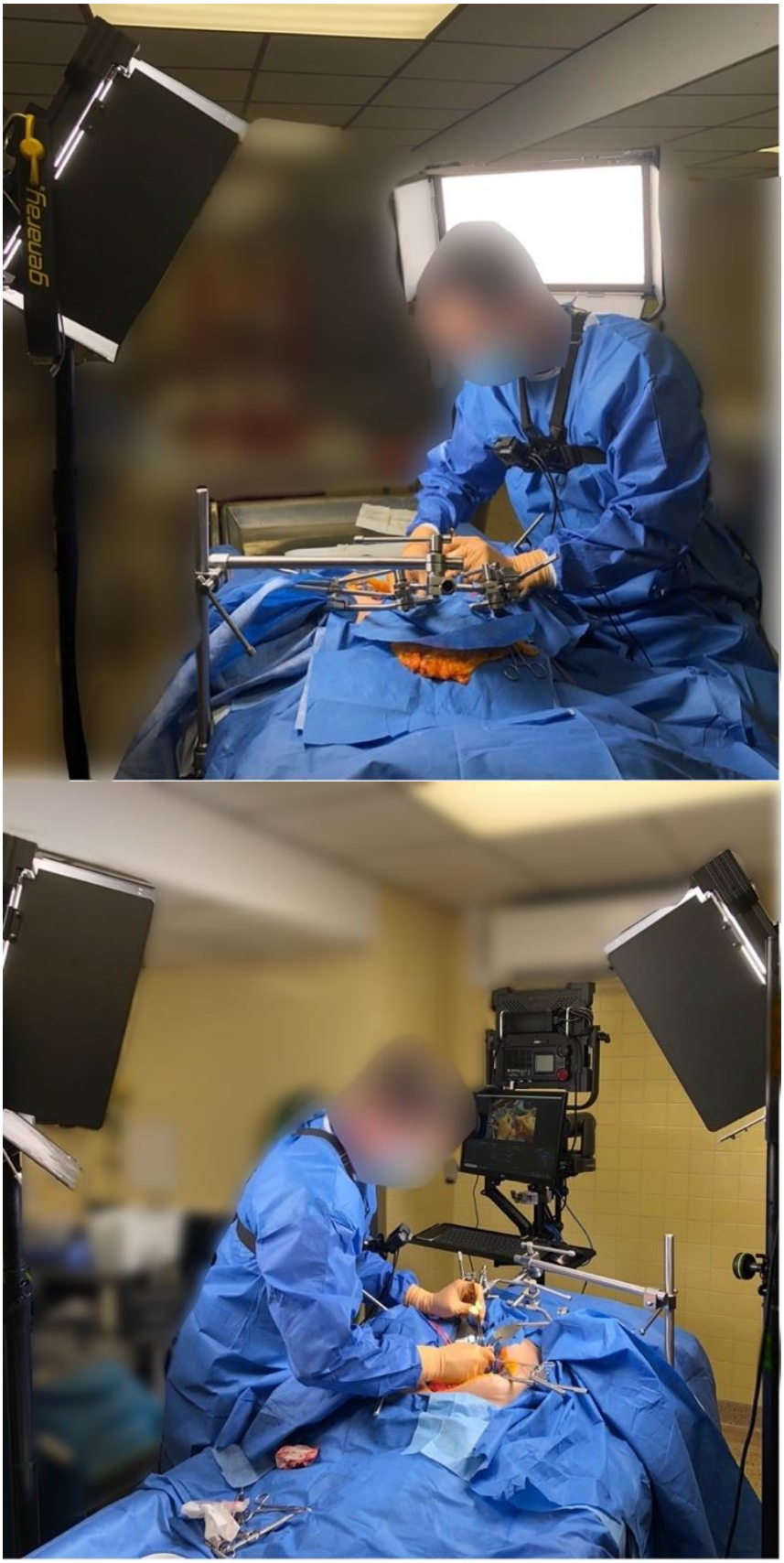


Figure 1. A participant performing left-sided nerve-sparing RPLND in a soft embalmed cadaver

The same set of surgical instruments were prepared in the surgical tray for each participant to use during the surgery. However, they could also ask for any additional surgical instruments that they preferred. The photo of the surgical instruments is shown in Figure 2.

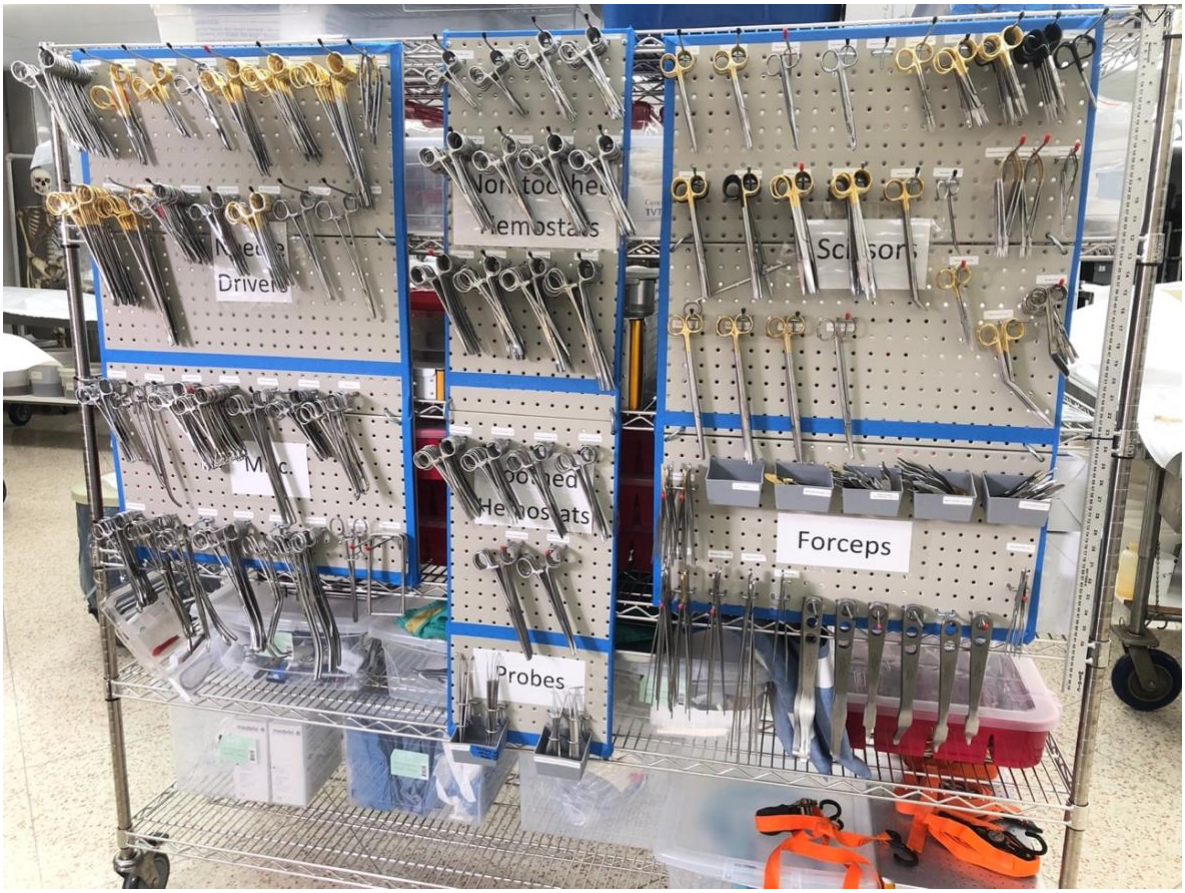


Figure 2. Provided surgical instruments

During the surgery, the participants could ask for additional surgical instruments that they preferred.

2.3.2.2 Expert-led Video Learning Material

We created a facilitator-led video learning material for the purpose of teaching the nerve-sparing RPLND surgical procedure. The content in our video is the same as in the article:

Beveridge TS, Allman BL, Johnson M, Power A, Sheinfeld J, Power NE. Retroperitoneal Lymph Node Dissection: Anatomical and Technical Considerations from a Cadaveric Study. J Urol. 2016 Dec;196(6)

This learning material included a video of real right-sided and left-sided RPLND surgical procedure performed by an expert, demonstrating surgical techniques with animation. The length of this material was 9 minutes and 30 seconds. The participants watched this video only once after completing the first surgery on the unilateral side. Then they went back to perform the second surgery on the contralateral side.

2.3.2.3 Right- and Left-Sided Nerve-sparing RPLND

Right-sided RPLND and left-sided RPLND are not just the mirror image of each other due to the different anatomical considerations on each side. Inter-aortocaval and paracaval lymph nodes are the primary metastatic sites for right testicular tumors. For left testicular tumors, the primary metastatic site is para-aortic lymph nodes. The borders for the right-sided RPLND in this study included the right renal hilum cranially, the right common iliac region and proximal right external iliac vessels caudally, extending laterally to the right ureter, and the interaortocaval region medially. The borders for the left-sided RPLND consisted of the left renal hilum cranially, the left common iliac region and proximal left external iliac vessels caudally, extending laterally to the left ureter, and the preaortic region medially.

The participants were assigned to perform the second RPLND surgery on the opposite side after watching the video-learning material in order to minimize the repeated measure bias, to minimize the fact that they might perform better in the second time either because of the practice effect, or worse because of boredom or fatigue. The task of performing the procedure was the same but the anatomy was different. The different anatomic considerations of each side might affect the difficulty in performing RPLND. To account for any order effect or experience bias, the participants were randomized into one of two groups with one group

performing the left-sided RPLND before watching the video learning material, and another group performing the right-sided RPLND before. The orders of the sides of RPLND that the participants had to perform would be revealed to them just before the surgery started.

2.3.2.4 Video Recordings for Surgical Performance Assessment

The evaluator qualitatively assessed the surgical performances both pre- and post-intervention from the blinded digital video recordings. The entire surgical procedures were video recorded using a GoPro video camera to capture the point of view actions. A two-point studio lighting set up was adjusted to mimic the light setting in the operative theaters, which also helped to improve the quality of the video recordings. Only hand and arm movements within the surgical field, while the participants were gloved and gowned, would be seen by the evaluator. A microphone was attached to the participants, so they could describe their surgical techniques during the procedures if they preferred. All audio was de-identified from the video recordings by voice distortion using Adobe Premier Pro. The photo of the setup for video recording is shown in Figure 3.

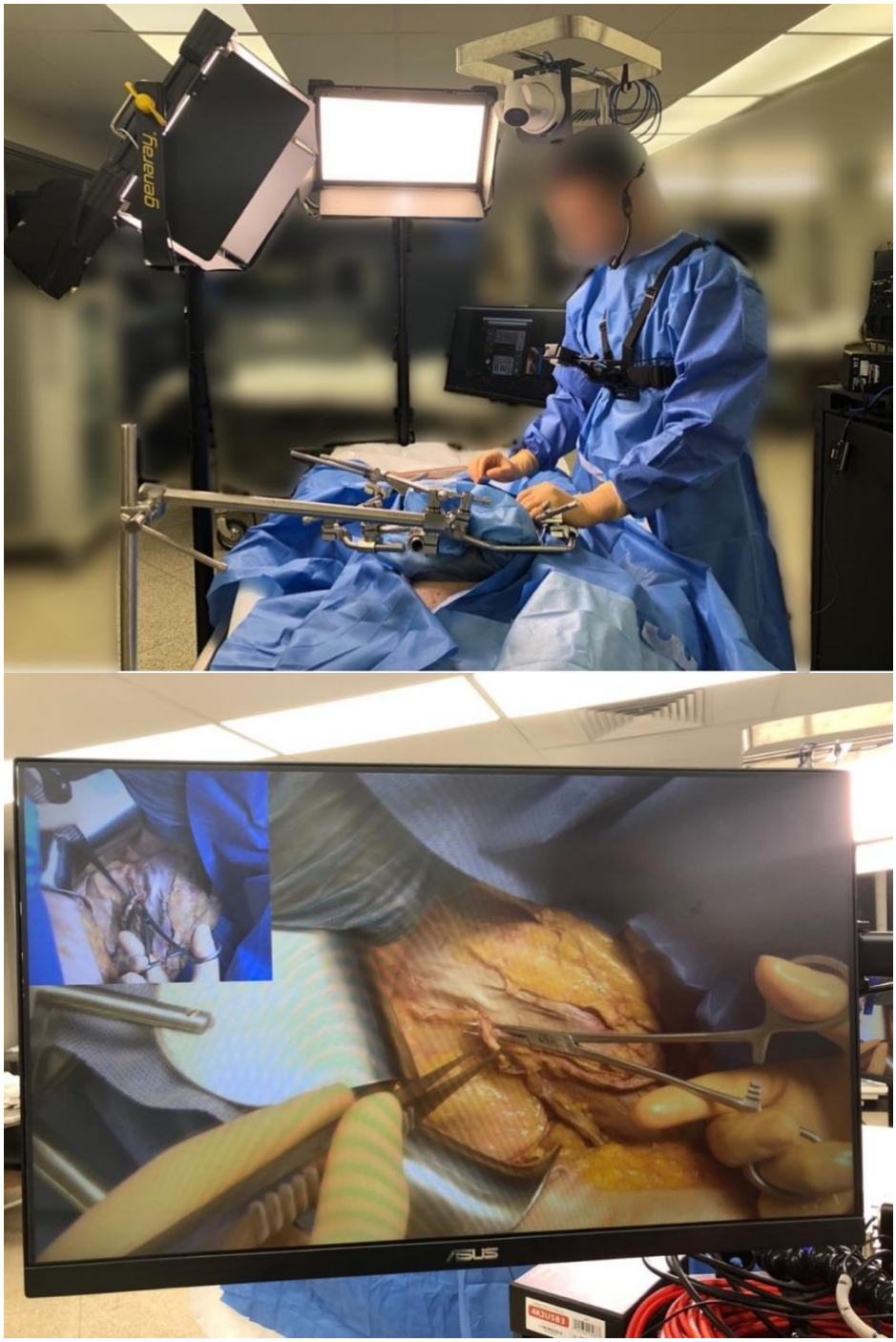


Figure 3. The setup for video recording

A GoPro video camera was used to capture the point-of-view actions with only hand and arm movements seen within the surgical field. The participants could narrate their procedures through an attached microphone. Their voices were de-identified from the video recordings. Moreover, half of the surgical field was blocked by a surgical drape to mask the evaluator who would assess the surgical performance from knowing if the participants were performing the pre- or post-intervention procedures as shown in Figure 4.

Figure 4. The surgical field

The left-side of the surgical view was blocked by a surgical drape in order to prevent the expert who assessed the video recordings from knowing if the procedure was the first or second surgery.

2.4 Study Outcomes and Variables

The aim of this study was to evaluate if the surgical performance of participants could be significantly improved within a short period of time after exposure to a high-fidelity surgical simulation utilizing a cadaveric model of around 2 hours and a facilitator-led video learning material of 9 minutes and 30 seconds.

The primary outcome was to compare the quantitative and qualitative performances of the participants as assessed by an expert before and after the exposure to the intervention. The secondary outcome was to compare the self-assessment of the participants before and after the exposure to the intervention.

2.5 Variables and Data Collection

The participant data was collected under unique ID study numbers and stored in the data collection form. The participant names were stored separately from their ID numbers. Documents with identifiable information (such as the names on the consent forms) were stored in the locked research office.

Survey data was collected from the participants and managed using the Survey Data Collection Form that was approved by the Western University Research Ethics Board (ID: 113634).

The video recordings were coded with unique ID numbers. They were all shared with the expert via Panopto at the same time. The expert was not made aware if each video recording was from the pre- or post-intervention. The expert assessed the performance of each video using the Expert Evaluation Form. All documents were stored in the locked research office.

2.5.1 Demographic Data

Data related to the participants' demographics included their postgraduate year (PGY), and dominant hand.

2.5.2 Quantitative Data

Quantitative data from each surgical procedure included the side of RPLND, operative time, and percentage of lymph node mass resected.

2.5.2.1 Operative time

The duration of each surgery was timed from the beginning of each procedure until the time that the participants finished. The operative time was measured in minutes.

2.5.2.2 Percentage of lymph node mass resected

After each participant finished both RPLND surgeries. An expert (different person from the expert who assessed the performance from video recordings) evaluated and performed a dissection to remove any remaining lymph nodes that the participants may have left in each location. The lymph node mass from each location performed by each participant and the expert was weighed using an Adventurer™ weighing scale. The unit of weight is gram with three decimals. The percentage of lymph node mass resected from each location was calculated by the equation:

$$\frac{\text{lymph node mass resected in g (participant)}}{\text{lymph node mass resected in g (participant)} + \text{lymph node mass resected in g (expert)}} \times 100\%$$

2.5.3 Expert-assessment Qualitative Performance

The surgical performances from the video recordings were assessed by the expert using the generic Objective Structured Assessment of Technical Skills (OSATS) global rating scale and a procedure-specific rating scale.

2.5.3.1 Generic Objective Structured Assessment of Technical Skills (OSATS) Global Rating Scale

The expert used generic OSATS global rating scale to assess the surgical performance of each procedure in six aspects which included:

1) Respect for tissue
2) Time and motion
3) Instrument handling
4) Knowledge of instruments
5) Flow of operation and forward planning
6) Knowledge of specific procedure.

Each scale was scored from 1–5. Therefore, the total generic OSATS score could range from 6–30. The generic OSATS global rating scale is shown in Table 4.

Table 4. Generic OSATS Global Rating Scale

	1	2	3	4	5
1. Respect for tissue	Frequently used unnecessary force on tissue or caused damage by inappropriate use of instruments		Careful handling of tissue but occasionally caused inadvertent damage		Consistently handled tissues appropriately with minimal damage
2. Time and motion	Many unnecessary moves		Efficient time/motion but some unnecessary moves		Economy of movement and maximum efficiency
3. Instrument handling	Repeatedly makes tentative or awkward moves with instruments		Competent use of instruments although occasionally appeared stiff or awkward		Fluid moves with instruments and no awkwardness
4. Knowledge of instruments	Frequently asked for the wrong instrument or used an inappropriate instrument		Knew the names of most instruments and used appropriate instrument or the task		Obviously familiar with the instruments required and their names
5. Flow of operation and forward planning	Frequently stopped operating or needed to discuss next move		Demonstrated ability for forward planning with steady progression of operative procedure		Obviously planned course of operation with effortless flow from one move to the next
6. Knowledge of specific procedure	Deficient knowledge. Needed specific instruction at most operative steps		Knew all important aspects of the operation		Demonstrated familiarity with all aspects of the operation

2.5.3.2 Procedure-specific Rating scale

As there was no available rating scale for assessing RPLND procedure specifically, we developed a new procedure-specific rating scale. This scale was used to assess two key aspects of the operation, which are the completeness of lymph node dissection and the preservation of nerve integrity. The Procedure-Specific Rating Scale is shown in Table 5.

2.5.3.2.1 Completeness of Lymph Node Dissection Score

We assessed the completeness of lymph node dissection in six different locations which included:
1) Paracaval Cranially (for right-sided RPLND)
2) Paracaval Caudally (for right-sided RPLND)
3) Interaortocaval Cranially (for right-sided RPLND)
4) Interaortocaval Caudally (for right-sided RPLND)
5) Paraaortic Cranially (for left-sided RPLND)
6) Paraaortic Caudally (for left-sided RPLND)
The inferior mesenteric artery was used as the landmark to define the areas cranially and caudally. Each scale was scored from 1–5. We then calculated the average score for each side of RPLND.

2.5.3.2.2 Preservation of Nerve Integrity Score

We assessed the degree of nerve preservation in six different locations which included:
1) Paracaval Cranially (for right-sided RPLND)
2) Paracaval Caudally (for right-sided RPLND)
3) Interaortocaval Cranially (for right-sided RPLND)
4) Interaortocaval Caudally (for right-sided RPLND)
5) Paraaortic Cranially (for left-sided RPLND)
6) Paraaortic Caudally (for left-sided RPLND)
The inferior mesenteric artery was used as the landmark to define the areas cranially and caudally. Each scale was scored from 1–5. We then calculated the average score for each side of RPLND.

Table 5. Procedure-specific Rating Scale

Procedure-specific Rating Scale

Completeness of lymph node dissection and preservation of nerve integrity in 6 locations (cranially and caudally to *inferior mesenteric artery*).

Right-sided RPLND

Paracaval Cranially	**1**	**2**	**3**	**4**	**5**
Completeness of lymph node dissection	Minimal amount of lymph node dissection completed		Half of the lymph nodes were dissected		Dissection of all lymph nodes
Preservation of nerve integrity	Minimal amount of nerve preservation		Half of the nerves were preserved		Preservation of all the nerves

Paracaval Caudally	**1**	**2**	**3**	**4**	**5**
Completeness of lymph node dissection	Minimal amount of lymph node dissection completed		Half of the lymph nodes were dissected		Dissection of all lymph nodes
Preservation of nerve integrity	Minimal amount of nerve preservation		Half of the nerves were preserved		Preservation of all the nerves

Interaortocaval Cranially	**1**	**2**	**3**	**4**	**5**
Completeness of lymph node dissection	Minimal amount of lymph node dissection completed		Half of the lymph nodes were dissected		Dissection of all lymph nodes
Preservation of nerve integrity	Minimal amount of nerve preservation		Half of the nerves were preserved		Preservation of all the nerves

Interaortocaval Caudally	**1**	**2**	**3**	**4**	**5**
Completeness of lymph node dissection	Minimal amount of lymph node dissection completed		Half of the lymph nodes were dissected		Dissection of all lymph nodes
Preservation of nerve integrity	Minimal amount of nerve preservation		Half of the nerves were preserved		Preservation of all the nerves

Left-sided RPLND

Paraaortic Cranially	1	2	3	4	5
Completeness of lymph node dissection	Minimal amount of lymph node dissection completed		Half of the lymph nodes were dissected		Dissection of all lymph nodes
Preservation of nerve integrity	Minimal amount of nerve preservation		Half of the nerves were preserved		Preservation of all the nerves

Paraaortic Caudally	1	2	3	4	5
Completeness of lymph node dissection	Minimal amount of lymph node dissection completed		Half of the lymph nodes were dissected		Dissection of all lymph nodes
Preservation of nerve integrity	Minimal amount of nerve preservation		Half of the nerves were preserved		Preservation of all the nerves

2.5.4 Self-assessment Performance

The participants were asked to assess their own surgical performances in the RPLND surgeries before and after the exposure to the intervention in five aspects. We decided to use line scales in order to minimize the response bias. The score in each aspect ranged from 0 – 100. The five aspects consisted of:

1) Efficiency
2) Technique
3) Thoroughness: Completeness of lymph node resection
4) Quality: Viability of nerve
5) Comfort level operating RPLND surgery

2.5.5 Paper vs Video Learning Materials

We also asked the participants to compare paper-based material and video learning material on how well each resource improved their competency in six aspects. They were asked to give the scores in line scales for each aspect. The score in each aspect ranged from 0–100.

The six aspects included:

1) Efficiency
2) Technique
3) Thoroughness: Completeness of lymph node resection
4) Quality: Viability of nerve
5) Comfort level operating RPLND surgery
6) Overall surgical skills

2.6 Statistical Analysis

Descriptive statistics were used to present demographic variables. Categorical variables in terms of PGYs of the participants were compared using the Fisher-Freeman-Halton Exact Test. For subgroup analysis, 'junior participants' was the term used to referred to participants who were in PGY3 and lower. Participants who were in PGY4 and higher were considered to be 'senior participants.'

The Shapiro-Wilk and Kolmogorov-Smirnov normality tests were used to determine if the data were parametric or non-parametric. Paired Samples T-Test was used to compare continuous, parametric variables between two related groups. The Wilcoxon signed rank test was used to compare continuous, non-parametric variables between two related groups. Continuous, parametric variables between two unrelated groups were compared using Student's T-Test. Mann-Whitney U test was used to compare continuous, nonparametric variables between two unrelated groups.

Categorical variables were reported as counts. Parametric variables were reported by means. Nonparametric variables were reported by median and IQR. A two-tailed p-value of less than

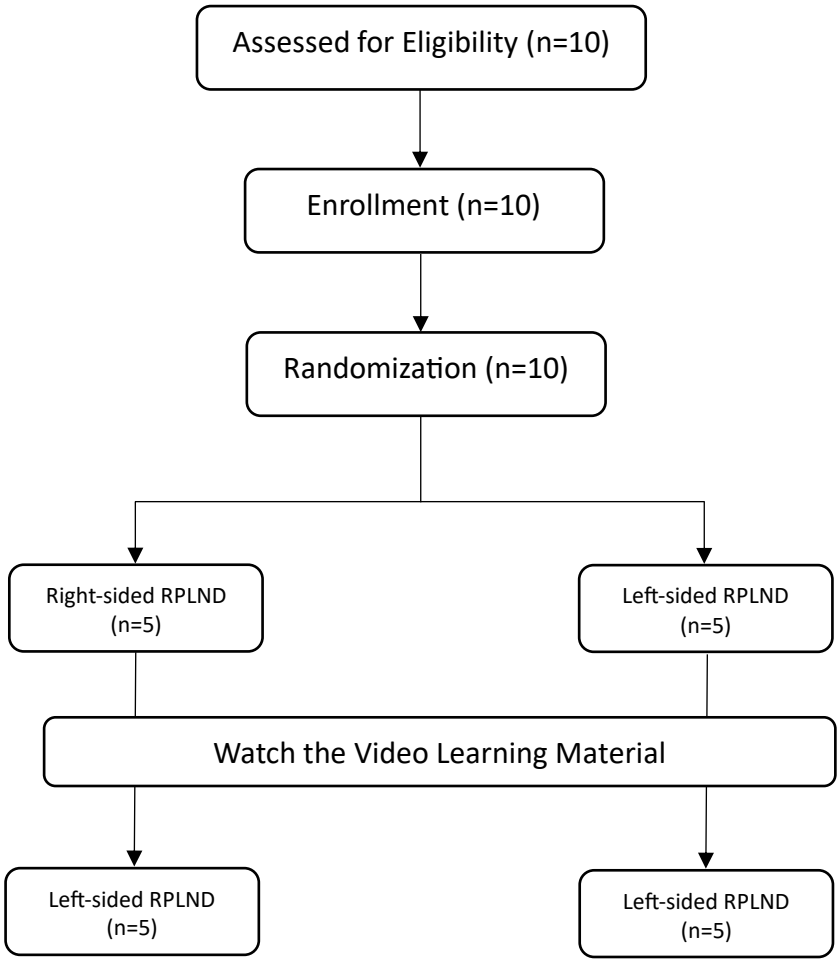
0.05 was considered to be statistically significant. The statistical analysis was performed using IBM SPSS 29 Statistical Software Package (IBM Corp. Released 2023. IBM SPSS Statistics for Macintosh, Version 29.0.2.0. Armonk, NY: IBM Corp.).

Chapter 3

3 RESULTS

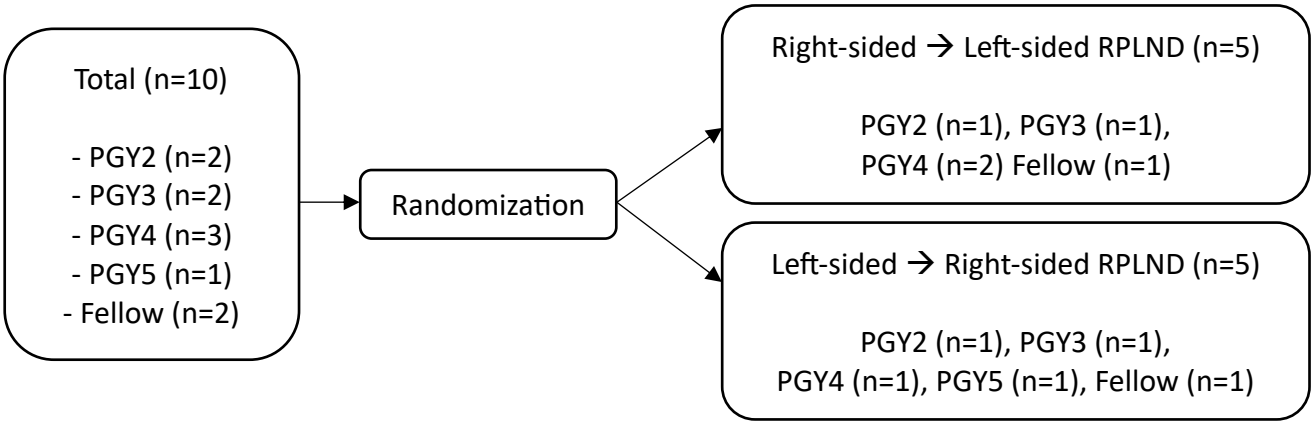
The recruitment of participants was initiated on Nov 28, 2023. Ten participants agreed to participate, met the inclusion criteria, and were enrolled in the study. No participant was excluded from the study. Ten participants were randomized to perform either the right-sided or the left-sided RPLND before watching the video learning material. After watching the video learning material, they performed RPLND on the contralateral side. Participant flow is shown in the Participant flow diagram in Figure 5. The ten participants consisted of two PGY2s, two PGY3s, 3 PGY4s, one PGY5, and 2 fellows. Five of them were randomized to perform right-sided RPLND first (one PGY2, one PGY3, two PGY4s, and one fellow). Another five participants were randomized to perform the left-sided RPLND first (one PGY2, one PGY3, one PGY4, one PGY5, and one fellow). All participants were right-handed dominant. The demographic data of the participants in each group is shown in the 'Participants categorized by year in training' diagram in Figure 6. There was no significant difference regarding the distribution of postgraduate years of the participants between two groups (Fisher-Freeman-Halton Exact Test, p=1.0).

Figure 5. Participant flow



RPLND: Retroperitoneal lymph node dissection

Figure 6. Participants categorized by year in training



Fisher-Freeman-Halton Exact Test, p=1.0

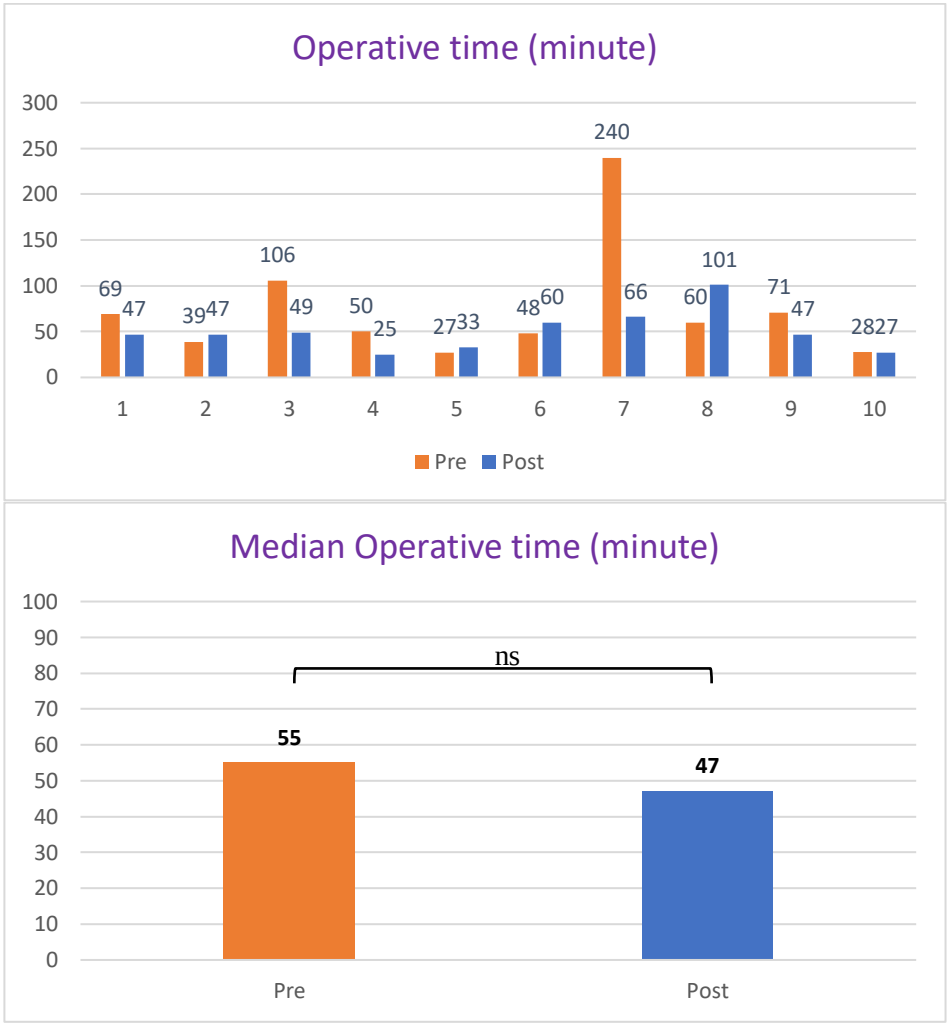
PGY: Postgraduate year, RPLND: Retroperitoneal lymph node dissection

3.1 Quantitative Outcomes

3.1.1 Quantitative Outcome: Operative Time

There was no significant difference in operative time of the second operation after watching the video learning material (Median=47 minutes, IQR=31.5-61.5 minutes) compared to the first operation (Median=55 minutes, IQR=36.25-79.75 minutes); [Wilcoxon Signed-Rank Test, z=-1.07, p=0.285]. The result is shown in Figure 7.

Figure 7. Operative Time Between the Pre- and Post-Surgery



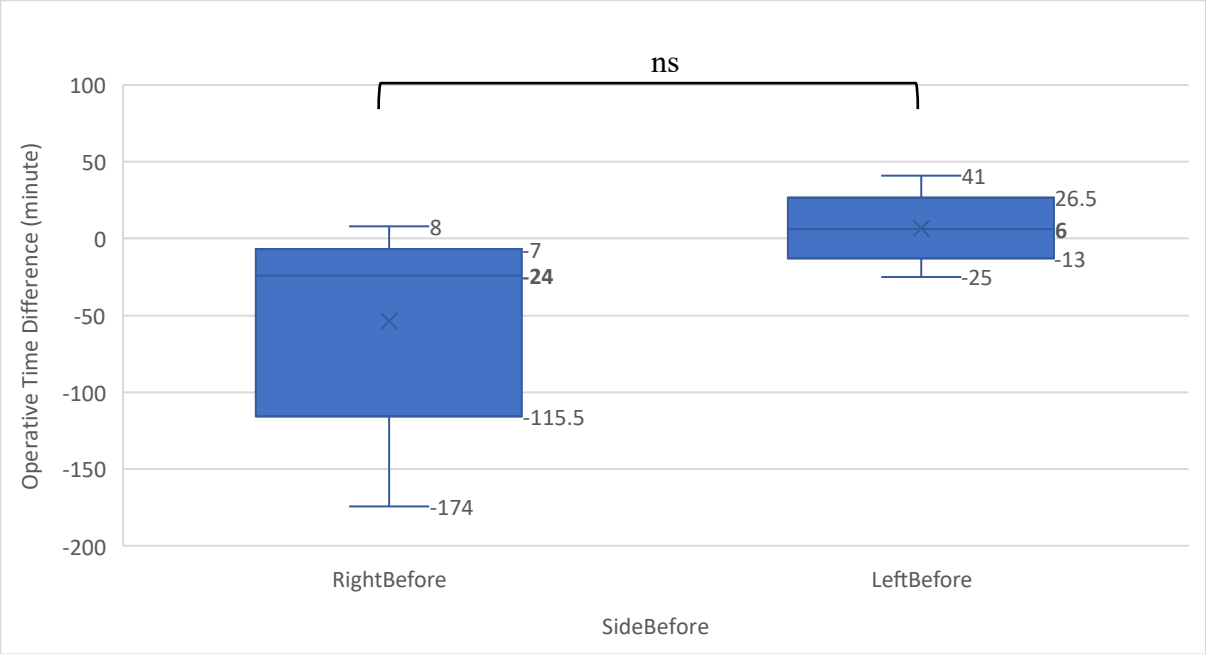
Wilcoxon Signed-Rank Test, z=-1.07, p=0.285; ns: not significant

There was no significant difference in operative time pre-surgery before watching the video module and post-surgery after reviewing the video module.

Operative Time: Right-sided vs Left-sided Before

We also compared the operative time difference (operative time of the second RPLND minus the operative time of the first RPLND in each participant) between the group of the participants who performed the right-sided RPLND first, and the group of the participants who performed the left-sided RPLND first. There was no significant difference in the difference of operative time between the group of participants who performed the right-sided RPLND before (Median=-24 minutes) and the group of participants who performed the left-sided RPLND before (Median=6 minutes); [Mann-Whitney U Test, p=0.151]. The result is shown in Figure 8.

Figure 8. Operative Time Difference Between Participants Who Performed the Right-sided or Left-sided RPLND First



Mann-Whitney U Test, p=0.151; ns: not significant

Operative Time Difference (minute) = Operative time of the second surgery – Operative time of the first surgery
Positive value = longer operative time in the second surgery
Negative value = shorter operative time in the second surgery

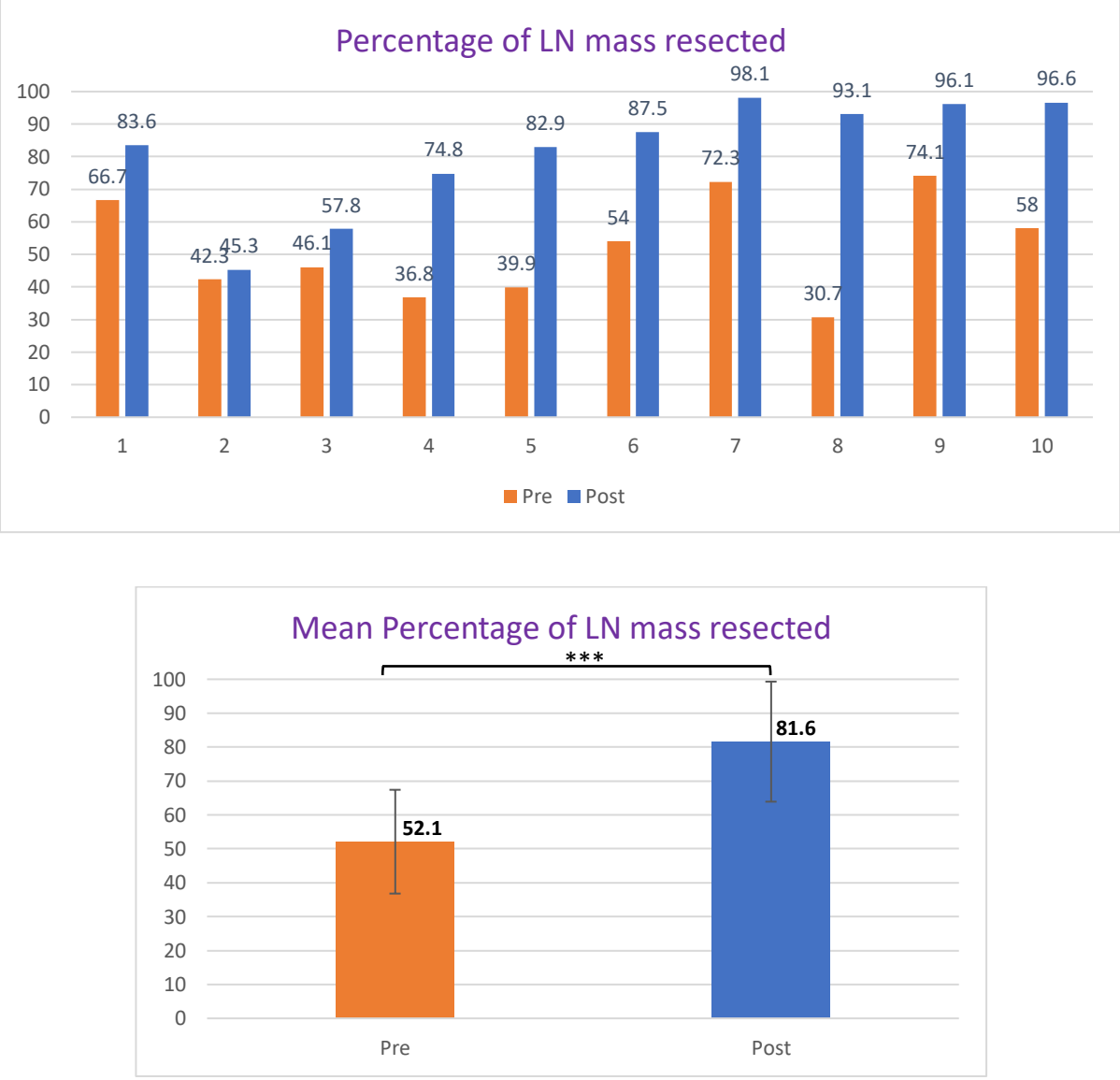
---

There was no significant difference in the operative time between the first and second surgeries, regardless of which sided RPLND the participants performed first.

3.1.2 Quantitative Outcome: Percentage of Lymph Node Mass Resected

The mean percentage of lymph node mass resected in the second operation after watching the video learning material (M=81.57; SD=17.67) was significantly higher than the first operation (M=52.07; SD=15.34); [Paired Samples T-test, t(9)=5.40, p<0.001]. The 95% confidence interval of the difference between the means ranged from 17.15 to 41.86, and indicated the difference between the means of the samples. The result is shown in Figure 9.

Figure 9. Percentage of Lymph Node Mass Resected



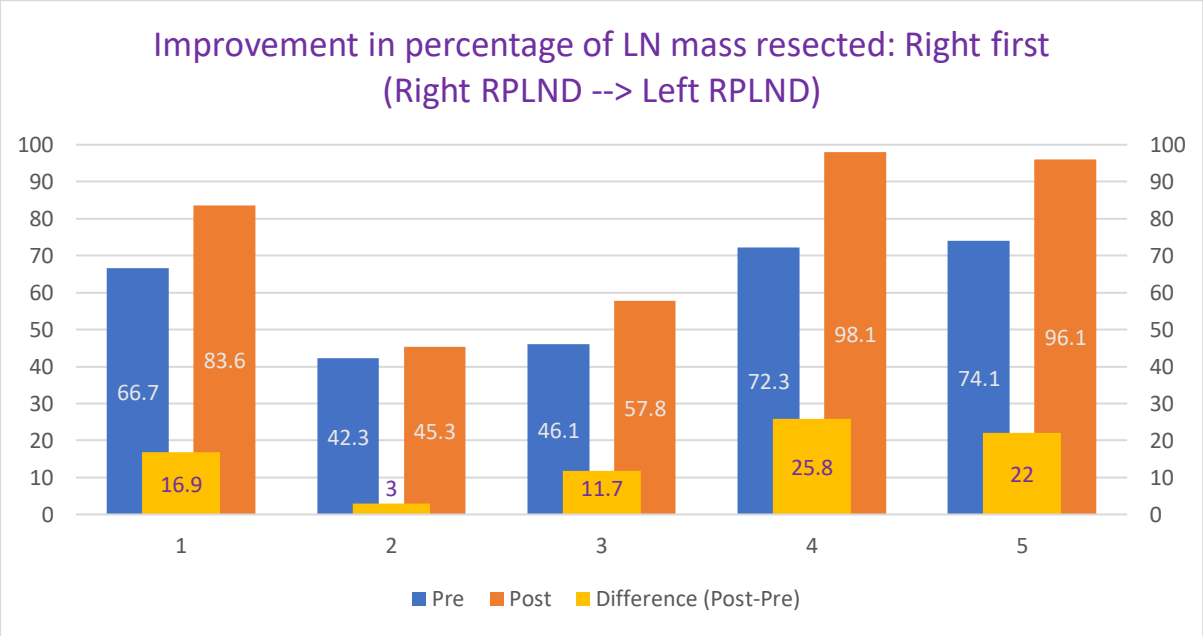
Paired Samples T-test, t(9)=5.40, p<0.001***

The percentage of lymph node mass resected increased consistently after reviewing the video module.

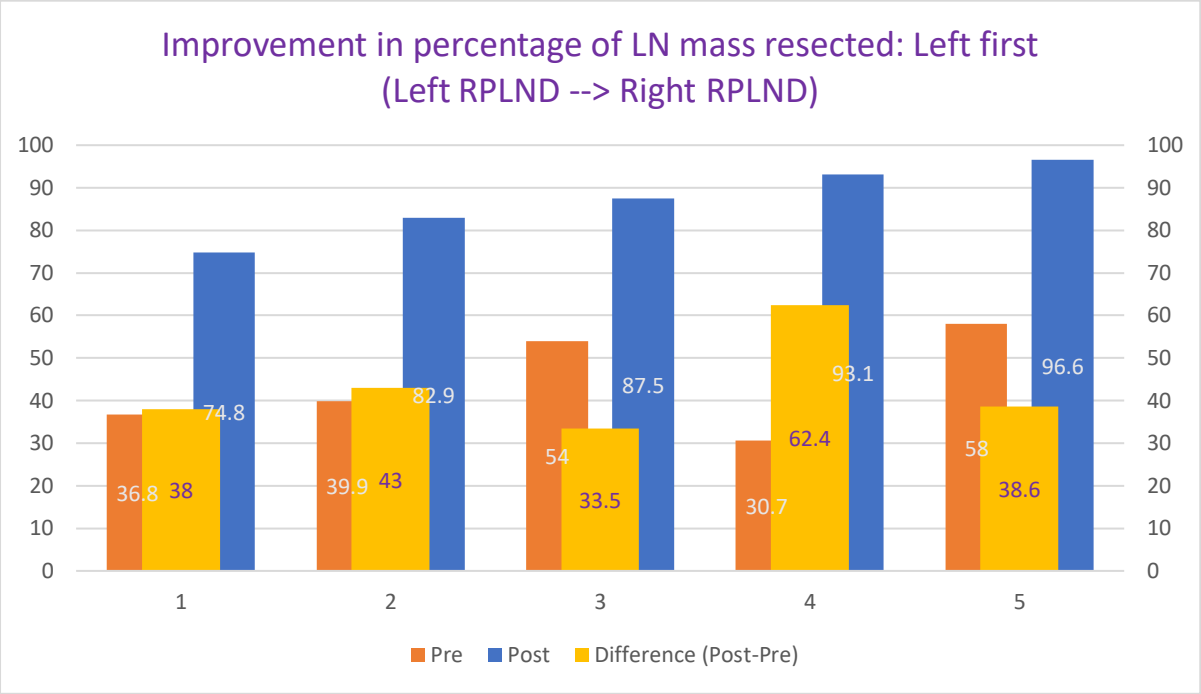
Percentage of Lymph Node Mass Resected: Right-sided vs Left-sided Before

We also compared the improvement in the percentage of lymph node mass resected between the group of the participants who performed the right-sided RPLND first, and the group of the participants who performed the left-sided RPLND first in order to determine if the order of the sides of surgery affected the improvement of percentage of lymph node mass resected or not. The mean improvement of the percentage of LN mass resected in participants who performed the right-sided RPLND before watching the video learning material and then performed the left-sided RPLND after was 15.88% (SD=8.92). The mean improvement of the percentage of LN mass resected in participants who performed the left-sided RPLND before watching the video learning material and then performed the right-sided RPLND after was 43.12% (SD=11.31). The group of participants who performed the left-sided RPLND before had significantly more improvement in the percentage of LN mass resected than the group of participants who performed the right-sided RPLND before (Student's T-test, p=0.003). The 95% confidence interval of the difference between the means ranged from -42.09 to -12.38, and indicated the difference between the means of the samples. The result is shown in Figure 10.

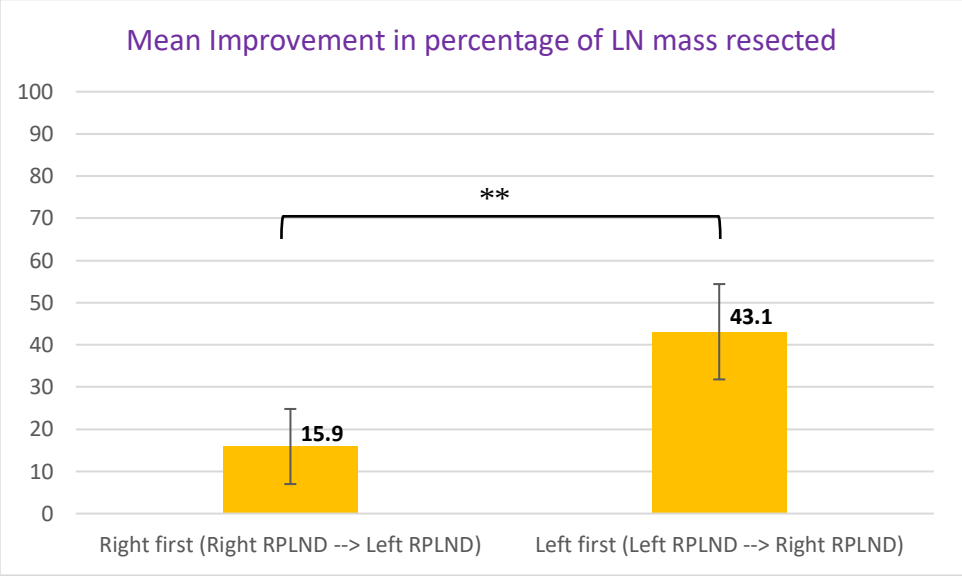
Figure 10. Improvement in the Percentage of Lymph Node Mass Resected Between the Participants Who Performed the Right-sided and Left-sided RPLND First



Mean=15.88%, SD=8.92



Mean=43.12%, SD=11.31



Student's T-test, p=0.003**

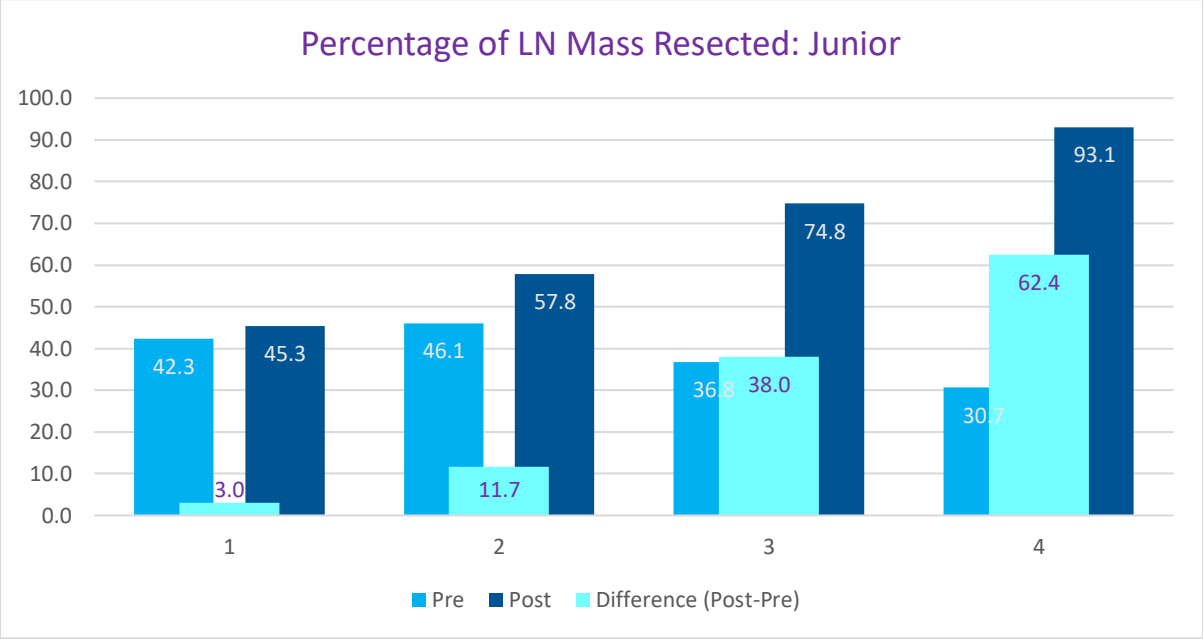
Improvement in the percentage of lymph node mass resected increased more in the participants who performed the left-sided RPLND first.

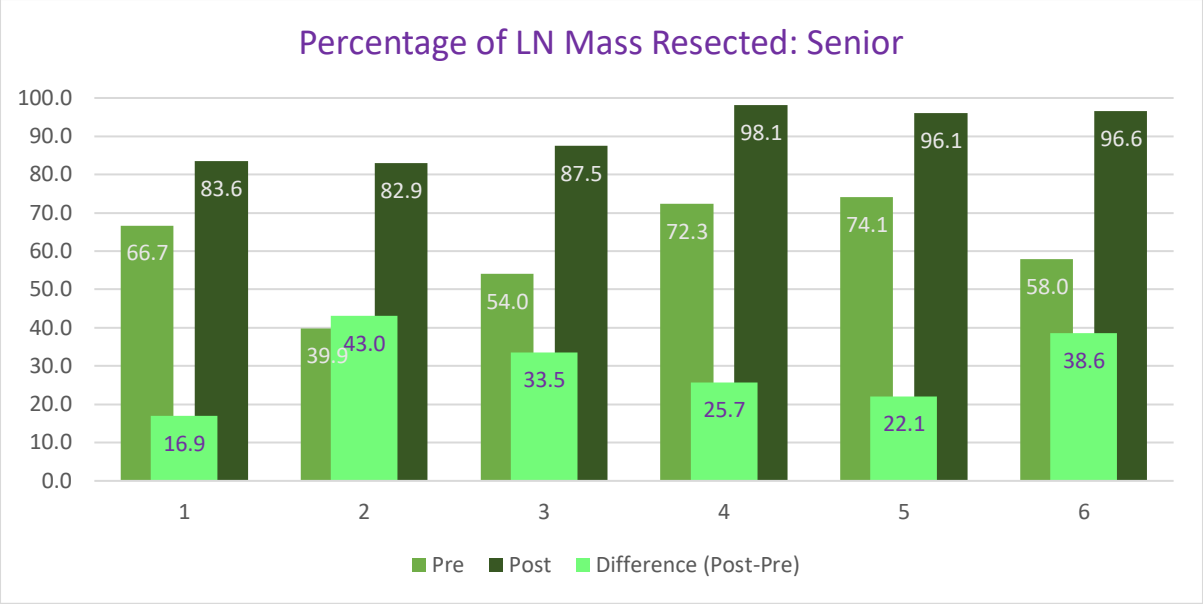
Percentage of Lymph Node Mass Resected: Junior vs Senior Participants

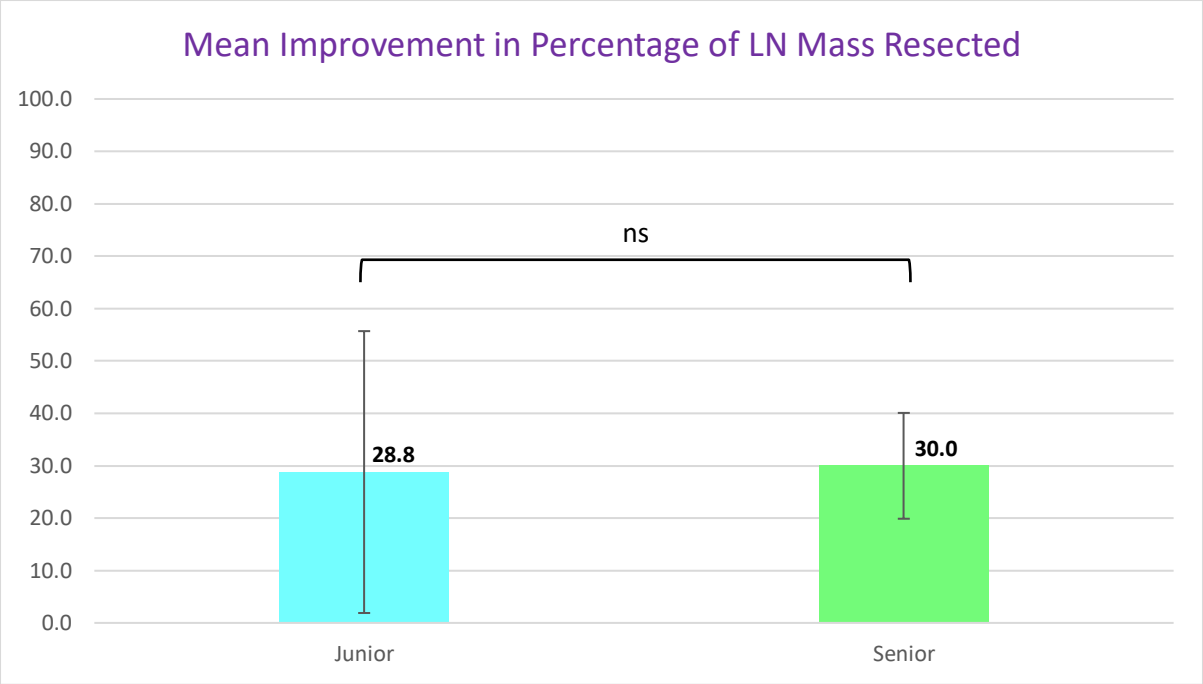
We also compared the improvement in the percentage of lymph node mass resected between the group of junior participants (two PGY2s and two PGY3s) and the group of senior participants (three PGY4s, one PGY5, and two fellows).

There was no significant difference in the mean improvement of the percentage of LN mass resected in the group of junior participants (M=28.79, SD=26.90) and the group of senior participants (M=29.98, SD=10.10); [Student's T-test, p=0.937]. The 95% confidence interval of the difference between the means ranged from -42.17 to 39.79, and did not indicate a difference between the means of the samples. The result is shown in Figure 11.

Figure 11. Improvement in the Percentage of Lymph Node Mass Resected Between the Junior and Senior Level Participants







Student's T-test, p=0.937; ns: not significant

Improvement in the percentage of lymph node mass resected was similar between the junior and senior level participants.

3.2 Expert-assessment Outcomes

3.2.1 Generic OSATS Global Rating Scale Components

3.2.1.1 Expert-assessment Outcome: Objective Structured Assessment of Technical Skills (OSATS) - Respect for Tissue Score

The median Respect for Tissue Score of the second operation after watching the video learning material (Median=4.0, IQR=3.0-4.0) was significantly higher than the first operation (Median=3.0, IQR=2.0-4.0); [Wilcoxon Signed-Rank Test, z=-2.07, p=0.038]. The result is shown in Figure 12.

Figure 12. OSATS – Respect for Tissue Score

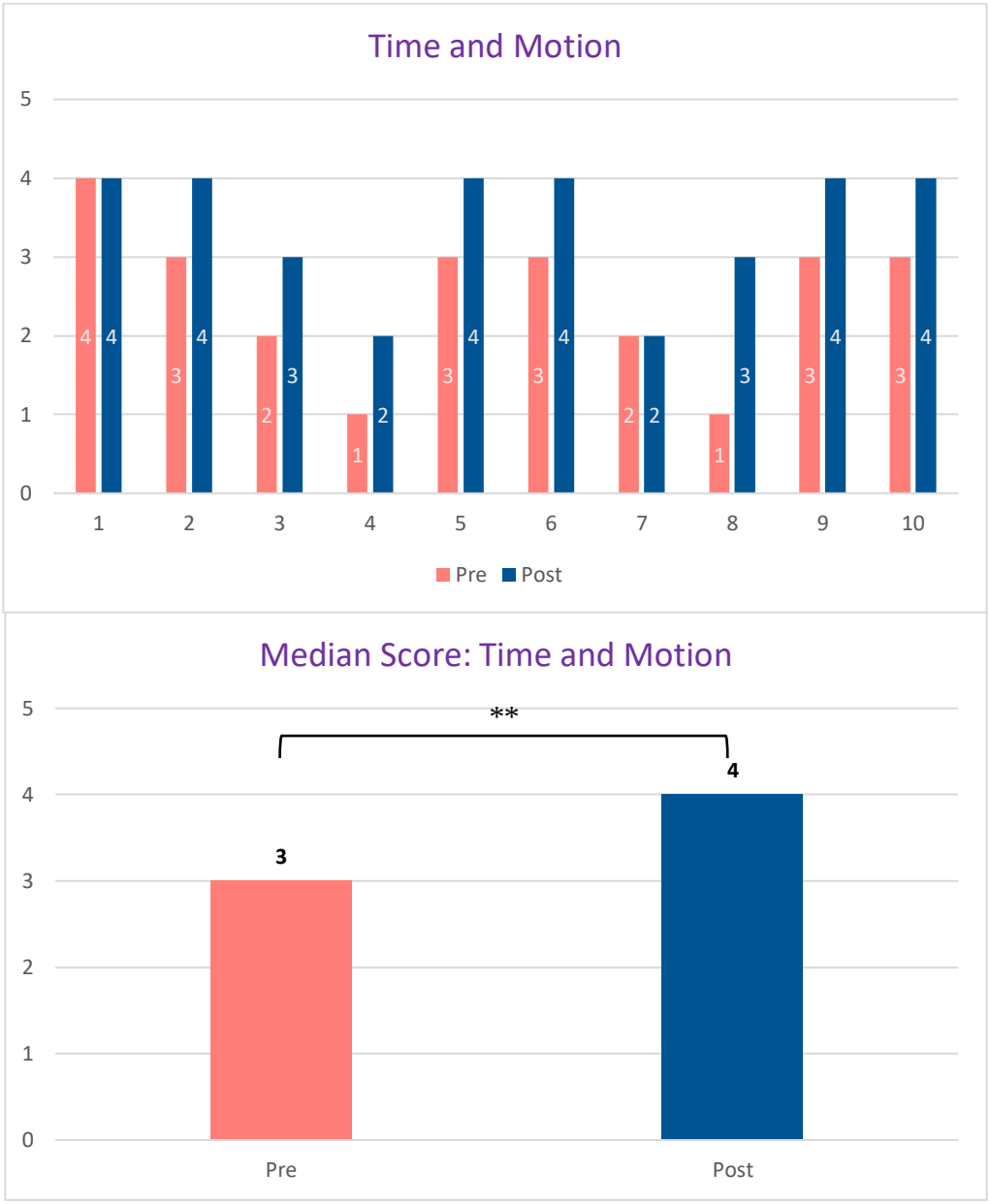
Wilcoxon Signed-Rank Test, z=-2.07, p=0.038*

The Respect for Tissue Score of the second operation after reviewing the video module was significantly higher than the first operation.

3.2.1.2 Expert-assessment Outcome: OSATS - Time and Motion Score

The median time and motion score of the second operation after watching the video learning material (Median=4.0, IQR=2.75-4.0) was significantly higher than the first operation (Median=3.0, IQR=1.75-3.0); [Wilcoxon Signed-Rank Test, z=-2.71, p=0.007]. The result is shown in Figure 13.

Figure 13. OSATS – Time and Motion Score



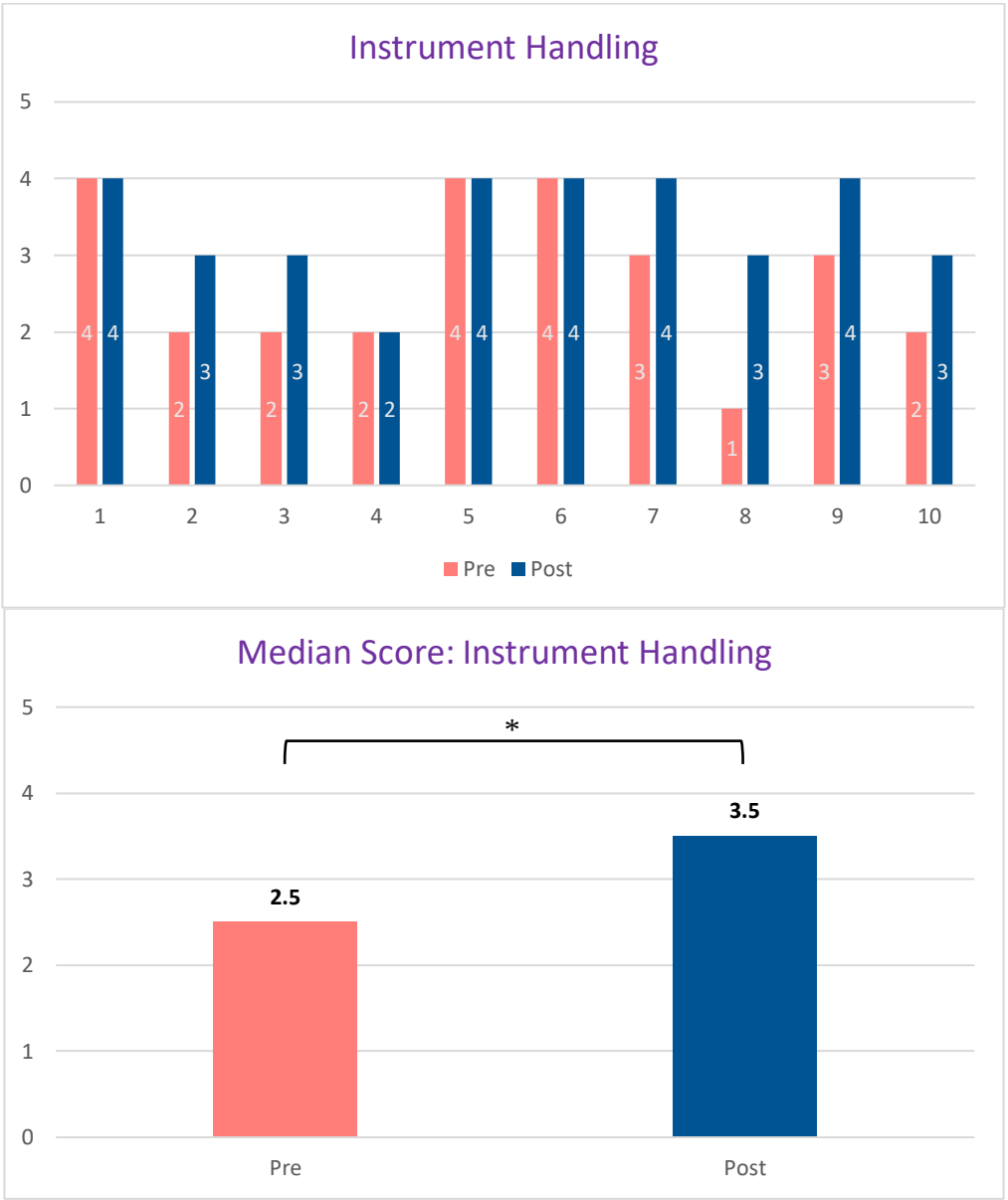
Wilcoxon Signed-Rank Test, z=-2.71, p=0.007**

The Time and Motion Score of the second operation after reviewing the video module was significantly higher than the first operation.

3.2.1.3 Expert-assessment Outcome: OSATS - Instrument Handling Score

The median instrument handling score of the second operation after watching the video learning material (Median=3.5, IQR=3.0-4.0) was significantly higher than the first operation (Median=2.5, IQR=2.0-4.0); [Wilcoxon Signed-Rank Test, z=-2.33, p=0.020]. The result is shown in Figure 14/

Figure 14. OSATS – Instrument Handling Score



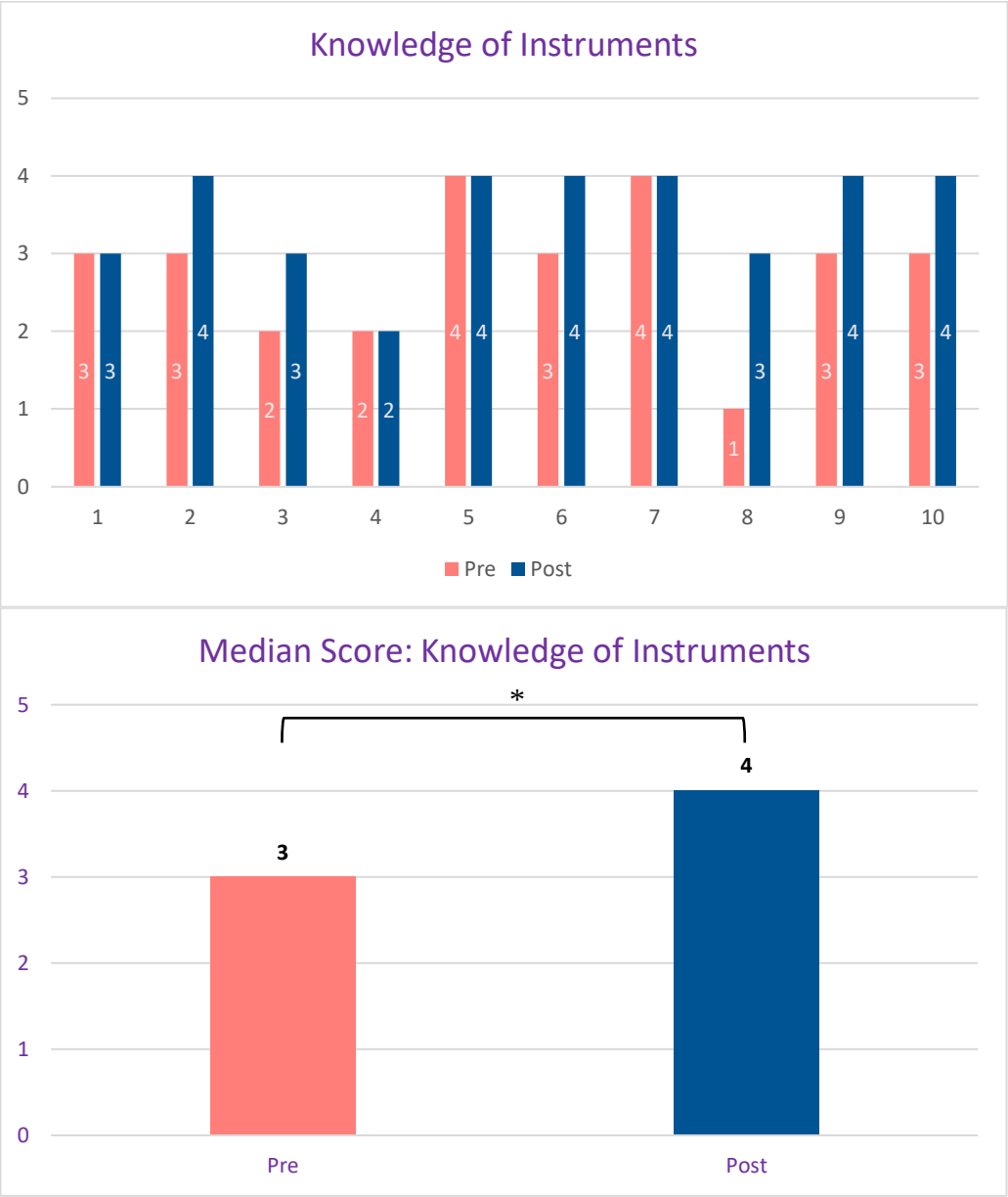
Wilcoxon Signed-Rank Test, z=-2.33, p=0.020*

The Instrument Handling Score of the second operation after reviewing the video module was significantly higher than the first operation.

3.2.1.4 Expert-assessment Outcome: OSATS - Knowledge of Instruments Score

The median knowledge of instruments score of the second operation after watching the video learning material (Median=4.0, IQR=3.0-4.0) was significantly higher than the first operation (Median=3.0, IQR=2.0-3.25); [Wilcoxon Signed-Rank Test, z=-2.33, p=0.020]. The result is shown in Figure 15.

Figure 15. OSATS – Knowledge of Instruments Score



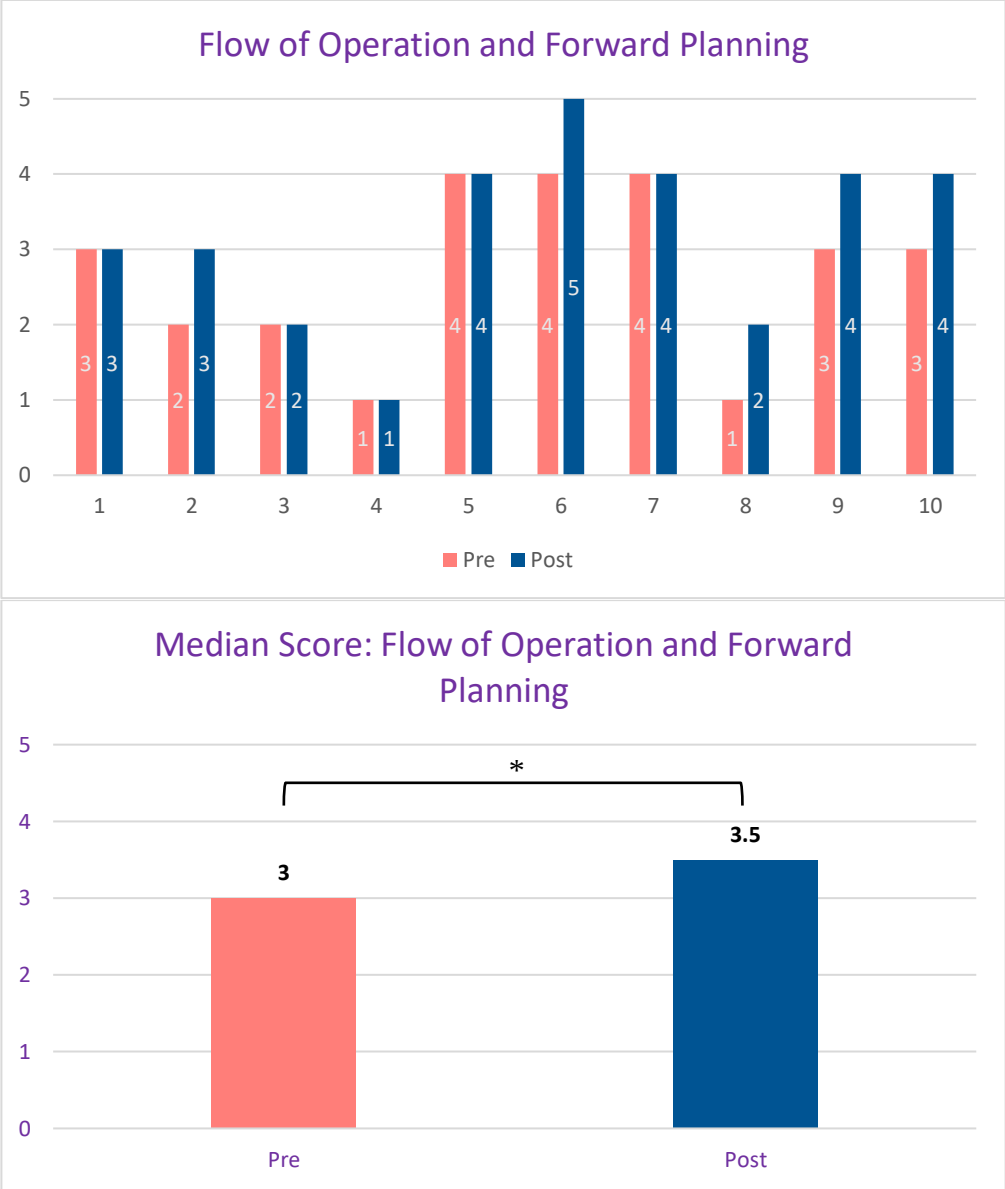
Wilcoxon Signed-Rank Test, z=-2.33, p=0.020*

The Knowledge of Instruments Score of the second operation after reviewing the video module was significantly higher than the first operation.

3.2.1.5 Expert-assessment Outcome: OSATS - Flow of Operation and Forward Planning Score

The median flow of operation and forward planning score of the second operation after watching the video learning material (Median=3.5, IQR=2.0-4.0) was significantly higher than the first operation (Median=3.0, IQR=1.75-4.0); [Wilcoxon Signed-Rank Test, z=-2.24, p=0.025]. The result is shown in Figure 16.

Figure 16. OSATS – Flow of Operation and Forward Planning Score



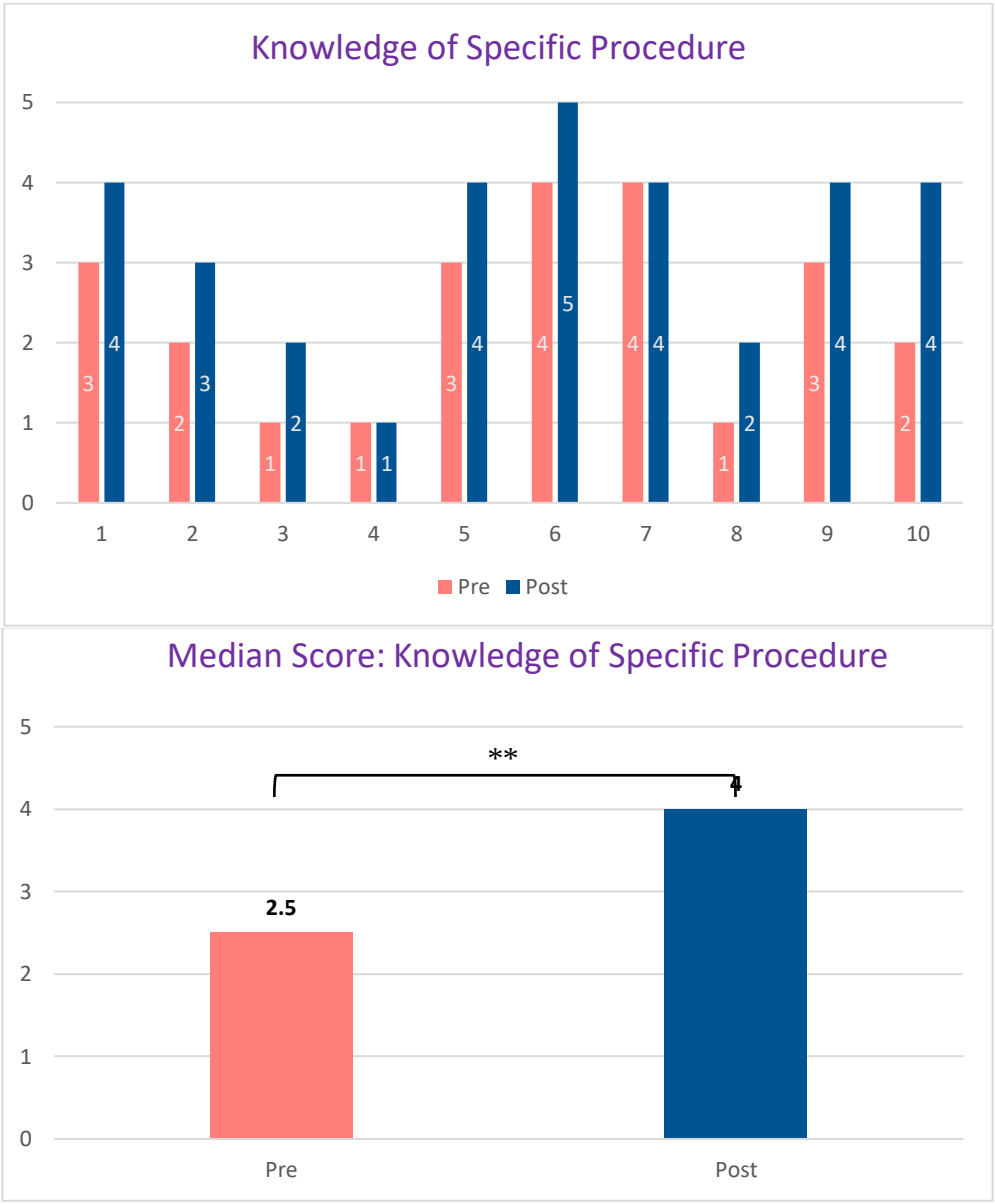
Wilcoxon Signed-Rank Test, z=-2.24, p=0.025*

The Flow of Operation Score of the second operation after reviewing the video module was significantly higher than the first operation.

3.2.1.6 Expert-assessment Outcome: OSATS - Knowledge of Specific Procedure Score

The median knowledge of specific procedure score of the second operation after watching the video learning material (Median=4.0, IQR=2.0-4.0) was significantly higher than the first operation (Median=2.5, IQR=1.0-3.25); [Wilcoxon Signed-Rank Test, z=-2.71, p=0.007]. The result is shown in Figure 17.

Figure 17. OSATS – Knowledge of Specific Procedure Score



Wilcoxon Signed-Rank Test, z=-2.71, p=0.007**

The Knowledge of Specific Procedure Score of the second operation after reviewing the video module was significantly higher than the first operation.

Table 6. Operative time for the surgeries before compared with after the exposure to the intervention

Quantitative outcome	Operative time Before (minute) Median (IQR)	Operative time After (minute) Median (IQR)	Z Wilcoxon Signed-Rank Test	P value Wilcoxon Signed-Rank Test (Two-sided)
Operative time	55.00 (36.25 – 79.75)	47.00 (31.50 – 61.50)	-1.070	0.285

Table 7. Mean percentage of lymph node mass resected for the surgeries before compared with after the exposure to the intervention

Quantitative outcome	Percentage Before Mean (± SD)	Percentage After Mean (± SD)	Mean difference (± SD)	95% CI of the difference	P value Paired Samples T Test (Two-sided)
Percentage of lymph node mass resected	52.07 (± 15.34)	81.57 (± 17.67)	29.50 (± 17.27)	17.15 – 41.86	<0.001

Table 8. Scores for each component in OSATS for the surgeries before compared with after the exposure to the intervention

OSATS	Score Before Median (IQR)	Score After Median (IQR)	Z Wilcoxon Signed-Rank Test	P value Wilcoxon Signed-Rank Test (Two-sided)
Respect of tissue	3.00 (2.00-4.00)	4.00 (3.00-4.00)	-2.070	0.038
Time and motion	3.00 (1.75-3.00)	4.00 (2.75-4.00)	-2.714	0.007
Instrument handling	2.50 (2.00-4.00)	3.50 (3.00-4.00)	-2.333	0.020
Knowledge of instruments	3.00 (2.00-3.25)	4.00 (3.00-4.00)	-2.333	0.020
Flow of operation and forward planning	3.00 (1.75-4.00)	3.50 (2.00-4.00)	-2.236	0.025
Knowledge of specific procedure	2.50 (1.00-3.25)	4.00 (2.00-4.00)	-2.714	0.007

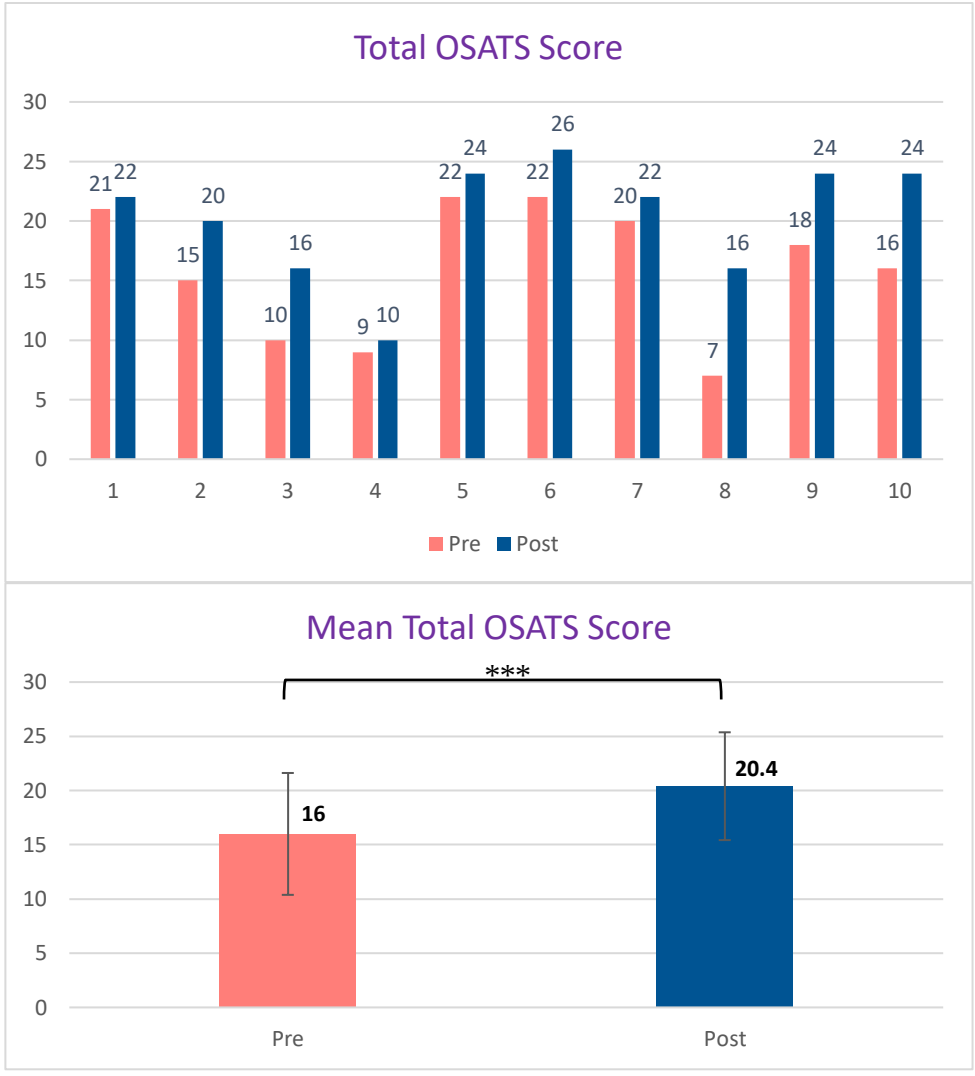
Table 9. Expert-assessment scores for total OSATS score and procedure-specific rating scale (completeness of lymph node dissection and preservation of nerve integrity scores) for the surgeries before compared with after the exposure to the intervention

Expert-assessment	Score Before Mean (± SD)	Score After Mean (± SD)	Mean difference (± SD)	95% CI of the difference	P value Paired Samples T Test (Two-sided)
Total OSATS score	16.00 (± 5.62)	20.40 (± 4.97)	4.40 (±2.88)	2.343 – 6.457	<0.001
Completeness of lymph node dissection score	2.38 (± 1.10)	3.63 (± 1.16)	1.25 (± 1.13)	0.44 – 2.06	0.007
Preservation of nerve integrity score	2.08 (± 1.26)	3.63 (± 1.24)	1.55 (± 1.52)	0.46 – 2.64	0.010

3.2.2 Expert-assessment Outcome: Total Objective Structured Assessment of Technical Skills (OSATS) Score

The mean total OSATS score of the second operation after watching the video learning material (M=20.40; SD=4.97) was significantly higher than the first operation (M=16.00; SD=5.62); [Paired Samples T-test, t(9)=4.84, p<0.001]. The 95% confidence interval of the difference between the means ranged from 2.343 to 6.457, and indicated the difference between the means of the samples. The result is shown in Figure 18.

Figure 18. Total OSATS Score



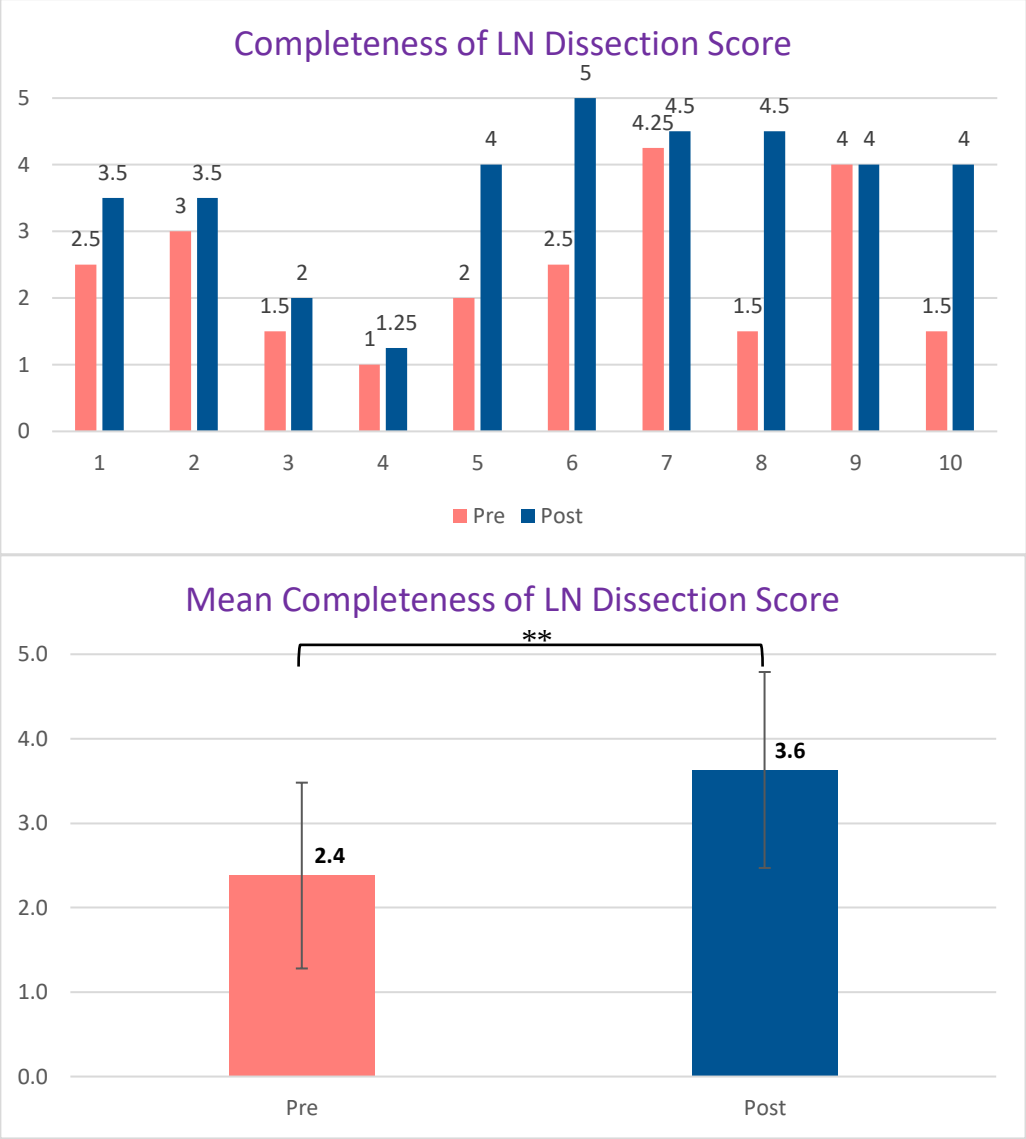
Paired Samples T-test, t(9)=4.84, p<0.001***

The Total OSATS Score of the second operation after reviewing the video module was significantly higher than the first operation.

3.2.3 Expert-assessment Outcome: Completeness of Lymph Node Dissection Score

The mean completeness of lymph node dissection score of the second operation after watching the video learning material (M=3.63; SD=1.16) was significantly higher than the first operation (M=2.38; SD=1.10); [Paired Samples T-test, t(9)=3.50, p=0.007]. The 95% confidence interval of the difference between the means ranged from 0.44 to 2.06, and indicated the difference between the means of the samples. The result is shown in Figure 19.

Figure 19. Completeness of Lymph Node Dissection Score



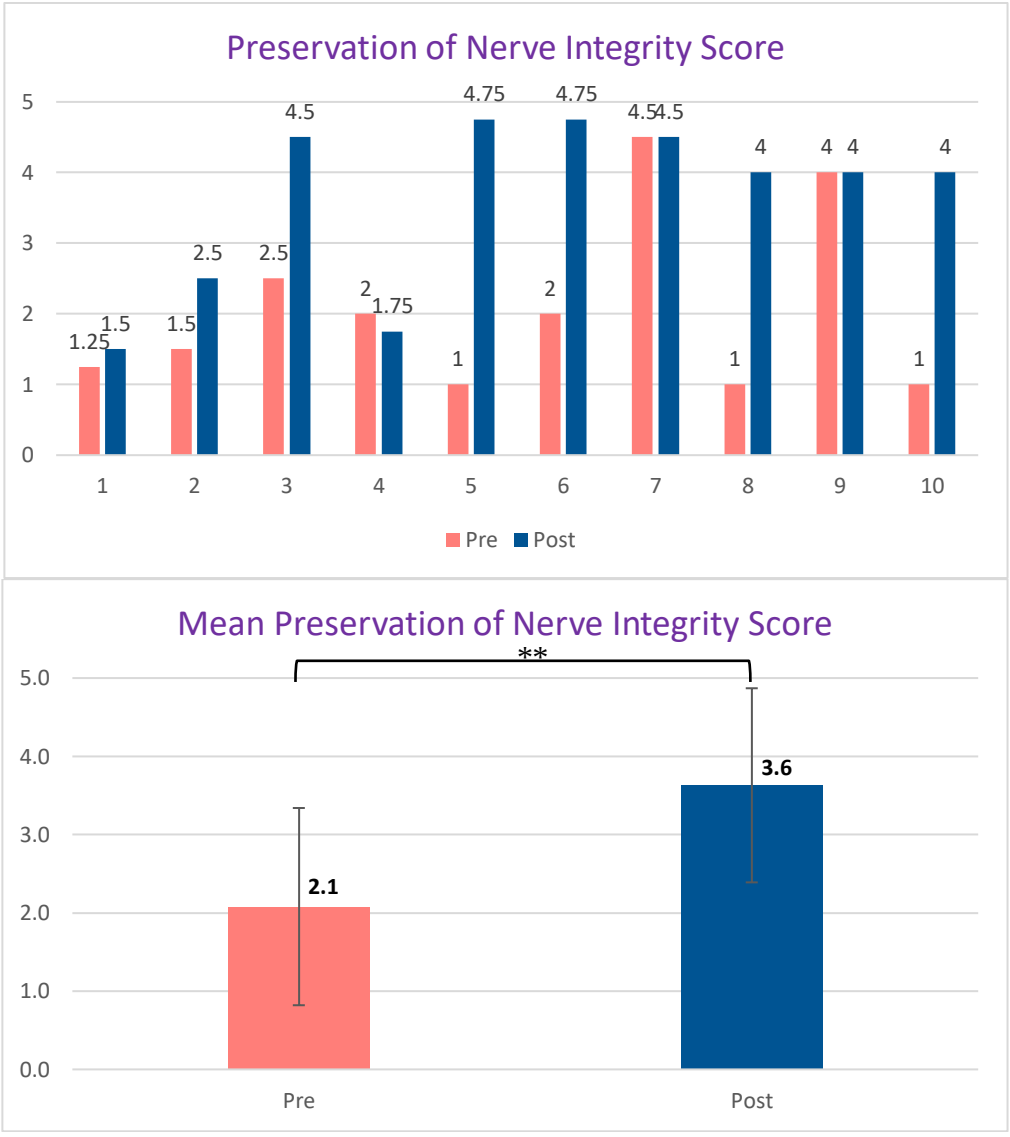
Paired Samples T-test, t(9)=3.50, p=0.007**

The Completeness of Lymph Node Dissection Score of the second operation after reviewing the video module was significantly higher than the first operation.

3.2.4 Expert-assessment Outcome: Preservation of Nerve Integrity Score

The mean preservation of nerve integrity score of the second operation after watching the video learning material (M=3.63; SD=1.24) was significantly higher than the first operation (M=2.08; SD=1.26); [Paired Samples T-test, t(9)=3.23, p=0.010]. The 95% confidence interval of the difference between the means ranged from 0.46 to 2.64, and indicated the difference between the means of the samples. The result is shown in Figure 20.

Figure 20. Preservation of Nerve Integrity Score



Paired Samples T-test, t(9)=3.23, p=0.010**

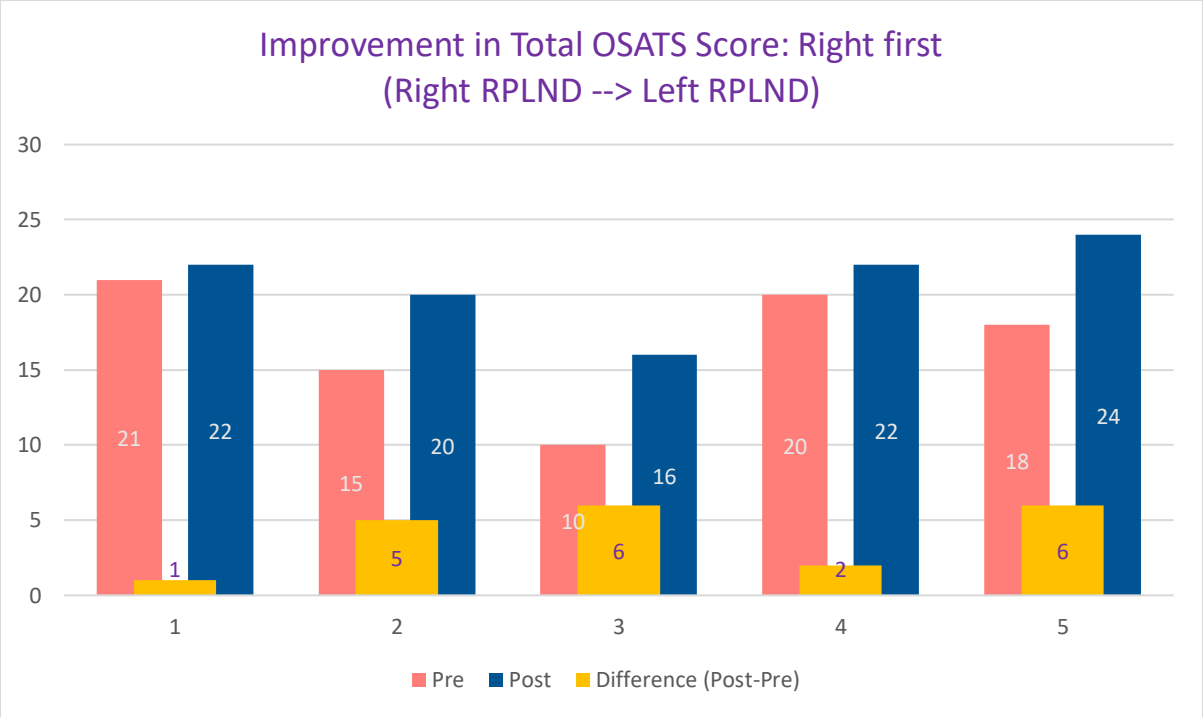
The Preservation of Nerve Integrity Score of the second operation after reviewing the video module was significantly higher than the first operation.

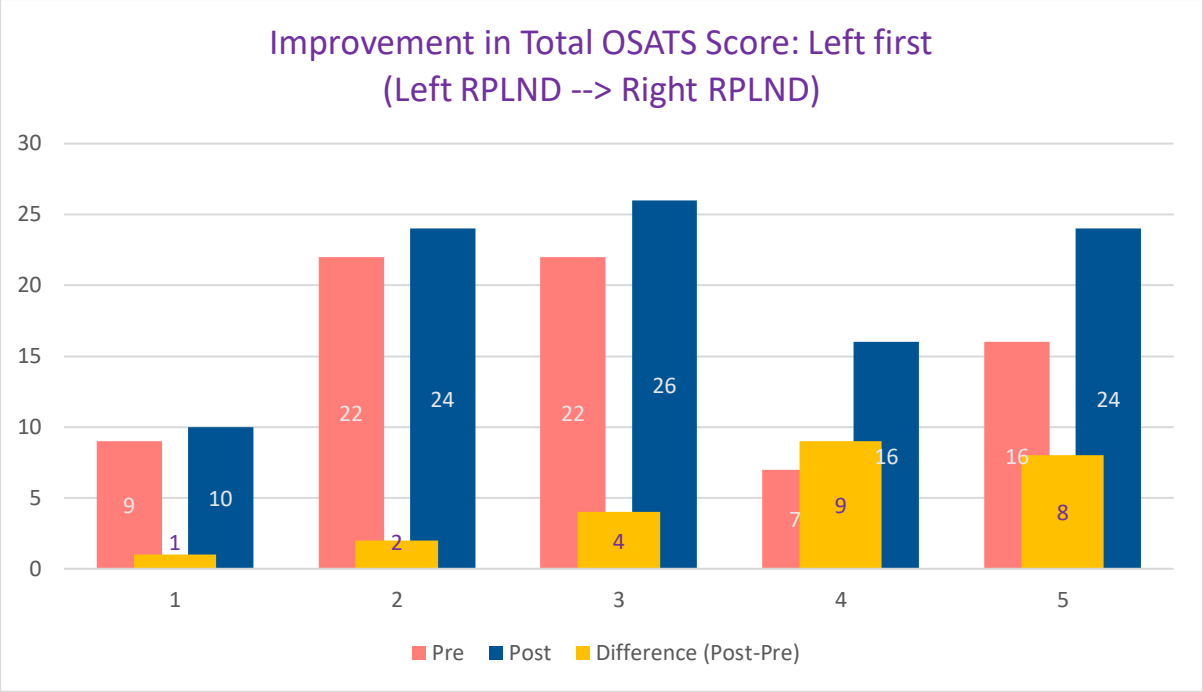
3.2.5 Total OSATS Score: Right-sided vs. Left-sided First

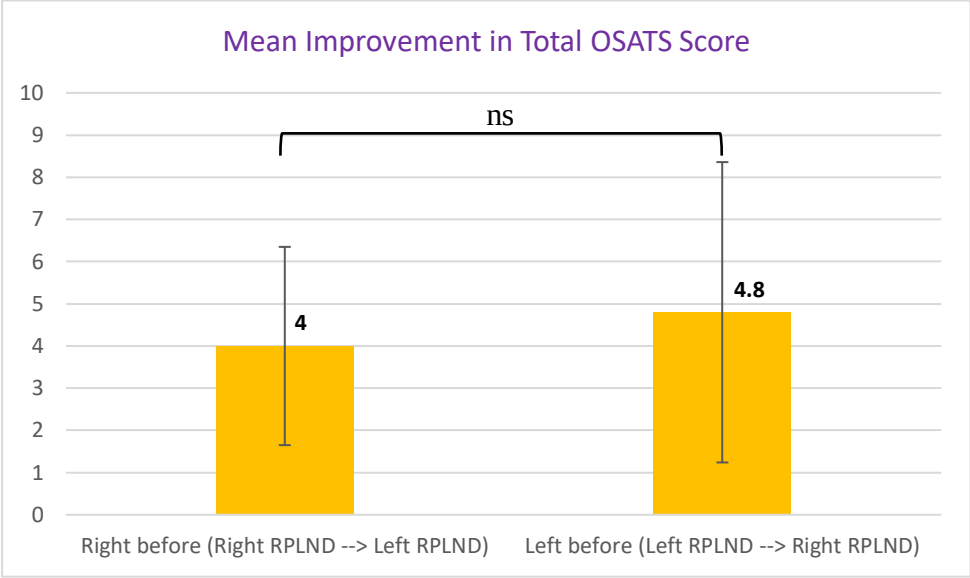
We also compared the improvement in total OSATS score between the group of the participants who performed the right-sided RPLND first, and the group of the participants who performed the left-sided RPLND first.

There was no significant difference in the improvement of total OSATS score between the group of participants who performed the right-sided RPLND before (M=4.00, SD=2.35) and the group of participants who performed the left-sided RPLND before (M=4.80, SD=3.56); [Student's T-test, p=0.686]. The 95% confidence interval of the difference between the means ranged from -5.20 to 3.60 and did not indicate a difference between the means of the samples. The result is shown in Figure 21.

Figure 21. Improvement in Total OSATS Score Between Participants Who Performed the Right-sided or Left-sided RPLND First







Student's T-test, p=0.686; ns: not significant

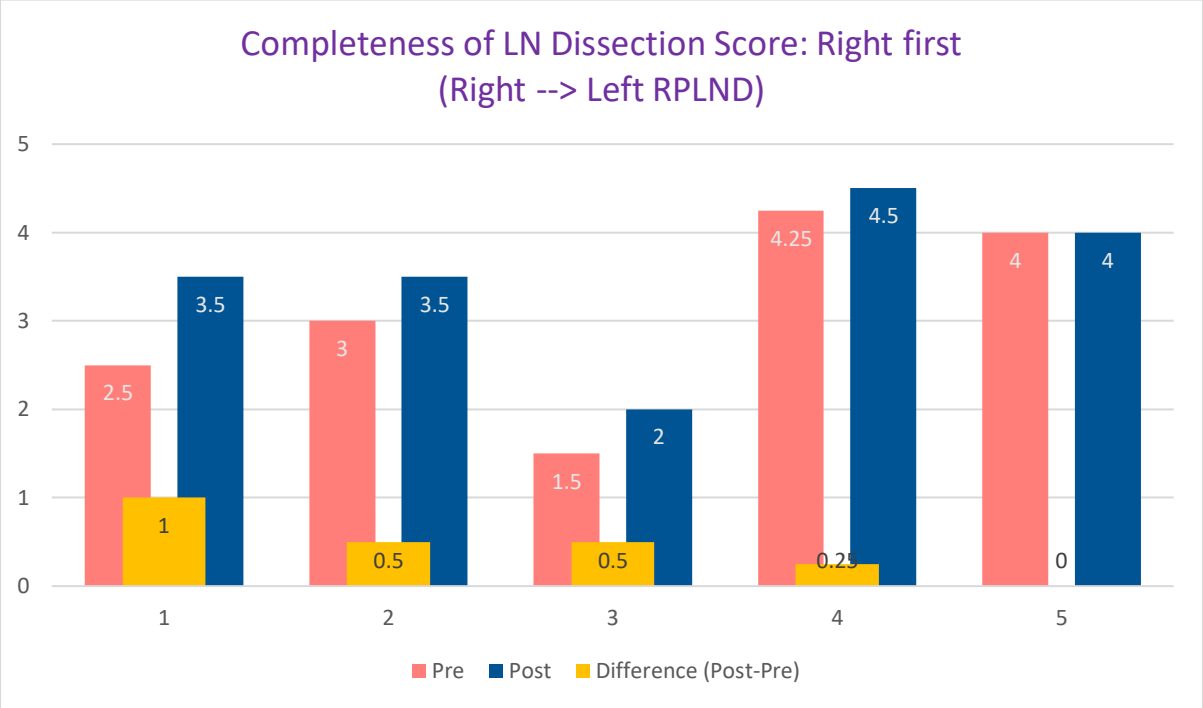
There was no significant difference in the improvement of Total OSATS Score between the participants who performed the right-sided or left-sided RPLND first.

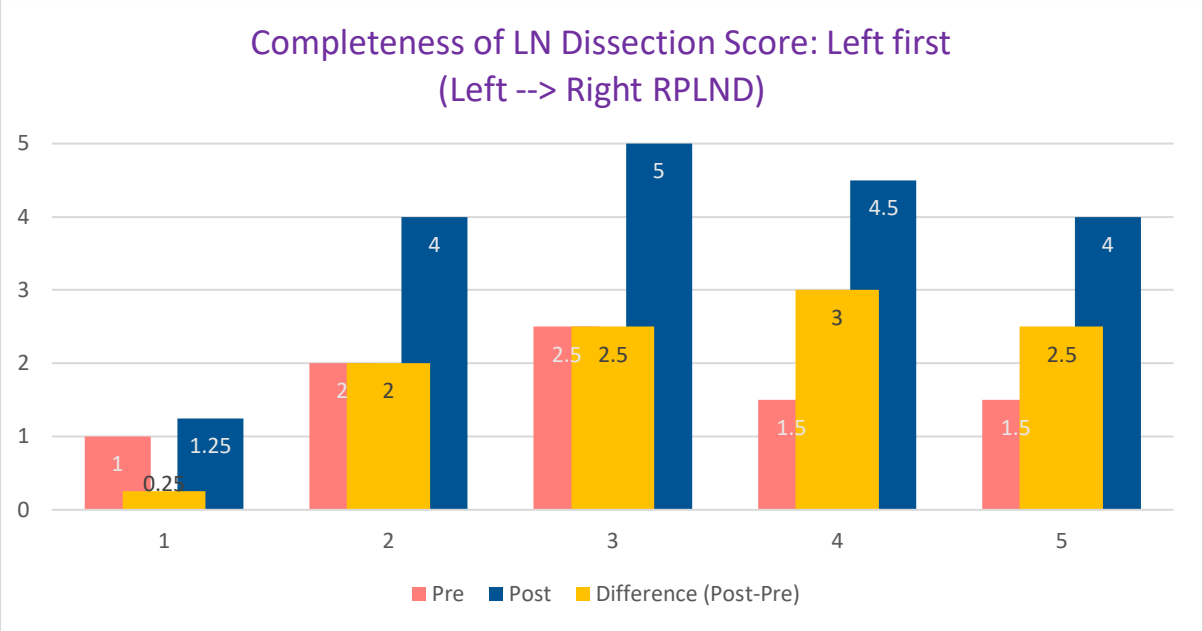
3.2.6 Completeness of Lymph Node Dissection Score: Right-sided vs Left-sided First

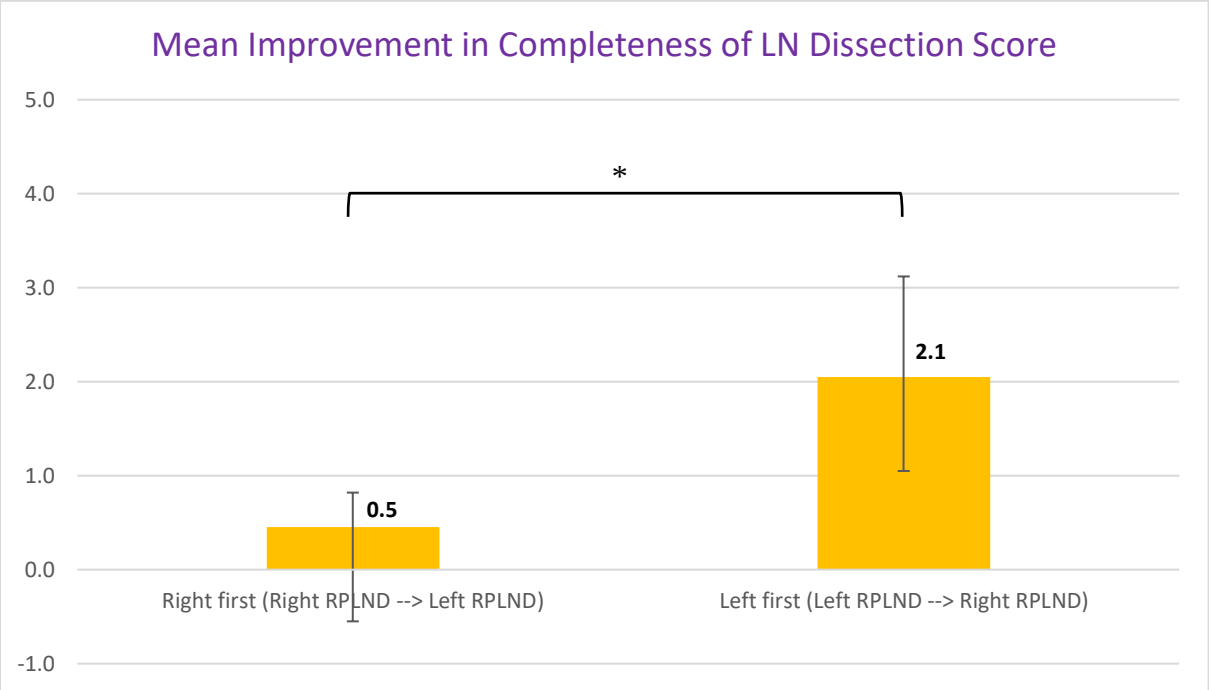
We also compared the improvement in completeness of lymph node dissection score between the group of the participants who performed the right-sided RPLND first, and the group of the participants who performed the left-sided RPLND first.

The group of participants who performed the left-sided RPLND before had significantly more improvement in completeness of lymph node dissection score (M=2.05, SD=1.07) than the group of participants who performed the right-sided RPLND before (M=0.45, SD=0.37); [Student's T-test, p=0.013]. The 95% confidence interval of the difference between the means ranged from -2.76 to -0.44 and indicated the difference between the means of the samples. The result is shown in Figure 22.

Figure 22. Improvement in Completeness of Lymph Node Dissection Score Between Participants Who Performed the Right-sided or Left-sided RPLND First







Student's T-test, p=0.013*

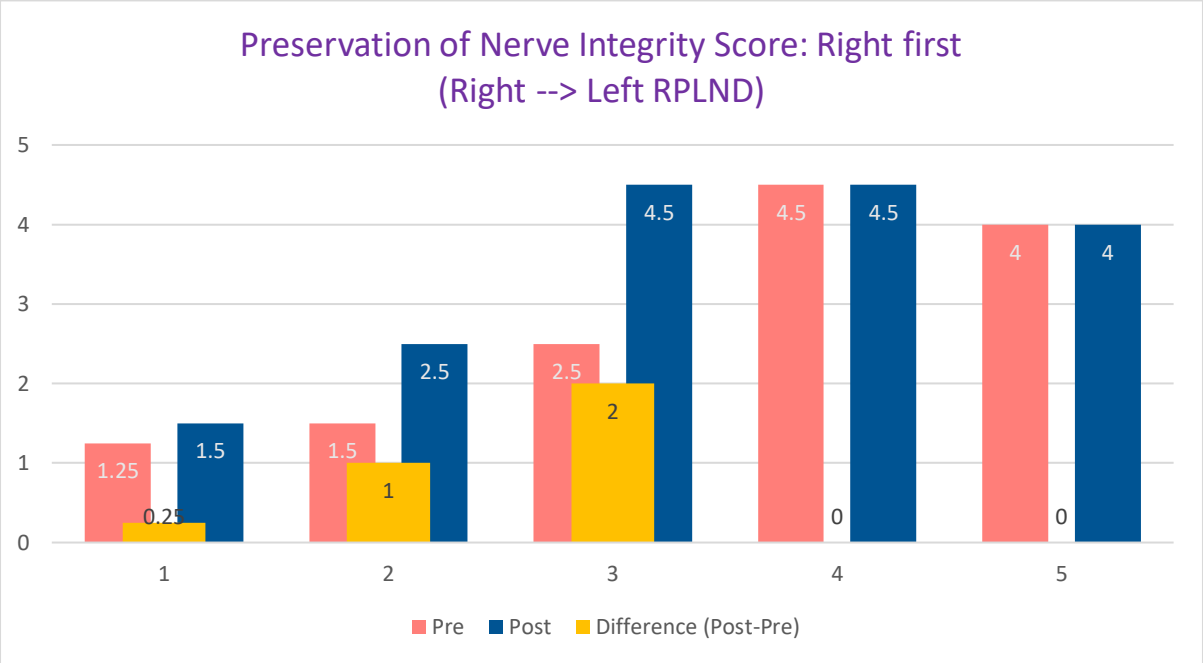
Participants who performed the left-sided RPLND first had significantly higher improvement in their Completeness of Lymph Node Dissection Score than participants who performed the right-sided first.

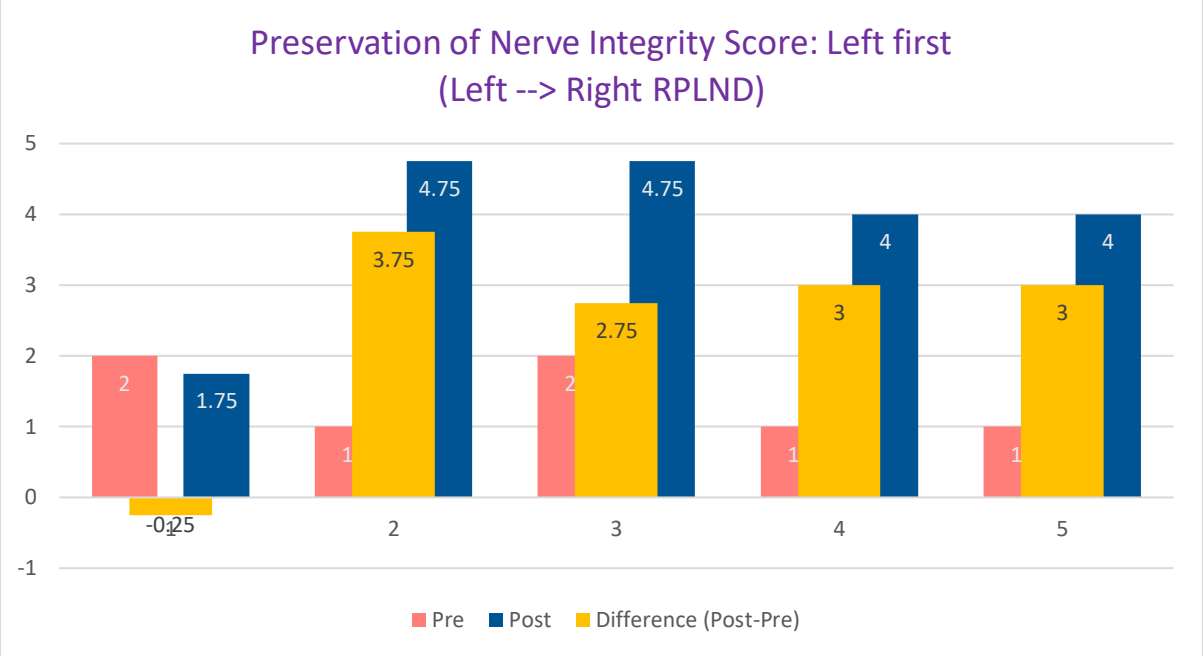
3.2.7 Preservation of Nerve Integrity Score: Right-sided vs Left-sided First

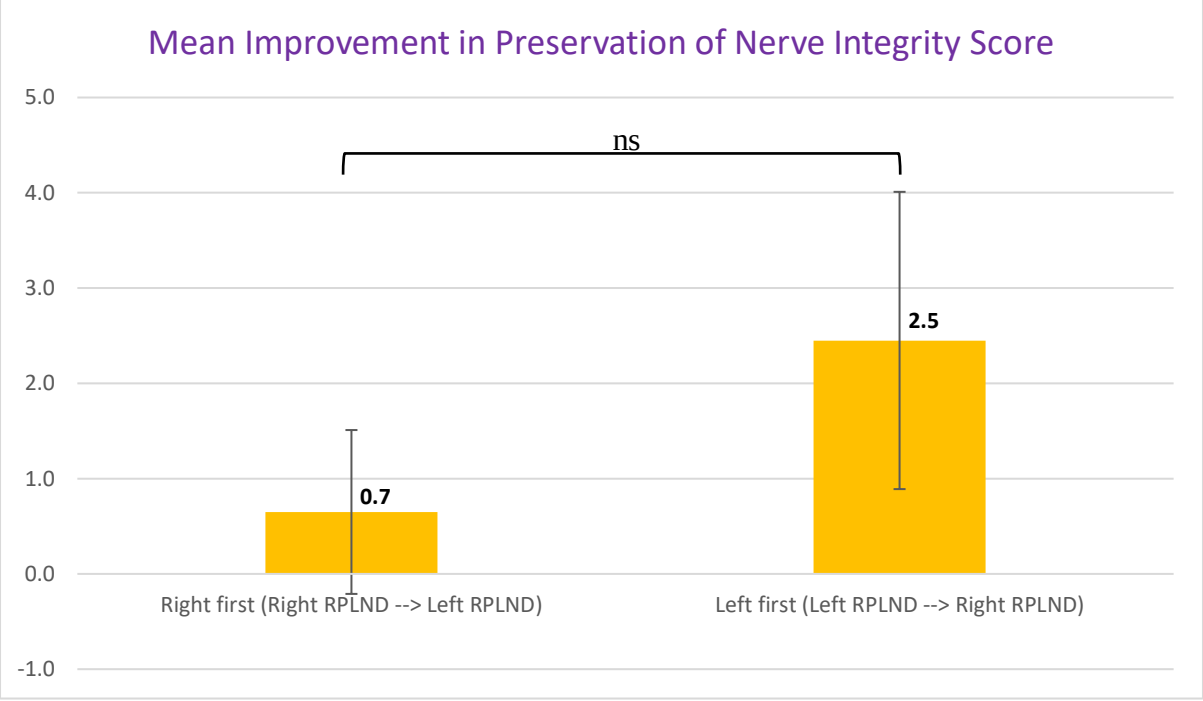
We also compared the improvement in preservation of nerve integrity score between the group of the participants who performed the right-sided RPLND first, and the group of the participants who performed the left-sided RPLND first.

There was no significant difference in the improvement of preservation of nerve integrity score between the group of participants who performed the right-sided RPLND before (M=0.65, SD=0.86) and the group of participants who performed the left-sided RPLND before (M=2.45, SD=1.56); [Student's T-test, p=0.053]. The 95% confidence interval of the difference between the means ranged from -3.63 to 0.03 and did not indicate a difference between the means of the samples. The result is shown in Figure 23.

Figure 23. Improvement in Preservation of Nerve Integrity Score Between Participants Who Performed the Right-sided or Left-sided RPLND First







Student's T-test, p=0.053; ns: not significant

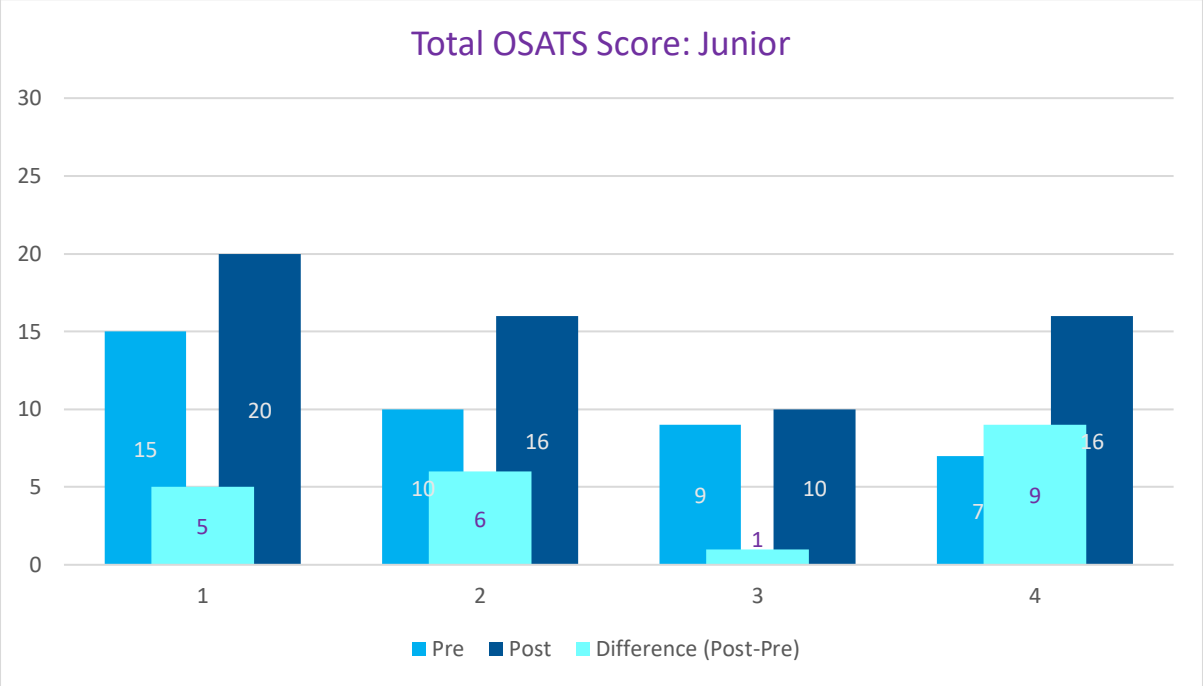
There was no significant difference in the improvement of Preservation of Nerve Integrity Score between the participants who performed the right-sided or left-sided RPLND first.

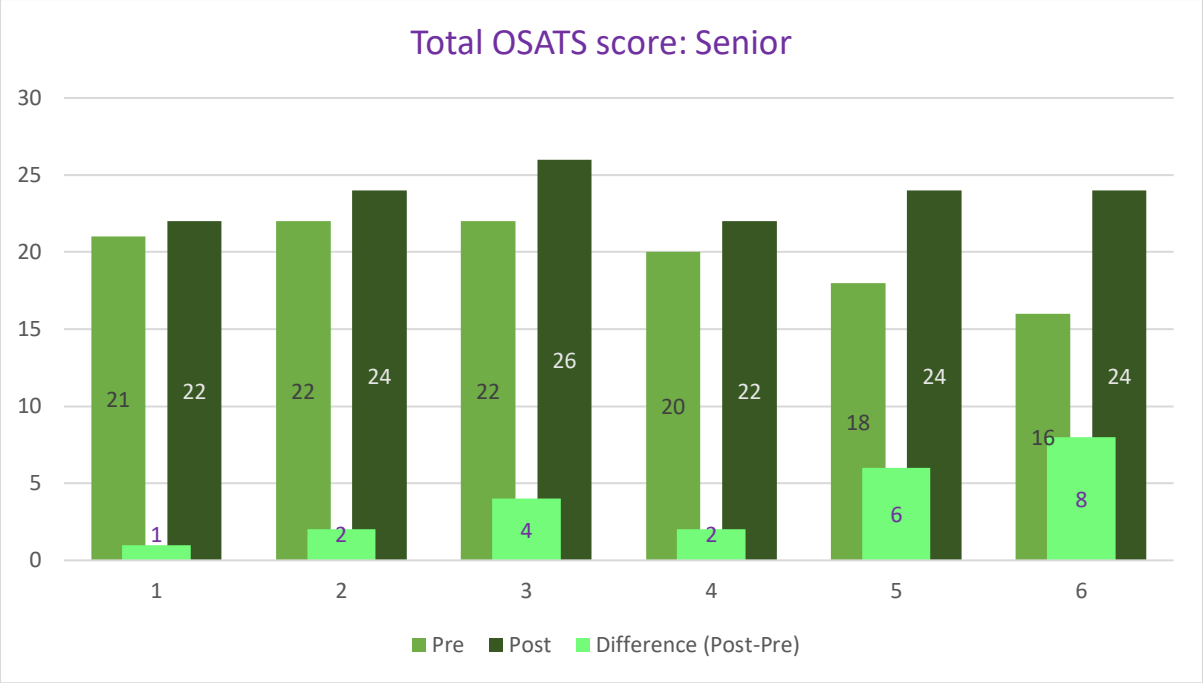
3.2.8 Total OSATS Score: Junior vs. Senior Level Participants

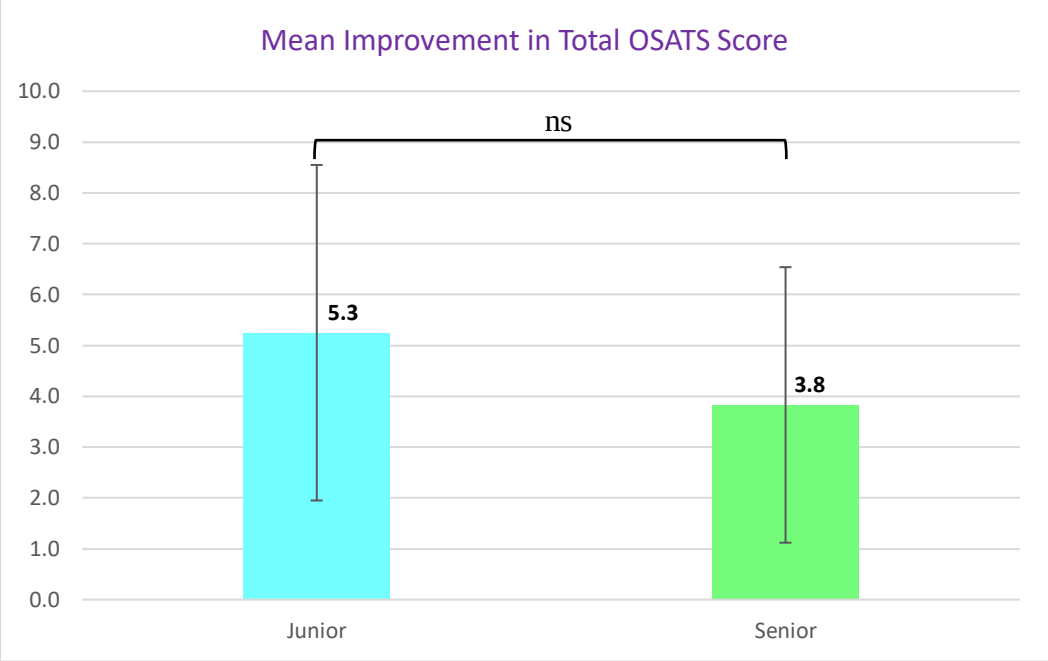
We also compared the improvement in total OSATS score between the group of junior level participants (two PGY2s and two PGY3s) and the group of senior level participants (three PGY4s, one PGY5, and two fellows).

There was no significant difference in the mean improvement of total OSATS score between the group of junior level participants (M=5.25, SD=3.30) and the group of senior level participants (M=3.83, SD=2.71); [Student's T-test, p=0.48]. The 95% confidence interval of the difference between the means ranged from -2.97 to 5.81, and did not indicate a difference between the means of the samples. The result is shown in Figure 24.

Figure 24. Improvement in the Total OSATS Score Between the Junior and Senior Level Participants







Student's T-test, p=0.48; ns: not significant

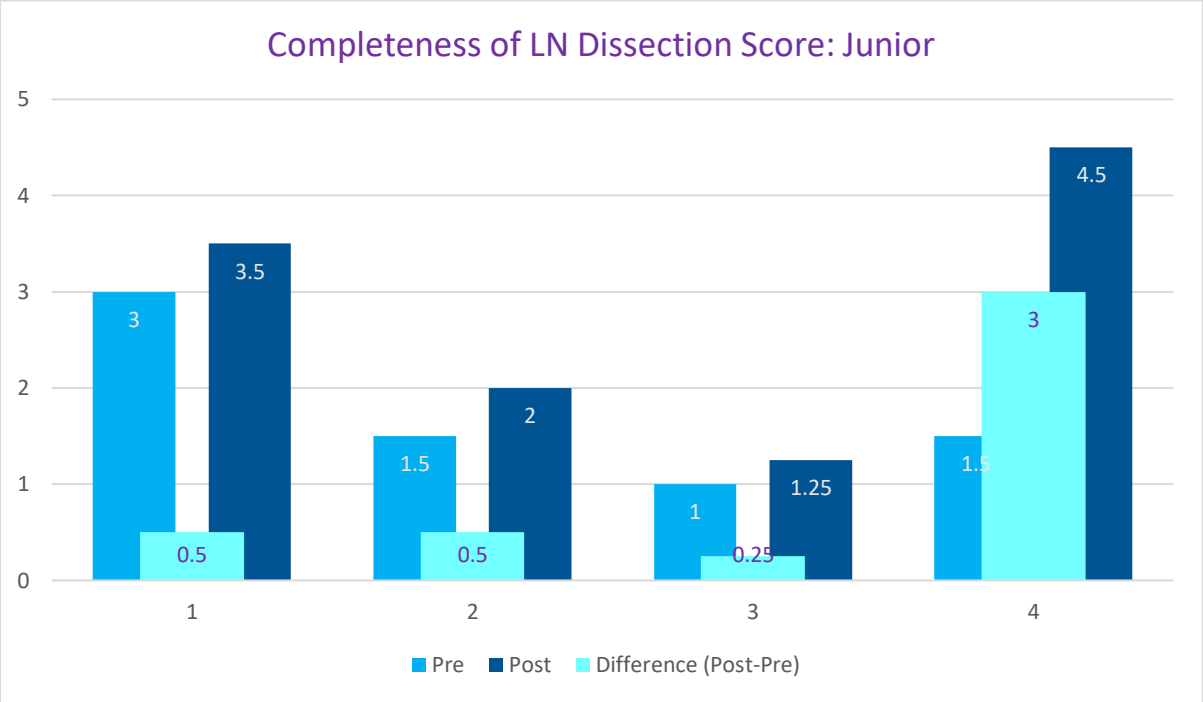
Improvement in the Total OSATS Score was similar between the junior and senior level participants.

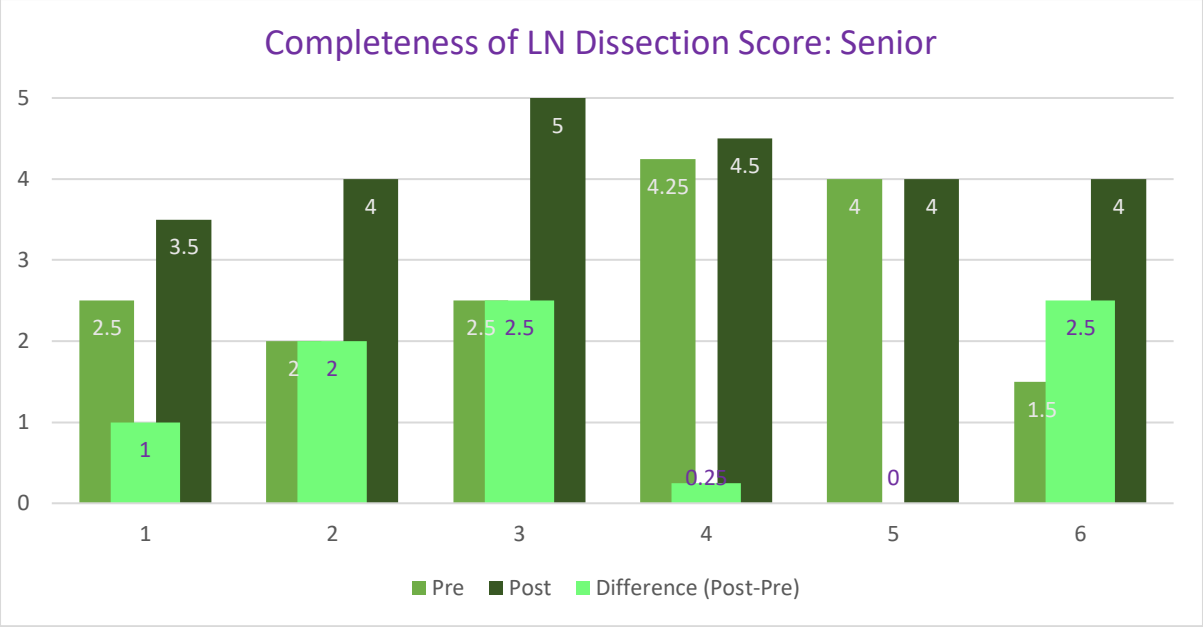
3.2.9 Completeness of Lymph Node Dissection Score: Junior vs. Senior Level Participants

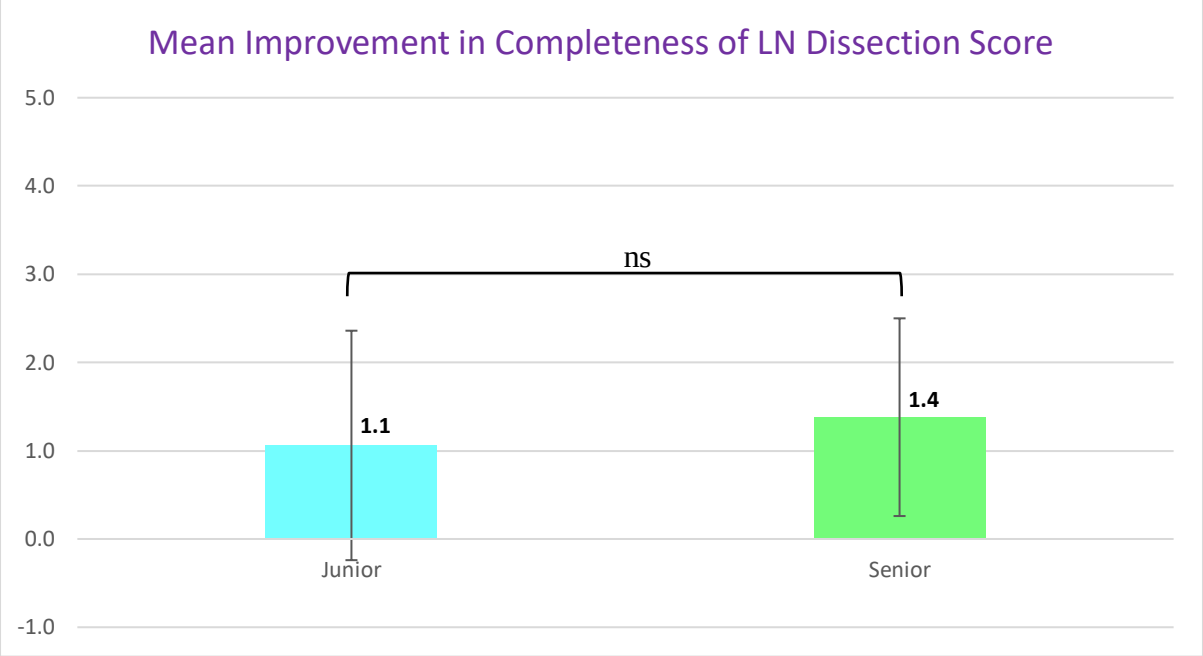
We also compared the improvement in completeness of lymph node dissection score between the group of junior level participants (two PGY2s and two PGY3s) and the group of senior level participants (three PGY4s, one PGY5, and two fellows).

There was no significant difference in the mean improvement of completeness of lymph node dissection score between the group of junior level participants (M=1.06, SD=1.30) and the group of senior level participants (M=1.38, SD=1.12); [Student's T-test, p=0.69]. The 95% confidence interval of the difference between the means ranged from -2.08 to 1.45, and did not indicate a difference between the means of the samples. The result is shown in Figure 25.

Figure 25. Improvement in the Completeness of Lymph Node Dissection Score Between the Junior and Senior Level Participants







Student's T-test, p=0.69; ns: not significant

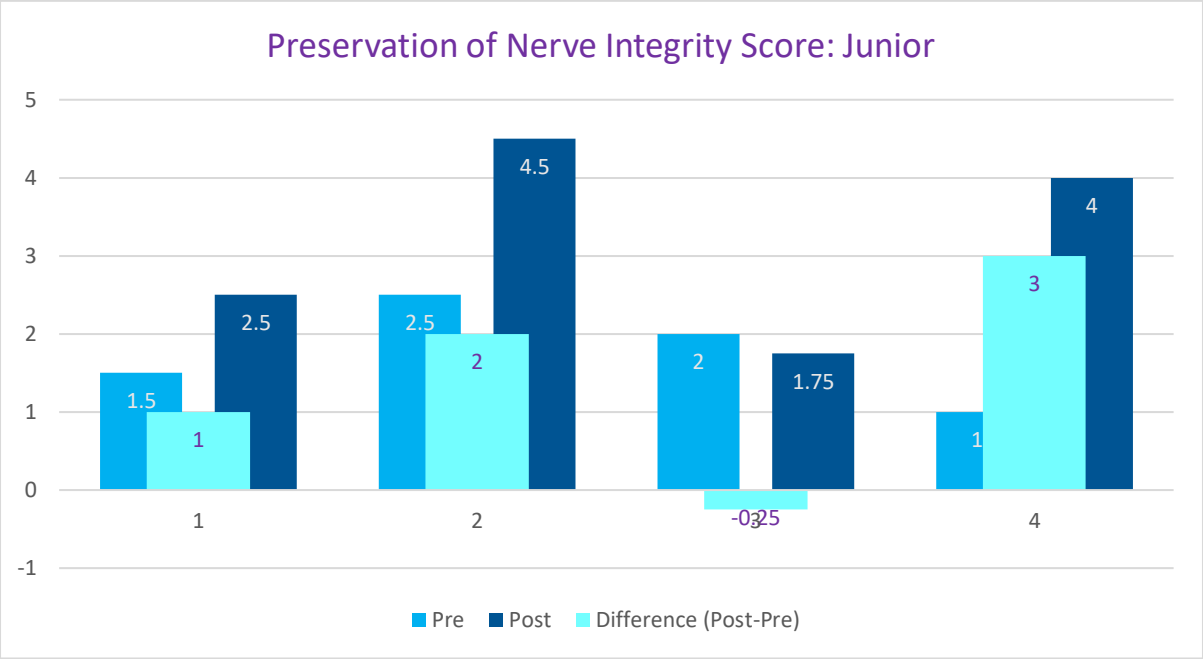
Improvement in the Completeness of Lymph Node Dissection Score was similar between the junior and senior level participants.

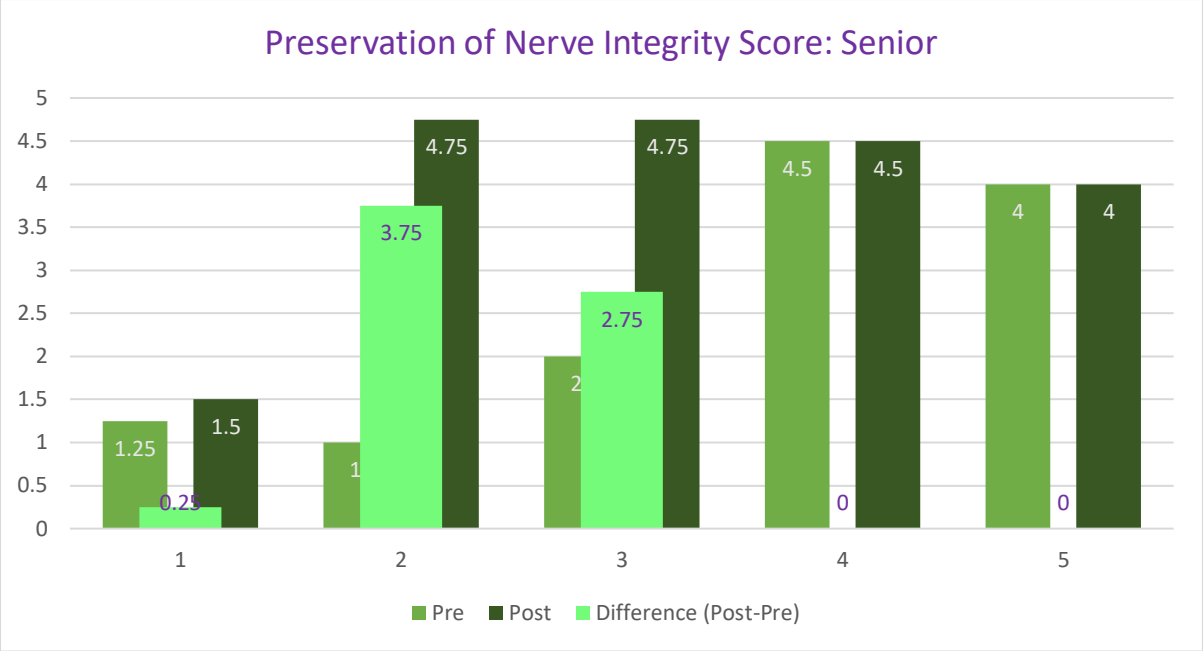
3.2.10 Preservation of Nerve Integrity Score: Junior vs Senior Level Participants

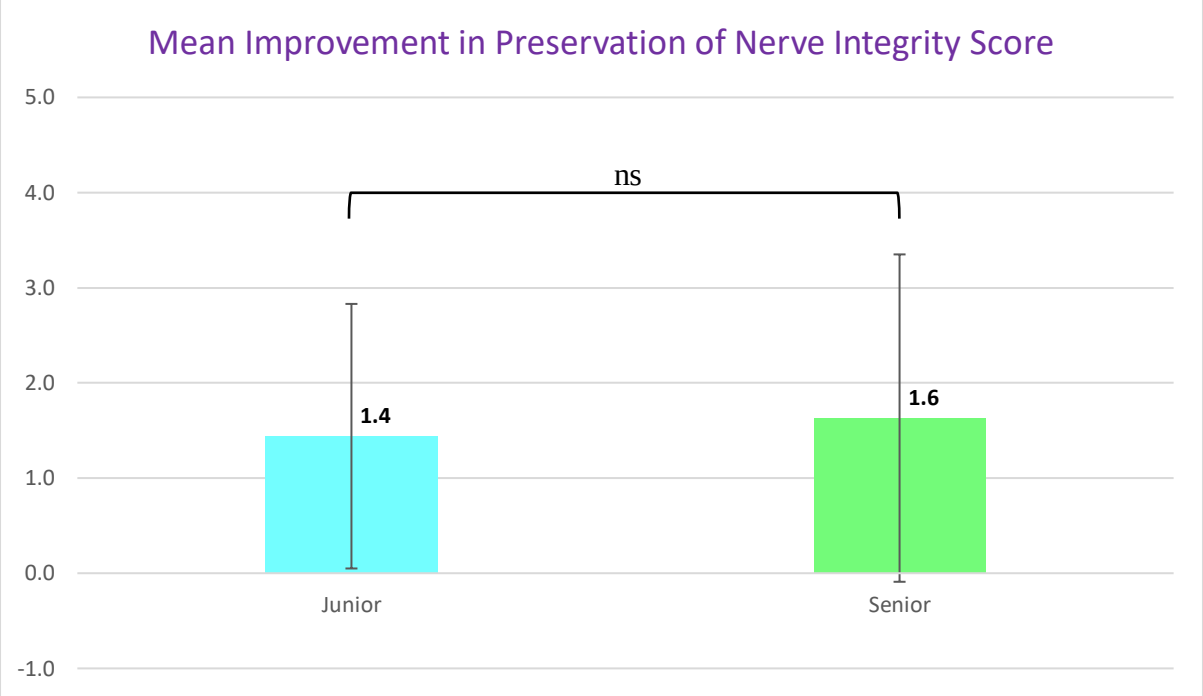
We also compared the improvement in the preservation of nerve integrity score between the group of junior level participants (two PGY2s and two PGY3s) and the group of senior level participants (three PGY4s, one PGY5, and two fellows).

There was no significant difference in the mean improvement of preservation of nerve integrity score between the group of junior level participants (M=1.44, SD=1.39) and the group of senior level participants (M=1.63, SD=1.72); [Student's T-test, p=0.86]. The 95% confidence interval of the difference between the means ranged from -2.58 to 2.20, and did not indicate a difference between the means of the samples. The result is shown in Figure 26.

Figure 26. Improvement in the Preservation of Nerve Integrity Score Between the Junior and Senior Level Participants







Student's T-test, p=0.86; ns: not significant

Improvement in the Preservation of Nerve Integrity Score was similar between the junior and senior level participants.

3.3 Self-assessment Outcomes

3.3.1 Self-assessment Score

3.3.1.1 Self-assessment Score: Efficiency

The mean self-assessment score for efficiency after the exposure to the intervention (M=51.40; SD=22.12) was significantly higher than before the intervention (M=24.20; SD=20.10); [Paired Samples T-test, t(9)=4.12, p=0.003]. The 95% confidence interval of the difference between the means ranged from 12.26 to 42.14, and indicated the difference between the means of the samples. The result is shown in Figure 27.

Figure 27. Self-assessment Score for Efficiency

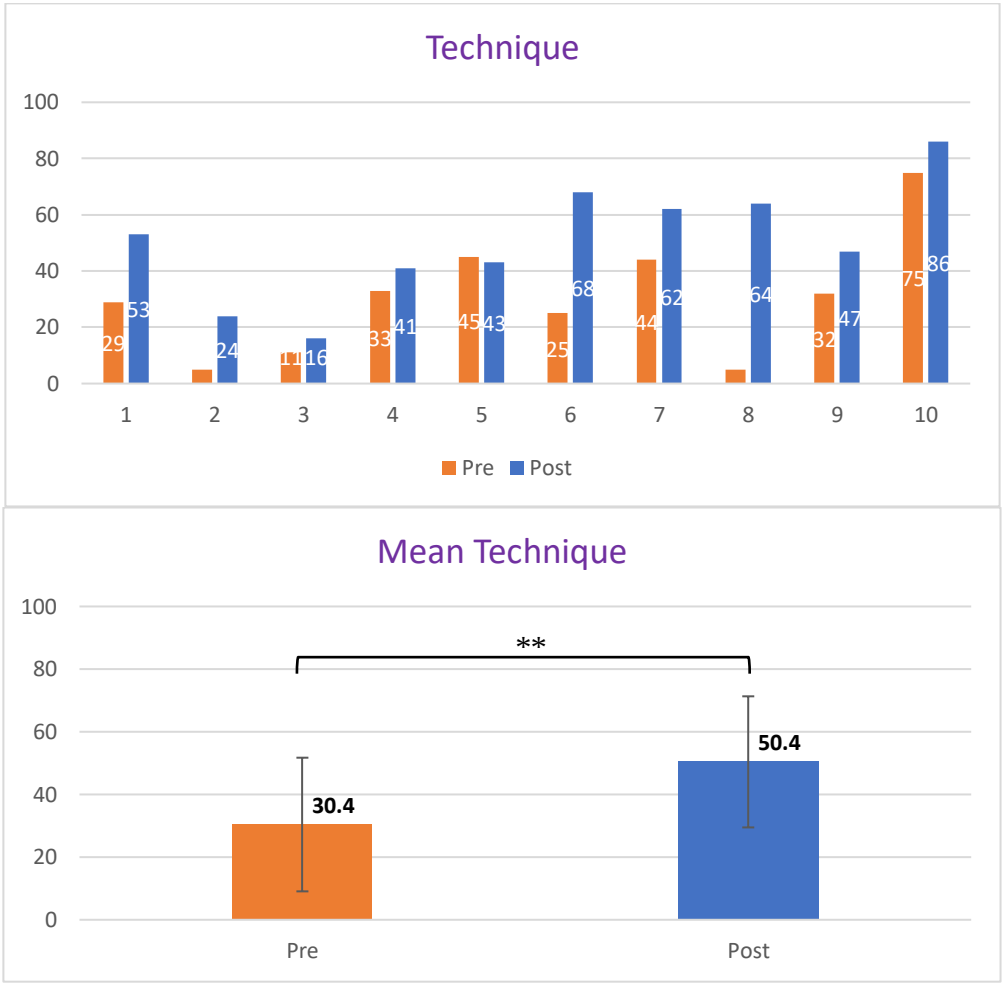
Paired Samples T-test, t(9)=4.12, p=0.003**

The Self-assessment Score for Efficiency consistently increased in the second operation.

3.3.1.2 Self-assessment Score: Technique

The mean self-assessment score for technique after the exposure to the intervention (M=50.40; SD=20.92) was significantly higher than before the intervention (M=30.40; SD=21.33); [Paired Samples T-test, t(9)=3.45, p=0.007]. The 95% confidence interval of the difference between the means ranged from 6.87 to 33.13, and indicated the difference between the means of the samples. The result is shown in Figure 28.

Figure 28. Self-assessment Score for Technique



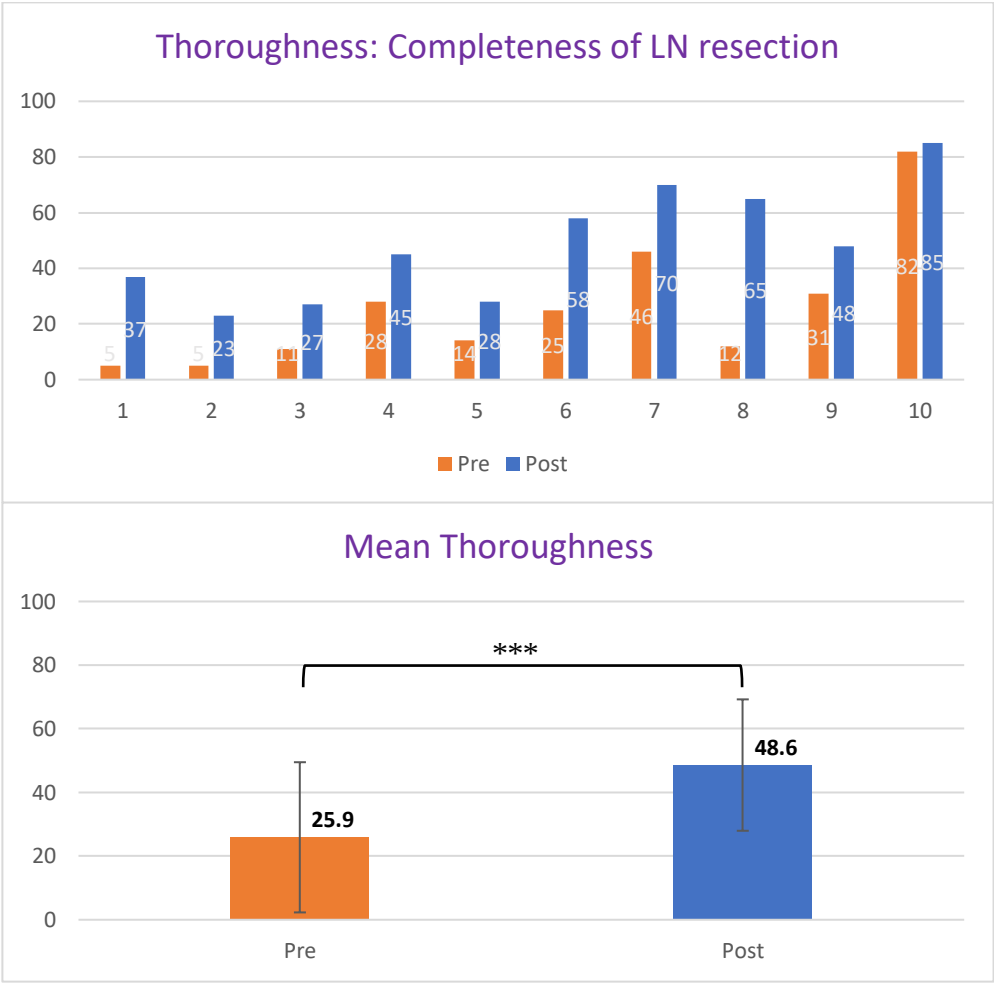
Paired Samples T-test, t(9)=3.45, p=0.007**

The Self-assessment Score for Technique consistently increased in the second operation.

3.3.1.3 Self-assessment Score: Thoroughness (completeness of lymph node resection)

The mean self-assessment score for thoroughness (completeness of lymph node resection) after the exposure to the intervention (M=48.60; SD=20.64) was significantly higher than before the intervention (M=25.90; SD=23.60); [Paired Samples T-test, t(9)=5.21, p<0.001]. The 95% confidence interval of the difference between the means ranged from 12.84 to 32.56, and indicated the difference between the means of the samples. The result is shown in Figure 29.

Figure 29. Self-assessment Score for Thoroughness (Completeness of Lymph Node Resection)



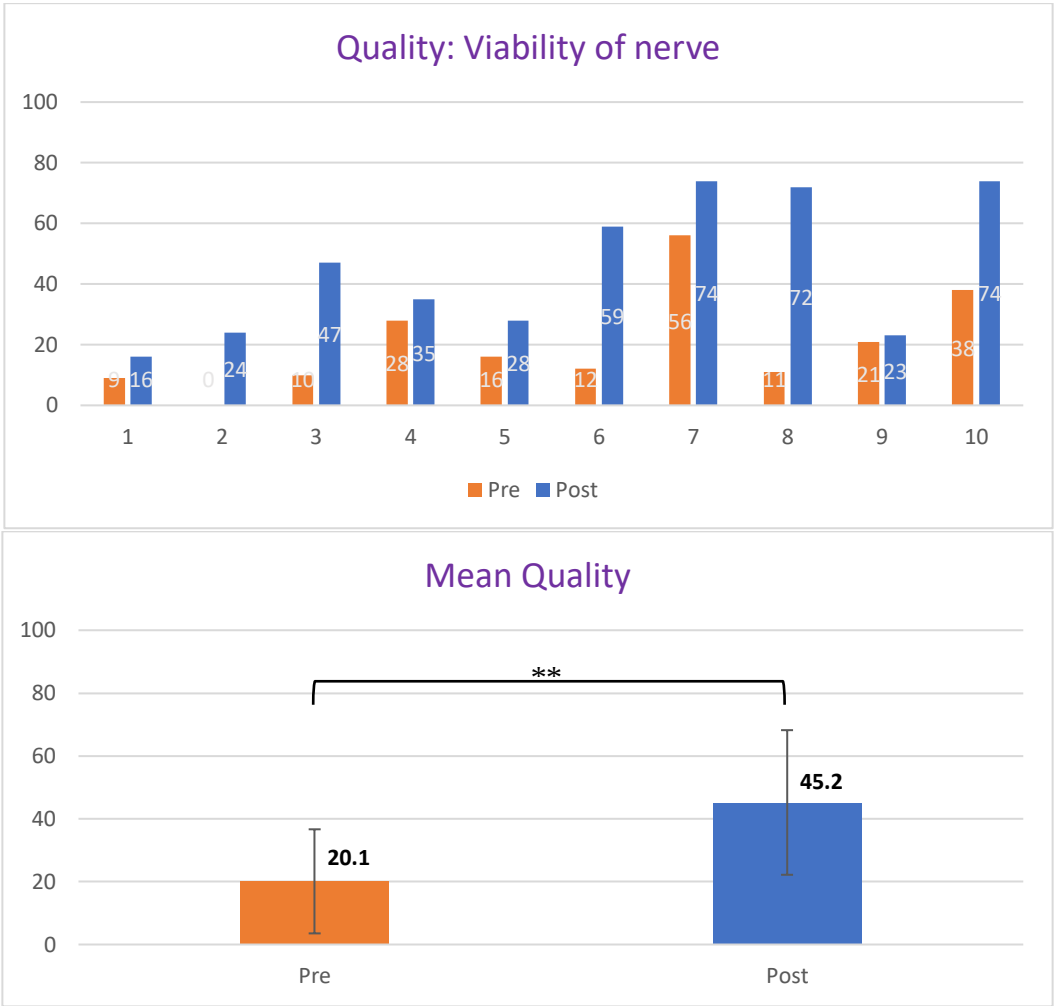
Paired Samples T-test, t(9)=5.21, p<0.001***

The Self-assessment Score for Thoroughness consistently increased in the second operation.

3.3.1.4 Self-assessment Score: Quality (viability of nerve)

The mean self-assessment score for quality (viability of nerve) after the exposure to the intervention (M=45.20; SD=23.01) was significantly higher than before the intervention (M=20.10; SD=16.56); [Paired Samples T-test, t(9)=4.06, p=0.003]. The 95% confidence interval of the difference between the means ranged from 11.11 to 39.09, and indicated the difference between the means of the samples. The result is shown in Figure 30.

Figure 30. Self-assessment Score for Quality (Viability of Nerve)



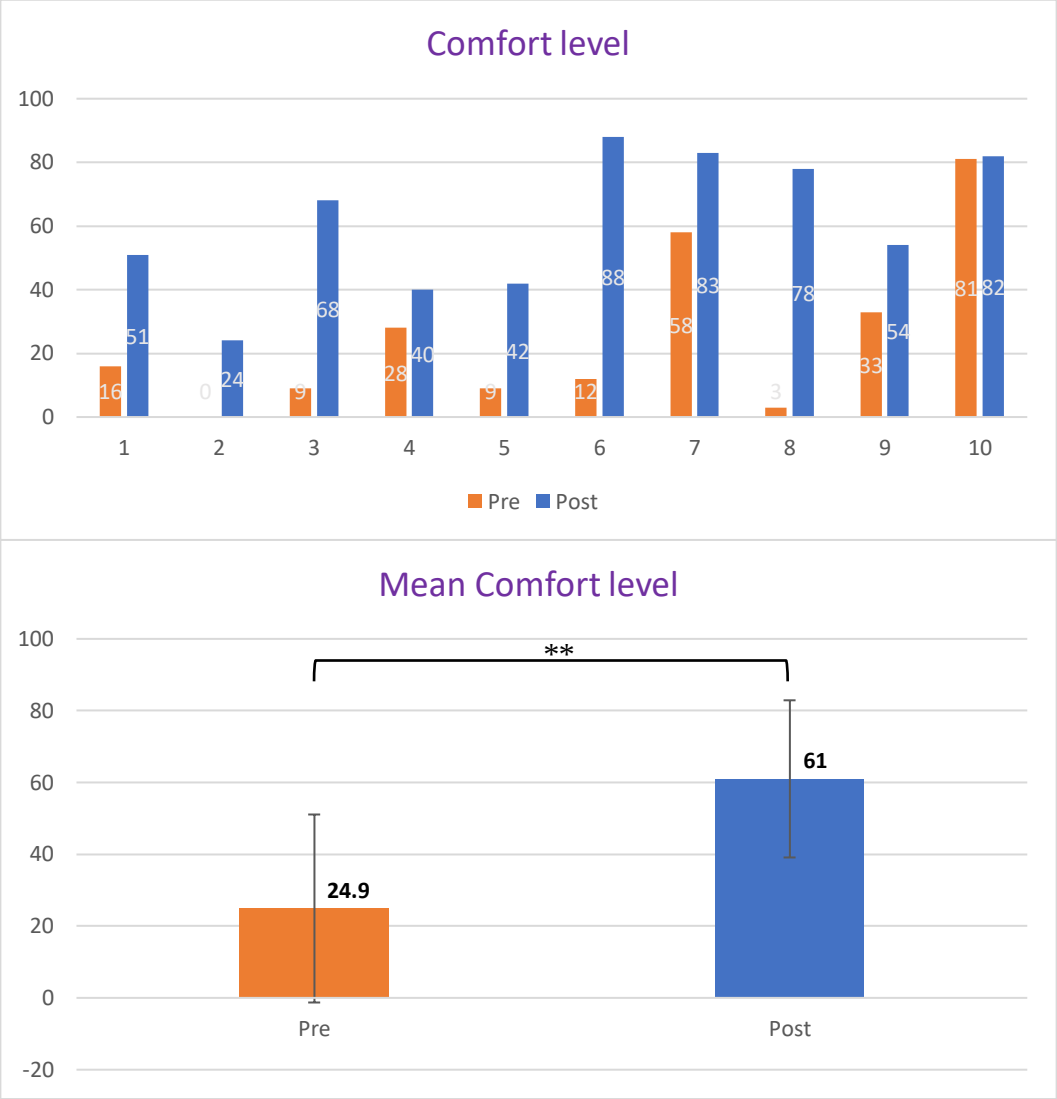
Paired Samples T-test, t(9)=4.06, p=0.003**

The Self-assessment Score for Quality consistently increased in the second operation.

3.3.1.5 Self-assessment Score: Comfort Level Operating RPLND

The mean self-assessment score for comfort level operating RPLND after the exposure to the intervention (M=61.00; SD=21.89) was significantly higher than before the intervention (M=24.90; SD=26.18); [Paired Samples T-test, t(9)=4.44, p=0.002]. The 95% confidence interval of the difference between the means ranged from 17.71 to 54.49, and indicated the difference between the means of the samples. The result is shown in Figure 31.

Figure 31. Self-assessment Score for Comfort Level Operating RPLND



Paired Samples T-test, t(9)=4.44, p=0.002**

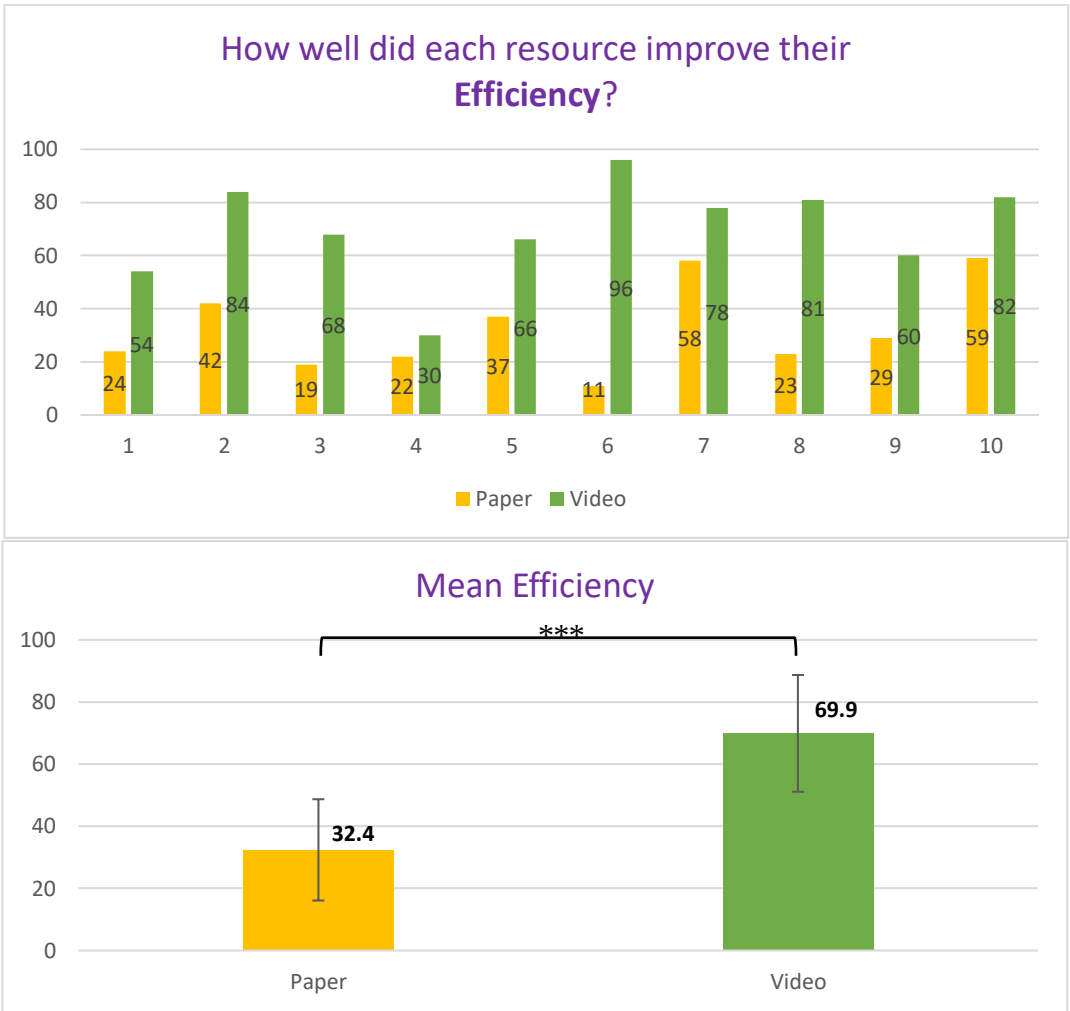
The Self-assessment Score for Comfort Level consistently increased in the second operation.

3.3.2 Paper vs. Video Learning Materials

3.3.2.1 Paper vs. Video Learning Materials: Efficiency

The mean score of the video learning material for the improvement of efficiency (M=69.90, SD=18.79) was significantly higher than the paper material (M=32.40, SD=16.30); [Paired Samples T-test, t(9)=5.37, p<0.001]. The 95% confidence interval of the difference between the means ranged from 21.71 to 53.29, and indicated the difference between the means of the samples. The result is shown in Figure 32.

Figure 32. Paper vs. Video Learning Materials for the Improvement of Efficiency



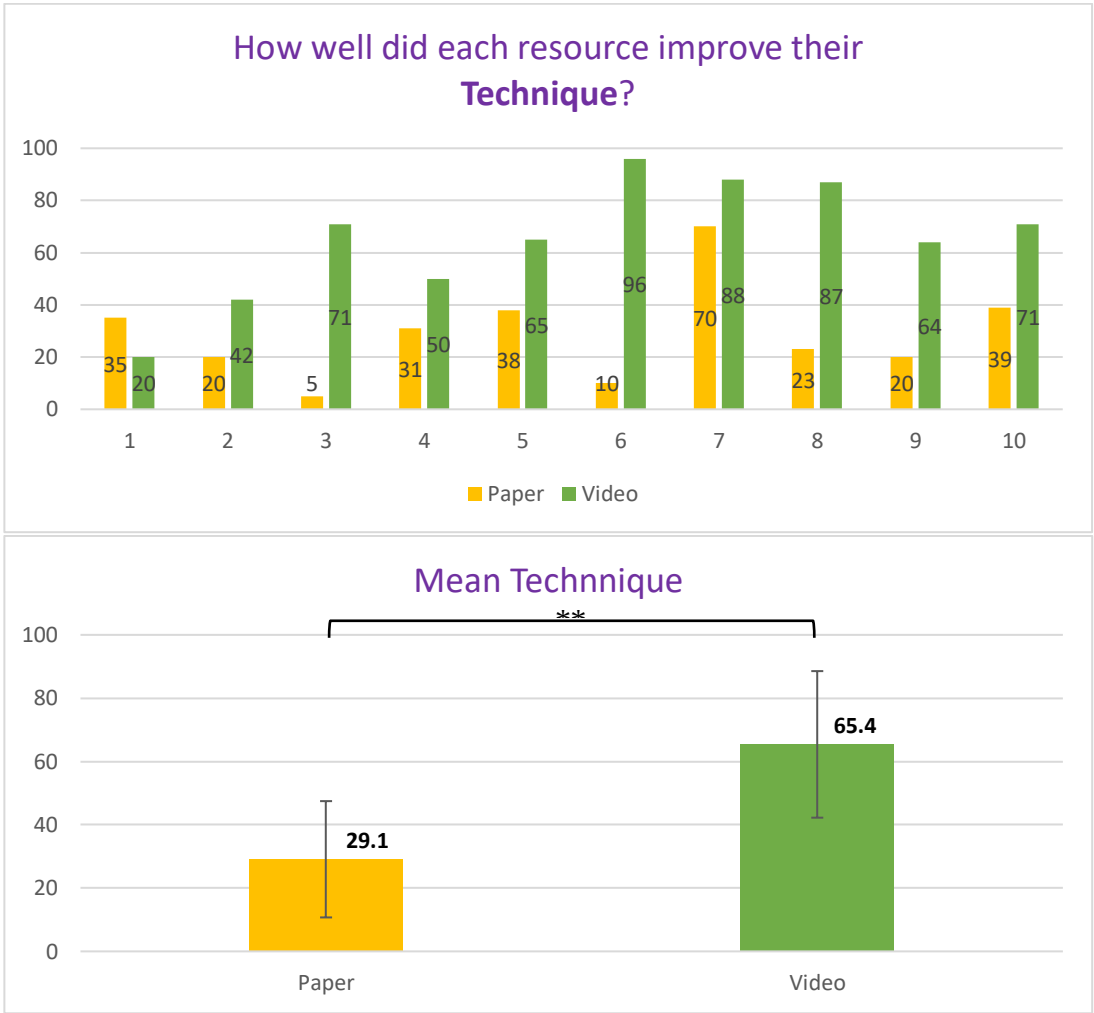
Paired Samples T-test, t(9)=5.37, p<0.001***

Participants consistently agreed that their Efficiency could be improved more by the video learning material.

3.3.2.2 Paper vs. Video Learning Materials: Technique

The mean score of the video learning material for the improvement of technique (M=65.40, SD=23.15) was significantly higher than the paper material (M=29.10, SD=18.37); [Paired Samples T-test, t(9)=3.91, p=0.004]. The 95% confidence interval of the difference between the means ranged from 15.30 to 57.30, and indicated the difference between the means of the samples. The result is shown in Figure 33.

Figure 33. Paper vs. Video Learning Materials for the Improvement of Technique



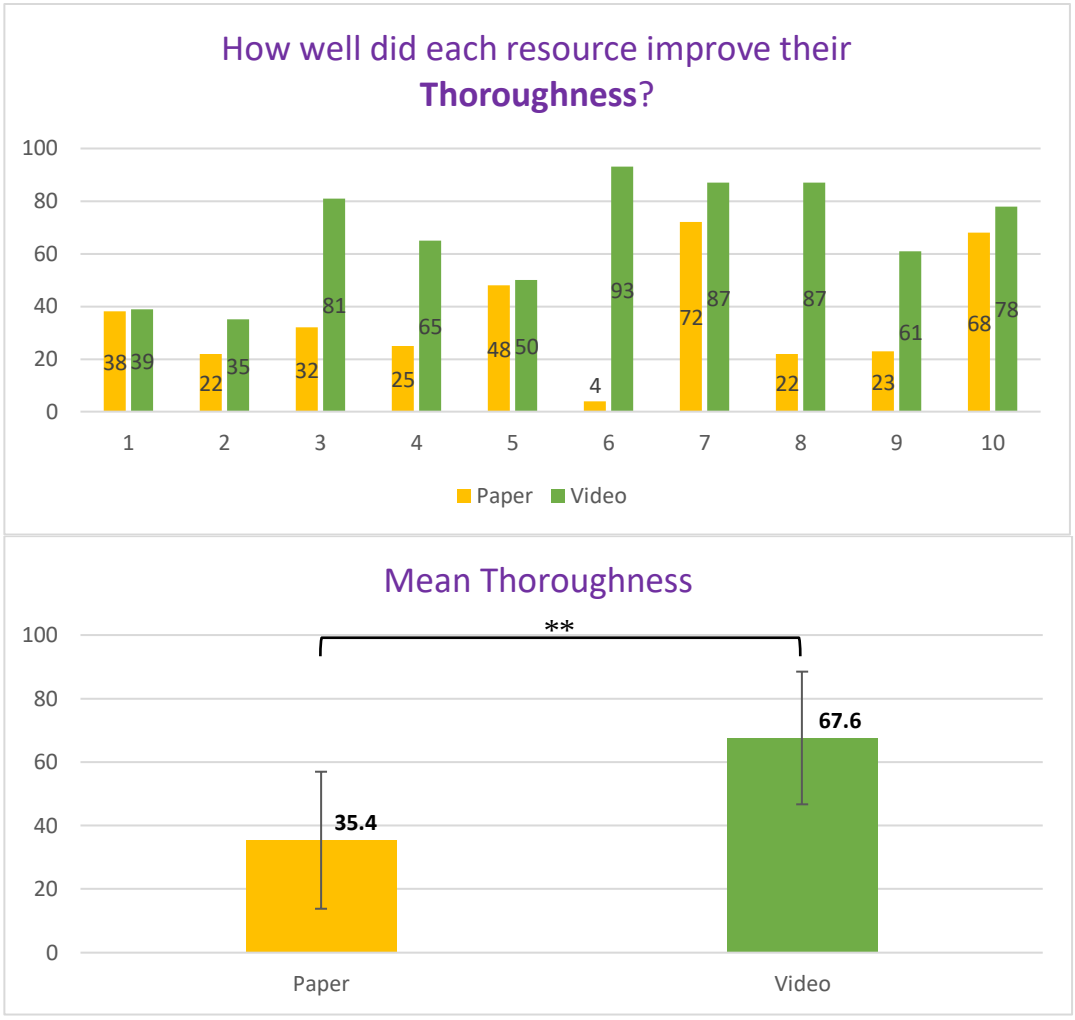
Paired Samples T-test, t(9)=3.91, p=0.004**

Participants consistently agreed that their Technique could be improved more by the video learning material.

3.3.2.3 Paper vs. Video Learning Materials: Thoroughness (completeness of lymph node resection)

The mean score of the video learning material for the improvement of thoroughness (M=67.60, SD=20.89) was significantly higher than the paper material (M=35.40, SD=21.57); [Paired Samples T-test, t(9)=3.48, p=0.007]. The 95% confidence interval of the difference between the means ranged from 11.25 to 53.15, and indicated the difference between the means of the samples. The result is shown in Figure 34.

Figure 34. Paper vs. Video Learning Materials for the Improvement of Thoroughness (Completeness of Lymph Node Resection)



Paired Samples T-test, t(9)=3.48, p=0.007**

Participants consistently agreed that their Thoroughness could be improved more by the video learning material.

3.3.2.4 Paper vs. Video Learning Materials: Quality (viability of nerve)

The mean score of the video learning material for the improvement of quality (M=65.30, SD=19.08) was significantly higher than the paper material (M=31.60, SD=18.50); [Paired Samples T-test, t(9)=4.23, p=0.002]. The 95% confidence interval of the difference between the means ranged from 15.66 to 51.74, and indicated the difference between the means of the samples. The result is shown in Figure 35.

Figure 35. Paper vs. Video Learning Materials for the Improvement of Quality (Viability of Nerve)

Paired Samples T-test, t(9)=4.23, p=0.002**

Participants consistently agreed that their Quality could be improved more by the video learning material.

3.3.2.5 Paper vs. Video Learning Materials: Comfort Level Operating RPLND

The mean score of the video learning material for the improvement of comfort level operating RPLND (M=71.30, SD=15.66) was significantly higher than the paper material (M=35.10, SD=19.19); [Paired Samples T-test, t(9)=5.31, p<0.001]. The 95% confidence interval of the difference between the means ranged from 20.78 to 51.62, and indicated the difference between the means of the samples. The result is shown in Figure 36.

Figure 36. Paper vs. Video Learning Materials for the Improvement of Comfort Level Operating RPLND

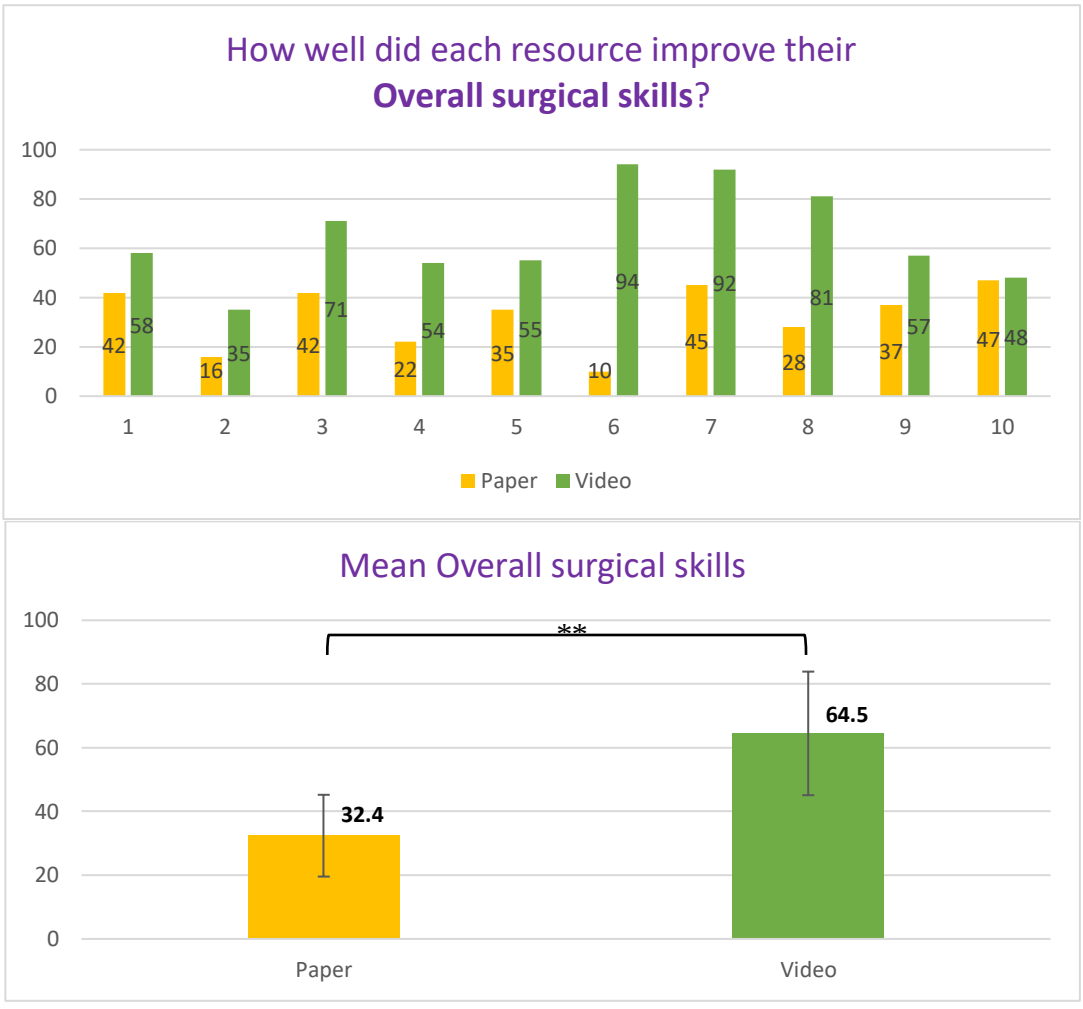
Paired Samples T-test, t(9)=5.31, p<0.001***

Participants consistently agreed that their Comfort Level could be improved more by the video learning material.

3.3.2.6 Paper vs. Video Learning Materials: Overall Surgical Skills

The mean score of the video learning material for the improvement of overall surgical skills (M=64.50, SD=19.39) was significantly higher than the paper material (M=32.40, SD=12.83); [Paired Samples T-test, t(9)=4.28, p=0.002]. The 95% confidence interval of the difference between the means ranged from 15.15 to 49.05, and indicated the difference between the means of the samples. The result is shown in Figure 37.

Figure 37. Paper vs. Video Learning Materials for the Improvement of Overall Surgical Skills



Paired Samples T-test, t(9)=4.28, p=0.002**

Participants consistently agreed that their Overall Surgical Skills could be improved more by the video learning material.

Table 10. Self-assessment scores for surgical skills in the surgeries before compared with after the exposure to the intervention

Self-assessment	Score Before Mean (± SD)	Score After Mean (± SD)	Mean difference (± SD)	95% CI of the difference	P value Paired Samples T Test (Two-sided)
Efficiency	24.20 (± 20.10)	51.40 (± 22.12)	27.20 (± 20.88)	12.26 – 42.14	0.003
Technnique	30.40 (± 21.33)	50.40 (± 20.92)	20.00 (± 18.35)	6.87 – 33.13	0.007
Thoroughness	25.90 (± 23.60)	48.60 (± 20.64)	22.70 (± 13.78)	12.84 – 32.56	<0.001
Quality	20.10 (± 16.56)	45.20 (± 23.01)	25.10 (± 19.55)	11.11– 39.09	0.003
Comfort level	24.90 (± 26.18)	61.00 (± 21.89)	36.10 (± 25.71)	17.71 – 54.49	0.002

Table 11. The scores for the improvement of surgical skills of the paper compared with video learning materials

Paper vs Video	Paper Score Mean (± SD)	Video Score Mean (± SD)	Mean difference (± SD)	95% CI of the difference	P value Paired Samples T Test (Two-sided)
Efficiency	32.40 (± 16.30)	69.90 (± 18.79)	37.50 (± 22.08)	21.70 – 53.29	<0.001
Technnique	29.10 (± 18.37)	65.40 (± 23.15)	36.33 (± 29.35)	15.30 – 57.30	0.004
Thoroughness	35.40 (± 21.57)	67.60 (± 20.89)	32.20 (± 29.29)	11.25 – 53.15	0.007
Quality	31.60 (± 18.50)	65.30 (± 19.08)	33.70 (± 25.22)	15.66 – 51.74	0.002
Comfort level	35.10 (± 19.19)	71.30 (± 15.66)	36.20 (± 21.55)	20.78 – 51.62	<0.001
Overall skills	32.40 (± 12.83)	64.50 (± 19.39)	32.10 (± 23.69)	15.15 – 49.05	0.002

3.3.3 Preference for Learning Materials

At the end of the study, the participants were asked if they would still use paper and/or video materials to study for RPLND procedure. All of the participants would still use both paper and video to study as shown in Table 12.

Table 12. Learning Materials (Paper and/or Video) That Participants Preferred to Study

Participant	Use Paper	Use Video
1	Yes	Yes
2	Yes	Yes
3	Yes	Yes
4	Yes	Yes
5	Yes	Yes
6	Yes	Yes
7	Yes	Yes
8	Yes	Yes
9	Yes	Yes
10	Yes	Yes

The participants were further asked about their preference to study from either paper or video learning material. All of the participants chose video over paper material as shown in Table 13.

Table 13. Preference of Participants for a Single Learning Material (Paper vs. Video)

Participant	Choose Paper	Choose Video
1	☐	☑
2	☐	☑
3	☐	☑
4	☐	☑
5	☐	☑
6	☐	☑
7	☐	☑
8	☐	☑
9	☐	☑
10	☐	☑

Chapter 4

4 DISCUSSION

4.1 Study Background

This study evaluated the performance of participating trainees in the nerve-sparing RPLND surgical procedure before and after a training intervention composed of expert designed and led video learning material combined with high-fidelity cadaveric simulation. The participants each performed the procedure twice in the cadaveric simulation, the first before watching the video learning material and the second after. The individual performances of each participant were assessed and compared, both qualitatively and quantitatively, between the first and second surgeries.

Left- and right-sided RPLNDs are not a mirror image of each other as each side has its own unique anatomical considerations.(133) However, the task the that participants had to perform for each side was fundamentally the same. For the left side, they were tasked with performing para-aortic lymph node dissection. And, for the right side, with inter-aortocaval and paracaval lymph node dissections. Furthermore, despite the difference in anatomy, we believe that the technique and the general skill required to complete the surgery successfully are similarly applicable to both sides.

To minimize the potential for repeated measures bias in the second surgery, as a consequence of practice effect, or worse, caused by fatigue or boredom,(186) participants were assigned to perform the second surgery on the opposite side to the first. We also acknowledge that the difficulty in performing left- and right-sided RPLNDs may be different. Therefore, to account for the potential of order effect or experience biases, we randomized the participants into one of two groups, with the first group performing the left side before watching the video learning material and the second performing the right side before. To eliminate the potential of the participants focusing their study on one specific side, we informed them of the order of sides that they would perform immediately before the first surgery.

The performance of a task once is not sufficient for the acquisition of an expert-level of skill, particularly with regard to complex surgical procedures, like nerve-sparing RPLND. It is widely accepted that expertise is attained through repetitive and deliberate practice.(135) It is for this reason that we believe, in terms of skills acquisition, the performance of the first surgery in the cadaveric simulation would not have a significant influence on the outcome of the second. However, we acknowledge that this is still practice nonetheless. Therefore, in this study we consider cadaveric simulation to be another form of learning material, in addition to the paper-based and video materials, as opposed to only an assessment model as was initially intended.

Traditional paper-based learning material is something we believe to be essential for surgical training. Trainees are best prepared for practice by both an in-depth theoretical knowledge and detailed representation of a procedure. Paper-based material remains an important part of pedagogy generally, and in this study particularly, due to limitations for the inclusion of detailed text-based information in video material with its main focus on visual representation. It was not the aim of this study to compare paper-based material with either video material or cadaveric simulation to find out which of these learning modalities is superior.

We provided each of the participants with four set paper-based learning materials to study the nerve-sparing RPLND procedure prior to the surgery day. Moreover, we also permitted the participants to study any other available paper-based materials (including textbooks) and any media and multimedia materials (including video), for an unlimited amount of time prior. On the day, we then evaluated if the training intervention would improve the performance of the participants after a short period of around 2 hours (1–2 hours from performing the first surgery in the cadaveric simulation and 9 minutes 30 seconds from watching the video learning material). The average time that the participants spent studying the four paper-based materials was 155 minutes and 9 minutes and 30 seconds for the video material (once only at the normal speed).

4.2 Primary Outcomes

4.2.1 Quantitative Outcomes

4.2.1.1 Operative Time

With regards to operative time, we initially expected the participants to perform faster in the second surgery compared to their first after watching the video learning material, which may be a reflection of improved surgical performance. However, the statistical analysis showed that there was no significant difference in the operative time of the second surgery compared to the first. In this study, some of the participants spent more time performing the first surgery and others spent more time on the second.

A study by Garnett et al. found that shorter operative times were linked with shorter hospital stays, and lower and fewer complications. They concluded that a shorter operative time may reflect superior surgical outcomes and that it may also be considered as a quality metric for surgical performance.(187) However, other studies have indicated that prolonged operative times due to trainee involvement have not been shown to adversely affect quality and outcomes.(189-192) In a clinical setting, shorter operative times can also improve operative efficiency and quality of care, reduce financial costs, and increase overall satisfaction.(188)

While operative time is usually used as a factor to determine the quality of surgeries in actual clinical settings, it may not be an ideal indicator to assess surgical performance in educational settings. Trainees performing a procedure for the first time will do so with different skill levels and learning styles, with some trainees choosing to spend more time performing a surgery meticulously, aiming for better outcomes. Thus, time may not be a good indicator of ability at this initial stage of training.

In this study, we assessed the ability of the participants to perform the complex nerve-sparing RPLND procedure effectively rather than efficiently. We allowed the participants an unlimited amount of time to perform both surgeries so they could take their time to correctly learn and excel in the procedure. In future, as participants continue to perform this procedure repeatedly, operative time may become a factor in assessing their improvement.

4.2.1.2 Percentage of Lymph Node Mass Resected

The objective of RPLND is to remove all of the lymph nodes within the template boundary. Any unresected lymph nodes may be metastatic, leading to disease recurrence. In this case, nerve fibers may also need to be sacrificed to avoid incomplete retroperitoneal lymph node resection.(105)

We believe that the concept of lymph node dissection is abstract and is difficult to understand by reading alone and without seeing the procedure. The split and roll technique to remove the lymph nodes as described in paper-based materials can be hard to understand. Demonstration of this technique, with a thorough lymph node resection, is better achieved with video. In this study, the mean percentage of lymph node mass resected by the participants was significantly improved after exposed to the training intervention.

It was impractical to count the actual number of lymph nodes resected in this study due to the surgeries being performed in cadaveric simulations. Moreover, total number of lymph nodes can vary from person to person. A effective means of objectively measuring the completeness of lymph node dissection without counting is by estimating the lymph node resection proportion.(194) However, despite this, we believed that surgical performance with regard to lymph node yield should still be quantitatively assessed. Therefore, we used the more reliable method of percentage of lymph node mass resected for quantitative assessment. To do this, we weighed the lymph node mass resected from each location by each participant. At the end of each surgery, an expert would dissect the remaining mass in each location to determine the percentage of lymph node yield calculated by proportion in weight.

We also performed data analysis to determine if the order of sides affected an improvement in the percentage of lymph node mass resected. Interestingly, the participants that performed the left-sided RPLND first had significantly more improvement than those that performed the right-sided first. The reason for this may be that the left side is regarded as more difficult due to its challenging anatomical considerations. The renal-lumbar vein, which is located between the first infrarenal lumbar splanchnic and the left intermesenteric nerves, or lateral to both, complicates the exposure of part of the sympathetic plexus in the left side. In-field recurrence as a result of incomplete para-aortic lymph node resection, particularly at the superior border, often occurs due to this challenging location.(133)

The participants that performed the left-sided RPLND first may have found it easier to later perform the right side, resulting in a greater improvement in the percentage of lymph node mass resected. This result may impact a concept of surgical training in which trainees better learn procedures from exposure to difficult or complex surgeries and, thereafter, may be able to perform the same types of surgeries with any difficulty levels in the future. However, in this study, all the participants demonstrated an improvement in the percentage of lymph node mass resected in the second surgery compared with the first regardless of the order of sides. The participants that performed the right-sided RPLND first had significant improvement in the left side as well, but with lesser increase in the percentage of lymph node mass resected.

4.2.2 Qualitative Assessment

A particular strength of our study was that the surgical performance of the participants was assessed from video recordings by a blinded expert. The identities of the participants were not known to the expert, as was if each surgery was the first or the second, which helped to minimize the potential for rater bias.

Scott et al. compared two evaluation methods used by raters between direct observation and watching edited 10-minute video recordings (initial step of 2 minutes, cystic duct/artery of 6 minutes, and fossa dissection of 2 minutes) for a measurement of operative performance in laparoscopic cholecystectomy using five global assessment criteria. They found that assessing the surgical performance of trainees by direct observation was more reliable than in the edited 10-minute video recordings. Although the edited video recordings might help to maximize the efficiency of the assessment process, they reported that the crucial information for the evaluation was lost from the shortened videos, such as the erratic hand movements of the trainees.(195) Therefore, in this study, we decided to maintain the full length of the video recordings, throughout the whole procedure, without editing or trimming, so that the blinded expert could assess the complete performance of participants.

We decided not to provide an assistant for the participants in this study because the assistant may be a confounding factor (for example, the assistant might unintentionally help to guide the surgery). Therefore, we did not use the assistant component of the generic OSATS global rating scale and the total score ranged from 6–30.

Because there were no previously procedure-specific rating scales designed for RPLND, we developed a new procedure-specific rating scale for nerve-sparing RPLND based on the principles of the procedure, which are removing all the lymph nodes in specific locations and the avoidance of nerve injury. Our procedure-specific rating scale assesses two components, completeness of lymph node dissection and preservation of nerve integrity, on a 5-point scale.

We found that the mean total OSATS global rating score was significantly increased after the participants were exposed to the training intervention. We further analyzed each component of the total OSATS global rating scale and found that the surgical skill of the participants was significantly improved in all the components (respect for tissue, time and motion, instrument handling, knowledge of instruments, flow of operation, and knowledge of specific procedure). Therefore, overall surgical performance was significantly improved in the short period of time that they spent viewing the video learning material.

For our procedure-specific rating scale, the completeness of the lymph node dissection score, which was a qualitative assessment, and the percentage of lymph node mass resected, which was a quantitative assessment, significantly increased in the second surgery after viewing the video learning material, which was more significantly improved in the participants that performed the left-sided RPLND first. Again, this may be because of the more challenging anatomical considerations of the left side. However, both assessments confirmed that the surgical skills of all the participants significantly improved after their exposure to the training intervention, regardless of the orders of sides.

In order to prevent the loss of antegrade ejaculation, meticulous lymph node dissection with caution not to injure the nearby nerve fibers should be taken into consideration.(105) For this reason, we included the preservation of nerve integrity score as one of the components in the procedure-specific rating scale for nerve-sparing RPLND. We believe that not only the lymph node yield but also the nerve preservation should be incorporated into the assessment of lymph node dissection performance. In this study, the mean preservation of nerve integrity score significantly increased in the second surgery. Thus, this result suggests an improvement in the performance of the participants in terms of nerve preservation after the exposure to the training intervention.

We believe the locations of the nerves can be better demonstrated in video rather than paper-based material. Moreover, the animations of the nerves in relation to the adjacent structures and in the RPLND surgical procedure demonstrated in the video may help the trainees to understand the concept of nerve-sparing techniques better. There was also a trend for higher improvement in the group of participants who performed left-sided RPLND first compared with those who performed the right-sided first; however, this difference was not statistically significant (Student's T-test, p=0.053).

We also compared the improvement in surgical skills between junior (PGY3 and lower) and senior (PGY4 and higher) level participants. We anticipated that there might be differences in the range of improvement between the two groups due to a greater potential for improvement at the junior level. However, we found that both the junior and senior level participants had a similar improvement in all assessment components (percentage of lymph node mass resected, total OSATS global rating scale, completeness of the lymph node dissection score, and preservation of nerve integrity score). This may be because nerve-sparing RPLND is a rare procedure in which all trainees had limited exposure during their training. For other surgeries that are more common, the junior level participants may have more improvement in surgical performance than the senior.

Foroushani et al. also studied the effects of an intraoperative role reversal between residents and surgeons to increase trustability and enhance the knowledge of general surgery residents. They found that the knowledge scores of all of the residents were significantly improved postoperatively. However, the improvement of knowledge was quantitatively higher for junior (PGY1-2) compared to senior (PGY4-5) residents.(196) Exposure to expert-designed and led video learning material combined with high-fidelity cadaveric simulation could potentially help to improve their surgical performance regardless of seniority. Therefore, the protocols of this study for the teaching of the nerve-sparing RPLND surgical procedure could be broadly applied to all trainees.

4.3 Secondary Outcomes

We believe that the feedback of participants on the improvement of their own skills through self-assessment is also important. Ward et al. found only a moderate correlation between the self-evaluations of experts and residents in a laparoscopic Nissen fundoplication in a porcine model.(197) Mandel et al. reported that the self-assessment of resident surgical performance is feasible with good validity and reliability. They also found that residents with poor performance were aware of their deficiencies. However, the residents in that study tended to underestimate their own skills by giving themselves lower scores than their evaluators.(198)

Conversely, Sidhu et al. reported that surgical trainees in their study overestimated their own surgical performance in a laparoscopic colectomy using a global rating scale for self-assessment. They also found no significant correlation between self-assessment scores and evaluator scores.(199) Therefore, we decided not to provide the generic OSATS global rating or procedure-specific rating scales to the participants for self-assessment and that these scales should be only used by the expert.

The aim of the self-assessment in this study was to evaluate if the participants could perceive an improvement in their own surgical performance after exposure to the training intervention. The participants were asked to assess their performance in five aspects (efficiency, technique, thoroughness, quality, and comfort level), comparing their own surgeries before and after the exposure to the intervention. To minimize the potential for response bias, participants used line scales to assess their performance after each operation. The mean self-assessment scores significantly increased in all aspects after exposure to the training intervention. This result suggests that the participants perceived an improvement in their surgical skills in the second surgery after watching the video learning material.

Although we did not want to compare the two different learning materials, we still asked the participants to evaluate both paper-based and video on how well each material improved their efficiency, technique, thoroughness, quality, comfort level, as well as overall surgical skills. The mean scores the participants gave to the video material were significantly higher than the paper-based material in every aspect.

We believe that both paper-based and video learning material have their own advantages and disadvantages. Therefore, access to both types of learning materials may be ideal for studying surgical procedures. Paper-based materials may be able to provide diagrams, detailed descriptions, and rationale behind the procedures. Whereas video material can demonstrate a more realistic approach in real surgeries, with animations and illustrations, the flow of the operation, and the techniques that are not possible to be clearly explained on paper. However, when the participants were asked to choose only one learning material to study nerve-sparing RPLND, all of them favored the video over the paper-based material.

Many participants stated that the video learning material had many advantages over paper-based. For instance, video could provide a very clear representation of actual anatomy with an actual sense of the flow of the procedure. Some participants said that the animations and live surgery included in the video were very useful. Moreover, they stated that the split and roll technique was better demonstrated by the video. Some participants felt that it was difficult to understand from the paper-based materials how the procedure flowed and what part of the procedure they were at when they were reading a specific section in terms of the whole procedure. Some participants suggested that the paper materials should have more pictures, diagrams, clearer depiction of every single step, and a live cadaver image instead of an animated one.

Many participants said that they would use the paper-based material to study the overview of background, theoretical knowledge, indication, complications, and other management rather than the technique. Then they would study the video material to actually understand the surgery with appropriate landmarks, steps, and techniques. Most participants believed that the video was very useful, the length was appropriate, and that they could learn how to perform the procedure within a short period of time. However, a few participants would like to watch a longer version of the procedure with one participant wanting to watch the whole procedure from start to finish.

4.4 Limitations

There are some limitations to be taken into account in this study. The sample size was small with 10 participants. This was due to a limited number of human cadavers available. Moreover, only fresh or soft embalmed (and not hard embalmed) cadavers could be used in this study due to the high-level of tissue quality required for simulation. However, this sample size had sufficient power to detect the large effect size between two groups with an α error value of 0.05.

There were also limitations to performing surgery in the cadavers. The simulation might not be able to fully mimic a real operative setting. For example, there was no circulating blood in the cadavers. Therefore, we could not assess blood vessel injury or the skill in the control of bleeding, which are important principles in performing RPLND as well as other surgeries. However, the two essential skills specifically for nerve-sparing RPLND, which are the lymph node dissection and nerve-sparing technique, could be appropriately assessed using cadavers.

Regarding the qualitative assessment of surgical performance, there was only one assessor in our study. We decided to limit the study to only one expert in RPLND who assessed all of the participants in order to improve the internal validity of the study.

Additionally, we were limited by the lack of a published procedure-specific evaluation scale that had been used for assessing nerve-sparing RPLND before. Therefore, we created a new procedure-specific rating scale for evaluating nerve-sparing RPLND, which showed significant improvement of the participants. However, further validation of the scale would be helpful. We hope that our new procedure-specific rating scale will be a reliable, valid, and feasible tool that can be used to assess surgical skills in nerve-sparing RPLND in the future.

Lastly, in reality, RPLND is a large and complex surgery that cannot be performed by a single surgeon. However, in our study, we decided to limit the provision of a surgical assistant for the participants because we believed that the use of the assistant may be a confounding factor that could affect the surgical performance.

4.5 Future Directions

4.5.1 Teaching Complex and Rare Surgery

Experience is crucial for the mastery of surgical skills. Throughout the five years of urology residency training programs, trainees have varying levels of exposure to different surgeries. Lowrance et al. evaluated the performing of RPLND in urological surgical resident training and found that urology residents had minimal training and exposure in this surgery. Half of the graduating urology residents performed RPLND as the primary surgeon less than twice and in the role of first assistant for once or none during their entire residency program.(200)

The trainees in our study stated that they had the opportunity to assist in RPLND 0–3 times. However, there was no data available on whether newly graduated urologists who were inexperienced in specific surgeries made an effort to perform these operations in the course of their practice or referred patients to an expert. RPLND is not only considered to be a rare surgery; it is also a complex surgery. Patients are at risk of both perioperative complications and disease recurrence from an inadequately performed RPLND. Every surgical procedure has a learning curve, and the more complicated the surgery, the steeper that learning curve is.

We tried to find an effective way to educate trainees in rare and complex surgical procedures, such as nerve-sparing RPLND. We believe that the use of video learning material that is expert-designed and led can solve the problem of the limited exposure that trainees have to this rare surgery. Moreover, we also believe that hands-on experience is important for the practice of surgery. Thus, we used human cadavers as high-fidelity simulations, as they can be used for the evaluation of trainee surgical performance as well.

The use of human cadavers also avoids the risk of complications, morbidities, and mortalities from practicing surgeries in patients. In this study, we demonstrated that the use of expert-designed video learning material in combination with high-fidelity cadaveric simulation as a training intervention was achievable effective for trainees to learn rare and complex surgical procedures such as nerve-sparing RPLND. For other surgeries, cadavers may not be as useful. However, we strongly believe that video learning material is very promising for the future of surgical training.

A potential limitation in the use of human cadavers for education is access. We believe that the use of cadaveric simulation is helpful for learning the RPLND procedure because it is a unique surgery in which trainees need to fully understand the anatomy of the retroperitoneum. For other surgeries, cadavers may not be as useful. However, we strongly believe that video learning material is a very promising source of education for the future of surgical training.

4.5.2 Video Learning Material for Surgical Education

Despite there being many accessible surgical videos online for trainees to study, such as those posted on YouTube, many of them are of poor quality and reliability.(148, 149) An available videos for studying a specific surgical procedures may also be difficult to find, especially in the case of open surgeries. Unlike minimally invasive surgeries, where the entire procedure can be easily recorded through a laparoscopic cameras used intraoperatively, recording open surgical procedures requires the setup of filming production equipment and the cooperation of filming crews and surgical team in the operating room. Our expert-designed and led video learning material was created with the collaboration of a clinical anatomist and an oncologic urologist, who are both experts in RPLND and are also educators.

The results of this study clearly show the preference of the trainees toward the video learning material for studying the RPLND surgical procedure. Using video as a learning material for nerve-sparing RPLND has many advantages. The use of video can alleviate the problem of the limited working hours of residents. Furthermore, residents can access the video anywhere and anytime at their convenience. The edited video is also condensed to include only the most important steps in a procedure; therefore, residents do not need to spend their time watching particularly lengthy procedures and this current generation of residents may be more familiar with learning from video.

Video can also provide consistency in standards set by experts of which some residents may not have access to in their respective programs. For complicated surgeries that are difficult to understand, the inclusion of animations and illustrations in the video can also enhance the learning experience. This type of material may be particularly useful for rare procedures such as RPLND.

A limited exposure to surgical procedures in residency training programs may come from a recent restrictions on working hours as well as the results the COVID-19 pandemic.(142, 144) We believe that a potential solution to this may be the use of video learning materials. The possibility of self-directed, video-based courses was the subject of a 2021 study by Szyld et. al. in which it was found that such training was not inferior to comparable facilitator-led instruction in neonatal resuscitation.(201) Additionally, based on a systematic review of 20 papers by Green et. al., 14 illustrated a significant improvement in trainee learning and performance with video and provided evidence-based recommendations for its effective use.(202) Self-directed, video-based courses are not considered to be inferior to comparable facilitator-led instruction, and a combination of instruction and video learning material may provide a superior model for surgical training.

4.5.3 Virtual Reality (VR) in Surgical Education

Developments in Augmented Reality (AR) and Virtual Reality (VR) have made it possible for these technologies to be widely used in medical education.(203, 204) Three-dimensional (3D) images and touchscreens have been used by platforms within VR environments to demonstrate surgical operations in a variety of medical fields.(205) Technical surgical skills have been taught using AR applications.(206, 207) Harrington et al. reported the successful development of a 360º operative video of laparoscopic cholecystectomy, which was considered to be the learning platform of choice by the majority of trainees.(208) The trainees could also use VR educational devices such as head-mounted displays (HMDs) to view content with an immersive VR experience.(209) In the future, we may further develop and expand our facilitator-led video learning material with the use of VR technology; which may help to better translate surgical knowledge into technical skills.

Chapter 5

5 CONCLUSIONS

Repetitive and deliberate practice is crucial for the mastery of surgical skills. Nerve-sparing RPLND is not only a complex surgery but also rare and limited in its exposure to urologic surgical trainees during their training.

Thus, study demonstrated that expert-designed learning material combine with high-fidelity cadaveric simulation helped to improve surgical performance in the nerve-sparing RPLND surgical procedure. Thus, it can afford substantial benefits in translating surgical research into technical prowess.

Paper-based and video-learning materials have their own advantages and disadvantages. However, there is a significant amount of potential for improvement in surgical performance with the opportunity to use video learning material in combination with cadaveric simulation. When participants in our study had to choose, they preferred to study nerve-sparing RPLND procedure using video learning material rather than paper-based.

We further expect that this model can be successfully applied to teaching complex and rare procedures in other fields.

We also believe it can be used as a template for teaching other complex and rare procedures in other fields. Moreover, it had the potential to be provided to programs in developing countries, which can improve healthcare outcomes globally.

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Curriculum Vitae

Name:	Pocharapong Jenjitranant
Post-secondary Education and Degrees:	Faculty of Medicine, Chulalongkorn University Bangkok, Thailand 2005-2011 Doctor of Medicine (cum laude)
	Division of Urology, Department of Surgery Faculty of Medicine Ramathibodi Hospital, Mahidol University Bangkok, Thailand 2011-2016 Diploma in Urological Surgery
	Urology Service, Memorial Sloan Kettering Cancer Center New York, United States 2018-2020 Research Fellow in Urologic Oncology
	Genitourinary Oncology Service, Peter MacCallum Cancer Centre Melbourne, Australia 2021-2022 Clinical Fellow in Robotic Surgery and Genito-Urinary Oncology
	The University of Western Ontario London, Ontario, Canada 2023-present Clinical Fellow in Urologic Oncology, Society of Urologic Oncology (SUO)
Honors and Awards	Mahidol Fast-Tracked Residency–Consultant Scholarship 2011-2016
	Winner of Thai Urological Association (TUA) Resident Contest Award 2015
	TUA Best Research in Thailand Award 2023
	Western Graduate Research Scholarship (WGRS) 2023-2024
Related Work Experience	Assistant Professor of Urology Faculty of Medicine Ramathibodi Hospital, Mahidol University Bangkok, Thailand 2016-present
	Assistant Professor of Urology Bumrungrad International Hospital Bangkok, Thailand 2021-present

Publications:

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