Original Article

Interfascial planes as surgical landmarks for laparoscopic upper retroperitoneal surgery: a cadaveric and retrospectively clinical study

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Background: Radiologists currently accept the concept of "interfascial plane (IFP)" to understand retroperitoneal anatomy, replacing Meyers' classic tricompartmental theory. Despite much research on retroperitoneal anatomy, its anatomical structure, embryonic origin and developmental process still require further exploration to guide the optimization of surgical process. This study aims to explore the anatomical basis of IFP related to laparoscopic upper retroperitoneal surgery (LURS) and to compare the clinical outcomes of trans-interfascial plane procedures for LURS (TIFP-LURS) with conventional LURS (Con-LURS).

Methods: The study consisted of two parts: cadaveric and clinical study. The cadaveric study involved dissecting and observing the retroperitoneal fasciae and IFP in 32 cadavers using gross anatomical and histological methods. This retrospective clinical study compared the perioperative data and complications of 229 patients who underwent TIFP-LURS and 121 patients who underwent Con-LURS for upper retroperitoneal lesions at our center.

Results: The cadaveric study revealed that the retroperitoneal space was composed of multilaminar fasciae that formed potential bloodless spaces among them, that could be used as surgical landmarks and operating planes. The clinical study showed that TIFP-LURS had a significantly less estimated blood loss, lower intraoperative complication rate, lower postoperative complication rate, shorter hospital-stay and lower long-term postoperative complications rate than Con-LURS. Multivariate analysis indicated that the TIFP procedure was an independent protective factor for decreasing the risk of postoperative complications.

Conclusions: The IFP are potential avascular spaces that can be used during laparoscopic surgery, and TIFP-LURS is a novel surgical approach that can improve the safety and efficacy of laparoscopic surgery for upper retroperitoneal lesions.

Keywords: Retroperitoneal anatomy; interfascial plane (IFP); laparoscopic upper retroperitoneal surgery (LURS)

Submitted Dec 06, 2023. Accepted for publication Mar 10, 2024. Published online May 24, 2024.

doi: 10.21037/tau-23-632

View this article at: https://dx.doi.org/10.21037/tau-23-632

Introduction

Laparoscopic upper retroperitoneal surgery (LURS) is a minimally invasive surgical treatment for retroperitoneal lesions of the adrenal gland, kidney, ureter and associated blood vessels, nerves and lymph nodes (1). Interfascial planes (IFP) are important anatomical landmarks for LURS and an ideal workspace for bloodless operations (2,3).

Since Meyes proposed the classic tricompartmental theory based on radiology in 1972, and Japanese scholars proposed the subfascial plane theory, the anatomy of the retroperitoneal space has been developing (4-7). However, the retroperitoneal fascial anatomy related to LURS has not been fully elucidated (8). A deeper understanding of the retroperitoneal fascial anatomy and identification of a bloodless surgical plane will promote the development of urological surgery (3,9).

This study combined anatomical and histological observations to further understand the anatomical basis of fascial planes in relation to upper urinary tract surgery. We designed and optimized surgical methods for establishing operative IFP during laparoscopic surgery, namely trans-interfascial plane procedures for laparoscopic upper retroperitoneal surgery (TIFP-LURS). Furthermore, this study retrospectively compared the perioperative efficacy of TIFP-LURS with conventional laparoscopic upper urinary tract surgery (Con-LURS) performed by the same surgical team at our center, providing scientific evidence for further optimization and promotion of the laparoscopic surgery system in urology. We present this article in accordance with the TREND reporting checklist (available at https://tau.amegroups.com/article/view/10.21037/tau-23-632/rc).

Highlight box

Key findings

- The interfascial plane (IFP) is a potential avascular space that can be used during laparoscopic surgery to improve the safety and efficacy of laparoscopic surgery for upper retroperitoneal lesions.

What is known and what is new?

- Retroperitoneal anatomy is complex and radiologists currently accept the concept of "IFP" to understand retroperitoneal anatomy, replacing Meyers' tricompartmental theory.
- This study demonstrated that the IFP is an avascular space that can be dissected and expanded during laparoscopic surgery, and developed a novel technique of trans-interfascial plane procedures for laparoscopic upper retroperitoneal surgery (TIFP-LURS).

What is the implication, and what should change now?

- This study provides a deeper understanding of the retroperitoneal fascial anatomy and revealed its surgical applications with favorable safety and efficacy.
- Surgeons need deeper understanding of IFP in retroperitoneum to guide laparoscopic surgery process. TIFP-LURS can be considered as a feasible and preferable surgical approach for upper retroperitoneal lesions.

Methods

Cadaveric study

The anatomical study was based on the dissection of one freezing male cadaver (70 years of age at death), one formalin-fixed male cadaver (61 years of age at death) and 30 fresh cadavers (18 males and 12 females) provided by the Laboratory of Anatomy of Zhongshan School of Medicine of Sun Yat-sen University, using one set of anatomic devices and one camera (PowerShot SX700 HS, Canon, Inc., Tokyo, Japan). All donors voluntarily declared before their deaths that their remains were donated for educational and scientific research purposes. The format of the informed consent form was in line with the guidelines of the China Organ Donation Administrative Center.

A frozen male cadaver (70 years of age at death) was used for sectional analysis. The specimens, including the thorax, abdomen and pelvis, was frozen at −80 ℃ and cut into 10-mm thick transverse sections to examine gross anatomy from the caudal aspect. One male cadaver (61 years of age at death) with no congenital and/or acquired abnormalities in the retroperitoneal structure was fixed by arterial perfusion with 10% formalin and preserved in 30% alcohol to prevent fungal growth and to maintain tissue softness. The formalin-fixed male cadaver was transversely cut at the intervertebral disc level between L1 and L2, and dissected from the anterior aspect. From the anterior aspect, the skin, muscles, and abdominal organs were removed, and the peritoneum and renal fascia (RF) were visualized to investigate the connective tissue continuity and vessel communication inside the RF in the retroperitoneal space. Thirty fresh cadavers (18 males and 12 females; mean age 65 years at death; range 45–78 years) were used for histological analysis. The cadavers were preserved at 4 ℃, and dissected from the anterior aspect, from which the fascial tissue was collected. Fascial tissue was fixed in 10% formalin, dehydrated and embedded in paraffin. After cutting into 5 μm thick sections, the histological sections were processed for hematoxylin and eosin (H&E) and Masson's trichrome staining. All images were obtained using a microscope (CX-41; Olympus, Tokyo, Japan).

Clinical study population

Retrospectively, subjects eligible for the study were continuous patients with upper retroperitoneal disease (more details in *Table 1*) who underwent Con-LURS between January 2012 to November 2018, and who underwent TIFP-LURS between October 2018 to July 2021, as performed by one experienced surgical team including surgeons, nurses and anesthetists. Patients with incomplete clinical data, those who underwent emergency surgery due to urgent conditions or surgery on organs other than the urinary system at the same time, and those who underwent palliative tumor reduction surgery were excluded from the study. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Committee of The Sixth Affiliation Hospital of Sun Yat-sen University (No. 2022ZSLYEC-171) and individual consent for this retrospective analysis was waived.

Surgery procedure

In the Con-LURS cohort, all patients underwent trans-retroperitoneal approach procedure.

In the TIFP-LURS cohort, patients underwent trans-abdominal approach procedure. Procedures for TIFP-LURS (left side):

(I) Surgical position and trocar placement are presented in *Figure 1*.
(II) Mobilization of the colon. Incise along the white line of Toldt medially and access the IFP between Toldt fascia and primitive parietal peritoneum (PPP).
(III) Exposure of the retroperitoneum. Dissect along the IFP between Toldt fascia and PPP medially, and reflect the descending colon (DC) to expose the urinary organs. Stay outside the paler yellow anterior renal fascia (ARF) and avoid entering the brighter yellow posterior mesentery. Loose areolar tissues with minute vessels inside can be observed along the IFP between different fasciae, which can be dissected without hemorrhage.
(IV) Renal hilum dissection. Dissect along the IFP among retropancreatic fascia, ARF and fasciae surrounding vessels, and expose the left renal vein (LV) and adrenal vein.
(V) Dissection along the ureter. Dissection along loose areolar tissues (black arrows) in the IFP between fasciae surrounding the left external iliac artery (LEIA) and Gerota's fascia surrounding the ureter.
(VI) Exposure of the psoas muscle. Enter the IFP between posterior renal fascia (PRF) and psoas fascia. Retract the kidney up but stay outside the PRF. The medial arcuate ligament of the diaphragm was the anatomical landmark continuous with the fasciae of the psoas muscle.
(VII) Lesion removal or reconstruction.

Procedures for TIFP-LURS in the right side is presented in *Figure 2*.

Outcomes

The primary endpoints were estimated blood loss, intraoperative complication rate (including severe hemorrhage, vascular injury, bowel injury, diaphragm injury, and other injuries) and postoperative complication rate and grading (according to the Dindo-Clavien classification) within 30 days (short-term). The secondary endpoints were duration of surgery, transfusion rate in surgery, conversion rate, length of hospital stay after surgery, and postoperative complication rate over 30 days (long-term) (including pyeloureteral stenosis, hydronephrosis, renal insufficiency, lumbar hernia, and others).

Statistical analysis

The results of the clinical study were analyzed using SPSS software (version 25.0, Chicago, USA). To compare the characteristics and differences between the two groups, the Student's *t*-test or Mann-Whitney rank-sum test was used for continuous variables, and the Pearson Chi-square test or Fisher exact test was used for categorical variables, as appropriate. Univariate and multivariate logistic regression analyses were used to determine the potential risk factors for postoperative complications. $P<0.05$ was considered statistically significant. (The incidence of postoperative complications was assessed using univariate and multivariate logistic regression analyses with clinical factors. Multivariate analysis was performed using the forward elimination method. All results were considered statistically significant when the 2-sided P value was less than 0.05).

Results

Gross anatomy of the retroperitoneum

Transverse-sectional diagrams of the abdomen from a male cadaver (70 years of age at death) were observed

Table 1 Baseline (demographic) characteristics of patients analyzed in the study

Characteristics	TIFP-LURS (n=229)	Con-LURS (n=121)	t/χ^2/Z	P value
Sex			χ^2=0.086	0.77
Male	123 (53.7)	63 (52.1)		
Female	106 (46.3)	58 (47.9)		
Age (years)	49.22±14.94	52.41±14.17	*t*=1.929	0.055
Body mass index (kg/m²)	22.86±1.76	22.78±1.87	*t*=−0.391	0.70
Location (side)			χ^2=0.009	0.92
Right	111 (48.5)	58 (47.9)		
Left	118 (51.5)	63 (52.1)		
ASA score			Z=−0.022	0.98
1	188 (82.1)	99 (81.8)		
2	35 (15.3)	20 (16.5)		
3	6 (2.6)	2 (1.7)		
Previous abdominal surgery	23 (10.0)	16 (13.2)	χ^2=0.808	0.37
Ipsilateral hydronephrosis	79 (34.5)	48 (39.7)	χ^2=0.916	0.34
Diagnosis			χ^2=7.833	0.25
Pyeloureteral stenosis	51 (22.3)	30 (24.8)		
Adrenal disease	62 (27.1)	29 (24.0)		
Renal cysts	27 (11.8)	24 (19.8)		
Renal masses	56 (24.5)	22 (18.2)		
UTUC	14 (6.1)	8 (6.6)		
Nonfunctioning kidney	15 (6.6)	4 (3.3)		
Other urinary disease	4 (1.7)	4 (3.3)		
Disease condition			χ^2=2.126	0.15
Malignant	80 (34.9)	33 (27.3)		
Benign	149 (65.1)	88 (72.7)		
Surgery			χ^2=9.045	0.17
Pyeloureteroplasty	29 (12.7)	17 (14.0)		
Adrenalectomy	62 (27.1)	29 (24.0)		
Renal cyst decompression	25 (10.9)	24 (19.8)		
Partial nephrectomy	26 (11.4)	9 (7.4)		
Nephrectomy	64 (27.9)	27 (22.3)		
Nephroureterectomy	18 (7.9)	9 (7.4)		
Other reconstruction or dissection surgery	5 (2.2)	6 (5.0)		

Values are presented as mean ± standard deviation or number (%). *t*, using the Student's *t*-test; χ^2, using the chi-square test; Z, using the Mann-Whitney rank-sum test. TIFP-LURS, trans-interfascial planes procedures for laparoscopic upper retroperitoneal surgery; Con-LURS, conventional laparoscopic upper retroperitoneal surgery; ASA, American Society of Anesthesiologists; UTUC, upper tract urothelial carcinoma.

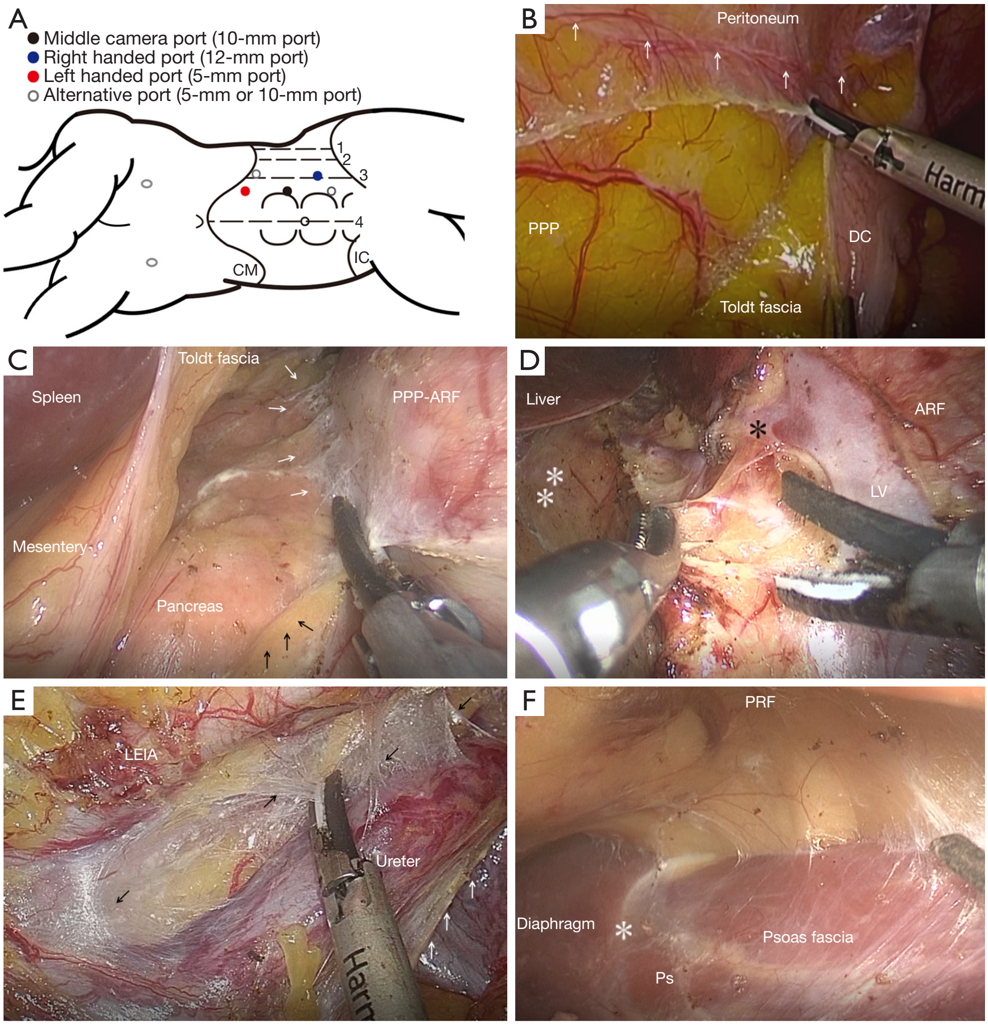

Figure 1 Demonstration of trans-interfascial planes procedures for laparoscopic upper retroperitoneal surgery on the left side. (A) Surgical position and trocar placement. The patient was placed in the right lateral decubitus with the left flank up. Dashed line 1: middle axillary line; dashed line 2: anterior axillary line; dashed line 3: the parallel line 2 cm away from the lateral aspect of the rectus abdominis muscle; dashed line 4: anterior median line; the middle camera port was placed lateral to the rectus abdominis muscle and 2 cm superiorly up to the level of the umbilicus. The left-handed port was at the junction of the lateral aspect of the rectus muscle (alternative choice: dashed line 3) and the subcostal border. The right-handed port was placed on dashed line 3 and 2 cm inferiorly down to the level of the umbilicus. Alternative right-handed port was marked half the distance between the anterior superior iliac spine and the umbilicus. (B) Mobilization of the colon. Incise along the white line of Toldt (white arrows) medially and access the IFP between Toldt fascia and PPP. (C) Exposure of the retroperitoneum. Dissect along the IFP between Toldt fascia and PPP medially, and reflect DC to expose the urinary organs. Stay outside the paler yellow ARF and avoid entering the brighter yellow posterior mesentery (black arrows). Loose areolar tissues (white arrows) with minute vessels inside can be observed along the IFP between different fasciae, which can be dissected without hemorrhage. (D) Renal hilum dissection. Dissect along the IFP among retropancreatic fascia (white asterisks), ARF and fasciae surrounding vessels, and expose LV and adrenal vein (black asterisk). (E) Dissection along the ureter. Dissecting along loose areolar tissues (black arrows) in the IFP between fasciae surrounding LEIA and Gerota's fascia surrounding the ureter (white arrows). (F) Exposure of the psoas muscle. Enter the IFP between PRF and the psoas fascia. Retract the kidney up but stay outside PRF. The medial arcuate ligament of diaphragm (white asterisk) is the anatomical landmark continuous with the fasciae of the psoas muscle. CM, costal margin; IC, iliac crest; IFP, interfascial plane; PPP, primitive parietal peritoneum; ARF, anterior renal fascia; DC, descending colon; LV, left renal vein; LEIA, left external iliac artery; Ps, psoas major; PRF, posterior renal fascia.

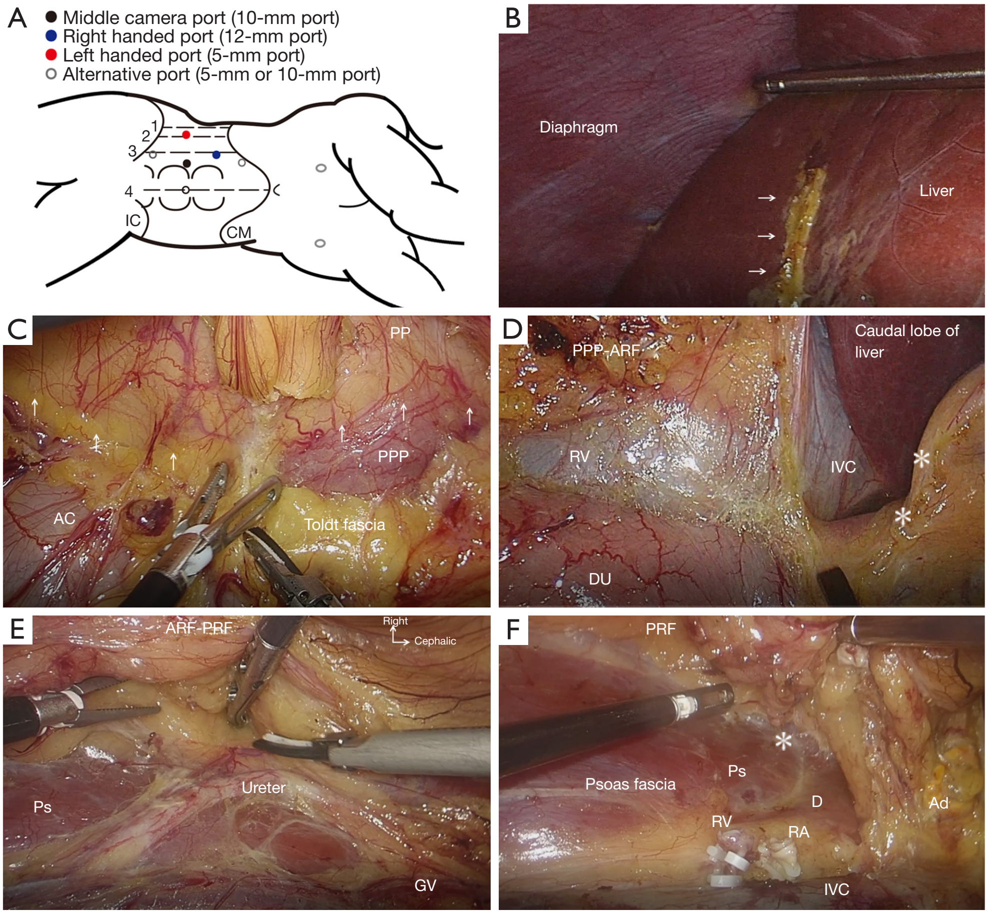

Figure 2 Demonstration of trans-interfascial planes procedures for laparoscopic upper retroperitoneal surgery on the right side. (A) Surgical position and trocar placement. The patient was placed in the left lateral decubitus with the right flank up. Dashed line 1: middle axillary line; dashed line 2: anterior axillary line; dashed line 3: the parallel line 2 cm away from the lateral aspect of the rectus abdominis muscle; dashed line 4: anterior median line; the middle camera port was placed lateral to the rectus abdominis muscle at the level of the umbilicus. The left-handed port was on dashed line 2 at the level of the umbilicus. The right-handed port was placed on dashed line 3 and 5 cm superiorly up to the level of the umbilicus. Alternative right-handed port was at the junction of the lateral aspect of the rectus muscle and the subcostal border. Alternative left-handed port was on dashed line 3 and 5 cm inferiorly down to the level of the umbilicus. (B) Retraction of the liver. Divide the hepatocolic ligament (white arrows indicated the cut edge) and retract the liver up. (C) Mobilization of the colon. Incise along the white line of Toldt (white arrows) medially and get the access to the IFP between Toldt fascia and PPP. Communicating vessels between PP and PPP were identified as the landmarks about correct surgical dissection plane between Toldt fascia and PPP. (D) Dissection at the renal hilum. Dissect along the IFP among the fusion fascia of Treitz (white asterisks, continuous with retropancreatic fascia), ARF and fasciae surrounding vessels, and expose IVC and RV. (E) Dissection along the ureter. Dissect along loose areolar tissues in the IFP between fasciae surrounding the GV and Gerota's fasciae (ARF-PRF) surrounding ureter. (F) Exposure of the psoas muscle. Ligate and divide the RA and RV. Then retract the kidney up but stay outside PRF and enter the IFP between PRF and psoas fascia. Medial arcuate ligament (white asterisk) of diaphragm (letter D) was the anatomical landmark continuous with fasciae of the psoas muscle. CM, costal margin; IC, iliac crest; IFP, interfascial plane; PPP, primitive parietal peritoneum; PP, parietal peritoneum; ARF, anterior renal fascia; AC, ascending colon; DU, duodenum; IVC, inferior vena cava; RV, right renal vein; RA, right renal artery; GV, gonadal vein; Ps, psoas major; PRF, posterior renal fascia; Ad, adrenal gland.

from the caudal aspect (*Figure 3A-3D*). Multilaminar fasciae surrounding the kidney in the retroperitoneal space were observed in transverse sectional specimens, including the renal capsule (RC), perirenal fat (PeRF), RF, parietal peritoneum, and pararenal fat (PaRF). There was a membranous structure with a clear demarcation between the PeRF and PaRF.

A transverse section of the retroperitoneum from a male cadaver (61 years of age at death) at the intervertebral disc level between L1 and L2 is presented in *Figure 3E,3F*. Fibrous connective tissue was observed between the PRF and muscular fascia. The vessel travelled and branched within the sub-peritoneal layer or internal space of the ARF independently, but no vessel anastomosis was observed between the two layers of fascia, which may be due to different embryonic origins.

Histological observation of the retroperitoneum

Regarding specimens taken from the anterior multilaminar fascia of the left kidney at the L1 vertebral body level (*Figure 4A-4E*), a fibrous connective tissue gap was observed between the peritoneum and ARF. As presented in *Figure 4B-4E*, the vessel ran in the internal space (sub-mesothelial tissue) of the peritoneum, and fascial tissue consisted of mesothelial and sub-mesothelial tissue, whereas the fusion layer of different fasciae consisted of multilaminar parallel strands of collagen fibers, which was pink in HE staining (*Figure 4D*) and blue in Masson staining (*Figure 4E*).

The specimens taken from the lateral multilaminar fascia of the left kidney at the L2 vertebral body level (*Figure 4F-4H*) indicated an observative fusion layer between the PRF and lateral conal fascia (LCF) and between the LCF and muscular fascia, which can be completely dissected in the LURS procedure.

Schematic diagram of retroperitoneal anatomy and TIFP procedures in surgery

Based on the result of anatomic and histological observation of the retroperitoneum above, and the concept of "IFP", the transverse sectional diagram of the left part of the retroperitoneum was drawn (*Figure 5*). The IFP is a potential space within a multilaminar membranous structure, indicated by asterisks (*) with different shapes and colors. We considered ARF continuous with PRF, which was composed of both mesothelial layer and submesothelial loose connective tissue. We considered the combination of the PPP, cone-like fat, and ARF as the traditional anterior layer of Gerota's fascia, and the combination of the PRF, LCF and fasciae of the psoas muscle and quadratus lumborum muscle as the posterior layer of Gerota's fascia (also known as Zuckerkandl's fascia). We considered the Toldt fascia sandwiched between the overlying mesothelial layer of the mesocolon and the underlying mesothelial layer of the PPP. The anterior layer of Gerota's fascia extended transversely in two directions: medially to fuse with the fascia overlying the adventitia layer of the aorta and IVC, laterally to fuse with Toldt fascia and the posterior layer, and then tapered at the area below the reflection of the visceral and parietal peritoneum. The IFP sandwiched by different fasciae comprised areolar tissues with minute vessels inside. Therefore, surgical dissection plane is readily developed within IFP.

We designed the TIFP-LURS (pink dashed line) using transperitoneal approach, which included: (I) incise along the white line of Toldt and get the access to IFP between Toldt fascia and PPP, which could mobilize and reflect the colon; (II) dissect along the IFP and medially get the access to the IFP between PPP and ARF, which actually stay outside ARF; (III) identify cone-like fat as an anatomical landmark and laterally dissect along the IFP between RF (ARF and PRF) and LCF; (IV) dissect along the IFP between PRF and LCF and then get the access to the IFP between PRF and fasciae of the psoas muscle and quadratus lumborum muscle, which divide the lateral and dorsal attachments of urinary system; (V) communicate the IFP between RF (ARF and PRF) and fascia around blood vessels, which could control and dissect the renal hilum with great care.

Clinical results

A total of 121 patients were included in the Con-LURS cohort and 229 patients were included in the TIFP-LURS cohort. There were no significant differences in baseline characteristics between the two cohorts (*Table 1*).

The primary endpoints of TIFP-LURS were significantly lower than those of Con-LURS, including estimated blood loss (72.24±134.97 *vs.* 118.23±229.78 mL, P=0.044), intraoperative complication rate [2/229 (0.9%) *vs.* 6/121 (5.0%), P=0.040], and postoperative complication rate [6/229 (2.6%) *vs.* 10/121 (8.3%), P=0.004].

The following secondary endpoints were identified in favor of TIFP-LURS versus Con-LURS: shorter length of hospital stay after surgery (P=0.007) and lower long-term postoperative complication rate (P=0.022). No

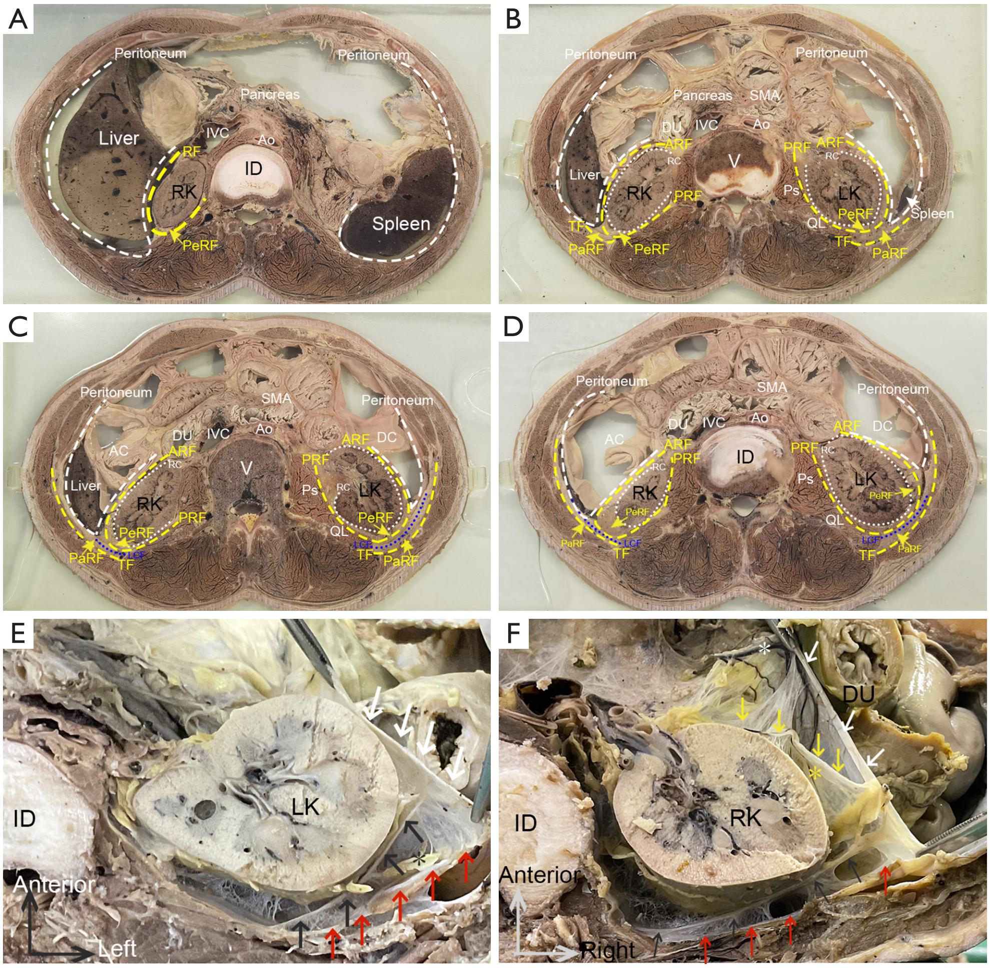

Figure 3 Transverse-sectional diagrams of abdomen and gross anatomy of the retroperitoneum (at the L1 and L2 level). (A-D) Transverse-sectional diagrams of the abdomen from a male cadaver (70 years of age at death) observed from the caudal aspect. Multilaminar fasciae surrounding the kidney in the retroperitoneal space were observed in transverse sectional specimens, including RC, PeRF, RF, parietal peritoneum, PaRF, etc. There was a membranous structure with a clear demarcation between PeRF and PaRF. (A) Transverse-section at the intervertebral disc level between T12 and L1. (B) Transverse-section at the L1 vertebral body level. (C) Transverse-section at the L2 vertebral body level. (D) Transverse-section at the intervertebral disc level between L2 and L3. (E,F) Gross anatomy of the retroperitoneum. A transverse section of the retroperitoneum from a male cadaver (61 years of age at death) at the intervertebral disc level between L1 and L2. (E) The interfascial planes of perirenal space of left kidney observed from the caudal aspect. The fibrous connective tissue was observed between PRF and muscular fascia. White arrow: parietal peritoneum; Black arrow: PRF; Red arrow: muscular fascia of diaphragm; Black asterisk (*): PaRF. (F) The interfascial planes of perirenal space of right kidney observed from the cephalic aspect. White arrow: parietal peritoneum; Yellow arrow: ARF; Black arrow: PRF; Red arrow: muscular fascia of diaphragm; White asterisk (*): the blood supply of peritoneum within the areolar connective tissue. The vessels travelled and branched within the sub-peritoneal layer. Yellow asterisk (*): the blood supply of ARF, which was independent of peritoneum. The vessels ran in the internal space of ARF and communicated with vessels within PeRF. SMA, superior mesenteric artery; IVC, inferior vena cava; Ao, aorta; RF, renal fascia; RK, right kidney; PeRF, perirenal fat; ID, intervertebral disc; DU, duodenum; ARF, anterior renal fascia; PRF, posterior renal fascia; RC, renal capsule; PaRF, pararenal fat; TF, transversalis fascia; Ps, psoas major; LK, left kidney; V, vertebra; QL, quadratus lumborum; AC, ascending colon; DC, descending colon; LCF, lateral conal fascia.

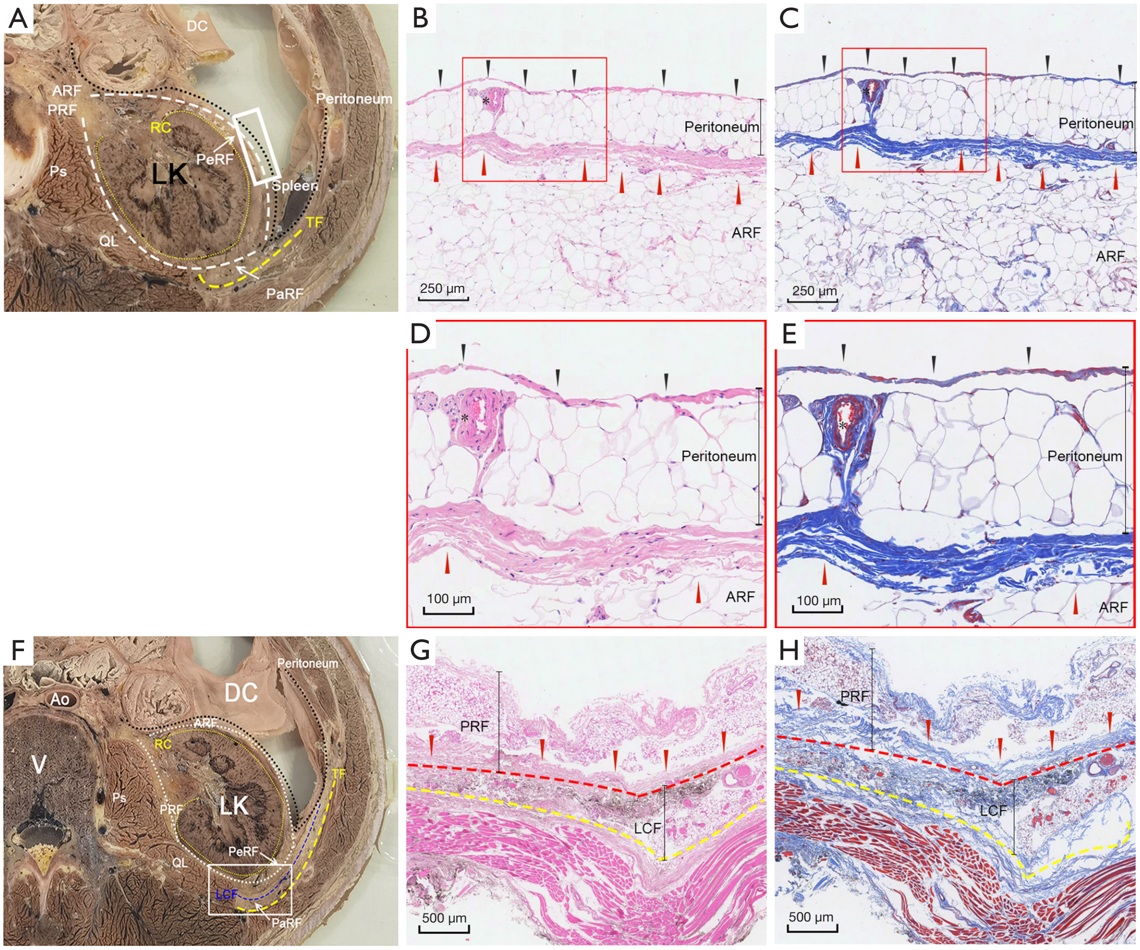

Figure 4 Histology of the retroperitoneum. (A) A transverse section of the left retroperitoneum at the L1 vertebral body level. (B,C) Representative images showed H&E staining (B) and Masson's trichrome staining (C) of white square section in (A). A fibrous tissue gap was observed between peritoneum and ARF (red arrowheads). Black arrowheads: abdominal aspect of the peritoneum; Black asterisk (*): the vessel ran in the internal space (sub-mesothelial tissue) of peritoneum. Bars, 250 μm. (D,E) High magnification of the red square sections in (B,C). Fascial tissue consisted of mesothelial (black arrowheads) and sub-mesothelial tissue while the fusion layer of different fasciae consisted of multilaminar parallel strands of collagen fibers (red arrowheads), which was pink in HE staining (D) and blue in Masson staining (E). Bars, 100 μm. (F) A transverse section of the left retroperitoneum at the L2 vertebral body level. (G,H) Representative images showed H&E staining (G) and Masson's trichrome staining (H) of white square section in (F). Red dashed line indicated the fusion layer between PRF and LCF. Yellow dashed line indicated the fusion layer between LCF and muscular fascia. Red arrowheads: strands of collagen fibers in fusion layer; Bars, 500 μm. Ao, aorta; DC, descending colon; LK, left kidney; V, vertebra; Ps, psoas major; QL, quadratus lumborum; TF, transversalis fascia; RF, renal fascia; ARF, anterior renal fascia; PRF, posterior renal fascia; RC, renal capsule; LCF, lateral conal fascia; PeRF, perirenal fat; PaRF, pararenal fat.

significant differences were noted in the duration of surgery, transfusion rate during surgery, or the rate of conversion to open surgery (P>0.05). The detailed data are presented in *Table 2*.

On univariate analysis, patients age, disease condition (malignant or benign), surgery procedure (TIFP or conditional), duration of surgery and estimated blood loss predicted the risk of short-term postoperative complications. However, on multivariate analysis, disease condition [odds ratio (OR) =4.726, 95% CI: 2.562–8.717, P<0.001], surgery procedure (OR =0.469, 95% CI: 0.260–0.848, P=0.012) and estimated blood loss (OR =1.003, 95%

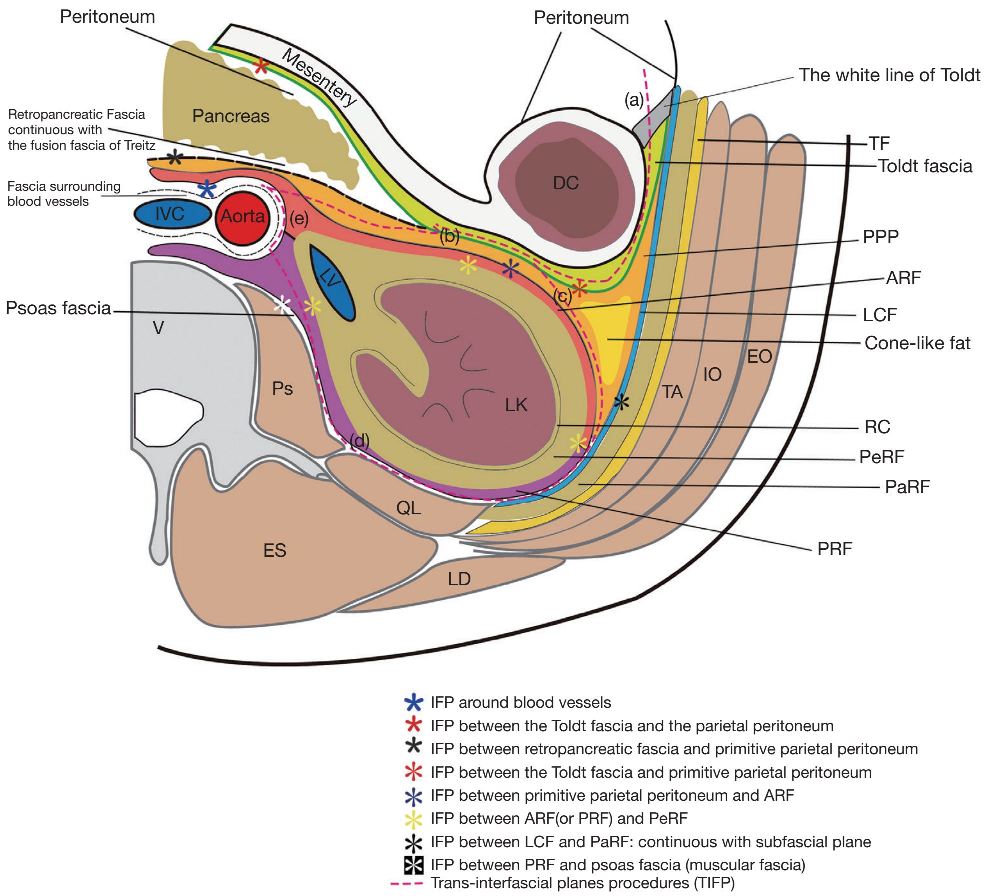

Figure 5 Schematic diagram of retroperitoneal anatomy and trans-interfascial planes procedures in surgery. The transverse sectional diagram of the left part of the retroperitoneum was drawn based on the concept of "interfascial plane". The interfascial plane is a potential space within a multilaminar membranous structure, indicated by asterisks (*) with different shapes and colors. We considered anterior renal fascia continuous with posterior renal fascia, which was composed of both mesothelial layer and sub-mesothelial loose connective tissue. We considered the combination of the primitive parietal peritoneum, cone-like fat, and anterior renal fascia as the traditional anterior layer of Gerota's fascia, and the combination of the posterior renal fascia, lateral conal fascia and fasciae of the psoas muscle and quadratus lumborum muscle as the posterior layer of Gerota's fascia (also known as Zuckerkandl's fascia). We considered Toldt fascia sandwiched between the overlying mesothelial layer of the mesocolon and underlying mesothelial layer of the primitive parietal peritoneum. The anterior layer of Gerota's fascia extended transversely in two directions: medially to fuse with the fascia overlying the adventitia layer of the aorta and IVC, laterally to fuse with Toldt fascia and the posterior layer, and then tapered at the area below the reflection of visceral and parietal peritoneum. The interfascial planes that sandwiched by different fasciae comprised areolar tissues with minute vessels inside. Therefore, surgical dissection plane is readily developed within interfascial planes. We designed the trans-interfascial planes procedures for laparoscopic upper retroperitoneal surgery (pink dashed line) using transperitoneal approach, which included: (a) incise along the white line of Toldt and get the access to IFP between Toldt fascia and primitive parietal peritoneum, which could mobilize and reflect the colon; (b) dissect along the IFP and medially get the access to the IFP between primitive parietal peritoneum and ARF, which actually stay outside ARF; (c) identify cone-like fat as an anatomical landmark and laterally dissect along the IFP between renal fascia (ARF and PRF) and LCF; (d) dissect along the IFP between PRF and LCF and then get the access to the IFP between PRF and fasciae of the psoas muscle and quadratus lumborum muscle, which divide the lateral and dorsal attachments of urinary system; (e) communicate the IFP between renal fascia (ARF and PRF) and fascia around blood vessels, which could control and dissect the renal hilum with great care. IFP, interfascial plane; IVC, inferior vena cava; DC, descending colon; LV, left renal vein; LK, left kidney; V, vertebra; Ps, psoas major; QL, quadratus lumborum; ES, erector spinae; LD, latissimus dorsi; TF, transversalis fascia; PPP, primitive parietal peritoneum; ARF, anterior renal fascia; PRF, posterior renal fascia; RC, renal capsule; LCF, lateral conal fascia; PeRF, perirenal fat; PaRF, pararenal fat; TA, transverse abdominis; IO, internal obliques; EO, external obliques.

Table 2 Operative and postoperative data of patients who underwent laparoscopic upper retroperitoneal surgery

Characteristics	TIFP-LURS (n=229)	Con-LURS (n=121)	t/χ^2/Ft	P value
Duration of surgery (min)	262.47±112.97	243.37±126.19	t=−1.444	0.15
Estimated blood loss (mL)	72.24±134.97	118.23±229.78	t=2.025	0.044*
Transfusion in surgery	5 (2.2)	5 (4.1)	χ^2=0.495	0.48
Intraoperative complications	2 (0.9)	6 (5.0)	χ^2=4.228	0.04*
Severe hemorrhage	0	2 (1.7)		
Vascular injury	1 (0.4)	1 (0.8)		
Bowel injury	1 (0.4)	1 (0.8)		
Diaphragm injury	0	1 (0.8)		
Other injury	0	1 (0.8)		
Conversions to open surgery	4 (1.7)	5 (4.1)	χ^2=0.972	0.32
Length of hospital stay after surgery (day)	6.08±3.42	7.16±3.76	t=2.699	<0.01*
Postoperative complications (short-term)	45 (19.7)	37 (30.6)	χ^2=5.270	0.02*
Grade I	16 (7.0)	9 (7.4)	χ^2=0.024	0.88
Fever	5 (2.2)	5 (4.1)		
Noninfectious diarrhea	2 (0.9)	0 (0.0)		
Hematuria	4 (1.7)	2 (1.7)		
Wound infection	5 (2.2)	2 (1.7)		
Grade II	25 (10.9)	27 (22.3)	χ^2=8.129	<0.01*
Hemorrhage treated by hemostatic agents	6 (2.6)	10 (8.3)		
Lymphatic leakage treated by agents	14 (6.1)	8 (6.6)		
Infection treated by antibiotics	5 (2.2)	9 (7.4)		
Grade IIIa	2 (0.9)	1 (0.8)	Ft	>0.99
Hemorrhage treated by endovascular embolization	2 (0.9)	1 (0.8)		
Grade IIIb	2 (0.9)	0	Ft	0.55
Hemorrhage treated by surgery	1 (0.4)	0		
Urinary leakage treated by surgery	1 (0.4)	0		
Grade IV	0	0	Ft	>0.99
Postoperative complications (long-term)	6 (2.6)	10 (8.3)	χ^2=5.782	0.02*
Pyeloureteral stenosis	1 (0.4)	2 (1.7)		
Hydronephrosis	0	3 (2.5)		
Renal insufficiency	5 (2.2)	3 (2.5)		
Lumbar hernia	0	1 (0.8)		
Others	0	1 (0.8)		

Values are presented as mean ± standard deviation or number (%). *, P<0.05. Postoperative complications (short-term) according to Dindo-Clavien classification. t, using the Student's t-test; χ^2, using the chi-square test; Ft, using the Fisher exact test. TIFP-LURS, trans-Interfascial planes procedures for laparoscopic upper retroperitoneal surgery; Con-LURS, conventional laparoscopic upper retroperitoneal surgery.

Table 3 Univariable and multivariable logistic regression analysis of risk factors for postoperative complications (short-term) among 350 patients analyzed in the study

Variable	Total (n=350)	Complications (n=82)	Univariable		Multivariable	
			OR (95% CI)	P	OR (95% CI)	P
Sex			1.246 (0.757–1.002)	0.39	Not included in the model	NC
Male	186 (53.1)	47 (57.3)				
Female	164 (46.9)	35 (42.7)				
Age (years)			1.019 (1.002–1.037)	0.03*	Not included in the model	NC
BMI (kg/m^2)			1.005 (0.918–1.212)	0.45	Not included in the model	NC
Location			1.325 (0.807–2.175)	0.27	Not included in the model	NC
Right	169 (48.3)	44 (53.7)				
Left	181 (51.7)	38 (46.3)				
ASA score			1.092 (0.216–5.515)	0.92	Not included in the model	NC
≥3	8 (2.3)	2 (2.4)				
<3	342 (97.7)	80 (97.6)				
Disease condition			5.466 (3.221–9.277)	<0.001*	4.726 (2.562–8.717)	<0.01*
Malignant	113 (32.3)	51 (62.2)				
Benign	237 (67.7)	31 (37.8)				
Previous abdominal history	39 (11.1)	9 (11.0)	0.978 (0.444–2.154)	0.96	Not included in the model	NC
Ipsilateral hydro-nephrosis	127 (36.3)	30 (36.6)	1.017 (0.608–1.700)	0.95	Not included in the model	NC
Surgery procedure			0.555 (0.355–0.921)	0.02*	0.469 (0.260–0.848)	0.01*
TIFP	229 (65.4)	45 (54.9)				
Con	121 (34.6)	37 (45.1)				
Duration of surgery			1.005 (1.003–1.008)	<0.001*	1.002 (0.999–1.001)	0.26
Estimated blood loss			1.005 (1.003–1.007)	<0.001*	1.003 (1.001–1.005)	<0.01*
Conversion	9 (2.6)	1 (1.2)	0.401 (0.049–3.256)	0.39	Not included in the model	NC

Values are presented as number (%) unless otherwise specified. *, P<0.05. Postoperative complications (short-term) according to Dindo-Clavien classification. OR, odds ratio; CI, confidence interval; BMI, body mass index; TIFP, trans-interfascial planes procedures for laparoscopic upper retroperitoneal surgery; Con, conventional laparoscopic upper retroperitoneal surgery; NC, not calculated; ASA, American Society of Anesthesiologists.

CI: 1.001–1.005, P=0.009) were independent predictors of the risk of short-term postoperative complications (*Table 3*).

Discussion

Surgical-related IFP refer to the multilaminar, avascular, loose connective tissue gap between the surface fascia of different organs in the abdominal and retroperitoneal spaces (2,3). Owing to the complexity of embryonic development of the main organs (urinary system organs) in the retroperitoneum, the IFP structure in the retroperitoneal space is the most complex. Radiologists currently accept the concept of "IFP" to understand retroperitoneal anatomy (10), replacing Meyers' classic tricompartmental theory. Despite much research on retroperitoneal anatomy, its anatomical structure, embryonic origin and developmental process still need further exploration, especially the anatomical relationship between the LCF, Gerota's fascia and Zuckerkandl's fascia, and how to understand the IFP to guide the optimization of surgical pathways.

According to the results of anatomic and histological observation in this study, "fascia tissue" is a three-dimensional structure that contains blood vessels and lymphatic pathways. The retroperitoneal space forms a layered structure with various layers of fascia, providing the potential to establish and expand a safe surgical space between fascial planes. The core principle of TIFP-LURS is to dissect and expand the inherent potential spaces between the organs of different embryonic origins during laparoscopic surgery. This allows for the creation of surgical operating planes free of blood vessels or adipose tissue, and ultimately removes or reconstructs upper urinary tract lesions.

The laparoscopic technique originated with the use of cystoscope and has revolutionized modern surgery. In 1976, Cortesi first reported its use for diagnosing undescended testicles (11). With advancements in equipment, laparoscopy has been used to treat abdominal organ lesions. In 1990, Clayman successfully performed the first laparoscopic nephrectomy (12). In 1992, Higashihara and Gagner reported successful laparoscopic adrenalectomies and Gaur developed a technique for expanding the retroperitoneal space using a balloon (13-15). Since then, laparoscopy has been rapidly developed in urology and has become the "gold standard" for many diseases because of its advantages over open surgery. New technologies such as 4K and 3D video, laparo-endoscopic single-site surgery, and robot-assisted surgery have greatly promoted innovation in urological surgery.

Currently, the main surgical approaches for LURS are trans-abdominal and retroperitoneal approaches. Both are technically mature and there is no statistically significant difference in efficacy between them for skilled surgeons performing Con-LURS (16-18). Surgeons can select the appropriate approach based on preoperative imaging, patient status, and surgical experience. In this study, the Con-LURS group used the retroperitoneal approach to directly access the lesion area and reduce interference with abdominal organs. The transabdominal approach was used in the TIFP-LURS group to obtain a larger operating space and clearer anatomical structures.

We contended that discussions such as "transabdominal or retroperitoneal approach" represent practical summaries of technical details. Ultimately, their theoretical foundations must rest on the understanding of anatomical structures. In 2015, Mike described the technique of "fascial anatomy" in colorectal cancer surgery, which involves finding the layers that make up the "holy plane" (19) and Gong (20) advanced a surgical theory named "membrane anatomy" in gastrointestinal surgery. Furtherly, several gastroenterologists confirmed surgical landmark based on fascial anatomy researches (21,22). With these surgical concepts in gastrointestinal surgery, we advanced the "TIFP" surgical theory based on the comprehension of retroperitoneal anatomy.

The key to performing TIFP-LURS successfully is to identify the correct surgical plane, specifically an avascular IFP. The challenge lies in preserving the integrity of the multiple thin layers of the fascia while smoothly entering the IFP. TIFP-LURS is based on IFP anatomy. Its technical characteristics include the realization of re-embryonic and "paginization" operations during the surgical process. "Paginization" refers to the concept of separating an object into layers, like pages in a book, which means establishing IFP in bloodless areas between the fusion edges of two series of organ surface fasciae in TIFP surgery. Through paginization operation, the retroperitoneal fascia layers are freed and a bloodless operating space is established. Following the path of rotation and translation during organ embryonic development (morphogenesis), surgical operation is performed to restore the organ position during embryonic development and achieve lesion removal and upper urinary tract reconstruction or repair. This surgical idea can be summarized as re-embryonic operation.

In this study, the results showed no statistically significant differences in disease type, surgical type, or preoperative data between the Con-LURS and TIFP-LURS groups ($P>0.05$) (*Table 1*), indicating the comparability of perioperative data between the two groups. Compared to Con-LURS, TIFP-LURS offers a larger operating space and employs paganization and re-embryonic surgical techniques. These differences in surgical approaches may account for variations in perioperative outcomes, and were measured by indicators such as duration of surgery, estimated blood loss, length of hospital stay, and the incidence and severity of postoperative complications.

Previous research indicated that factors that may affect the occurrence of postoperative complications after LURS include patient, surgical, and perioperative management factors (23). Patient factors included age >60 years, male sex, tumor disease, ascites, American Society of Anesthesiologists (ASA) grade ≥3, preoperative anemia, and hypoalbuminemia (24-27). However, BMI and obesity are not independent risk factors for laparoscopic nephrectomy or partial nephrectomy (28). Surgical factors include the use of minimally invasive surgery in pediatric urology and the use of a retroperitoneal approach in laparoscopic partial nephrectomy (29). Perioperative management factors include an increased investment in patient care resources (23). Currently, there is no consensus regarding the factors that affect postoperative complications.

In the multivariable analysis in this study, TIFP procedure was an independent protective factor for decreasing the incidence of postoperative complications, while prolonged duration of surgery and increased blood loss in surgery were independent risk factors for increasing incidence of postoperative complications. These factors may lead to the incidence of postoperative complications after LURS through the following mechanisms: (I) prolonged surgery time could increase abdominal carbon dioxide absorption and increase the burden on cardiopulmonary function in elderly or high ASA grade patients. (II) Increased blood loss during surgery may increase the risk of hypothermia, and increased intraoperative bleeding (30). (III) Paginization operation in TIFP-LURS can reduce intraoperative bleeding by minimizing damage to the microvascular network in the fasciae. TIFP-LN can reduce damage to perirenal tissue by freeing the kidney and renal fascia through the fascial space. TIFP-LA can expose important blood vessels and prevent intraoperative injuries.

The novelty of this study is that we found anatomic basis for TIFP-LURS through cadaveric study, and furtherly developed a completely described technique of TIFP-LURS and indicated its advantages in perioperative outcomes. Specifically, on the one hand, according to observation results of cadaveric study, we provided new understanding about retroperitoneal fascia anatomy, and highlighted the IFP as potential avascular space that can be used during LURS. One the other hand, according to the new understanding of anatomy, we developed technique of TIFP-LURS, and demonstrated its advantage in perioperative outcomes, including less blood loss, lower operative complication rate, shorter hospital stay. Additionally, the concept of TIFP procedure theoretically is applicable to different surgical approaches or types. It is possible useful for trans-retroperitoneal approach, for the reason that the understanding of IFP in retroperitoneal fascia anatomy and the TIFP procedure help urologists to better dissect perirenal structure and complete LURS. But further clinical study is required.

This study had several limitations. The number of anatomical and histological specimens observed was relatively small, which may have affected the results owing to anatomical variations. Meanwhile, direct evidence from embryological observations is lacking. The clinical study was a single-center, non-randomized retrospective comparison of surgical outcomes, which may introduce various retrospective biases.

Conclusions

Fasciae is a three-dimensional structure containing a microvascular network, and the IFP are potential avascular spaces that can be dissected and expanded during laparoscopic surgery. TIFP-LURS is a novel and feasible surgical approach based on IFP anatomy, which can reduce intraoperative bleeding and postoperative complications, and improve the safety and efficacy of laparoscopic surgery for upper retroperitoneal lesions.

Acknowledgments

All authors thank the Laboratory of Anatomy of Zhongshan School of Medicine of Sun Yat-sen University for providing cadavers for this study.
Funding: This work was supported by a grant from the Basic and Applied Basic Research Foundation of Guangdong Province of China (No. 2019A1515010386).

Footnote

Reporting Checklist: The authors have completed the TREND reporting checklist. Available at https://tau.amegroups.com/article/view/10.21037/tau-23-632/rc

Data Sharing Statement: Available at https://tau.amegroups.com/article/view/10.21037/tau-23-632/dss

Peer Review File: Available at https://tau.amegroups.com/article/view/10.21037/tau-23-632/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tau.amegroups.com/article/view/10.21037/tau-23-632/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the

Institutional Committee of The Sixth Affiliation Hospital of Sun Yat-sen University (No. 2022ZSLYEC-171) and individual consent for this retrospective analysis was waived.

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Cite this article as: Huang J, Zhang T, Mo J, Ye L, Zhong W, Xu D, Song Z, Liu J, Liu D, Tao Y, Wang D, Qiu J. Interfascial planes as surgical landmarks for laparoscopic upper retroperitoneal surgery: a cadaveric and retrospectively clinical study. Transl Androl Urol 2024;13(5):720-735. doi: 10.21037/tau-23-632