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Retroperitoneal Lymph Node Dissection: Anatomical and Technical Considerations from a Cadaveric Study

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Abstract

PURPOSE—Metastatic testis cancer in the retroperitoneum presents a technical challenge to urologists in the primary and post-chemotherapy setting. Where possible, bilateral nerve-sparing retroperitoneal lymph node dissection (RPLND) should be performed in an effort to preserve ejaculatory function; however, this is often difficult to achieve given the complex neurovascular anatomy. To address this, we performed the first comprehensive examination of the anatomical relationships between the sympathetic nerves of the aortic plexus and the lumbar vessels to facilitate navigation and nerve-sparing during bilateral RPLND.

MATERIALS AND METHODS—The relative anatomy of the infrarenal vasculature (lumbar vessels, right gonadal vein, and inferior mesenteric artery) was investigated in 21 embalmed human cadavers. The complex relationships between these vessels and the sympathetic nerves of the aortic plexus were examined by dissection of an additional 8 fresh human cadavers.

RESULTS—Analysis of the infrarenal vasculature from 21 cadavers demonstrated that the position of the right gonadal vein and the inferior mesenteric artery may be useful to locate the right superior lumbar vein and 1st pair of infrarenal lumbar arteries; and the common lumbar trunk (vein) and 2nd pair of infrarenal lumbar arteries, respectively. Furthermore, it was revealed that the

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lumbar splanchnic nerves supplying the aortic plexus were most often positioned antero-medial to the respective lumbar vein.

CONCLUSIONS—The present study describes the complex neurovascular relationships that are crucial to performing a successful nerve-sparing RPLND, and surgical techniques are discussed. Collectively, these results may help surgeons to reduce post-operative retrograde ejaculation and/or anejaculation.

Keywords

RPLND; lumbar artery; sympathetic nervous system; retrograde ejaculation; nerve-sparing

Introduction

Retroperitoneal lymph node dissection (RPLND) for non-seminomatous germ cell tumors (NSGCT) remains an effective treatment for metastatic disease [1–5]. With the advent of cisplatin-based chemotherapy, primary RPLND has become less popular for treating early stage disease [2]. Currently, surveillance and/or chemotherapy following orchiectomy remain the common practice for managing Stage-I disease, whereas chemotherapy is the primary treatment for low-risk Stage-II NSGCT [1]. Therefore, with the improvement in treating early stage NSGCT, RPLND is most often used to treat advanced staged disease and post-chemotherapy residual masses. However, primary RPLND may re-emerge as a treatment for early stage disease given our understanding of increased long-term risk of secondary malignancies and cardiovascular morbidity following chemotherapy [6,7].

Today, modified surgical templates that limit contralateral dissection [8–12] continue to be used in many international centers to improve rates of antegrade ejaculation post-operatively [3,13,14]. However, studies have since challenged their usefulness on the basis of viable extra-template disease [15,16]. It is estimated in the post-chemotherapy setting, at least 7–32% of patients would exhibit extra-template disease, depending on the template used [16]. Because an effort to spare ejaculation should never be made at the risk of incomplete cancer resection [2], it was concluded that a full bilateral infrahilar template (spanning: left renal vein, superiorly; ureters, laterally; and aortic bifurcation, inferiorly) is most prudent and nerve-sparing should only be performed where possible [16].

When performed, nerve-sparing in the post-chemotherapy setting is associated with variable rates of antegrade ejaculation. For example, in a 2012 review, Heidenreich and Pfister reported ejaculatory dysfunction in 75% of patients undergoing bilateral post-chemotherapy RPLND [1], while Pettus et al. (2009) demonstrated that antegrade ejaculation was maintained in 79% of their patients undergoing bilateral post-chemotherapy RPLND [17]. Although differences in stage and/or size of the residual mass are apparent between the reports, the surgeon's comfort with the normal neurovascular anatomy of the retroperitoneum is a significant factor to the success of an RPLND [2] and is a possible contributing factor to these disparate results. Surprisingly, literature on the neurovascular anatomy of the infrarenal retroperitoneum is relatively sparse, and much of what is known about the topic has only emerged recently.

Today, it is generally accepted that the lumbar arteries are regularly spaced and bilaterally paired with the 2nd–4th pairs commonly encountered below the level of the left renal vein (LRV) [18,19]. In contrast, the lumbar veins are variable, unpaired vessels that preferentially drain into the left-posterior side of the inferior vena cava (IVC) [18,19], positioned at a distance from one another that segmentally increases closer to the ilio caval confluence [19]. Studies have also described the anatomy of the sympathetic nerves comprising the aortic plexus. Specifically, it has been shown that the aortic plexus is supplied by at least two lumbar splanchnic nerves (LSN)¹ on each side and is composed of two parallel nerves (cords), each containing two major ganglia [21]. Collectively, these studies provide a strong foundation for understanding the retroperitoneal neurovascular anatomy. However, the clinical usefulness of this information is limited by the lack of studies which integrate the aforementioned anatomy by examining their relationships with one another.

In the present study, we aim to address this issue by performing an examination of the relationship between the sympathetic nerves and the lumbar vessels within the boundaries of an infrahilar bilateral template. This was achieved through dissection of human cadavers and our findings are extrapolated to discuss strategies to navigate these structures during RPLND.

Materials and Methods

In a population of 22 embalmed cadavers with no evidence of retroperitoneal disease, the positions of the lumbar vessels, the inferior mesenteric artery (IMA), and the right gonadal vein were measured from the inferior border of the LRV. All measurements were normalized by the length of the infrarenal abdominal aorta before statistical analysis. Since these cadavers had been previously dissected by medical students, we excluded one specimen where the retroperitoneum was grossly over-dissected.

The relationship of the sympathetic nerves comprising the aortic plexus to that of the lumbar vessels was explored during eight fresh cadaveric dissections using a transabdominal approach.

All data was obtained in accordance with Western's Committee for Cadaveric Use in Research [approval #15052013]. Statistical analyses were completed using SPSS Statistics 20, whereas power was determined using G*Power v3.1.9.2. The final vascular dataset was analyzed using a Welch ANOVA with sufficient power ($1-\beta = 0.8$; $\alpha = 0.05$) to detect small-moderate (0.30) effect size. All assumptions of the statistical test were satisfied.

¹In much of the urologic literature, lumbar splanchnic nerves are referred to as postganglionic nerves/fibers [2,3,15,17]. In this manuscript, the former (anatomical) nomenclature will be used. This decision was made because the latter (urologic) nomenclature misconstrues the fact that these nerves are mainly comprised of preganglionic/presynaptic axons that will not synapse until the prevertebral ganglia of the aortic plexus [20].

Results

Infrarenal Vascular Relationships

In the included population of 21 embalmed cadavers, several vascular relationships were identified as shown in graphical/illustrative form in Figure 1. A significant difference in vessel position was found [Welch's $F_{8,59,3}=130.7$, $p<0.05$; partial $\eta^2 = 0.868$]. In particular, Games-Howell post-hoc analyses indicated significantly different positions between the superior vessels (right gonadal vein, right superior lumbar vein, 2nd pair of lumbar arteries), middle vessels (common lumbar trunk, IMA, 3rd pair of lumbar arteries) and inferior vessels (left and right inferior lumbar veins, 4th pair of lumbar arteries). Within each vessel grouping (e.g., superior vessels: right gonadal vein vs. right superior lumbar vein vs. 2nd pair of lumbar arteries) no significant differences in position were seen (Fig. 1). These findings suggest that the right gonadal vein may be useful to approximate the location of the right superior lumbar vein (if present) and/or the 2nd pair of lumbar arteries. Likewise, the IMA may be useful to approximate the location of the common lumbar trunk (if present) and/or the 3rd pair of lumbar arteries.

The Sympathetic Nerves and the Infrarenal Lumbar Vessels

In eight fresh cadavers, the relationship of the sympathetic nerves to the lumbar vessels was explored.

On the right side, the origin of the first infrarenal LSN coursed from the sympathetic chain, often just superior to the inferior border of the LRV (Fig. 2). Its position within the interaortocaval adipose tissue was often complicated given the close association to the right superior lumbar vein which was often observed in this region. Usually the first infrarenal LSN coursed medial to this lumbar vein where it then intersected the right cord of the aortic plexus near the right testicular artery. The second infrarenal LSN coursed in parallel to the first, originating from the sympathetic chain approximately one vertebral level caudal. This nerve most often coursed antero-medial to the middle common lumbar trunk and/or 3rd (2nd infrarenal) lumbar artery before intersecting the right cord of the aortic plexus, at the position of the prehypogastric ganglion (Fig. 2A). As seen in this specimen, the neurovascular anatomy may be complicated by the presence of an accessory LSN which often runs in parallel with the LSN proper. This neural variation is common to both the right and left side of the aortic plexus.

On the left side, the first infrarenal LSN originated from the sympathetic chain near the level of the inferior border of the LRV. It typically extended antero-inferior to merge with the intermesenteric nerve from the more rostral sympathetic plexuses, forming the left cord of the aortic plexus (Fig. 2). The renal-lumbar vein, if present, often complicated exposing this portion of the sympathetic plexus given its position either between the first infrarenal LSN and the left intermesenteric nerve (Fig. 2B) or lateral to both. The second infrarenal LSN typically branched from the sympathetic chain more superiorly than its right-sided counterpart. Its origin was at approximately the level of the left testicular artery, and was seen branching off the sympathetic chain as high as where the 2nd (1st infrarenal) pair of lumbar arteries disappeared deep to psoas major.

Discussion

Several studies exist which describe the anatomy of the nerves and vasculature in the retroperitoneum as it pertains to surgical interventions [22–24]; however, given the complexities of retroperitoneal masses during bilateral RPLND, nerve-sparing and complete vascular control of the lumbar vessels may be difficult to achieve [2]. In the present study, we describe the neurovascular relationships of the lumbar vessels and the sympathetic nerves of the aortic plexus, which may aid in managing these structures during RPLND. In the following sections, we discuss our findings in a regional context as it pertains to the practice of RPLND. Note that nerve-sparing is never performed at the cost of potentially leaving residual tumor [2,25].

Paracaval Node Dissection

Care must be taken to dissect and protect the right ureter while separating the paracaval nodal tissue from Gerota's fascia [25]. After ligating the right gonadal vein [25], nodal tissue can be dissected from the caval adventitia with ease given this region is void of sympathetic nerves [22]. With the IVC rolled left, a variable number of lumbar veins (usually 2–3) may be encountered draining the right side. Typically, the right superior lumbar vein (usually of large diameter) will be located near the right reno-caval junction, often superior to the right gonadal vein. Midway along the infrarenal IVC, a smaller lumbar vein may be encountered that has a tendency to drain into the left side of the IVC or form a common trunk with one of the left-sided lumbar veins [19]. Lastly, the right inferior lumbar vein may be encountered draining near the level of the ilio caval confluence.

With a right-sided approach, the plane between the paracaval nodal tissue and the fascia overlying the psoas major muscle can be cleaved to expose the sympathetic chain and the origin of the LSNs. In a minority of individuals, a lumbar vessel may aberrantly course lateral to the sympathetic chain.

Interaortocaval Node Dissection

Using the split-and-roll technique on the IVC, the plane between the interaortocaval nodal tissue and the caval adventitia can be separated without encountering sympathetic nerves. This plane can be followed to identify the left lumbar veins (variable), which were typically observed draining centrally (i.e., *between* the most cranial and caudal right lumbar veins) and into the left side of the IVC. Usually, two left lumbar veins were observed; the largest and most prevalent of which (common lumbar trunk) may be landmarked using the IMA, and often receives multiple left-sided tributaries. Therefore, ligation of this singular vessel should be noted because it may necessitate multiple paraaortic ligations. The second most common vessel, the left inferior lumbar vein, is located closer to the ilio caval confluence, approximately where the right common iliac artery crosses the IVC. If a right inferior lumbar vein was present, the left is typically slightly rostral. Once ligated, full control of the lumbar veins should be achieved and the IVC can be fully mobilized (Fig. 3).

With the right sympathetic chain exposed, meticulous dissection should be made anterior to identify the LSNs. Usually, there are two LSNs joining the infrarenal portion of the aortic

plexus, spaced approximately one vertebral level apart; however, the presence of accessory LSNs of comparable size, coursing near and in parallel with the LSN proper is a common possibility. Vessel loops should be placed around the LSNs for reference [25] (Fig. 4). Following the right LSNs anteriorly will reveal the right cord of the aortic plexus, a longitudinal nerve running along the antero-medial aspect of the infrarenal abdominal aorta which contributes to the formation of the superior hypogastric plexus [21]. With the right-sided nerves spared, the preaortic nodes can be split, with care to preserve any preaortic nerves that may connect with the contralateral cord of the aortic plexus. Most often, branches extend from the prehypogastric ganglion (near the intersection of the second infrarenal LSN and the right cord) to join the inferior mesenteric plexus. Subsequently, dissection can then proceed along the aortic adventitia to identify the right lumbar arteries.

Usually three pairs of lumbar arteries are present along the infrarenal abdominal aorta, with the position of the middle pair (3rd lumbar arteries) approximated using the origin of the IMA (Fig. 1). Once identified, the adjacent pairs of lumbar arteries can be identified at a distance away equal to one third of the length of the infrarenal abdominal aorta [19].

Preaortic Node Dissection

Preaortic node removal will primarily focus on preserving the rostral portions of the cords (intermesenteric nerves). Nerves of interest to maintain antegrade ejaculation should course posterior the LRV (as opposed to intraperitoneal nerves entering the mesentery which, during RPLND, will appear to course anterior to the LRV after the abdominal viscera is reflected superiorly). To aid dissection, the IMA may be sacrificed if adequate blood supply to the colon is maintained by the marginal artery (of Drummond) [25].

Paraaortic Node Dissection

The paraaortic dissection is often challenging, particularly at the superior border which can be a potential source of in-field recurrence. Care must be taken to identify and preserve the left ureter that often requires ureterolysis if a residual mass is present. Dissection can proceed along the plane of the aortic adventitia to identify the left lumbar artery(ies). Studies have indicated a strong tendency for the lumbar arteries to be positioned at similar levels [18,19], therefore, the position of the right lumbar arteries can facilitate locating their respective left-sided pairs. Sparing of the intermesenteric nerve as it joins with the first infrarenal LSN may be complicated by a renal-lumbar vein, coursing lateral to the aorta, draining aberrantly into the LRV at a position just posterior to the left gonadal vein [19,26]. The intermesenteric nerve will course medial to the renal-lumbar vein (Figs. 2B, 5), whereas the first infrarenal LSN can course antero-medial or postero-lateral to this vein.

While the aortic plexus is usually bilaterally symmetric in its *organization* [21], it should be appreciated that it rarely exhibits a bilateral symmetric *position*. Thus, the position of the right LSNs cannot be used to landmark the left LSNs.

Near the origin of the IMA, at about the intersection of the second infrarenal LSN with the left cord of the aortic plexus, the inferior mesenteric ganglion can be identified. Numerous branches will extend along the IMA to form the inferior mesenteric plexus to the hindgut;

however, the left cord will continue posterior to the IMA to join the right cord, forming the superior hypogastric plexus, which is usually situated left of the aortic midline [24].

Accessing the inferior paraaortic nodal tissue can be achieved by incising the white line of Toldt to mobilize the descending colon, facilitating medial reflection of the distal bowels and their mesentery [25]. Care should be made to identify the distal lumbar sympathetic chain and the retroaortic LSN, if present (Fig. 1). Note that retroaortic LSNs will course between the left common iliac artery and vein to join the superior hypogastric plexus directly [21].

Conclusions

The present study examined the complex relationships of the lumbar vessels and sympathetic nerves in the infrarenal retroperitoneum. This information is crucial in performing a successful nerve-sparing bilateral RPLND and may reduce the incidence of post-operative retrograde ejaculation and/or anejaculation.

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Abbreviations Key

RPLND	Retroperitoneal Lymph Node Dissection
NSGCT	Non-Seminomatous Germ Cell Tumors
LRV	Left Renal Vein
IVC	Inferior Vena Cava
LSN	Lumbar Splanchnic Nerve
IMA	Inferior Mesenteric Artery

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Figure 1.

The relative position of the infrarenal lumbar arteries and veins, the right gonadal vein and the inferior mesenteric artery are shown in both graphical and illustrative format. Post-hoc analyses demonstrated statistically significant difference between the superior vessels (right gonadal vein, right superior lumbar vein, 2nd pair of lumbar arteries), middle vessels (common lumbar trunk, inferior mesenteric artery, 3rd pair of lumbar arteries) and inferior vessels (left and right inferior lumbar veins, 4th pair of lumbar arteries). Within each vessel grouping (e.g., superior vessels: right gonadal vein vs. right superior lumbar vein vs. 2nd pair of lumbar arteries) no significant differences (ns) in position were seen. Error bars represent ± 1 SD. Dotted gray lines are used to show the positions of the inferior border of the left renal vein, the origin of the inferior mesenteric artery, and the bifurcation of the common iliac arteries.

Figure 2.

A comprehensive illustration showing the relationships of the sympathetic nerves and ganglia of the aortic plexus (yellow) to the position of the infrarenal lumbar arteries and veins. Panel A demonstrates the neurovascular relationship of the second infrarenal lumbar splanchnic nerve to the lumbar vein in addition to an accessory second infrarenal lumbar splanchnic nerve. Panel B exhibits a specimen where the renal-lumbar vein can be seen joining the left renal vein, coursing between the intermesenteric nerve and the first infrarenal lumbar splanchnic nerve. Alternatively, the first infrarenal lumbar splanchnic nerve may course antero-medial to this vein in some specimens. Panel C shows the full left-sided dissection of the cadaver shown in Panel B. The arrow heads approximate the position of the two left-sided constituent ganglia of the aortic plexus. IMA inferior mesenteric artery.

PARACAVAL & INTERAORTOCAVAL NODAL DISSECTION

Will usually involve ligation of 2-3 right-sided lumbar veins; the most superior one being of largest calibre (*) - positioned near the right reno-caval confluence.

Care must be taken to dissect and protect the right ureter and separate the para-caval nodal tissue from Gerota's fascia.

Figure 3.

An illustration showing the position of the sympathetic nerves within the interaortocaval nodal tissue (translucent brown colour). This image illustrates how dissection in the plane of the caval adventitia allows for ligation of the right and left lumbar veins as they join the inferior vena cava, without complication by sympathetic nerves. After ligation, the inferior vena cava can be mobilized to facilitate interaortocaval node dissection (see Fig. 4).

PARACAVAL & INTERAORTOCAVAL NODAL DISSECTION (CONT.)

Using the split-and-roll technique on the IVC, remaining lumbar veins can be isolated and divided.

A minimum of two infrarenal lumbar splanchnic nerves are present. The splanchnic nerves (*) are identified at their origin from the right sympathetic chain under the IVC as the first step of nerve-sparing.

Nerve-sparing is never performed at the cost of potentially leaving tumor.

Figure 4.

An illustration depicting the first steps of nerve-sparing following mobilization of the inferior vena cava. With the inferior vena cava rolled laterally, the plane between the nodal tissue (translucent brown colour) and the fascia overlying the psoas major muscle can be separated to identify the right sympathetic chain and the origin of the lumbar splanchnic nerves. Vessel loops help maintain visualization of the infrarenal lumbar splanchnic nerves as they are spared from the interaortocaval nodal tissue. IMA inferior mesenteric artery; SMA superior mesenteric artery.

PREAORTIC & PARAAORTIC NODAL DISSECTION

The inferior mesenteric artery can be sacrificed to aid dissection if adequate blood supply to the colon is maintained by the marginal artery (of Drummond)

Dissection of the paraaortic nerves and lymphatic tissue may be complicated by the presence of a lumbar vein (*) draining aberrantly into the left renal vein, posterior to the left gonadal vein

The superior paraaortic dissection is often the most challenging and the superior border can be a potential source of in-field recurrence. Care must be taken to identify and preserve the left ureter that often requires ureterolysis if a residual mass is located in this area

Figure 5.

A figure illustrating a lateral perspective of the preaortic and paraaortic nodal dissection. Ligation of the lumbar vessels is performed as they disappear deep to psoas major. Care should be made to identify the sympathetic chain in this plane of dissection, along with the associated lumbar splanchnic nerves which course through the paraaortic nodal packet (translucent brown colour). Note that often, ligation of more lumbar veins may be necessary given the tendency for the upper veins to drain into a common trunk along the middle of the inferior vena cava (ligated during the interaortocaval dissection). At the cranial border, the dissection is often complicated by a lumbar vein aberrantly draining into the left renal vein which intimately courses along the first infrarenal lumbar splanchnic nerve and/or the intermesenteric nerve from the superior mesenteric/aorticorenal plexuses.