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Anatomo-radiological mapping of the arrangement of ascending lumbar veins in relation to renal veins: is there a way to predict the risk of intraoperative lesions?

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SUMMARY

The aim of our study was to describe the critical area for iatrogenic lesions of the lumbar veins during the intraoperative manipulation of the renal veins and propose predictive indications for identifying those veins found in potential risk for iatrogenic lesions. Adult human cadavers were dissected and contrast enhanced images of CT and MR scans were randomly selected and analyzed. The distances from the first lumbar veins to the right and left renal veins were measured, respectively. The diameter of the renal veins and of the inferior vena cava was calculated. Correlation of the distances between the first lumbar veins and the corresponding renal veins, as well as the diameter of the renal veins and the inferior vena cava was performed.

We obtained 205 specimens. The average distances between the right and left first lumbar veins and their respective renal veins was 3,5cm and 3,8cm, respectively ($p<0.0001$). We found 40 (20%), 96 (46%) and 69 (34%) lumbar veins at high, moderate and low risk for intraoperative lesion, on the right side, respectively, and 34 (17%), 86 (42%) and 85 (41%) lumbar veins, on the left side, respectively. The correlation between the size of the renal veins and the first lumbar vein-renal vein distance found a statistically significant difference, only on the left side ($p=0.02$). We describe the arrangement of the lumbar veins in relation to the renal veins, proposing a way to predict the existence of a "risk zone" for inadvertent, intraoperative vascular lesions.

Key words: Iatrogenic disease – Kidney neoplasms – Renal transplantation – Renal veins – Anatomy

INTRODUCTION

Kidney surgeries, especially those related to kidney transplants (Li et al., 2011) and the resection of tumors that invade the inferior vena cava (Abbasi et al., 2012), can lead to various complications, but iatrogenic lesions of a lumbar vein, although uncommon, during the manipulation of the renal vein and/or the inferior vena cava are perhaps the most dramatic ones for the urologist. As they are short and relatively small, when lesioned, they may retract into the adjacent adipose tissue,

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making them almost impossible to repair, and thus evolving to intense local bleeding that is difficult to control (Lawindy et al., 2012). Other specialists who work in this pre-vertebral area, such as vascular surgeons and orthopedists specializing in the spine, can also face difficulties when they do not take into consideration the anatomical arrangement of the lumbar veins (Costa et al., 2005; Flouzat-Lachaniette et al., 2013; Marchi et al., 2015).

According to the classic anatomy texts, lumbar veins are responsible for the drainage of the muscles of the abdomen's posterior wall and have direct communication with the veins of the vertebral venous plexus, without the presence of valves, thereby allowing for the free circulation of blood flow in both directions (Hollinshead, 1971; Hollinshead, 1974; Williams et al., 1989a, b). Although some studies have demonstrated that these veins are tributaries from the posterior area of the inferior vena cava and, eventually, of the left renal vein, the exact arrangement of these veins -especially in relation to the renal vein- has not been described in a precise way (Anson, 1948; Anson and Kurth, 1955; Davis, 1958; Monkhouse and Khalique, 1986). These findings are generally based on dissections of cadavers and radiological examinations involving a small number of specimens.

Our study carefully analyzed the critical area for iatrogenic lesions of the lumbar veins during the intraoperative manipulation of the renal veins, basing ourselves on the distance from the lumbar veins to the renal veins through cadaver dissections and imaging examinations. As a consequence, we propose predictive indications for identifying those veins found in the potential risk area for iatrogenic lesions.

MATERIALS AND METHODS

Adult human cadavers preserved in a 5% formaldehyde solution and contrast enhanced images of CT and MR scans were selected. The cadavers were randomly obtained from the anatomy laboratory of the Faculty of Medicine at the Estácio de Sá University (Rio de Janeiro, Brazil) after study approval from the institutional Research and Ethics Committee. Epidemiological data for each cadaver from the respective death certificates were obtained.

The imaging examinations were obtained via a random, computerized selection using the archive of the Radiology Department of the Servidores do Estado Federal Hospital (Rio de Janeiro, Brazil) of examinations performed from January to July 2015. The images from computed tomography (CT) and magnetic resonance (MR) scans were analyzed by OsiriX MD™ (Pixmeo, Geneva-Switzerland) workstation performing with 1.25 collimation/1mm reconstruction, and 1mm width, in the arterial and venous phases with a fixed scan delay of 30 and 70 seconds.

Cadavers and radiological examinations from patients with retroperitoneal or macroscopic peritoneal changes, such as aneurisms and tumors, and those with a history of any kind of abdominal surgery, either on the death certificate (cadavers) or on the clinical docket (radiological examinations) were excluded.

An experienced radiologist was invited to analyze the CT and MR images. These examinations measured the distances from the upper edge of the first lumbar vein, right and left, to the lower edge of the right and left renal veins, respectively. The distance was obtained by adding up the number of tomographic slices between the limits of the vascular structures noted above. The diameter of the renal veins, bilaterally, and of the inferior vena cava were calculated in the same way.

The cadavers were dissected through a xyphopubic median incision, in the subcostal and bilateral inguinal section. Next, the abdominal wall was pulled back, with visualization and lateral removal of the abdominal organs to allow for visualization of the inferior vena cava. Once identified, a dissection of the renal and lumbar veins was conducted. Anatomical specimens dissected were photographed using a high-resolution digital camera. The Image Pro PlusÔ software, version 4.5, from Media CyberneticsÔ (Bethesda, MD, USA) was used for the analysis of the distance between the upper edge of the right first lumbar vein and the lower edge of the right renal vein, as well as the distance between the upper edge of the left first lumbar vein and the lower edge of the left renal vein (Fig. 1), and also the diameter of the renal veins and the inferior vena cava. Each measurement was carried out 3 times and the average among these measures was adopted by us.

Next, a correlation of the distances between the first lumbar veins and the corresponding renal veins was obtained, as well as the diameter of the renal veins and the inferior vena cava.

The statistical analysis was performed using a commercially available data analysis program, GraphPad PrismÔ, version 5 (La Jolla, CA, USA), applying the Kolmogorv-Smirnov´s test for the analysis of normality. For data with a Gaussian distribution, a comparative inter-group evaluation using Student's t-test was used. For data with a non-Gaussian distribution, the Mann Whitney test was used, adopting the standard significance value of $p < 0.05$.

RESULTS

We analyzed 205 specimens, 15 from cadavers and 190 from imaging examinations, divided into 120 computed tomography images and 70 magnetic resonance images of the abdomen. In terms of gender, 90 examinations and 5 cadavers from women and 100 examinations and 10 cadavers from men were obtained.

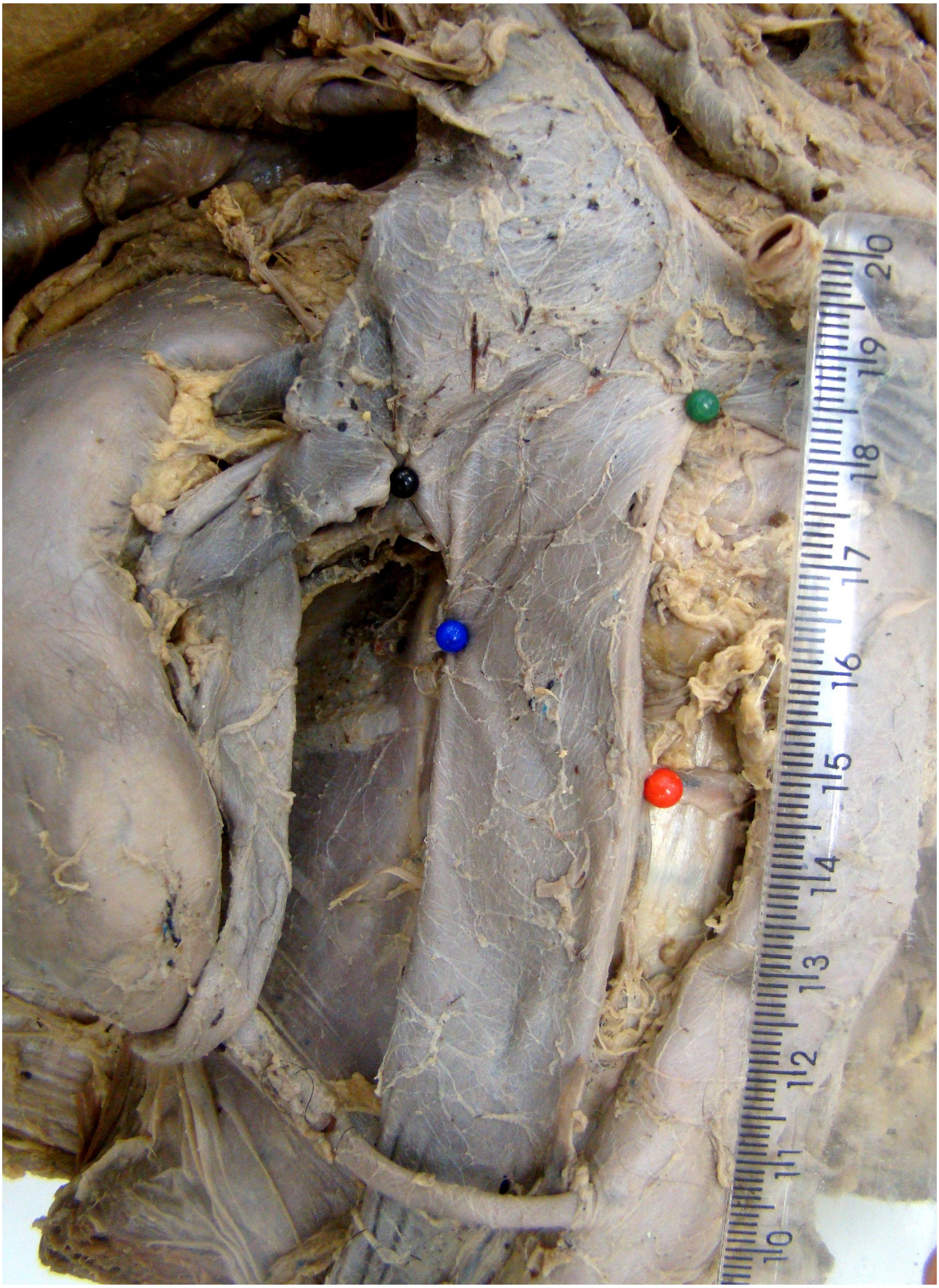

Fig 1. Digital picture of one cadaver with the inferior vena cava exposed. We measured the distance between the upper edge of the right first lumbar vein (blue pin) and the lower edge of the right renal vein (black pin), as well as the distance between the upper edge of the left first lumbar vein (red pin) and the lower edge of the left renal vein (green pin).

Table 1 shows the distances between the right and left first lumbar veins and their respective renal veins. In table 2, the distances are divided into groups, stratified by the risk of intraoperative iatrogenic lesion.

The correlation between the size of the renal veins and the first lumbar vein-renal vein distance found a statistically significant difference, as table 3 shows (p=0.02). There was no statistically significant correlation between the distance from the right first lumbar vein to the ipsilateral renal vein and the diameter of the right renal (p=0.054). Similarly, there was no statistically significant correlation between the distance from the first lumbar vein to the ipsilateral renal vein and the diameter of the inferior vena cava, either on the right side (p=0.33) or on the left side (p=0.30).

DISCUSSION

As they are located in a particular place, on the posterior side of the inferior vena cava, and near the renal veins, lumbar veins can be inadvertently damaged during surgeries in this area, be they conventional surgeries or videolaparoscopic ones (Leventhal et al., 2004). Our study focused on locating the first lumbar veins, since these are the ones most exposed to iatrogenic lesion during surgical manipulation of the kidneys and the inferior vena cava, in order to develop a way to predict the veins at greatest risk.

Descriptive anatomy of the lumbar veins and their variations

General surgery, surgical oncology, liver transplantation and urology texts (Woodeburne and Burkel, 1988; Standing, 2005; Gaujoux et al., 2006) describe lumbar veins, four in number on each side, collecting the blood by dorsal tributaries from the muscles and integument of the loins, and by abdominal tributaries from the walls of the abdomen, where they communicate with the epigastric veins. At the vertebral column, they receive veins from the vertebral plexuses, and then pass forward, around the sides of the bodies of the vertebrae beneath the psoas major muscle, and end in the back part of the inferior cava. The lumbar veins connect to the azygos and hemiazygos venous systems, ultimately draining into the superior vena cava (Standring, 2005).

Interest in anatomical variations in the location of the lumbar veins has increased in recent years, especially with the development of new technologies in the area of urology, such as videolaparos-

Table 1. Minimum, maximum, and average distances from the upper edge of the right and left 1st lumbar veins to the lower edge of the right and left renal veins, respectively.

	Average (mm)	Minimum (mm)	Maximum (mm)	p
Right first lumbar vein-right renal vein distance	35	3	80	
Left first lumbar vein-left renal vein distance	38	zero (lumbar vein flowing directly into the renal vein found in only one specimen)	81	<0.0001

Table 2. Distances from the right and left first lumbar veins to the respective renal veins, grouped according to the risk of intraoperative iatrogenic lesion, considering their proximity to each other.

	AREA OF HIGHEST RISK FOR INTRAOPERATIVE LESION (lumbar vein flowing into the renal vein or up to 10 mm away from the ipsilateral renal vein)	**AREA OF HIGH RISK FOR INTRAOPERATIVE LESION** (lumbar vein between 11 and 20 mm away from the ipsilateral renal vein)	**AREA OF MODERATE RISK FOR INTRAOPERATIVE LESION** (lumbar vein between 21 and 40 mm away from the ipsilateral renal vein)	**AREA OF LOW RISK FOR INTRAOPERATIVE LESION** (lumbar vein more than 40 mm away from ipsilateral renal vein)
Number of specimens found on the right	13 (7%)	27 (13%)	96 (46%)	69 (34%)
Number of specimens found on the left	9 (5%)	25 (12%)	86 (42%)	85 (41%)

copy and robot-assisted videolaparoscopy, in an effort to avoid intraoperative hemorrhage of an unknown origin. Abbasi et al. (2012) dissected 49 cadavers and described the existence of atypical lumbar veins in the renal supra-hilal area, above the renal veins, characterizing the area as a potential focus of hemorrhage by an inadvertent lesion during surgical resection of kidney tumors, with thrombosis in the interior of the inferior vena cava.

Another anatomical variation that may function as a hidden focus for intraoperative hemorrhage is the presence of the lumbar vein as a direct tributary of the renal vein. A study based on the dissection of 102 cadavers found the presence of this variation in approximately 40% of the specimens, on the left side (Baniel et al., 1996). Our study, however, verified only one person with this condition (0.5%), also on the left side.

Raheem et al. (2008) evaluated the specific area where the left first lumbar vein flows into the ipsilateral renal vein, in a study of 21 cadavers. This group's findings demonstrated that in the majority of the cases, the drainage point of the left lumbar tributary was halfway between the left adrenal vein and left gonadal vein. This further emphasizes the importance of dividing the left renal vein near its inferior vena cava juncture, and occasionally even over the abdominal aorta, particularly in juxtarenal abdominal aortic aneurism repair operations. Baniel et al. (1995), evaluated the prevalence of lumbar veins in the posterior area of the inferior vena cava during retroperitoneal lymphadenectomy surgeries on 102 patients. They verified that the first lumbar vein -the target of our study- is present in 93% of cases on the left side and in 73% of the cases on the right side. These authors proposed 7 different types of arrangement for these veins, in relation to the renal veins, after evaluating 61 cases of retroperitoneoscopic left living donor nephrectomy.

However, no specific descriptions for the distance between the first lumbar veins and the ipsilateral renal veins were found. For this reason, we believe that the results of this research will complement the findings mentioned above by facilitating the triangulation needed to locate these veins during surgeries in which it is necessary to manipulate the structures of the renal hilum.

Viability of tomographic evaluation of the lumbar veins in everyday urology

This study is primarily based on CT examinations. We noticed that because of the quality of the image generated -inherent to this examination- and the ability to obtain narrow sections, the lumbar and renal veins were easily identified, allowing for the measurement of the distance between them, as well as the diameter of the renal vessels.

Our proposal to use computed tomography as an instrument to predict the area of greatest risk for iatrogenic lesions does not add any cost to or require any changes in the routine diagnosis of a patient who will undergo kidney surgery. In the diagnostic investigation of kidney tumors (Motzer et al., 2015), including those with invasion of the inferior vena cava (Woodruff et al., 2013), tomography is considered the gold-standard examination. As well as its standard use to detect kidney masses, tomography can also predict the existence of veins and arteries that can pose a danger during surgical action in patients who are candidates for kidney transplants, both as donors and recipients (Lewis et al., 2004; Schlunt et al., 2006).

Predicting the existence of risk areas for iatrogenic vascular lesion: an embryological hypothesis

Not only are they uncommon, but damage to the lumbar veins during surgery can also be catastrophic, providing a rationale for studies that attempt to map the distribution of these vessels. Our analysis sought to verify whether an evaluation of the diameter of the regional vessels might be related to the detection of those lumbar veins most exposed to inadvertent lesion, precisely because they are extremely close to the renal veins.

In analyzing the left side, our findings show that the larger the size of the left renal vein, the more distant the first lumbar vein is located in relation to this vessel, which certainly makes a surgical approach to the renal hilum more secure. We no-

Table 3. Correlation between the risk areas for intraoperative lesion of the left lumbar vein and the diameter of the left renal vein.

	AREA OF HIGHEST RISK FOR INTRAOPERATIVE LESION (lumbar vein flowing into the renal vein or up to 10 mm away from the ipsilateral renal	**AREA OF HIGH RISK FOR INTRAOPERATIVE LESION** (lumbar vein between 11 and 20 mm away from the ipsilateral renal vein)	**AREA OF LOW RISK FOR INTRAOPERATIVE LESION** (lumbar vein between 21 and 40 mm away from the ipsilateral renal vein)	p
Average diameter of the left	10,1 mm	10,6 mm	11,6 mm	0.02

ticed that, although it was statistically significant, the difference between the average diameter of the left renal vein from a "high-risk" area (10.1 mm) and the average diameter of a low-risk area (11.6 mm) was very small (15 mm). However, since computed tomography can obtain thin slices, on a scale of millimeters, it is quite likely that it would be possible for a radiologist or urologist to evaluate this difference in diameter with relative ease.

The idea of correlation was based on the complex embryological formation of the vessels in this area. The renal venous collar is made up laterally by the paired dorsal and ventral primitive renal veins on each side, which are linked to the centrally paired ventral subcardinal and dorsal supracardinal veins, and anastomoses of these four craniocaudally oriented subcardinal-supracardinal veins. Three pairs of veins (posterior cardinal, subcardinal and supracardinal veins) appear in succession with regression of some portions and persistence of others. After completion of embryogenesis, the right renal vein is formed by the ventral limb of the primitive right renal vein. The left renal vein develops from intersubcardinal anastomosis, left supra-subcardinal anastomosis and the ventral limb of the primitive left renal vein. Dorsal intersupracardinal anastomosis regresses (Mathews et al., 1999; Srivastava et al., 2005; Eldefrawy et al., 2011).

Hypothetically, our explanation lies in the embryological segmentation of the inferior vena cava. As cited above, there is a complex of segments that gives rise to the left renal vein (supra-subcardinal anastomosis and intersubcardinal anastomosis) that is closely tied to the formation of the infrarenal segment of the vena cava (supra-subcardinal anastomosis and supracardinal vein), exactly where it flows into the lumbar veins. Perhaps, in some as yet unstudied way, there is some mechanism for the autoregulation of the left kidney's venous efflux, induced in this embryological period. Thus, a left renal vein capable of accommodating a higher volume of blood, because it is larger, in some way allows for the formation of more distant lumbar vessels and, by contrast, a renal vein with a smaller diameter induces the formation of more juxtaposed lumbar veins.

Research evaluating the cellular phenomena involved in vascular embryogenesis is still very new, and we can only develop theories about it. Nonetheless, there is already some evidence of the influence of the origin of vascular smooth muscle cells, for instance, on the predisposition to certain diseases, including regional susceptibility to atherosclerosis, vascular calcification and aortic aneurysm distribution (Cheung et al, 2012; Bargehr et al., 2016). Thus, as the embryonic cells that form the wall of the renal and lumbar veins have different origins (the supracardinal vein and the subcardinal vein), perhaps the diameter and location of these vessels are also interconnected, supporting our correlations.

Our study throws more light on a theme that is being discussed more and more widely, with the advent and evolution of the techniques used for kidney surgery: the prevention of inadvertent lesions. Our belief is that we have contributed more knowledge to the mapping of the arrangement of the lumbar veins in relation to the renal veins, proposing a way to predict the existence of a "zone of risk" for inadvertent, intraoperative vascular lesions, using for this purpose an exam commonly ordered in the preoperative investigation for the main kidney diseases for which surgery is indicated.

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