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Identification of Bleeding Sources During Removal of Inferior Vena Cava Tumor Thrombi: Multidetector Computed Tomography Study

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ABSTRACT

Objectives: The purpose of this study was to investigate the sources of bleeding from the lumen of the inferior vena cava (IVC) during removal of the tumor thrombus. We have studied the multidetector computed tomography (MDCT) anatomy of the posterior tributaries of the IVC, including variant lumbar veins and lumbar veins of the infrarenal IVC.

Materials and Methods: The retrospective study included 302 patients who underwent the bolus contrast-enhanced MDCT of the abdomen for various indications. We analyzed the anatomy of the variant lumbar veins and infrarenal IVC lumbar veins.

Results: Variant lumbar veins were detected in 50% of patients (151 out of 302). The diameter of these vessels ranged from 1 mm to 5 mm and averaged 2.5 mm. The distance from the upper edge of the right renal vein mouth to the variant vein mouth varied from 0 mm to 51 mm and averaged 13.7 mm. In 71% of cases the variant veins entered the subhepatic IVC. In 26.3% of cases it drained at the level of the upper edge of the renal vein mouths (cavarenal segment) and only in 2% of cases—to the retrohepatic IVC. Lumbar veins entered the IVC immediately next to the lower edge of the right renal vein mouth in 35 (11.6%) cases. Their average diameter was 4.7 mm. On the left side of the "risk zone" the lumbar veins drained only in 2 (0.7%) patients at a distance of 7 mm and 8 mm from the mouth of the left renal vein.

Conclusion: The variant lumbar veins rarely are the main source of bleeding during thrombectomy. From our point of view, the right upper lumbar veins of the infrarenal IVC draining into the inferior vena cava in close proximity to the mouths of the renal veins played the leading role in this matter.

INTRODUCTION

Modern surgical approaches to removal of tumor intravenous thrombi of the inferior vena cava (IVC) are based on the technique of vascular isolation, which prevents pulmonary embolism with tumor masses and reduces the risk of excessive bleeding from the lumen of the vein. This method involves applying clamps on the IVC above and below the thrombus, as well as on the contralateral renal vein (3 tourniquets technique) [1-3] (Figure 1). With “high” tumor extension, a Pringle’s maneuver is used to stop hepatic blood flow. However, in some situations, with the use of classical vascular isolation during cavatomy, there is active discharge of blood from the lumen of the vena cava. This is due to blood inflow to the operation site from the other tributaries, which in most cases are lumbar veins [4,5].

KEYWORDS: Inferior vena cava, lumbar veins, variant lumbar vein, tumor thrombus, source of bleeding, MDCT

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Figure 1. Vascular isolation of the subhepatic IVC segment with the tumor thrombus.

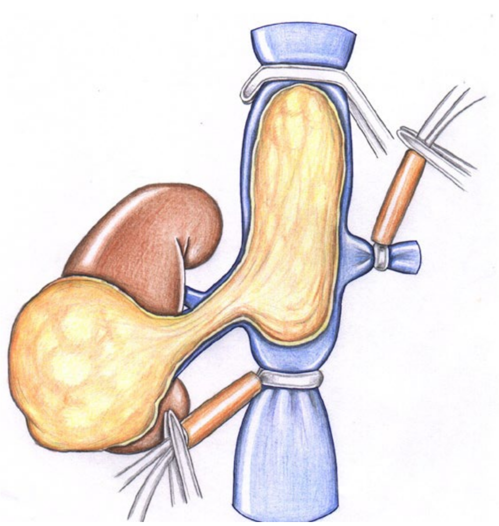
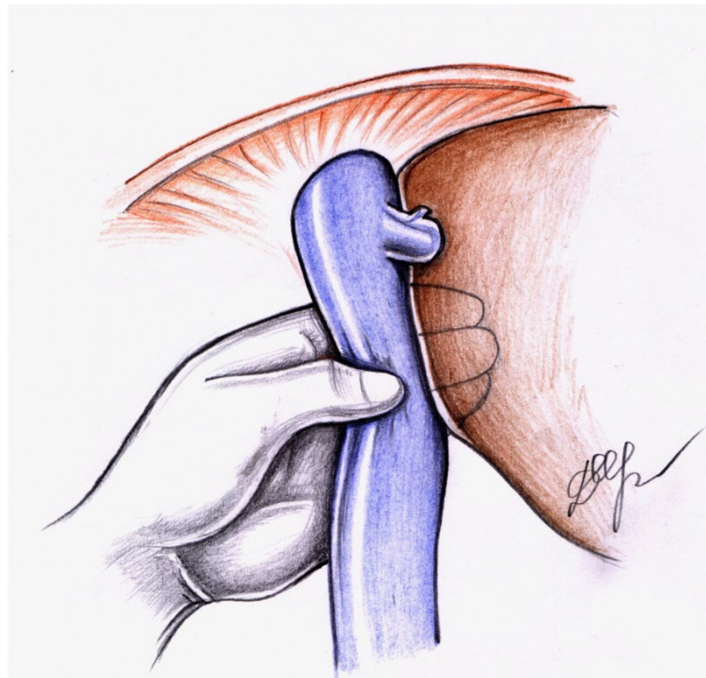


Figure 2. Mobilization of the posterior surface of the retrohepatic IVC before thrombectomy.



Incomplete vascular control can cause significant hemorrhage, which not only makes it difficult to view the internal surface of the IVC and prevents radical removal of the tumor, but is also accompanied by large blood loss.

A detailed study of surgical anatomy of the lumbar veins is presented in the paper by Baniel et al. [6]. At the same time there is significant variation in the number and topography of these vessels. However, this work is focused on the anatomy of infrarenal lumbar veins and the problems associated with retroperitoneal lymphadenectomy, but not vena cava thrombectomy.

Recently a group of American researchers examining 49 corpses for the first time has discovered an unpaired lumbar vein opening into the retrohepatic IVC in 38.8% of cases [7]. This anatomical feature was prevalent in men. The authors called this vessel the variant lumbar vein. The mean diameter of the mouth of the variant lumbar vein was 3.7 mm, and the mean distance from the mouth of the variant lumbar vein to the mouth of the right renal vein was 7.4 cm. In most cases the mouth of the vein was located between the 6 and 7 o'clock positions. The authors believe that it is the variant lumbar vessel that is the major cause of bleeding from the isolated area during IVC thrombectomy. Retrospective evaluation of our own experience of surgery on the inferior vena cava during radical nephrectomy demonstrated that bleeding from the lumen of the IVC occurred with the same frequency during removal of both retrohepatic and subhepatic tumor thrombi. In our clinical practice we apply the technique of thrombectomy described by Ciancio et al., which comprises "piggyback" mobilization of the liver and digital displacement of the thrombus below the mouths of the major hepatic veins [8-10]. In this case the use of posterior retrohepatic inferior vena cava mobilization is always required (Figure 2). However, during the operations we did not encounter large lumbar vessels in the area.

From our point of view, most frequently the main sources of hemorrhage were lumbar veins draining into the cavarenal or subrenal segment of the IVC (within 1.0 cm below the mouth of the renal veins). This assumption is also supported by frequent detection of large lumbar veins draining into the IVC just below its cavarenal segment during computed tomography (CT) scanning.

Considering these facts, in order to support the presented hypothesis, we performed MDCT examination of the anatomy of tributaries of the infrarenal, cavarenal, and subhepatic IVC segments, as well as nonhepatic tributaries of retrohepatic vena cava, including variant lumbar veins.

MATERIALS AND METHODS

The retrospective study included 302 patients who were examined and treated in the hospital of V. I. Shapoval Regional Clinical Center of Urology and Nephrology in the city of Kharkov. Patients underwent MDCT for various indications. The study was approved by the local ethics committee for V. I. Shapoval Regional Clinical Center of Urology and Nephrology (Protocol No. 3 dated May 17, 2012).

Patients with tumor thrombi of the inferior vena cava, as well as those who had undergone surgery, including retroperitoneal lymphadenectomy or vena cava thrombectomy, were not included in the study.

Among 302 patients there were 104 (34.4%) women and 198 (65.6%) men. Their average age was 57.5 (18 to 85 years). MDCT was performed using a CT scanner (Toshiba Aquilion S16, model TSX-101A, Japan). The examinations were performed with a section thickness of 1 mm, tube rotation time of 0.5s, voltage of 120V, and an electric current of 400 mA. As a contrast medium, 100 mL of a nonionic contrast agent (ultravist 300, 370 and tomogexol 300, 350) via the venous cubital catheter with the automatic bolus injector was administered at the rate of 3.0 to 3.5 mL using SureStart and with further multiplanar and 3-dimensional reconstructions.

The study protocol included the arterial (20 to 25s after administration of the contrast agent), venous (50 to 70s), and delayed (5 to 7 minute) phases. All received data was analyzed by 1 radiologist.

The venous vessels that drained along the posterior IVC at the level of its retrohepatic, subhepatic and cavarenal segments and which were neither adrenal nor lower diaphragmatic veins, were classified as the variant lumbar veins.

RESULTS

Variant Lumbar Veins

Variant lumbar veins were detected in 50% (151 of 302) of patients. The diameter of these vessels ranged from 1 mm to 5 mm and averaged 2.5 mm. In 85.4% of cases this parameter was not more than 3 mm (Table 1).

The distance from the upper edge of the right renal vein mouth to the mouth of the variant vein varied from 0 mm to 51 mm and averaged 13.7 mm (Table 2). In 40 (26.3%) cases the variant vein ran into the IVC at the level of the upper edge of the mouth of the renal veins (cavarenal segment); in 3 (2.0%) cases the variant vein ran into the retrohepatic IVC segment; in 1 (0.7%) case it was connected to the upper right lumbar vein of the infrarenal IVC (Figure 3).

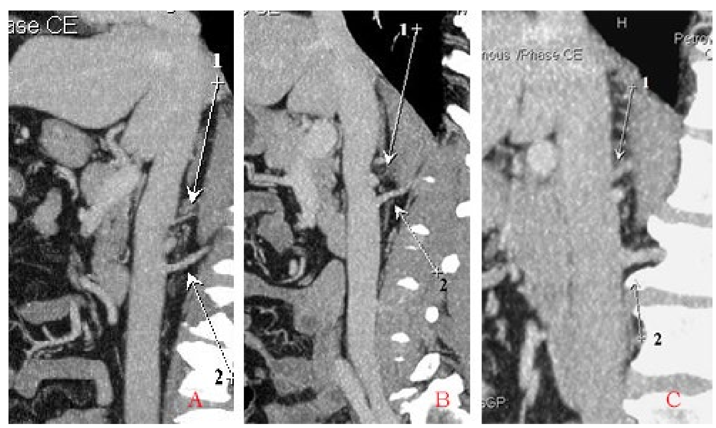
Table 1. Characteristics of the diameter of the variant lumbar veins.

Vein diameter	≤ 2 mm	> 2 mm ≤ 3 mm	> 3 mm ≤ 4 mm	> 4 mm
n/%	90/59.6	39/25.8	17/11.3	5/3.3

Table 2. Localization characteristics of the variant lumbar vein.

The distance from the mouth of the right renal vein to the mouth of the variant vein	0 to 10 mm	11 to 20 mm	21 to 30 mm	31 to 40 mm	41 to 51 mm	Total
n/%	75/49.7	34/22.5	27/17.9	10/6.6	5/3.3	151/100

Figure 3. MDCT of the variant lumbar veins: a, b, c) sagittal reconstruction. The variant veins opening into the subhepatic IVC (arrow 1) and the upper lumbar vein of the infrarenal IVC (arrow 2) are visualized.



The variant vein mouths opened into the IVC most commonly at the 4 to 5 o'clock position (Table 3).

Lumbar Veins of the Infrarenal IVC

In the infrarenal part of the inferior vena cava the lumbar veins were most often detected on the right side (833 vs. 633). On average, 2.8 veins were found on the right, and 2.2 veins were

Table 3. Localization characteristics of the variant lumbar vein using conventional zones in clockwise order.

Localization characteristics of the variant lumbar vein mouths with the use of conventional zones in clockwise order	2 o'clock	3 o'clock	4 o'clock	5 o'clock	6 o'clock	7 o'clock	Total
n/%	1/0.7	15/9.9	58/38.4	60/39.8	15/9.9	2/1.3	151/100

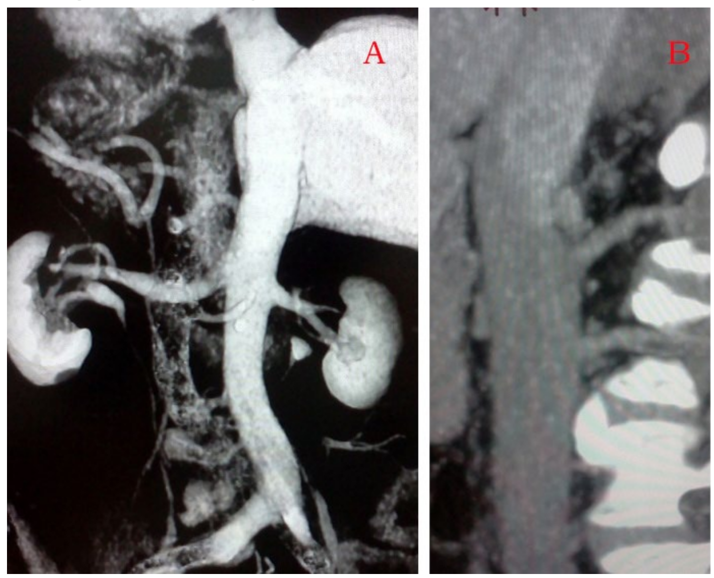
Table 4. Detailed distribution of the lumbar veins depending on their number and location.

Number of veins	1	2	3	4	5	Total
On the right	11 (3.6%)	109 (36.1%)	133 (44%)	40 (13.3%)	9 (3%)	302 (100%)
On the left	56 (18.5%)	157 (52%)	73 (24.2%)	14 (4.6%)	2 (0.7%)	302 (100%)

Table 5. Characteristics of the upper lumbar veins of the infrarenal IVC.

	All the upper right lumbar veins	All the upper left lumbar veins	Upper right lumbar veins of the "risk zone"	Upper left lumbar veins of the "risk zone"
The average diameter of the mouth	3.7 mm (1 to 10 mm)	2.7 mm	4 mm (2 to 8 mm)	3 mm (2 to 4 mm)
The distance from the mouth of the ipsilateral renal vein to the mouth of the lumbar vein	17.2 mm (0 to 98 mm)	53.0 mm (7 to 115 mm)	4,3 mm (0 to 10 mm)	7.5 mm (7 to 8 mm)
Localization of the lumbar vein mouth with the use of conventional zones in clockwise order	5.2 o'clock	3.9 o'clock	5.2 o'clock	3.5 o'clock

Figure 4. MDCT of the upper lumbar veins entering the "risk zone". a) Coronal reconstruction of the IVC (the rear view). The right upper lumbar vein flowing into the IVC at the level of the lower edge of the renal vein mouths is visualized. b) Sagittal reconstructions show the large upper lumbar veins draining into the IVC at the level of the right renal artery.



found on the left. The detailed distribution of the lumbar veins, depending on their amount, is presented in Table 4.

The mean diameter of all lumbar veins on the right did not exceed 3 mm, and on the left did not exceed 2.5 mm. The mean distance from the right renal vein to the first right lumbar vein reached 17.2 mm, and from the left renal vein to the first lumbar vein on the left was 53 mm.

Considering the problem of hemorrhage from the lumbar veins during thrombectomy, we have identified a conditional "risk zone" where the upper lumbar veins flow into the area of vascular isolation of a thrombus. This "risk zone" included an IVC portion of 10 mm long below the mouth of the ipsilateral renal vein. Therefore, the study assessed such parameters as the size and location of the lumbar vein mouths closest to the cavarenal segment of the IVC.

Drainage of the right side lumbar veins in the "risk zone" was identified in 116 (38.4%) patients. (Table 5). The lumbar veins ran into the IVC immediately next to the lower edge of the right renal vein mouth in 35 (11.6 %) cases (Figure 4). Their average diameter reached 4.7 mm. On the left side of the "risk

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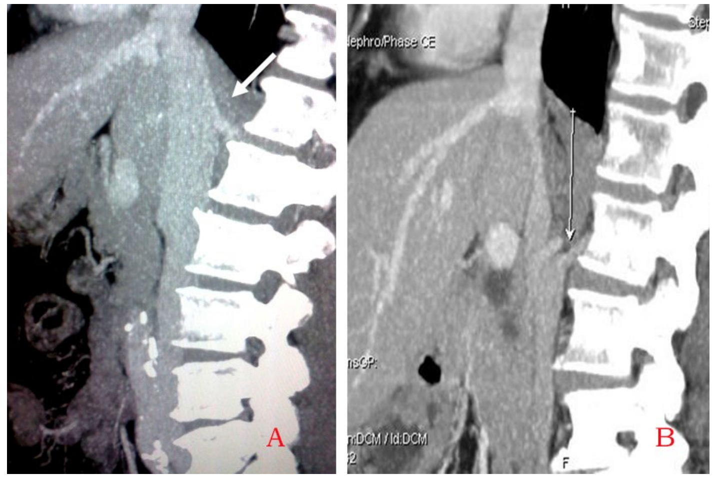
Table 6. Detailed distribution of the lumbar veins depending on their number and location.

Localization of the lumbar vein mouths of the "risk zone" with the use of conventional zones in clockwise order	2 o'clock	3 o'clock	4 o'clock	5 o'clock	6 o'clock	7 o'clock	Total
On the right	1/0.9	0	8/7	74/63.8	30/25.8	3/2.5	116/100
On the left	0	1/50	1/50	0	0	0	2/100

Figure 5. MDCT of the inferior vena cava. a, b) Sagittal reconstruction. A large variant vein draining into the retrohepatic IVC is visualized.



zone" the lumbar veins drained only in 2 (0.7%) patients at a 7 mm and 8 mm distance from the mouth of the left renal vein.

The mouths of right upper lumbar veins were more often located between the 5 and 6 o'clock positions, while on the left side they were located between the 3 and 4 o'clock positions (Table 5 and Table 6).

Fusion of infrarenal lumbar veins was found in 88 (29.1%) cases. At the same time a lot of variants of their junction were revealed (Figure 5). In most cases there was fusion of 1 pair of veins (88.7 %); in 9 (10.2%) cases it was 2 pairs; in 1 (1.1%) case there were 3 pairs. Mainly, the veins joined on the contralateral sides, but in 3 (3.4 %) patients fusion of the veins was detected on the ipsilateral side. In 4 (4.5%) cases the lumbar veins were joined with the renal veins (in 1 case there was fusion of the first right lumbar vein, the first left one, and the left renal vein). In 1 patient there was fusion of the first right lumbar vein with the variant lumbar vein.

DISCUSSION

The problem of bleeding from the lumen of the IVC during removal of the intravenous tumor thrombi is very important, as the operation can result in significant blood loss and cause problems with the examination of the endothelial surface after removal of the tumor mass. All of this ultimately can heavily deteriorate the radicality of the surgery.

Analyzing the sources of bleeding in a particular patient, it is necessary to take into account several factors, which include the degree of thrombus extension, anatomical parameters of the patient, and special aspects of thrombectomy technique.

During standard vascular isolation of the IVC thrombus, which includes placing clamps or tourniquets on the contralateral renal vein, as well as above and below the thrombus, the potential source of bleeding can be actually all venous tributaries draining into the IVC at this level (lumbar, infradiaphragmatic, and adrenal veins). The clinical significance of these vessels as sources of bleeding cannot be considered equivalent. If we consider the venous vessel mouth with the diameter of more than 3 mm as an important parameter for bleeding during thrombectomy, the lower right diaphragmatic veins can hardly be considered a source of significant blood loss. Typically, their diameter does not exceed 3 mm. However, in the presence of caval obstruction and development of collateral venous outflow, they can come to a larger diameter and be the source of bleeding during thrombectomy. In most cases the diameter of the right adrenal veins is much larger than the diameter of the lower phrenic veins; however, their importance as a source of bleeding is not high due to the low volume of blood flow in the adrenal gland. In addition, the role of the right lower phrenic and adrenal veins should be taken into account mainly during removal of the retrohepatic or "higher" thrombi.

There is no doubt that lumbar veins are the most important source of bleeding from the lumen of the IVC. Anatomical studies, including the authors' own work, demonstrate considerable variations of their number, size, and topography [6,11,12]. In particular, their mouths can be located not only in the infrarenal vena cava segment, but in the retrohepatic, subhepatic, or cavarenal segments of the IVC. Taking into account the diameter of the lumbar veins, and a relatively high intensity of blood flow (due to the association with the vertebral venous plexus), it can be stated that these vessels play the leading role in the development of bleeding from the lumen of the IVC during thrombectomy.

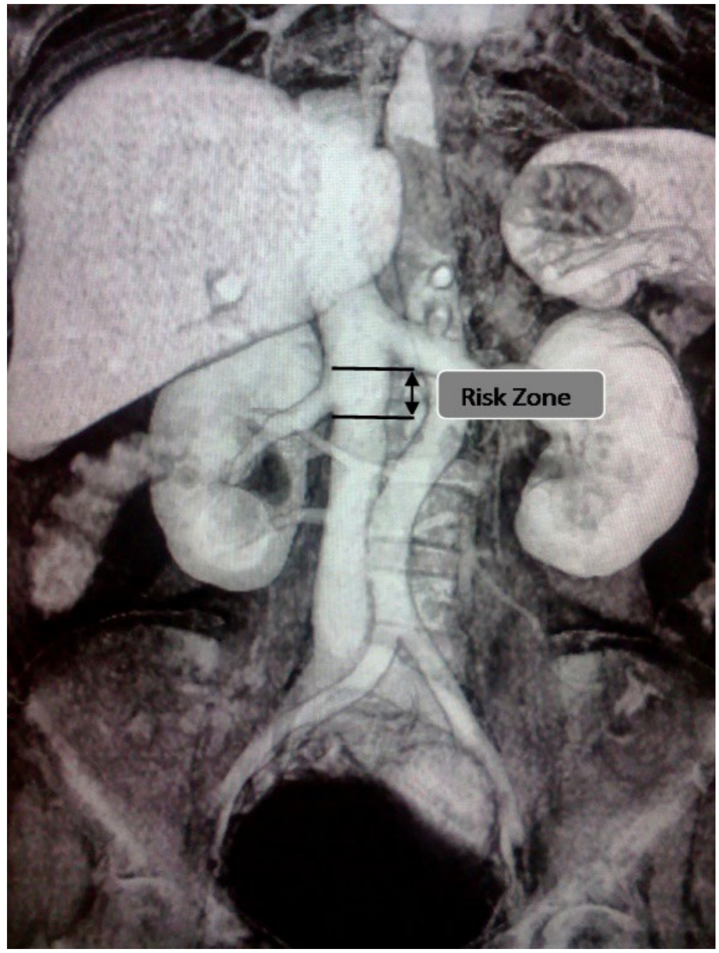
Recently Abbasi et al. have found a variant lumbar vein opening into the retrohepatic IVC [7]. These vessels were identified in 38.8% of cases in 49 observations that mainly occurred in men. The average diameter of a variant lumbar vein mouth was 3.7 mm, and the mean distance from the mouth of a variant lumbar vein to the mouth of the right renal vein was 7.4 cm. In most cases the mouth of this vein was located between the 6 and 7 o'clock positions. The authors believe that it is the variant lumbar vessel that is the major cause of bleeding from the isolated area during IVC thrombectomy.

In our investigation, the variant lumbar vein was detected in 50% of cases. In contrast to the results of Abbasi et al., draining of the variant lumbar vein into the retrohepatic IVC was found only in 3 cases (2%) [7]. In 40 (26.3 %) cases the variant vein ran into the IVC at the level of its cavarenal segment; in 1 (0.7 %) case it was connected to the upper right lumbar vein of the infrarenal IVC. In 71% of patients the variant veins drained into the subhepatic segment of the vena cava.

The distance from the mouth of the right renal vein to the mouth of the variant lumbar vein ranged from 0 mm to 51 mm and averaged 13.7 mm. Another difference between the results obtained in this study was that the average diameter of the mouth of the variant lumbar veins did not exceed 2.5 mm. Therefore, from our point of view, they are unlikely to be a significant source of bleeding during thrombectomy, except for the rare situations. These situations may include the diameter of a variant vein greater than 3 mm (7.3% of all patients) and localization of the mouth of the variant vein in the retrohepatic segment of the IVC (1% of all patients) (Figure 6).

To reduce the risk of bleeding from the lumen of the inferior vena cava, the surgeon before the operation should carefully plan the stage of vascular thrombus isolation and evaluate the anatomy of the variant lumbar vein on the basis of visual research methods; in particular, multispiral CT. On the other hand, the use of surgical technique proposed by Ciancio et al., which includes mobilization of the liver and manual displacement of the thrombus below the mouths of the major hepatic veins to remove the IVC tumor thrombus, greatly facilitates control of the lumbar veins at the level of subhepatic

Figure 6. MDCT. Frontal reconstruction. The right and left renal veins flow into the IVC at different levels.



and retrohepatic vena cava [8-10].

Analyzing the anatomy of the lumbar veins of the infrarenal segment of the inferior vena cava, one should note the apparent variability in the number of these vessels and localization of their mouths. The results of our study have demonstrated predominance of the right lumbar veins in the infrarenal IVC (2.8 vs. 2.2), although in the work by Baniel et al. the left-side lumbar veins were more frequent [6].

Taking into account that during vascular isolation of the thrombus it is not always possible to place the lower clamp immediately under the mouths of the renal veins, we performed a detailed study of the upper (first) lumbar veins that flow into the IVC closest to the renal veins, and may happen to be in the area of vascular isolation of the thrombus. At the same time, the “risk zone” where the upper lumbar veins may enter the area of thrombectomy while placing the lower clamp on the IVC was defined. The area included the IVC segment of 10 mm long below the mouth of the ipsilateral renal vein. By choosing this option we give reasons from several points of view:

In some situations the tumor thrombus extends not only in the antegrade direction, but also in the retrograde direction 5 to 7 mm downwards.

The right and the left renal veins in many cases flow into the IVC at different levels. These differences can amount up to 10 mm, so placing of a clamp under the lowest renal vein may result in the situation where the area of vascular isolation of the thrombus is entered by a lumbar vein from the contralateral side.

During placement of the upper clamp above the IVC thrombus, downward displacement of the thrombus is often performed (especially when the expansion of intraluminal tumor above the mouths of the hepatic veins takes place); therefore, the lower part of the thrombus may be displaced below the mouths of the renal veins.

During clamp placing under the mouth of the right renal vein, a “risk zone” occurs where the first lumbar vein may enter the area of vascular isolation of the thrombus. We discovered that the right upper lumbar vein drained into the “risk zone” in 38.4% of cases, and the left only in 0.7%. These differences can be explained by the fact that the upper left lumbar vein often flows not into the IVC but directly into the left renal vein. It is interesting that in 35 (11.6%) cases the lumbar veins drained directly into the IVC next to the lower edge of the right renal vein mouth. The average diameter of these vessels amounted to 4.7 mm.

The distance from the mouth of the ipsilateral renal vein to the mouth of the upper lumbar veins in the “risk zone” averaged 4.3 mm (0 to 10 mm) on the right and 7.5 mm (7 to 8) on the left. The mouths of the right lumbar veins opened in the IVC more often between the 5 and 6 o’clock positions, and the left ones between the 3 and 4 o’clock positions.

This data suggests the high prevalence of the upper lumbar veins, which may enter the area of vascular isolation of the thrombus during clamp placing 10 mm below the renal vein mouths. Taking into account that the average diameter of these vessels is more than 4 mm, it can be assumed that they are the main source of bleeding during removal of the IVC tumor thrombi.

Although control of the infrarenal IVC lumbar veins during thrombectomy is normally performed by most surgeons, it is quite difficult in some situations to complete this control since the right upper lumbar veins open into the IVC posteriorly at the 5 to 6 o’clock positions. In case of massive thrombi restricting the mobility of the vena cava and causing caval obstruction, these thin-walled veins can amount to large diameters and can be easily injured during their ligation or clamping. This maneuver is the most difficult to perform with the increased paracaval lymph nodes, as well as with large tumors expanding to the perinephric fat. In such situations we can control the upper lumbar veins after removal of the thrombus from the lumen of the inferior vena cava.

Taking into account the importance of the upper lumbar veins in the development of bleeding from the lumen of the IVC, during removal of the tumor thrombus, the surgeon must carefully examine the anatomy of these vessels before the operation with the use of multispiral CT or magnetic resonance imaging. This will enable us to plan the stage of vascular thrombus isolation properly and avoid serious complications associated with bleeding.

CONCLUSION

The results of our study have demonstrated that the variant lumbar veins occur in about 50% of patients and in most cases their mouths open in the subhepatic segment of the IVC. The average diameter of these vessels does not exceed 2.5 mm, so we believe that they are not the main source of bleeding during vena cava thrombectomy. From our point of view, the right lumbar veins of the infrarenal IVC, which flow into the inferior vena cava in the immediate proximity to the mouth of the renal veins, play the leading role in this matter. These veins have an average diameter of 4 mm and occur in 38.4% of cases. A surgeon before the operation should carefully plan the stage of vascular thrombus isolation and evaluate the anatomy of the lumbar veins with the use of the data presented with visual methods.

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