Basic Science

Clinical Anatomy and Possible Clinical Significance of the Intervertebral Vein in the Lumbar Intervertebral Foramina

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Disclaimer: This study has been supported by grants from The Science and Technology Project of Guangzhou (Grant No. 201704020033),The Science and Technology Project of Tianhe District, Guangzhou (Grant No. 201604KW012), and The Science and Technology Project of Guangdong (Grant No. 2017B020210010); and there are no potential conflict of interest-associated biases in the text of the manuscript.
Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted manuscript.

Manuscript received: 06-17-2018
Revised manuscript received: 08-04-2018
Accepted for publication: 08-13-2018

Free full manuscript: www.painphysicianjournal.com

Background: The detailed structure of the lumbar intervertebral foramina has been well-studied. Nevertheless, detailed descriptions of branches of the intervertebral vein (IV) through the lumbar intervertebral foramina are lacking.

Objectives: This study aimed to provide an anatomical basis for invasive treatment targeting the branches of the IV using an approach through the lumbar intervertebral foramina, particularly for the purposes of transforaminal epidural steroid injection.

Study Design: This research involved a dissection-based study of 10 embalmed human cadavers.

Setting: The research took place at The Third Affiliated Hospital of Southern Medical University.

Methods: One hundred lumbar intervertebral foramina from 10 embalmed cadavers were studied. Branches of the IV in the intervertebral foramina were observed. The length and diameter of the veins were measured using a Vernier caliper.

Results: At a rate of 100%, branches of the IV were observed in the 100 lumbar foramina examined in our study. The following 4 types of branches of the IV were routinely found: Type I in 27 (27%) of the IV foramina, in which a superior branch of the IV ran along the inferior margin of the vertebral pedicle; Type II in 18 (18%) of the intervertebral foramina, in which an inferior branch of the IV ran along the superior margin of the inferior vertebral pedicle; Type III in 41 (41%) of the intervertebral foramina, in which the IV was divided into a superior and inferior branch; and Type IV in 14 (14%) of the intervertebral foramina, in which the IV was divided into 2 superior branches and an inferior branch.

Limitations: The greatest weakness of this study is that it lacks actual clinical verification. Future clinical trials are expected to contribute more objective data concerning the IV branches. Due to the relative changes in vascular position during dissection, the relevant data warrant improvement.

Conclusions: The lumbar IVs are an important part of the anatomical structure of the intervertebral foramina. Adequate knowledge of the IV may be of clinical importance to physicians performing transforaminal epidural steroid injection.

Key words: Clinical anatomy, intervertebral veins, lumbar vertebra, Kambin's triangle, safe triangle, intervertebral foramina, vertebral venous system, inadvertent injection, transforaminal epidural steroid injection

Pain Physician 2019; 22:E225-E232

Transforaminal epidural steroid injection (TFESI) is currently a useful treatment method for low back pain (1-4). Kambin's triangle approach and the "safe triangle" approach (subpedicular approach) are efficacious methods of transforaminal epidural steroid injection (3,4). The "safe triangle" is defined by the pedicle superiorly, the lateral border of the vertebral body laterally, and the outer margin of the exiting nerve root medially. The Kambin's triangle is defined by the hypotenuse, base, and height. The hypotenuse is the exiting nerve root, the base is the superior border of the caudal vertebra, and the height is the dura/traversing nerve root (5). However, the approach of TFESI may sometimes cause complications resulting from direct intravascular injection or vascular injury (5-7). To prevent these complications, the detailed structure of the lumbar intervertebral foramina (LIFs) has been studied (8-11). Nevertheless, few articles have described in detail the intervertebral vein (IV) at LIFs (8-11). However, good anatomic knowledge of the IV is equally important for interventional pain physicians.

The lumbar vertebral venous system (VVS) consists of the internal vertebral venous plexus (IVVP), which is divided into the anterior and posterior plexus (AIVVP and PIVVP), the basivertebral veins, and the external vertebral venous plexus (EVVP) (12,13). Branches of the lumbar IV are considered junctions surrounding the nerve roots, which medially accept the AIVVP and PIVVP, and then are connected laterally with the ascending lumbar vein (ALV), lumbar vein (LV), or iliolumbar vein after leaving the foramina (12).

In 1997, Groen et al (13) studied the human VVS after Araldite CY 221 (a casting resin system with low initial viscosity) injection to update the morphological characteristics of the internal VVS. Chaynes et al (14) subsequently studied in detail the topography of the internal VVS in relation to the posterior longitudinal ligament and the dura. Demondion et al (12) provided a basis of knowledge regarding the anatomy of the venous plexuses in the lumbar spine, both in anatomical slices and in magnetic resonance (MR) images, to aid the analysis of these structures in MR images of living subjects. In 2012, Demondion et al (15) further surveyed the anatomy of LIFs and spinal cord vascularization. Yuan et al (8) clarified the ligament, nerve, and blood vessel anatomy of the lateral zone of LIFs. Previous researchers have focused on VVS; however, the venous structure of the LIFs where TFESIk are performed, particularly the IV branches, has rarely been described.

The aim of this study was to investigate and clarify the morphology of the IV branches in LIFs and their possible clinical significance. Detailed knowledge of the IV branches may be advantageous to increase the efficacy and decrease the incidence of TFESI complications, thus improving the safety of interventional pain treatment.

Methods

One hundred LIFs from 10 embalmed human cadavers (8 men, 2 women) without spinal surgery were studied using a surgical microscope. The age range of these cadavers at the time of death was 35 to 85 years (mean age, 50 years). Because of the small number, there was no grouping of the cadavers based on demographic characteristics such as age, gender, ethnicity, height, or weight. No specimen showed any evidence of spinal pathology.

An electric band saw was used to cut lumbar (T11-S5) spinal columns, which were separated from the T10-T11 disc and sacroiliac joint. The skin, muscle, and fascia of the posterior and bilateral aspects of the lumbar spine were removed, exposing the LIFs and the adjacent veins and nerves. The lamina around the LIFs were removed to clearly observe the veins. For all the branches, the origin, insertion, and spatial orientation of branches of the IV in the LIFs were examined. A Vernier caliper (accurate to 0.01 mm) was used to measure the diameter and length of the IV branches under the surgical microscope.

The data were measured repeatedly by the same researcher who was not blinded during the analysis. We used the average values of the repeated measurements for the statistical analysis. SPSS Version 20.0 (IBM Corporation, Armonk, NY) was used to analyze the recorded measurements. The measurement data were expressed in the form " $x \pm s$ (min–max)" .

Results

Branches of the IV were observed at a rate of 100% in the 100 LIFs in our study. Branches of the IV associated with IVVP were routinely found according to the following 4 types (Fig. 1): Type I in 27 (27%) of the 100 lumbar intervertebral foramina, in which a superior IV branch (SBIVa) ran along the inferior margin of the vertebral pedicle located at the anterior aspect of the nerve root and joined the IVVP (Figs. 1 and 2); Type II in 18 (18%) of the 100 lumbar intervertebral foramina, in which an inferior IV branch (IBIV) that ran along the superior margin of the inferior vertebral pedicle joined

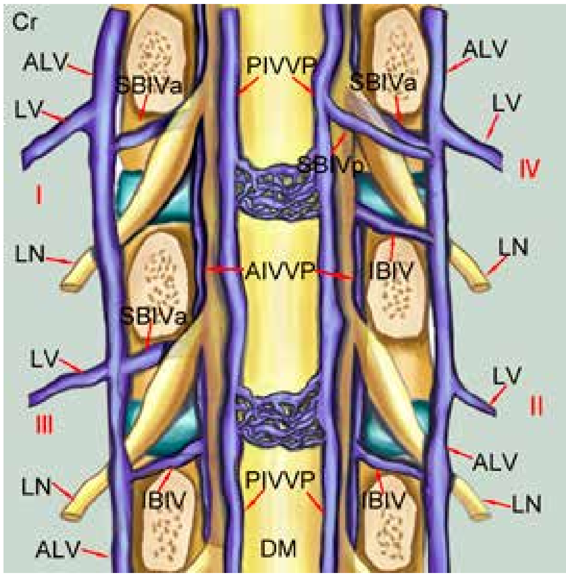

Fig. 1. *The simulated diagram of branches of the lumbar intervertebral vein for four types I, II, III and IV of the red numbers represent four types of the intervertebral vein in foramen intervertebral foramen: Type 1, Type 2, Type 3, and Type 4.*
Cr: cranial; LV: lumbar vein ; ALV: ascending lumbar vein; SBIVa: superior branch of the IV runs along the inferior margin of the vertebral pedicle, located at the anterior aspect of the nerve root; SBIVp: superior branch of IVs runs along the inferior margin of the vertebral pedicle, located at the posterior aspect of the nerve root ; IBIV: inferior branch of the IV runs along the superior margin of the inferior vertebral pedicle; AIVVP: the anterolateral longitudinal vein, which was part of the anterior internal vertebral venous plexus; PIVVP: the anterolateral longitudinal vein, which was part of the posterior internal vertebral venous plexus; LN: the lumbar nerve root; DM: dura mater.

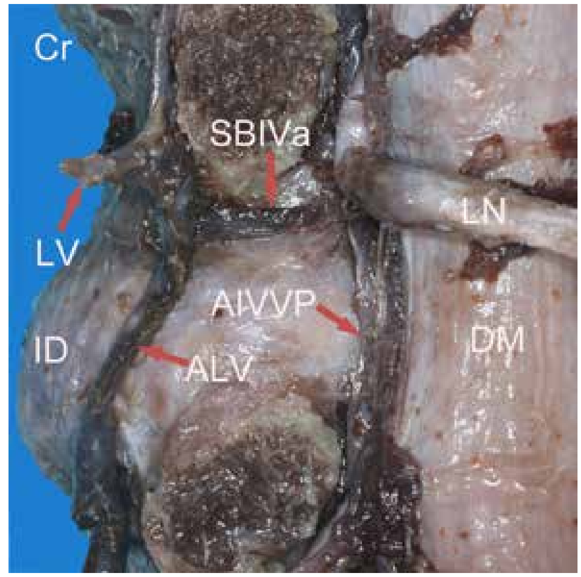

Fig. 2. *Type* I *anatomical diagram of the intervertebral veins through LIFs.*
Cr:cranial; LV: lumbar vein; ALV: ascending lumbar vein; SBIVa: superior branch of the IV runs along the inferior margin of the vertebral pedicle, located at the anterior aspect of the nerve root; AIVVP: the anterior internal vertebral venous plexus; LN: the lumbar nerve root; DM: dura mater; ID: intervertebral disc.

the IVVP (Figs. 1 and 3); Type III in 41 (41%) of the 100 lumbar intervertebral foramina, in which the IV was divided into a superior branch (SBIVa), located at the anterior aspect of the nerve root, and an inferior branch (IBIV), which respectively ran along the inferior margin of the vertebral pedicle and the superior margin of the inferior vertebral pedicle (Figs. 1 and 4); and Type IV in 14 (14%) of the 100 lumbar intervertebral foramina, in which the IV was divided into 2 superior branches, located separately at the anterior aspect (SBIVa) and posterior aspect (SBIVp) of the nerve root, and an inferior branch, which respectively ran along the inferior margin of the vertebral pedicle and the superior margin of the inferior vertebral pedicle (Figs. 1 and 5). The measurements of branches of the IV for 4 types at each level are presented in Table 1.

One hundred and sixty-nine branches of the IV were found in 100 LIFs. The diameter of branches of the IV was 2.12 ± 0.60 mm (range, 0.70-4.08 mm). At the lumbar level, the IVVP drains into the EVVP via the LIFs, where branches of the IV distance were 12.54 ± 5.23 mm (range, 4.85-28.76 mm). Branches of the IV were connected medially with the anterolateral longitudinal vein, which was part of the AIVVP, and with the PIVVP; and laterally with the ALV, LV, or iliolumbar vein after leaving the foramina (Figs. 1 and 5).

In this study, we observed that 138 (81.66%) branches of the IV were connected to the AIVVP via the anterolateral longitudinal vein (Figs. 3, 4, and 5), and 31 (18.34%) branches of the IV were connected to the PIVVP in 100 LIFs (Figs. 4 and 5). Only 8 Kambin's triangles lacked any veins and 96 branches of the IV existed in the "safe triangle" of the 100 lumbar intervertebral foramina in our study (Fig. 3). The measurements of branches of the IV at each level are presented in Table 2.

Discussion

The anatomy of the vertebral venous system has been studied in detail (8,12-14,16,17). Chaynes et al (14)

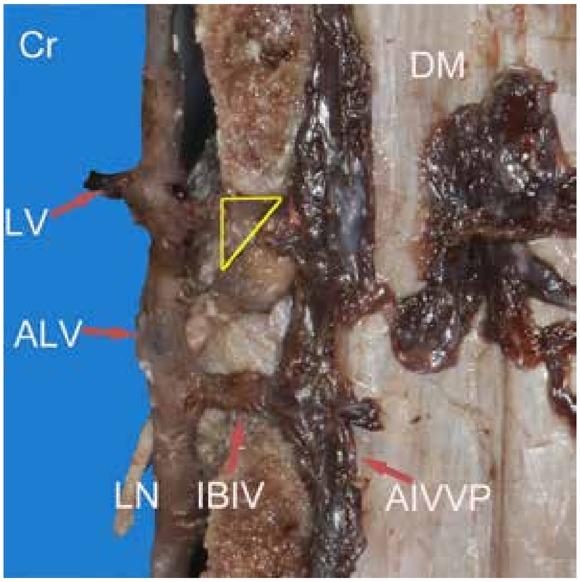

Fig. 3. *Type II anatomical diagram of the intervertebral veins through LIFs.*
Cr: cranial; LV: lumbar vein; ALV: ascending lumbar vein; IBIV: inferior branch of the IV runs along the superior margin of the inferior vertebral pedicle; AIVVP: the anterior internal vertebral venous plexus; LN: the lumbar nerve root; DM: dura mater; yellow triangle: "safe triangle".

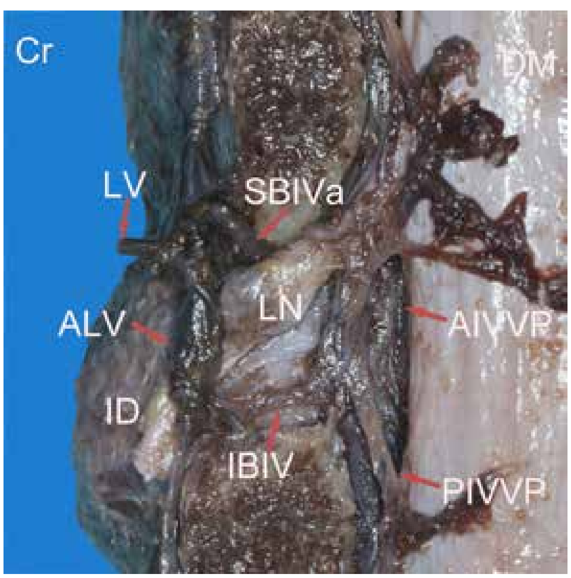

Fig. 4. *Type III anatomical diagram of the intervertebral veins through LIFs.*
Cr: cranial; LV: lumbar vein; ALV: ascending lumbar vein; SBIVa: superior branch of the IV runs along the inferior margin of the vertebral pedicle, located at the anterior aspect of the nerve root; IBIV: inferior branch of the IV runs along the superior margin of the inferior vertebral pedicle; AIVVP: the anterior internal vertebral venous plexus; PIVVP: the posterior internal vertebral venous plexus; LN: the lumbar nerve root; DM: dura mater; ID: intervertebral disc.

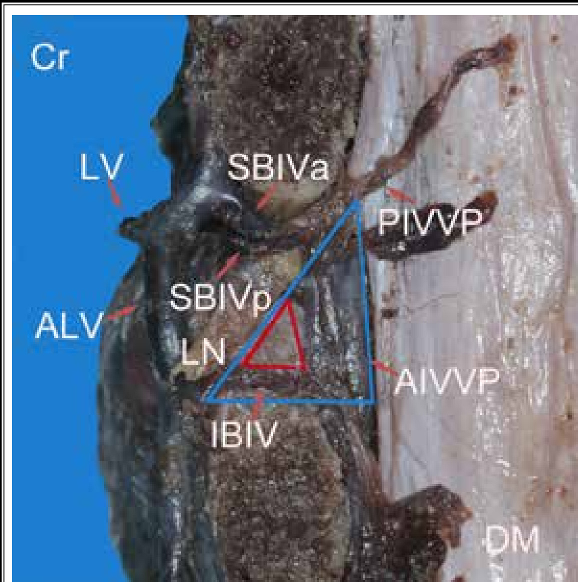

Fig. 5. *Type IV anatomical diagram of the intervertebral veins through LIFs.*
Cr: cranial; LV: lumbar vein; ALV: ascending lumbar vein; SBIVa: superior branch of the IV runs along the inferior margin of the vertebral pedicle, located at the anterior aspect of the nerve root; SBIVp: superior branch of the IV runs along the inferior margin of the vertebral pedicle, located at the posterior aspect of the nerve root; IBIV: inferior branch of the IV runs along the superior margin of the inferior vertebral pedicle; AIVVP: the anterior internal vertebral venous plexus; PIVVP: the posterior internal vertebral venous plexus; LN: the lumbar nerve root; DM: dura mater; blue triangle: Kambin's triangle; red triangle: a relatively safe injection area.

descriptively clarified the morphology of the IVVP and concluded that the 2 IV branches were separate. The superior branch of the IV was located in the superior part of the foramen while the inferior branch of the IV was located in its inferior part via the wide intervertebral foramen at the lumbar level. With the aid of MR technology, Demondion et al (12) analyzed the number and localization of the IV branches in the sagittal plane and demonstrated that 2 to 3 veins ventrally and smaller individualized veins dorsally were located at the upper part of the intervertebral foramen, and one or more veins were located at the inferior part of the intervertebral foramen; moreover, they observed that branches of the IV were connected medially with the anterolateral longitudinal vein and the IVVP and laterally with the ALV. Yuan et al (8) observed that branches of the IV, whether joining the ALV or LV, were divided into a superior branch, which ran upward from the superior transforaminal ligament, and an inferior branch,

Table 1. *The measurements of branches of the intervertebral vein for four types "$\bar{x} \pm s$ (minimum-maximum)"*

Vertebral Segments	Number	Type	SBIVa		SBIVp		IBIV	
			D	L	D	L	D	L
L1-L2	7	I	2.35 ± 0.36 (1.64-2.75)	6.36 ± 1.77 (4.85-9.68)	-	-	-	-
	3	II	-	-	-	-	2.03 ± 0.11 (1.91-2.12)	8.74 ± 2.35 (6.45-11.14)
	7	III	2.27 ± 0.25 (2.01-2.66)	7.49 ± 1.09 (5.37-8.74)	-	-	1.94 ± 0.25 (1.57-2.31)	7.72 ± 1.07 (6.01-9.04)
	3	IV	2.70 ± 0.68 (2.23-3.48)	8.05 ± 2.32 (6.16-10.64)	0.92 ± 0.19 (0.70-1.04)	8.29 ± 1.11 (7.32-9.50)	2.50 ± 0.87 (1.68-3.42)	8.86 ± 2.16 (7.44-11.34)
L2-L3	5	I	2.45 ± 0.18 (2.25-2.73)	10.64 ± 1.01 (9.79-12.34)	-	-	-	-
	3	II	-	-	-	-	2.21 ± 0.28 (1.89-2.42)	8.98 ± 0.71 (8.21-9.62)
	8	III	2.36 ± 0.78 (1.43-4.08)	10.35 ± 0.88 (9.38-11.89)	-	-	1.90 ± 0.74 (0.83-2.87)	10.12 ± 0.58 (9.6-11.46)
	4	IV	2.35 ± 0.22 (2.17-2.67)	10.32 ± 0.67 (9.64-11.25)	0.91 ± 0.09 (0.80-0.98)	10.10 ± 0.98 (9.01-11.02)	2.12 ± 0.32 (1.80-2.54)	10.54 ± 0.70 (9.92-11.54)
L3-L4	7	I	2.59 ± 0.58 (1.78-3.64)	11.29 ± 1.58 (8.30-13.20)	-	-	-	-
	4	II	-	-	-	-	2.10 ± 0.09 (1.96-2.15)	11.06 ± 0.73 (10.45-12.03)
	7	III	2.39 ± 0.40 (1.98-3.10)	11.14 ± 0.52 (10.54-11.84)	-	-	1.85 ± 0.30 (1.36-2.21)	10.99 ± 0.62 (10.20-11.86)
	2	IV	2.30 ± 0.10 (2.23-2.37)	11.59 ± 0.81 (11.02-12.16)	1.13 ± 0.14 (1.03-1.23)	11.29 ± 0.11 (11.21-11.36)	1.87 ± 0.40 (1.59-2.15)	12.28 ± 0.11 (12.20-12.36)
L4-L5	5	I	1.92 ± 0.40 (1.25-2.26)	9.87 ± 1.61 (7.72-11.66)	-	-	-	-
	4	II	-	-	-	-	2.10 ± 0.45 (1.46-2.51)	11.78 ± 0.89 (11.02-13.01)
	8	III	2.50 ± 0.68 (1.55-3.49)	11.78 ± 1.28 (10.24-13.63)	-	-	1.84 ± 0.59 (1.17-2.59)	11.86 ± 1.24 (10.02-13.46)
	3	IV	2.50 ± 0.23 (2.25-2.70)	11.99 ± 0.69 (11.23-12.59)	1.01 ± 0.19 (0.83-1.21)	11.70 ± 0.59 (11.20-12.35)	2.20 ± 0.76 (1.32-2.66)	12.01 ± 1.01 (11.01-13.02)
L5-S1	3	I	2.28 ± 0.05 (2.25-2.34)	19.80 ± 0.29 (19.62-20.13)	-	-	-	-
	4	II	-	-	-	-	2.65 ± 0.79 (2.02-3.77)	19.01 ± 4.31 (12.63-22.07)
	11	III	2.23 ± 0.43 (1.41-2.92)	22.42 ± 3.87 (17.97-27.99)	-	-	2.12 ± 0.39 (1.32-2.60)	23.13 ± 3.88 (18.69-28.76)
	2	IV	2.27 ± 0.21 (2.12-2.41)	19.45 ± 0.81 (18.88-20.02)	0.88 ± 0.21 (0.73-1.02)	19.81 ± 0.10 (19.74-19.88)	2.32 ± 0.13 (2.23-2.41)	21.08 ± 0.85 (21.02-21.14)

The measurements of branches of the intervertebral vein for four types at L1-L5 level. Type I: the IV were divided into only a superior branch that ran along the inferior margin of the vertebral pedicle, located at the anterior aspect of the nerve root (SBIVa); Type II: the IV were divided into only an inferior branch that ran along the inferior margin of the vertebral pedicle (IBIV); Type III: the IV were divided into a superior branch that ran along the inferior margin of the vertebral pedicle, located at the anterior aspect of the nerve root (SBIVa) and an inferior branch that ran along the inferior margin of the vertebral pedicle (IBIV); Type IV: the IV were divided into a superior branch that ran along the inferior margin of the vertebral pedicle, located at the anterior aspect of the nerve root (SBIVa); a superior branch that ran along the inferior margin of the vertebral pedicle, located at the posterior aspect of the nerve root (SBIVp); and an inferior branch that ran along the inferior margin of the vertebral pedicle (IBIV); D: The diameter of the branch of the intervertebral vein; L: The length of the branch of the intervertebral vein.

Table 2. *The measurements of the branches of the intervertebral vein "$\bar{x} \pm s$ (minimum-maximum)"*

Vertebral Segment	Number	Branch	D	L
L1-L2	17	SBIVa	2.38 ± 0.39 (1.64-3.48)	7.12 ± 1.66 (4.85-10.64)
	3	SBIVp	0.92 ± 0.19 (0.70-1.04)	8.29 ± 1.11 (7.32-9.50)
	13	IBIV	2.08 ± 0.47 (1.57-3.42)	8.22 ± 1.61 (6.01-11.34)
L2-L3	17	SBIVa	2.38 ± 0.53 (1.43-4.08)	10.43 ± 0.84 (9.38-12.34)
	4	SBIVp	0.91 ± 0.09 (0.80-0.98)	10.10 ± 0.98 (9.01-11.02)
	15	IBIV	2.02 ± 0.57 (0.83-2.87)	10.00 ± 0.81 (8.21-11.54)
L3-L4	16	SBIVa	2.47 ± 0.46 (1.78-3.64)	11.26 ± 1.08 (8.30-13.20)
	2	SBIVp	1.13 ± 0.14 (1.03-1.23)	11.29 ± 0.11 (11.21-11.36)
	13	IBIV	1.93 ± 0.27 (1.36-2.21)	11.21 ± 0.74 (10.20-12.36)
L4-L5	16	SBIVa	2.32 ± 0.56 (1.25-3.49)	11.22 ± 1.55 (7.72-13.63)
	3	SBIVp	1.01 ± 0.19 (0.83-1.21)	11.70 ± 0.59 (11.20-12.35)
	15	IBIV	1.98 ± 0.57 (1.17-2.66)	11.88 ± 1.04 (10.02-13.46)
L5-S1	16	SBIVa	2.24 ± 0.36 (1.41-2.92)	21.56 ± 3.43 (17.97-27.99)
	2	SBIVp	0.88 ± 0.21 (0.73-1.02)	19.81 ± 0.10 (19.74-19.88)
	17	IBIV	2.27 ± 0.51 (1.32-3.77)	21.92 ± 4.01 (12.63-28.76)
Total	82	SBIVa	2.35 ± 0.47 (1.25-4.08)	12.23 ± 5.22 (4.85-27.99)
	14	SBIVp	0.96 ± 0.16 (0.70-1.23)	11.61 ± 3.75 (7.32-19.88)
	73	IBIV	2.07 ± 0.50 (0.83-3.77)	13.06 ± 5.48 (6.01-28.76)

The measurements of branches of the intervertebral vein at L1-L5 level. SBIVa: superior branch of the IV that ran along the inferior margin of the vertebral pedicle, located at the anterior aspect of the nerve root; SBIVp: superior branch of the IV that ran along the inferior margin of the vertebral pedicle, located at the posterior aspect of the nerve root; IBIV: inferior branch of the IV that ran along the superior margin of the inferior vertebral pedicle; D: The diameter of the branch of the intervertebral vein; L: The length of the branch of the intervertebral veins; Number: the number of branches of the intervertebral vein.

which ran downward from the inferior transforaminal ligament. In addition, the ALV drained the superior and inferior branches of the IV, the dorsal superior and inferior articular veins, and the transverse process anterior veins at the lateral zones of the lumbar IVF. Our findings were similar with respect to the relation of the IV branches, the IVVP, and the EVVP described in previous articles. We also found that the IV branches at the lumbar level were not only connected with the ALV, but also connected with the LV or with the iliolumbar vein directly after leaving the foramen.

Kambin's triangle approach and the "safe triangle" approach are the 2 most commonly used approaches of transforaminal epidural steroid injection for low back pain (Figs. 3 and 5). While intraforaminal arteries were found to be predominantly in the superior or midportion of the foramen anterosuperior to the exiting nerve root, placing the tip of the needle in the "safe triangle" may potentially damage or result in injection of particulate steroids into the artery; this could result in spinal infarction and paraplegia (18). In addition, a lot of the IV branches within the "safe triangle" may be damaged during the "safe triangle" approach of TFESI. During the Kambin's triangle approach of TFESI, for accurate injection, a high concentration of the medication must be placed at the site of pathology through Kambin's triangle (Fig. 5), where there are no large vessels. Knowledge of the microsurgical anatomy of the LIFs, particularly that of the main blood vessels, is critical for physicians performing interventional pain treatment for low back pain (2,6). Furthermore, damage to or inadvertent injection of the LIFs occurs more often than injury to or inadvertent injection into large vessels, particularly the arteries at Kambin's triangle (2,18,19). However, few studies have clarified the precise morphology of the IV branches at the lumbar level. The anatomic study presented here investigated the morphology of the IV branches in LIFs and their possible clinical significance.

The Kambin's triangle approach of TFESI makes it possible to inject drugs into LIFs or the anterior epidural space (3). Intravenous injections into the IV branches in Kambin's triangle may also produce a false-negative result from a diagnostic block and decrease the effectiveness and accuracy of the therapeutic injections to relieve the low back pain. Such occurrences increase the rates of reintervention and reoperation because the partial or total intravenous administration of the corticosteroids is contrary to the purpose of epidural injection: to place a high concentration of the medication at the site of the pathology. Therefore, we considered that inadvertent injection to the IV branches may be avoided during TFESI if the surgeon is able to identify and carefully avoid these branches of the IV and to develop a relatively safe injection area (Fig. 5); a small triangle could form by keeping away from branches of the IV in Kambin's triangle, allowing for accurate placement of a high concentration of medication at the targeted site and thereby increasing surgical efficacy and safety. A relatively safe area may be defined as a small triangle bordered inferiorly by the inferior IV branch, medially by the anterolateral longitudinal vein of IVVP, and laterally (obliquely) by the hypotenuse formed by the exiting nerve root (Fig. 5). A spinal needle was inserted medially in the 5 o'clock direction of the upper pedicle at the anteroposterior view, without further advancement and posteroinferior to the intervertebral foramen at the lateral view (3). As the Kambin's triangle boundary is rich in the IV branches, when injecting with a puncture needle, the tip of the needle is slightly superiorly inclined 2-3° in the intervertebral foramen under the premise of the normal puncture needle positioning operation . The tip of the needle is mainly aimed at the relatively safe area mentioned in this study, which is likely to reduce intravascular injection or vascular injury. Injection of drugs in the safe zone, which may be the potential zone for least vascularity in our study, would reduce the risk of intravenous injections, thus improving the safety of interventional pain treatment.

Limitations

The greatest weakness of this study is that it lacks actual clinical verification. Future clinical trials are expected to contribute more objective data concerning the IV branches. Due to the relative changes in vascular position during dissection, the relevant data warrant improvement.

Conclusions

The lumbar intervertebral veins are an important part of the anatomical structure of the intervertebral foramina. Adequate knowledge of the intervertebral veins may be of clinical importance to surgeons performing transforaminal epidural steroid injection.

Acknowledgments

This study has been supported by grants from The Science and Technology Project of Guangzhou (Grant No. 201704020033) and The Science and Technology Project of Tianhe District, Guangzhou (Grant No. 201604KW012), The Science and Technology Project ofGuangdong (Grant No. 2017B020210010); and there are no potential conflict of interest-associated biases in the text of the manuscript. Hai Lu and Qingchu Li contributed equally to this work. Hai Lu is the corresponding author. Zhihai Su, Min Wang, and Qinghao Zhao contributed equally to this work and should be considered as co-first authors.

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