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The anatomy of retroperitoneal and pelvic vein systems

Die Anatomie des retroperitonealen und pelvinen Venensystems

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ABSTRACT

Venous disorders are not limited to the extremities. Diseases of the leg veins, such as varicose veins and phlebothrombosis, can also affect the veins of the pelvic organs and the retroperitoneum. At the same time, pelvic and abdominal symptoms can sometimes have a phlebogenic cause. Chronic pelvic congestion syndrome has become widely recognised as a counterpart to chronic venous insufficiency of the leg veins, however the term does not adequately capture the complexity of the disorder, neither anatomically nor functionally.
Clinical diagnoses and imaging, especially Duplex sonography of the retroperitoneal veins, prove to be considerably more difficult than in leg veins. In addition, there is a wide variation in the vessels. A profound knowledge of the anatomy of the pelvic and retroperitoneal vessels is needed to accurately interpret the findings. Knowledge of the major stages of embryonic development facilitates one's understanding of the pathophysiological mechanisms.

ZUSAMMENFASSUNG

Venenleiden sind nicht auf die Extremitäten beschränkt. Einerseits können Erkrankungen der Beinvenen wie Varikose und Phlebothrombose auch die Venen der Beckenorgane und des Retroperitoneums mit betreffen, andererseits sind pelvine und abdominelle Symptome mitunter auch phlebogen erklärbar. Als Pendant zur chronischen venösen Insuffizienz der Beinvenen hat sich der Begriff des chronischen pelvinen Stauungssyndroms etabliert, der die Komplexität der Störung weder anatomisch noch funktionell adäquat erfasst.
Die klinische Diagnostik und die Bildgebung, insbesondere die Duplexsonografie der retroperitonealen Venen, sind erheblich schwieriger als die der Beinvenen. Darüber hinaus sind die Gefäße sehr variantenreich. Die fundierte Kenntnis der Anatomie der pelvinen und retroperitonealen Gefäße ist unersetzlich, um die möglichen Befunde deuten zu können. Das Wissen um die wichtigsten embryologischen Entwicklungsschritte erleichtert das Verständnis pathophysiologischer Mechanismen.

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Introduction

Varicose veins and deep vein thrombosis are common disorders that predominantly affect the limbs, especially the legs. However, diagnostic investigation and possible therapeutic approaches should not be confined to the veins in the extremities. Proximal thrombosis often involves the pelvic veins and the inferior vena cava (*V. cava inferior*). Varicose veins may also originate in the pelvic veins.

On closer consideration, it can be seen that the leg veins form a functional unit, not only with the inferior vena cava, but also with the veins of the urogenital system. This is one reason why the phlebologist's field of activity is not restricted to the limbs, but also extends to include abdominal symptoms.

The term 'pelvic congestion syndrome', which is mainly used today, inadequately covers the complexity of the associated disorders. Congestion is not the only underlying cause, nor does it exclusively involve the pelvic veins. The pathophysiological cause identified is far more often venous insufficiency, affecting both the pelvic and the retroperitoneal veins.

The close relationship between the leg veins and the retroperitoneal veins as far as the renal veins can be explained by the embryonic development.

The functional relationship between the leg veins and the retroperitoneal veins starts with the embryology

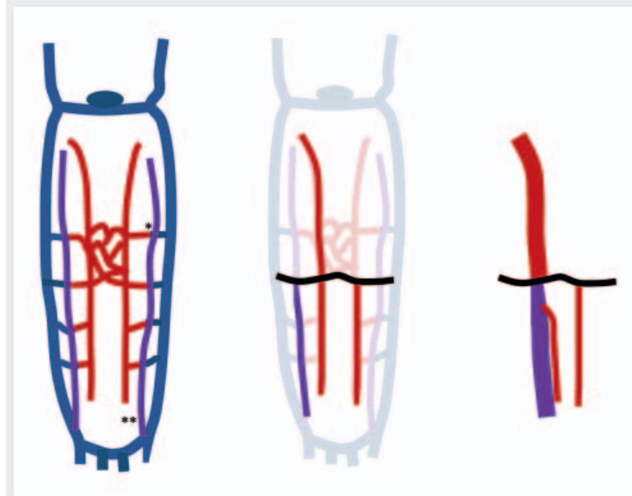
A particular feature of the venous system in the limbs is that the paired leg and pelvic veins as well as the gonadal veins and the renal veins empty into the single (unpaired) inferior vena cava (IVC). The abdominal aorta (*Aorta abdominalis*), which runs parallel to it, divides into its two terminal branches to supply the limbs. While the IVC lies to the right of the abdominal aorta, the leg veins do not follow the same logic and also lie on the right of the accompanying artery, but rather lie medial to the artery on both sides of the body. This results in the closely neighbouring vessels crossing each other at various times, which, based on the topographical relationship, may have haemodynamic effects. The gonadal veins do not run symmetrically either. While the right gonadal vein – the ovarian or testicular vein (*V. ovarica* or *V. testicularis*) – empties into the IVC, the left gonadal vein drains into the left renal vein. This arrangement can be understood by considering the process of embryonic development.

The vascular system develops in several stages from the third week of gestation onwards. An initial capillary network develops into a reticular network. The primitive arteries and veins appear at a later stage of development. During this stage, the blood from the inferior part of the body drains through a temporary embryonic venous system – known as the cardinal vein system. It consists of paired cardinal trunk veins and paired subcardinal and supracardinal veins.

The two parts of the system communicate via two anastomoses. The distal anastomosis of the subcardinal system is known as the iliac anastomosis. By the 7th week of gestation, the iliac veins develop from this anastomosis and the distal parts of the cardinal veins. Another anastomosis – the sub-supracardinal anastomosis – appears in the renal segment, giving rise to both renal veins during the course of development.

The cardinal vein trunks themselves regress completely on both sides. A notable feature is that the supracardinal vein on the left also regresses, while the one on the right develops into the infrarenal inferior vena cava and remains as an unpaired vein. In turn, the proximal part of the IVC develops from the right subcardinal vein. Thus, at the end of embryonic development, out of the initially symmetrical six paired cardinal veins only the distal part of the right supracardinal vein and the proximal part of the right subcardinal vein remain as the IVC and the distal parts of the subcardinal veins as the ovarian or testicular veins [1–3] (▶ **Fig. 1**).

Deciphering these complicated developmental steps has led phlebologists to three important conclusions: they show how the symmetrical venous system of the legs develops with an unpaired inferior vena cava; they explain why the left ovarian or testicular vein drains into the IVC via the left renal vein ('renal segment'), while the right opens directly into the IVC. And, of particular relevance, the developmental stages also explain the numerous individual anatomical variants resulting from disrupted or altered growth phases.



▶ **Fig. 1** The inferior vena cava, the pelvic veins and the leg veins develop from the embryonic cardinal vein system. Left: The paired cardinal veins (blue), the supracardinal veins (purple), and the subcardinal veins (red), with the sub-supracardinal anastomosis in the renal segment (proximal) (*) and the iliac anastomosis (distal) (**). Middle and right: The cardinal veins regress almost completely. Only the proximal subcardinal vein on the right and the distal supracardinal vein on the right remain and form the inferior vena cava. The two renal veins (black) develop from the renal anastomosis. The distal subcardinal veins remain as the gonadal veins (according to Avery [3]).

Distal vascular segment: pelvic veins and inferior vena cava

The epifascial veins, the great saphenous vein (*V. saphena magna*) and the frequently likewise large-calibre anterior accessory saphenous vein (*V. saphena accessoria anterior*) drain into the femoral vein (*V. femoralis*) in the groin. In contrast to the simplified picture often found in the literature, the external pudendal veins (*Vv. pudendae externae*) also drain into the saphenous opening. In this way, the epifascial leg veins also communicate with the venous plexuses associated with the urogenital organs and their supporting structures in the lesser pelvis.

The deep leg veins run strictly axially and, depending on the level, are classified as the femoral vein (*V. femoralis*) – formerly known as the superficial femoral vein – and the common femoral vein (*V. femoralis communis*). The femoral veins continue as the external iliac veins (*Vv. iliacae externae*) and the common iliac veins (*Vv. iliacae communes*), which together join the inferior vena cava at the level of the umbilicus. This topography is important in ultrasound scanning, meaning that the pelvic bifurcation and inferior vena cava should be not sought in the lesser pelvis, but rather to the right of the midline clearly proximal to the groin.

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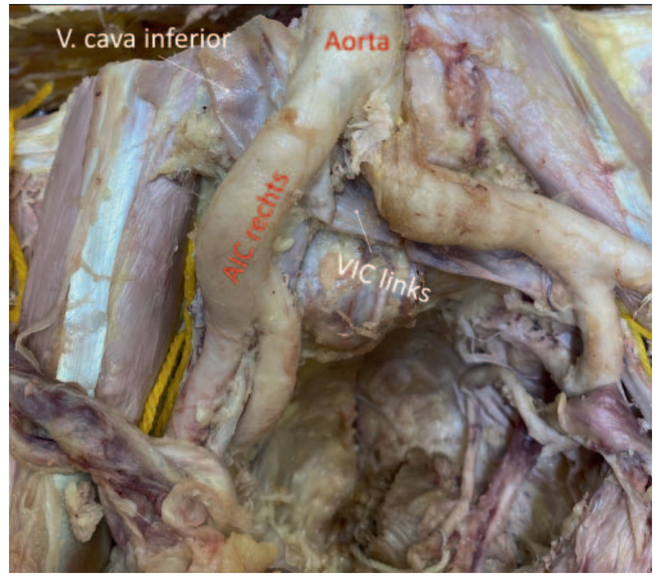
From the embryonic development described above, we can conclude that the paired leg vessels merge into the unpaired trunk vessels. The right common iliac artery (*A. iliaca communis dextra*) originating from the aorta on the right therefore crosses over the left common iliac vein (*V. iliaca communis sinistra*), which comes from the left leg, to empty into the IVC lying to the right of the aorta (▶ **Fig. 2**). Consequently, the vein finds itself between two firm abutments (the lumbar spine behind and the right common iliac artery (*A. iliaca interna dextra*) in front), which may cause a narrowing. As a result of chronic mechanical compression, a narrowing or a septum-like change in the wall is found at the arterial crossover point in 15–22 % of subjects examined. This leads to endothelial proliferation and intimal hyperplasia. In some cases, web-like changes in the lumen can also be detected. This phenomenon, named after the anatomists May and Thurner from Innsbruck (Austria), who first described it, explains why proximal thrombosis occurs up to eight times more frequently on the left than the right (May-Thurner syndrome) [4–6].

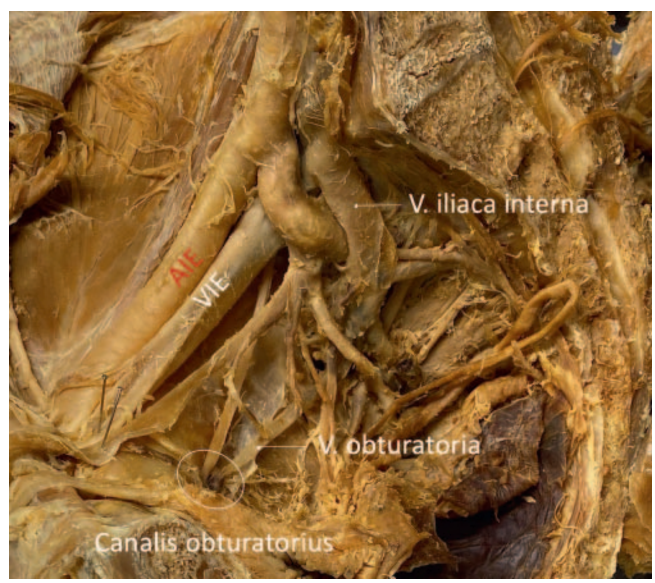
The external iliac vein (*V. iliaca externa*) is the continuation of the straight running deep leg veins proximal to the inguinal ligament. In contrast, the tributaries of the internal iliac vein (*V. iliaca interna*) are not easily identifiable linear vessels. The veins in the lesser pelvis, for example, the obturator vein (*V. obturatoria*), branches of the internal and external pudendal veins (*Vv. pudendae internae* and *externae*) and the gluteal veins (*Vv. gluteae*), show a strongly twisted morphology in their distal course and connect with the venous plexuses of the urogenital organs (▶ **Fig. 3**). In addition, there are connections to the epifascial leg veins through anatomical gaps such as the obturator canal (▶ **Fig. 3**) and the inguinal canal. In this way, the internal iliac vein is confluent with the external iliac vein in the lesser pelvis and is likewise involved in the transport of blood from the medial thigh (obturator vein), from the perineum (internal and external pudendal veins) and from the buttocks (gluteal veins) [7].

These anatomical openings, which allow the connection between the epifascial leg veins and the pelvic veins, are designated 'pelvic leak points' or 'pelvic escape points'.

Knowledge of these anatomical openings is essential for planning the treatment of non-saphenous varicose veins (see Phlebologie 4/20 [8]).



▶ **Fig. 2** Dissection of the lesser pelvis. The bladder and the genital organs have been removed. The aortic bifurcation is slightly rotated to the top right due to the age-related elongation of the aorta in the donor. The right common iliac artery (A. iliaca communis, AIC rechts) crosses over the inferior vena cava at the transition from the left common iliac vein (V. iliaca communis, VIC links).



▶ **Fig. 3** View of the right side of the lesser pelvis in a sagittal dissection. The obturator canal with the obturator vein can be seen as an example of a pelvic escape point (source of reflux for venous insufficiency in the legs from the lesser pelvis). Tributaries of the internal iliac vein, including the gluteal veins and internal pudendal veins, can be seen to the right. AIE: A. iliaca externa, VIE: V. iliaca externa.

Proximal vascular segment: gonadal veins and renal veins

Besides the development of the caval and iliac veins from the embryonic cardinal veins described above, knowledge of a further prenatal developmental step is important in the understanding of the retroperitoneal venous system. In the immediate vicinity of the renal blastema, the steroidogenic zone forms in the first weeks of embryogenesis. The adrenal glands and the testes or ovaries develop from this organ blastema; these organs have the production of steroid hormones (cortisol, oestrogen, testosterone, etc.) in common. While the adrenals remain directly adjacent to the kidneys in the course of further development, the gonads are distanced from the renal blastema, but keep their vascular supply. This explains why the comparatively long gonadal veins (ovarian or testicular vein) drain into the proximal inferior vena cava on the right and into the renal vein on the left.

The gonadal vessels are long and represent a particular orthostatic stress in humans due to their erect posture. This is particularly important in the case of reduced or absent venous valves

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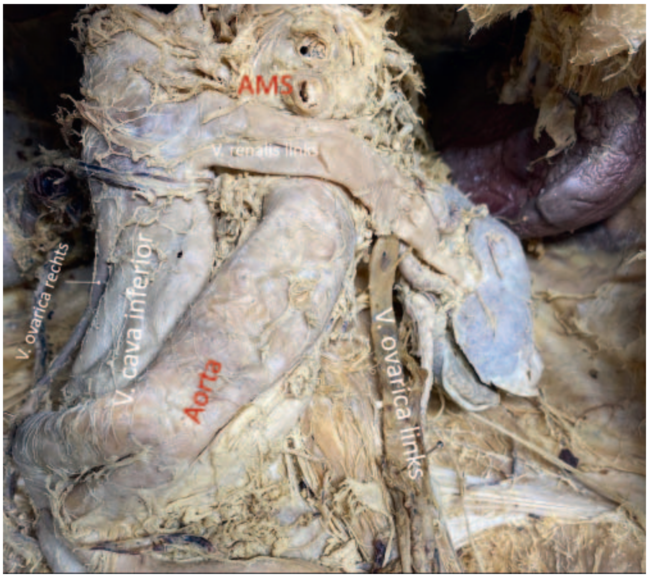
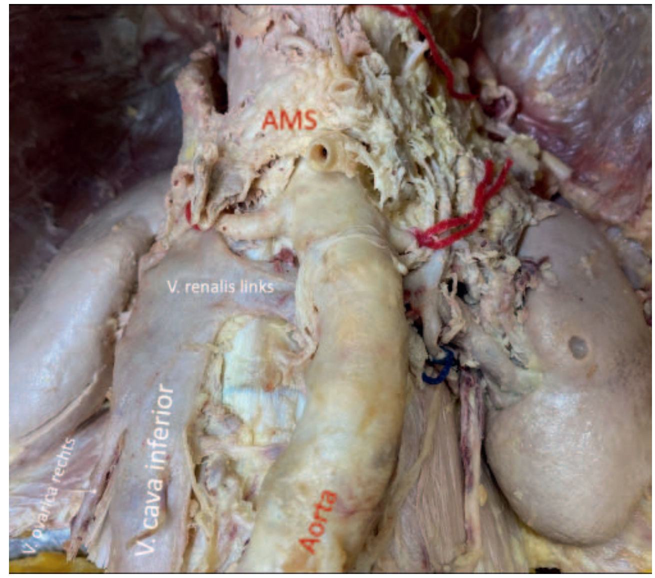


▶ **Fig. 4** Retroperitoneal site at the level of the renal vessels. The left renal vein crosses over the abdominal aorta – the anatomy giving rise to an anterior nutcracker phenomenon. Comparing the two sides, the dilated left ovarian vein (V. ovarica links) is noticeable and shows multiple lumens in its distal course. The marked aortic elongation is an incidental finding. (AMS: stump of the superior mesenteric artery).

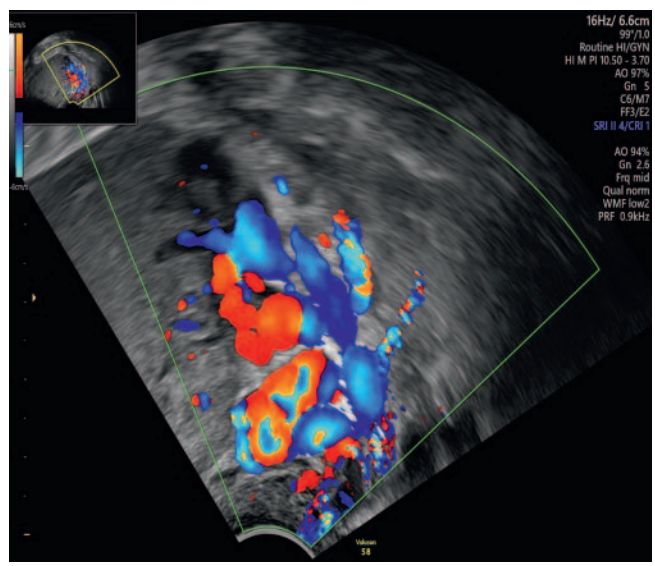


▶ **Fig. 5** As a variant, the left renal vein (V. renalis links) crosses under the abdominal aorta – the posterior nutcracker phenomenon.

(normally there are two or three). Some 13–15 % of women do not have any valves in the left ovarian vein. The resulting venous insufficiency is increased by the raised intra-abdominal pressure during a current or repeated pregnancy or by external compression. An incompetent left ovarian vein can be demonstrated in one out of every two women [9]. However, the ovarian veins are often multiple and numerous variants have been reported. In post-mortem examinations of 100 individuals, Miles et al. found variants in 13 cases; they included duplex ovarian and/or renal veins, the right ovarian vein draining into the right renal vein, connections between the left ovarian vein and the IVC, etc. [10].

The embryological relationship between the left ovarian or testicular vein and the renal vein has a further functionally relevant topographical effect. The left gonadal vein drains into the renal vein to the left of the aorta. The renal vein then crosses *over* the aorta to drain into the IVC, which, for its part, lies to the right of the aorta. Similar to the May-Thurner syndrome, this crossover may result in compression of the left renal vein, which could lead to symptomatic stasis in the kidney itself or in the ovarian or testicular vein. Various morphological arrangements are possible thereby: the left renal vein crosses *over* the aorta and *under* the superior mesenteric artery (*A. mesenterica superior*), which may have an acute-angled take-off from the aorta. This most common variant is called the 'anterior nutcracker phenomenon' (▶ **Fig. 4**). Crossing *under* the aorta in front of the vertebral column as abutment is also possible ('posterior nutcracker phenomenon') (▶ **Fig. 5**).

This anatomical variant is seen significantly more often in patients with a varicocele [11]. It has already been mentioned that the renal veins may show further variations. Multiple vessels may be encountered, and the vessels may run around the aorta. The right renal vein shows more variation than the left [12, 13].



▶ **Fig. 6** Varicose veins around the uterus and parametrium seen with duplex ultrasound scanning using a sector probe (endo/vaginal 2.9–9.7 MHz). Demonstration of reflux with a Valsalva manoeuvre (Quelle: Beate Scheufler, Halle).

However, unlike the limbs, the venous flow from all the urogenital organs is not along linear vessels. On the contrary, it comes from venous networks or plexuses: the ovarian plexus (*plexus ovaricus*), the pampiniform plexus (*plexus pampiniformis*) of the testis, the venous plexus of the prostate (*plexus venosus prostaticus*) and the venous plexus of the bladder (*plexus venosus vesicalis*). These plexuses communicate with each other through numerous anastomoses as well as with the internal iliac vein via the obturator vein, the internal and external pudendal veins and

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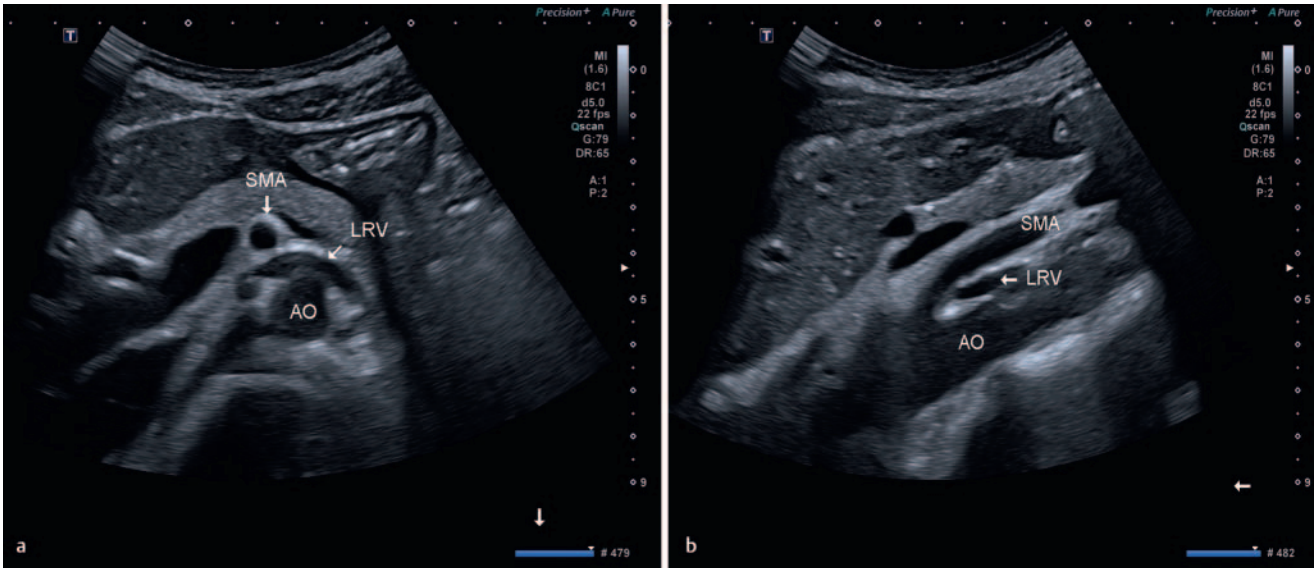
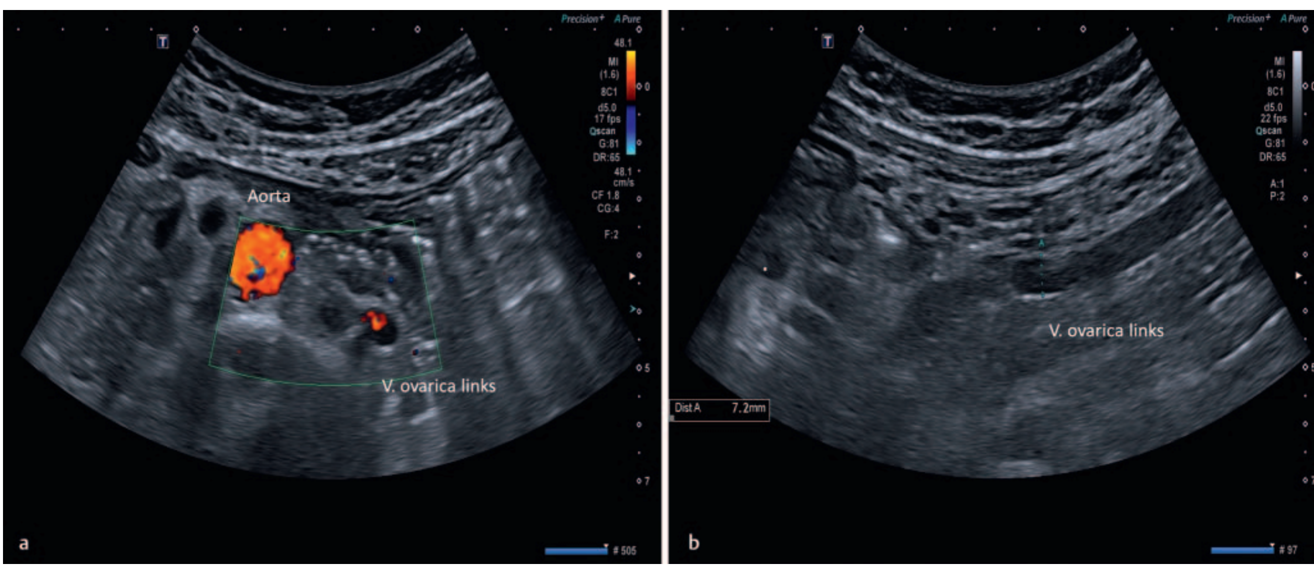


▶ **Fig. 7 a** Positioning and alignment of a convex probe (5 MHz) on the abdomen for an optimal transverse view. The left renal vein (LRV) can be seen in longitudinal section between the aorta (AO) and the superior mesenteric artery (SMA). **b** The longitudinal section shows the acute-angled take-off of the superior mesenteric artery, which then crosses the left renal vein (seen here in cross section). When there is a haemodynamically relevant compression of the renal vein, it is known as the anterior nutcracker syndrome.



▶ **Fig. 8 a** In the standing position, the left ovarian vein with a wide lumen can be seen adjacent to the aorta in the paramedian transverse view. The red Doppler signal, showing the same direction of flow as the aorta, confirms the reflux. **b** Paramedian longitudinal view of the left ovarian vein (V. ovarica links). A diameter of > 6 mm in the standing patient is considered pathognomic of an incompetent ovarian vein.

the gluteal veins (see above; described in detail in issue 1/2021: Delfrate Roberto, Pelvic leak points).

The value of duplex ultrasound scanning

Diagnostic imaging of the pelvic and retroperitoneal veins focusses on the large draining vessels: the internal iliac vein and the ovarian/testicular veins, while the classification of the individual intrapelvic veins is very difficult. Ultrasound examination with a vaginal probe allows the pelvic plexuses to be demonstrated when they are abnormally dilated (▶ **Fig. 6**). Classification of the individual tributaries of the internal iliac vein is not possible. Superimposed gastrointestinal air and abdominal fat make the investigation more difficult.

Providing evidence of reflux is one of the great advantages of duplex ultrasound scanning over radiologic imaging methods. The retroperitoneal location of the vessels means that an optimal view can only be obtained with a convex probe of low frequency. As a rule, the proximal IVC, the aorta and the renal veins as well as the superior mesenteric artery can be easily identified in the

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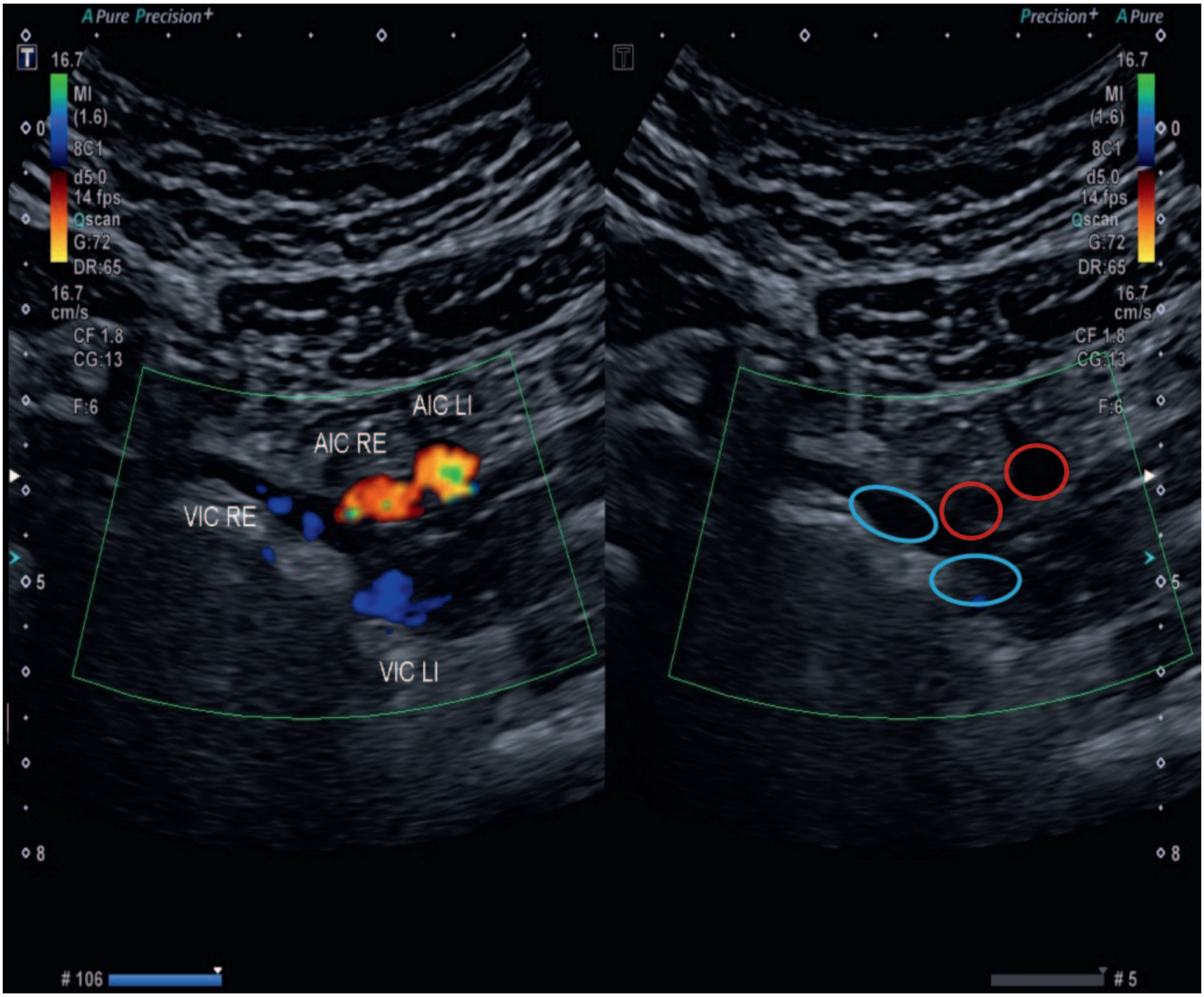

▶ **Fig. 9** Demonstration of the proximal common iliac arteries and veins. The right common iliac artery (AIC) crosses over the left common iliac vein (VIC). A mild collapse of the veins can be seen with the patient lying down. This does not automatically mean that there is haemodynamically relevant compression in terms of a May-Thurner syndrome (16-year-old female subject, no symptoms).

fasting patient. It is recommended that the patient changes position from lying to standing, in order to rule out any false positive compression of the left renal vein by the superior mesenteric artery (▶ **Fig. 7a, b**).

If the gonadal vein is normal, it usually cannot be seen. In contrast, an incompetent left ovarian (or testicular) vein may be dilated to more than 6 mm. In this case, it is possible to demonstrate the vein to the left of the aorta on the psoas major muscle in the standing patient. The distinguishing feature is the signal in the same colour as the aorta that is seen immediately after standing, indicating reflux (▶ **Fig. 8a, b**).

Using a convex probe, the pelvic veins can also be demonstrated (▶ **Fig. 9**). A full bladder may be of assistance. The pudendal veins, obturator vein and gluteal veins cannot be identified with an ultrasound scan. Indirect evidence of incompetence may be found in in the dilated lumens of parametrial veins or in a colour change during a Valsalva manoeuvre. Besides the use of a vaginal probe, special technical ultrasound modalities such as B-Flow (General Electric) or Superb Microvascular Imaging (Canon) may be of use to demonstrate a slow flow regardless of direction.

Conclusions

Investigation of the leg veins does not end at the inguinal ligament. Besides the external iliac vein connecting the superficial and the deep leg veins to the inferior vena cava, there are numerous connections to the pelvic venous system and the internal iliac vein, as well as to the gonadal and renal veins.

Ultrasound investigations should be performed with a convex transducer in order to increase the pre-test probability of a radiological diagnosis. The examination is time-consuming and depends greatly upon the patient. It also requires experience and a good knowledge of the anatomy.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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