Learning objectives

- Review the anatomical variations of the inferior vena cava (IVC) and its embryology.

- Highlight relevant MDCT findings of the most important and frequent anatomical variations to be considered before surgical procedures.

- Differentiate anatomical variations of the IVC from pathology and avoid pitfalls.

Background

INTRODUCTION

Variations from the normal anatomy of the IVC occur in 3% of the population [1] and most of variations are asymptomatic and incidental.

Multidetector computed tomography (MDCT) obtained with intravenously administered contrast material is the suitable technique for depicting these variations, due to its wide availability, reproducibility and anatomical resolution.

Knowledge of different types of anatomical variations by the radiologist is useful for correct interpretation of cross-sectional images, to avoid diagnostic mistakes of retroperitoneal and mediastinal masses or adenopathy.

Anatomical details of vasculature are also fundamental to alert the surgeon and angiographer of potential sources of complications before interventions. Therefore pre-therapeutic evaluation by MDCT helps to choose the optimal therapeutic procedure. Knowledge of interventional procedures is essential to give the appropriate information to surgeons.

EMBRYOGENESIS

The existence of anatomical variations of the IVC is explained by embryology. Any abnormality in the regression or persistence of embryologic veins may cause different anatomical variations.

There are three paired embryologic veins that contribute to development of the inferior vena cava (IVC) between the 6th and 8th weeks of embryologic life (Fig 1). They are on both sides of the aorta. In order of appearance: posterior cardinal vein (pink), subcardinal vein (green) and supracardinal vein (blue). The vitelline vein (deep blue) is another important embryologic vein but not paired.
In the normal development, a regression of left and communicating veins that connect paired veins, occurs. On the other hand, the right subcardinal and supracardinal veins and the vitelline vein persist and develop into a right IVC. The segments derived from each one are:

- Subcardinal vein: resulting in the prerenal (infrahepatic and suprarenal) portion of the IVC.
- Supracardinal vein: develops into the infrarenal portion of the IVC, and continues as the azygous (right) and hemiazygous (left) veins.
- Vitelline vein: derives into the hepatic portion of the IVC.

Anastomoses connect the various segments of the IVC.

The intersubcardinal communicating vein forms between the paired subcardinal veins anterior to the aorta and caudal to the superior mesenteric artery. This one persists and leads to the renal left vein. Intersupracardinal and interposterior cardinal communicating veins regress.

Iliac primitive veins derive from the persistence of posterior cardinal veins.

Anastomosis between the supracardinal and subcardinal veins forms the renal segment of the IVC. Subcardinal vein (infrahepatic and suprarenal IVC) anastomoses cranially to vitelline vein (hepatic segment of the IVC). Right supracardinal vein (infrarenal IVC) anastomoses caudally to posterior cardinal veins (iliac veins).

Embryologic ureter passes behind to the posterior cardinal vein and anterolateral to the supracardinal vein.

We will discuss different anatomical variations, what procedures can be relevant and what pathological findings can simulate.

**Images for this section:**
Fig 1. Illustration of the embryologic development of the IVC shows the relative positions and interrelationships of the embryonic vessels.

Fig. 1: Embryogenesis.
Imaging findings OR Procedure details

We illustrate the different anatomical variations of IVC with images obtained from our data base of 11 patients. Patients are studied with MDCT from lung apex to pelvis. Some MDCT are performed with intravenous contrast and evaluated in the portal venous phase (60-70 seconds after the injection of 100 mL of contrast material at a rate of 3-4 mL/sec). Since some studies are not directed to find anatomical variations, some MDCT are unenhanced. Suitable reconstructions are obtained using a dedicated workstation.

ANATOMICAL VARIATIONS

1. Left IVC

The prevalence of left IVC is between 0.2% and 0.5% [2]. It results from a persistent left supracardinal vein with a regression of the right supracardinal vein. The left IVC receives the left renal vein, and once united crosses anterior to the aorta, joins the right renal vein and continues as right prerenal IVC (Fig 2, Fig 3, Fig 4), which presents its normal position. The clinical relevance of this variant is that it may be confused with left paraaortic adenopathy, it may complicate an abdominal aortic aneurysm surgery [3], and it also difficults the placement of infrarenal IVC filter through a transjugular access [4,5].

2. Double IVC

The prevalence of double IVC is between 1% and 3% [2]. It results from persistence of both supracardinal veins. The left IVC ends at the left renal vein, which crosses anterior to the aorta and joins the right renal vein to continue as a normal right prerenal IVC (Fig 5, Fig 6, Fig 7). But differences in this version may occur. We explain them in sections 3 and 4. A difference in size between the two veins may be present. The clinical relevance of this variation is that an aberrant vessel may be confused with paraaortic adenopathy, as with left IVC, especially if a poor contrast enhancement or thrombosis occurs [6]. The double IVC should be suspected in cases of pulmonary embolism that recurs despite the presence of an IVC filter [2]. Options range includes a filter placement in the common suprarenal IVC, an infrarenal IVC filter placement on each side [1], or embolization with coils of smaller IVC, besides the placement of a contralateral IVC filter [5].
3. Double IVC with retroaortic right renal vein and hemiazygous continuation of the IVC

It results from a persistent left thoracic supracardinal and the intersupracardinal vein with a right subcardinal-hepatic anastomosis failure. The right IVC drains into the right renal vein, crossing posterior to the aorta and joining the left renal vein to form a hemiazygous continuation (Fig 8, Fig 9). The different pathways of hemiazygous continuation are exposed in section 6.
This variation may be mistaken for a left mediastinal mass. It should be noted in planning cardiopulmonary bypass surgery and cardiac catheterization to avoid complications.

4. Double IVC with retroaortic left renal vein and azygous continuation of the IVC

This variant is a result from persistence of the left supracardinal vein and the intersupracardinal vein, with a right subcardinal-hepatic anastomosis failure [4].
Left IVC joins the left renal vein and cross posterior to the aorta. Then joins the right IVC and continues as azygous vein in retrocrural space (Fig 10, Fig 11).
The clinical significance is the same that in cases of section 3.

5. Interruption of the IVC with azygous continuation

The prevalence of this variation is about 0.6% [4]. It is due to a failure of the right subcardinal-hepatic anastomosis causing ipsilateral subcardinal vein atrophy (suprarenal IVC) [4]. The hepatic segment is not really absent but drains directly into the right atrium. The infrarenal IVC passes to retrocrural space, continues in the thorax as the azygous vein and drains into the normal SVC (Fig. 12, Fig 13, Fig 14) [7].
This variation is classically associated with situs ambiguous anomalies, but it has become increasingly recognized in asymptomatic patients since the advent of cross-sectional imaging.
An increase of size of the azygous vein may be mistaken for a right paratracheal mass or a retrocrural adenopathy. It is important in planning cardiopulmonary bypass surgery and cardiac catheterization to avoid complications.

6. Interruption of the IVC with hemiazygous continuation

As an alternative of the previous variation, in cases of left IVC the infrarenal IVC passes to retrocrural space and continues as the hemiazygous vein (Fig 15) [4], which crosses posterior to the aorta in the thorax at T8 or T9 to join the azygous vein (Fig 16). Two alternative ways of hemiazygous continuation exist: superior continuation to join the coronary vein via a persistent left superior vena cava (SVC) (Fig 17, Fig 18a), and an
accessory hemiazygous continuation to the left brachiocephalic vein [1]. Both of these may be mistaken for a left mediastinal mass; or for an aortic dissection in an accessory hemiazygous continuation [4] (Fig 18b). Accidental ligation of hemiazygous-to-azygous continuation of a left IVC during thoracic surgery may occur. The clinical significance of hemiazygous continuation is the same that in previous section.

7. Absence of the infrarenal IVC with preservation of the suprarenal segment

This is an extremely rare variation [8]. The origin of the absence of the infrarenal IVC is not embryologic, is secondary to an intrauterine or perinatal thrombosis of the IVC [5]. Suprarenal portion is preserved (Fig 19).

Lower limb venous return is via the ascending lumbar veins, which join azygous-hemiazygous system via anterior paravertebral collateral veins.

The clinical relevance is the risk of deep venous thrombosis and chronic venous insufficiency [8], and a paraspinal mass can be simulated by increased collateral vessels (Fig 20).

8. Retroaortic left renal vein

The prevalence of this variation of the normal vascular anatomy is between 1.7% and 3.4% [5].

The normal left renal vein derived from the intersubcardinal communicating vein, which crosses anterior to the aorta.

The retroaortic left renal vein is formed from intersupracardinal communicating vein, which courses posterior to the aorta. In this case the intersubcardinal communicating vein regresses (Fig 21).

It must be considered in planning nephrectomy and abdominal aortic aneurysm surgery to avoid complications.

It also can be misdiagnosed as an adenopathy [4] (Fig 22).

The retroaortic left renal vein compression may occur on rare occasions (nutcracker phenomenon), and it can cause periureteric varices, hypertension and hematuria.

9. Circumaortic left renal vein

The prevalence of this variation is between 2.4% and 8.7% [5]. It results from persistent intersubcardinal and intersupracardinal communicating veins.

Two left renal veins are present: one vein courses anterior to the aorta and superior, and the other vein lies posterior to the aorta and inferior (Fig 23).

The left adrenal vein drains into the superior renal vein and the left gonadal vein drains into the inferior renal vein, which crosses posterior to the aorta 1-2 cm inferior to the superior renal vein (Fig 24).
The clinical significance is the same that in cases of the retroaortic left renal vein.

10. Retrocaval ureter

It is also known as circumcaval ureter. It is a problem of the infrarenal IVC development, which develops from the right posterior cardinal vein (anterolateral to the ureter) instead from the right supracardinal vein. This anomaly always occurs on the right side and its way is posteromedial to the IVC, turns to the right and becomes anterior to the IVC and the right iliac vessels (Fig 25, Fig 26, Fig 27).

Symptoms may occur due to a partial right ureteral obstruction causing hydronephrosis or recurrent urinary tract infections. It may be treated by ureter relocation anterior to the IVC surgery [2].

Images for this section:

![Fig 2: Illustration of a left IVC ending at the left renal vein.](image)

**Fig. 2:** Left IVC.
**Fig. 3.** Left IVC in a 26-year-old man. CT scans presented from caudal to cranial. (a) Left IVC (arrow) inferior to the renal veins. (b) Left IVC joining the left renal vein (arrow). (c) A normal right-sided prerenal IVC (red arrow) is formed from the confluence of the left and right (blue arrow) renal veins. (d) Normal intrahepatic IVC.

**Fig. 3:** Left IVC.
Fig. 4. Left IVC in the same patient than figure 3. Coronal curved reformatted CT image of a left IVC (blue arrow) crossing anterior (red arrow) to the aorta, joining the right renal vein to form a right suprarenal IVC (normal position). Portal vein is seen in the same image (yellow arrow).

**Fig. 4:** Left IVC.
Fig 5. Illustration of a double IVC shows left and right infrarenal IVCs. The left IVC joins the left renal vein.

Fig. 5: Double IVC.
**Fig 6.** Hepatic cirrhosis and double IVC in a 70-year-old man. (a-d) CT scans presented from caudal to cranial. (a) Right (blue arrow) and left (red arrow) IVCs at infrarenal level. (b-d) Left IVC ending at the left renal vein (arrow in b), which crosses anterior (arrow in c) to the aorta and joins the right IVC forming prerenal IVC (arrow in d).

**Fig. 6:** Double IVC.
Fig. 7. Double IVC in the same patient than figure 6. (a-b) Coronal CT and volume rendering images of a double IVC (red arrows). The left IVC joins the left renal vein (yellow arrows), which crosses anterior to the aorta to form a right suprarenal IVC (blue arrows). Aortic calcium helps to differentiate the aorta from the IVC.

Fig. 7: Double IVC.
**Fig. 8:** Illustration of a double IVC with retroaortic right renal vein and hemiazygous continuation. Failed development of the right prerenal IVC.

**Fig. 8:** Double IVC with retroaortic right renal vein and hemiazygous continuation of the IVC.
Fig. 9: Double IVC with retroaortic right renal vein and hemiazygous continuation in a 2-year-old boy. (a-d) MR images presented from caudal to cranial. (a) Right (straight arrow) and left (curved arrow) IVCs. (b) The right renal vein (arrowhead) receive the right IVC and crosses posterior to the aorta (arrow) to join the left IVC. (c) The left IVC continues cephalad as the hemiazygous vein (arrow) within retrocrural space. (d) In the thorax, the hemiazygous vein (straight arrow) crosses posterior to the aorta (arrowhead) to join an azygous vein (curved arrow) approximately 1-2 cm below the carina.

Fig. 9: Double IVC with retroaortic right renal vein and hemiazygous continuation of the IVC.
**Fig. 10**: Double IVC with retroaortic left renal vein and azygous continuation of the IVC.
**Fig. 11:** Double IVC with retroaortic left renal vein and azygous continuation in a 31-year-old woman. (a-d) CT scans presented from caudal to cranial. (a) The right IVC joins the right renal vein (straight arrow). The left IVC (curved arrow) is also seen. (b) The left IVC (arrow) joins the left renal vein. (c) The left renal vein (arrow) crosses posterior to the aorta and joins the right IVC. (d) The right IVC continues cephalad as the azygous vein (arrow) under the diaphragmatic crus.

**Fig. 11:** Double IVC with retroaortic left renal vein and azygous continuation of the IVC.
**Fig. 12:** Interruption of the IVC with azygous continuation, where a lack of contiguity between the prerenal IVC and the hepatic IVC is seen.

**Fig. 12:** Interruption of the IVC with azygous continuation.
**Fig. 13.** Interruption of the IVC with azygous continuation in 80-year-old woman. (a-d) CT scans presented from caudal to cranial. (a) Normal right IVC (arrow). (b) Azygous vein within retrocruural space (arrow). (c) Azygous vein (red arrow) at the level of the thorax with hepatic segment present (blue arrow). (d) Enlarged azygous vein arch (red arrow) draining into the SVC (blue arrow).

**Fig. 13:** Interruption of the IVC with azygous continuation.
Fig 14. Interruption of the IVC with azygous continuation in the same patient than figure 13. (a-c) Sagital and coronal CT images. (a) Enlarged azygous vein arch (arrow) draining into the SVC. (b) Enlarged azygous vein (arrow) parallel to the aorta. (c) Hepatic segment (arrow) draining directly into the right atrium.

Fig. 14: Interruption of the IVC with azygous continuation.
Fig. 15: Interruption of the IVC with hemiazygous continuation in 56-year-old man with disseminated colon neoplasm. (a-d) CT scans presented from caudal to cranial. (a) Left IVC (arrow). (b) Hemiazygous vein within retrocrural space (arrow). (c) Hemiazygous vein (arrow) at the level of the thorax crossing posterior to the aorta to continue as azygous vein, which is the most frequent pathway. (d) Azygous vein arch (red arrow) draining into the SVC (blue arrow).

Fig. 15: Interruption of the IVC with hemiazygous continuation.
**Fig. 16:** Interruption of the IVC with hemiazygous continuation in the same patient than figure 15. (a-b) Volume rendering and coronal CT images. (a) IVC continues as hemiazygous vein (arrow) parallel to the aorta. (b) Hemiazygous vein (red arrow) crosses posterior to the aorta at T8-T9 level to join the azygous vein (blue arrow).

**Fig. 16:** Interruption of the IVC with hemiazygous continuation.
**Fig. 17:** Interruption of the IVC with hemiazygous continuation in 44-year-old woman. (a-d) CT scans presented from caudal to cranial. (a) Hemiazygous vein (arrow) at the level of the thorax. (b-c) Hemiazygous continuation (arrow in b) via a persistent left SVC (arrow in c) towards the coronary vein, (arrow in d) as an alternative pathway. A left subclavian central line depicts the path of left SVC.

**Fig. 17:** Interruption of the IVC with hemiazygous continuation.
Fig. 18: Interruption of the IVC with hemiazygous continuation. (a-b) Sagital and coronal CT images. (a) Hemiazygous continuation (red arrow) to a persistent left SVC depicted with a central line in its lumen (blue arrow), as an alternative pathway. (b) Aortic dissection pitfall (arrow).
**Fig. 19:** Illustration of an absence of the infrarenal IVC with preservation of the suprarenal segment. Prominent ascending lumbar veins are shown.

**Fig. 19:** Absence of the infrarenal IVC with preservation of the suprarenal segment.
**Fig. 20:** Absence of the infrarenal IVC with preservation of the suprarenal segment in a 12-year-old girl. (a-d) CT scans presented from caudal to cranial. (a) Thrombosed common iliac veins (arrows), as a secondary complication. (b) Enlarged ascending lumbar veins (blue arrows) are present simulating a paraspinal mass. Collateral veins are present too (red arrows). (c) Absence of the IVC (arrow). (d) Prominent paravertebral collateral veins (blue arrow), which lead to a prominent hemiazygous vein (red arrow). Hepatic segment is present (yellow arrow).

**Fig. 20:** Absence of the infrarenal IVC with preservation of the suprarenal segment.
Fig. 21: Illustration of a retroaortic left renal vein.

**Fig. 21:** Retroaortic left renal vein.
Fig. 22: Retroaortic left renal vein in 70-year-old man. (a-b) Axial and sagital CT images show the left renal vein crossing posterior to the aorta (arrow).

Fig. 22: Retroaortic left renal vein.
Fig. 23: Illustration of a circumaortic left renal vein. There are two left renal veins, with the inferior vein crossing posterior to the aorta.

**Fig. 23:** Circumaortic left renal vein.
Fig 24. Circumaortic left renal vein in 78-year-old man. (a-c) Axial CT scans presented from cranial to caudal, and sagittal CT image. (a) The superior left renal vein (red arrow) crosses anterior to the aorta. (b) The inferior vein (blue arrow) descends approximately 2 cm and crosses posterior to the aorta. (c) Sagittal MPR showing superior (red arrow) and inferior (blue arrow) left renal veins.

Fig. 24: Circumaortic left renal vein.
**Fig. 25**: Retrocaval ureter.
Fig. 26. Retrocaval ureter in 51-year-old man. (a-c) CT scans in excretory phase presented from cranial to caudal. (a) Retrocaval ureter (arrow) crossing posterior to the IVC. (b) The ureter (arrow) courses medial to the IVC. (c) The ureter (arrow) crosses anterior to the IVC.

Fig. 26: Retrocaval ureter.
Fig 27. Retrocaval ureter in the same patient than figure 26. (a-b) Volume rendering images depicting the whole course of the retrocaval ureter (arrow), coursing posterior, medial and anterior to IVC, surrounding it.

Fig. 27: Retrocaval ureter.
Conclusion

- Knowledge of anatomical variations of the IVC is important for the radiologist to avoid erroneous diagnosis and to provide suitable pre-surgical and pre-angiography information of potential sources of complications.

- Knowledge of embryology helps us to understand the different IVC variations.

- MDCT is the suitable technique for pre-surgical evaluation, due to its wide availability, reproducibility and anatomical resolution.

Personal Information

References


