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Case Report

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Anomalous drainage of left renal vein into the azygos venous system without inferior vena cava interruption: a novel anatomic variant

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Abstract

Anomalies of the Left Renal Vein (LRV) are often asymptomatic and found incidentally, but can have major ramifications on both surgical and interventional procedures. We present the case of a 63-year-old male who was incidentally found to have a novel venous anatomic variant, not previously described in the literature. His LRV drains into the azygos venous system up into the chest via the hemiazygos vein, despite the presence of a normal, patent and uninterrupted right-sided Inferior Vena Cava (IVC), and with no communication to the IVC. This configuration differs from known variants that lead to azygous venous drainage such as posterior nutcracker syndrome of a retroaortic left renal vein or azygos continuation of the IVC with congenital interruption. Venous anomalies involving the LRV, including in this patient, may increase the risk of bleeding during retroperitoneal surgery or complicate endovascular procedures involving the left renal, adrenal or gonadal veins. Recognition of variant venous anatomy is key for pre-procedural planning to avoid unnecessary complications.

Introduction

Anatomic variation of the Inferior Vena Cava (IVC) and renal veins, whether congenital or acquired, have significant implications in both surgical and interventional procedures. Anatomical variations in renal vessels are quite prevalent with 35% and 18% of the population carrying variations in arterial and venous renal vessels, respectively.[1,2] The Left Renal Vein (LRV) normally courses anterior to the aorta to drain into the IVC. There are several anatomic variations involving the LRV including retroaortic LRV drainage and circumaortic LRV drainage. Additionally, specific anomalies of the azygos system include azygos vein agenesis, right-sided azygos lobe, and left-sided IVC draining into the LRV with an interrupted IVC and azygos continuation.

These anatomic variations are typically asymptomatic and discovered incidentally, but their recognition is important as they can have important perioperative implications.[3-5] For example, unrecognized variant venous anatomy may increase the risk of complications during surgical procedures or pose challenges during endovascular interventions.

This manuscript describes a novel anatomic variant, to our knowledge never previously described in the literature, of a left renal vein that drains into the azygos venous system via the hemiazygos vein, in the setting of a normal and patent right-sided IVC that drains the right renal vein into the IVC without congenital or acquired interruption.

Case Report

In this manuscript we describe the case of a 63-year-old male who presented to the Emergency Department with abdominal pain and clinical suspicion for colitis. Contrast-Enhanced Computed Tomography (CECT) of the abdomen and pelvis was performed which demonstrated no acute pathologic findings. This patient had no prior cross-sectional imaging of the chest, abdomen or pelvis available for comparison. Incidentally noted was variant venous anatomy involving the LRV, which has not previously been described in the literature. In this patient, the left renal vein drains completely into the azygos venous system via the hemiazygos vein (Figure 1C) and is partially visualized traveling up the dilated collateral venous network into the chest (Figure 2). Of note, the patient's left gonadal vein (Figure 1A) is non-dilated and drains normally into the left renal vein. In addition, the patient has a normal appearing, patent and uninterrupted right-sided IVC that drains the right renal vein into the IVC and ultimately into the right atrium (Figure 1A). Although there is no cross-sectional imaging of the chest or venography available for further evaluation, a frontal and lateral radiograph of the chest demonstrates a dilated azygos vein (Figure 3).

Discussion

Embryology of the inferior vena cava, renal veins, and azygous system

To understand the venous anomalies such as the one presented in this case, it is important to review the embryological development of the venous system. The development of the IVC, renal veins, and azygos venous system is a complex process involving the formation, regression, and

anastomosis of three paired embryonic veins: the posterior cardinal, subcardinal, and supracardinal veins.[6,7]

The IVC forms from segments of all three paired veins, with the infrarenal IVC developing from the right supracardinal vein, the renal segment developing from the right subcardinal vein and subcardinal-supracardinal anastomosis, and the suprarenal segment forming from the right vitelline and right subcardinal veins.[8] The left renal vein normally forms from the left subcardinal vein and intersubcardinal anastomosis.

The azygos venous system develops primarily from the right supracardinal vein (forming the azygos vein) and the left supracardinal vein (forming the hemiazygos vein). Anomalies in the regression or persistence of embryonic venous segments can lead to various venous malformations, classified as truncular malformations according to the International Union of Phlebology.[7]

The anomaly described in this case likely results from persistence of the left supracardinal vein with anastomosis to the left renal vein, coupled with regression of the normal subcardinal-derived connection between the left renal vein and the IVC. This developmental variation occurred while maintaining normal development of the right-sided IVC, resulting in this unique anatomic pattern.

This presentation of LRV drainage has not previously been described in the literature. As previously mentioned, common LRV variants include retroaortic or circumaortic left renal veins. LRV drainage through the azygos venous system is seen in patients with posterior nutcracker syndrome of a retroaortic left renal vein or with an interrupted IVC and azygos continuation, but

has not yet been described in a patient with a patent right-sided IVC that drains into the right atrium. This highlights the novelty of this anatomic venous variant.

Venous anomalies like the one described in this case are classified as truncular venous malformations according to the Hamburg classification system, representing developmental errors occurring in the later stages of embryonic vascular trunk formation (Lee *et al*., 2015).[7] Unlike extratruncular malformations, which retain evolving characteristics, truncular malformations are fully developed mature vessels with distinct hemodynamic impacts, making their preoperative identification crucial.

Various anomalies involving the azygos venous system have been reported in the literature. Chronic Cerebrospinal Venous Insufficiency (CCSVI) has been described in patients with multiple sclerosis, hypothesizing a relationship between impaired venous drainage through the internal jugular and azygos veins and MS pathophysiology.[9] Other documented anomalies include azygos continuation of the IVC, azygos lobe of the lung, partial or complete absence of the azygos vein, and variations in the number and course of the hemiazygos and accessory hemiazygos veins.[10,11] Renal vein anomalies, though typically asymptomatic, can occasionally present with flank pain, hematuria, varicocele in males or pelvic congestion syndrome in females.[12] These anomalies can have significant clinical implications, particularly in the context of surgical and interventional procedures, where misdiagnosis or vascular injury may occur.

The most significant clinical implications of this particular anomaly would be encountered during nephrectomy procedures, either for tumor resection or donor nephrectomy for transplantation. Knowledge of renal venous variations is critical for the safe performance of left donor nephrectomy.[13] Surgeons encountering this variant would need to modify their approach to identify, isolate, and secure the anomalous venous drainage pathway. During donor nephrectomy, this anomaly would necessitate careful planning to ensure adequate venous outflow reconstruction in the recipient.[14,15]

Aberrant renal venous anatomy is particularly worrisome with retroperitoneal surgery, including radical nephrectomy or renal transplantation, laparoscopic and robotic surgical approaches may make identification of variant vascular anatomy more challenging due to the smaller window for visualization intraoperatively. Pre-procedural planning with cross-sectional imaging is crucial to properly identify the anatomy prior to surgery and avoid potentially life-threatening complications such as hemorrhage. Detailed preoperative imaging has been emphasized in cases of complex venous anatomy to avoid inadvertent injury during surgery.[16] Similarly, Mu highlighted the value of 3D reconstruction in surgical planning for cases with venous anomalies.[17]

One endovascular implication of aberrant left renal venous drainage such as in our case includes IVC filter placement, as left gonadal or left renal vein thromboemboli would not be protected by a traditionally placed suprarenal IVC filter. In addition, the left renal, adrenal and gonadal veins cannot be accessed through normal pathways for procedures such as gonadal vein embolization, retrograde transvenous obliteration of gastric varices via a splenorenal shunt, or renal/adrenal

venous sampling. Attempting any of these endovascular procedures without prior knowledge of the cross-sectional anatomy would not only be difficult to perform intraoperatively, but also impossible to complete successfully.

Furthermore, the presence of a dilated azygos vein can be interpreted as a mediastinal mass on chest x-ray (Figure 3) and lead to additional unnecessary cross-sectional imaging with ionizing radiation. A dilated azygos vein can also complicate central venous access procedures such as PICC line, medication port, or central line placement as the catheter tip may unexpectedly land in the dilated azygos vein as opposed to the distal superior vena cava.

With an increasing focus on perioperative planning with imaging, variant vascular anomalies such as this can be identified early prior to surgical or endovascular intervention and appropriate surgical planning can be performed prior to intervention.

Conclusions

This manuscript describes a novel anatomic variant of the left renal vein by which drainage is through the azygos venous system via the hemiazygos vein, in the presence of a patent, uninterrupted right-sided IVC. To our knowledge this anomalous venous drainage of the LRV has not previously been described in the literature, and may be more prevalent given its asymptomatic nature and incidental discovery. As described, venous anomalies such as this may have significant implications particularly in renal surgery, including donor nephrectomy and tumor resection procedures, where recognition of the variant anatomy is essential for safe surgical outcomes.

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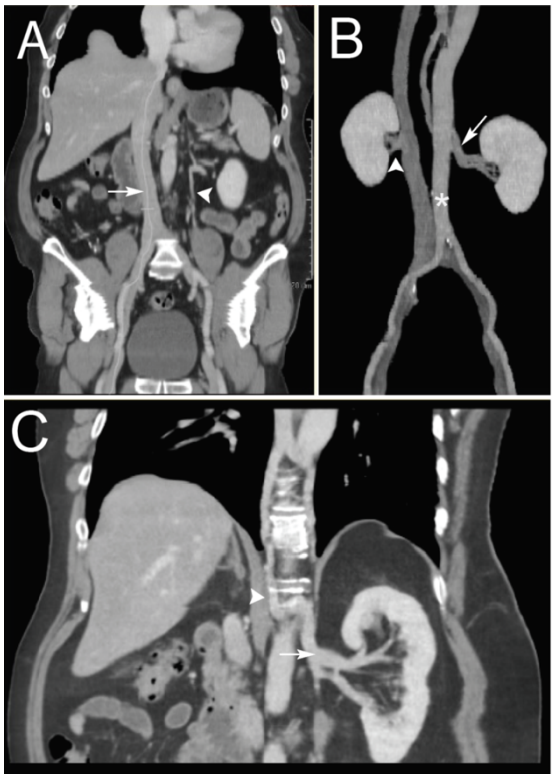

Figure 1. (**A**) Coronal contrast enhanced CT of the abdomen with MIP reformats demonstrates a normal appearing, right-sided, patent and uninterrupted IVC (arrow) as well as a non-dilated left gonadal vein with normal drainage into the left renal vein (arrowhead). (**B**) Coronal 3D MIP subtracted reconstruction depicts the right renal vein draining into the uninterrupted IVC (arrowhead), the left renal vein draining into the azygos venous system (arrow), and the unremarkable abdominal aorta (star). (**C**) Additional coronal CT with MIP reformat depicts the drainage of the left renal vein (arrow) into the azygos venous system (arrowhead).

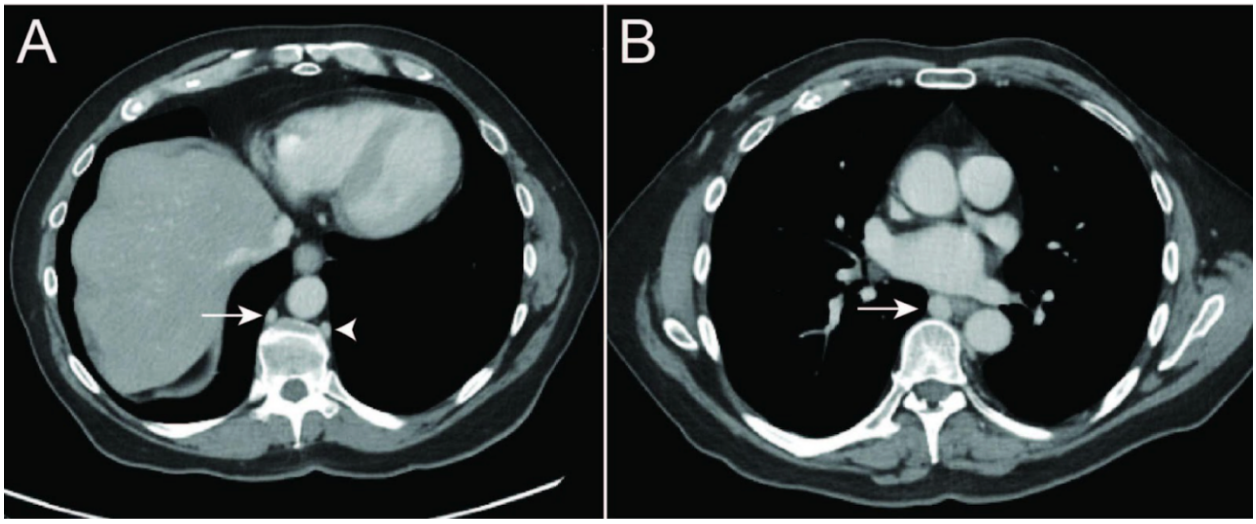

Figure 2. (**A**) Axial contrast-enhanced CT images of the upper abdomen and lower chest demonstrate a dilated hemiazygos vein (arrowhead) and azygos vein (arrow). (**B**) These veins join together into the chest (arrow).

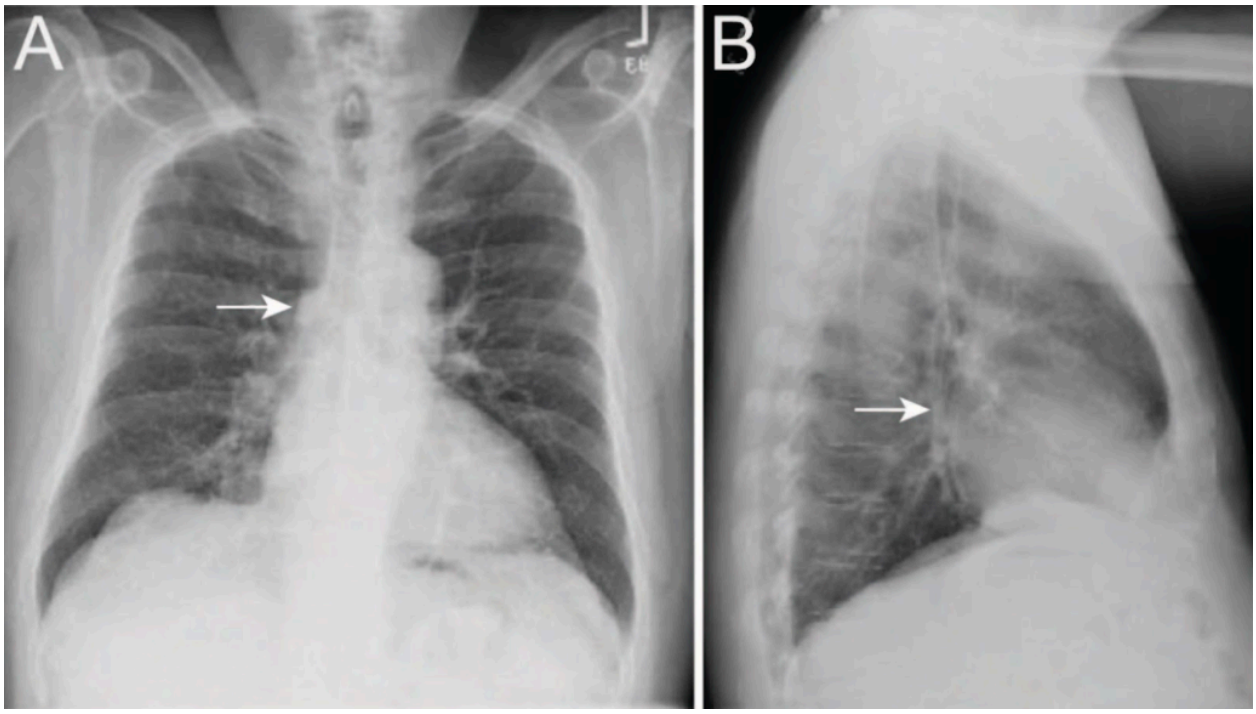

Figure 3. Frontal (**A**) and lateral (**B**) radiographs of the chest demonstrate a dilated azygos vein draining into the SVC (arrow).