

Rare Horseshoe Venous Confluence of Retroaortic Left Brachiocephalic Vein and Dual-Column Azygos Veins

Eric B. Lu

Saint Louis University

Tess A. Korte

Saint Louis University

Maureen R. Cranley

Saint Louis University

Joseph Cherullo

Saint Louis University

Yun Tan

Saint Louis University

Daniel T. Daly

daniel.daly@health.slu.edu

Saint Louis University

Research Article

Keywords: dual azygos column, horseshoe venous confluence, retroaortic left brachiocephalic vein, azygos venous system variation

Posted Date: July 25th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9999980/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Purpose.

The azygos system, vital for thoracic venous drainage, significantly varies due to complex embryologic development. Predominantly, the azygos, hemiazygos, accessory hemiazygos veins, and their tributaries comprise this system. This case presents a previously unreported azygos system variation with clinical implications for thoracic imaging and surgery.

Methods.

Routine anatomical dissection was performed on a 61-year-old male cadaver donated through the Saint Louis University School of Medicine's Gift Body Program.

Results.

A previously unreported horseshoe venous confluence, formed by a dual-column azygos venous system and associated with a retroaortic left brachiocephalic vein (LBCV), was identified between the fifth and sixth thoracic vertebral levels (TV5-TV6). Each azygos column received the fifth to eleventh posterior intercostal veins (PICVs) from its respective sides. The right azygos column received the first four PICVs via the right superior intercostal vein (SICV), which drained into the LBCV's posterior side. The left SICV was absent; the first four left PICVs drained directly into the retroaortic LBCV.

Conclusion.

This horseshoe venous confluence, formed within a unique dual-column azygos system and associated with a retroaortic LBCV, presents important clinical implications for imaging, interpretation, surgical planning, and procedural safety. The retroaortic LBCV and horseshoe venous confluence may complicate central venous catheter placements and increase venous injury risk. Aortic aneurysms may compress this atypical venous pathway, potentially compromising cardiac hemodynamics and venous return. Awareness of this unprecedented venous configuration supports improved medical education and clinical practice by emphasizing the role of anatomical variations in enhancing patient safety and outcomes.

Introduction

The azygos venous system primarily functions to drain venous blood from the body wall and select thoracic viscera upward into the superior vena cava (SVC). The azygos venous system also provides a collateral systemic passage between the SVC and the inferior vena cava (IVC) when there is an obstruction of either one. The azygos system consists of two longitudinal venous channels, positioned on either side of the vertebral column. The left channel is typically composed of the hemiazygos vein inferiorly and the accessory hemiazygos vein superiorly. The hemiazygos vein, formed by the left subcostal and left ascending lumbar veins, receives the left ninth through eleventh PICVs and then

typically drains into the azygos vein at the TV8-TV9 level. The accessory hemiazygos vein receives the left fifth through ninth PICVs and drains into the azygos vein at the TV7-TV8 level, which is superior to the drainage of the hemiazygos vein. However, these two left-sided veins can interconnect or independently drain into the azygos vein at different thoracic vertebral levels [1]. The right longitudinal channel is typically formed by the azygos vein. The azygos vein, formed by the right subcostal and right ascending lumbar veins, receives the fifth through eleventh right PICVs, the right SICV which is formed by the second through fourth PICVs, the hemiazygos vein, and accessory hemiazygos vein before draining into the SVC.

The complex embryologic development of the azygos venous system derives from caudal (posterior) cardinal veins. By Carnegie Stage 20, the azygos system develops from the cranial portions of the caudal cardinal veins [2]. Although the caudal cardinal veins regress caudally during development, their cranial segments persist and form the primary precursor of the azygos system. By the end of development's seventh week, the cranial portions of the caudal cardinal veins transform into the right-sided azygos vein and left-sided hemiazygos vein. Classical embryologic models attributed azygos venous system development to various contributions of the caudal cardinal, subcardinal, supracardinal, medial and lateral sympathetic line, and sacrocardinal veins. However, detailed analysis of a closely spaced series of human embryos demonstrated that the azygos venous system did not require contributions from separate supracardinal, sacrocardinal, or sympathetic line venous systems and instead developed directly from the caudal cardinal veins or from a plexus sprouting from the caudal cardinal veins [2].

On each side of the root of the neck, the subclavian vein and internal jugular vein unite to form the corresponding brachiocephalic vein, which drains blood from the head, neck, and upper limb on its respective side. The LBCV typically receives several tributaries including the left SICV, which is formed by the second, third, and occasionally fourth PICVs. In contrast, the shorter right brachiocephalic vein (RBCV) receives fewer direct tributaries, with venous drainage from the right SICV usually occurring via the azygos vein. The LBCV courses obliquely from left to right across the superior mediastinum, whereas the RBCV descends more vertically; together, they form the SVC.

Both brachiocephalic veins develop from the cardinal venous system. The RBCV develops from the proximal right anterior cardinal vein, right common cardinal, and right horn of sinus venosus. The LBCV forms from the left anterior cardinal vein and precardinal anastomosis with the right anterior cardinal vein [3, 4]. This is dependent on the regression of the middle and lower portion of the left common cardinal vein [4]. During the eighth week of fetal development, an anastomosis between the left anterior cardinal vein and the common cardinal vein becomes the LBCV [5]. Superior to anastomosis, the anterior cardinal vein becomes the internal jugular vein. Distal to this transverse anastomosis forms a part of the SVC [5].

The SICV is another highly variable venous structure in the thoracic cavity, with similar embryologic development from the cardinal veins. Due to the frequent occurrence of SICV anomalies, the eight most common variations of the right SICV and the six most common variations of the left SICV have been

categorized [6]. Variation type I account for 36.4% of right SICV variations and is characterized by the SICV collecting the second through fourth PICV and terminally draining into the azygos vein. Variation type III occurs in 9.1% of right SICV cases and is characterized by drainage of the first through fourth posterior intercostal veins with communication to the fifth PICV and termination into the azygos vein. The most common left SICV, type I, drains the second through fourth PICVs and communicates with the LBCV and the azygos system. In some cases, the SICV is absent. Previous studies reported over 50% of cases missing a left SICV and 8% of cases missing a right SICV [6].

The azygos system forms a vital collateral circulation pathway due to its connections between tributaries of the SVC and IVC. The cavo-caval and porto-caval connections provide alternative venous return pathways in cases of venous occlusion and portal hypertension. Serving as major sites for central venous access, the brachiocephalic veins are frequently used in clinical procedures like central venous catheter placement and venous chemotherapy port placement [4]. Anatomical variation of the azygos system or brachiocephalic veins can significantly impact both the physiology and the clinical practice involving central venous access and thoracic procedures.

Due to the complex network of vessels and tributaries within the azygos system, anatomical variation is possible. The azygos vein may anomalously drain into the RBCV or the right subclavian vein. Rare cases report the azygos vein passing through the aortic hiatus and directly draining into the right atrium [7]. More common variations include incomplete formation of the accessory hemiazygos and hemiazygos veins, direct drainage of the accessory hemiazygos vein into the hemiazygos vein as a common trunk, and additional anastomoses beyond the typical TV8-TV9 azygos connections [3]. These anastomoses between the accessory hemiazygos and hemiazygos veins usually form posterior to the aorta; however, in 3.6% of cases, common channels between the accessory hemiazygos vein and hemiazygos vein, known as interazygos veins, form ventral to the aorta [1]. It is very rare for the accessory hemiazygos vein and hemiazygos vein to have a direct connection and form a single continuous channel [1]. The brachiocephalic veins can also have an incidence of variation with the retroaortic LBCV reported to be present in 0.5% of cases [8]. While many variations have been observed, the incidence of combined brachiocephalic and azygos variations is rarely reported. Thus, this report aims to highlight the anatomy, relevance, and clinical impact of a previously unreported horseshoe confluence of the retroaortic left brachiocephalic vein and dual-column azygos veins.

Case Report

Dissection of a 61-year-old male cadaver revealed bilateral azygos columns that formed a horseshoe-shaped venous confluence at the TV5-TV6 vertebral level and connected to a retroaortic LBCV (Fig. 1A-B). The fifth to eleventh PICVs drained into their respective azygos columns (Fig. 1A). The right and left azygos columns measured 14.4 cm and 14.2 cm respectively, indicating near-identical lengths. The right azygos column was wider than the left both superiorly (6.40 mm vs. 4.32 mm) and inferiorly (3.39 mm vs. 2.95 mm). In contrast, the left azygos column exhibited greater width at the midportion (7.88 mm vs. 5.39 mm) (Fig. 1A-B).

Atypically, the retroaortic LBCV joined with the azygos horseshoe venous confluence at the TV4 level. The left first through fourth PICVs drained directly into the retroaortic LBCV, with the absence of the left SICV. The azygos horseshoe venous confluence measured 37.14 mm in length and 32.34 mm in width. Additionally, the right SICV, which received the right first through fourth PICVs, drained into the posterior aspect of the LBCV before joining the RBCV to form the SVC (Fig. 1A-B).

Discussion

During embryogenesis, the azygos venous system develops directly from the cranial remnants of the caudal cardinal veins. A duplicated or dual-column azygos venous system may result from bilateral persistence of the caudal cardinal veins [2]. Additionally, if there is abnormal development of the transverse anastomosis between the left and right anterior cardinal veins, a retroaortic LBCV can develop [8]. Thus, these variations in the azygos and LBCV development likely occurred during the fifth to eighth weeks of gestation due to abnormal venous remodeling [2, 5]. These unusual developmental patterns may account for the formation of a unique horseshoe-shaped venous confluence that drains both the retroaortic LBCV and the dual-column azygos structure observed in Figs. 1 and 2B.

A retroaortic LBCV is a rare venous anomaly, seen in 0.5% of patients with congenital cardiac abnormality, with a strong association to Tetralogy of Fallot and a right-sided aortic arch [8, 9]. Dual-column venous channels, interpreted as duplicated azygos veins, have been seen in up to 10% of cadaveric case studies [4]. However, a complete dual-column azygos system converging with a retroaortic LBCV to form a single, horseshoe-shaped venous confluence has not been previously described in the literature (Figs. 1 and 2B). Additionally, the 61-year-old male donor in this case was an individual with Down Syndrome, which is associated with higher rates of congenital variations. These anatomical variations are thought to be due to alterations in embryologic vessel development; however, the exact mechanisms underlying the association between Down Syndrome and congenital anatomic variation remain unclear [9]. This atypical development is a novel variant, expanding the spectrum of known azygos and brachiocephalic venous anomalies and emphasizes the need for refined classifications of thoracic venous anatomy.

Unusual venous formations in the posterior mediastinum can impact the interpretation of computed tomography (CT) angiography, especially in oncologic or trauma patients. A large, retroaortic venous confluence could be mistaken as a mediastinal lymphadenopathy, vascular malformation, a persistent left SVC or even an azygos vein aneurysm [10]. Misidentification of this structure may lead to diagnostic errors, unnecessary procedures such as biopsies, and increased patient fear. Thoracic venous anomalies can pose significant risks during cardiothoracic surgery, especially in aortic repairs, mediastinal mass resections, or pacemaker implantation. The presence of a retroaortic LBCV and anomalous venous confluence increases the likelihood of an iatrogenic venous injury. Moreover, these variations can complicate central venous access, especially via the left internal jugular or subclavian routes. In patients with kidney failure, tunneled hemodialysis catheters are often placed in the brachiocephalic veins when the internal and external jugular veins are not accessible. Thus, a retroaortic LBCV may lead to catheter

misplacement, prolonged procedures, or vessel perforation. Additionally, because the venous confluence is enlarged, it may be at risk of compression by aortic aneurysms or mediastinal tumors, resulting in venous obstruction or hemodynamic instability.

This case demonstrates the importance of venous variations in anatomy and radiology education. While standard anatomical curriculum emphasizes typical vasculature, venous anomalies are reported in the literature and can have equally critical implications for diagnosis, surgery, and interventional procedures. Cadaveric dissection remains an invaluable method for identifying rare variations, complementing imaging-based instruction, and strengthening spatial understanding. Documentation of such cases through anatomical donation programs continues to provide critical insights into clinical anatomy, embryologic diversity, and surgical risk.

Conclusion

This case study describes a previously unreported anatomical variation involving a horseshoe-shaped venous confluence formed from the convergence of a dual-column azygos system and its connection to a retroaortic left brachiocephalic vein. This unusual venous arrangement reflects a complex developmental pattern which has the potential to influence clinical decision-making across several contexts.

Detailed assessment of these rare variations may help guide planning in radiologic, surgical, and interventional fields to mitigate risks of serious complications, including major blood loss or accidental organ injury. Through anatomically informed care, accurate diagnosis and procedural safety may improve clinical practice. Sustained anatomic exploration and novel case reports like this remain critical to refine understanding of the diverse ways the thoracic venous system may present.

Declarations

Acknowledgements

The authors sincerely thank those who donated their bodies to science so that anatomical research could be performed. Results from such research can potentially increase mankind's overall knowledge that can then improve patient care. Therefore, these donors and their families deserve our highest gratitude.

To conduct this study, donor cadavers provided through the Saint Louis University School of Medicine Gift Body Program were used.

Funding

The authors have no relevant financial or non-financial interests to disclose. No funding was received to assist with the preparation of this manuscript.

Consent to Participate

Informed consent was obtained from the donor included in the study through the Saint Louis University Gift Body Program.

Consent to Publish

The participant has consented to the submission of the case report to the journal through the Saint Louis University Gift Body Program.

Compliance with Ethical Standards

Conflict of Interest

The authors declare that they have no conflicts of interest.

Research involving Human Participants and/or Animals

This study was performed on donated human cadaveric material obtained through the Saint Louis University Gift Body Program. No live human participants or animals were involved in this research.

Informed Consent

Signed informed consent for body donation and the use of donor tissues for education and research was obtained through the Saint Louis University Gift Body Program of the Center for Anatomical Science and Education (CASE).

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Eric B. Lu, Tess A. Korte, Marueen R. Cranley, and Joseph Cherullo. The first draft of the manuscript was written by Eric B. Lu and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

References

1. Blackmon JM, Franco A (2011) Normal variants of the accessory hemiazygos vein. *Br J Radiol* 84(1003):659–660. <https://doi.org/10.1259/bjr/13695502>
2. Hikspoors JP, Soffers JH, Mekonen HK, Cornillie P, Köhler SE, Lamers WH (2015) Development of the human infrahepatic inferior caval and azygos venous systems. *J Anat* 226(2):113–125. <https://doi.org/10.1111/joa.12266>
3. Bordoni B, Omole AE (2025) Anatomy, Thorax, Brachiocephalic (Innominate) Veins. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. Updated 9 Dec 2025. <https://www.ncbi.nlm.nih.gov/books/NBK544339/> PMID:31335059

4. Spratt JD (2016) Intrathoracic veins. In: Tubbs RS, Shoja MM, Loukas M (eds) Bergman's Comprehensive Encyclopedia of Human Anatomic Variation. Wiley, New York, NY, pp 832–853. <https://doi.org/10.1002/9781118430309.ch65>
5. Chen SJ, Liu KL, Chen HY, Chiu IS, Lee WJ, Wu MH, Li YW, Lue HC (2005) Anomalous brachiocephalic vein: CT, embryology, and clinical implications. *AJR Am J Roentgenol* 184(4):1235–1240. <https://doi.org/10.2214/ajr.184.4.01841235>
6. Liu HF, Xiong YL, Kim IB, Won HS, Jin CZ (2024) Morphologic variations of the superior intercostal vein: An anatomical study with clinical applications. *Clin Anat* 37(6):613–619. <https://doi.org/10.1002/ca.24106>
7. Piciucchi S, Barone D, Sanna S, Dubini A, Goodman LR, Oboldi D et al (2014) The azygos vein pathway: an overview from anatomical variations to pathological changes. *Insights Imaging* 5(5):619–628. <https://doi.org/10.1007/s13244-014-0351-3>
8. Curtil A, Tronc F, Champsaur G, Bozio A, Sassolas F, Carret JP (1999) The left retro-aortic brachiocephalic vein: morphologic data and diagnostic ultrasound in 27 cases. *Surg Radiol Anat* 21(4):251–254. <https://doi.org/10.1007/BF01631395>
9. Heinke D, Isenburg JL, Stallings EB, Short TD, Le M, Fisher S et al (2021) Prevalence of structural birth defects among infants with Down syndrome, 2013–2017: A US population-based study. *Birth Defects Res* 113(2):189–202. <https://doi.org/10.1002/bdr2.1854>
10. Kulkarni S, Jain S, Kasar P, Garekar S, Joshi S (2008) Retroaortic left innominate vein - Incidence, association with congenital heart defects, embryology, and clinical significance. *Ann Pediatr Cardiol* 1(2):139–141. 10.4103/0974-2069.43881. PMID: 20300257; PMCID: PMC2840759

Figures

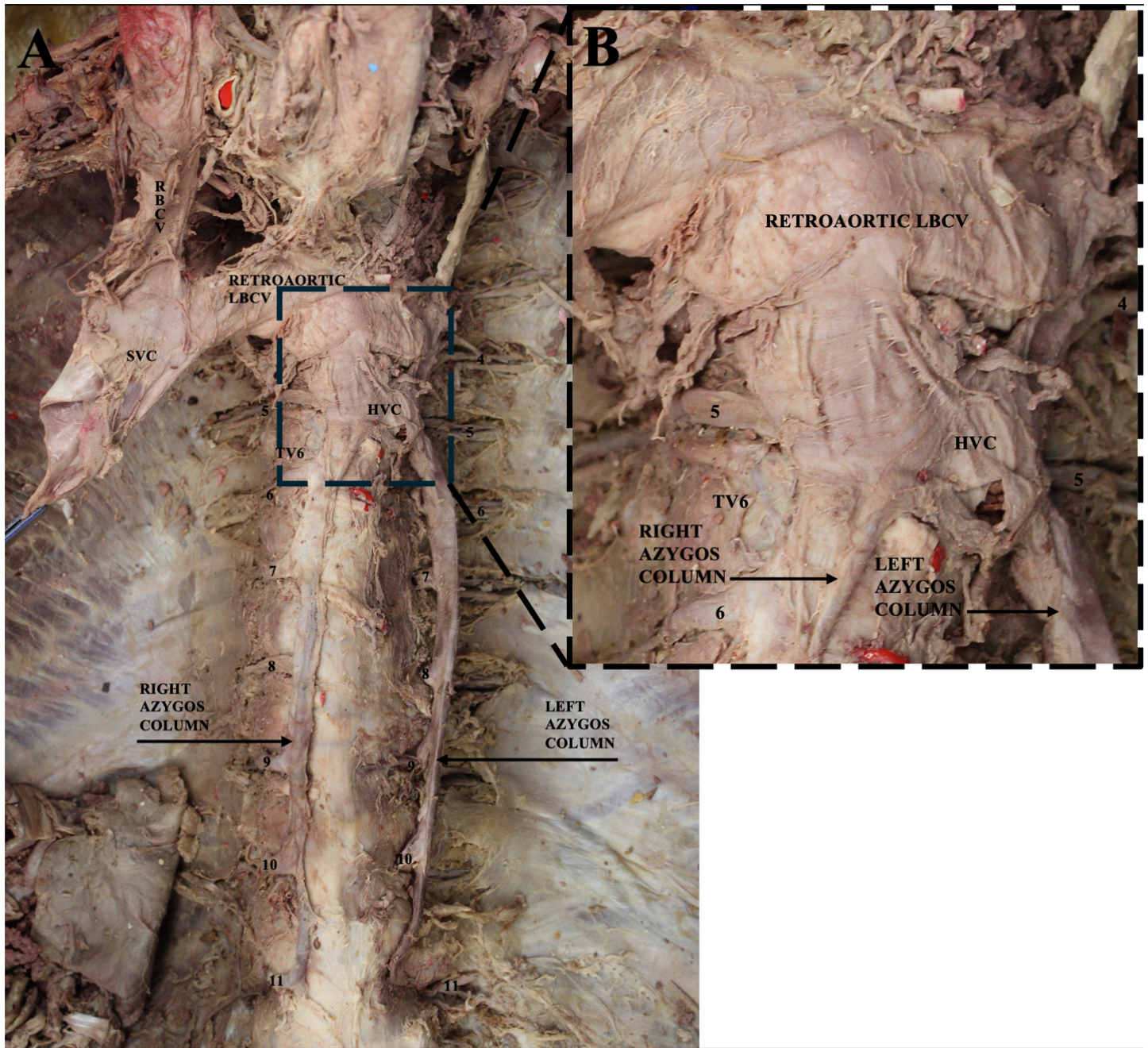


Figure 1

A) Posterior thoracic dissection showing bilateral azygos columns forming a horseshoe venous confluence (HVC) at the TV5-TV6 level, receiving the fifth through eleventh posterior intercostal veins, with abnormal junction of the retroaortic left brachiocephalic vein (LBCV) at the TV4 level **(B)** Magnified view of the HVC demonstrating the right and left azygos columns convergence and its connection with the retroaortic LBCV

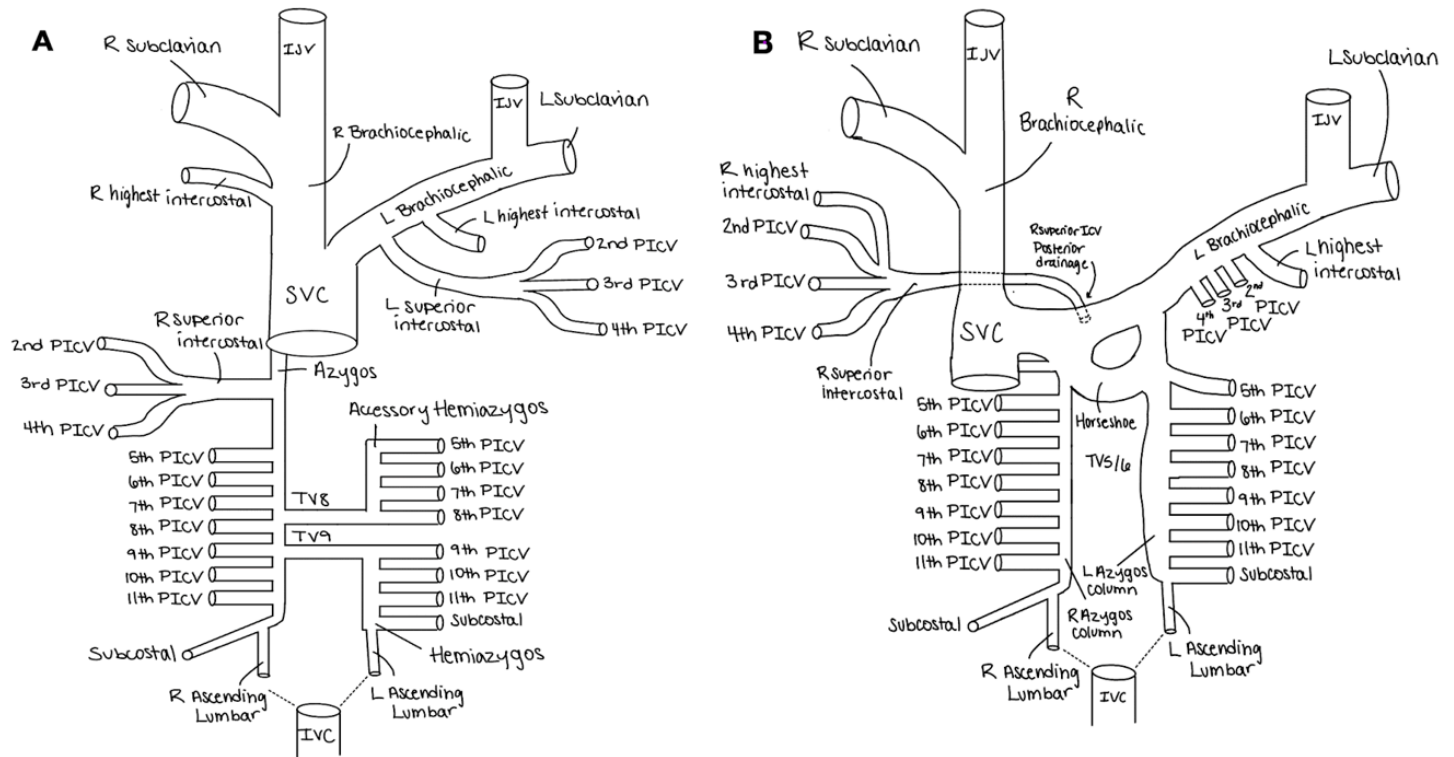


Figure 2

(A) A schematic diagram of the typical azygos venous system anatomy and **(B)** a schematic diagram of the horseshoe confluence formed by dual azygos columns with a retroaortic left brachiocephalic vein as observed in this case report