

An asymptomatic double aortic arch with separate right vertebral artery and left subclavian artery originating from Kommerell diverticulum combined with congenital asplenia and absence of celiac trunk

Efstratios Georgakarakos¹, Dimos Karangelis², Chrysovalantis Stylianou³,
Georgios I. Karaolanis⁴, Nikolaos Triantafyllou¹, Aliki Fiska⁵

¹Department of Vascular Surgery, University Hospital of Alexandroupolis, Democritus University of Thrace, Alexandroupolis, Greece

²Department of Cardiac Surgery, University Hospital of Alexandroupolis, Democritus University of Thrace, Alexandroupolis, Greece

³Department of Radiology, University Hospital of Alexandroupolis, Democritus University of Thrace, Alexandroupolis, Greece

⁴Vascular Unit, Department of Surgery, University Hospital of Ioannina, School of Medicine, Ioannina, Greece

⁵Department of Anatomy, Medical School of Alexandroupolis, Democritus University of Thrace, Alexandroupolis, Greece

[Received: 10 July 2023; Accepted: 7 November 2023; Early publication date: 30 October 2023]

This report describes the unique case of a completely patent Double Aortic Arch (DAA) combined with Kommerell diverticulum (KD), absence of celiac trunk, and congenital asplenia. The anatomical variants described were identified and assessed in a 51-year-old female from computed-tomography angiography (CTA) images with 3D-volume rendered reconstructions during her follow-up after hysterectomy. The reconstructed CTA images showed a DAA with the left common carotid artery stemming from the hypoplastic left aortic arch while the left subclavian artery originated from a KD in the descending thoracic aorta. A symmetric arrangement of the aortic arch branches was demonstrated, comprising a full vascular ring. Since the patient had been completely asymptomatic and with no symptoms of compression of the oesophagus or trachea, no surgical management was advised. The abdomen CTA imaging revealed absence of the celiac trunk with direct origin of the common hepatic and the left gastric artery from the superior mesenteric artery as well asplenia. The authors present a case of asymptomatic DAA of completely patent arches with the right vertebral artery branching separately of and the left SCA originating from KD in the descending aorta. The term KD can be identified also in arch anomalies other than the one originally described. Because anatomical anomalies can frequently be combined, thorough imaging inspection with CTA of both the thorax and abdomen is suggested. (Folia Morphol 2024; 83, 3: 727–733)

Keywords: gross anatomy, vascular rings, double aortic arch, aorticcongenital anomalies, anatomical variations

Address for correspondence: Prof. Efstratios Georgakarakos, MD, MSc, PhD, Democritus University of Thrace, Medical School and Department of Vascular Surgery, University Hospital of Alexandroupolis, 68100 Dragana, Alexandroupolis, Greece; e-mail: efstratiosgeorg@gmail.com

This article is available in open access under Creative Common Attribution-Non-Commercial-No Derivatives 4.0 International (CC BY-NC-ND 4.0) license, allowing to download articles and share them with others as long as they credit the authors and the publisher, but without permission to change them in any way or use them commercially.

INTRODUCTION

Aortic arch anomalies can result either from the persistence of 2 completely patent aortic arches (double aortic arch, DAA) or the presence of the anatomical continuity of both with an atretic segment in one of them (usually present as a fibrous band or ligament) [2, 18]. The variations emerging during the development of the aortic arch can lead to a wide variety of anomalies, the acknowledgement of which has significant meaning not only for cardiothoracic surgery but also for the rapidly emerging field of complex endovascular aortic surgery.

The commonest aortic arch variations include right aortic arch with aberrant left subclavian artery (SCA) originating from a Kommerell diverticulum (KD), left arch with aberrant right SCA stemming from KD, double aortic arch (DAA) with mirror imaging of the great vessels, right-sided aortic arch (RAA) with mirror imaging of the great vessels, and right arch with aberrant left innominate artery off the KD and circumflex aorta [2, 18].

Although DAA has been associated mainly with intracardiac malformations, the literature lacks reports on DAA with other vascular and extravascular anomalies. We present a case of asymptomatic DAA forming a vascular ring in an adult female combined with absence of celiac trunk and congenital asplenia. The need to scan for concurrent anatomic anomalies when initially detecting an aortic one is discussed.

CASE PRESENTATION

We illustrate the case of an asymptomatic 51-year-old female who underwent a computed-tomography angiography (CTA) as a standard follow-up control after hysterectomy. All CTA imaging examinations were conducted in a 128-slice CT scanner (PHILIPS INGENUITY CORE 128) with spiral technique of 0.625mm thickness after intravenous injection of contrast-agent. The CT acquisition parameters were prescribed as follows: 268 mAs, 120 kVp, 5 sec scan time, 22.1 mm feed/rotation ration, 2 mm slice thickness, 0.75–1.5 mm reconstruction spacing/increment, 0.5 mm slice overlap, and a 512 × 512 image matrix size. CT angiography was triggered at 150 Hounsfield units.

Chest X-ray had showed a RAA (Fig. 1A, arrow) with the computed tomography revealing mild deviation of the trachea and the oesophagus (Fig. 1B, C). A symmetric encirclement of the trachea by vascular structures was revealed (Fig.1D), but causing no strictures or symptoms. Her cardiac examination

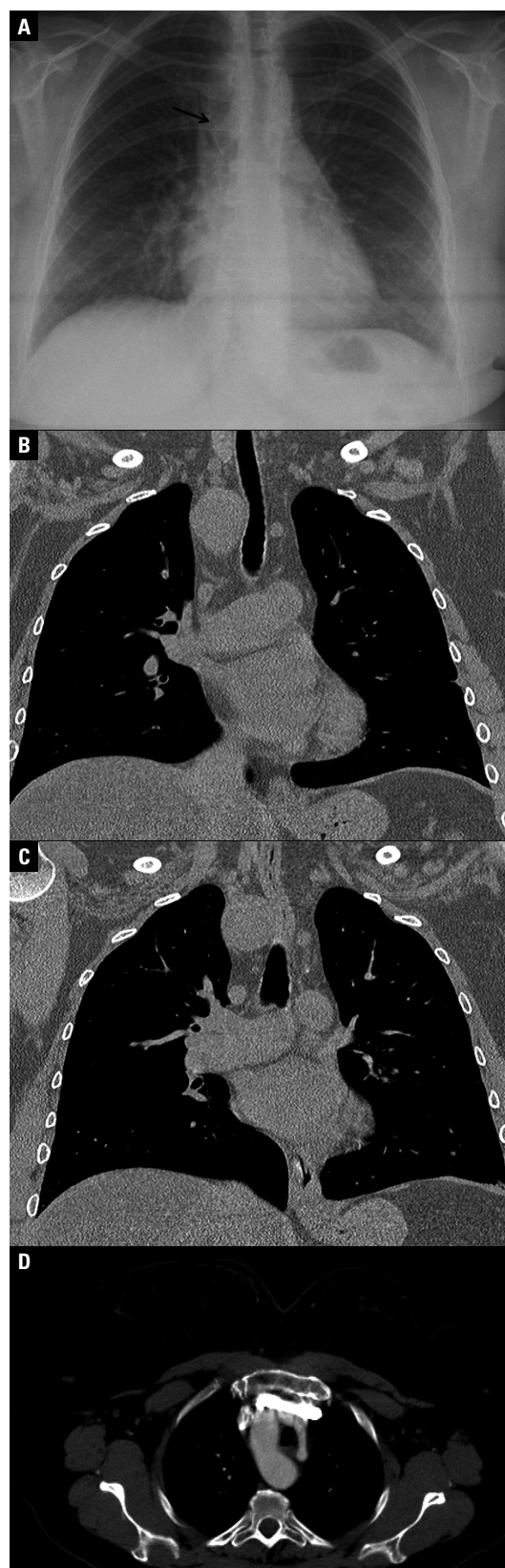


Figure 1A. Chest X-ray showing right-sided aortic arch (*arrow*) with mild deviation of the trachea (**B**) and the oesophagus (**C**). Computed tomographic scan showing the trachea encircled by aortic structure on the right and a left-sided vessel in the form of a vascular ring (**D**).

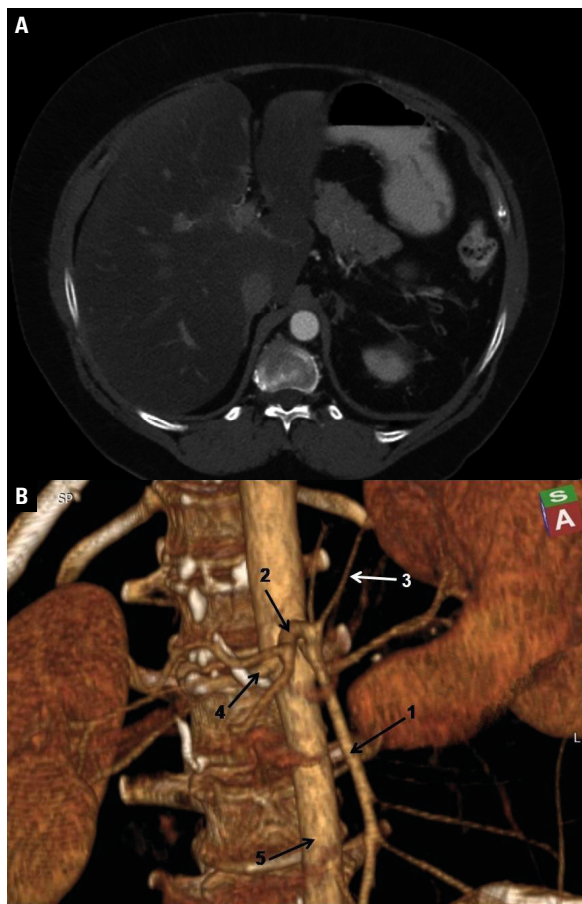


Figure 2A. Computed tomography showing complete absence of spleen. **B.** Absence of celiac trunk with direct origin of the gastric artery (LGA) and common hepatic artery (CHA) from the superior mesenteric artery (SMA). Note the normal origin of the inferior mesenteric artery (IMA) and the right renal artery (RRA). 1 — SMA; 2 — CHA; 3 — LGA; 4 — RRA; 5 — IMA.

excluded any cardiac anomalies (and, specifically, intracardiac defects) while her past medical history documented hysterectomy for endometrial cancer and inflammatory mesenteric panniculitis managed with corticosteroids.

The CTA revealed the absence of splenic artery (congenital, since there was no history of trauma or splenectomy) (Fig. 2A) and direct origin of the common hepatic artery (CHA) and the left gastric artery (LGA) from the superior mesenteric artery (SMA) (Fig. 2B). Moreover, the 3D volume rendering view (Fig. 3A) showed a morphology accordant with a DAA with the left common carotid artery (CCA) of 5mm stemming from the hypoplastic left aortic arch of 6.5 mm while the left SCA originated from a 12 × 16 mm KD (Fig. 3B). Moreover, a right isolated right vertebral artery (VA) was documented in a 3D volume rendering view of the superior thoracic inlet (Fig. 3C). The left

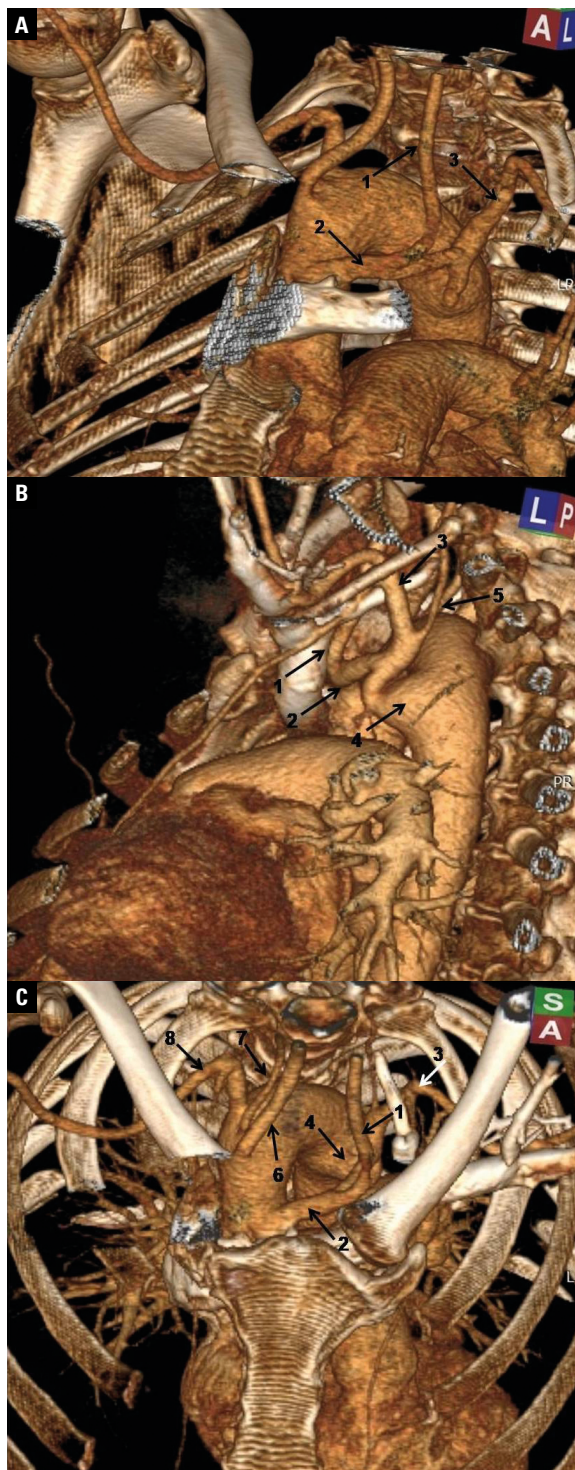


Figure 3A. 3D reconstruction of the computed tomography angiography shows the left common carotid artery (LCCA) stemming from a rudimentary left aortic arch (LAA). **B.** The left subclavian artery (LSA) originates from Kommerell's diverticulum (KD) and is connected to the LAA. (Note: the clavicles and sternum have been removed). **C.** While the left vertebral artery (LVA) originates from LSA, the right vertebral artery (RVA) originates separately between the right common carotid artery (RCCA) and the right subclavian artery (RSA). Note: the proximal right clavicle has been removed. 1 — LCCA, 2 — LAA, 3 — LSA, 4 — KD, 5 — LVA, 6 — RCCA, 7 — RVA, 8 — RSA.

common carotid artery (CCA) was tethered and deflected posteriorly (red arrow) to approximate the left SCA (Fig. 3C). A symmetric arrangement of the aortic arch branches was demonstrated in the three-dimensional (3D) volume-rendered images, comprising a full vascular ring. Since the patient had been completely asymptomatic and had no symptoms of compression of the oesophagus or trachea, no surgical management was advised. The patient is followed-up on an annual basis.

DISCUSSION

Vascular rings occur in less than 1% of all cardiovascular malformations and can cause symptoms related to the trachea and oesophagus compression, being diagnosed very early in life (infants and childhood) [2, 18]. After conducting a routine first-trimester ultrasound examination in 33,202 pregnancies, Vigneswaran et al. identified 5.4 and 1.5 per 10,000 cases of isolated RAA cases and DAA, respectively, comprising a 2–3 fold higher incidence than that reported in postnatal studies [23].

Embryologically, the paired dorsal and ventral aorta are connected by 6 paired branchial arches, the development of which begins by the second week of gestation and continues until the seventh week [16]. All of these arches are not present at the same time, but they appear and undergo regression sequentially in a cranial to caudal direction. The first, second, and fifth arches involute while the third, fourth, and sixth form the aortic branches. The third arch forms the common carotid and a segment of the internal carotid arteries, while the fourth arch forms the definitive aortic arch. The ventral portion of the sixth arch forms the distal segments of the pulmonary artery, while the dorsal portion of the arch gives the ductus arteriosus. The ventral aorta forms the truncus arteriosus, dividing later into the ascending aorta and the proximal segment of the main pulmonary artery. The paired dorsal aorta fuses to form a single trunk. The seventh intersegmental artery (branch of dorsal aorta) forms a part of the subclavian arteries. Normal left aortic arch is formed by the regression of the right aortic arch, right sided ductus, and right dorsal aorta. The proximal portion of right dorsal aorta forms part of right subclavian artery. The left dorsal aorta forms the distal aortic arch and the descending thoracic aorta [16].

DAA results from persistence of both the left and right fourth embryonic aortic arches and is impli-

cated in nearly half of the symptomatic cases. Three morphologies of DAA are recognised according to the dominance of the right or the left arch or their equivalence. Moreover, the ligamentum arteriosum running between the aorta and the left pulmonary artery is an additional factor that can cause compression to the trachea [3].

The term KD was initially introduced to describe an outpouching or dilatation of the proximal portion of an aberrant right SCA near its origin from a left aortic arch or the descending aorta with the diameter of the aberrant artery near its origin measuring twice the size of its distal diameter. Likewise, the term has also been used to describe the bulge in a RAA from which the aberrant analogue (i.e. left SCA) branches. Yu et al. described also the origin of a “nonaberrant-aberrant” left SCA arising from a KD located on the left side of a LAA, while Komiyama and Yasui documented the origin of a left SCA from a KD located on the right side of a LAA [12, 26]. Therefore, KD is used to describe a specific form of outpouching met also in normal arches, which is associated with an anomaly in the SCA development. It is not generally appreciated that patients with vascular rings due to DAA can also have a KD because “aberrant” arteries do not, by definition, exist in this anomaly [17]. However, in current clinical practice the KD term has also been adapted to describe a relevant bulge accompanying (less commonly) DAA [12].

DAA can be associated with segmental atresia of one of its arches; while the location of the atretic part either between the descending thoracic aorta and the left ligamentum arteriosum or between the latter and the SCA artery is mentioned commonly, the atresia between the left subclavian artery and the left CCA (i.e. the “C” segment) is reported extremely rarely [1]. Interestingly, it seems prudent to recognise that modern advanced imaging techniques can identify cases of incomplete DAA that previously would have been angiographically mistaken as RAA with aberrant left SCA, lowering the index of suspicion for KD in patients with DAA [3, 6, 8, 9, 11, 19]. Modern documentation of these variations should acknowledge the difference between a DAA with atretic left dorsal aortic arch from a normal mirror-image RAA, where the left dorsal aortic arch has been interrupted [10].

The presence of a KD in our case is rather unusual, because KD has been associated with RAA with dorsal left arch atresia or with aberrant left SCA [3, 10]. Backer et al. have recently addressed the presence of KD in

a series of operated patients with symptomatic DAA; however, the distal left aortic arches were atretic in all patients [3]. The presence of the particular variant in our case cannot be explained based on the existing schemes proposed in the literature.

Because the patient was asymptomatic, no surgical management was undertaken. DAA can be asymptomatic and, therefore, documented for the first time in old age [6, 8, 9]. Occasionally they can present late symptoms owing to atherosclerotic changes of the aorta (e.g. becoming tortuous or aneurismal), age-related changes of the chest, or further dilatation of the KD. Some authors suggest a KD > 1.5 times the aberrant left SCA origin as an operative indication for primary resection [3, 25].

DAA can be accompanied also by anomalies in its branches with respect to their morphology or origin [19]. Our case demonstrates separate take-off of the right CCA, SCA, and VA. Embryologically, involution of the 1st–5th cervical intersegmental arteries with persistence of the 6th and 7th and involution of longitudinal connection between these led to a separate origin of the right SCA [7]. Moreover, the absence of an innominate artery is anticipated because both aortic arches were preserved with maintenance of the dorsal segments between the 7th cervical intersegmental artery and the descending aorta.

The existence of DDA in our case was combined with congenital asplenia and the absence of the celiac trunk; rather, the common hepatic and left gastric artery originated directly from the superior mesenteric artery while the inferior mesenteric artery branched normally from aorta. The celiac trunk is absent in 0.1–4% of cases [14, 22, 24]. The celiac axis, the superior mesenteric artery, and their major aortic branches frequently show diverse anomalies in their origins. Wang et al. [24] classified systematically complex variant origins of the celiac axis, the superior mesenteric artery and their major branches based on a retrospective evaluation of 1500 abdominal multi-detector CTA images, identifying a hepatomesenteric trunk in 4.47% of cases.

Notably, Natsis et al. [15] identified 8 types of aortic arch variations with respect to the origins and anatomical relations of the vessels. The generated symptoms can include dyspnoea, dysphagia but also misinterpretation of radiological examinations and complications during neck and thorax surgery [15]. More interestingly, the authors underline that such variations are frequently accompanied by other con-

genital abnormalities [15]. Indeed, it is our belief that when a “single” vascular anomaly is identified — whether symptomatic or not — the patient should also be examined for other anomalies not exclusively detected in the vascular system. This tack is nowadays significantly facilitated by the evolved, sophisticated, and easily utilised imaging modalities providing detailed anatomic information. Although DAA has been reported to accompany intracardiac anomalies, its association with asplenia has been reported only scarcely, whereas the combination in our case (i.e. DAA with asplenia and absence of celiac trunk) has never been reported [4].

3D volume-rendered imaging modalities not only provide thorough morphological inspection of anatomical variations and anomalies of the aortic arch but also enable preoperative planning in the modern era of staged or hybrid endovascular treatments where the detailed mapping of the size, origin sites, and take-off angles of aortic branches are of paramount importance [13, 20, 21]. Also, the incidence of aortic arch variants such as bovine aortic arch, isolated left VA, and aberrant right SCA is significantly increased in patients undergoing surgical management for thoracic aortic disease; for example, a recent study by Dumfarth et al. [5] recorded a prevalence of 33.5% of arch anomalies among 556 patients operated for thoracic aortic disease when compared with the general population (18.2%). In this study, the patients with aortic branch variations were significantly younger and needed aortic arch intervention more frequently than patients with normal arch anatomy. Therefore, atypical branching variants should no longer be considered clinically irrelevant or innocent — let alone aortic arch anomalies or combinations of these entities — but rather markers for thoracic aortic disease.

CONCLUSIONS

We presented a case of asymptomatic DAA with completely patent arches depicting a separate origin of the right VA and the presence of KD in the descending aorta giving rise to the left SCA. The term KD can be applied also in arch anomalies other than the one originally described because these analogue morphologies share the same potential complications and pose the same surgical difficulties when receiving the traditional surgical treatment or modern endovascular options. Since anatomical anomalies can be frequently combined, thorough imaging inspection with CTA of both thorax and abdomen is suggested.

ARTICLE INFORMATION AND DECLARATIONS

Ethics statement

All patients gave approval for the operative illustrations. Permission to reproduce material from other sources: no third-party material was used.

Author contributions

Efstratios Georgakarakos: conceptualisation; investigation; methodology; project administration; writing — original draft. Dimos Karangelis: writing — original draft & editing. Chrysovalantis Stylianou: investigation; methodology. Georgios I. Karaolanis: writing — original draft & editing. Nikolaos Triantafyllou: writing — original draft & editing. Aliko Fiska: supervision & editing.

Funding

The manuscript received no funding.

Conflict of interest

The authors declare that there is no conflict of interest.

REFERENCES

- Adachi I, Krishnamurthy R, Morales DLS. A double aortic arch mimicking a right aortic arch with an aberrant subclavian artery. *J Vasc Surg.* 2011; 54(4): 1151–1153, doi: [10.1016/j.jvs.2011.04.045](https://doi.org/10.1016/j.jvs.2011.04.045), indexed in Pubmed: [21784601](https://pubmed.ncbi.nlm.nih.gov/21784601/).
- Atkin GK, Grieve PP, Vattipally VR, et al. The surgical management of aortic root vessel anomalies presenting in adults. *Ann Vasc Surg.* 2007; 21(4): 525–534, doi: [10.1016/j.avsg.2007.04.001](https://doi.org/10.1016/j.avsg.2007.04.001), indexed in Pubmed: [17521875](https://pubmed.ncbi.nlm.nih.gov/17521875/).
- Backer CL, Bharadwaj SN, Eltayeb OM, et al. Double aortic arch with Kommerell diverticulum. *Ann Thorac Surg.* 2019; 108(1): 161–166, doi: [10.1016/j.athoracsur.2019.01.062](https://doi.org/10.1016/j.athoracsur.2019.01.062), indexed in Pubmed: [30849335](https://pubmed.ncbi.nlm.nih.gov/30849335/).
- Dixon CM, Dyar D, Aurigemma D, et al. Double choker: double aortic arch with bilateral aortic coarctation associated with heterotaxy-asplenia syndrome and complex atrioventricular canal defect. *CASE (Phila).* 2020; 4(3): 142–145, doi: [10.1016/j.case.2020.02.001](https://doi.org/10.1016/j.case.2020.02.001), indexed in Pubmed: [32577594](https://pubmed.ncbi.nlm.nih.gov/32577594/).
- Dumfarth J, Chou AS, Ziganshin BA, et al. Atypical aortic arch branching variants: a novel marker for thoracic aortic disease. *J Thorac Cardiovasc Surg.* 2015; 149(6): 1586–1592, doi: [10.1016/j.jtcvs.2015.02.019](https://doi.org/10.1016/j.jtcvs.2015.02.019), indexed in Pubmed: [25802134](https://pubmed.ncbi.nlm.nih.gov/25802134/).
- Garti IJ, Aygen MM, Vidne B. Type C double aortic arch. Double aortic arch with aberrant left subclavian artery. *Cardiovasc Radiol.* 1978; 1(3): 143–145, doi: [10.1007/BF02552023](https://doi.org/10.1007/BF02552023), indexed in Pubmed: [743709](https://pubmed.ncbi.nlm.nih.gov/743709/).
- Hashemi S, Parks WJ, Sallee D, et al. Double aortic arch with previously undescribed head and neck vessel branching. *Can J Cardiol.* 2017; 33(4): 555.e21–555.e23, doi: [10.1016/j.cjca.2016.11.020](https://doi.org/10.1016/j.cjca.2016.11.020), indexed in Pubmed: [28159377](https://pubmed.ncbi.nlm.nih.gov/28159377/).
- Kafka H, Uebing A, Mohiaddin R. Adult presentation with vascular ring due to double aortic arch. *Congenit Heart Dis.* 2006; 1(6): 346–350, doi: [10.1111/j.1747-0803.2006.00062.x](https://doi.org/10.1111/j.1747-0803.2006.00062.x), indexed in Pubmed: [18377508](https://pubmed.ncbi.nlm.nih.gov/18377508/).
- Kajikawa Y, Takemoto S, Suganami Y, et al. Asymptomatic double aortic arch. *Intern Med.* 2005; 44(4): 356–357, doi: [10.2169/internalmedicine.44.356](https://doi.org/10.2169/internalmedicine.44.356), indexed in Pubmed: [15897653](https://pubmed.ncbi.nlm.nih.gov/15897653/).
- Kaldararova M, Simkova I, Varga I, et al. Double aortic arch anomalies in children: a systematic 20-year single center study. *Clin Anat.* 2017; 30(7): 929–939, doi: [10.1002/ca.22955](https://doi.org/10.1002/ca.22955), indexed in Pubmed: [28726262](https://pubmed.ncbi.nlm.nih.gov/28726262/).
- Kleine P, Balci M, Moritz A. Primary complete repair of partial double aortic arch and Kommerell diverticulum. *Ann Thorac Surg.* 2011; 91(2): 627–629, doi: [10.1016/j.athoracsur.2010.06.060](https://doi.org/10.1016/j.athoracsur.2010.06.060), indexed in Pubmed: [21256339](https://pubmed.ncbi.nlm.nih.gov/21256339/).
- Komiyama M, Yasui T. Left subclavian artery originating from Kommerell diverticulum in the left aortic arch. *J Thorac Cardiovasc Surg.* 2006; 132(6): 1477, doi: [10.1016/j.jtcvs.2006.08.014](https://doi.org/10.1016/j.jtcvs.2006.08.014), indexed in Pubmed: [17140986](https://pubmed.ncbi.nlm.nih.gov/17140986/).
- Mangialardi N, Ronchey S, Kasemi H, et al. Hybrid treatment option for aortic arch anomalies and descending thoracic aortic aneurysm. *J Vasc Interv Radiol.* 2013; 24(7): 1063–1065, doi: [10.1016/j.jvir.2013.03.031](https://doi.org/10.1016/j.jvir.2013.03.031), indexed in Pubmed: [23796094](https://pubmed.ncbi.nlm.nih.gov/23796094/).
- Mao Yi, Yao Y, Li X, et al. Absence of the celiac trunk: Definition, classification, multidetector computed tomography angiographic findings, and their probable embryological mechanisms. *Vascular.* 2023; 31(6): 1214–1221, doi: [10.1177/17085381221106318](https://doi.org/10.1177/17085381221106318), indexed in Pubmed: [35634715](https://pubmed.ncbi.nlm.nih.gov/35634715/).
- Natsis KI, Tsitouridis IA, Didagelos MV, et al. Anatomical variations in the branches of the human aortic arch in 633 angiographies: clinical significance and literature review. *Surg Radiol Anat.* 2009; 31(5): 319–323, doi: [10.1007/s00276-008-0442-2](https://doi.org/10.1007/s00276-008-0442-2), indexed in Pubmed: [19034377](https://pubmed.ncbi.nlm.nih.gov/19034377/).
- Priya S, Thomas R, Nagpal P, et al. Congenital anomalies of the aortic arch. *Cardiovasc Diagn Ther.* 2018; 8(Suppl 1): S26–S44, doi: [10.21037/cdt.2017.10.15](https://doi.org/10.21037/cdt.2017.10.15), indexed in Pubmed: [29850417](https://pubmed.ncbi.nlm.nih.gov/29850417/).
- Saeed G, Neuzner J, Gradaus R. Double aortic arch and Kommerell's diverticulum. *Asian Cardiovasc Thorac Ann.* 2014; 22(7): 882–883, doi: [10.1177/0218492313503642](https://doi.org/10.1177/0218492313503642), indexed in Pubmed: [24887877](https://pubmed.ncbi.nlm.nih.gov/24887877/).
- Saran N, Dearani J, Said S, et al. Vascular rings in adults: outcome of surgical management. *Ann Thorac Surg.* 2019; 108(4): 1217–1227, doi: [10.1016/j.athoracsur.2019.04.097](https://doi.org/10.1016/j.athoracsur.2019.04.097), indexed in Pubmed: [31229482](https://pubmed.ncbi.nlm.nih.gov/31229482/).
- Sierra-Galan LM, Shveid-Gerson D, Gomez-Garza G, et al. Double incomplete aortic arch and Kommerell's Diverticulum as a cause of chronic cough. *Arch Cardiol Mex.* 2015; 85(2): 158–160, doi: [10.1016/j.acmx.2014.12.009](https://doi.org/10.1016/j.acmx.2014.12.009), indexed in Pubmed: [25700574](https://pubmed.ncbi.nlm.nih.gov/25700574/).
- Tanaka K, Yoshitaka H, Chikazawa G, et al. Hybrid repair of right aortic arch aneurysm with a Kommerell's di-

- verticulum. *Asian Cardiovasc Thorac Ann.* 2014; 22(6): 725–727, doi: [10.1177/0218492313481465](https://doi.org/10.1177/0218492313481465), indexed in Pubmed: [24887812](https://pubmed.ncbi.nlm.nih.gov/24887812/).
21. Tigkiropoulos K, Kousidis P, Lazaridis I, et al. Hybrid repair of distal aortic arch dissection aneurysm with dissected kommerell diverticulum. *Vasc Endovascular Surg.* 2020; 54(4): 375–377, doi: [10.1177/1538574420911261](https://doi.org/10.1177/1538574420911261), indexed in Pubmed: [32270759](https://pubmed.ncbi.nlm.nih.gov/32270759/).
 22. Venieratos D, Panagouli E, Lolis E, et al. A morphometric study of the celiac trunk and review of the literature. *Clin Anat.* 2013; 26(6): 741–750, doi: [10.1002/ca.22136](https://doi.org/10.1002/ca.22136), indexed in Pubmed: [22886953](https://pubmed.ncbi.nlm.nih.gov/22886953/).
 23. Vigneswaran TV, Jabak S, Syngelaki A, et al. Prenatal incidence of isolated right aortic arch and double aortic arch. *J Matern Fetal Neonatal Med.* 2021; 34(18): 2985–2990, doi: [10.1080/14767058.2019.1676413](https://doi.org/10.1080/14767058.2019.1676413), indexed in Pubmed: [31578117](https://pubmed.ncbi.nlm.nih.gov/31578117/).
 24. Wang Yi, Cheng C, Wang Lu, et al. Anatomical variations in the origins of the celiac axis and the superior mesenteric artery: MDCT angiographic findings and their probable embryological mechanisms. *Eur Radiol.* 2014; 24(8): 1777–1784, doi: [10.1007/s00330-014-3215-9](https://doi.org/10.1007/s00330-014-3215-9), indexed in Pubmed: [24859597](https://pubmed.ncbi.nlm.nih.gov/24859597/).
 25. Yu Di, Guo Z, You X, et al. Long-term outcomes in children undergoing vascular ring division: a multi-institution experience. *Eur J Cardiothorac Surg.* 2022; 61(3): 605–613, doi: [10.1093/ejcts/ezab432](https://doi.org/10.1093/ejcts/ezab432), indexed in Pubmed: [34632492](https://pubmed.ncbi.nlm.nih.gov/34632492/).
 26. Yu PJ, Balsam LB, Mussa FF, et al. Aberrant left subclavian artery associated with a Kommerell's diverticulum and a left-sided aortic arch. *J Card Surg.* 2012; 27(5): 607–608, doi: [10.1111/j.1540-8191.2012.01520.x](https://doi.org/10.1111/j.1540-8191.2012.01520.x), indexed in Pubmed: [22978838](https://pubmed.ncbi.nlm.nih.gov/22978838/).