Frequency and Imaging Findings of Variations in Human Aortic Arch Anatomy Based on Multidetector Computed Tomography Data

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Purpose

To describe the frequency of the variations in the positioning and branching pattern of the aortic arch according to multidetector computed tomography imaging findings in an unselected population.
Methods and Materials

A total of 1361 consecutive patients referred to the radiology department between January 2009 and June 2010 for computed tomography (CT) of the chest or CT angiography of the thoracic aorta or the pulmonary arteries were considered for the study, irrespective of the indication for the examination. A local ethics committee approval has been obtained for the study.

The CT examinations were performed on a 8 channel MDCT system (GE Medical Systems, Milwaukee, WI, USA). Data retrieval and analysis was performed using a patient archive and communication system (PACS) Workstation (Centricity RA 1000, GE Medical Systems, Milwaukee, WI, USA). The anatomy of the AA and its branches were evaluated in axial and multiplanar reformatted (MPR) images retrospectively by two radiologists at the same time by consensus. The axial CT images were interpreted first, followed by MPR images at the same review session. The studies suggesting a variation were reevaluated for a second time at a later session. The data were recorded on an imaging evaluation form.

We used the term 'bovine-type arch' when the RSA, RCCA and the LCCA stemmed from the arcus within a single common trunk. It can be either a common root of the LCCA and the BA or origination of the LCCA and the BA from a common trunk.

Arch sidedness was evaluated according to the position of the AA with respect to the trachea as it crossed a mainstem bronchus. A "right-sided arch" was diagnosed when the AA curved to the right side of the trachea, crossing the right main bronchus in a ventral-to-dorsal direction.

CT examinations without a contrast enhancement were not included in the study. Examinations in which the technical quality of the procedure (e.g motion artifact, inadequate distribution of contrast medium) rendered a thorough assessment of the vascular structures difficult were also excluded. As a result of this, 1136 cases were considered suitable for the evaluation and analysis.
Results

Eleven different branching patterns of the AA were observed, including the normal configuration.

In 845 patients (74.4%) the arch branching had a normal configuration, with three branches arising from the AA: 1- BA, branching later into RSA and RCCA, 2- LCCA and 3-LSA.

The most common anatomical variant was the bovine-type arch, observed in 240 patients (21.1%): 1- RSA, RCCA and LCCA arising from a common root, 2- LSA (Fig. 1).

The second most common variation which occurred in 41 patients (3.7%) was an independent origin of the left vertebral artery (LVA) from the AA (Figs. 2-5). In 33 of these patients a four-branch pattern was observed: 1- BA, branching into RSA and RCCA, 2- LCCA, 3- LVA, 4- LSA (Fig. 2). Five patients had a three-branch pattern: 1- common origin of RSA, RCCA and LCCA as in the bovine-type, 2- LVA, 3- LSA (Fig. 3). In 3 patients the origin of the LVA was distal to the LSA: 1- common origin of the RSA, RCCA and LCCA, 2- LSA, 3- LVA in 2 patients (Fig. 4) and 1- BA, 2- LCCA, 3- LSA, 4- LVA in 1 patient (Fig. 5).

An aberrant retro-oesophageal RSA (ARORSA) was the third most common anomaly in 8 patients (0.8%) (Figs. 6-7). Three different configurations were observed in this group. Four patients had 1- RCCA, 2- LCCA, 3- LSA, 4- ARORSA. In one of these patients a total occlusion in the proximal segment of the ARORSA was present, resulting in blood pressure difference between the two arms (Fig. 6). Three patients had 1- RCCA and LCCA with a common origin (bicarotid trunk), 2- LSA, 3- ARORSA (Fig. 7). One patient had 1- a bicarotid trunk, 2- LVA arising independently, 3- LSA, 4- ARORSA.

A right sided AA was observed in 2 patients (0.2%), with further variations also present in this group. One of these patients had mirror-image branching of the vessels: 1- a left BA branching into LSA and LCCA, 2- RCCA, 3- RSA (Fig. 8). A Kommerell diverticulum was present in this patient (Fig. 8). An aberrant LSA was seen in the other patient: 1- LCCA, 2- RCCA, 3- RSA, 4- aberrant LSA.
Images for this section:

**Fig. 1:** Axial MDCT image of a patient with bovine-type arch showing the brachiocephalic artery and the left common carotid artery originating from the common root (bovine-typed arch) (white arrow).

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Fig. 2: Oblique coronal MPR MDCT image of a patient with left vertebral artery arising directly from the arch. BA indicates brachiocephalic artery; LCCA, left common carotid artery; LSA, left subclavian artery; LVA, left vertebral artery.

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Fig. 3: Left oblique volume rendered 3D MDCT images showing bovine-type arch (arrow head), left vertebral artery arising directly from the arch (small white arrow), and left subclavian artery (large white arrow).

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Fig. 4: Left oblique coronal MPR MDCT image of the bovine-type arch in combination with a left vertebral artery arising directly from the arch distal to the left subclavian artery. LCCA indicates left common carotid artery; LSA, left subclavian artery; LVA, left vertebral artery.

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**Fig. 5:** Left sagittal oblique MPR MDCT image showing the left vertebral artery arising independently distal to the left subclavian artery. BA indicates brachiocephalic artery; LCCA, left common carotid artery; LSA, left subclavian artery; LVA, left vertebral artery.

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Fig. 6: Coronal MPR MDCT image showing the aberrant retro-oesophageal right subclavian artery (arrow).

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**Fig. 7**: Axial MDCT image showing the aberrant retro-oesophageal right subclavian artery.

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Fig. 8: Axial MDCT image showing right-sided arch with mirror-image branching of vessels and the aortic diverticulum. AA indicates aortic arch.

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Conclusion

There is a wide range of variability in the frequency of different branching patterns of the AA, depending on the population studied. Most of the current knowledge on the subject is based on several post-mortem and a few radiological study series dating back to the 19th century. Until recently, clinical reports describing the radiological or surgical findings have been limited to selected individual cases, far from reflecting the distribution of these variations on a population basis. Meanwhile, recent developments in radiodiagnostic techniques and increasing availability and widespread use of these tools created a new source of data available from unselected living subjects.

Four large series depicting the frequency of AA variations based on radiological data have been recently published. The first, by Natsis et al. reports conventional angiography findings of 633 patients from Thessaloniki, Greece (4). An other study, by Jakanini et al. analyzes MDCT data from 861 patients from Leicester, UK, possibly of diverse ethnicity, as the authors stated (1). Thirth one, by Berko et al. reports CT angiograms of 1000 patients from Bronx, America (19). The last and the largest one, by Müller et al. reveals 2033 contrast CT scans from Ulm, Germany (18). In our study, although a demographic analysis is not intended, it is possible to accept that the patient profile reflects the population characteristics of a typical middle-sized anatolian province.

To our knowledge, this is one of the largest series relying on radiological data. It also adds data from Turkish population to already existent British, Greek, Amerikan and German series. Comparing the findings in the current study to those in the order, ethnically different populations have similar aortic arch branching patterns. The widespread use of MDCT for several indications other than vascular diseases may provide a rich information source for future studies involving larger patient populations.
References


