Asian Biomedicine Vol. 5 No. 6 December 2011; 817-823 DOI: 10.5372/1905-7415.0506.106

Original article

Aortic arch branches' variations detected on chest CT

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Background: Knowing aortic arch branches' variations before surgery of supraaortic arteries is important. Failure to detect critical variation at surgery may cause serious consequences. There is different incidence of variation reported in the literatures, and is possibly due to different race.

Objective: We determined the incidence and pattern of the aortic arch branches' variation in Asian adults observed in chest computed tomography (CT).

Materials and methods: We retrospectively reviewed 687 chests CT between January 2006 and April 2007. The incidence and pattern of variations of aortic arch branches were analyzed.

Results: Of 687 studies, the variations of aortic arch branches were present in 76 patients. Six of 76 patients had more than one variant. The incidence of each variation was as follows: 5.97% common origin of left common carotid artery and brachiocephalic artery or left common carotid artery arising from brachiocephalic artery, 4.08% left vertebral artery arising from aortic arch, 0.29% right vertebral artery arising from brachiocephalic artery, 0.29% right vertebral artery arising from right common carotid artery, 1.16% aberrant right subclavian artery and 0.15% common origin of left common carotid artery and right common carotid artery with aberrant right subclavian artery.

Conclusion: There are some racial variations of the aortic arch branches. Our data provide information on the incidence of aortic arch branches' variations in an Asian population. Despite these variations are usually asymptomatic, they may cause symptoms or complication during surgery of the head, neck and thorax in certain conditions.

Keywords: Aortic arch branch, variation, vascular anatomy

Wide spectrum of variation of great arteries at the thoracic region is well recognized [1-4]. Since the computed tomography (CT) has been performed increasingly, congenital abnormalities of the aortic arch and great vessels are often readily detected. Awareness of anomalous origins has the significant impact for the surgery and intervention in the neck and thorax [1]. Failure to recognize a critical aortic arch branch variation at surgery may cause serious consequences. For example, injury to the vertebral artery from cervical spine surgery is increased in case with anomalous vertebral artery [5]. Therefore, preoperative imaging studies such as magnetic resonance imaging or CT should be carefully reviewed to prevent the complication. The incidence of variation of the aortic arch branches from previous studies in different race ranged from 5% to 35% [1, 3, 6-11]. There has been only one study on anomalies of the subclavian artery in cadavers in Thailand [12]. However, to our knowledge, no study includes all anomalies of the aortic arch branches in our country. Furthermore, there is no study reporting the variation by using CT. The aim of our study is to determine incidence and pattern of aortic arch branches' variations in our population detected by contrast-enhanced chest CT.

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Materials and methods

The study was approved by the Institutional Review Board (IRB), Faculty of Medicine, Chulalongkorn University. Six hundred eighty seven studies of post contrast enhanced chest CT between January 2006 and April 2007 were retrospectively reviewed.

All the MDCT scans were obtained using 16-channel multi-detector CT scanner (Somatom sensation 16, Siemens Medical solution, Germany). The post contrast images to assess aortic arch and aortic arch branches were obtained 50 seconds after 80 ml intravenous bolus of non-ionic contrast material (Iobitridol, 350mgI/mL; Xenetix or Iopromide 370mgI/mL; Ultravist), using the power injector with the rate of 2-5 ml/sec. The scanning parameters were contiguous 0.75-mm collimation at 120 kVp, 100 mAs. The slice thickness was generally reconstructed at 5 mm for axial images. The multiplanar reconstruction (MPR) or maximum intensity projection (MIP) techniques were used in every study.

The inclusion criterion was Asian adults who are at least 15 years old. We excluded the patients who previously underwent chest vascular operation, patients with the lesion that complicated the images analysis, congenital heart disease, aortic arch anomaly, dextrocardia, non-contrast CT and chest CT that did not include the origins of all aortic arch branches.

All CT images were retrospectively analyzed independently using a picture archiving and communication system (PACS) by two experienced radiologists. Disagreements on the variations were resolved by consensus review. The aortic arch was considered as normal if it gives three branches of the brachiocephalic artery (BCA) with right subclavian artery (RSA) and right common carotid artery (RCCA) as its branches, left common carotid artery (LCCA) and left subclavian artery (LSA) in succession from right to left. All variations and each pattern were calculated as percentage.

Results

Six hundred eighty seven patients, age 18-94 years, 361 male and 326 female were included and then analyzed.

The demographic data and variations are shown in **Table 1**. The variations of aortic arch branches are found in 76 patients (11.06%), and 6 of 76 patients had combination of anomalies. Of these 76 patients, 41 patients having common origin of BCA and LCCA (**Figure 1**) or LCCA arising from BCA (**Figure 2**); 28 patients, left vertebral artery (LVA) arising from aortic arch (**Figure 3**); 2 patients, right vertebral artery (RVA) arising from BCA (**Figure 4**); 2 patients, RVA arising from RCCA (**Figure 5**); 8 patients having aberrant RSA (**Figure 6**); and another one patient having common origin of LCCA and RCCA (bicarotid trunk) with aberrant RSA (**Figure 7**). Six of 76 patients who had more than one variation of aortic arch branches were as follows;

1. Two had common origin of BCA and LCCA with LVA arising from aortic arch i.e. three branches arising from aortic arch; 1) common origin of BCA and LCCA, 2) LVA and 3) LSA.
2. One had LVA arising from aortic arch and RVA arising from BCA i.e. four branches arising from aortic arch; 1) BCA giving branch of RVA, 2) LCCA, 3) LVA, and 4) LSA.
3. One had LVA arising from aortic arch and RVA arising from RCCA i.e. four branches arising from aortic arch; 1) BCA with RVA arising from RCCA, 2) LCCA, 3) LVA, and 4) LSA.
4. One had bicarotid trunk and LVA arising from aortic arch and aberrant RSA i.e. four branches arising from aortic arch; 1) bicarotid trunk, 2) LVA, 3) LSA and 4) aberrant RSA.
5. One had aberrant RSA with RVA arising from RCCA i.e. four braches arising from aortic arch; 1) RCCA which giving branch of RVA, 2) LCCA, 3) LSA, and 4) RSA.

Table 1. Demographic data of each variation of aortic arch branches in this study

Variation	Male	Female	Total	Percent
Common origin of LCCA and BCA	17	17	34	4.95
LCCA arising from BCA	3	4	7	1.02
LVA arising from aortic arch	21	7	28	4.08
RVA arising from BCA	1	1	2	0.29
RVA arising from RCCA	1	1	2	0.29
Aberrant right subclavian artery	1	7	8	1.16
Bicarotid trunk with aberrant RSA	1	-	1	0.15
Total variation	45	37	82	11.94

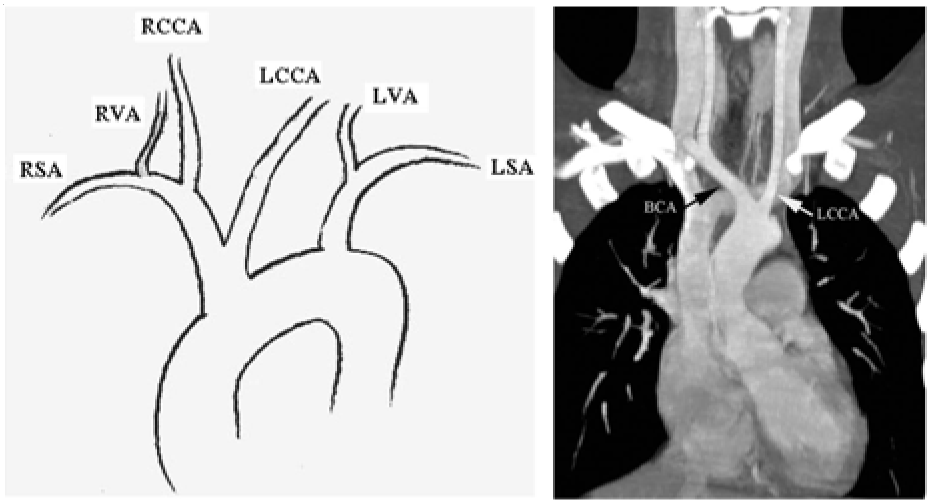

Figure 1. Schematic and chest CT coronal MIP reconstruction show common origin of the brachiocephalic artery (BCA) and left common carotid artery (LCCA).

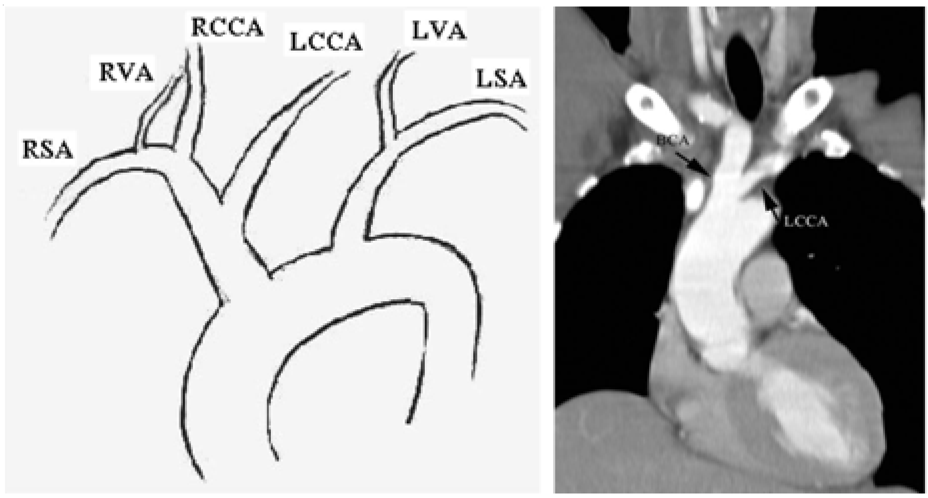

Figure 2. Schematic and chest CT coronal MPR reconstruction show the left common carotid artery (LCA) arising from brachiocephalic artery (BCA).

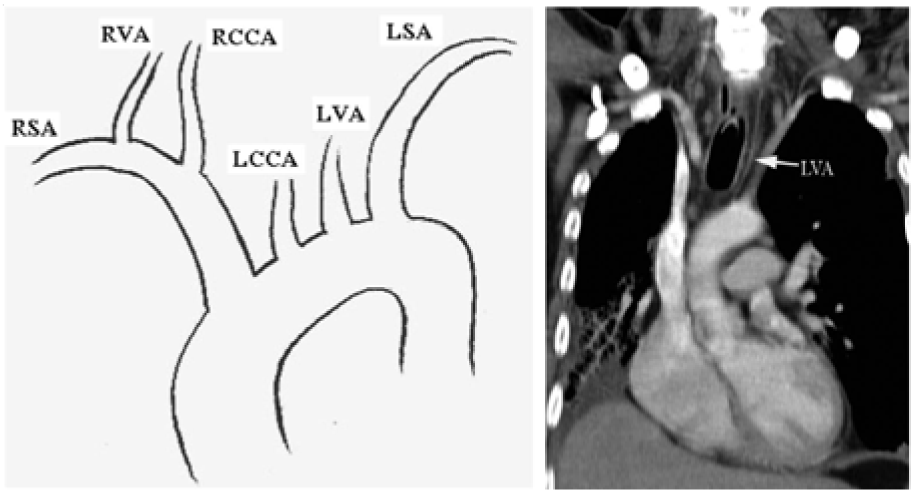

Figure 3. Schematic and chest CT coronal MPR reconstruction show left vertebral artery (LVA) arising directly from the aorta proximal to the left subclavian artery (LSA).

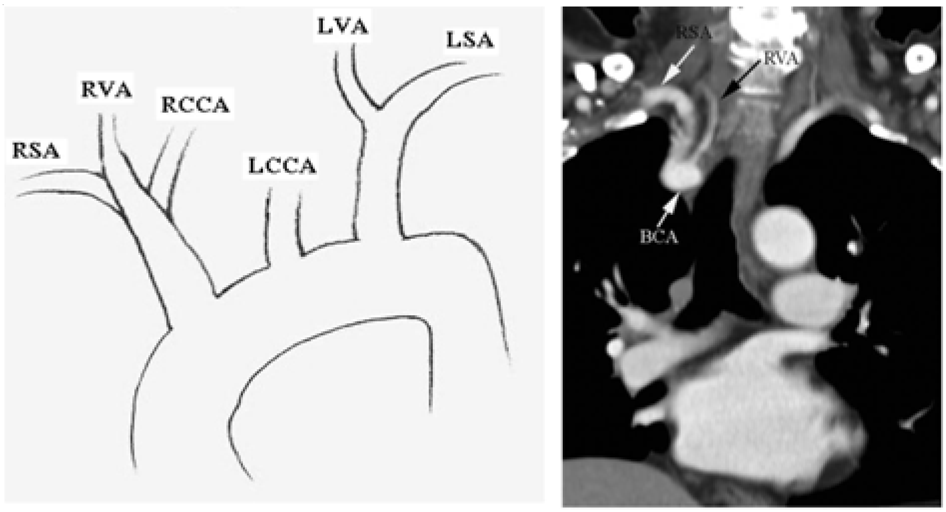

Figure 4. Schematic and chest CT coronal MPR reconstruction show right vertebral artery (RVA) arising from brachiocephalic artery (BCA).

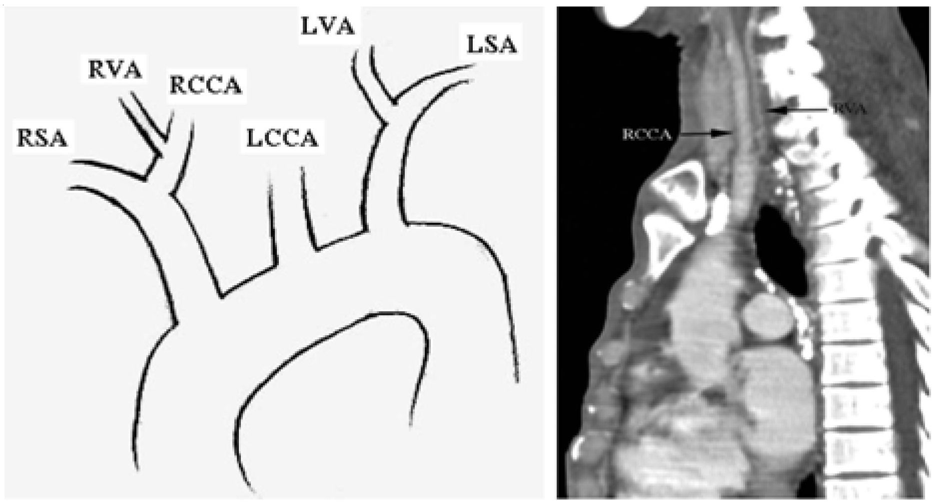

Figure 5. Schematic and chest CT sagittal MPR reconstruction show right vertebral artery (RVA) arising from the right common carotid artery (RCCA).

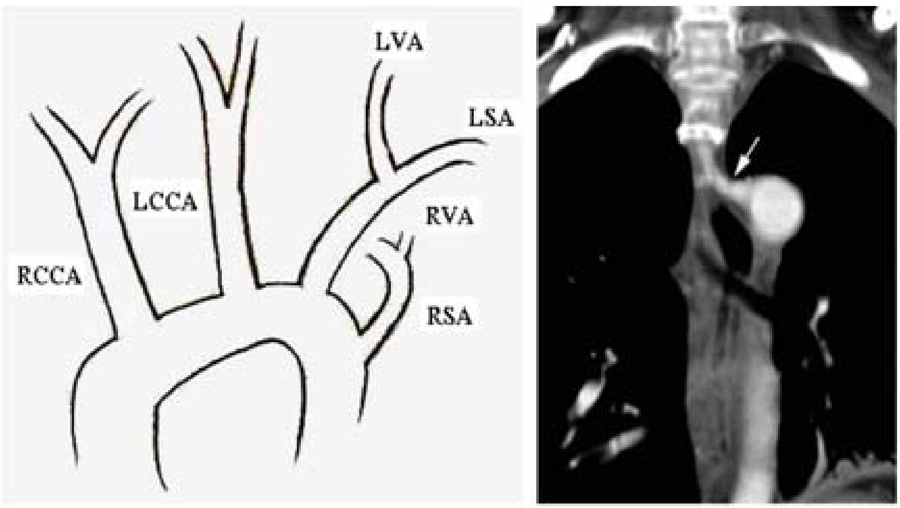

Figure 6. Schematic and chest CT coronal MPR reconstruction show aberrant right subclavian artery (RSA, arrow) arising from aortic arch as the last branch.

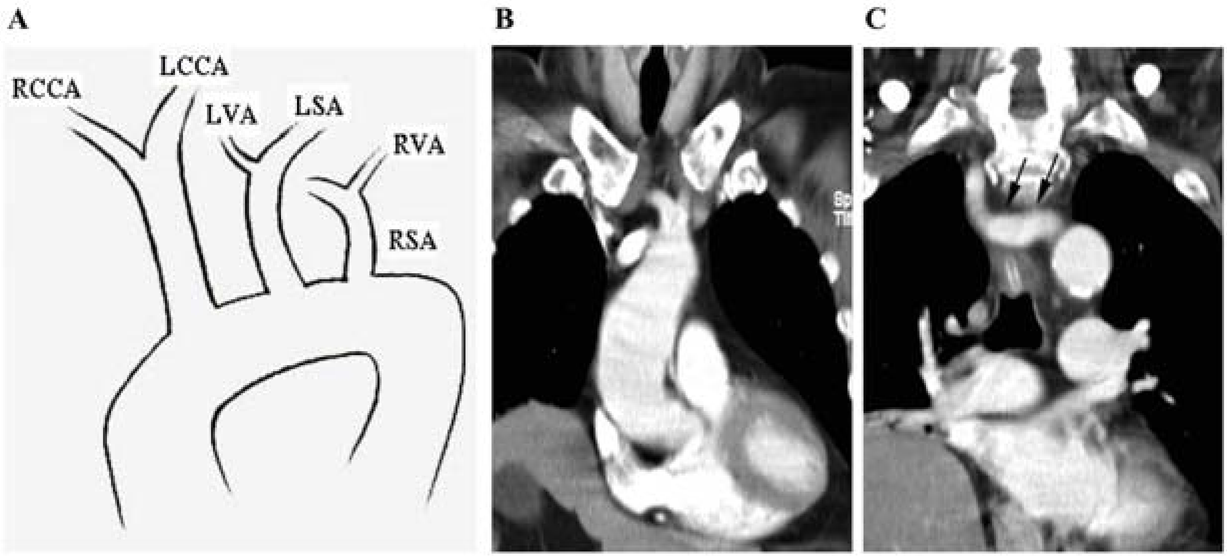

Figure 7. Schematic (**A**) and chest CT coronal MPR reconstruction (**B, C**) shows common origin of right and left common carotid arteries (bicarotid trunk) (**A, B**) with aberrant right subclavian artery (arrows in **C**)

Discussion

The aortic arch develops from the aortic sac, left fourth aortic arch and part of the left dorsal aorta [4]. The primordial aortic arch pattern becomes modified to the final fetal arterial arrangement during the eighth week [13]. Alteration in the extent of the fusion process and absorption of some of aortic arch during embryonic period results in variation of aortic arch branches.

Overall, the variation of aortic arch branches in our population were 11.06%, which was comparable to the study of Nayak et al in Indian population (9.6%) [1], but was lower than the study of Caucasian Greek by Natsis et al (17%), and was higher that study of Bhatia et al in south Australian population (7.41%) [4], and of Nelson and Sparks in American-Japanese men (6.2%) [2]. In our study, the most common variation was common origin of LCCA and BCA or LCCA arising from BCA, which was similar to the study on Nayak et al. This variant was found more often in blacks [8]. It is also called bovine aortic arch, a misnomer. Cattle has only a single great vessel originating from the aortic arch, a brachiocephalic trunk, which gives rise to both subclavian arteries and a bicarotid trunk, and the bicarotid trunk then bifurcates into the LCCA and RCCA [8]. Despite this variation rarely causes clinical symptom, stenosis, or occlusion of a common trunk can cause severe ischemic consequences [14]. It may also attribute to widening of superior mediastinum [3].

The second most common variation in our study was the LVA arising from the aortic arch (4.08%), which was comparable to the study on Nelson and Spark (4.15%) [2]. Bhatia et al were reported higher incidence of this variant (7.41%), and they postulated that this may be due to both genetic and environmental causes which may include changes in maternal nutrition, healthcare and a multitude of other environmental factors [4]. This variation was reported to have higher incidence of vertebral artery dissection than normal origin of vertebral artery [15], and can cause variant of subclavian steal syndrome with resultant brain ischemia [16]. In cases that vertebral artery originating from the carotid artery or its branches, the ligation of the common carotid artery may compromise the posterior fossa blood supply [17].

The incidence of aberrant RSA in our study was 1.16%, which was comparable to the study of Apichitruengdej and Chentanez (0.89%) [12] and to study of Nayak et al [1]. This variation may cause esophageal compression with resultant dysphagia, a syndrome known as dysphagia lusoria. In long-term placement of nasogastric tube, the possibility of fistulization and fatal hemorrhage should be aware. Additionally, the right recurrent laryngeal nerve cannot form a loop around the aberrant RSA, the non-recurrent laryngeal nerve, and may complicate in some operations such as thyroidectomy [18]. The details are shown in **Table 2**.

Table 2. Comparison of incidence of each variation of aortic arch branches to other studies (%)

Variation	**Present study** (n=676)	**Nayak et al** [1] (n=62)	**Nelson and Sparks** [2] (n=193)	**Natsis et al** [3] (n=633)	**Bhatia et al** [4] (n=83)
1. Common origin of LCCA and BCA or LCCA arising from BCA	5.97	4.8	1.04	15	-
2. LVA arising from aortic arch	4.08	1.6	4.15	0.79	7.41
3. RVA arising from BCA	0.29	-	-	-	-
4. RVA arising from RCCA	0.29	-	-	-	-
5. Aberrant RSA	1.16	1.6	-	-	-
6. Common origin of LCCA from BCA with aberrant RSA	0.15	-	-	0.16	-
7. Two brachiocephalic trunks with left coronary artery originating from aortic arch directly	-	1.6	-	-	-
8. Four vessels arising from the aortic arch: RSA, LSA, RCCA and LCCA	-	-	0.52-	-	-
9. Three vessels arising from aortic arch: RSA, bicarotid trunk and LSA	-	-	-	0.16	-
10. Two vessels arising from aortic arch: bicarotid trunk, common trunk of RSA and LSA	-	-	-	0.16	-
11. Four vessels arising from the aortic arch: RSA, RCCA, LCCA and LSA	-	-	-	0.16	-
12. Four vessel arising from the aortic arch: BCA, thyroidea ima artery, LCCA and LSA	-	-	-	0.16	-
Total	11.94	9.6	5.71	17	7.41

The difference in incidence of variation of aortic arch among the various reports could be possibly due to the different race of the population [3]. Thailand's population is a diverse entity comprising of people from different races and ethnicities. Ten to 15% of population is of Chinese descent. There are also Malaysian, Lao, Vietnamese, Burmese, Mon, Cambodian, and a significant number of registered foreigners from Asia, Europe, and North America in Thailand. The overall incidence of aortic arch branches' variation and of bovine aortic arch, the most common variation in our study, was comparable to the study in Indian population [1]. The incidence of LVA arising from aortic arch was similar to the study of Nelson and Spark in American-Japanese.

The drawback of our study is that some minor variants such as thyroidea ima artery may not be detected by CT. In addition, in case of aplasia or hypoplasia of the vertebral artery was possibly unintentionally excluded.

Conclusion

There are some racial variations of the aortic arch branches. Our data provide information in the incidence of aortic arch branches' variations in an Asian population. Despite these variations are usually asymptomatic, they may cause symptoms or complication during surgery of the head, neck and thorax in certain conditions. .

Acknowledgement

We would like to thank Chowarat Sritananun for assisting to retrieve the CT from the picture archiving and communication system (PACS). The authors have no conflict of interest to report.

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