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Diameters of three major branches of arch of aorta and their correlation with each other, age and gender- A computed tomographic study

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Abstract

Objective: Objective of the study was to determine the normal range of the diameters of three major branches of arch of aorta brachiocephalic trunk (BCT), left common carotid artery (LCCA), left subclavian artery (LSA) and to correlate diameters of branches of aortic arch with each other, age and gender.

Material and Method: Multi slice CT scans were performed on 84 subjects (both male and female) in department of Anatomy, in collaboration with department of Radiology of Moti Lal Nehru Medical College, Allahabad and Kriti scanning center, Allahabad. The diameters of BCT, LCCA and LSA were measured at just distal to its origin from arch of aorta.

Results: Mean diameter of BCT, LCCA and LSA were 1.14±0.20 cm, 0.71±0.16 cm and 0.93±0.17 cm respectively. Significantly high correlation was found between BCT and LCCA ($r=0.62$, $p<0.001$), BCT and LSA ($r=0.59$, $p<0.001$) and LCCA and LSA ($r=0.59$, $p<0.001$). Mean diameters of all three branches were increasing with the increase of age. Mean diameters of all variables were slightly higher in males as compared to females. Comparing the mean diameters between the two genders, t test revealed similar ($p>0.05$) diameters between the two genders i.e. not differed statistically.

Conclusion: Among, branches of arch of aorta, the mean diameter of brachiocephalic trunk was the highest and left common carotid artery was the least (BCT > LSA > LCCA). Age had significant effect on diameters (diameters of branches of arch of aorta). Knowledge of normal diameters of branches of arch of aorta is helpful in the cardiovascular surgery, such as stenting and aneurysm.

Keywords: Radiological study, arch of aorta, brachiocephalic trunk, left common carotid artery, left subclavian artery.

Introduction

Like other mammals, Humans have a closed circulatory system. The main components of this closed circulatory system are the heart, blood vessels and blood. There are three main types of blood vessels in the human body: arteries, veins and capillaries.[1]

The aorta is the largest principal artery of the human body. It gives off branches that go to the head, neck, arms, the major organs in the chest and abdomen, and the legs. The diameter of vessel at any given height tends to increase slightly with age.[2] The aortic arch begins at the origin of the right brachiocephalic artery and ends at the attachment of the ligamentum arteriosum. The descending thoracic aorta begins after the ligamentum arteriosum and extends to the aortic hiatus in the diaphragm. The ascending aorta is normally always larger than the descending aorta.[3]

The aortic arch and its branches are important anatomical structures for both surgeons and interventionalists. Aneurysms or dissections of the aortic arch need to be treated with complex surgical procedures. These procedures evolved to enable replacement of the aortic arch and reconstruction of its continuity to the aorta and supra-aortic arteries with less risk of ischemic and/or embolic cerebral damage.

Computed tomographic aortography is a superb modality to assess diseases of the aorta. After the introduction of helical computed tomography (CT) in the late 1980s, imaging of the aorta became a routine procedure for evaluation of the aorta in patients with aortic dissection, stenosis, or aneurysm formation.[4]

In performing endovascular surgery, the most common technique is to puncture the femoral artery and advance a catheter toward the aortic arch through the abdominal aorta, as well as the major branches originating from the aortic arch. However, despite the improvement of catheter quality and the rapid development of fluoroscopic imaging, this usual technique may be very difficult to perform in some cases due to the anatomical variations of the aortic arch and its major branches. Also, serious complications may develop due to these procedures.[2,5]

Knowledge of normal diameters of aortic arch and its branches may help surgeons in performing surgery and stenting of aortic arch and its branches.

Aims and Objective

1. To determine the expected normal range of the diameters of three major branches of arch of aorta brachiocephalic trunk (BCT), left common carotid artery (LCCA) and left subclavian artery (LSA),

2. To correlate diameters of branches of aortic arch with each other.
3. Effect of age and gender on the diameters

Material and Method

Study was conducted in department of Anatomy in collaboration of department of Radiology of M.L.N. Medical College, Allahabad and Kriti scanning center, Allahabad (U.P.) covering the peripheral population. This was a prospective, cross sectional, observational study to create reference ranges for diameter of brachiocephalic trunk, left common carotid artery and left subclavian artery at its origin from aortic arch (Fig. 1).

Exclusion Criteria

- Subjects with poor visualization of the aorta, any aortic arch variations, long standing hypertension, previous history of thoracic aortic aneurysm, atherosclerosis.
- History of prolonged substance abuse, such as alcohol, smoking or tobacco.

Multi slice CT scans were performed on 84 subjects and Reconstruction was achieved every 4 mm with the 180° linear interpolation algorithm. Multi planar reconstruction (MPR) was generated on workstation. The slices were manually adjusted for each aortic level to get an oblique plane strictly perpendicular to the course of the branch. The internal diameter of the vessel was measured with an electronic caliper in three different directions in centimeters (Fig. 2). The arithmetic means of those three estimates were used for further calculations.

Collected data of measurement of all three diameters were grouped according to age. The results were also calculated separately for the age classes of ≤20 years, 21-40 years, 41-60 years and > 60years. The diameters were correlated with age and sex. For each age group, all diameter measurements mean and SD were tabulated using MS Excel 07 and on STATISTICA software (Windows 7)

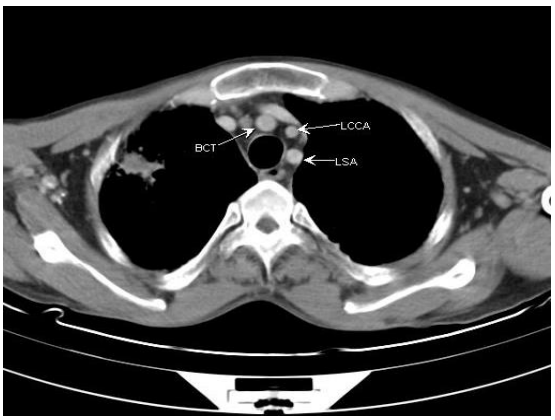

Fig. 1: Transverse section of thorax just above arch of aorta showing brachiocephalic trunk (BCT), left common carotid artery (LCCA) and left subclavian artery (LSA)

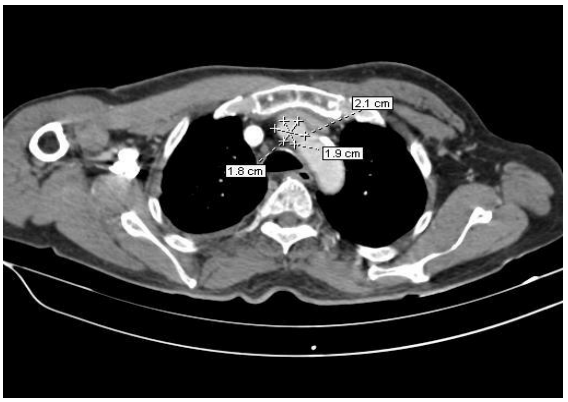

Fig. 2: Showing method of measuring the diameter of BCT in 3 different directions and the arithmetic mean of those three estimates was used for further calculations

Observation and Results

1. **Estimation of diameters:** Three diameters of branches of arch of aorta (brachiocephalic trunk, left common carotid artery and left subclavian artery) of 84 subjects were measured using computed tomography and summarized in Table 1 and also depicted graphically in Fig. 3.

Table 1: Summary of observed diameters of branches of arch aorta

Diameters (cm)	Variables	N	Min	Max	Mean	SD
Branches of arch aorta	BCT	84	0.6	1.7	1.14	0.20
	LCCA	84	0.5	1.3	0.78	0.16
	LSA	84	0.4	1.4	0.93	0.17

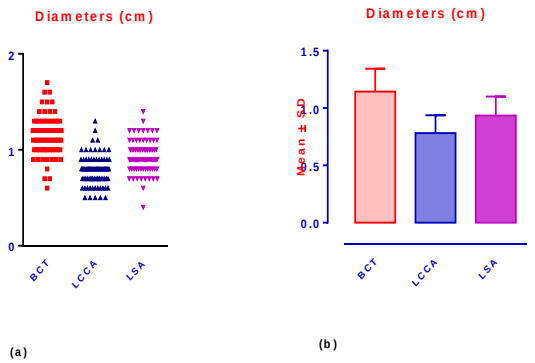

Fig. 3: Observed diameters of studied subjects (a) and their mean (± SD) values (b)

Mean diameter of BCT, LCCA and LSA were 1.14±0.20 cm, 0.71±0.16 cm and 0.93±0.17 cm respectively. Among, these diameters, the mean diameter of brachiocephalic trunk was the highest and

left common carotid artery was the least (BCT > LSA > LCCA).

2. **Correlation among diameters of branches of arch of aorta:** Pearson correlation analysis revealed a significant and positive correlation (direct association) among diameters of branches of arch of aorta. Significantly high correlation was found between BCT and LCCA (r=0.62, p<0.001), BCT and LSA (r=0.59, p<0.001) and LCCA and LSA (r=0.59, p<0.001). In other words, diameters of branches of arch of aorta had direct association with each other.

Table 2: Inter-correlation (n=84) of diameters of branches of arch of aorta

Variables	BCT	LCCA	LSA
BCT	1.00		
LCCA	0.62***	1.00	
LSA	0.59***	0.59***	1.00

***- p<0.001

3. **Effect of age and gender:**
   a. **Effect of age:** The age wise distributions of diameters are summarized in Table 3. The data shows that as age increases mean diameters of all branches increases except left common carotid artery. Evaluating the effect of age on diameters, ANOVA revealed significant (p<0.05 or p<0.01 or p<0.001) effect of age on all diameters except left common carotid artery.

Further, Tukey test (Table 4) showed that mean diameter of brachiocephalic trunk of ≥61 years aged subjects was significantly (p<0.01) different and higher as compared to both ≤ 20 years and 21-40 years aged subjects. Similarly, mean diameter of LSA of both 41-60 years and ≥61 years aged subjects were also found significantly (p<0.05) different and higher as compared to ≤ 20 years aged subjects.

Table 3: Effect of age on diameters

Diameters	≤20 years (n=7)	21-40 years (n=20)	41-60 years (n=33)	≥61 years (n=24)	ANOVA F value (3,80DF)	p value
BCT	0.99±0.26	1.07±0.16	1.14±0.16	1.26±0.21	5.95	0.001
LCCA	0.80±0.22	0.77±0.11	0.77±0.17	0.80±0.15	0.32	0.808
LSA	0.77±0.20	0.91±0.13	0.95±0.17	0.98±0.16	3.48	0.020

Table 4: Comparison (p value) of mean diameters with different age groups by Tukey test

Comparisons-age group (years)	BCT	LCCA	LSA
≤20 vs. 21-40	0.722	0.973	0.200
≤20 vs. 41-60	0.191	0.958	0.043
≤20 vs. ≥ 61	0.005	1.000	0.013
21-40 vs. 41-60	0.543	1.000	0.827
21-40 vs. ≥ 61	0.006	0.893	0.425
41-60 vs. ≥ 61	0.082	0.816	0.845

   b. **Effect of gender:** The gender wise distributions of diameters are summarized in Table 5. Table 5 showed that the mean diameters of all variables were slightly higher in males as compared to females. On comparing the mean diameters between the two genders, t test shows that the difference is not significant (P>0.05)

Table 5: Effect of genders on diameters

Diameters	Females (n=32)	Males (n=52)	t value (DF=82)	p value
BCT	1.11±0.17	1.16±0.21	1.14	0.257
LCCA	0.77±0.14	0.79±0.17	0.41	0.681
LSA	0.90±0.15	0.95±0.17	1.37	0.174

Discussion

Many methods have been used to assess the normal diameters of branches of aortic arch such as echocardiography, magnetic resonance imaging, angiography, or even cadaveric studies, although differences in measurement should be small.

Cadaveric study done by Shin et al (2008)[6] in Korean population shows the greater internal diameters of all branches of aortic arch than our study, while another cadaveric study in Argentina population done by Yeri et al (2011)[7] shows a little higher external diameters and about same internal diameters. Internal diameters measured by Chhabra et al (2015)[8], a cadaveric study in Mumbai population shows lesser diameters than our study. Alsaif HA and Ramadan WS (2010)[9] measured cadaveric diameter of BCT, LCCA and LSA in population of Saudi Arabia; on performing 'Student t- test' we found there is significant difference between the present CT study and the cadaveric diameters. This significant difference may be because of the different methods used.

Many of the researchers have measured cadaveric diameters of above 3 branches of arch of aorta but it was difficult to found correlation studies of these diameters. In the present study Pearson correlation

analysis revealed a significant and positive correlation (direct association) among diameters of branches of arch of aorta. Significantly high correlation was found between brachiocephalic trunk and left common carotid artery ($r=0.62$, $p<0.001$), brachiocephalic trunk and left subclavian artery ($r=0.59$, $p<0.001$) and left common carotid artery and left subclavian artery ($r=0.59$, $p<0.001$).

Conclusion

- The geometry of arch of aorta is of great importance in the hemodynamics. Blood pumped from heart is distributed through arch of aorta by its three branches and descending aorta. Knowledge of diameters of these vessels is very useful in predicting fraction of blood flow through these vessels. A minor change in geometry of arch of aorta may have substantial effect on flow.[10-12]
- We have tried to establish the normal value for reference for diameters of branches of arch of aorta (brachiocephalic trunk, left common carotid artery, left subclavian artey) which also help surgeons in cardiovascular procedures such as stenting of above arteries.

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