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RESEARCH ARTICLE

MORPHOMETRY OF THE AORTIC ARCH AND ITS BRANCHES

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ABSTRACT

The present study was conducted in Department of Anatomy and 64-slice CT center of Department of Radio diagnosis, King George's Medical University, U.P. Lucknow. Morpho metric data of the aortic arch can be of help for conceiving, designing and optimizing all types of diagnostic and therapeutic interventions involving the aortic arch. We measured aortic arch diameters at following levels: Aorta just proximal to the innominate artery, Proximal transverse aortic arch, Distal transverse aortic arch and Aortic isthmus. Diameter of major branches of arch of aorta at their origin was also measured. All the parameters were corelaed with age and gender. Aortic diameters were 25.02 ± 5.76 mm proximal to the in nominate artery, 22.48 ± 5.14 mm at the proximal transverse arch, 20.60 ±4.81 mm at the distal transverse arch and 18.26 ± 4.49 mm at the isthmus. Mean diameter of brachiocephalic trunk in female subjects was 11.35+2.87 and in male subjects was 12.39+3.02.Left common carotid artery diameter in males had a mean value 7.2±1.3 mm as compared to females who had 7.0±1.7 mm diameter. Left subclavian artery diameter in females was 8.2+2.6 mm and in males was 10.5±3.1 mm We observed that among all these parameters only diameters of arch of aorta at different levels and left subclavian artery diameter were associated with age and gender. Diameters of arch of aorta were significantly higher in male subjects as compared to female subjects. Diameter of arch of aorta at various levels in age group 0-15 years was found to be significantly lower than that of other age groups. It gradually increases with age till 60yrs then it decreases. Significantly higher left subclavian artery diameter was found in male subjects as compared to female subjects.

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INTRODUCTION

Aortic arch is the continuation of ascending aorta, its origin, slightly to the right, is at the level of upper border of the second right sternocostal joint. The arch first ascends diagonally back and to the left over the anterior surface of trachea then back across its left side then finally descends to the left of the fourth thoracic vertebral body, continuing as descending thoracic aorta**.** Its diameter at the origin is the same as in the ascending aorta, 28 mm, but it is reduced to 20 mm at the end, after the issue of its large collateral branches (Standring *et al*)**.** Three branches arise from the convex aspect of the arch: the brachiocephalic trunk (BCT), left common carotid (LCA) and left subclavian artery (LSA). They may branch from the beginning of the arch or the upper part of the ascending aorta.
The aortic arch and supra-aortic branches are important anatomical structures for both surgeons and interventionalists.

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Aneurysms or dissections of the aortic arch need to be treated with complex surgical procedures such as deep hypothermic circulatory arrest and selective antegrade cerebral perfusion. 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 embolic cerebral damage. General and neurological morbidity however, are still significant especially in elderly patients and in patients already burdened with significant co-morbidities. Knowledge of morphometric data of the aortic arch can be of help for conceiving, designing and optimizing all types of diagnostic and therapeutic interventions involving the aortic arch. In any individual case, physicians have the opportunity to assess individual anatomy and plan the procedure accordingly. However, for developing new procedures or optimizing existent ones, knowledge of the distribution, regularity or irregularity and typology of several anatomical characteristics is crucial. In the present study morphometric details of aortic arch and its supraaortic branches was observed with an objective to provide normogram of these parameters for north

indian population as the literature is lacking with these values. All the parameters were corelated with age and gender also.

MATERIALS AND METHODS

The study was conducted in department of Anatomy and department of Radiodiagnosis, King George's Medical University, UP. The study included 110 patients, out of which 62 were males and 48 females. Age of subjects ranged from 3 months to 75 years across 5 age groups. Written informed consent from the patients was obtained. The images of patients with previous history of allergy to contrast agent, renal insufficiency,distortion of anatomy of arch of aorta due to any pathology were excluded from this study. CT Angiography was performed on 64-slice multidetector spiral CT scanner.A single unenhanced low-dose scan was first obtained. After that 350mg/ml non-ionic contrast medium (Omnipaque) is injected in the antecubital vein at the rate of 5.5 ml/sec. A region of interest was drawn on the aorta at the level of the diaphragm. After an appropriate delay to allow passage of the contrast agent into the renal arterial circulation, a series of thin cuts(0.9mm) were obtained throughout the aorta All the images were analysed using Philips DICOM viewer. Morphometry of arch of aorta were studied in axial, multiplanar reconstructions (MPR) images, and in volume rendered images.

(A) We measured aortic arch diameters (AAD) at following levels in parasaggital view:

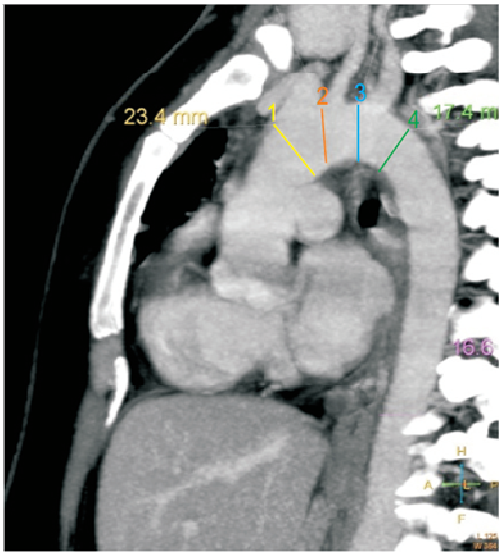

Fig1 -Parasaggital MPR showing measurment of aortic arch diameters at various levels (1) aorta proximal to innominate artery;(2) proximal transverse arch; (3) distal transverse arch;(4) aortic isthmus

The internal diameter of the aortic arch was measured with an electronic caliper in three different directions. The arithmetic mean of those three estimates was used for further calculations. B) Diameter of major branches at their origin was measured with the help of electronic calipers in axial MIP image (Fig 2).

RESULTS

Age of subjects ranged from 3 months to 75 years across 5 age groups. Except for age groups 0-15 and 61-75 years, all the three age groups had 26 (23.64%) subjects each.

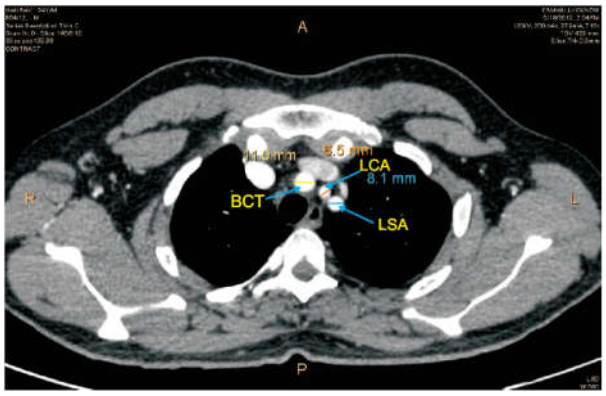

Fig. 2. Axial MIP image showing measurement of the diameters of major branches of aortic arch, BCT= brachiocephalic trunk, LCA= left common carotid artery, LSA= left subclavian artery

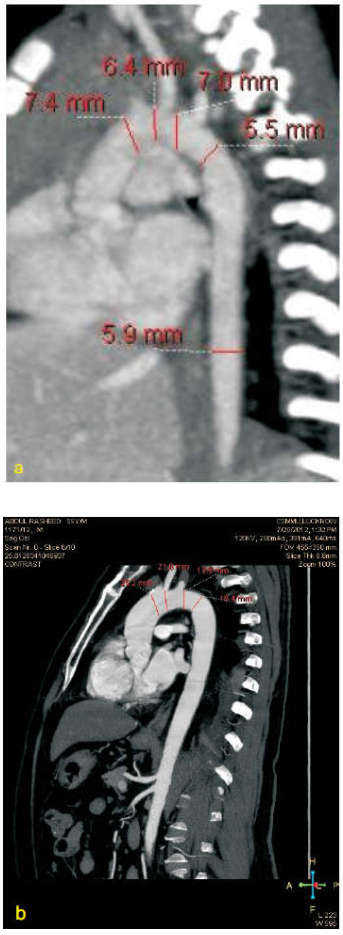

Fig 3 Showing aortic arch diameters in (a) 3 month old child, (b) adult male and (c) adult female in parasaggital MPR images

In age group 0-15 years there were 20 (18.18%) and in age group 61-75 years, there were 12 (10.91%) cases. Mean age of subjects was 36.4±19.2 years. The study population consisted of 48 (43.64%) females and 62 (56.36%) males. The efforts were made to include sufficient number of subjects from each age group, though subjects aged 61-75 years and 0-15 years were lower in proportion. Diameter of aortic arch proximal to innominate artery (PIA) ranged from 7.3 to 37.1 mm with a mean value of 25±5.8 mm**.** Wide variation in mean aortic arch diameter at PIA level was observed across with minimum value at age group 0-15 yrs (18.8±7.6 mm) and maximum value at age group 46-60 yrs (28.4±3.3 mm).Diameter gradually increased with age till 60yrs then it decreased, on evaluating the data statistically, a significant difference was observed among different age groups ($p<0.001$). Females had significantly lower mean aortic arch diameter (22.6±5.3 mm) as compared to males (26.9±5.5 mm) ($p=0.006$). Diameter at proximal transerve arch ranged from 6.4 to 35.2 mm with a mean value of 22.5±5.1 mm. Among different age groups mean value ranged from 16.5±7.0 mm (0-15yrs) to 24.8±2.8 mm (31-45yrs), thus showing a significant difference among different age groups ($p<0.001$). Gender wise females had a lower mean value (20.5±4.7 mm) as compared to males (24.0±5.0 mm), which was statistically significant ($p=0.012$). Diameter at distal transerve arch ranged from 6.1 to 29.4 mm with a mean value of 20.6±4.8 mm. Among different age groups mean value ranged from 14.4±6.3 mm (0-15yrs) to 23.0±4.1 mm (31-45yrs), thus showing a significant difference among different age groups ($p<0.001$). Gender wise females had a lower mean value (18.7±4.6 mm) as compared to males (22.1±4.5 mm), thus showing a significant difference between two genders ($p=0.008$). Diameter at Isthmus of aorta ranged from 4.5 to 27.2 mm with a mean value of 18.3±4.5 mm. Among different age groups mean value ranged from 12.2±5.4 mm (0-15yrs) to 20.9±2.0 mm (61-75yrs), thus showing a significant difference among different age groups ($p<0.001$). Gender wise females had a lower mean value (16.2±4.7 mm) as compared to males (19.9±3.6 mm), thus showing a significant difference between two genders ($p=0.002$).

Aortic diameters of aortic arch gradually decrease as we approached from proximal to distal level. Diameters of supra-aortic arteries were measured at their origin in axial images with electronic caliper. This parameter was studied in 76 cases (34 females and 42 males). The cases with common trunk for brachiocephalic trunk and left common carotid artery were excluded from the study. Brachiocephalic trunk diameter ranged from 5.3 to 17.5 mm with a mean of 11.9±3.0 mm. Among different age groups mean value ranged from 11.1±2.9 mm (16-30yrs) to 12.8±3.1 mm (46-60yrs) but the difference was not significant statistically among age groups ($p=0.763$). Though mean brachiocephalic trunk diameter in female subjects (11.35$\pm$2.87) was lower than male subjects (12.39$\pm$3.02), but this difference was statistically non-significant ($p=0.289$). The diameter of left common carotid artery was studied in 76 subjects out of whom 34 were females and 42 males and the cases having common trunk for brachiocephalic trunk and left common carotid artery were excluded. Mean LCA diameter ranged from 2.7 to 10.3 mm with a mean value of 7.1±1.4 mm. Among different age group, mean value ranged from 6.8±2.5 mm to 7.5±1.7 mm but the difference among groups was not significant statistically. Males had a higher mean value (7.2±1.3 mm) as compared to females (7.0±1.7 mm) but the difference was not significant statistically ($p=0.651$).

Variation in left subclavian artery diameter was studied in 102 subjects (44 females and 58 males), after excluding the cases having common trunk for LCA and LSA. LSA diameter ranged from 2.9 to 16.8 mm with a mean value of 9.5±3.1 mm. Although mean values in younger age groups were lower as compared to older age groups yet the difference was not significant statistically ($p=0.497$). However, as compared to females, males had significantly higher mean value ($p=0.005$).

DISCUSSION

In present study aortic diameters were 25.02 ± 5.76 mm proximal to the innominate artery, 22.48 ± 5.14 mm at the proximal transverse arch, 20.60 ±4.81 mm at the distal transverse arch and 18.26 ± 4.49 mm at the isthmus.These diameters were quite less than that observed by Hager *et al* (2001) who studied seventy adults (17 to 89 years old) and found aortic diameters 29.4 ±4.2 mm proximal to the innominate artery, 27.7 ±3.7 mm at the proximal transverse arch, 26.1 ±4.1 mm at the distal transverse arch and 24.7 ± 4.0 mm at the isthmus. Possible reason for this discrepancy could be the selection of a wide age range (3 months-75yrs) in our study. In the present study we reported that diameters were decreased as we approached towards proximal to distal level of aortic arch. This observation is similar to the previous studies done by Hager *et al* ,2001; Malkawi *et al* ,2010; Yeri *et al* ,2011;. Shakeri *et al* .2013. According to Yeri *et al* (2011) AAD at ascending aorta and distal to subclavian artery was 26.8 mm and 21 mm respectively. Shakeri *et al*, 2013 reported mean cross sectional diameter of aorta arch immediately before and after separation of the first and last branches was 32.05±4.99 and 23.82±3.48 mm, respectively. Malkawi *et al* (2010) found the diameter of the aortic arch increased as it approached the aortic root. They found mean diameter 38.9±6.4 mm at the sinotubular junction and 30.7±16.6 mm at the left subclavian artery. In present study we found that aortic diameters vary with age and gender. Diameters were found to be significantly lower ($p<0.001$) in subjects aged $\leq$15 yrs , further it showed increase up to 60yrs and after that it decreased. Concerning the influence of age, Aronberg *et al* (1984) and Hager *et al* (2001) additionally found that aortic diameters increase about 1 mm per decade during adulthood. Diameter of aortic arch at various levels was significantly lower ($p=0.002$) in females as compared to males which is concurrent with the findings of Hager *et al* (2001). Planning for endovascular interventions involving the aortic arch requires a detailed familiarity with arch morphology also knowledge of normal aortic diameters at different levels is essential especially for defining and classification of structural abnormalities, such as aneurysm, aortomegaly, ectasia, stenosis, coarctation, and hypoplasia.

Diameters of BCT, LCA and LSA in the present study were 11.93 ± 2.96 mm, 7.15 ± 1.45 mm, and 9.15 ± 3.09 mm, respectively. These diameters were comparable to that observed by Malkawi *et al* (2010) but less than that reported by Shin *et al* (2008) and Alsaif & Ramadan *(*2010). Malkawi *et al* (2010) studied 49 patients through computed tomography scans and found that mean diameters of the BCT, LCA, and LSA were 12.3±3.2, 7.6±1.5, and 11.0±2.9 mm, respectively. Shin *et al* (2008) found it to be 18.3± 7.00 mm, 9.5 ± 1.9 mm and 10.6 ±2.4 mm for BCT, LCA and LSA respectively. Alsaif & Ramadan *(*2010) studied 30 adult human cadavers and found that mean diameter of BCT, LCA and LSA were 17.97 ± 3.85 mm, 9.77 ± 1.91 mm, and 14.33 ± 3.09 mm, respectively.

The difference in the values could be possibly because, we have studied the parameters on CTA while the studies of Shin *et al* (2008) and Alsaif & Ramadan *(*2010) were cadaveric. In the present study no statistically significant difference were found when age and diameters of branches of study population was compared. Diameters of BCT and LCA of female subjects were lower than that of male subjects. This difference was statistically non-significant, while LSA diameter was significantly higher (p=0.005) in male subjects as compared to female subjects. In the present study we found that BCT, LCA and LSA diameters had mild correlation(r=0.316-0.406) with each other. Alsaif & Ramadan *(*2010) reported that the diameter of BCT and LSA had significant correlation(r=.467) with each other. The inner diameter of the major branches of the aortic arch varies depending on investigators (Gupta and Sodhi, 2005). During endovascular surgery that requires the insertion of a guiding catheter within a major branch of aortic arch, before hand knowledge of inner diameter of the blood vessels is mandatory. This data would be helpful in selecting the appropriate size of catheter for each blood vessel.

Conclusion

It was concluded from the study that diameter of arch of aorta gradually decreases from proximal to distal level. Diameter of arch of aorta at various levels was significantly higher in male subjects as compared to female subjects. The diameters at various levels in age group 0-15 years was found to be significantly lower than that of other age groups. It gradually increased with age till 60yrs then it decreased. This study will provide basic anatomical data to cardiac surgeons for catheterization of aortic arch and its branches for safely performing endovascular surgery.

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