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Anatomical variations of the aortic knob in chest radiographs

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Summary

There is a paucity of data regarding the normal anatomical variations of the aortic knob (AK) on routine postero-anterior chest radiographs (PACR). The aims of the present study were to document and analyze the anatomical variations of the AK on PACRs' in an adult Indian population. This was a cross-sectional study of PACRs' in a tertiary care hospital with attached medical college in Bangalore, India. The AKs' in 108 (77 males and 31 females) PACRs' of normal, healthy adults were studied using the following measurements: minimum distance of the left edge of the aortic knuckle from the midline (AKW); straight and curved length of the AK (AKS and AKC). The ratio of the AKC to the AKS was calculated and termed the AK index (AKI). The mean and standard deviation were determined for AKW, AKS and AKI. The unpaired t-test was used to check for significant sex differences in the above parameters. Spearman's rank order correlation coefficient of the AKW, AKS and AKI with the age, BMI, CD, CA and CTR was calculated. The mean value of the AKW was significantly higher in males as compared to females. The majority of the values of AKI were between 1 and 1.2 in both sexes. The AKW showed significant positive correlations with age, the body mass index and cardiac diameter. The AKI showed a weak, although significant positive correlation with the age and the cardiothoracic ratio. The present study describes the anatomical variations of the AK, using the AKI to quantify its prominence.

Key words: Aortic knob – Chest radiographs – Anatomical variations – Aortic knob index

Introduction

The postero-anterior chest radiograph (PACR) is the commonest imaging modality of the heart (Sutton and Gregson, 2003). The left border of the cardiac silhouette on a PACR is composed of a series of convex arcs, one of which is the aortic knob or knuckle (AK). The AK is not a specific anatomical structure but represents the distal-most portion of the aortic arch, where it turns downwards to become the descending aorta. The medial border of the arch of the aorta blends with the shadows of the mediastinum and cannot be identified. Laterally, where it abuts on the left lung, it is seen as a localised bulge (Fig. 1) (Baron, 1999).

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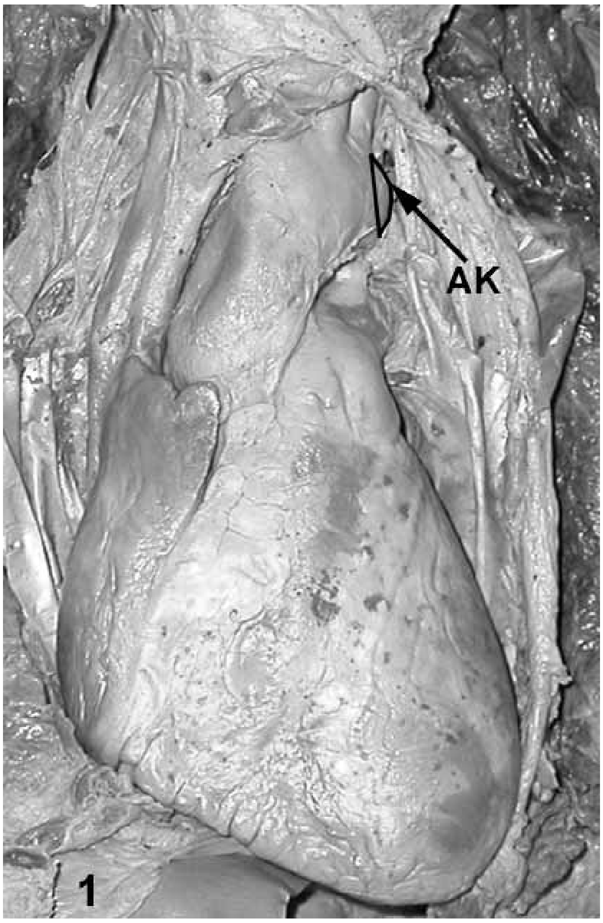

Figure 1. Frontal picture of a cadaveric heart in-situ showing the position of the aortic knob (AK).

Abnormalities of the AK are observed in some congenital cardiac conditions, coarctation of the aorta, and aortic aneurysms (Le Roux, 1973; Kim and Choi, 2000; Hartnell and Raphael, 2001). Also, its role in the detection of left paratracheal oesophageal masses and as a reliable radiologic landmark for the placement of an intra-aortic balloon pump tip has been documented (Yang et al., 2005; Lee et al., 2006). An increase in the transverse diameter of the arch of the aorta has been associated with hypertension and cardiac dysfunction (Anyanwu et al., 2007). Aortic knob calcification can provide important predictive information about coronary atherosclerosis (Yun et al., 2006). Although the PACR remains a cheap and common initial imaging modality of the heart, there is a paucity of data regarding the normal anatomical variations of the AK on routine PACRs' (Yoshida and Yoshida, 2000). The aim of the present study was to document and analyze the anatomical variations of the AK on routine PACRs' in an adult Indian population.

Materials and Methods

Subjects

The PACRs' were obtained from normal, healthy adult subjects from India who came to St. John's Medical College Hospital in Bangalore, for routine health assessment, such as for pre-employment and pre-admission screening or as a prerequisite for visa applications. The subjects signed an informed consent form to permit the use of their PACR for the study. Ethical clearance for the study was obtained from the Institutional Ethical Review Board (IERB). The PACRs' of a total of 108 subjects consisting of 77 males and 31 females were studied. Males and females of the age of 18 years and above were included in the study. The mean age of the subjects was 29 years (range 19-65 years). Subjects with a history of cardiac disease, hypertension, diabetes, hyperthyroidism and those with chest wall deformi-

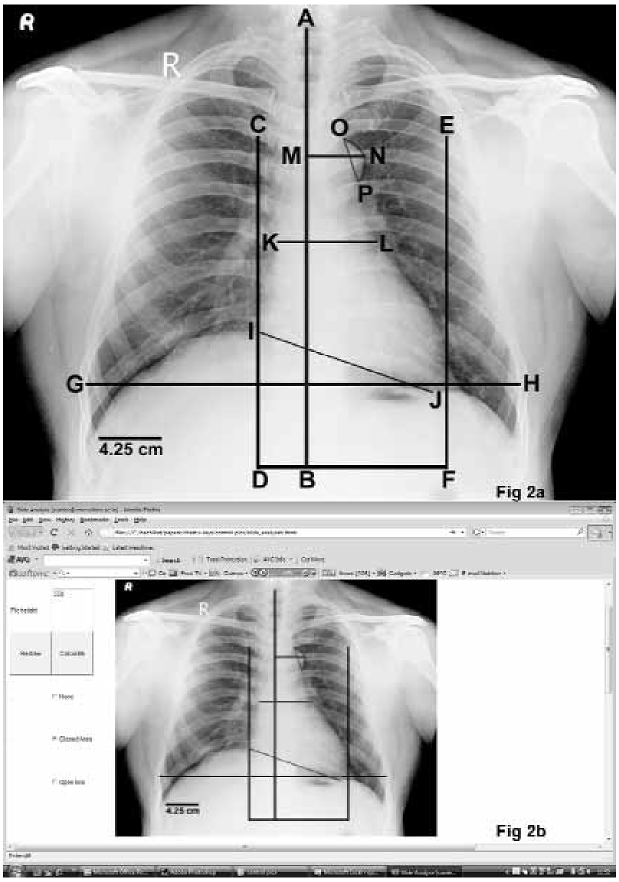

Figure 2. 2a. The various measurements made on the PACR. AB – midline; CD – vertical line through maximum right extension of cardiac silhouette; EF - vertical line through maximum left extension of cardiac silhouette; DF – maximum cardiac diameter; GH – maximum transverse thoracic diameter at the level of the left hemidiaphragm; IJ – inferior border of cardiac silhouette; KL – superior border of cardiac silhouette; MN - minimum distance of the left edge of the aortic knob (AK) from the midline; OP - straight length of the AK; ONP - curved length of the AK; Scale bar = 4.25 cm. 2b. The 'print screen' image of the software that was used for the analysis.

ties were excluded from the study. All PACRs' were analyzed by a single investigator.

Chest x-rays

The PACR was done as follows: The target-to-film distance was 6 feet. The radiograph was taken at full inspiration, without straining, with the subject completely still and the central ray centered over the 6th thoracic vertebra. Adequate rotation of the scapulae was required so that they did not obscure the lung fields (Meschan, 1978). The digitized versions of the radiographs were subsequently analyzed.

Measurements

The AK was visualized and the following measurements were made in cm, as shown in Fig. 2a:

– minimum distance of the left edge of the aortic knob from the midline (AKW) (MN in Fig. 2a)
– straight length of the AK (AKS) (OP in Fig. 2a)
– curved length of the AK (AKC) (ONP in Fig. 2a)
– maximum transverse cardiac diameter (CD) (DF in Fig. 2a)
– maximum transverse thoracic diameter at the level of the cupola of the left hemidiaphragm (TD) (GH in Fig. 2a)
– cardiac area (CA) (Fig. 2b)

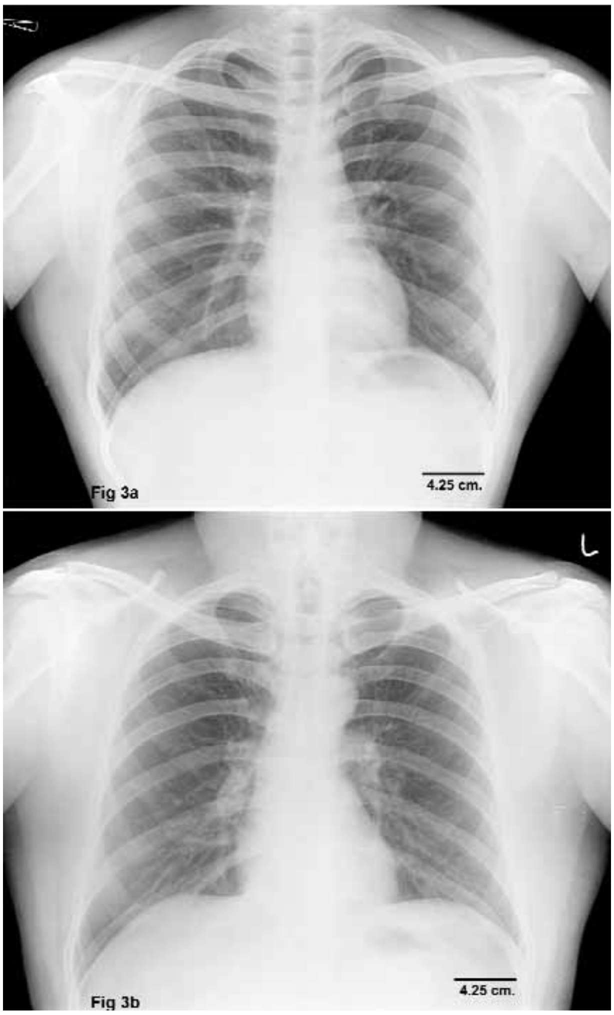

Figure 3. 3a. Absent aortic knob (AK) with an AKI value of 1. Scale bar = 4.25 cm. 3b. A very prominent AK with an AKI value of 1.48. Scale bar = 4.25 cm.

The required outlines were drawn on the digitized images using Adobe Photoshop version CS2 software. All the above measurements were made using a computer program written in JAVA. The computer program for making the measurements on the images provided a user interface which allowed manual, interactive marking of selected areas on the image. Once the path had been marked by the user, the area enclosed within the perimeter was calculated by the program. Similarly, lengths, both straight and curved, were calculated. The appropriate scale for each PACR was drawn for each image to aid in the length and area calculations. From the above measurements the ratio of the AKC to the AKS was calculated and termed the AK index (AKI). The rationale behind using this index is discussed later. When the AK was not visible, the AKS and AKI values were taken to be zero and one respectively. The cardio-thoracic ratio (CTR) and body mass index (BMI) of all subjects were also calculated. The CTR was determined by dividing the CD by the TD (Miller et al., 2000). The BMI was calculated as the quotient of weight in kilograms and the square of height in metres.

Statistical analysis

The mean and standard deviation were determined for AKW, AKS and AKI. The unpaired t-test was used to check for significant sex differences in the above parameters. The range of values of the AKI in both the sexes was tabulated. Spearman's rank order correlation coefficient of the AKW, AKS and AKI with the age, BMI, CD, CA and CTR was calculated. All statistical analysis was performed using SPSS version 15.0 for Windows.

Results

The results are summarized in Tables 1, 2 and 3. The mean value of the AKW was significantly higher in males as compared to females. The mean AKS, although greater in males, was not significantly so. However, the

Table 1. Sex differences in the AKW, AKS and AKI. n – number of PACRs studied; SD – standard deviation; AKW – distance of the left edge of the aortic knuckle from the midline; AKS – the straight length of the aortic knob; AKI – aortic knob index; † - measurements in cm.; ‡ - unpaired t-test.

	AKW† mean ± SD (range)	AKS† mean ± SD (range)	AKI mean ± SD (range)
Combined (n = 108)	3.04 ± 0.59 (2.12 – 5.25)	2.66 ± 1.08 (0 – 6.00)	1.14 ± 0.11 (1 – 1.48)
Male (n = 77)	3.16 ± 0.6 (2.12 – 5.25)	2.70 ± 1.22 (0 – 6.00)	1.13 ± 0.11 (1 – 1.48)
Female (n = 31)	2.75 ± 0.35 (2.2 – 3.82)	2.55 ± 0.58 (1.6 – 3.53)	1.16 ± 0.11 (1.009 – 1.48)
Significance‡ (male vs female)	0.001	0.51	0.19

Table 2. Distribution of aortic knob index (AKI) values. n – number of PACRs studied; aortic knob; AK – aortic knob; AKI – aortic knob index

	No AK	Range of AKI values				
		1 – 1.1	1.1 – 1.2	1.2 – 1.3	1.3 – 1.4	1.4 – 1.5
Total (n = 108)	8 (7.4%)	40 (37%)	35 (32.4%)	17 (15.7%)	5 (4.6%)	3 (2.8%)
Males (n = 77)	8 (10.4%)	27 (35.1%)	27 (35.1%)	10 (13%)	3 (3.9%)	2 (2.6%)
Females (n = 31)	0	12 (38.7%)	9 (29%)	7 (22.6%)	2 (6.5%)	1 (3.2%)

Table 3. Correlation coefficient of the AKW, AKS and AKI with several other parameters. AKW – distance of the left edge of the aortic knuckle from the midline; AKS – the straight length of the AK aortic knob; AKI – aortic knob index; BMI – body mass index; CD – maximum cardiac diameter; CA – cardiac area; CTR – cardio-thoracic ratio; * - significant correlation.

Parameter	Age	BMI	CD	CA	CTR
AKW	0.29*	0.37*	0.34*	-0.1	0.08
AKS	0.15	-0.05	0.16	0.01	0.07
AKI	0.20*	-0.03	0.06	0.09	0.17*

mean AKI was greater in females, though this was not significant (Table 1). The AK was absent in 8 subjects, all of them males. In these subjects, although the outline of the aorta could be discerned, it did not form a knob along the left border of the cardiovascular silhouette (Fig. 3a). When the range of values of the AKI was tabulated, it was found that the majority of the values of the AKI were between 1 and 1.2 in both males and females (Table 2). A less number of data were noted between 1.2 and 1.3, above which the numbers rapidly tailed off (Fig. 3b). The AKW showed significant positive correlations with age, the BMI and the CD. The AKI showed a weak positive correlation with the parameters mentioned above, although the correlation with the age and the CTR were significant. The AKS did not show significant correlations with any of the parameters mentioned above (Table 3).

Discussion

Although the PACR is one of the most common investigations performed, there is little information regarding the normal anatomical variations of the AK (Yoshida and Yoshida, 2000). In the present study the authors attempted to characterize the anatomical variations of AK in a normal, healthy adult Indian population. Three parameters were considered; distance of the left edge of the aortic knuckle from the midline (AKW), the straight length of the AK (AKS) and the aortic knuckle index (AKI).

The width of the AK has been measured using various methods. Anyanwu et al. measured the width of the aortic shadow as the sum of the maximum extension of the aortic shadow to the right and left of the midline (Rose et al., 1982; Anyanwu et al., 2007). Using this method, the mean aortic arch diameter was found to be 4.7 ± 0.5 cm. Some investigators found higher values in other African populations (Ikeme et al., 1976; Umerah, 1982; Obikili and Okoye, 2004). These variations were probably due to methodological differences (Anyanwu et al., 2007). Other investigators have measured AK width from the left edge of the tracheal shadow to the left edge of the AK (Felson, 1973; Yun et al., 2006). In a study of 500 normal PACRs' using the above method, it was noted that AK width measured less than 3 cm in a large majority of the subjects. In no subject was the AK width found to be more than 4 cm (Felson, 1973). Kim and Choi (2000) observed that an AK width of more than 4 cm occurred more frequently in patients with thoracic aortic disorder as compared to normal subjects. Yun et al. (2006) found that AK width was significantly correlated with the severity of coronary artery disease, but did not specify the values of the AK width. In the present study, AKW was measured as the minimum distance of the left edge of the AK from the midline. The method used in this study is probably more suitable, since the right extension of the aortic shadow in the PACR is difficult to define. Also, the position of the trachea is not constant in different individuals, making comparisons difficult.

Sex differences in AK width have been reported by other investigators, higher values being recorded in males than in females of the same age group (Ikeme et al., 1976; Obikili and Okoye, 2004; Anyanwu et al., 2007). Similar results were obtained in the present study. A significant positive correlation between age and AK width has been found by other investigators (Felson, 1973; Fiore and Querin, 1979; Obikili and Okoye, 2004; Anyanwu et al., 2007). This was also noted in the present study. An explanation for this finding could be that the arch of the aorta unravels with age, thus causing a widening of the mediastinum at this level. Another possibility is that the thickness of the aortic wall increases with age, due to an increase in blood pressure. AK width was significantly correlated with the CD and the BMI in the present study. This is in concurrence with previous studies (Obikili and Okoye, 2004; Anyanwu et al., 2007).

Yoshida and Yoshida (2000) classified the anatomical variations of the AK in six types, based on their prominence and shape. A survey of the literature did not uncover any other study describing the variations in the appearance of the AK in healthy individuals, although the visibility and proximity of the cephalic margin of the AK to the clavicles has been studied (Felson, 1973). In the present study, the AK was characterized by two measurements, the AKS and the AKI. For a given AKS, the curvature (prominence) of the AK is directly proportional to the AKI. Thus, the use of the AKI affords a quantitative estimate of the prominence of the AK. An added advantage is that, since the AKI is a ratio independent of absolute measurements. Thus, it is better suited for comparisons to be made between different populations.

In this study, the AK was found to be absent in eight male subjects (Fig. 3a), but was always present in females. The highest value of the AKI in both sexes was 1.48 (Fig. 3b). In more than 90% of the subjects of either sex, the value of the AKI was less than 1.3, with a mean value of 1.13 and 1.16, respectively, in males and females. Anatomical variations in either the size of the aortic arch or its orientation could be responsible for the variable appearance of the AK on the PACR. The aortic arch passes upwards, backwards and to the left from its origin to its termination. For a given size of the aortic arch, the AK will be more prominent if it passes more towards the left and less backwards. Thus, a possible explanation for an absent AK is that the aortic arch passes more backward and less to the left than usual. It is possible that this occurs more often in males than females, thus accounting for the greater incidence of an absent AK in them. Another issue that needs to be considered is the requirement of a good, centered PACR. Even minimal rotation could change the appearance of the AK.

A limitation of the present study is the relatively low number of PACRs' from females analyzed. As a result, the correlation coefficients were calculated for the subjects considered together, irrespective of sex. Thus, sex differences in these coefficients, if any, were not documented. Also, a large majority of the subjects were younger than 40 years. A wider distribution of age groups in the subjects would have provided a more complete picture of the age-related changes in the AK. In addition, the role of the course of the aortic arch from its origin to its termination in the appearance of the AK on PACRs, needs to be elucidated. More studies are required to determine the magnitude of the AKI in patients with hypertension, as well as its role, if any, in the prediction of future adverse cardiovascular events. The correlation between the AKI and several echocardiographic parameters warrants further consideration.

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