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Aortic Diameters in Infants and Young Children: Normative Angiographic Data

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SUMMARY. **Cineangiographic measurements, in the left anterior oblique view, of the diameter of the ascending aorta, arch, isthmus, postisthmic region, and descending aorta were made in 18 infants and children with no detectable cardiac anomaly and in 47 with congenital heart disease that did not involve the aorta. Results are tabulated according to age and body surface area. They provide normative data from which variations from usual can be judged.**

KEY WORDS: **Aortic diameters — Cineangiographic normative data — Coarctation of aorta — Aortic arch hypoplasia**

Knowledge of the size of the aorta in its various parts and their relationship to one another is of importance in the assessment of the effects of disease processes and their modification by surgical treatment. This is especially pertinent in coarctation of the aorta. Reference to the literature provided some information [1, 3–7, 9] but it seemed that additional data based on angiographic measurements would be of value.

This study was undertaken to provide such information in infants and young children, in particular the relationship between the sizes of the transverse arch proximal to the left subclavian artery, the aortic isthmus, and the lower thoracic aorta.

Materials and Methods

Cineangiocardiograms of 65 patients, aged one day to five years, were randomly selected from our files with a view to providing a reasonable scatter of ages. Body surface area was calculated [2]. Patients were chosen because there was no detectable cardiac anomaly (18 patients) or because the type of congenital heart disease was considered unlikely to alter the configuration of the aorta (ventricular septal defect, 32; atrial septal defect, 7; and pulmonary stenosis, 8 patients). Those with aortic stenosis or other abnormalities of the aorta (including persistent ductus arteriosus and right aortic arch) were excluded, as were those with tetralogy of Fallot and more complex problems. Only those with good-quality aortograms were used. The left anterior oblique view was examined in all cases.

A thin white ruler with a fine black millimeter scale was used to measure the internal diameter of the mid ascending aorta, arch, isthmus, the postisthmus region, and descending aorta above the diaphragm (Fig. 1) from 35-mm cine films projected onto a standard viewing screen (Tagarno). The largest systolic diameter was recorded: account was taken of the transmission of the pulse wave. Measurements of the ascending and transverse aorta were usually obtained from a single frame. Commonly the largest systolic diameter of the descending aorta was noted a few frames later than in the ascending aorta.

Measurements were corrected for the variable degree of magnification (2–3 times actual size) by comparison with the known diameter of the angiographic catheter, and also in some cases by measurement of the projection of a grid of known dimensions filmed under the same geometric conditions following the cineangiocardiographic study. The position of the aorta (and subsequent grid position) was determined by fluoroscopy at the time of angiographic study and routinely recorded.

Intensifier distortion was allowed for by measuring the grid across the area of the film wherein most of the measurements of the aorta were made. As this did not encompass the region of the lower thoracic aorta, grid measurements were also made in the latter region. Measurements were made to the nearest 0.5 mm and the calculated aortic diameters were rounded off to the nearest 0.5 mm.

The use of a grid to obtain aortic diameters was considered the more accurate method and was used in 28 patients. In these cases the correction factor thus obtained was compared with that obtained using the catheter. In seven cases the conversion factor found by each method was identical. Random differences were seen in the other 21 cases, but these led to no difference in the final calculated aortic diameters in 24% of the remaining measurements, a difference of 0.5 mm in 56%, 1 mm in 14%, and 1½ mm in 6%.

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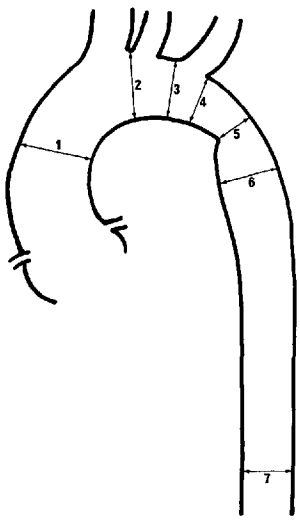

Fig. 1. Diagram to show sites where measurements were made, (*1*) mid ascending aorta, (*2*) between innominate and left common carotid arteries, (*3*) between left common carotid and left subclavian arteries, (*4*) distal to left subclavian artery, (*5*) isthmus (i.e., region between left subclavian artery and the ductus arteriosus)—the narrowest part of the upper descending aorta was measured, (*6*) widest part of postisthmic region, and (*7*) lower descending aorta above the diaphragm.

As the grid measurements were made in the area of the film wherein most of the aortic measurements were done, the correction factors thus obtained were compared with those obtained from grid measurements made in the region of the lower thoracic area in 16 cases. In most cases the figures obtained were identical but in four cases there were small differences that could have resulted in the final measurement of the lower descending aortic diameter being overestimated by up to 0.5 mm.

An estimate was also made of the reproducibility of the calculated aortic diameters. Sixty measurements were repeated from ten randomly selected cases without knowledge of the original results. Measurements from the projected images were reproducible, being either exactly the same or varying by 1 mm in 55 cases. They varied by 2 mm in four and by 3 mm in one instance. The correction factor calculated from the grid was identical in eight cases and showed trivial variation in two.

Calculated aortic diameters on the second series of measurements when compared with the initial series were identical or varied by 0.5 mm in 92% of instances. In 8% the difference was 1 mm. Correction factors obtained using the catheter diameters were less reproducible, though they were identical on both occasions in six cases. In four they varied because of a difference of 0.5 mm in the measurement from the projected image of the catheter diameter, which was usually 5–6 mm. Thus, when a catheter was used to obtain the correction factor, 78% of the calculated aortic diameters were found to be identical or to vary by 0.5 mm, 15% varied by 1 mm, and 7% by 2 mm.

Results

The measurements have been grouped according to age and to body surface area and are summarized in Table 1. In general the various diameters increase with increasing age and size.

The transverse arch between the left common carotid artery and the left subclavian artery was a little smaller than the lower thoracic aorta during the first week of life (average 90%) and in three of the seven infants aged 1–2 months was proportionally similar. In the remaining 58 (with one exception) this diameter was the same or greater than that of the lower thoracic aorta.

The isthmus was obviously smaller than the lower thoracic aorta up to three weeks of age (73%–83%) as it also was in some other young infants with normal hearts or left to right shunts. Beyond three months of age the isthmus was the same size or larger than the descending aorta, exceptions being seen in five of 48 patients where it was 83%–94% of the descending aortic diameter.

The immediate postisthmic region was significantly larger than the isthmus ($P < 0.05$) in children less than two years of age (Table 1). In young infants this measurement included the ductal ampulla (Fig. 1). In older children the distinction tended to be lost.

Although the descending aortic diameters in infants aged less than one month appeared larger than in those aged 1–6 months the difference in size was not significant ($2P > 0.5$).

Six patients with left to right shunts (which were large in five) were studied at 3–15 months of age and restudied 2–6 years postoperatively when aged 3–7 years. The relation of the transverse arch between the left common carotid and left subclavian arteries and the isthmus to the descending aorta was similar on each occasion.

Discussion

This study was undertaken to provide some information on the relative sizes of the transverse aorta and isthmus in relation to the lower thoracic aorta. We elected to use the lower descending aorta for comparative purposes rather than the ascending aorta because it is unlikely to be affected by aortic valve lesions and therefore more likely to be useful under most conditions.

The grid method used to measure the various aortic diameters can be expected to be more accurate than the catheter comparison, because the margins of the catheter on the held projected cine frame are less clear and the measured catheter diameter is small compared with the aorta. Errors of measurement are therefore magnified. Reproducibility of calculated diameters was greater when the grid was used. The comparison between the two methods

Table 1. Aortic diameters

No. cases	Age	Asc Ao	I-LCC	LCC-LSC	Beyond LSC	Isthmus	Post-isthmus	DA	LCC-LSC % DA	Isthmus % DA
4	<1 wk	8.2[a] (0.7)[b]	6.5 (0.4)	6.2 (0.5)	5.6 (0.5)	5.5 (0.4)	7.6 (1.3)	7.0 (0.8)	90 (6)	79 (3)
6	1 wk </mo	9.1 (0.9)	—	6.5 (0.6)	5.7 (0.7)	5.2 (0.8)	7.3 (0.7)	6.0 (0.3)	108 (11)	87 (12)
16	1 < 6 mo	9.9 (1.8)	7.7 (1.4)	6.6 (0.9)	6.0 (1.0)	5.7 (0.9)	7.1 (0.9)	5.8 (0.6)	113 (15)	98 (16)
6	6 < 12 mo	12.7 (1.2)	—	8.7 (1.1)	8.0 (0.9)	7.7 (0.9)	9.2 (0.8)	7.7 (1.1)	114 (7)	101 (9)
10	1 < 2 yr	11.8 (1.0)	—	9.3 (0.9)	8.8 (0.7)	8.3 (0.7)	9.5 (1.3)	8.1 (0.9)	116 (9)	103 (5)
6	2 < 3 yr	13.7 (1.9)	—	10.4 (1.7)	10.0 (1.3)	9.7 (1.5)	11.2 (1.6)	9.2 (1.2)	113 (14)	106 (14)
6	3 < 4 yr	14.1 (2.2)	—	11.2 (1.3)	10.9 (1.5)	10.6 (1.5)	11.5 (1.7)	9.4 (0.9)	118 (7)	112 (10)
6	4 < 5 yr	15.1 (2.0)	—	10.2 (2.1)	10.2 (2.1)	9.7 (2.2)	10.5 (2.1)	8.9 (1.3)	114 (9)	108 (12)
5	5 < 6 yr	14.9 (0.9)	—	13.0 (0.6)	12.6 (1.5)	11.6 (1.3)	11.6 (1.1)	10.3 (0.8)	127 (16)	113 (10)
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17	<0.25	9.0 (1.0)	6.9 (1.0)	6.3 (0.6)	5.7 (0.7)	5.4 (0.7)	7.2 (1.0)	6.1 (0.7)	104 (13)	90 (16)
9	0.25 < 0.30	10.7 (1.9)	8.2 (1.1)	7.2 (0.7)	6.5 (0.7)	6.1 (0.8)	7.6 (0.6)	6.0 (0.7)	120 (11)	102 (11)
4	0.30 < 0.40	12.5 (0.9)	—	8.4 (0.5)	8.0 (0.9)	7.5 (0.7)	9.4 (0.7)	7.6 (0.5)	110 (4)	98 (6)
10	0.40 < 0.50	12.2 (1.7)	—	9.4 (1.3)	8.9 (1.0)	8.4 (1.0)	9.6 (1.4)	8.2 (1.1)	115 (13)	103 (11)
10	0.50 < 0.60	13.8 (1.7)	—	10.7 (1.3)	10.1 (1.5)	9.8 (1.6)	11.2 (1.6)	9.2 (0.9)	116 (6)	106 (10)
7	0.60 < 0.70	13.9 (2.1)	—	10.4 (2.2)	10.3 (2.0)	9.8 (1.8)	10.4 (1.6)	8.8 (1.1)	118 (14)	110 (10)
7	0.70–0.83	15.4 (1.1)	—	12.2 (1.5)	12.0 (1.6)	11.2 (1.7)	11.6 (1.7)	10.1 (0.9)	120 (8)	110 (11)

[a] Diameter (mm).

[b] Figures in parentheses refer to ISD.

Asc Ao, ascending aorta; BSA, body surface area; DA, descending aorta; I, innominate artery; LCC, left common carotid artery; LSC, left subclavian artery; SD, standard deviation.

suggests, however, that in only a small percentage of cases measured by the catheter method alone might the results be erroneous. Moreover, the ratios would not be affected by this. In fact, the change of aortic diameter throughout the cardiac cycle was greater than the error of measurement by either method, an error minimized by always taking the largest observed diameter.

Like others [1, 4, 6], we noted increasing aortic size with increasing age and body surface area. Mean internal diameters measured from casts made at autopsy tended to be a little smaller than ours [6], but given the different methods and the fact that systolic frames were measured in the cineangiograms the results are similar. Moss et al. [4] measured the lower descending aorta angiographically in infants and children, most of whom had congenital heart disease. The results reported by Moss et al. are similar, but ours tended to be a little smaller, especially in children over two years of age. The reason for this is not clear.

In the normal fetus, less blood flows across the aortic isthmus than after birth. This is reflected in the smaller diameter of the isthmus in relation to the descending aorta in normal newborns [3, 7, 10]. In children beyond three months of age, however, our data indicate that the isthmus is the same size or larger than the descending aorta in 90%. It is unlikely that the small size of the isthmus beyond the neonatal period in some of our patients is related to the presence of a left to right shunt, as it also occurred in the absence of a shunt. Systemic blood flow was measured in eight of the ten children over a month of age with a relatively small isthmus and found to be normal. Major changes in the size of the isthmus relative to the descending aorta were not seen after surgical abolition of left to right shunts.

Knowledge of the size of the transverse arch in normal children is important in defining hypoplasia of this part of the aorta, and a diagnosis of arch hypoplasia without any reference to normal is inappropriate [8]. Sinha et al. [9] attempted to define tubular hypoplasia of the aortic arch using autopsy and angiocardiographic measurements in normal infants and those with coarctation of the aorta. They found the ratio of the diameter of the transverse arch to descending aorta to range from 0.65 to 1.15 in normal infants at autopsy. They did note that the diameter of the ascending aorta was smaller than that of the descending aortic diameter in a proportion of cases—a finding that would be unusual in our experience and that of others [3].

The method described here for measuring aortic diameters has the advantage of being readily applicable to everyday use. Reproducible results can be obtained. Despite the fact that measurements from the projected cineangiogram frames were made only to the nearest 0.5 mm, we consider the measurements sufficiently accurate to serve as a reasonable guide in determining variations from the usual.

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