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Length growth of the various aortic segments in human foetuses

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This study defines normal growth for the various aortic segments in 128 spontaneously aborted human foetuses aged 15–34 weeks. With the use of anatomical dissection, digital-image analysis (using the Leica Q Win Pro 16 system) and statistical analysis (ANOVA, regression equation), a range of length measurements for the ascending aorta, aortic arch and thoracic aorta was examined. No significant gender differences were found ($p \geq 0.05$). The length of the ascending aorta ranged from 2.63 ± 0.42 to 10.80 ± 1.49 mm, according to the linear function $y = -4.678 + 0.4647 x \pm 0.8447$. The aortic arch length increased from 3.93 ± 0.57 to 15.25 ± 1.98 mm, in accordance with the linear model $y = -6.079 + 0.6370 x \pm 1.1133$. The length of the thoracic aorta ranged from 12.49 ± 1.85 to 48.82 ± 6.31 mm, according to the linear pattern $y = -19.654 + 2.0512 x \pm 3.5168$. The sum of the lengths of these aortic segments generated the linear function $y = -30.410 + 3.153 x \pm 5.4332$. The relationships between the lengths of the various aortic segments generated the linear regressions: $y = -0.2256 + 0.7276 x \pm 0.3093$ (for the ascending aorta vs. *the aortic arch), $y = 0.0252 + 0.3105 x \pm 0.2189$ (for the aortic arch* vs. *the thoracic aorta), and $y = -0.2408 + 0.22709 x \pm 0.2026$ (for the ascending aorta* vs. *the thoracic aorta). The ascending aorta, aortic arch and thoracic aorta also increased proportionally (5:7:22) during gestation.* (Folia Morphol 2008; 67: 245–250)

Key words: ascending aorta, aortic arch, thoracic aorta, length

INTRODUCTION

Previous morphometric studies on the foetal aorta have been conducted in relation to its diameter only, using echocardiographic [1, 3, 6] and autopsy [2, 3, 7, 11, 12] methods. There has been no information to date concerning the lengths of the different aortic segments or their proportions during gestation. The limited anatomical data that there is suggests that the length of the aortic arch increases linearly in relation to the advance of foetal age [4].

This study was undertaken to clarify the increase in length of the various aortic segments in human foetuses. The aims of the present study were to establish the following:
— reference ranges for the length of different aortic segments at various gestational ages;
— growth curves for the length of different aortic segments in relation to foetal age;
— the relationships between the lengths of the ascending aorta, the aortic arch and the thoracic aorta;

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Table 1. Age and number of foetuses studied

Foetal age		Crown-rump length [mm]				Number	Sex	
Months	Weeks (Hbd-life)	Mean	SD	Min.	Max.		Male	Female
4	15	89.4	6.1	85.0	92.0	10	5	5
	16	103.7	6.1	95.0	106.0	7	3	4
5	17	114.9	8.2	111.0	121.0	6	4	2
	18	129.3	6.6	124.0	134.0	8	3	5
	19	142.7	7.7	139.0	148.0	6	3	3
	20	155.3	5.8	153.0	161.0	4	1	3
6	21	167.1	4.7	165.0	173.0	3	2	1
	22	178.1	6.9	176.0	186.0	7	4	3
	23	192.3	6.3	187.0	196.0	9	4	5
	24	202.9	5.7	199.0	207.0	11	6	5
7	25	215.2	4.8	211.0	218.0	7	5	2
	26	224.7	5.2	220.0	227.0	7	4	3
	27	234.1	4.3	231.0	237.0	4	0	4
	28	244.2	5.1	240.0	246.0	5	2	3
8	29	253.8	4.5	249.0	255.0	6	1	5
	30	262.7	3.1	260.0	264.0	6	5	1
	31	270.7	5.2	268.0	275.0	4	1	3
	32	281.4	3.7	279.0	284.0	5	4	1
9	33	290.3	6.1	286.0	293.0	9	4	5
	34	301.4	3.2	296.0	302.0	4	2	2
					Total	128	63	65

— the influence of gender on the value of the parameters studied.

MATERIAL AND METHODS

The material examined consisted of 128 spontaneously aborted human foetuses of both genders (63 males, 65 females) aged 15–34 weeks (Table 1). The crown-rump length measurements were taken as the basis for determining foetal age, according to Iffy et al. [8]. The study was approved by the research ethics committee of the university (KB/217/2006). Specimens that had detectable morphological malformations were excluded from the study. For the analysis foetuses were grouped into six monthly cohorts, ranging from the fourth to the ninth month of gestation.

The foetal arteries were slowly injected with white latex LBS 3060 via the abdominal aorta under a controlled pressure of 50–60 mm Hg using a SEP 11S syringe infusion pump. The foetuses were fixed by the immersion technique in a 10% neutral formalin solution for 4–24 months and then dissected under a stereoscope at a magnification of 10. In each foetus the dissected ascending aorta, aortic arch and thoracic aorta were placed, with a millimetre scale, perpendicular to the optical lens axis, recorded and digitalised to JPEG images. Next, digital pictures of the aorta were analysed by a Leica Q Win Pro 16 digital-image analysis system (Cambridge). Automatic length measurements of the various aortic segments filled with latex constituted the central axis of the flexible cylinder. For each foetus, the three following length measurements were made:

— the length of the ascending aorta from its origin (at the level of the aortic valve annulus) to its ending (just proximal to the brachiocephalic trunk origin);
— the length of the aortic arch from its origin (just proximal to the brachiocephalic trunk origin) to its ending (just proximal to the entry of the ductus arteriosus);
— the length of the thoracic aorta from its origin (just proximal to the entry of the ductus arteriosus) to its ending (at the level of the diaphragm).

The results obtained were elaborated using the one-way ANOVA test for unpaired data. Post hoc inter-group comparisons were then performed using the RIR Tukey test. Regression analysis was used:

— to derive the line of best fit for the plot for each length examined against gestational age;
— to establish the relationships between the lengths of the various aortic segments.

Correlation coefficients (r) were estimated between the parameters examined. The a priori level of significance was set at $p < 0.05$.

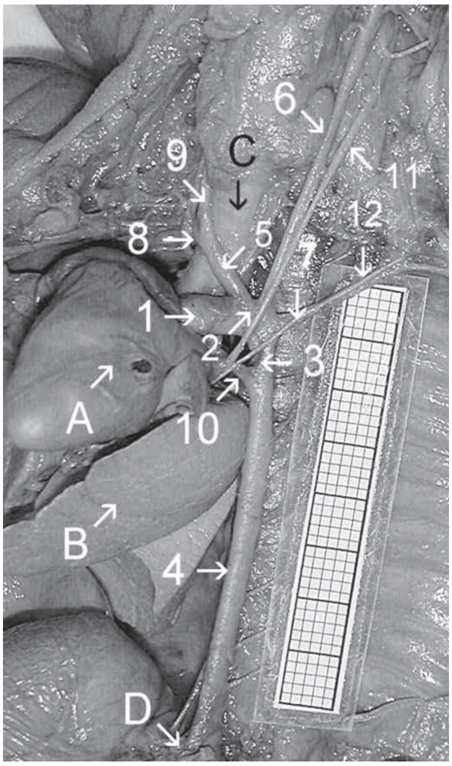

Figure 1. The great chest arteries (*in situ*) in a male foetus aged 28 weeks (*aspectus lateralis*): A — heart, B — right lung, C — trachea, D — abdominal diaphragm, 1— ascending aorta, 2 — aortic arch, 3 — aortic isthmus, 4 — thoracic aorta, 5 — brachiocephalic trunk, 6 — left common carotid artery, 7 — left subclavian artery, 8 — right subclavian artery, 9 — right common carotid artery, 10 — ductus arteriosus, 11 — left vagus nerve, 12 — left phrenic nerve.

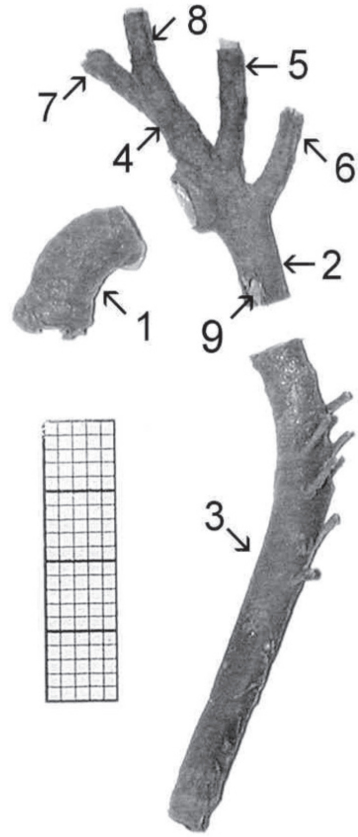

Figure 2. Proportions of the various aortic segments in a female foetus aged 28 weeks: 1— ascending aorta, 2 — aortic arch, 3 — thoracic aorta, 4 — brachiocephalic trunk, 5 — left common carotid artery, 6 — left subclavian artery, 7 — right subclavian artery, 8 — right common carotid artery, 9 — entry of the ductus arteriosus.

Table 2. Block scheme of the statistical analysis of the length of the various aortic segments

Foetal age [months]	Length (mean ± SD) [mm]		
	Ascending aorta	Aortic arch	Thoracic aorta
4	2.63 ± 0.42 ↓ (p < 0.01)	0.93 ± 0.57 ↓ (p < 0.01)	12.49 ± 1.85 ↓ (p < 0.01)
5	3.79 ± 0.59 ↓ (p < 0.001)	5.56 ± 0.89 ↓ (p < 0.001)	17.80 ± 2.76 ↓ (p < 0.001)
6	5.96 ± 0.80 ↓ (p < 0.001)	8.55 ± 1.08 ↓ (p < 0.001)	27.46 ± 3.42 ↓ (p < 0.001)
7	7.30 ± 1.02 ↓ (p < 0.001)	10.22 ± 1.30 ↓ (p < 0.001)	33.02 ± 4.07 ↓ (p < 0.001)
8	9.68 ± 1.20 ↓ (p < 0.05)	13.56 ± 1.55 ↓ (p < 0.01)	43.62 ± 4.99 ↓ (p < 0.05)
9	10.80 ± 1.49	15.25 ± 1.98	48.82 ± 6.31

RESULTS

The source pictures of the various aortic segments are displayed in Figures 1 and 2. The aortic lengths examined were similar in both genders ($p > 0.05$), and so the morphometric values have been presented in Table 2 without regard to sex. Several transformations were generated concerning length against foetal age but proved to be no better

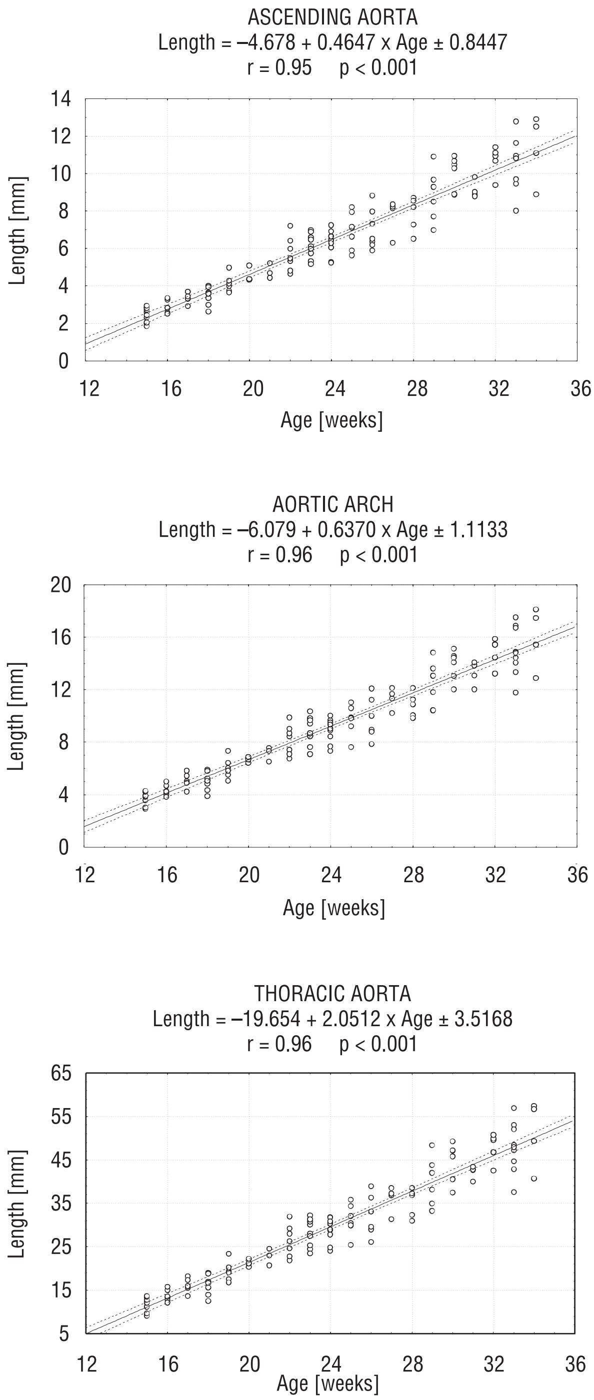

Figure 3. The lengths of the various aortic segments in relation to foetal age.

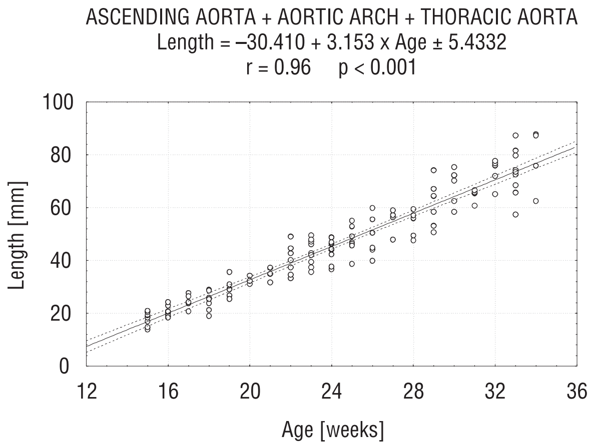

Figure 4. Sum of the lengths of the various aortic segments in relation to foetal age.

than the simple linear model (Fig. 3). During the study period the lengths of the aortic segments presented a linear pattern as foetal age advanced. The values for the length of the ascending aorta ranged from 2.63 ± 0.42 to 10.80 ± 1.49 mm for the groups of foetuses at 4 and 9 months of gestation respectively. The results showed that the ascending aorta length as a function of foetal age, was expressed by the regression $y = -4.678 + 0.4647\,x \pm 0.8447$ ($r = 0.95$; $p < 0.001$). The increase in the length of the aortic arch ranged from 3.93 ± 0.57 to 15.25 ± ± 1.98 mm, according to the linear function $y = -6.079 + 0.6370\,x \pm 1.1133$ ($r = 0.96$; $p < 0.001$). The thoracic aorta length increased from 12.49 ± 1.85 to 48.82 ± 6.31 mm and modelled the linear regression $y = -19.654 + 2.0512\,x \pm 3.5168$ ($r = 0.96$; $p < 0.001$). In addition, the sum of the lengths of these aortic segments generated the linear function $y = -30.410 + 3.153\,x \pm 5.4332$ ($r = 0.96$; $p < 0.001$) (Fig. 4).

The relationships between the lengths of the various aortic segments indicated the following linear regressions (Fig. 5): $y = -0.2256 + 0.7276\,x + 0.3093$ (for the ascending aorta *vs.* the aortic arch), $y = 0.0252 + 0.3105\,x \pm 0.2189$ (for the aortic arch *vs.* the thoracic aorta), and $y = -0.2408 + 0.22709\,x \pm 0.2026$ (for the ascending aorta *vs.* the thoracic aorta). Analysis of the variance revealed that these linear models were highly significant statistically (for each $p < 0.001$). The value of $r \approx 1.0000$ confirmed a strong correlation between the lengths of the different aortic segments. The regression analysis therefore supported the finding that the ascending aorta, aortic arch, and thoracic aorta increased proportionally during gestation in the ratio of 5:7:22 respectively.

DISCUSSION

Reference data for the lengths of the various aortic segments are scarce in foetuses and children. This study presents novel data and information

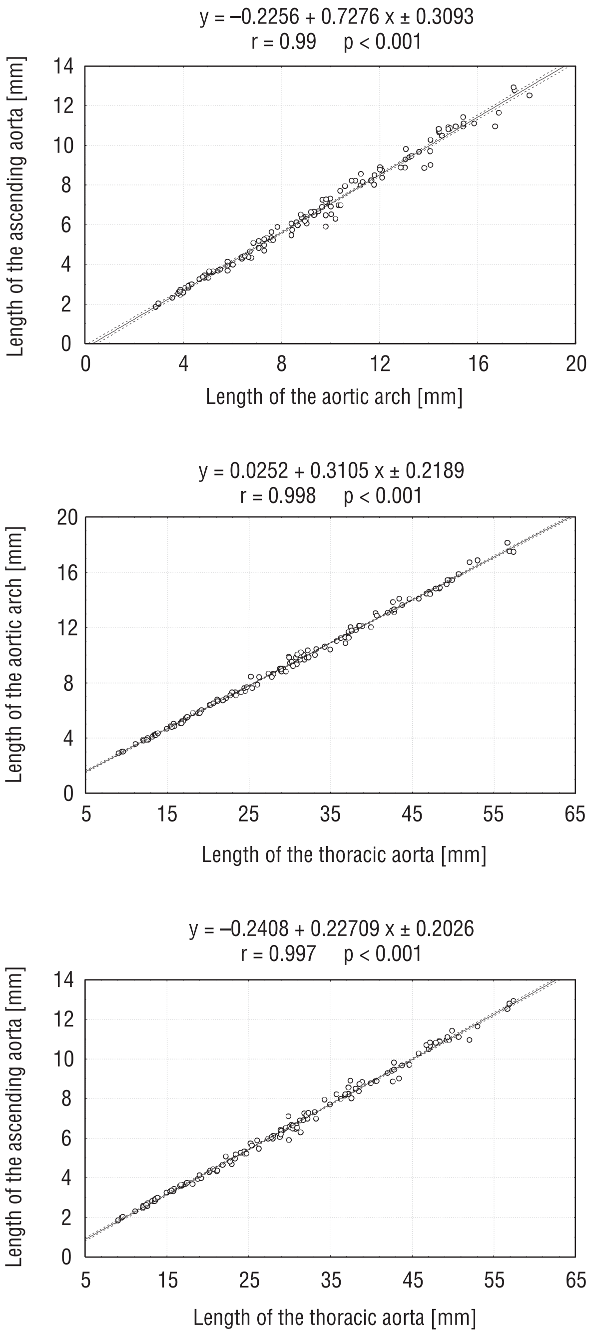

Figure 5. Relative proportions of the lengths of the various aortic segments.

about the normal lengths of different parts of the aorta and their relationships to one another. Normal ranges for the lengths were constructed as follows: from 2.63 ± 0.42 to 10.80 ± 1.49 mm for the ascending aorta, from 3.93 ± 0.57 to 15.25 ± 1.98 mm for the aortic arch, and from 12.49 ± 1.85 to 48.82 ± ± 6.31 mm for the thoracic aorta. The measurements were similar in both genders ($p > 0.05$). As reported by some authors the dimensions of the aorta have been found to be independent of gender [9, 10]. From the present data the growth of all portions of the aorta appears to be related linearly to foetal age. The length of the various aortic segments increased with the advance of foetal age according to the following functions: $y = –4.678 + 0.4647 x ± 0.8447$ for the ascending aorta, $y = –6.079 + 0.6370 x ± ± 1.1133$ for the aortic arch, and $y = –19.654 + + 2.0512 x ± 3.5168$ for the thoracic aorta. It should be noted, that the aortic length summarised increased in accordance with the model $y = –30.410 + + 3.153 x ± 5.4332$. Linear growth of the length of the aortic arch was suggested by Gielecki et al. [4], although in their material the correlation coefficient between length and gestational age was much lower ($r = 0.72$; $p < 0.05$) than in this study ($r = 0.96$; $p < 0.001$).

This study showed prenatal growth of the aorta to be uniformly distributed over the different segments, because their relationships to one another were constant. The lengths of the ascending aorta, aortic arch and thoracic aorta were in a ratio of 5:7:22, and showed no change throughout gestation. In contrast, Hirata [5] performed an anatomical study of the foetal aorta in 20 specimens aged 6–8 months and claimed that growth rates of the aortic subdivisions differed. Proportions of the aortic arch to the whole aorta increased in foetuses aged 6–7 months. On the other hand, the proportions of the thoracic aorta decreased during this period. However, over the 7–8 month period the proportions of each subdivision were unchanged. The present results are therefore in accordance with the findings of Hirata's study in foetuses aged 7–8 months only.

In the professional literature there has been a paucity of quantitative anatomical data concerning the length of the different aortic segments addressed by this study. The lengths presented of the various aortic segments, obtained from a large group of foetuses, will serve as normal data for further studies on this subject.

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