

Postmortem Computer Tomography Appearance of the Aortic Arch in Children: What Is Considered Normal?

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ABSTRACT: **Background:** Virtual autopsies by computer tomography (CT) or magnetic resonance imaging can be valuable in cases of unexplained infant death. The radiologist must be familiar with the normal appearance of all the segments of the thoracic aorta in normal and deceased children. A thorough review of the literature revealed no prior articles describing CT changes in the ascending aorta or the aortic arch in pediatric virtual autopsies. **Objectives:** To compare the CT appearance of the thoracic aorta in deceased children and in those younger than 3 years of age.

Methods: Hospital registries were searched for cases of unexpected deaths in children younger than 3 years old, with a postmortem CT available, as well as for clinically indicated chest CT in children of the same age during a 5 year period. The ascending aorta (AA), aortic arch (arch), and the descending aorta (DA) diameters were measured. Student's *t*-tests and Mann–Whitney U-tests were used to compare the two groups.

Results: A total of 64 scans were reviewed: 35 postmortem and 29 performed on living patients. The differences in the diameter and the ratios of the diameter between the AA and the arch, as well as between the arch and the DA in the postmortem and living groups were statistically significant ($P < 0.05$).

Conclusions: On postmortem CT scans, we found focal tapering of the aortic caliber at the level of the arch between the origin of the brachiocephalic artery and left subclavian artery. This finding should not be misinterpreted as a hypoplastic aortic arch.

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KEY WORDS: postmortem imaging, computer tomography (CT), aortic arch, aorta, pediatric

malformation is one of the important causes of sudden death in infancy [2]. The postmortem appearance of the descending aorta has been described in several articles, and includes hypostasis [3,4], blood sedimentation [5,6], and reduction of the descending aorta diameter [7]. The reduction in the descending and abdominal aorta diameter was reported to be more salient in younger patients than in older ones [8]. The radiologist must be familiar with the normal appearance of the thoracic aorta including the ascending segment, the descending segment, and the aortic arch in normal and deceased children. However, a thorough review of the literature revealed no prior articles describing CT changes in the ascending aorta or the aortic arch in pediatric virtual autopsies.

The goal of this study was to investigate for the first time the appearance of all the segments of the thoracic aorta in healthy and deceased children up to 3 years of age, in order to determine normal post-mortal changes.

PATIENTS AND METHODS

Institutional review board approval was obtained for this retrospective study, and the informed consent was waived.

Hospital registries at Hebrew University Medical Center and Assaf Harofeh Medical Center were searched to find records of all unexpected cases of death in pediatric populations during the preceding 5 years for whom postmortem CT imaging was available. A hospital picture archiving and communication system (PACS) was searched for the available contrast-enhanced chest CT scans of children within the same age range (0–3 years), who had undergone clinically indicated chest CT. Studies performed on patients with known cardiovascular anomalies, any history of trauma, or internal or external hemorrhage were excluded from both groups.

CT scans were performed using a 16-slice scanner (LightSpeed, GE Healthcare, Milwaukee, WI, USA), a 128-slice scanner (Optima 660, GE HealthCare), or Phillips 256-slice scanner (Brilliance iCT, Philips, Eindhoven, The Netherlands). The CT scan parameters for the GE scanner were according to the hospital pediatric protocol and utilizing 80 kV, automated milliampere-seconds (mAs), with a slice thickness of 1.25–1.5 mm reconstructed in 2.5–3 mm. The pitch was set at 1, with a

When unexplained cases of death occur in children, they require investigation to exclude cases of non-accidental trauma, as well as clinically unsuspected hereditary diseases or other forms of pathology. Given the declining rate of conventional autopsies [1], virtual autopsies by computer tomography (CT) or magnetic resonance imaging (MRI) can be of great value in cases of unexplained infant death. To properly interpret a postmortem study, knowledge of normal postmortem changes is mandatory. Unrecognized congenital cardiovascular

rotation time of 0.5 seconds and a small field of view (FOV). The CT parameters for the Philips scanner were defined at 100 kV, maximal 200 mAs, with a slice thickness of 1 mm. The pitch was set at a 0.586 rotation time of 0.5 seconds and a small FOV.

All examinations were reviewed on the hospital's PACS system (Centricity PACS, GE Healthcare, Milwaukee, WI, USA; and SECTRA PACS, Phillips, Eindhoven, The Netherlands). Measurements were carried out by two expert radiologists separately (N.S., N.H.) on the axial images using the PACS software measurement tool. Two different measurements were made by each radiologist, and the average values of the total of four measurements were considered as the true value. The ascending aorta (AA) at its widest level, the aortic arch (arch) in between the origin of the brachiocephalic trunk and the origin of the left common carotid artery, as well as the proximal descending aorta (DA) were measured on all scans. All the measurements were made anterior to posterior, outer edge to outer edge of the wall. Measurements of the arch were performed on the slice in the middle to avoid measuring the top or bottom of the arch. Both radiologists were blinded to which group the scan belonged to. However, it should be stated that the appearances of postmortem CTs of the chest differs so much between the deceased and alive children, that experienced radiologists can easily see the difference. To compare the two groups, Student's *t*-test was used. To eliminate the influence of gender, the groups were divided based on the gender of the subjects, so that females and males could be compared separately in the living and postmortem groups.

RESULTS

A total of 37 postmortem examinations were available. Aortic measurements could not be obtained on two scans due to poor tissue contrast, and these scans were excluded. The total study population consisted of 64 scans, of which 55% (35/64) were postmortem, and 45% (29/64) were from living patients. The postmortem group was comprised of 14 female (60%) and 21 male (40%) subjects, aged 9 days to 3 years (mean age 9 months, median age 5 months, respectively). The group of living patients consisted of 29 patients, of which 10 (35%) were female and 19 (65%) were male, age 3 months to 2 years 11 months (mean age 16 months, median 15 months).

The measurements of the aortic diameter in our study group are presented in Table 1.

The findings showed that the mean diameter of all aortic segments was consistently larger in the living children group than in the postmortem group, attributed to the age difference between the groups.

The mean difference between the AA and the arch was 0.93 mm in the living group and 3.99 mm in the postmortem group. The mean difference between the arch and the DA was 2.45 mm in the living group and -0.61 mm in the postmortem group. The

Table 1. Measurements of aortic diameter (mm)

Group		AA	Arch	DA	Difference AA-Arch	Difference Arch-DA	Difference AA-DA
Living 29 pts	Mean	12.66	11.72	9.28	0.93	2.45	3.38
	Median	13.00	12.00	9.00	1.00	2.00	3.50
	Minimum	9.00	8.00	6.00	0.00	0.00	0.50
	Maximum	17.00	15.00	11.00	2.50	6.00	7.00
	Standard deviation	2.15	2.00	1.41	0.78	1.50	1.70
PM 35 pts	Mean	8.81	4.82	5.43	3.99	-0.61	3.37
	Median	9.00	5.00	5.80	4.00	-0.10	3.20
	Minimum	0.00	0.00	0.00	0.00	-6.80	0.00
	Maximum	13.20	7.10	12.60	7.40	4.00	8.50
	Standard deviation	2.31	1.47	2.53	1.66	1.99	2.21

AA = ascending aorta, Arch = aortic arch, DA = descending aorta

Table 2. Results of *t*-tests between groups

	Living group (mean)	Postmortem group (mean)	P Value
AA-Arch	0.93	3.99	< 0.001
Arch-DA	2.45	-0.61	< 0.001
AA-DA	3.38	3.37	0.99

AA = ascending aorta, Arch = aortic arch, DA = descending aorta

Table 3. Comparison between ratios of the two study groups using the Student test

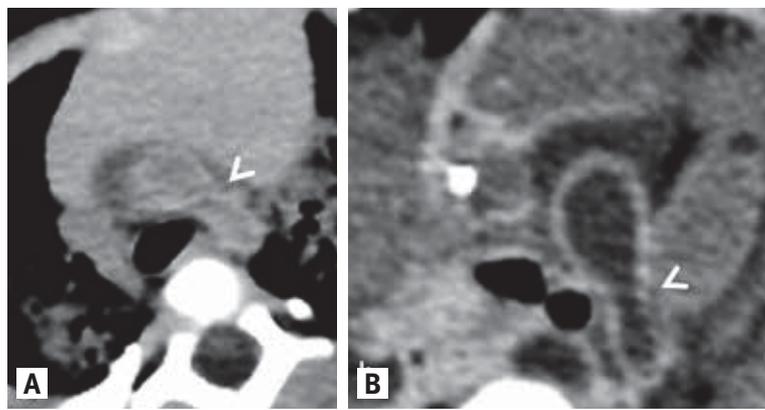
	Living group (mean)	Postmortem group (mean)	P Value
AA/Arch	1.08	1.91	< 0.001
DA/Arch	0.80	1.14	< 0.001
AA/DA	1.38	1.68	0.009

AA = ascending aorta, Arch = aortic arch, DA = descending aorta

mean difference between the AA and DA was 3.38 mm in the living group and 3.37 mm in the postmortem group. The difference between the AA and the arch, as well as between the arch and the DA was significant (*P* < 0.05) as shown in Table 2. The difference in diameters between the AA and the arch, as well as the difference between the arch and the DA was significant. Age did not affect the outcome, and the difference in the diameter in the AA-arch and the DA-arch was significant in both age groups. Gender did not affect the outcome. In addition, ratios of aortic diameter between AA to arch, DA to arch, and AA to DA were calculated. Statistically significant difference was demonstrated between the alive and postmortem groups [Table 3]. A visible focal decrease in the diameter of the arch in between the origin of the brachiocephalic trunk and the origin of the left subclavian artery was apparent on all the postmortem scans [Figure 1].

In the postmortem group, there was a considerable decrease in the aortic arch diameter compared to the AA. In living

Figure 1. Typical focal narrowing of the aortic arch (arrowheads) on postmortem computer tomography scans of 3 month old [A] and 8 month old [B] infants



patients, there was more moderate tapering of the arch caliber as compared to AA, and the arch was larger in diameter than the DA. In all postmortem scans the diameter of the DA progressively declined caudally, with almost complete flattening of the aorta at the level of the diaphragm. In 17 patients from the postmortem group, alveolar consolidations were found on the CT scan, accompanied by pleural effusion in two. In one patient, a nasopharyngeal polyp was diagnosed. In the remaining 17 patients in this group no significant abnormality was identified by virtual CT autopsy. No mention of the aortic diameter was found in the radiology reports, except for one postmortem scan where the focal narrowing of the arch was interpreted as possible aortic coarctation or hypoplasia.

DISCUSSION

This study shows that in virtual CT autopsies, focal salient tapering of the aorta can be found at the level of the aortic arch. This finding was not observed in the group of living patients. Such changes should be considered normal, and not misdiagnosed as a hypoplastic aortic arch.

Familiarity with normal postmortem changes is clearly needed to avoid misinterpretation of normal findings as disease. An erroneous diagnosis of the cause of death in young children can have serious ramifications for the families, and may have legal consequences. It is also important to understand the pathophysiology behind this appearance of the aorta observed shortly after death.

Several studies based on CT and magnetic resonance angiography of living subjects have reported that the aortic diameter decreases gradually distally in children from the ascending aorta, through the arch and into the descending aorta [9,10,11]. The properties of the aortic wall depend on the adventitia, media, and intima. The media consists of lamellar units, each of which consists of vascular smooth muscle cells sandwiched between elastic lamellae and surrounded by collagen fibers and

proteoglycans of the extracellular matrix. The lamellar unit is responsible for the strength and elastic recoil [12]. Previous pathological and physiological studies have shown that the amount of elastin in the aortic wall decreases with age, resulting in an increase in aortic wall stiffness. In the ascending aorta, the number of elastin fibers is higher at birth than in the descending aorta. However, in the descending aorta the collagen density is the highest [13,14]. Large arteries provide vascular buffering adequate to absorb the impact of blood from each ventricular contraction. The histological structure of the aorta varies according to its site and function as a reservoir and conductive system (the Windkessel principle). The proximal aorta is rich in elastin that enables the support of each systolic impulse and accommodates the stroke volume, whereas more distal vessels show a predominance of collagen fibers [15]. This difference could explain why the descending aorta is collapsed more prominently than the ascending aorta; however, it does not explain why the arch in this study was relatively more collapsed than the AA and the DA on postmortem scans. The answer may lie in the fact that the ascending aorta and pulmonary artery together are enclosed in the serous pericardium and share a common sleeve in the fibrous pericardium. The fibrous pericardium is rigidly attached to the posterior surface of the sternum by sterno-pericardial ligaments. The apex of the pericardium is continuous with the adventitia of the great vessels. At the level of the ascending aorta the pericardia ends just below the origin of the brachiocephalic artery. The DA is fixed posteriorly to the spine by intercostal arteries. Only the arch is “suspended” on the vessels originating from it. It is possible that once the aorta is “free” of the pericardium and from posterior fixation to the ribs, its ability to sustain its form becomes more limited, causing it to collapse more easily in the absence of blood pressure.

Another factor that may account for the differences in behavior of the three segments of the thoracic aorta is the fact that each segment has different embryological origins. The truncus arteriosus divides into the ventral aorta and pulmonary trunk by the aortic-pulmonary septum, representing the respective outflow channels of the heart. After this, the aortic sac forms right and left horns. The right horn becomes the brachiocephalic artery and the left becomes the proximal (ascending) part of the aorta. The arch of the aorta has a different embryologic origin from the embryonal left 4th aortic arch. The descending aorta is formed by fusion of both dorsal embryonic aortae [16].

STUDY LIMITATIONS

This study has several limitations. Although the data were collected over a period spanning 5 years, the number of patients was relatively small. In addition, the mean age of the control group was higher than that of the postmortem group. Measurements were performed solely on the axial images. It would be worthwhile to conduct additional measurements using

multiplanar reformations in future studies. However, as in regular reporting of the chest CT, no measurements are performed routinely on the reformats, and our study follows the standard procedure. One can also argue that because no autopsy correlation was available, the deceased children all had hypoplastic arch or coarctation. However, the prevalence of the hypoplastic arch or coarctation is low in the population, making such a coincidence extremely unlikely.

CONCLUSIONS

On postmortem CT scans there is focal flattening of the aortic caliber at the level of the arch between the origin of the brachiocephalic artery and left subclavian artery. This finding should not be misinterpreted as a hypoplastic aortic arch.

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Capsule

A site-specific switch for cancer cells

To metastasize, cancer cells must switch from epithelial (polarized and fixed) into mesenchymal (motile and invasive) phenotypes to disseminate and colonize both primary and metastatic sites. Zhou and colleagues found that the long non-coding RNA H19 acted as a site-specific microRNA sponge to promote an epithelial or mesenchymal switch in tumor cells. In epithelial-like tumor cells in primary and metastatic sites, H19

sequestered miR-200b/c and ultimately inhibited migration. In mesenchymal-like disseminated cells in circulation, H19 sequestered a different microRNA, Let-7b, and ultimately promoted migration.

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Capsule

Double duty for mammary stem cell niche

The stem cell niche is a complex local signaling micro-environment that regulates stem cell activity for tissue and organ maintenance and regeneration. As well as responding locally, during puberty, the mammary gland stem cell niche also responds to systemic hormonal signals. Zhao et al. have found that Gli2, a transcriptional effector of Hedgehog signaling, coordinates the niche-signaling program and

activates expression of receptors for the mammatrophic hormones estrogen and growth hormone throughout the mammary gland (see the Perspective by Robertson). Disease may result not only from stem cell defects, but also from dysregulation of the microenvironment.

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