Isthmus Aortae – Its Definition and Significance

By

Tatsuo KASAI, Takao SUZUKI, Masashi KODAMA and Yuko OKUNO

Department of Anatomy, Hirosaki University Medical School,
Hirosaki 036, Japan

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Summary: In order to reach a clear definition of the Isthmus aortae (BNA, INA and PNA), the outer and inner diameters of six portions of the aortic arch, as shown in Fig. 1, were measured in 24 human adults and 20 fetuses. The narrowing of the vessel was actually located between the origin of the left subclavian artery and the insertion of the ductus arteriosus in fetuses, but was found to be unremarkable in adults. The term Isthmus aortae thus belongs to the embryological nomenclature.

Summarizing the previously reported cases of anomalies of the aortic arch, it can be said that the ductus arteriosus usually remains in loco, in spite of the transformation of the aortic arch, connecting the pulmonary trunk with the left aortic arch or the beginning of the descending aorta, crossing over the left bronchus. When this situation is considered from the standpoint of embryology together with the upward migration of the developing left subclavian artery, the presence of a developmental weak point (*Locus minoris resistentiae*) can be suspected in the developing left aortic arch. This portion corresponds to the Isthmus aortae in normal cases, and most anomalies of the aortic arch are genetically based on maldevelopment of this portion.

The term 'Isthmus aortae' has been used in the anatomical nomenclature of the BNA, INA and PNA, without attracting particular attention to date. However, when we consider what it means and where in the aorta it is located, we cannot help but note that the meaning of this term is quite indefinite, since no marked constriction can be seen in the aorta of human adults. Moreover, discrepancies of definition are found in anatomy textbooks. According to textbooks written in English, the Isthmus aortae is defined as the part of the aortic arch between the origin of the left subclavian artery and the insertion of the ductus arteriosus

(or the ligamentum arteriosum). On the other hand, authors of Japanese and German textbooks cite it as representing the transitional part of the aortic arch into the descending aorta. Both definitions may indicate almost the same part of the aorta, but the description in the latter case is inappropriate. The reason for this will be discussed in this paper. Furthermore, the morphological significance of this condition as well as its embryological derivation will be evaluated.

Materials and Methods

To ascertain whether the constriction cor-

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responding to this term actually exists in the aortic arch, and if so, where in the aorta it is located, the authors measured the outer and inner diameters of the aorta in 24 human adults and 20 fetuses ranging from 18.5 to 29 cm in C-R length. The measurements were carried out on the following six portions (Fig. 1): 1) the beginning of the ascending aorta, 2) between the roots of the innominate and the left common carotid

Fig. 1. Six portions (1–6) of the aortic arch of the human adult and fetus at which the outer and inner diameters were measured in this study.

arteries, 3) between the roots of the left common carotid and the left subclavian arteries, 4) between the root of the left subclavian artery and the insertion of the ductus arteriosus (or ligamentum arteriosum), 5) immediately distal to the insertion of the ductus arteriosus, and 6) at the level of the aortic hiatus of the diaphragm.

Results and Discussion

As shown in Table 1, the outer and inner diameters of the aortic arch of adults were conclusively found to taper distalwards, without forming any marked constrictions on the way. On the other hand, portion 4) of the fetuses revealed a constriction as compared with the other parts of the aorta. The term *Isthmus aortae* should thus be applied to fetuses, not to adults. It will be readily understood that the narrowing is genetically related to the patency of the ductus arteriosus. After birth, it gradually increases in size following closure of the ductus arteriosus. These changes are clearly

Table 1. Outer and inner diameters of six portions of the aortic arch. Each value shows the arithmetic mean and standard deviation calculated for 24 human adults and 20 fetuses ranging from 18.5 to 29 cm in C-R length. The numbers in parentheses in the first column indicate the measured portions of the arch, as illustrated in Fig. 1. Note that the aortic arch in adults progressively diminishes in diameter distalwards, forming no markedly narrow portion on the way, whereas in fetuses, portion (4) clearly shows a constriction as compared with the adjacent portions.

	Adult diameter(mm)		Fetus diameter (mm)	
	outer	inner	outer	inner
(1)	29.04 ± 3.06	25.50 ± 2.86	5.67 ± 0.86	3.75 ± 0.92
(2)	27.46 ± 3.23	23.63 ± 3.25	5.50 ± 1.08	3.52 ± 1.10
(3)	26.46 ± 3.45	23.04 ± 3.28	5.00 ± 0.79	3.12 ± 0.88
(4)	23.96 ± 3.49	20.42 ± 3.32	3.90 ± 0.73	2.32 ± 0.67
(5)	24.38 ± 3.35	20.96 ± 3.27	5.15 ± 0.84	3.14 ± 0.71
(6)	20.88 ± 3.06	17.83 ± 2.90	5.22 ± 0.80	3.12 ± 0.72

illustrated in Patten's textbook of embryology (1930, 1953).

A large number of case reports on anomalies of the aortic arch have been published, and Kasai (1962), one of the authors, has summarized them. As regards their embryological derivation, he considered a developmental weak point at the left dorsal aorta just proximal to the sixth aortic arch. Most of the anomalies of the aortic arch originate from maldevelopment of this area, which corresponds to the future Isthmus aortae.

To explain this, the right-sided aortic arch, especially of the N-type or Type II of Felson and Palayew (1963), will be discussed first. In this anomaly, the left subclavian artery arises from the descending aorta and passes behind the esophagus. The ductus arteriosus connects the pulmonary trunk with the root of the left subclavian artery. No exceptional cases have been reported on this point (Kasai et al. 1962). From these findings, this anomaly can be based on interruption of the left dorsal aorta proximal to the sixth aortic arch (see Kasai's previous

paper for details). The other type of right aortic arch is the so-called M-type or Felson's Type I, and in this case, the left subclavian artery arises from the left innominate artery. Therefore, embryologically, it is considered that the left dorsal aorta is interrupted distal to the origin of this artery. However, the course and insertion of the ductus arteriosus are variable and, in some cases, it connects with the left subclavian artery as shown in Fig. 2, or with the beginning of the descending aorta, while in other cases, it appears on the right side or is completely absent (Kasai et al. 1968).

Next, the double aortic arch should be discussed (Fig. 3). Griswold and Young (1949) summarized the cases reported by others. According to them, as well as to Kasai (1962), the anatomical findings of the double aortic arch resemble those of the N-type right aortic arch. That is, the ductus arteriosus connects the pulmonary trunk with the left aortic arch, which is embryologically identical to that of the right aortic arch. Moreover, the left aortic arch is, in most cases, thinner than the right, and,

Fig. 2. Two types of right aortic arch. The left diagram shows the so-called M-type in which the left subclavian artery arises from the common trunk with the left common carotid artery. The right diagram shows the N-type in which the left subclavian artery arises from the beginning of the descending aorta.

Fig. 3. Two types of double aortic arch. Constriction of the vessel was usually observed in the left arch distal (on the left) or proximal (on the right) to the origin of the left subclavian artery.

in some cases, part of the left arch shows a narrowing or obliteration proximal or distal to the origin of the left subclavian artery.

Another type of anomaly is the coarctation and interruption of the aorta (Fig. 4). In such cases, the basic pattern of the aortic arch is normal, and the ductus arteriosus con-

nects the pulmonary trunk with the aortic arch. Celoria and Patton (1959) classified the interruption into three types: A, B and C. Recently, Suzuki (1980), one of the present authors, summarized the previous reports and described the frequency of each type. According to him, the most frequent ones are types A and B (41% and 53%, respec-

Fig. 4. Two types of interruption of the aortic arch. The aortic arch was interrupted distal (on the left) or proximal (on the right) to the origin of the left subclavian artery.

tively), and, in these cases, the left aortic arch is interrupted proximal (type B) or distal (type A) to the origin of the left subclavian artery.

From the above findings, the features common to all these anomalies can be outlined as follows. Firstly, the left aortic arch is involved in serial changes showing narrowing, obliteration and interruption of the vessel lumen during the developmental period, and these changes occur proximal or distal to the origin of the left subclavian artery. Secondly, the ductus arteriosus in most cases remains in loco connecting the pulmonary trunk with the left aortic arch or the beginning of the descending aorta. Nevertheless, a few exceptional cases have been reported. In particular, the ductus arteriosus of the M-type right aortic arch is variable in course and insertion, as mentioned above. However, the two above-mentioned features were commonly observed in a majority of the anomalies. Thus, when the development of these anomalies is considered together with the upward migration of the developing left subclavian artery (Congdon, 1922, and others), a developmental weak

point (*Locus minoris resistentiae*) can be suggested in the left aortic arch just proximal to the insertion of the ductus arteriosus (Fig. 5).

The reason why such a weak point exists in the left arch remains uncertain, although some previous theories to explain the pathogenesis of coarctation of the aorta can be cited. The most famous and classic one is the Skodaic hypothesis, which states that the tissue composing the wall of the ductus arteriosus spreads into the aortic arch. Bremer (1948) expressed almost the same opinion based on his findings in rat embryos. Freiberg (1941) considered stagnation of blood flow between the ascending and descending aorta. Edwards et al. (1948) described a thickening of the tunica media in the affected part of the aorta as a possible cause of the coarctation, while Shaner (1956) reported that the open end of the rudimental fifth aortic arch was projected into the lumen of the aorta and acted as a valve-like structure. Moffat (1960) examined human fetuses and described shelf formation by the vessel wall of the upward-migrating left subclavian artery at the aortic orifice. Schwartz-Karsten (1959) also mentioned shelf-like formation at the distal margin of the opening of the left subclavian artery. Clagett et al. (1954) proposed a similar theory and considered a curtain-like infolding of the aortic wall to be associated with the upward migration of the left subclavian artery.

In conclusion, the Isthmus aortae is part of the aortic arch and is situated between the left subclavian artery and the insertion of the ductus arteriosus. It represents a developmental weak point which is involved in serial changes of the vessel lumen—narrowing, obliteration and interruption—during the development period. The pathogenesis of most anomalies of the aortic arch is closely related to this.

Fig. 5. Developmental weak point in the developing aortic arch (at mark X). This portion corresponds to the future Isthmus aortae.

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Abbreviations for figures

B:	ductus arteriosus (or ligamentum arteriosum)	Sd:	right subclavian artery
Ccd:	right common carotid artery	Ss:	left subclavian artery
Ccs:	left common carotid artery	T:	trachea
P:	pulmonary trunk	Vd:	right vagus nerve
Pd:	right pulmonary artery	Vs:	left vagus nerve
Ps:	left pulmonary artery		