Variations of Aortic Arch Derivatives in the Chick (Hatchlings)

By

Masayuki KUDO, Kazuya YOSHINAGA and Toyoaki FUJIMOTO

Department of Anatomy, Kumamoto University Medical School, Kumamoto 860, Japan

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Summary: The branching patterns of the arteries deriving from the embryonic aortic arches were investigated in 1,046 spontaneous chick hatchlings of White Leghorn. An incomplete ductus arteriosus (Botalli) was found on each side of every case observed. An unusual branching patterns were found in 14 hatchlings and were classifiable into the following 4 (B to E) types. Type A (Normal pattern): The aorta arose from the left ventricle and gave off the left and right brachiocephalic arteries. Each brachiocephalic artery was divided into the common carotid and the subclavian arteries. Type B: The right brachiocephalic artery had a slightly higher origin on the aorta. Type C: The right subclavian artery had a slightly lower origin on the right brachiocephalic artery. Type D: The right brachiocephalic artery was absent and the right subclavian and right common carotid arteries arose directly from the arch of aorta. Type E: The distal end of the right brachiocephalic artery fused with the distal part of the arch of aorta.

It is well known that the development and disappearance of the aortic arches during the embryonic period exhibit various differences depending upon the species of vertebrates. For instance, in mammals the fourth aortic arch persists on the left side, while in birds it persists on the right side to form an aortic arch which is the mirror image of the mammals. Grenny ('55) detailed the arrangement of the aortic arch system in the families and the orders of birds, in which he found a functional left radix aorta in the belted kingfisher. Fujimoto ('66) also studied the arteries derived from the aortic arches in the chick. He did not find cases of the left sided arch of aorta as in mammals, but did report some variations of the branching patterns of aortic arch derivatives system (Fig. 6). Recently, the arterial patterns in White Leghorn chick hatchlings (Levinsohn, et al., '84) and spontaneous aortic arch malformations in the chick embryo (Kuhlmann and Kolesari, '84) have been described. The present study further describes the branching patterns of arteries deriving from the aortic arches in chick hatchlings.

Materials and Methods

A total of 1,046 White Leghorn male chickens were procured from the local market, 8–12 hours after hatching. After fixation in 10% formalin, they were autopsied and dissected under a dissecting microscope.

Results

Normal branching (type A) of the arteries...
deriving from the aortic arches was found in 1,032 of 1,046 hatchlings (98.7%). Unusual branching patterns were found in 14 hatchlings. These were divided into four types, B–E of the following.

Type A: Usual pattern (Fig. 1)
A short (5 mm in length) ascending aorta arose from the left ventricle and immediately gave off two large arteries, the left and right brachiocephalic arteries, which were in close contact at their bases. The aorta then curves to the right and descended to form the right sided arch of aorta that became the descending aorta. Each brachiocephalic artery ascended a short distance and was divided into the common carotid and the subclavian arteries on each side.

The pulmonary trunk arising from the right ventricle soon branched to form the left and right pulmonary arteries. The right pulmonary artery ran behind the basal portion of the arch of the aorta and entered the right lung (R.P. in Fig. 1). In all hatchlings examined, an incomplete ductus arteriosus (Botalli) persisted bilaterally between the pulmonary artery and the terminal portion of the arch of aorta and was in the processes of regression (L. D. and R. D., Fig. 1).

Unusual patterns
Type B (Fig. 2)
The right brachiocephalic artery originated about 1.0 mm above the left brachiocephalic artery which originated from the transitional portion of the ascending aorta and entered the arch of aorta to the arch of aorta.

Type C (Fig. 3)
This type was found in 4 hatchlings. The right subclavian artery originated at a more proximal part of the brachiocephalic artery than that in normal hatchlings; the distance of the arising point of this subclavian artery to the base of brachiocephalic artery was about 3.0 mm (normal: 5.5 mm). In addition the proximal part of the right subclavian artery was slightly twisted and the wall of the right common carotid artery was thicker than that in normal hatchlings.

Type D (Fig. 4)
This type was found in one hatchling. The right brachiocephalic artery was absent. The right subclavian artery branched directly from the arch of the aorta, which was almost normal in size. In addition, a small aberrant branch and the right common carotid artery branched off from the arch of aorta.

Type E (Fig. 5)
This type was found in 2 hatchlings. The right brachiocephalic artery originated from the normal position and ran along the arch of aorta, but joined and fused with the distal part of the arch of aorta (arrow in Fig. 5). This artery branched into the right subclavian artery and the right common carotid artery. Moreover, the right brachiocephalic artery was larger in diameter and its distal part was slender than the normal one.

Discussion
Levinsohn et al. ('84) reported that the hatchling arterial pattern strongly resembles that of an adult chick. In vertebrate embryos, six pairs of aortic arches are formed during development, some of which persist and contribute to the adult patterns of arteries. The first, the second, and the fifth aortic arches disappear at early developmental stages. The third aortic arch usually remains throughout life and forms the common carotid artery. In birds only the right branch of the fourth aortic arch remains and this serves as the functional systematic aortic arch connecting the systematic root with the dorsal radix on the right side. The left arch entirely disappears. The proximal half of both right and left sixth aortic arches remains and connects with the newly formed pulmonary artery; the distal half atrophies
and disappears. The left ductus arteriosus completely disappears, while the right one remains as the ligamentum Botalli, which connects with the right radix aorta.

Why the incidence of the aortic arch malformation is different in each study remains unclear. The unusual branching patterns of main arteries deriving from the aortic arches were observed in 1.3% (14 or 1,046) in the present study. This differs greatly from previous studies. Fujimoto ('66) reported a rate of 7.8% (16 of 205) and he also described the presence of a slender supernumerary artery arising from the basal portion of the left brachiocephalic artery in 14 of the unusual cases. Kuhlmann and Kolesari ('84) also reported a rate of 7.1% (14 of 196) aortic arch malformations in White Leghorn chick embryos.

Warkany ('71) suggested that genetic predispositions or environmental factors such as incubation temperature or humidity may disturb the normal process of development of embryonic aortic arches and the arrangement of their derivatives in chick hatchlings. The low incidence rate of malformation obtained in this study may be due to the material used, which was incubated in a rather good environment.

In all hatchlings observed in the present study, an incomplete regressing ductus arteriosus was found on each side. This represents the transition from the embryonic vascular pattern to that of the adult.

The unusual patterns seen in the present study may be plausibly ascribed to developmental events. For instance, in case C, the right subclavia artery would arise at a lower position as a result of hypoplasia of the right brachiocephalic artery. The type D pattern could result from the incorporation of the third into the fourth aortic arch following the degeneration of the third arch. The type E pattern may result from the persistence of the third dorsal aortic root which usually atrophies and disappears. Kuhlmann and Kolesari ('84) suggested that the most common type of spontaneous aortic arch malformation in the chick embryo is hypoplasia of the third aortic arch. This is consistent with the present result, since the all unusual cases found are consistent with an anomalous development of the third and the fourth aortic arches on the right side during the embryonic period.

References

Explanation of Figures

Plate I

Fig. 1. Type A: Normal pattern. A single aortic trunk arising from the left ventricle immediately gives rise to the left brachiocephalic artery and next to the right brachiocephalic artery. Each brachiocephalic artery is divided into the common carotid and the subclavian arteries. A single aortic trunk curves to the right to form the arch of aorta and become the descending aorta.

Left plate: dissected specimen. (x6.8; common to figs. 1–5).
Right plate: Schematic diagram of the left. (common to figs. 1–5).

Fig. 2. Type B: The right brachiocephalic artery originates at a slightly higher level than in normal, so that the right and the left arteries do not contact with each other at their bases.

Abbreviations

A.a: Arch of aorta
R.Cc: Right carotis communis artery
L.Cc: Left carotis communis artery
R.Sb: Right subclavian artery
L.Sb: Left subclavian artery
R.Bc: Right brachiocephalic artery
L.Bc: Left brachiocephalic artery
R.P: Right pulmonary artery
L.P: Left pulmonary artery
R.D: Right ductus arteriosus
L.D: Left ductus arteriosus
S.f: Superfluous artery
(Common to Figs. 1–6)
Fig. 1. Type A

Fig. 2. Type B
Plate II

Fig. 3. Type C: The right subclavian artery originates at a more proximal portion of the brachiocephalic artery than in normal.

Fig. 4. Type D: The right brachiocephalic artery is absent, and the right subclavian artery arises directly from the arch of aorta.
Fig. 3. Type C

Fig. 4. Type D
Plate III

Fig. 5. Type E: The right brachiocephalic artery fuses at its distal end with the distal portion of the arch of aorta. From this brachiocephalic artery the subclavian artery and the common carotid artery branch out.
Fig. 5. Type E
Plate IV

Fig. 6. Various patterns of aortic arch derivatives in the chick hatchlings reported by Fujimoto ('66). Note the supernumerary branch (Sf: blackly drawn).
Type A (189/205)
(Normal)

Type B (1/205)

Type C (9/205)

Type D (1/205)

Type DE (2/205)

Type FC (1/205)

Type CG (1/205)

Type H (1/205)