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CASE REPORT

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A case report of an Adachi-Williams type CG plus H aortic arch anomaly and implications for the development of the cervicothoracic circulation

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ABSTRACT

Background: It is unclear whether the development of the branches of the subclavian artery is dependent on the proximal part of this artery since great vessel formation is partially regulated by haemodynamic stress. For example, the vertebral artery that usually arises from the subclavian artery might be affected by anomalies in the aortic arch branches. This uncertainty is partly due to the limited reports of highly anomalous cases of proximal and distal branching morphologies. Here, we report an Adachi-Williams type CG plus H aortic arch case found during student dissection and discuss the development of the cervicothoracic circulation.

Case report: Here, we report an aberrant right subclavian artery that arose from the aorta distal to the left subclavian artery, via a retroesophageal course, whereas the right and left common carotid arteries arose from a short common trunk from the aorta (the carotid trunk) (Adachi-Williams type H). In addition, the left vertebral artery arose directly from the aortic arch between the carotid trunk and the left subclavian artery (Adachi-Williams type CG). Anomalies in the branching arteries from this aberrant right subclavian artery (the right vertebral artery, internal thoracic artery, thyrocervical trunk, costocervical trunk and thoracoacromial artery) were unidentifiable. The right vagus nerve directly innervates the laryngeal muscles without forming the recurrent nerve.

Conclusions: The development of an aberrant right subclavian artery might affect haemodynamic stress in both the proximal and distal regions of the anterior limb region. The distal branching morphology, however, was normal, suggesting an independence of proximal and distal vasculature development. Since the concomitance of Adachi-Williams-type CG and H is rare, rather than sequentially develop, the distal arteries develop in a fine-tuned manner to adapt to anomalies in the proximal arteries.

Keywords: angiogenesis, arteria lusoria, branchial artery, cadaver, common carotid artery, dorsal aorta, haemodynamic stress, intersegmental artery, vascular remodelling, vertebral artery

INTRODUCTION

The right subclavian artery (RSA) usually arises from the brachiocephalic artery, which is the first branch of the definitive aortic arch. Many branches (the vertebral artery, internal thoracic artery, thyrocervical trunk, costocervical trunk and thoracoacromial artery) arise from this artery, along with the axillary artery. The thyrocervical trunk supplies the laryngeal muscles that originate from the fourth branchial arch while sending additional branches to the upper limb girdle and upper thoracic region. In addition, the RSA is responsible for the arterial blood supply in the upper extremities as well as in a part of the brain via the vertebral artery.

Anomalies in the aortic arch and RSA are frequently observed. For example, the left vertebral artery may arise directly from the aortic arch between the left common carotid artery and the left subclavian artery (approximately 0.6–5.5% [3]). The RSA may arise from distal to the left subclavian artery via a retroesophageal course, namely the aberrant right subclavian artery (ARSA) or arteria lusoria (approximately 0.4–2.0% [4]). These anomalies are classified on the basis of their accompanying vessel branching morphology [15]. For example, the coexistence of the ARSA and the left vertebral artery arising directly from the aortic arch is classified as Adachi-Williams type CG. In addition, the coexistence of the ARSA and a common trunk for the right and left common carotid artery (the carotid trunk) is classified as Adachi-Williams type H.

The development of RSA is complicated since it is achieved by vascular remodelling [1, 5]. This starts from embryonic Day 10.5 (E10.5) in rats, when a few sprouts arise from the bilateral dorsal aortae. Importantly, when the fusion of the bilateral dorsal aortae reaches the level of the anterior forelimb region at E11.0, these sprouts form a vascular network in the anterior limb bud both in its proximal and distal regions, while the intersegmental arteries run dorsally. By E12.0, the vertebral artery develops from the intersegmental arteries, while the sprouts from the dorsal aorta are fused with the seventh intersegmental artery to form the seventh primary subclavian artery. Afterwards, the right dorsal aorta involutes to form a normal RSA arising from the brachiocephalic artery. In contrast, the persistent right dorsal aorta is considered to form the ARSA [11]. In summary, the vertebral artery usually arises from the subclavian artery as the dorsal branch of the seventh intersegmental artery, whose formation is dependent on the fusion of several sprouts from the dorsal aorta.

There are at least two mechanisms behind the formation of great vessels (gene expression and haemodynamic stress). For example, a key transcription factor, *Pitx2*, is exclusively expressed on the left side of the embryonic aortic arch (the primary regulatory mechanism), which leads to dominant haemodynamic stress on the left side (the secondary regulatory mechanism), causing involution of the proximal part of the right aortic arch [12]. Therefore, anomalies in the proximal part of the anterior limb vasculature might influence the development of its distal part by altering haemodynamic stress. In this context, a description of distal vascular morphology in human cadavers with anomalies in the aortic arch and its associated great vessels might contribute to elucidating the morphogenesis mechanisms in the anterior limb region. In this case report, we described a case of ARSA concomitant with the carotid trunk where the left vertebral artery arose directly from the aortic arch (Adachi-Williams type CG plus H), with an emphasis on its branching morphology.

Case report

The case involved a dissection by students from the College of Medicine, School of Medicine and Health Sciences, University of Tsukuba, Japan. The cadaver examined was a 74-year-old Japanese female who died of cerebral infarction.

The ARSA arose from the distal part of the aortic arch just distal to the left subclavian artery without Kommerell’s diverticulum (Fig. 1a) and passed behind the oesophagus and anterior scalene muscle. The right and left common carotid arteries arose from the carotid trunk (Adachi-Williams type H) (Fig. 1b). In addition, the left vertebral artery arose directly from the aortic arch (Adachi-Williams type CG) (Fig. 1a). The right recurrent nerve was unidentifiable, and instead, the right vagus nerve innervated directly to the laryngeal muscles, as is usual in ARSA cases [9] (Fig. 1c). Importantly, the vertebral artery, internal thoracic artery, costocervical trunk and thoracoacromial artery on the right side arose from this ARSA (Fig. 1c). The right vertebral artery arose from the ARSA and entered the transverse foramen of the sixth cervical vertebra. The major findings of the present case are summarized in Figure 1d.

DISCUSSION

Vascular remodelling in the embryonic circulation is a dynamic and complex process in which rearrangements sequentially occur. This process is linked to the surrounding tissues and haemodynamic stress within the developing vessels. For example, the disruption of branchial arch formation by perturbing the *Tbx1* gene results in malformation of the fourth branchial artery and ARSA development [2]. Indeed, another case report suggested that involution of the entire right fourth branchial artery leads to the development of the ARSA [6]. In *Tbx1* mutant mice, the right dorsal aorta becomes the main route for the blood supply to the upper extremity to form the ARSA, possibly owing to haemodynamic stress or the absence of paracrine signalling, such as vascular endothelial growth factor A [14].

In the present case report, we observed an ARSA that arose from the distal part of the aortic arch and followed a retroesophageal course, and then branched into many vessels, including the right vertebral artery, internal thoracic artery, thyrocervical trunk, costocervical trunk and thoracoacromial artery, before becoming the brachial artery, while the left vertebral artery arose directly from the aortic arch between the carotid trunk and the left subclavian artery. This anomaly corresponds to Adachi-Williams type CG plus H, which was first reported by Kawai et al. [8] and then Wang et al. [13] in 2011 and, finally, to the best of our knowledge, in our study as the third report in the literature. In contrast to the findings of the present report, the distal branching morphology of the ARSA is beyond the scope of previous reports since they focused on the proximal development of the ARSA. Therefore, inspired by the idea that haemodynamic stress is important for great vessel development [12], we tried to examine the developmental connection of the proximal and distal parts of the RSA by analysing this Adachi-Williams type CG plus H cadaver. As expected, the right vagus nerve directly innervated the laryngeal muscles without forming a recurrent nerve, suggesting that the fourth branchial artery contributes to the ARSA differently from normal cases.

Angiogenesis is highly involved in the development of the cervicothoracic circulation. For example, the vertebral artery develops by connecting the dorsal branches of the intersegmental arteries [1]. In this situation, angiogenesis-mediated vascular formation could be a possible mechanism involved in the connection of vessels because the right vertebral artery connection site varies in ARSA cases (ARSA, the right common carotid artery and aortic arch) [10]. In this cadaver, the left vertebral artery also had an anomaly in the connection sites to the great vessels, supporting the notion of flexibility of angiogenesis-mediated vascular connection. Angiogenesis-mediated vascular remodelling is as robust as the development of the great vessels themselves. Therefore, RSA formation can be considered a flexible and robust process that depends on the development of other arterial circuits, such as the right fourth branchial artery and right dorsal aorta, even when minor variations may exist. One of the limitations was that we were unable to examine genetic mutations in the cadaver, making it difficult to clarify whether the primary cause of the anomaly was gene expression or haemodynamic stress in this cadaver.

Another finding was the conserved distal branching morphology. There are three anomalies in the carotid trunk, left vertebral artery and ARSA in this cadaver, potentially leading to abnormal haemodynamic stress in the anterior limb region. Nevertheless, the distal branching morphology was conserved and paired with the muscle groups. For example, the thyrocervical trunk supplies blood to the fourth branchial arch-derived laryngeal muscles, and the thoracoacromial artery supplies blood to the upper limb girdle muscles. These observations suggest that, concerning RSA development, the proximal part and the distal part might be independent to some degree, although the former may affect the latter via haemodynamic stress. This is possibly because distal vascular formation precedes proximal vascular fusion in the anterior limb region [1]. Since the branching morphology corresponded to the muscle groups, paracrine signalling may dominantly drive angiogenesis-mediated vascular formation in the distal cervicothoracic region. Unfortunately, why vascular remodelling is fine-tuned spatiotemporally rather than proceeding from the proximal to the distal region driven by haemodynamic stress is unknown.

CONCLUSIONS

We report a case of ARSA with multiple concomitant anomalies in the proximal region of the cervicothoracic region. The branching morphology in the distal region was conserved, suggesting independence of proximal and distal vascular circuit development in this region. Angiogenesis might contribute to the flexible and robust formation of great vessels, although there may be mechanisms that coordinate vascular remodelling in the proximal and distal regions, which are independent of each other to some degree.

ARTICLE INFORMATION AND DECLARATIONS

Ethics statement

Written informed consent was obtained from the participant and her family included in the study.

Author contributions

Conceptualization: Masaharu Yoshihara; investigation: Masaharu Yoshihara, Momo Morikawa, Suguru Iwata, Michito Hamada, Tetsuya Sasaki, Noriko Homma; writing — original draft: Masaharu Yoshihara, Yoshitoku Watabe; writing — review and editing: Momo Morikawa, Suguru Iwata, Michito Hamada, Tetsuya Sasaki, Noriko Homma, Yosuke Takei; visualization: Masaharu Yoshihara, Yoshitoku Watabe; supervision: Yosuke Takei; project administration: Masaharu Yoshihara; funding acquisition: Masaharu Yoshihara.

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Conflict of interest

The authors declare that they have no conflict of interest.

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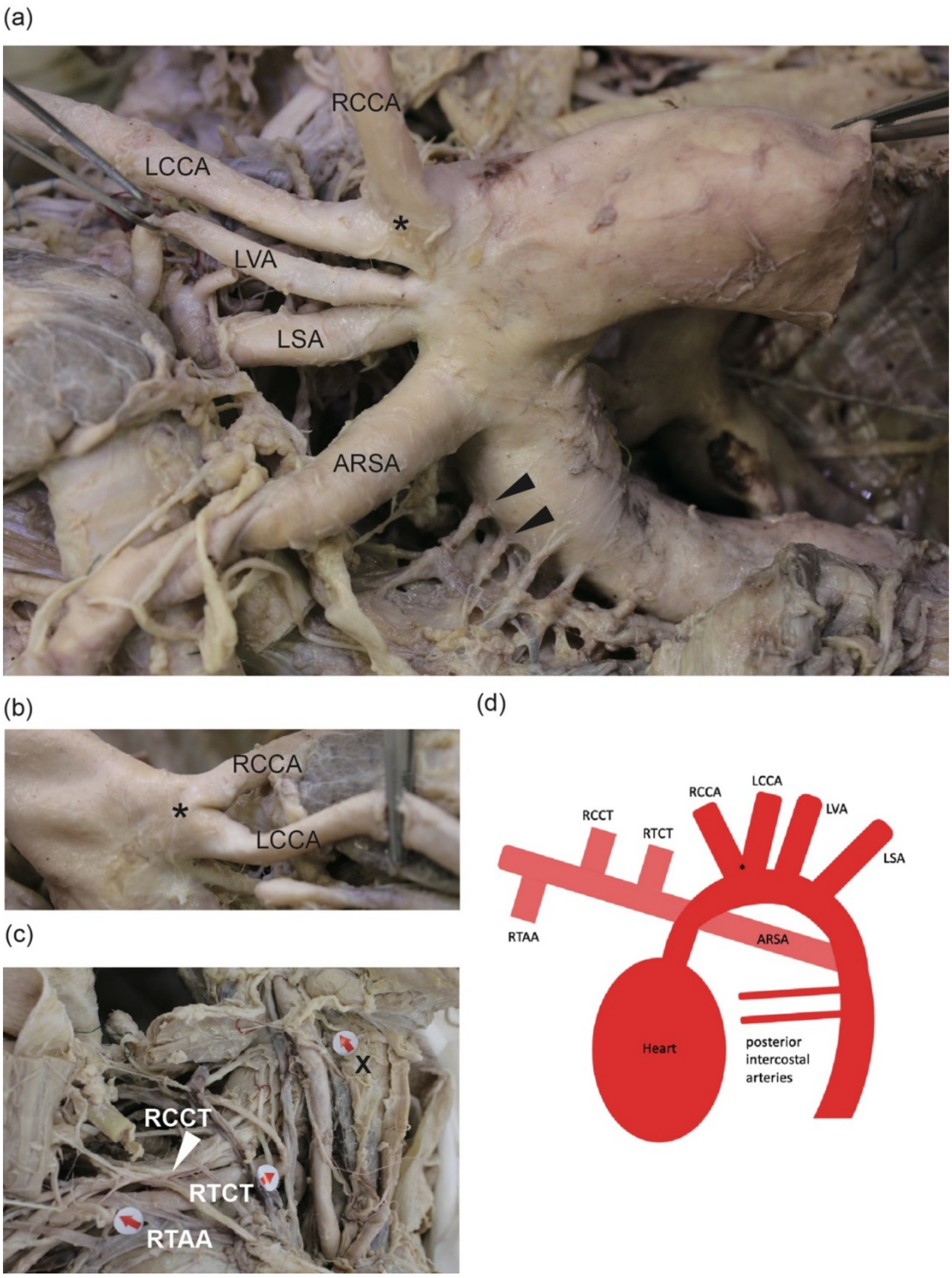

Figure 1. Adachi-Williams type CG plus H aortic arch. **A.** The right subclavian artery arose from the aorta just distal to the left subclavian artery without Kommerell's diverticulum. Note that, to clearly show the origins of the subclavian arteries, the common carotid arteries and left vertebral artery, the trachea and oesophagus were cut and moved behind the aortic arch, and the aortic arch was pulled and flipped anteriorly to the left before being photographed from the right dorsal side. The right and left

common carotid arteries arose from the carotid trunk (asterisk). In addition, the left vertebral artery arose directly from the aortic arch between the carotid trunk and the left subclavian artery. Arrowheads: posterior intercostal arteries. **B.** High-magnification image of the origin of the right and left common carotid arteries arising from the carotid trunk (asterisk). **C.** A branch of the right vagus nerve directly innervated the laryngeal muscles without forming a recurrent nerve (X, red arrow). The branching morphology of the right vertebral artery, internal thoracic artery, thyrocervical trunk (RTCT, red arrow), costocervical trunk (RCCT, white arrowhead) and thoracoacromial artery (RTAA, red arrow) was conserved. **D.** Summary of the present case. ARSA — aberrant subclavian artery; LCCA — left common carotid artery; LSA — left subclavian artery; LVA — left vertebral artery; RCCA — right common carotid artery; RCCT — right costocervical trunk; RTAA — right thoracoacromial artery; RTCT — right thyrocervical trunk.