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Anatomical relationships between the superficial brachial arteries and the brachial plexus in humans, and their morphological significance

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Since the significance of a superficial subscapular artery was reported by Yamada [22], macroscopic anatomical studies of axillary artery morphogenesis have been conducted by many authors. Notably, Japanese anatomists have reported important and groundbreaking theories on the morphogenesis of normal and aberrant axillary arteries. These include a description of the superficial brachial artery (BS) and Adachi's brachial plexus (AxC) by Chiba [6–7], the possible routes of the axillary artery by Aizawa et al. [3] and the morphological significance of the inferior pectoral artery (Pi) by Kodama et al. [16] and the deep axillary artery by Honma et al. [10, 11].

We have also identified 11 BS among 322 sides of 161 adult human cadavers. We traced the BS with the AxC in 1 case, the development of a superficial subscapular artery in 3 cases, the development of a Pi in 3 cases, an unclear situation in 3 cases and a lateral median superficial brachial artery (BSML) in 1 case. Moreover, we carried out a fibre analysis of the BSML in order to understand the morphology more completely. Our findings are discussed herein.

We have therefore described our cases and compare them with references, presenting gross anatomical data on their morphogenesis in an effort to unify experimental embryological data.

Key words: superficial brachial artery, brachial plexus, human, gross anatomy

INTRODUCTION

According to textbooks, an axillary artery penetrates the dorso-ventral divisions of the brachial plexus at the median nerve ansa (Am). Rarely, an aberrant axillary artery is unable to penetrate the brachial plexus when a case of Adachi's C-type brachial plexus (AxC) unites a single cord [1]. In this case an axillary artery is positioned superficially to the brachial plexus and this is termed the superficial brachial artery (BS). The brachial artery has been reported by many authors because of its relatively high frequency in comparison with other vascular variations [2, 5, 12, 13, 14, 17, 18, 19, 21, 23, 24]. On the other hand, interestingly, Honma et al. [10, 11] observed a rare axillary artery penetration of the dorsal division, in addition to the ventral division, of the brachial plexus. They named this the deep axillary artery. Thus, many human anatomists have been interested in this region.

It is necessary, however, to pay attention to the branches originating from the aberrant axillary arteries, in addition to the various courses of the axillary arteries, in order to understand their morphogenesis.

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As a matter worthy of special mention, Yamada [22] clarified the normal continuous variation in the branches of an axillary artery. Although a subscapular artery (SbS), the 4th branch, usually originated after passing through the Am, it rarely originated before them. This is termed the superficial SbS. These results show that it becomes the BS in the event of further development.

Various authors have since examined the BS and attempted to clarify its morphogenesis. Chiba [6–8] reported various types of AxC by analysing nerve fibre tracings as they peeled off the epineurium and examining the anatomical relationship between the AxC and BS. Aizawa et al. [3, 4] investigated the possible routes of normal and abnormal axillary arteries based on positional relationships between the branches of the axillary artery and the posterior division of the brachial plexus. Kodama et al. [16] observed the continuous variation of the branch to the major pectoral muscle, defining this branch as the inferior pectoral artery (Pi) from the viewpoint of morphological significance. This artery might induce the BS.

We place strong emphasis on those results which are based on actual cases and not only hypothetical considerations. We therefore present our cases, in relation to the references, with gross anatomical data on the morphogenesis. Our aim is to unify the experimental embryological data in the future.

MATERIAL AND METHODS

A gross anatomical analysis was carried out on 11 cases (3.42%) of BS from 322 sides of 161 adult human bodies included in the 2000–2003 anatomical practice cases at Tokyo Women's Medical University. In particular, we carried out nerve fibre analysis by peeling off the epineurium of 1 BSML case in order to fully understand the detailed architecture. The results were recorded by means of photographs and/or sketches.

RESULTS

We identified 11 cases (3.42%) of BS in 322 sides of 161 adult human bodies. All were unilateral.

The normal course of the axillary artery (2000XX-d) (Fig. 1A)

The brachial plexus was made up of the 5th cervical (C5) to 1st thoracic (T1) nerves, and the upper, middle, and lower trunks. Each trunk separated into ventral and dorsal divisions. The ventral division formed the lateral and medial cords. Thereafter, lateral and medial cords constituted the Am of the pectoral branches and ramified to the musculocutaneus (MC), median (M) and ulnar (U) nerves. This is a normal brachial plexus. The main trunk of the axillary artery penetrated between the dorso-ventral divisions of the brachial plexus through the Am. The 1st to 3rd branches (highest thoracic, thoraco-acromial, and lateral thoracic arteries) originated from the axillary artery before penetrating the Am, whereas the 4th branch went downward (the SbS, anterior, and posterior humeral circumflex arteries), originating after penetration of the Am.

The normal course of the axillary artery with the superficial subscapular artery (Fig. 1B)

This brachial plexus was normal, being composed of the C5 to T1 with the usual divisions. The main trunk of the axillary artery penetrated between the dorso-ventral divisions of the brachial plexus through the Am. However, this case was different from the former in terms of the branching pattern from the axillary artery. Although the 4th branch (SbS) usually originates from the axillary artery after penetrating the Am, the SbS originated as a common trunk with a lateral thoracic artery before penetrating the Am. We also observed the BS with a common trunk of the lateral thoracic artery and SbS in 3 of the 11 BS cases.

The superficial brachial artery with AxC (2000 VIII-s) (Fig. 2A)

The brachial plexus comprised C5 to T1 divided into dorso-ventral divisions. However, this brachial plexus was different from the usual form, showing incomplete bifurcation as the so-called AxC. As a result of the incomplete brachial plexus bifurcation, the axillary artery did not penetrate the brachial plexus but ran superficially to the brachial plexus. On the other hand, a common trunk of the SbS, anterior and posterior circumflex humeral arteries and deep brachial artery penetrated the dorso-ventral divisions of the brachial plexus as usual. This type of BS was observed in 1 of the 11 BS cases.

The superficial brachial artery with the normal course of the subscapular artery (2001 XIV-d) (Fig. 2B)

This brachial plexus also showed normal division and this case also had the BS. However, a common trunk of the anterior and posterior circumflex humeral arteries, SbS and/or the lower half of a lateral thoracic artery, originating from the dorsal aspect of an axillary artery, entered the brachial plexus at

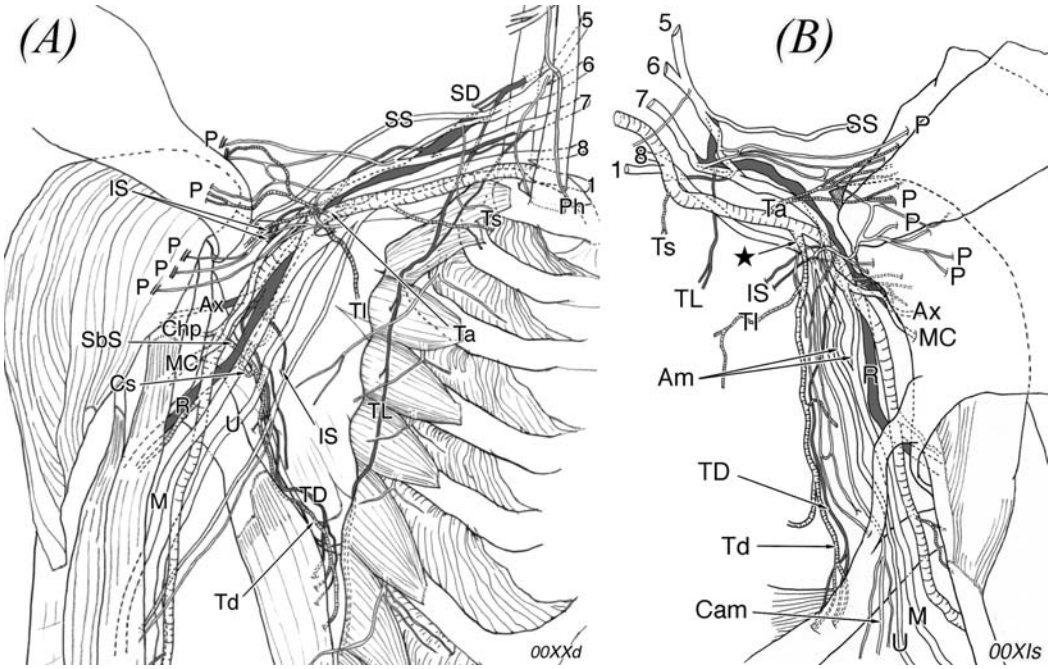

Figure 1. Diagrams showing the normal course of the axillary artery to the brachial plexus in a normal specimen. **A.** The subscapular artery (SbS) originates from the axillary artery after passing through the median nerve ansa (Am); **B.** The SbS originates as a common trunk, indicated by a star, with the lateral thoracic artery before the Am. Nerve: Am — median nerve ansa, Ax — axillary nerve, Cam — medial antebrachial cutaneous nerve, Cbm — medial brachial cutaneous nerve, IS — subscapular nerve, M — median nerve, MC — musculocutaneus nerve, P — pectoral nerve, Ph — phrenic nerve, R — radial nerve, SC — nerve to subclavius muscle, SD — dorsal scapular nerve, SS — suprascapular nerve, TL — lateral thoracic nerve, TD — dorsal thoracic nerve, U — ulnar nerve; Artery: Cha — anterior circumflex humeral artery, Chp — posterior circumflex humeral artery, Cs — circumflex scapular artery, Pi — inferior pectoral artery, SbS — subscapular artery, Ta — thoraco-acrominal artery, Td — dorsal thoracic artery, Tl — lateral thoracic artery, Ts — highest thoracic artery.

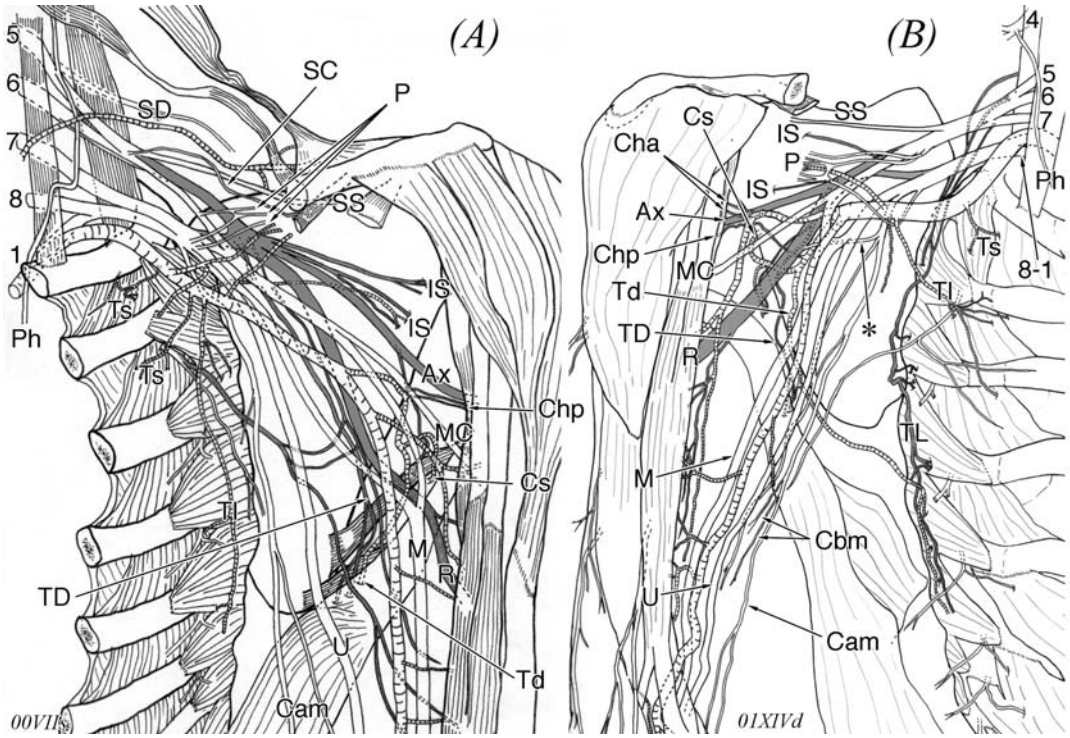

Figure 2. Diagrams showing two cases with a superficial brachial artery (BS) superficial to the brachial plexus. **A.** The BS with an abnormal brachial plexus (Adachi's C type brachial plexus), united single cords; **B.** The BS with a normal axillary arterial, with a branch running from the axillary artery. An asterisk shows the communicating branch between the medial cord and radial nerve.

the Am and coursed the dorso-ventral divisions as usual for the main trunk of the axillary artery. These cases differed from other BS cases in terms of the origin of the SbS, that is to say whether it was proximal or distal to the Am. This type of BS was also observed in 3 of the 11 BS cases.

A superficial brachial artery with an inferior pectoral artery (2003 XVI-d) (Fig. 3A)

The brachial plexus shown represents a normal division, but this was also a BS case. The characteristic of these BS cases was the Pi branching from the axillary artery as a common trunk of the thoraco-acrominal artery before penetrating the Am. The Pi ran along the lower border, distributing to the major pectoral muscle. This type of BS was also observed in 3 of the 11 BS cases.

A lateral median superficial brachial artery (1963d) (Fig. 3B)

The brachial plexus comprised C5 to T1 and had a communication from the MC to the M at the level of the *latissimus dorsi* muscle insertion except at the Am. The axillary artery entered the brachial plexus at the Am and ran between the dorsal and ventral divisions as the axillary artery usually does. However, a distal axillary artery was superficial to the ventral division of the brachial plexus at the communication from the MC to the M. This type of BS is termed the BSML. In addition, this case was observed to have a Pi near the ascending portion of the distal axillary artery. This type of BS was seen in only 1 case (Fig. 3B, 4).

Next, we carried out a nerve fibre analysis of this brachial plexus in order to understand this phenomenon. The Am was found to be in close relation to a communication from the MC to the M, and in the pectoral ansa as compared with other nerves. Notably, the communicating branch and the Am were more closely related (Fig. 4, 5).

DISCUSSION

Aberrant course of the axillary artery and Adachi's C-type brachial plexus

Many human anatomists have been interested in these structures and have reported the AxC [1, 6–9, 15, 20] and various types of the BS [2, 5, 12, 13, 14, 17, 18, 19, 21, 23, 24]. Consequently, most research-

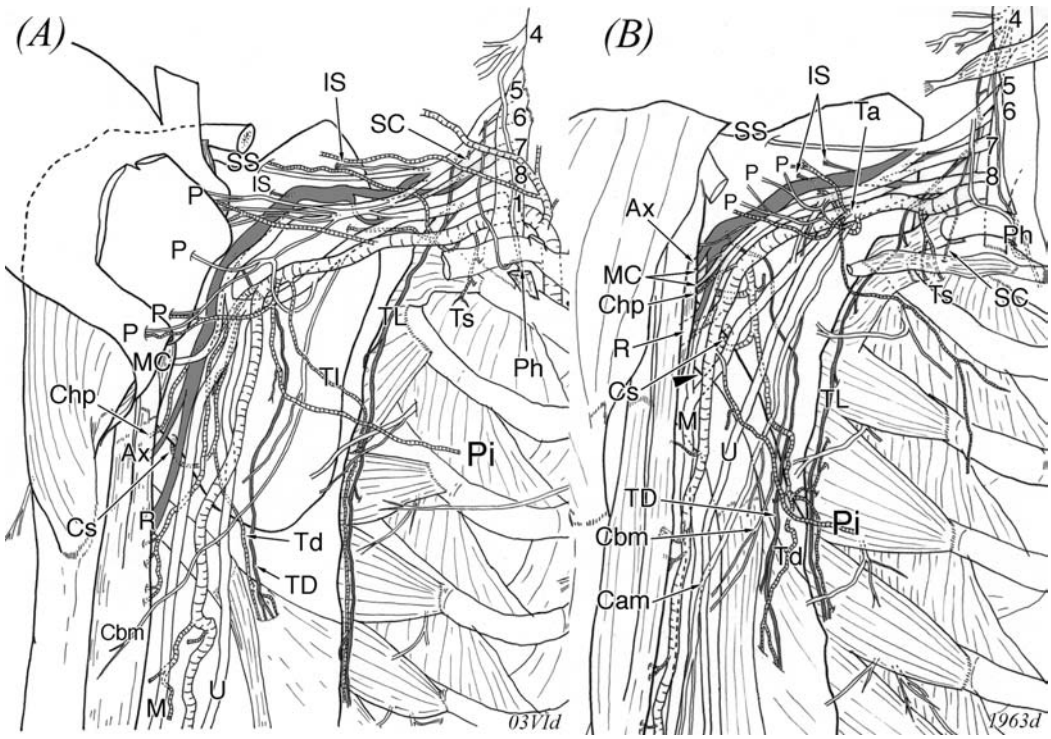

Figure 3. Diagrams showing another two cases with a superficial brachial artery (BS), superficial to the brachial plexus. **A.** The BS with the inferior pectoral artery (Pi); **B.** The lateral median superficial brachial artery. The axillary artery enters the brachial plexus at the Am, and runs between the dorsal and ventral divisions as the axillary artery usually does. However, the distal axillary artery runs, as indicated by the arrowhead, superficially to the ventral division of the brachial plexus at the communication from the musculocutaneous (MC) to the median (M) nerves.

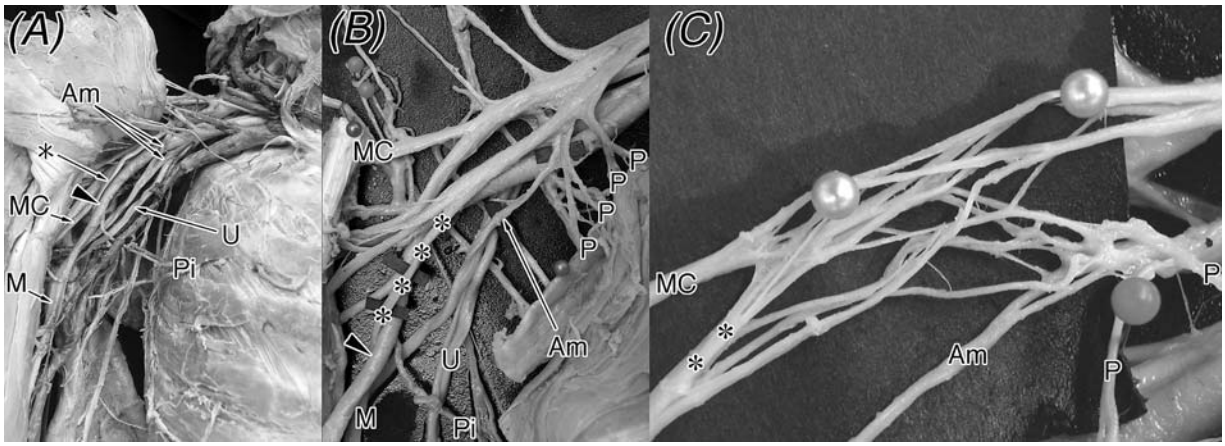

Figure 4. Photographs of one case with a lateral median superficial brachial artery (BSML). **A.** The relationship between the BSML and the brachial plexus; **B.** The nerve-muscle specimen removed en bloc; **C.** The nerve fibre analysis of the BSML peeled off the epineurium. The communicating branch and the elevation point of the axillary artery to the brachial plexus are indicated by the asterisks and arrowhead, respectively.

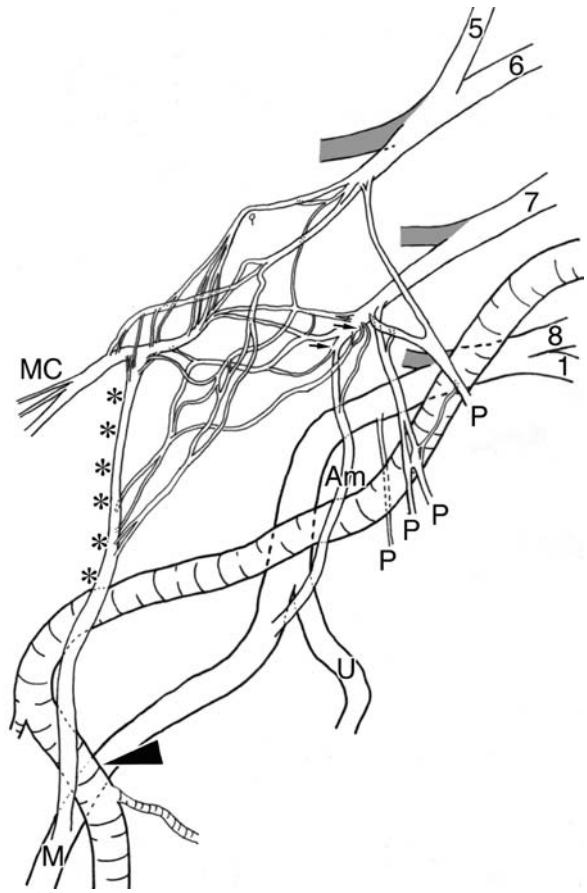

Figure 5. A diagram showing the nerve fibre analysis of the BSML, which was peeled off the epineurium under a binocular stereomicroscope. The communicating branch and the elevation point of the axillary artery to the brachial plexus are indicated by the asterisks and arrowhead, respectively. The communicating branch, median nerve ansa (Am), and the pectoral nerves are closely related. The former two are particularly closely related because they make a common trunk in the nerve component.

ers have concluded that aberrant arteries are explained by the disappearance of the arterial mesh surrounding the brachial plexus. However, it is unreasonable to suggest that every aberrant artery can be explained by the hypothesis of the arterial mesh. Despite the absence of certain routes, it is an oversimplified account of the mesh. It is therefore necessary to examine the topological changes to branches of the axillary artery to the brachial plexus in order to understand or speculate about the morphogenesis of the BS and AxC.

The concept of morphogenesis of the superficial brachial artery

There are 4 interesting studies of normal and aberrant axillary arteries with special reference to topological changes in their branches from the point of view of real continuous variation.

Yamada [22] examined branches from the axillary arteries to the ventral division of the brachial plexus. Most commonly the axillary artery gave off a lateral thoracic artery as a 3rd branch before penetrating the Am, and a SbS as a 4th branch after penetrating the Am. However, the axillary artery sometimes gave off a SbS before penetrating the Am. If this type of SbS were developed further, this artery would induce a BS, judging from the continuous variation in branches of the axillary artery. Therefore Yamada [22] advocated a new term "superficial SbS", emphasising the morphological significance of this type of artery. Anatomists have since been interested in the morphology and morphogenesis of the BS from a macroscopic anatomical viewpoint.

Thereafter, Chiba [6–8] reported the morphology of the AxC found in 2.8% of specimens, a nerve fibre analysis of the AxC, and the relationship between the AxC and brachial plexus. He mentioned the possibility of the development of the nutritional artery as one factor in the morphogenesis of the BS.

Aizawa et al. [3, 4] assessed the possible routes of an axillary artery with special attention to the positional relationship not only of the ventral division but also the dorsal division of the brachial plexus.

Kodama et al. [16] suggested that the Pi might be a derivative of or a trigger for BS morphogenesis.

The account of BS morphogenesis provided by Japanese macroscopic anatomists thus does not involve an arterial mesh as an anlage of the disappearance of various parts of the mesh which might be manifest as various types of axillary artery. Their concepts are based on observations of large numbers of actual cases and their continuous variations.

The morphology of our cases based on topological changes to their branches originating from the aberrant arteries

From a macroscopic anatomical viewpoint we support the theories of Japanese anatomists and explanations of BS morphogenesis based on these theories as follows (Fig. 6).

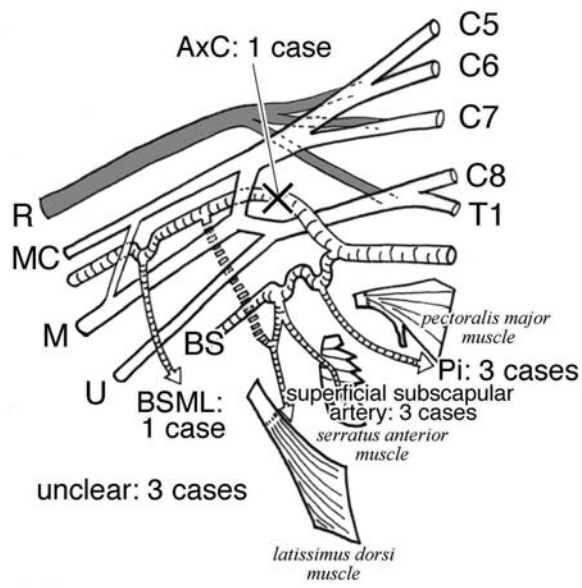

Figure 6. A possible model, presented schematically, of the causes of our 11 superficial brachial arteries (BS) judging from their branches and Japanese conventional descriptions. It itemises the BS with Adachi's C-type brachial plexus (AxC) in 1 case, the development of a superficial subscapular artery in 3 cases, the development of the inferior pectoral artery (Pi) in 3 cases, an unclear situation in 3 cases, and a lateral median superficial brachial artery (BSML) in 1 case.

Our 3rd BS case with an AxC was formed due to the persistence and development of a superficial route to the brachial plexus because the brachial plexus morphology differed from the norm and an axillary artery anlage could not penetrate between the ventral and dorsal divisions.

Our 5th BS case was formed by triggering of the Pi. However, we observed 3 cases of the 4th SbS originating from the axillary artery and passing between the ventral and dorsal divisions as a normal axillary artery. These cases could not be explained by the development of the superficial SbS and/or the Pi. Yoshinaga et al. [23, 24] reported some cases that could not be explained by conventional theory. These findings will thus need to be reconsidered in the future. On the other hand, our 6th case, that with BSML, could be attributed to triggering of a distal Pi because its superficial course to the ventral division of the brachial plexus accorded with the position of a branch coming off the Pi from the axillary artery. In addition, we re-examined the BSML from our nerve fibre analysis. The results showed a close relationship between the Am and the communication from the MC to the M. The significance of these results is that the aberrant axillary artery would have penetrated the Am from the deep to the superficial aspect.

Although the morphogenesis of an artery in the upper extremity has been clarified as a progression of experimental embryology, this approach has focused only on vessels. We strongly recommend that examination of the relationship of the surrounding structures is necessary to clarify the actual morphogenesis. Thus, it is essential that both approaches, the macroscopic anatomical study and experimental embryology, be employed to gain greater resolution of the morphogenesis of normal and aberrant arteries.

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