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Complex Variations in Branches of the Axillary Artery

Variaciones Complejas en Ramas de la Arteria Axilar

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SUMMARY: The axillary artery is a continuation of the subclavian artery and transitions into the brachial artery. Variations in the axillary artery are not uncommon. During the upper-limb dissection of a 95-year-old Korean female cadaver, assorted anatomical variations of the axillary artery branches were identified. On the right side, no branches emerged from the first part of the axillary artery. The thoracoacromial artery (excluding the pectoral branch) and the common subscapular trunk arose from the second part, with the common subscapular trunk giving origins to the pectoral branch, lateral thoracic artery, and subscapular artery. The subscapular artery is divided into the thoracodorsal artery, circumflex scapular artery, and accessory posterior circumflex humeral artery. Additionally, the superior thoracic artery arose from the lateral thoracic artery. The third part of the axillary artery gave rise to the anterior and posterior circumflex humeral arteries, accessory acromial branch, and accessory thoracodorsal artery. On the left side, the thoracoacromial artery (excluding the pectoral branch) and the superior thoracic artery arose from the first part. The common subscapular trunk arose from the second part, which included the pectoral branch, lateral thoracic artery, and subscapular artery. The subscapular artery is divided into the thoracodorsal artery, circumflex scapular artery, accessory posterior circumflex humeral artery, and accessory lateral thoracic artery. The third part gave rise to the anterior and posterior circumflex humeral arteries and the accessory acromial branch. This study presents variations of the axillary artery, emphasizing their rarity, considering their embryologic basis, and highlighting their importance not only for educational purposes but also surgical and radiological applications.

KEY WORDS: Axillary Artery; Cadaver; Common subscapular trunk; Variations.

INTRODUCTION

Beginning at the lateral margin of the first rib, the axillary artery is a continuation of the subclavian artery and transitions into the brachial artery at the inferior margin of the teres major muscle. The artery is divided into three parts by the pectoralis minor muscle, which crosses anteriorly to the vessel. Typically, six branches arise from the axillary artery: the superior thoracic artery (ST) from the first part, the thoracoacromial artery (TA) and lateral thoracic artery (LT) from the second part, and the subscapular artery (SS), anterior circumflex humeral artery (ACH), and posterior circumflex humeral artery (PCH) from the third part. The SS divides into two terminal branches: the circumflex scapular artery (CS) and the thoracodorsal artery (TD) (Drake *et al*., 2023).

The axillary artery develops as an extension of the subclavian artery, which is enlarged by the aortic arch system, and the seventh cervical segmental artery, originating from the vascular plexus of the upper limb bud (Carlson, 2023). During this development process, unusual blood vessels can occur due to the choice of unusual paths in the primitive vascular plexuses, the persistence of normally obliterated vessels, the disappearance of normally retained vessels, incomplete development, and the fusion and absorption of usually distinct parts (Jurjus *et al*., 1999).

Therefore, variations in axillary artery branching patterns are common. The SS, which is the largest branch of the axillary artery, usually arises directly from the third part of the axillary artery (67.5 %), while the LT typically arises directly from the second part (52.2 %), and the ST predominantly arises from the first part (86.6 %) (Huelke, 1959). De Garis & Swartley (1928) reported that the origin of TA is typically 12.1 %. Occasional reports have presented the LT and PCH as arising from the SS (Brilakis *et al*., 2023). The existence of accessory arteries of the TD and PCH also

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were noted in specific cases (Jurjus *et al*., 1999; Natsis *et al*., 2006; Astik & Dave, 2012). Some variations have been consistently reported, contributing to our anatomical and clinical understanding. However, other variations are rarely described, and comprehensive insights are lacking.

An understanding of axillary artery variations is crucial not only for anatomists in education but also for surgeons and radiologists who are providing diagnosis and treatment. The axillary artery is utilized in coronary artery bypass (Bonatti *et al*., 2000), as an access in transcatheter aortic valve replacement (TAVR) (Dahle *et al*., 2019), and as a donor artery in reconstructive surgery (Chepeha *et al*., 2010; Hwang *et al*., 2013). The importance of axillary artery variations is emphasized in breast surgery (Markou *et al*., 2023). Also, the axillary artery is prone to damage from an open fracture, a shoulder dislocation, or a scapula fracture (Menendez *et al*., 2015). Therefore, it is essential to report the diverse forms of axillary artery variations so that they are integrated into the body of research.

CASE REPORT

During an educational dissection at Chonnam National University Medical School, the standard procedure cadaver was a 95-year-old Korean female. The authors state that every effort was made to follow all local and international ethical guidelines and laws that pertain to the use of human cadaveric donors in anatomical research (Iwanaga *et al*., 2022). The present study was performed in accordance with the requirements of the Declaration of Helsinki (64th WMA General Assembly, Fortaleza, Brazil, October 2013). The dissection followed this sequence: careful removal of the skin, superficial fascia, and fat to prevent damage to the axillary sheath. The axillary sheath was then opened, veins were removed, and arteries and nerves around the axilla were preserved without damage for the clear observation of the axillary artery.

On the right side, the typically expected ST was absent from the first part, with no branches emerging. In the second part, the TA arose directly and then trifurcated into the acromial, clavicular, and deltoid branches. The common subscapular trunk (CST), which is not normally present, arose from the axillary artery, and the pectoral branch (Pb), which typically branches from the TA, originated separately from the CST. The LT, which commonly originates directly from the axillary artery, branched from the CST. The CST became the SS, and, as commonly expected, the CS and TD divided from the SS. We also observed arteries originating from the SS and coursing around the surgical neck of the humerus, resembling the path taken by the PCH. (We named these arteries the accessory posterior circumflex humeral artery [aPCH]). The ST arose from the LT. In the third part, the ACH and PCH were located where they were commonly expected. Arteries ran toward the latissimus dorsi muscle, mirroring the TD's path, and were designated as the accessory thoracodorsal artery (aTD). Moreover, we identified arteries coursing toward the deltoid muscle, following the course of the TA's acromial branch (We named these arteries the accessory acromial branch [aAb]) (Table I, Fig. 1).

	Usual	Right	Left
First part	ST		TA → Ab, Cb, Db ST
Second Part	TA → Ab, Cb, Db, Pb LT	TA → Ab, Cb, Db CST → Pb, LT, ST SS → TD, CS, aPCH	CST → Pb, LT SS → TD, CS, aPCH, aLT
Third part	ACH PCH SS → CS, TD	aAb aTD ACH PCH	aAb ACH PCH

Table I. Summary of the usual axillary artery branches and the branching patterns described in this report. ST: superior thoracic artery, TA: thoracoacromial artery, Ab: acromial branch, Cb: clavicular branch, Db: deltoid branch, Pb: pectoral branch, CST: common subscapular trunk, LT: lateral thoracic artery, SS: subscapular artery, TD: thoracodorsal artery, CS: circumflex scapular artery, ACH: anterior circumflex humeral artery, PCH: posterior circumflex humeral artery, aPCH: accessory posterior circumflex humeral artery, aTD: accessory thoracodorsal artery, aAb: accessory acromial branch, aLT: accessory lateral thoracic artery

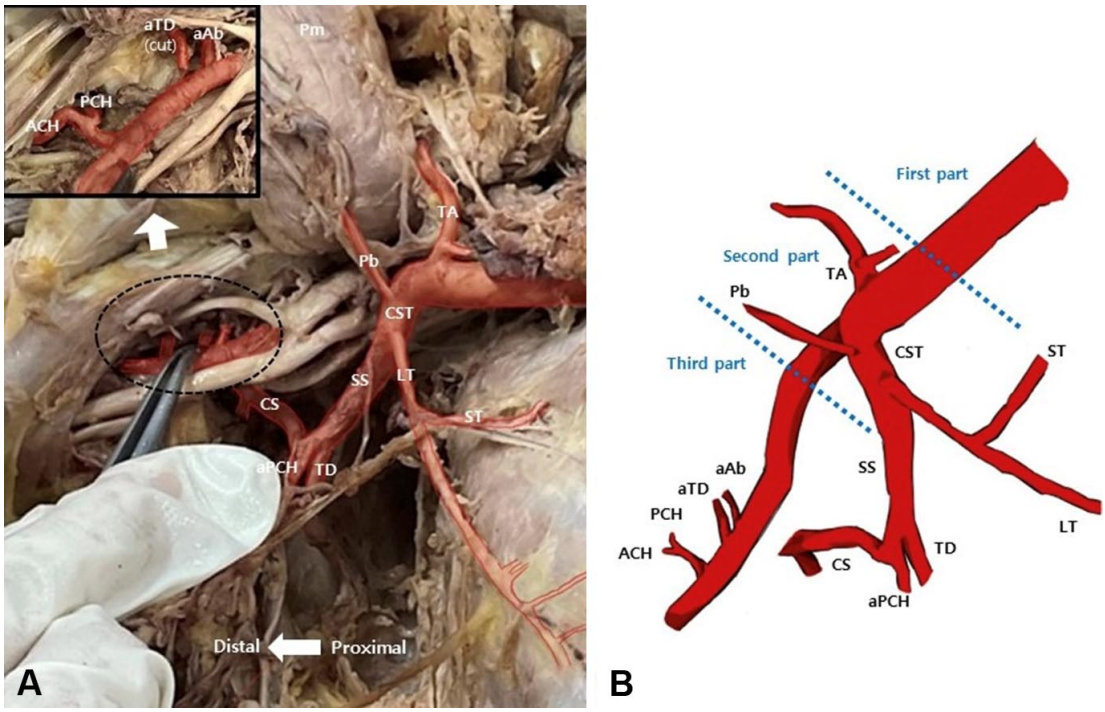

Fig. 1. Anterior view of the right side of the axilla (a) and a sketch of its arteries (b). ST: superior thoracic artery, TA: thoracoacromial artery, Pb: pectoral branch, CST: common subscapular trunk, LT: lateral thoracic artery, SS: subscapular artery, TD: thoracodorsal artery, CS: circumflex scapular artery, ACH: anterior circumflex humeral artery, PCH: posterior circumflex humeral artery, aPCH: accessory posterior circumflex humeral artery, aTD: accessory thoracodorsal artery, aAb: accessory acromial branch.

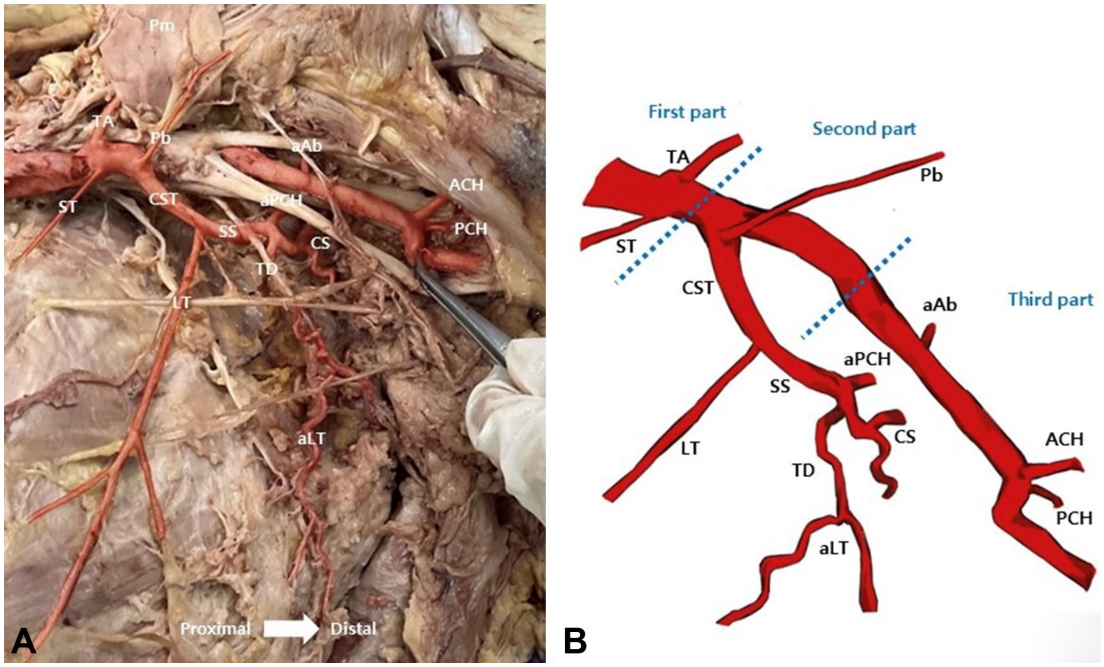

Fig. 2. Anterior view of the left side of the axilla (a) and a sketch of its arteries (b). ST: superior thoracic artery, TA: thoracoacromial artery, Pb: pectoral branch, CST: common subscapular trunk, LT: lateral thoracic artery, SS: subscapular artery, TD: thoracodorsal artery, CS: circumflex scapular artery, ACH: anterior circumflex humeral artery, PCH: posterior circumflex humeral artery, aPCH: accessory posterior circumflex humeral artery, aAb: accessory acromial branch, aLT: accessory lateral thoracic artery.

On the left side, the ST arose from the first part, as commonly expected. Although typically present in the second part, the TA arose from the first part and then trifurcated into the acromial, clavicular, and deltoid branches. The CST, which usually is not found there, also emerged in the second part, and the Pb, which typically branches from the TA, arose from the CST. The LT was located where commonly expected, but it also arose from the CST. The CST became the SS, and, as typically expected, the CS and TD were divided from the SS. Similar to the variation observed on the right, the aPCH also originated from the SS. Moreover, an accessory lateral thoracic artery (aLT) arose from the TD. In the third part, the ACH and PCH arose directly, as commonly expected. The aAb also arose from the third part (Table I, Fig. 2).

DISCUSSION

We identified complex variations on both sides of the axillary artery. On the right side, unusual origins were observed for the Pb, ST, LT, and SS, and additional arteries for the aPCH, aTD, and aAb. On the left side, unusual origins were observed for the TA, Pb, SS, and LT, and additional arteries for the aPCH, aAb, and aLT.

Diverse variations of the axillary artery have been reported in previous research, including the presence of a common trunk from the axillary artery, which has been frequently reported. De Garis & Swartley (1928) classified 256 cadavers according to 22 patterns and found that four cadavers had a common trunk, which included the TA, LT, SS and sometimes ACH, and PCH (Goldman *et al*., 2012). Venieratos & Lolis (2001) reported the finding of a common trunk that gave origins to the CS, TD, ACH, PCH, profunda brachii, and ulnar collateral arteries, and proposed the term "common subscapular trunk". Saralaya *et al*. (2008) and Goldman *et al*. (2012) identified common trunks with different compositions than the common trunk reported by Venieratos & Lolis (2001). In these studies, the common trunk formed a larger trunk than that observed in standard cases. We identified a large common trunk in the second part of the axillary artery that gave rise to the Pb, LT, SS, TD, and aPCH bilaterally, and to the ST on the right side. In previous research, this common trunk was identified as the CST (Venieratos & Lolis, 2001; Saralaya *et al*., 2008; Goldman *et al*., 2012).

Some researchers have documented the origins of the PCH and LT. In a study by Park *et al*. (2017) the SS branched with the PCH and LT from the second part of the axillary artery in 7 % (9/128) of Korean cadavers and from the third part in 12.5 % (16/128). Yang *et al*. reported that the SS branched with the PCH and LT in 1/59 (1.69 %) of Korean cadavers (Brilakis *et al*., 2023). These reports suggest that it is uncommon for the PCH, which typically originates from the third part of the axillary artery, to arise from the SS. In our case, the normal PCH arose from the third part of the axillary artery, along with additional arteries that coursed a similar path to the PCH, and originated from the SS. As far as we know, only two cases of a double circumflex humeral artery have been reported (Jurjus *et al*., 1999; Astik & Dave, 2012). In one reported case, a double PCH arose from the third part of the axillary artery and the brachial artery (Astik *et al*., 2012). The other case reported the presence of a double axillary artery, with each containing the TA, ACH, and PCH, resulting in the presence of two sets of these branches on both sides (Jurjus *et al*., 1999). One PCH arose from the third part of the regular axillary artery, and the other arose from the SS of the second axillary artery. This case appears to be quite similar to the present case, given the presence of the typical PCH and the additional emergence of the PCH from the SS. Previous research did not name this additional emergence, so we suggest the term aPCH. In addition, while the acromial branch originated from the TA, we identified an additional artery in the third part and named it aAb. To the best of our knowledge, this is the first report of the aAb.

On the right side of the axillary artery, the ST arose from the LT. In previous research, the ST originated from the second part of the axillary artery in 2.2 % and from the LT in 1.7 % (Huelke, 1959). In our case, the aTD originated unilaterally from the third part; the TD normally branches from the common subscapular trunk. There have been few case reports of the aTD (Natsis *et al*., 2006; Hwang *et al*., 2013; Odeh *et al*., 2023). Saadeh *et al*. first reported the presence of a unilateral aTD from the first part of the axillary artery (Natsis *et al*., 2006), Natsis *et al*. (2006) reported a bilateral aTD from the third part, and Odeh *et al*. (2023) reported an aTD from the common trunk in the first part. Also, there have been reports of surgical use of the aTD (Hwang *et al*., 2013). In our case, the TA arose from the first part on the left side but not on the right side. Studies of TA's origins have yielded contradictory results, with Huelke (1959) reporting 29.8 % from the first part and 68.5 % from the second part, and De Garis & Swartley (1928) reporting 85.7 % from the first part and 12.1 % from the second part. According to research on LT variations, multiple LTs were present in 3.09 % of specimens (Loukas *et al*., 2014). While the presence of an additional thoracic artery arising from the TD has been frequently reported (Natsis *et al*., 2006; Saralaya *et al*., 2008; Odeh *et al*., 2023), there hasn't been consistent usage of a specific name. Hence, we propose calling this additional thoracic artery the aLT.

An understanding of embryonic development can provide insights into variations of the axillary artery. The

earliest vascularization of the limb bud arises from multiple segmental branches of the aorta. At first, the limb vasculature consists of a fine capillary network, with certain channels selectively enlarging to form a substantial central artery responsible for supplying blood to the limb bud (Carlson, 2023). On the right side, a fourth segment of the aortic arch system, combined with the seventh segmental artery, forms the proximal segment of the right subclavian artery. On the left side, however, the seventh segmental artery is exclusively involved in this process (Sadler, 2023). As development advances, a sustained connecting vessel emerges from the subclavian artery as a single axis that develops into the axillary, brachial, and interosseous arteries. Unusual blood vessels are believed to occur during the developmental process, involving the choice of unusual paths in the primitive vascular plexuses, the persistence of normally obliterated vessels, the disappearance of normally retained vessels, incomplete development, and the fusion and absorption of typically distinct parts (Sadler, 2023). The occurrence of the complex variations and numerous accessory arteries presented in this report can be attributed to these reasons.

Knowledge of branching patterns holds significant clinical importance for radiologists and surgeons. The use of the axillary artery in coronary artery bypass is feasible when the ascending aorta cannot be utilized and as an alternative when the internal mammary artery is inadequate for minimally invasive direct coronary artery bypass surgery (Bonatti *et al*., 2000). Trans-subclavian or transaxillary TAVR is a preferred alternative to the use of a femoral access (Dahle *et al*., 2019). In head and neck procedures, the utilization of a scapular tip autogenous transplant from the thoracodorsal artery has proven to be an excellent reconstruction option (Chepeha *et al*., 2010). The branches of the axillary artery can act as effective perforators (Garieri *et al*., 2023), and anatomical variations, such as the aTD, can be beneficial perforators (Hwang *et al*., 2013). Since the axillary artery supplies blood to the breast, axillary artery variations are considered important in breast surgery, such as axillary lymph node biopsy, lymphadenectomy, and breast reconstruction (Markou *et al*., 2023). The axillary artery also is prone to damage from atherosclerosis, open fracture, plexus injury, shoulder dislocation, scapula fracture, and rib fracture (Menendez *et al*., 2015).

The present report documents multiple uncommon bilateral variations of the axillary artery, including a bilateral common subscapular trunk, Pb, aPCH, aAB, and unilateral aTD. There are anatomical variations that occur infrequently. As some of these variations might influence patient prognosis, it is important to understand a range of variations.

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RESUMEN: La arteria axilar es una continuación de la arteria subclavia y luego esta continua como arteria braquial. Las variaciones en la arteria axilar no son infrecuentes. Durante la disección de los miembros superiores de un cadáver de una mujer coreana de 95 años, se identificaron diversas variaciones anatómicas de las ramas de la arteria axilar. En el lado derecho no se originaban ramas de la primera parte de la arteria axilar. La arteria toracoacromial (excluyendo la rama pectoral) y el tronco subescapular común surgieron de la segunda parte, y el tronco subescapular común dio origen a la rama pectoral, la arteria torácica lateral y la arteria subescapular. La arteria subescapular se dividía en arteria toracodorsal, arteria circunfleja escapular y arteria humeral circunfleja posterior accesoria. Además, la arteria torácica superior se originaba de la arteria torácica lateral. La tercera parte de la arteria axilar dio origen a las arterias circunflejas humerales anterior y posterior, la rama acromial accesoria y la arteria toracodorsal accesoria. En el lado izquierdo, de la primera parte surgían la arteria toracoacromial (excluyendo la rama pectoral) y la arteria torácica superior. De la segunda parte se originaba el tronco subescapular común, que incluía la rama pectoral, la arteria torácica lateral y la arteria subescapular. La arteria subescapular se dividía en arteria toracodorsal, arteria circunfleja escapular, arteria circunfleja humeral posterior accesoria y arteria torácica lateral accesoria. La tercera parte daba origen a las arterias circunflejas humerales anterior y posterior y a la rama acromial accesoria. Este estudio presenta variaciones de la arteria axilar, enfatizando su rareza, considerando su base embriológica y destacando su importancia no sólo para fines educativos sino también para aplicaciones quirúrgicas y radiológicas.

PALABRAS CLAVE: Arteria axilar; Cadáver; Tronco subescapular común; Variaciones.

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