

# Vascular patterns of upper limb: an anatomical study with accent on superficial brachial artery

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## ABSTRACT

The aim of the study was to evaluate the terminal segmentation of the axillary artery and to present four cases of anomalous branching of the axillary artery, the superficial brachial artery (*arteria brachialis superficialis*), which is defined as the brachial artery that runs superficially to the median nerve. Totally, 130 cadaveric upper arms embalmed by classical formaldehyde technique from collections of the Department of Anatomy, Third Faculty of Medicine, Charles University in Prague, were macroscopically dissected with special focus on the branching arrangement of the axillary artery. The most distal part of the axillary artery (infrapectoral part) terminated in four cases as a bifurcation into two terminal branches: the superficial brachial artery and profunda brachii artery, denominated according to their relation to the median nerve. The profunda brachii artery primarily gave rise to the main branches of the infrapectoral part of the axillary artery. The superficial brachial artery descended to the cubital fossa where it assumed the usual course of the brachial artery in two cases and in the other two cases its branches (the radial and ulnar arteries) passed superficially to the flexors. The incidence of the superficial brachial artery in our study was 5% of cases. The reported incidence is a bit contradictory, from 0.12% to 25% of cases. The anatomical knowledge of the axillary region is of crucial importance for neurosurgeons and specialists using the radiodiagnostic techniques, particularly in cases involving traumatic injuries. The improved knowledge would allow more accurate diagnostic interpretations and surgical treatment.

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KEY WORDS: anatomical variations, axillary artery, profunda brachii artery, superficial brachial artery.

## INTRODUCTION

The superficial brachial artery (*arteria brachialis superficialis*, SBA) is not a rare vascular variation of the superior extremity. It was already reported and defined by Adachi [1] as the brachial artery running superficially to the median nerve. However, according to recent findings, the definition regarding the course of the SBA in relation to the median nerve is not so stringent. Rodriguez-Niedeführ recalled attention to the SBA and stated that "its course is rather superficial". The SBA then descends as far as the cubital fossa where it bifurcates as the proper brachial artery into both the radial and ulnar arteries and their branches [2]. To understand the anatomy and terminology of the SBA, its relations and developmental background properly, it is necessary to mention first some basic facts regarding the axillary artery (*arteria axillaris*, AA). The extent of the AA is set by different structures as reported in our previous publication [3]. We followed the prevailingly

accepted concept describing the beginning of the AA as passing under the clavicle and the end of the distal border of pectoralis major muscle. The whole AA can be divided into three segments [4-9], which we propose to denominate according to their relation to the pectoralis minor muscle (Table 1). The textbook description regarding the branching pattern of the AA refers to it as an artery possessing 6 principal branches: superior thoracic artery (*arteria thoracica superior*), thoroacoacromial artery (*arteria thoracoacromialis*), lateral thoracic artery (*arteria thoracica lateralis*), subscapular artery (*arteria subscapularis*) and both the anterior and posterior circumflex arteries (*arteria circumflexa humeri anterior et posterior*, ACHA and PCHA) [1,9]. But many authors disagree with the above mentioned data: De Garis reported the span of branch numbers to be 5-11 and documented the most frequent pattern to be 8 branches [10]; Trotter published a study in which a differing frequency for both men (47%) and women (30%) was documented [11]; Huelke suggested the normotype with 7 independent branches (incidence of 24% of cases), including the upper subscapular artery, described in 86% of cases, following the course of the subscapular nerve to the subscapular muscle (corresponding to the *largest ramus subscapularis*), and, simultaneously, he reported the most frequent pattern to be 6 branches (present in 37.3% of cases) [12].

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**TABLE 1.** The proposal of arbitrary segmentation of the axillary artery, based on the clinical-anatomical approach

Segment	Extent	Branches
suprapectoral part (pars suprapectoralis)	from clavicle to proximal border of pectoralis minor muscle	superior thoracic artery thoracoacromial artery
retropectoral part (pars retropectoralis)	limited by width of pectoralis minor muscle, located dorsally and covered by its belly	lateral thoracic artery subscapular artery
infrapectoral part (pars infrapectoralis)	From distal border of pectoralis minor muscle to distal border of pectoralis major muscle (or surgical neck of humerus)	anterior humeral circumflex artery posterior humeral circumflex artery

## MATERIALS AND METHODS

One hundred and thirty preparations of upper limbs of the cadaverous material (Czech population, Caucasian race, 44-89 years old, 61 males, 69 females), fixed with classical formaldehyde method, were dissected at the Department of Anatomy of the Third Faculty of Medicine, Charles University in Prague. The atypical courses of SBA were followed and registered.

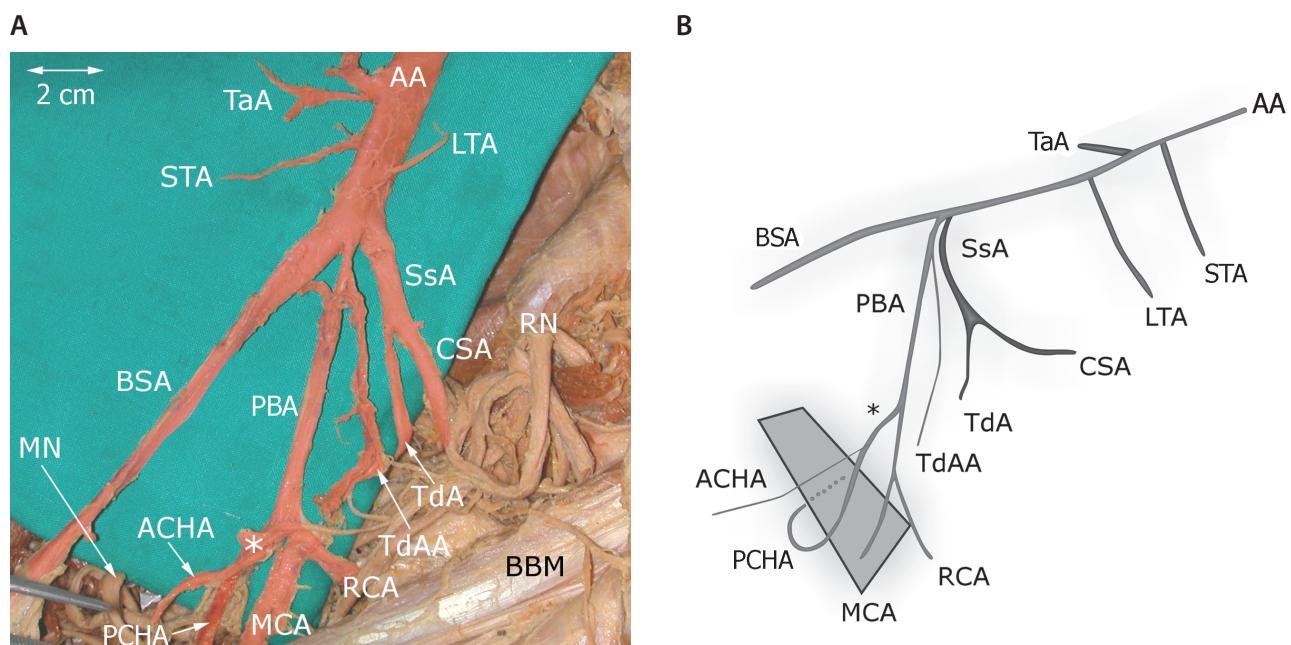
## RESULTS

The four different arterial branching patterns of the AA, concerned the superficial brachial artery, were observed. All four patterns deviated from the above mentioned textbook pattern, scilicet in various sites of origin, course, arrangement of terminations, branches, and calibre.

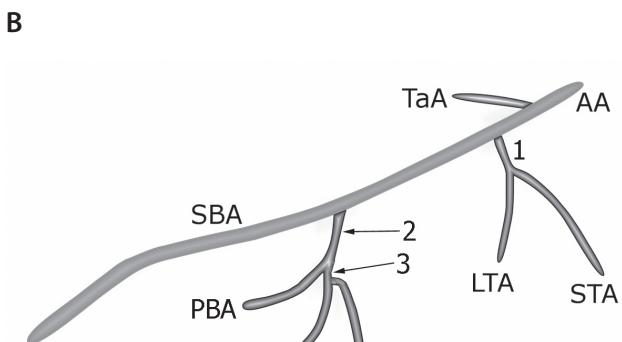
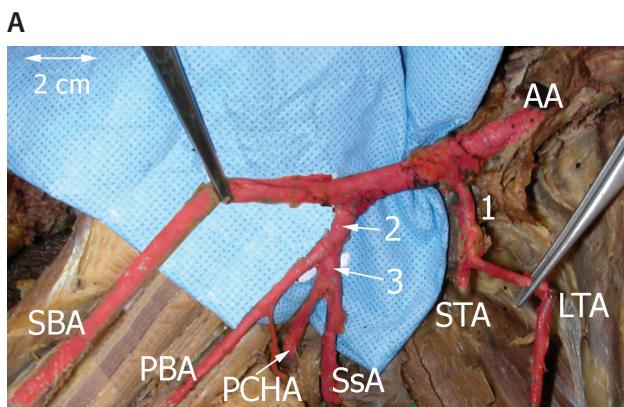
### Case 1:

This case presented a very unique type of branching pattern of the AA. It was observed in the left arm of a female cadaver

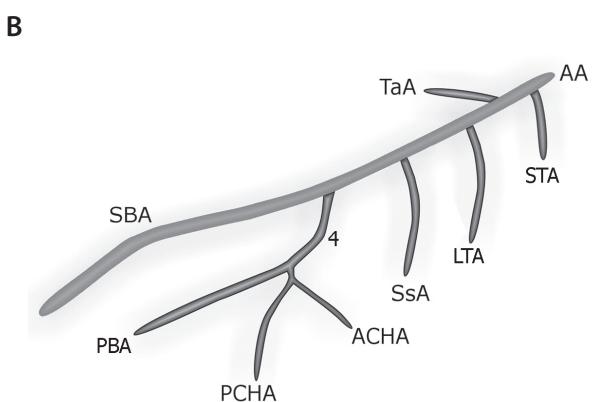
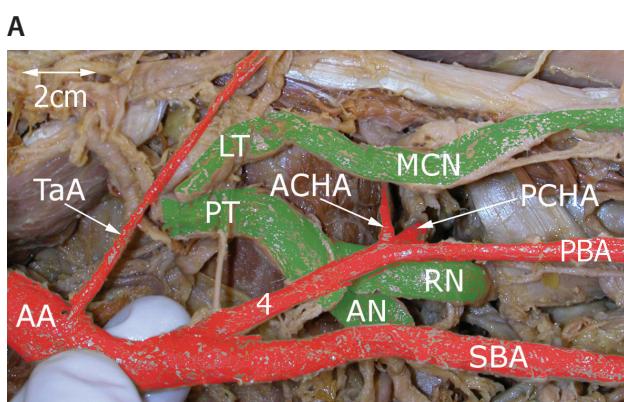
(aged 65). The AA terminated as a trifurcation into three large branches: superficial brachial artery, profunda brachii artery (*arteria profunda brachii*, deep artery of arm, incorrectly "deep brachial artery", PBA), and subscapular artery (Figure 1). The thoracoacromial and superior thoracic artery originated from the suprapectoral part of the axillary artery; the retropectoral part gave rise to the lateral thoracic artery. The remaining branches, which under normal conditions ramify from the infrapectoral part of the AA, branched from the PBA, with the exception of the subscapular artery, which was a branch of the unique AA terminal trifurcation. The profunda brachii artery gave rise not only to both circumflex humeral arteries but also to the accessory thoracodorsal artery (*arteria thoracodorsalis accessoria*) and terminated as the medial and radial collateral arteries (*arteria collateralis media et radialis*). The SBA descended in front of the median nerve and proceeded to branch into both the ulnar and radial arteries in the cubital fossa. The length of the AA from its origin (the inferior border of



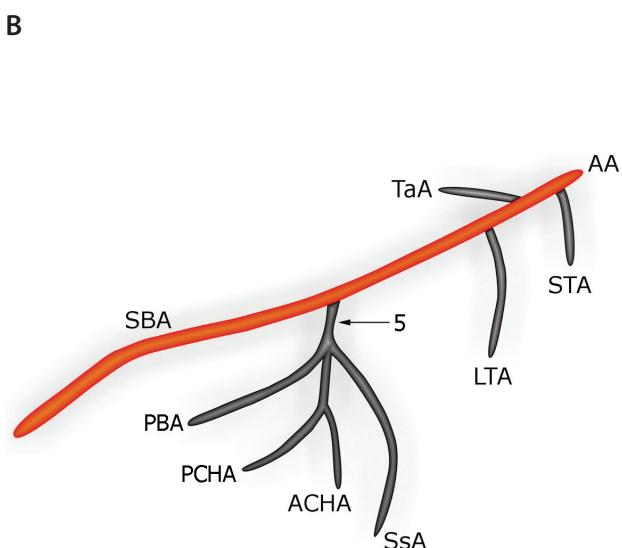
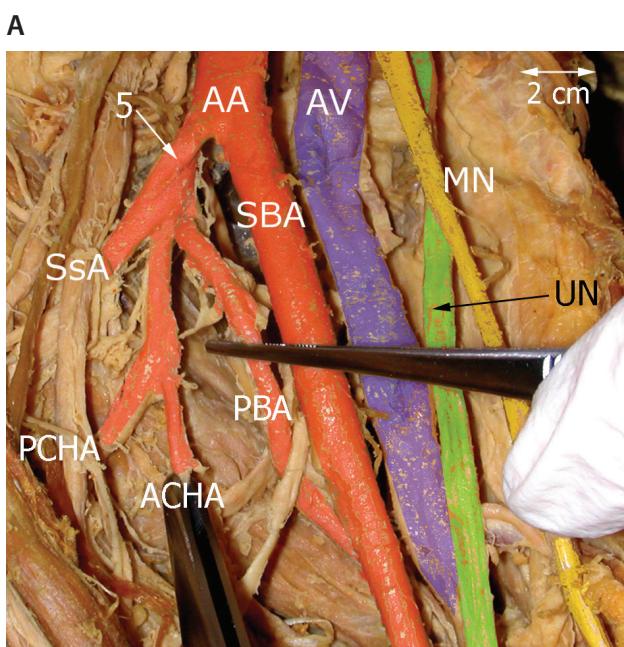
**FIGURE 1.** The real (A) and schematic (B) situation of the Case 1. AA – axillary artery, ACHA – anterior circumflex humeral artery, BBM – biceps brachii muscle, CSA – circumflex scapular artery, LTA – lateral thoracic artery, MCA – medial collateral artery, MN – median nerve, PBA – profunda brachii artery, PCHA – posterior circumflex humeral artery, RCA – radial collateral artery, RN – radial nerve, SBA – superficial brachial artery, SsA – subscapular artery, STA – superior thoracic artery, TaA – thoracoacromial artery, TdA – thoracodorsal artery, TdAA – accessory thoracodorsal artery, \* – common trunk for circumflex humeral arteries.



**FIGURE 2.** The real (A) and schematic (B) situation of the Case 2. AA – axillary artery, PBA – profunda brachii artery, PCHA – posterior circumflex humeral artery, SBA – superficial brachial artery, SsA – subscapular artery, LTA – lateral thoracic artery, STA – superior thoracic artery, 1 – common trunk (No. 1) for LTA and STA, 2 – common trunk (No. 2) for PBA, PCHA and SsA, 3 – common trunk (No. 3) for PCHA and SsA.



**FIGURE 3.** The real (A) and schematic (B) situation of the Case 3. AA – axillary artery, ACHA – anterior circumflex humeral artery, LTA – lateral thoracic artery, PBA – profunda brachii artery, PCHA – posterior circumflex humeral artery, SBA – superficial brachial artery, SsA – subscapular artery, STA – superior thoracic artery, 4 – common trunk (No.4) for circumflex humeral arteries and PBA.



**FIGURE 4.** The real (A) and schematic (B) situation of the Case 4. AA – axillary artery, ACHA – anterior circumflex humeral artery, AV – axillary vein, LTA – lateral thoracic artery, MN – median nerve, PBA – profunda brachii artery, PCHA – posterior circumflex humeral artery, SBA – superficial brachial artery, SsA – subscapular artery, STA – superior thoracic artery, UN – ulnar nerve, 5 – common trunk for (No.5) for circumflex humeral arteries and PBA.

**TABLE 2.** The caliber of arteries in the aforementioned cases

Artery	Case 1	Case 2	Case 3	Case 4
Axillary artery	9 mm	8 mm	8 mm	9 mm
Thoracoacromial artery	5 mm	5 mm	4 mm	4 mm
Subscapular artery	6 mm	4 mm	4 mm	4 mm
Profunda brachii artery	5 mm	4 mm	5 mm	5 mm
Posterior circumflex humeral artery	4 mm	4 mm	4 mm	4 mm
Superficial brachial artery	6 mm	5 mm	5 mm	5 mm
Lateral thoracic artery	3 mm	3 mm	3 mm	3 mm
Superior thoracic artery	3 mm	4 mm	3 mm	3 mm
Circumflex scapular artery	4 mm	4 mm	3 mm	4 mm
Thoracodorsal artery	3 mm	3 mm	3 mm	3 mm
Accessory thoracodorsal artery	3 mm	-	-	-
Anterior circumflex humeral artery	2 mm	2 mm	2 mm	2 mm
Radial collateral artery	3 mm	-	-	-
Medial collateral artery	3 mm	-	-	-
Common trunk No. 1	-	6 mm	-	-
Common trunk No. 2	-	5 mm	-	-
Common trunk No. 3	-	5 mm	-	-
Common trunk No. 4	-	-	5 mm	-
Common trunk No. 5	-	-	-	5 mm

clavicle) to its trifurcation was 40 mm. A large subscapular artery ran for 30 mm from the trifurcation to its terminal bifurcation into the thoracodorsal artery (*arteria thoracodorsalis*) and circumflex scapular artery (*arteria circumflexa scapulae*). Immediately after stemming from the termination of the AA, the PBA gave rise to the accessory thoracodorsal artery for the latissimus dorsi muscle, which thus received the arterial blood from two different sources. A common trunk for both the anterior and posterior circumflex humeral arteries, which stemmed from the PBA 6 cm from its origin, was also observed. After giving rise to this common circumflex humeral trunk, the PBA bifurcated into the medial and radial collateral artery. For the caliber of all the aforementioned arteries, see Table 2.

#### Case 2:

The second case of the abnormal branching pattern of the AA included again the SBA and another associated variation. It was observed in the right arm of a female cadaver (aged 50). The retropectoral part of the AA featured a common trunk (No. 1) which bifurcated and gave rise to the superior thoracic artery and the lateral thoracic artery. The common trunk (No. 1, being 6 mm wide and 20 mm long) stemmed 50 mm distally to the arbitrary beginning of the AA. The superior thoracic artery adhered to the lateral thoracic wall and supplied prevailingly the upper part of the serratus anterior muscle. The lateral thoracic artery descended towards the latissimus dorsi muscle and entered the muscle 75 mm far from the muscle insertion to the crest of the lesser tubercle

of the humerus (*crista tuberculi minoris humeri*). The infraclavicular part of the AA terminated 70 mm distally to the arbitrary beginning of the AA with a bifurcation into the SBA and a common trunk (No. 2). The SBA descended along the arm and terminated as a bifurcation into the radial and ulnar arteries at the level of the interepicondylar line. Both the radial and ulnar arteries were located superficially to the flexor muscles of the forearm and distally they rejoined their "common" textbook position. The common trunk (No. 2) gave rise to the profunda brachii artery immediately and continued as a common trunk (No. 3) to terminate 10 mm farther as a bifurcation into the subscapular artery and posterior circumflex humeral artery. The PBA ran distally without any other deviation. The subscapular artery ramified (as is the textbook pattern) into the circumflex scapular artery and thoracodorsal artery, which entered the latissimus dorsi muscle 20 mm from the point of muscle insertion into the humerus. The observed case presented the latissimus dorsi muscle being supplied by two different large regular branches of the AA: the lateral thoracic artery and the thoracodorsal artery (Figure 2).

#### Case 3:

The third case also represented a combined variation of the SBA and another vascular variation of the AA branching pattern: a common trunk for the anterior and posterior circumflex humeral arteries and the PBA (Figure 3). The variation was observed in the left arm of a female cadaver (aged 60). The first two parts of the AA did not feature any deviation from the textbook pattern; however, the infraclavicular part of the AA gave rise to the subscapular artery, which 20 mm distally ramified into a common trunk (No. 4 - for ACHA, PCHA, and PBA) and SBA. The SBA descended along the arm and coursed superficially to the median nerve and, in the area of interepicondylar line, divided into the ulnar and radial arteries. The rather long common trunk (No. 4) terminated after 40 mm with a trifurcation.

#### Case 4:

The last case represented a typical AA branching pattern associated with SBA (Figure 4). The first two parts of the AA did not show any deviation from normal textbook patterns; however, the third part terminated with a bifurcation into the SBA and a common trunk (No. 5) for the PCHA, PBA, and the subscapular artery. The subscapular artery then continued without any other variation. The caliber of the common trunk (No. 5) was quite large – 6 mm. The SBA descended along the arm, ran superficially to the median nerve and terminated in the cubital fossa with a bifurcation into the ulnar and radial arteries at the level of the interepicondylar line. Both of these arteries ran along the forearm superficially to the flexor muscles (as in Case 2).

## DISCUSSION

The definition of the superficial brachial artery was set for the first time by Adachi in 1928 and runs as follows: "The superficial brachial artery is the brachial artery that runs superficially to the median nerve." [1]. On the contrary, the profunda brachii artery always descends dorsally to the median nerve, i.e. deeper from the surface. In such a case, all the branches from the infraclavicular part of the AA (ACHA, PCHA and the subscapular artery) are branches from the proximal part of the profunda brachii artery, which caliber is then evidently larger. This variant is the only one listed in the Terminologia Anatomica, as the item A12.2.09.019 at page No. 86 [13]. The most interesting case out of those aforementioned ones was the Case 1, featuring the terminal trifurcation of the AA. The artery ramified into the PBA, SBA and subscapular artery. In reference literature, only one similar case has ever been reported, mentioned by De Garis and classified as the "G" pattern [10]. When both cases were compared, two notable differences were identified between the "G" pattern and our Case 1. At first, there was no posterior circumflex humeral artery passing under the tendons of the teres minor and latissimus dorsi muscles. At second, there was another variation in the arrangement of the branching pattern of the third part of the AA. De Garis described a terminal bifurcation into the SBA and a short common trunk which gave rise to the PBA and the subscapular artery; this differs from our Case 1, which featured a terminal trifurcation [10]. Moreover, the PBA, immediately after stemming from the termination of the AA, gave rise to the accessory thoracodorsal artery, supplying the latissimus dorsi muscle. This variation can be denominated as the "inferior thoracodorsal artery" as well, in order to distinguish it from the proper artery situated more proximally. Such finding is of a great clinical relevance due to the wide use of the latissimus dorsi muscle as a flap in the plastic and reconstructive surgery. Such double main pedicle of the muscle can either aggravate the flap harvesting or can be useful for splitting the donor flap for more acceptor sites. In our previous study, the frequency of the accessory thoracodorsal artery was 12% of cases [3]. In the Case 2, the latissimus dorsi muscle was supplied by two different large regular branches of the AA as well: the lateral thoracic artery and the thoracodorsal artery. In the Case 3, the present common trunk for the posterior circumflex humeral artery and profunda brachii artery belongs to quite frequently reported variations, 15% [1,3,10]. In the case of SBA existence, the profunda brachii artery replaces the proximal part of the brachial artery. It can be completed with the variations of the infraclavicular part of the AA, with "common" branches stem, in the case of SBA, mainly from the profunda brachii artery. The SBA

then retakes its position of the "usual" brachial artery in the distal arm and the elbow region by bifurcating into the radial and ulnar arteries. Nevertheless, frequently, it runs rather superficially, i.e. its terminal branches also follow this superficial course in relation to the forearm muscles. As for the nomenclature, it is necessary to mention a classification set by Bergman et al. [14], who proposed different new terms. But we strictly recommend to follow the clear and simple nomenclature as published by Rodriguez-Niedenführ et al. in 2001 [2] due to easy and non-problematic communication between experts worldwide [15,16]. The embryological background of these variations in the vasculature of the upper limb may be explained as abnormal deviations in the normal vascular patterns. The proximal part of the right subclavian artery arises from the right aortic arch and the distal part of the artery is derived from the right seventh intersegmental artery. The left subclavian artery has a different embryological background with the entire artery being formed from the seventh intersegmental artery. The AA and its branches are derived from the axial artery, being a distal continuation of the seventh intersegmental artery on both sides of the body. Every vascular variation can be traced back to an embryological origin. Arey and Jurus mentioned six explanations for the variations observed [17,18]:

1. The choice of unusual paths in the primitive vascular plexus.
2. The persistence of vessels which are normally obliterated.
3. The disappearance of vessels which are normally retained.
4. An incomplete development.
5. The fusion and absorption of parts which are normally distinct.
6. A combination of factors leading to an atypical pattern normally encountered.

When mentioning the upper limb, in particular its vascular system, it is necessary to discuss the embryology of the region [19,20]. The most interesting fact is that the arterial system of the upper limb develops as a capillary network at Day 26 (2-3mm bud of the future upper limb begins to form), connected to the axial artery, which pierces the condensed nervous tissue within future axilla at Day 28 – the circulatory system of the bud can be characterized as a capillary network. On Day 50, the SBA is defined and, on Day 52, the entire limb acquires a mature appearance. The distal section of the radial artery is completely developed and the connections with deeper parts of the vascular systems (deviations of the axial artery) are now degenerated. The SBA and the brachial artery are anastomosed, the radial artery is now established as a major branch of the

**TABLE 3.** Incidence of the superficial brachial artery in various studies.

Author (Year)	Number of Dissected Specimens	Number
Quain (1844) [28]	429	0.2%
Gruber (1848) [29]	1200	0.4%
Poirier (1886) [30]	****	6%
Müller (1903) [22]	100	1%
Linell (1921) [31]	-	6%
De Garis (1928)** [10]	512	4.6%
Adachi (1928) [1]	1198	3.1%
Miller (1939) [21]	100	3%
Treves (1947) [32]	-	15%
McCormack (1953) [33]	750	0.12%
Lanz (1959) [25]	-	25%
Skopakoff (1959) [34]	610	19.7%
Keen (1961) [35]	284	3.6% (12.3%*)
Fuss (1985) [36]	200	17%
Lippert (1985) [37]	***	22%
Rodriguez-Baeza (1995) [27]	160	11.9%
Kapur (2000) [38]	-	5%
Prasada Rao (2001) [39]	24	4.2%
Rodriguez-Niedeführ (2001) [40]	384	4.9%
Patanik (2002) [23]	49	6%
Rodriguez-Niedeführ (2001)*** [2]	168	7.7%
Kachlik (2010)	130	5%

\*Comprises three different variants: the superficial brachial artery (3.6%), brachioradial artery = high origin of radial artery (5.9%) and brachioulnar artery = high origin of ulnar artery (2.8%) in one group. \*\*The superficial brachial artery is more frequent in Afro-Americans (13.4%) than in white race (4.6%). \*\*\* Research based on literature review

forearm vascular system and the SBA begins to fade away. The structures involved in the development of the AA are derived from the seventh intersegmental artery, whereas the thoracodorsal-subscapular trunk corresponds to the ninth intersegmental artery. The regular persistence of the ninth intersegmental artery was observed by Miller in primates and Lemur and Galago gorillas [21]. It is generally admitted that anomalies in the arrangement of the branches of the brachial plexus are secondary to an aberrant distribution of the AA [19,21,22]. The SBA is presented as a concentration of vascular elements in the area close to the proximal portion of the brachial artery, or, more precisely, to the infraclavicular part of the AA. The consecutive branching of the SBA is divided into a superficial anteribrachial medial and superficial anteribrachial lateral arteries. The latter of the aforementioned arteries runs distally as the definitive radial artery. The former one bifurcates into the median and ulnar branches, anastomosing with certain segments of the primitive axial artery [22-24]. The only regularly persisting branch of the SBA is the main section of the radial artery [26]. The ulnar and common interosseous arteries (*arteria interossea communis*) are set by the distal portions of the primitive axial artery. Consequently, a process of degradation begins. Due to different hemodynamic conditions, the proximal part of

the SBA successfully degenerates. The distal part of the SBA develops into the radial artery and median artery (*arteria comitans nervi mediani*) and serves as the developmental base for the majority of arterial variations in the upper limb [27]. All the embryological and developmental facts discussed indicate that the SBA is an important variant. The Table 3 summarizes the most important studies concerning the SBA and its reported incidence. A particularly interesting phenomenon can be traced throughout the years of the studies. Originally, the SBA was observed in only 1-3% of cases; however, later studies, published in 1940's, reported its frequency to be 12-25% of cases. In the last 10 years, the incidence has been documented to be only 5-6% (Table 3). The reasons for this sinusoid characteristic of the result incidence can be attributed to new specification guidelines, classification of the variations and melioration in study methods, which have been improved thanks to the conclusions of the previous findings and observations. Adachi defined the SBA as coursing superficially to the median nerve and Rodriguez-Niedeführ stated, more than 70 years later, that it ran "rather superficially" [1,2]

## CONCLUSION

We reported, for the first time, the trifurcation of the axillary artery (into the superficial brachial artery, profunda brachii artery and subscapular artery), combined with an accessory thoracodorsal artery (stemming from the PBA) and the superficial brachial artery. The SBA descended in front of the median nerve and proceeded to branch into both the ulnar and radial arteries in the cubital fossa at the level of the interepicondylar line. It is a remnant of the complex development of the arm and forearm arterial supply, persisting in various forms in approximately 5-6% of cases. It can be concluded that it is quite frequent arterial variant of the upper limb vasculature. The anatomic knowledge of the axillary region is of crucial importance not only for neurosurgeons, but for all those involved in radiodiagnosis, particularly in cases involving traumatic injuries, as improved knowledge would allow more accurate diagnostic interpretation and surgical treatment.

## DECLARATION OF INTEREST

The authors state that there is no conflict of interest.

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