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Anatomical variations of the axillary artery and their clinical significance

Foivos-Michail Loizos, Dimosthenis Chrysikos, Arezina Manoli, Georgios Tsakotos, Nikolaos Georgopapadakos, Panagiotis Kalogeropoulos, Theodore Troupis

Department of Anatomy, Medical School, National and Kapodistrian University of Athens, Athens, Greece

ABSTRACT

The axillary artery conveys oxygenated blood to the lateral aspect of thorax, axilla upper limb and it is divided into three parts by the pectoralis minor muscle. Anatomical variations of the axillary artery are common and might be encountered during surgical, vascular interventions or minimally invasive procedures in the axillary region.

Clinically significant anatomical variations of the axillary artery are those of the third part which form an anastomotic network surrounding the scapula and providing alternative pathways for collateral circulation of the arm, scapular area or lateral thoracic wall. From surgical point of view any inadequate knowledge of the potential vascular variations of the axillary artery could lead to irreversible flap loss as this may occur during a reconstructive surgery using a pedicled flap based on a branch of the axillary artery.

Key Words: *Axillary artery; anatomy; anatomical variations; clinical significance*

INTRODUCTION

The axillary artery has a length of approximately 15 cm. It forms the connective part of artery between the subclavian artery and brachial artery, thus it starts at the lateral border of the first rib and ends at the inferior border of the teres major muscle. After this point it continues as the brachial artery [1]. The axillary artery is divided into three parts by the pectoralis minor muscle as a landmark.

The first part lies proximal to the pectoralis minor muscle and gives rise to only one branch the superior thoracic artery, coursing medially providing blood supply to the muscles of first two intercostal spaces. The second part lies underneath the pectoralis minor muscle and gives rise to two branches: the thoracoacromial and lateral thoracic arteries. The thoracoacromial artery offers a rich collateral circulation, arising as a short trunk and divided into four branches to supply the acromioclavicular area, the pectoral and deltoid muscles. The lateral thoracic artery runs along the lower border of pectoralis minor muscle supplying the lateral chest wall.

The third part lies laterally to the pectoralis minor muscle giving rise to three branches: the subscapular, the anterior and posterior circumflex humeral arteries. The subscapular branch is the largest one descending along the lower border of the scapula as the circumflex scapular artery branch, while its counterpart namely the thoracodorsal artery branch supplies the muscles of the posterior axillary wall. Finally the anterior and posterior circumflex arteries wrap around the humeral neck as a ring. The posterior circumflex humeral artery anastomoses with the ascending branch of the profunda brachii artery proving an extra collateral circulation [2].

The branching pattern variations of axillary artery can be due to the defects in the embryonic development of the vascular plexus of upper limb bud. The precursor axial

Corresponding author:
T. Troupis, MD, PhD
Department of Anatomy, School of Medicine, Faculty of Health Sciences, National and Kapodistrian University of Athens
75 Mikras Asias str., Goudi, 11527 Athens, Greece
Tel.: +30-210-7462388, fax: +30-210-7462398
e-mail: ttroupis@gmail.com, ttroupis@med.uoa.gr

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artery is derived from lateral branch of 7th inter-segmental artery and the proximal part of it forms the axillary and the brachial artery. This variation may be due to an arrest at any stage of development of vessels of upper limb. This could happen due to a regression, retention, or reappearance of new vessels and may lead to variations in the arterial origins and courses [3].

MATERIALS AND METHODS

The protocol of this review has been submitted to the Institutional Review Board of Department of Anatomy, National and Kapodistrian University of Athens, Greece and is available upon request. Eligible articles were identified by search of the Medline Embase, Cinahl and Google Scholar bibliographical databases for the period from October 2010 up to May 2020. The study protocol was agreed by all co-authors. The search strategy included the following keywords (axillary artery "OR" axilla AND anatomical variations" ('anatomical variants' OR 'anomalies)). Language restrictions were applied (only articles in English, French and German were considered eligible); two investigators (LFM and DC), working independently, searched the literature and extracted data from each eligible study.

Reviews were not eligible, while all prospective and retrospective studies, as well as case reports, were eligible for this systematic review. Manuscripts that did not state the names of the authors were excluded. In addition, we checked all the references of relevant reviews and eligible articles that our search retrieved, so as to identify potentially eligible conference abstracts. Titles of interest were further reviewed by abstract. The strategy retrieved 214 articles, 93 of these were considered as eligible and possible sources from the title and abstract presented. The other articles were excluded, (applying exclusion criteria) and finally 14 of them were selected to be included in this literature review.

RESULTS

In our present study totally 470 male and female of Caucasian race cadaveric axillary arteries were recorded, aged 25-80 years old, both their left and right-side axillary artery branches. According to this literature review results, the most frequently observed anatomical variations of axillary artery takes place on branches of the third segment, however we are presenting all of those variations found on (65%) of our dissected axillary arteries with descending order of frequency as follows below (Table 1, figure 1).

In advance, the most frequent variation is observed on lateral thoracic artery arising from subscapular artery in (20%) of cases (Table 2, figure 2). The second variation with (15%) takes place again in 3rd part of axillary artery where a common trunk gives rise to the anterior humeral circumflex artery, posterior humeral circumflex artery and profunda brachii artery. The third commonest axillary

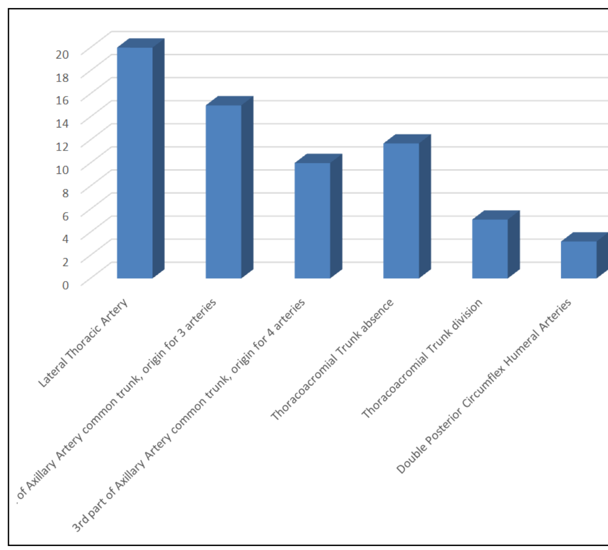

FIGURE 1. Variations found on our dissected axillary arteries with descending order of frequency.

TABLE 1

Anatomical Variations of Axillary Artery	Number of Specimens (470 Cadaveric Axillary Arteries)
Lateral Thoracic Artery	94 (20%)
3rd part of Axillary Artery common trunk, origin for 3 arteries	71 (15%)
3rd part of Axillary Artery common trunk, origin for 4 arteries	47 (10%)
Thoracoacromial Trunk absence	55 (11,7%)
Thoracoacromial Trunk division	24 (5,1%)
Double Posterior Circumflex Humeral Arteries	15 (3,2%)
Total Number (%) of Variations	(65%)

artery variation (10%) is same to the previous one with addition of the subscapular artery. We observed in (11,7%) total absence of thoracoacromial trunk, however the four vessels consisting this trunk namely pectoral, acromial, deltoid and clavicular arose directly from axillary artery. At the same second part of axillary artery (5,1%) of our review we found out a division of the thoracoacromial trunk into a deltoacromial trunk and a clavipectoral trunk. Lastly (3,2%) exist double posterior humeral circumflex arteries; one arising from the third part of axillary artery while the other arises more distally from the brachial artery.

In advance, the average number of branches arising from axillary artery has been observed many years ago. First were De Garis and Swartley [1] who claimed in 1928 it can be 6-11 branches. Later in 1959 Heulke [4] decreased this number to 4-7. In our study this number is approximately 6-8 (Table 3, figure 3).

Moreover, there are the results mentioned about the branches of axillary artery in white and negro stocks, where there are noticed the journal articles and researches of De Garis and Swartley (1928) [1], Heulke (1959) [4], O'Dey, Prescher, Pallaa, [13] and Trotter, Henderson, Gass, et al. [17]. The mean no. of the branches of axillary artery in white and negro stocks, are about 9, 6, 6 and 5 in the specific researches accordingly, according to Table 4 and figure 4.

Moreover, there are the results mentioned about the management of axillary vessel injuries, where there are noticed the journal articles and researches of Vu, Sciaretta, Prichayudh, et al. Operative [2], Kogan, Lewinson, [9], Vu,

TABLE 2

Origin of Lateral Thoracic Artery from Subscapular Artery	Author's name
14,6%	Huelke (1959) [4]
23,4%	Trotter M et al. (1930) [17]
20%	Present study (2020)

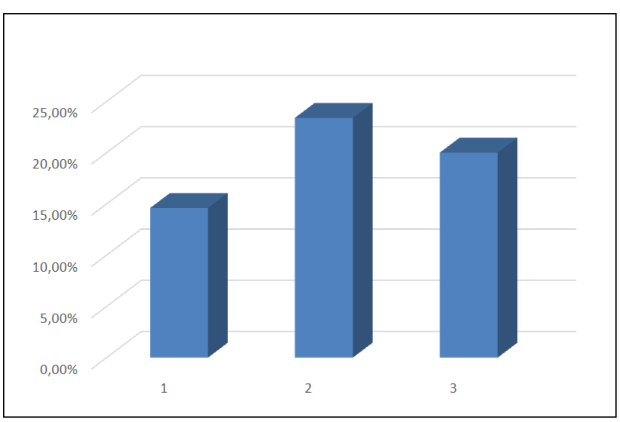

FIGURE 2. Origin of lateral thoracic artery arising from subscapular artery in (20%) of cases.

TABLE 3

Branches arising from Axillary Artery	Author's name
6-11	De Garis and Swartley (1928) [1]
4-7	Heulke (1959) [4]
6-8	Present study (2020)

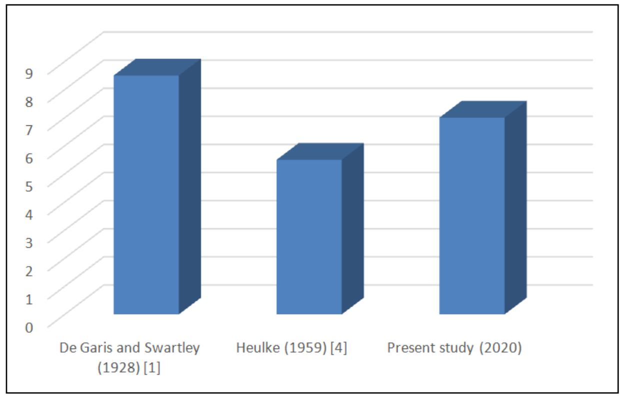

FIGURE 3. Mean Number of Branches Arising from Axillary Artery.

TABLE 4

Branches of Axillary Artery in White and Negro Stocks	Author's name
6-11	De Garis and Swartley (1928) [1]
4-7	Heulke (1959) [4]
5-7	O'Dey, Prescher, Pallaa, [13]
4-6	Trotter, Henderson, Gass, et al. [17]

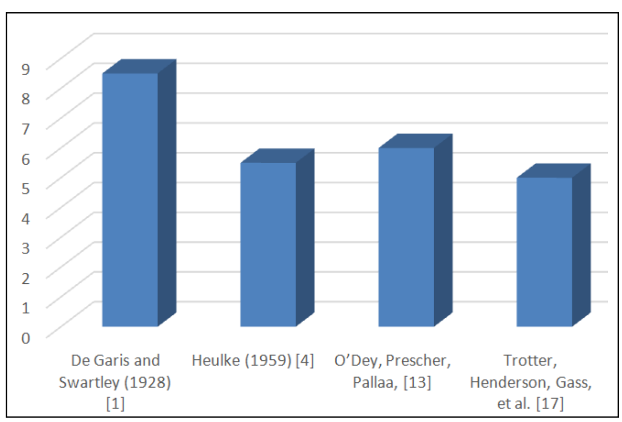

FIGURE 4. Mean Number of Branches of Axillary Artery in White and Negro Stocks.

Sciaretta, Prichayudh S, et al. [15] and Donaldson, Louras, Buckman, A. [19]. The mean no. of vessel injuries is about 3, 4, 3 and 5 in the specific researches accordingly, according to Table 5 and figure 5.

Finally, there are the results mentioned about the variations of the Axillary Branches in the Axillary Artery, where there are noticed the journal articles and researches of Huelke [4], Magden, Gocmen-Mas, Caglar [5], Yoshinaga, Kodama, Kameta, et al. [6] and Kogan, Lewinson [9]. The mean no. of variations of axillary branches in the axillary artery is about 7, 4, 5 and 6 in the specific researches accordingly, according to Table 6 and figure 6.

TABLE 5

Management of Axillary Vessel Injuries	Author's name
2-4 techniques of management	Vu, Sciaretta, Prichayudh, et al. Operative [2]
3-5 techniques of management	Kogan, Lewinson, [9]
2-4 techniques of management	Vu, Sciaretta, Prichayudh S, et al. [15]
3-5 techniques of management	Donaldson, Louras, Buckman, A. [19]

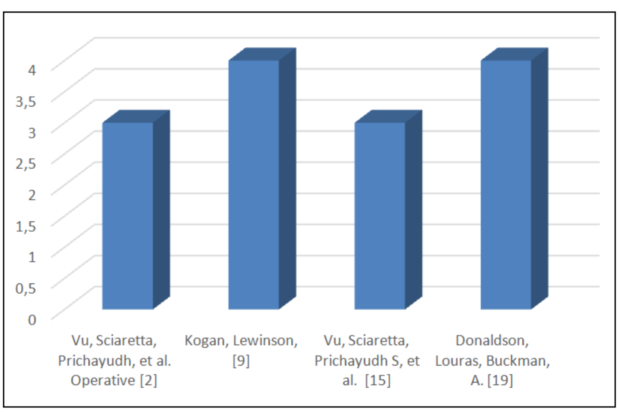

FIGURE 5. Mean Number of Axillary Vessel Injuries.

TABLE 6

Variations of Axillary Branches in the Axillary Artery	Author's name
7 direct named branches	Huelke [4]
4 direct named branches	Magden, Gocmen-Mas, Caglar [5]
5 direct named branches	Yoshinaga, Kodama, Kameta, et al. [6]
6 direct named branches	Kogan, Lewinson [9]

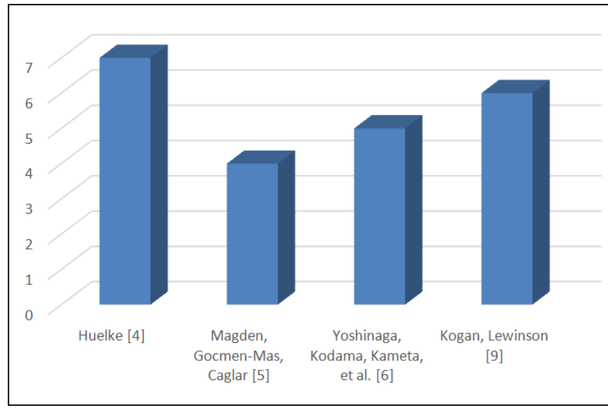

FIGURE 6. Mean number of variations of axillary branches in the axillary artery.

DISCUSSION

According to Arey, the unusual blood vessels may be due to the choice of unusual paths in the primitive vascular plexuses, persistence of vessels normally obliterated or disappearance of vessels normally retained. Another possibility is incomplete development and fusions and absorption of the parts usually distinct [1].

Variations of the anatomical structure and its clinical significance lie in the observed extensive collateral circulation between the branches of subclavian and axillary arteries, particularly around the scapula [4]. Variations in the branching pattern of the axillary artery are very common [4]. According to Magden et al. [5] an unusual branch in the serratus anterior muscle was originated directly from the first part of the axillary artery as the first branch. While, a subscapular artery absence, an out-of-position superior thoracic artery and "a lateral thoracodorsal" common trunk were recorded, the circumflex scapular artery arisen from the third part of the axillary artery [5]. According to Yoshinaga et al. [6] anatomic variations in the major arteries of the upper limb, namely absence of the radial artery and presence of a superficial ulnar artery were recorded.

The number of branches is usually six but is often varying from 5 to 11 due to abnormalities, such as two or more arteries often arise together instead of separately, or two branches of an artery arise separately instead of the usual common trunk [7]. According to Johnson and Ellis [8] subscapular artery can arise from a common trunk with the posterior circumflex humeral artery in the one third of the reported cases. According to Kogan and Lewinson [9] who reported first a rare abnormality of the medial branch, which descended on the anterior aspect of the axillary fossa, reaching the hypogastric region, and anastomoses with the superficial epigastric artery, which is a branch of the femoral artery.

By the number of the reported cases, it seems that the third part of the axillary artery is under a varying anatomical pattern. According to Bergman et al. [10] the two circumflex arteries may arise from a common trunk, usually alone, rarely either together or they may give rise to a common trunk, where the subscapular, anterior and posterior circumflex humeral, the profunda brachii, and the ulnar collateral arteries are arisen. Good knowledge of the axillary artery abnormalities will contribute to less breast surgery complications during lymph node dissections, such as breast cancer-related lymphoedema (BCRL) and better surgical prevention of breast cancer metastasis [11].

Another example is the Latissimus Dorsi Flap breast reconstruction where the survival of the flap is based on the technically atraumatic surgical manipulation of the thoracodorsal artery which is branch of subscapular artery after branching of axillary artery. This famous workhorse flap can be used besides a primary or secondary breast reconstruction also in cases of chest wall or shoulder sarcoma resections, axillary contractures following a burn injury as well as a free flap covering a remote body area. Flaps of up to 15 cm can be safely raised, based on a single perforator of the thoracodorsal artery depending on the recipient site dimensions and the potential of primary closure of the donor site [12].

The lateral thoracic artery is an important vessel contributor to the major blood supply of the nipple–areola complex, especially in the female breast [13]. During a mastectomy for a cancer or even for cosmetic reasons like a mastopexy or breast augmentation, maintenance of the nipple–areola complex is essential [14]. Among aforementioned procedures and in particular the breast reduction surgery and mastopexy procedures, the most catastrophic is nipple necrosis due to arterial insufficiency and that's unfortunately irreversible [15]. During a pectoralis major pedicled flap often in cases of head and neck cancer reconstruction the artery used in this procedure is the pectoral branch of thoracoacromial artery. This flap is very versatile especially in post irradiated patients [11].

Since the upper limb arterial branches have been used for coronary bypass in cardiac surgery, an accurate knowledge of the existing and possible varying patterns is important both for heart surgery, angiography or for an arterial cannulation as happens during a repair of an aortic arch dissection. Axillary-coronary artery bypass is an effective alternative to those patients requiring a revision surgery of coronary artery revascularization, although the extrathoracic section of the graft makes it susceptible to kinking or occlusion [18]. In vascular surgery axillofemoral bypass is used since 1963 in order to salvage lower extremities from threatening ischemia, or for those patients who cannot undergo aortic reconstruction, usually in urgent settings, however nowadays with increasing endovascular alternatives the former methods become declining [19].

Moreover, the clinical significance of the detailed anatomy of the axillary artery lies under the more accurate evaluation of its stenotic areas during the surgical interventions. Thus, it may help to prevent diagnostic errors, influence surgical tactics while on interventional procedures and avoid complications during the surgery of the axilla region. Chronic crutch-induced axillary artery injury is not rare, sometimes ordering an intervention. It is associated with axillary artery thrombosis, aneurysm formation, or secondary axillobrachial thromboembolic disease. Their treatment is thrombolysis or percutaneous transluminal angioplasty [20].

Moreover, in the world of sports medicine whenever the axillary artery is repetitively compressed in athletes like baseball players, it can result in aneurysm formation, intimal hyperplasia and segmental dissection which can lead ultimately into a thrombosis and a catastrophic distal embolism. The role of Doppler study or Angiography mapping can preoperatively prevent almost any unwanted vascular injuries and ease dramatically the surgical procedures [16].

CONCLUSIONS

Theoretical and practical experience regarding normal and variant anatomy of the axillary artery is of paramount importance while operating in the region of chest and arm. Flaps based on branches of axillary artery are exploited very often in reconstructive plastic surgery with most frequent the Latissimus Dorsi flap during a breast reconstruction. A potential wrong choice of arterial pedicle could end up in intraoperative bleeding or even worse into a badly vascularised flap with ultimate result the flap necrosis.

Cardiac surgeons harvest vascular grafts while on coronary bypass surgery or vascular interventionists use almost daily branches of the axillary artery catheterizing their wires. Orthopedic surgeons could possibly damage distal branches of axillary artery whenever they try to reduce an upper third humeral fracture or a shoulder dislocation. Finally plastic surgeons work in close vicinity with axillary artery while they repair brachial plexus palsy. All aforementioned specialties should be familiar with the anatomical variations and branching patterns of the axillary artery.

Conflicts of Interest: *None. The authors declare no funding was received related to their research.*

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