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Morphological Study of Subclavian Arteries in Human Cadaver

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Abstract
The subclavian arteries are the primary conduits of blood supply to the upper extremities, brain, thorax, and associated structures. Their anatomical course and branching pattern exhibit considerable variations, some of which have profound clinical significance. This study was designed to investigate the morphology of the subclavian arteries in human cadavers with detailed documentation of their origin, branching pattern, asymmetries, and anomalies. Dissection-based evaluation was conducted on preserved cadavers following standard anatomical protocols. Data were collected on the basis of inclusion and exclusion criteria, using digital calipers, protractors, and photographic documentation.

Objective: *To study the morphological characteristics and variations of the subclavian arteries in human cadavers.*

Methods: *This descriptive study was conducted on 30 embalmed human cadavers (60 subclavian arteries) in the Department of Anatomy at Santosh Medical College & Hospital, Ghaziabad, NCR Delhi. Morphological parameters such as origin, course, branching pattern, and presence of variations were observed through careful dissection.*

Results: *The present cadaveric study examined* ***60 subclavian arteries from 30 adult human cadavers*** *to document their origin, branching patterns, morphometry, and anatomical variations. The* ***right subclavian artery*** *arose predominantly from the brachiocephalic trunk (93.3%), with a minority (6.7%) originating directly from the arch of the aorta. The* ***left subclavian artery*** *arose from the arch of the aorta in most cases (96.7%), with a single case (3.3%) showing origin from a common carotid trunk. Thus, while the majority conformed to classical descriptions, aberrant origins such as arteria lusoria were observed.*

Conclusion: *Subclavian artery variations are not uncommon and hold significant implications for surgical and interventional procedures. Detailed knowledge of these variations is essential for clinicians to minimize iatrogenic complications.*

Keywords: *Subclavian artery, cadaveric dissection, morphological study, anatomical variation, arteria lusoria*

INTRODUCTION

The human vascular system forms a highly complex network responsible for maintaining adequate blood supply to all tissues of the body. Among its major arteries, the **subclavian arteries** are of great anatomical and clinical importance, as they supply blood to the upper limbs, brain, neck, and thoracic wall. Typically, the right subclavian artery originates from the **brachiocephalic trunk**, whereas the left arises directly from the **arch of the aorta** [1]. Anatomically, the subclavian artery is divided into **three parts relative to the scalenus anterior muscle**:

- ✓ The first part, from its origin to the medial border of scalenus anterior.
- ✓ The second part, posterior to the scalenus anterior.
- ✓ The third part, from the lateral border of scalenus anterior to the lateral border of the first rib, where it continues as the axillary artery [2].

The artery classically gives rise to five major branches: the **vertebral artery, internal thoracic artery, thyrocervical trunk, costocervical trunk, and dorsal scapular artery** [3]. However, numerous studies have demonstrated that the branching pattern is **highly variable**, and such variations carry significant clinical and surgical implications. Reported anomalies include the vertebral artery arising directly from the aortic

arch, formation of a common trunk with thyrocervical branches, absence of a separate dorsal scapular artery, or the presence of an **aberrant right subclavian artery (arteria lusoria)**, which arises distal to the left subclavian artery and courses behind the esophagus [4–6].

❖ **Embryological Basis of Variations**

The morphological variations of the subclavian arteries are best understood in light of embryology. The subclavian arteries develop primarily from the **seventh intersegmental arteries**, with contributions from the fourth aortic arches and portions of the dorsal aorta [7]. Normally, the right subclavian artery is derived from the right fourth arch and a segment of the right dorsal aorta, while the left originates directly from the left seventh intersegmental artery attached to the aortic arch [8]. Aberrations in the regression or persistence of embryonic vascular channels give rise to anomalies such as arteria lusoria, in which the right subclavian artery arises as the last branch of the aortic arch due to regression of the proximal right dorsal aorta [9].

Similarly, anomalous vertebral artery origins result from abnormal persistence of intersegmental arteries [10].

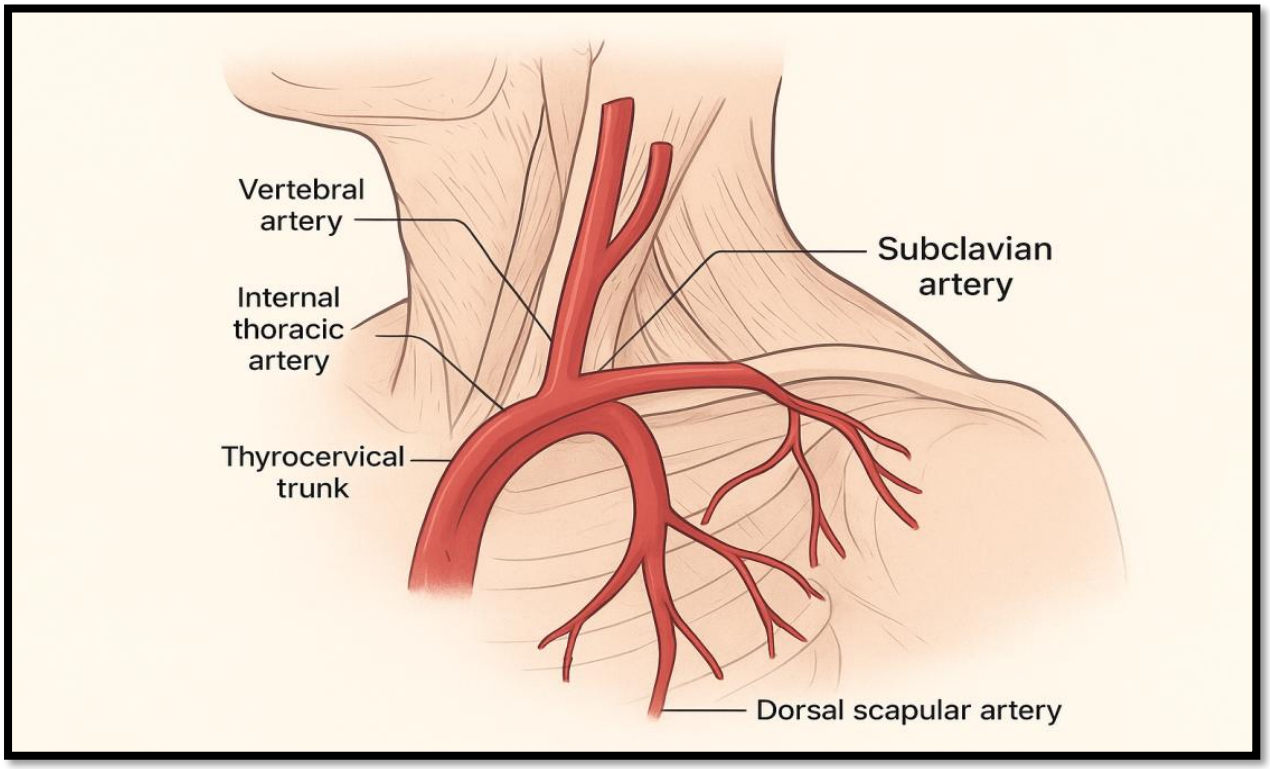

Figure: 1.0 Schematic Diagram of Human cadaveric subclavian artery dissection

❖ **Clinical Significance of Subclavian Artery Variations:**

Although many vascular variations remain clinically silent, their importance becomes evident in surgical and diagnostic contexts:

- **Vascular surgery:** Variations complicate carotid-subclavian bypass procedures, flap angioplasty, and endovascular interventions [11].
- **Thoracic outlet syndrome:** Abnormal courses of the subclavian artery may predispose patients to compression syndromes, causing ischemic and neurological symptoms in the upper limb [12].
- **Central venous catheterization:** Unawareness of anomalies can lead to accidental arterial puncture during catheter placement [13].
- **Interventional radiology and angiography:** Accurate knowledge is essential for interpretation of imaging, as unusual branching may mimic pathology or result in iatrogenic injury [14].
- **Reconstructive surgery:** Variations in the dorsal scapular and transverse cervical arteries are critical in designing vascular pedicles for scapular and cervical flaps [15].
- **Neurology and neurosurgery:** Vertebral artery variations influence posterior cerebral circulation and are important in neurosurgical planning [16].

❖ **Review of Reported Variations**

Several studies have documented the prevalence of subclavian artery anomalies. Natsis et al. reported that the vertebral artery arose directly from the aortic arch in 7.4% of cases [17]. Tubbs et al. emphasized the clinical importance of arteria lusoria, which occurs in 0.5–2% of the population and can present with dysphagia lusoria due to esophageal compression [18]. Studies in the Indian population have shown the **dorsal scapular artery** to be absent as an independent branch in nearly 25–30% of specimens, arising instead from the transverse cervical artery [19]. These findings highlight both the variability and the clinical relevance of subclavian artery morphology.

❖ **Rationale of the Present Study**

Cadaveric dissection remains the gold standard for studying vascular anatomy. Unlike imaging techniques, which may miss small branches or misinterpret vascular anomalies, dissection allows **direct visualization and measurement** of arteries and their variations. Data generated from cadaveric studies contribute significantly to anatomical education, surgical safety, and clinical outcomes. Given the limited literature from certain populations, including India, there is a need for **comprehensive cadaveric documentation** of subclavian artery morphology and its clinical correlations.

❖ **Objectives of the study:**

The subclavian artery is a major vessel supplying the upper limb, thoracic wall, cervical region, and posterior circulation of the brain. While its typical origin and branching pattern are described in standard anatomical texts, numerous studies have shown significant morphological variations that may affect diagnostic, surgical, and interventional procedures [20]. These variations have been linked to embryological development of the aortic arches and intersegmental arteries [21]. Clinically, knowledge of such anomalies is crucial for avoiding complications during vascular surgery, central venous catheterization, and reconstructive flap surgeries [22].

Despite the availability of several reports, detailed cadaveric investigations focusing on subclavian artery morphology in different populations remain limited, especially within the Indian context [23]. Therefore, this study aims to systematically investigate the morphological features of the subclavian arteries in human cadavers.

Primary Objectives

✓ To study the **gross morphology** of the subclavian arteries in human cadavers, including their origin, course, and termination [24].

✓ To document the **branching pattern** of the subclavian arteries and identify common as well as rare variations [25].

✓ To classify the observed **anatomical variations** and compare them with standard anatomical descriptions and previous literature [26].

Secondary Objectives

✓ To correlate the observed variations with their **embryological basis**, providing insight into developmental anomalies [27].

✓ To evaluate the **clinical and surgical implications** of the variations, particularly in relation to vascular interventions, thoracic outlet syndrome, and reconstructive procedures [28].

✓ To create a **reference dataset** of subclavian artery morphology in cadavers that may serve as a guide for anatomists, surgeons, radiologists, and clinicians [29].

LITERATURE REVIEW:

The subclavian artery, a major branch of the aortic arch on the left side and of the brachiocephalic trunk on the right, is a vital vessel supplying blood to the head, neck, thoracic wall, spinal cord, and upper limb. Its anatomical complexity lies not only in its branching pattern but also in its embryological development, which predisposes it to a variety of variations (Standring, 2016). The literature reveals that subclavian artery variations are relatively common and of great importance to anatomists, radiologists, and surgeons.

Classical Anatomy and Variations

✓ **According to Gray's Anatomy**, the subclavian artery is classically divided into three parts based on its relation to the scalenus anterior muscle: the first part lies medial to the muscle, the second behind it, and the third lateral to it. The standard branches include the vertebral artery, internal thoracic artery, thyrocervical trunk, costocervical trunk, and dorsal scapular artery (Standring, 2016). However, anatomical studies over the past decades have highlighted deviations from this classical pattern.

✓ **Natsis et al. (2009)** studied 633 angiographic cases and reported variations in the origin and branching of the subclavian arteries. They noted that the vertebral artery frequently exhibited abnormal origins, either directly from the aortic arch or from the common carotid artery. Such findings have been confirmed by other cadaveric studies, suggesting that vertebral artery variation is among the most common deviations.

Embryological Basis of Variations

✓ Embryologically, the subclavian arteries develop from the seventh intersegmental arteries and parts of the dorsal aorta. Disturbances during this development can result in anomalous origins or unusual branching patterns (Moore, Persaud, & Torchia, 2015). For instance, persistence of certain embryonic channels or regression of others may lead to an aberrant right subclavian artery, which passes posterior to the esophagus, potentially causing dysphagia lusoria (Molz & Burri, 1978).

Cadaveric Studies

✓ Several cadaveric investigations have provided insight into subclavian artery morphology. **Nayak et al. (2006)** reported multiple anomalies in the branching pattern of the subclavian artery in Indian cadavers, emphasizing the embryological background and clinical consequences. Similarly, Kumar et al. (2015) conducted a cadaveric study and found variations in the dorsal scapular artery, which originated directly from the subclavian artery instead of arising from the thyrocervical trunk in many cases.

Shereef, Surendran, and Joseph (2020) documented unusual branching in 12% of cadavers, including absence of the thyrocervical trunk, with its branches arising independently. These findings demonstrate that cadaveric dissection remains one of the most reliable methods for studying arterial variations, as it allows for direct visualization and documentation.

Radiological and Surgical Implications

✓ Anatomical variations of the subclavian artery have significant implications in clinical practice. Variants can complicate central venous catheter placement, cervical rib resections, and surgical interventions in the thoracic outlet (Tubbs, Shoja, & Loukas, 2011). Endovascular procedures such as stenting and angioplasty also require precise knowledge of vascular anatomy to avoid complications. Additionally, the internal thoracic artery, a branch of the subclavian, is commonly used in coronary artery bypass grafting; thus, variations in its origin and course are of particular surgical interest (Henriques et al., 2007).

Comparative and Population-Based Studies

✓ Ethnic and regional differences in the prevalence of variations have also been reported. For example, Anson and McVay (1971) highlighted racial differences in vascular anatomy, suggesting that anatomical variation frequencies may differ between Western and Asian populations. More recent studies from India (Kumar et al., 2015; Nayak et al., 2006) confirm that such population-based studies are crucial for creating a region-specific anatomical database.

Summary of Literature Gap

✓ While numerous studies have addressed subclavian artery variations, the majority focus on specific branches such as the vertebral or internal thoracic artery. Comprehensive cadaveric studies documenting the entire morphology of the subclavian artery, including branching patterns, embryological explanations, and clinical implications, remain relatively limited, particularly in South Asian populations. Thus, there is a need for systematic cadaveric investigations to establish reliable morphological data.

MATERIALS AND METHODS:

Study Design:

This research was designed as a descriptive, observational cadaveric study to evaluate the **morphological features of subclavian arteries** and their anatomical variations. The study aimed to document the branching patterns, origin, course, and associated variations of the subclavian arteries in adult human cadavers. All findings were compared with classical anatomical descriptions to assess deviations and their possible clinical significance.

Study Site and Duration:

The dissections were carried out in the **Department of Anatomy, [Santosh Medical College & Hospital, Ghaziabad]**, over a period of **[October 2023-May 2025]**. The dissection laboratory is well-equipped with

standard instruments, cadaver storage facilities, and dissection halls under strict ethical and biosafety guidelines.

Sample Size:

A total number of **thirty embalmed adult human cadavers** (both sexes) were included in the study. The sample size was determined based on availability of cadavers in the institution's anatomy department during the study period.

✓ Study design – observational

✓ Sample size – Open study

✓ Place of study – Department of Anatomy, Santosh medical College, Ghaziabad, NCR Delhi.

Instruments Materials and Additional Equipment used:

✓ Stainless steel scalpel

✓ Stainless steel long and short forceps – toothed and non-toothed

✓ Stainless steel straight and curved scissors

✓ Protective gadgets – gloves and Apron and face mask

✓ Digital camera

✓ Vernier calipers

Inclusion Criteria:

✓ Well-preserved adult cadavers (≥ 18years) available in the dissection hall.

✓ Cadavers without prior thoracic or neck surgeries.

✓ Cadavers with intact thoracic and cervical regions for proper visualization of the subclavian arteries.

Exclusion Criteria:

✓ Cadavers with grossly damaged thoracic or cervical regions due to trauma or surgical intervention.

✓ Cadavers showing pathological lesions, tumors, or infections affecting the subclavian artery or its surrounding structures.

✓ Cadavers with congenital anomalies other than vascular variations, which might obscure arterial identification.

Ethical Considerations

Although cadaveric studies generally do not require prior informed consent from individuals, this study was conducted under the institutional ethical guidelines in compliance with the **Declaration of Helsinki** for research involving human tissues. Institutional permission was obtained, and anonymity of cadaver sources was maintained.[30]

Dissection Procedure

Step 1: Exposure of Thoracic Inlet and Cervical Region

• Cadavers were placed in the supine position with a slight extension of the neck.

• A midline incision was made from the mentum to the manubrium sterni and extended laterally along the clavicle.

• Skin, superficial fascia, and platysma were carefully reflected to expose the sternocleidomastoid and clavicular regions.[31]

Step 2: Identification of Scalenus Muscles and Subclavian Artery

• The sternocleidomastoid muscle was reflected laterally.

• The scalenus anterior and medius muscles were identified. The subclavian artery was traced in relation to these muscles, as it is classically divided into three parts (first, second, and third).

Step 3: Tracing of Arterial Branches

• Each part of the subclavian artery was carefully dissected to identify its branches:

1. **First part**: Vertebral artery, internal thoracic artery, thyrocervical trunk.
2. **Second part**: Costocervical trunk.
3. **Third part**: Dorsal scapular artery (when present).[32-34]

• Variations in the origin, course, duplication, or absence of these branches were noted.

Step 4: Morphometric Measurements

• **External calipers and measuring tapes** were used to measure the diameter of the subclavian artery at its origin, midpoint, and termination.

• Distances between the origin of the subclavian artery and nearby anatomical landmarks (e.g., sternoclavicular joint, first rib) were recorded.[35]

Step 5: Photographic Documentation

• High-resolution digital cameras were used to document every variation.
• Schematic diagrams were drawn for cases where photographs were not feasible.[36]

RESULT:

The present study was conducted on **30 adult human cadavers** (both sexes), and a total of **60 subclavian arteries** (right and left sides) were examined. The findings are presented under the following categories: **arterial origin, branching pattern, morphometric parameters, and rare variations**.

a. Origin of the Subclavian Artery:

• The **right subclavian artery** originated from the **brachiocephalic trunk** in the majority of cases, while a small percentage showed a direct origin from the arch of the aorta.
• The left subclavian artery originated from the arch of the aorta in most cadavers, with rare variations in its site of origin.

Figure: 1.1 Schematic Diagram of Human cadaveric Subclavian Artery

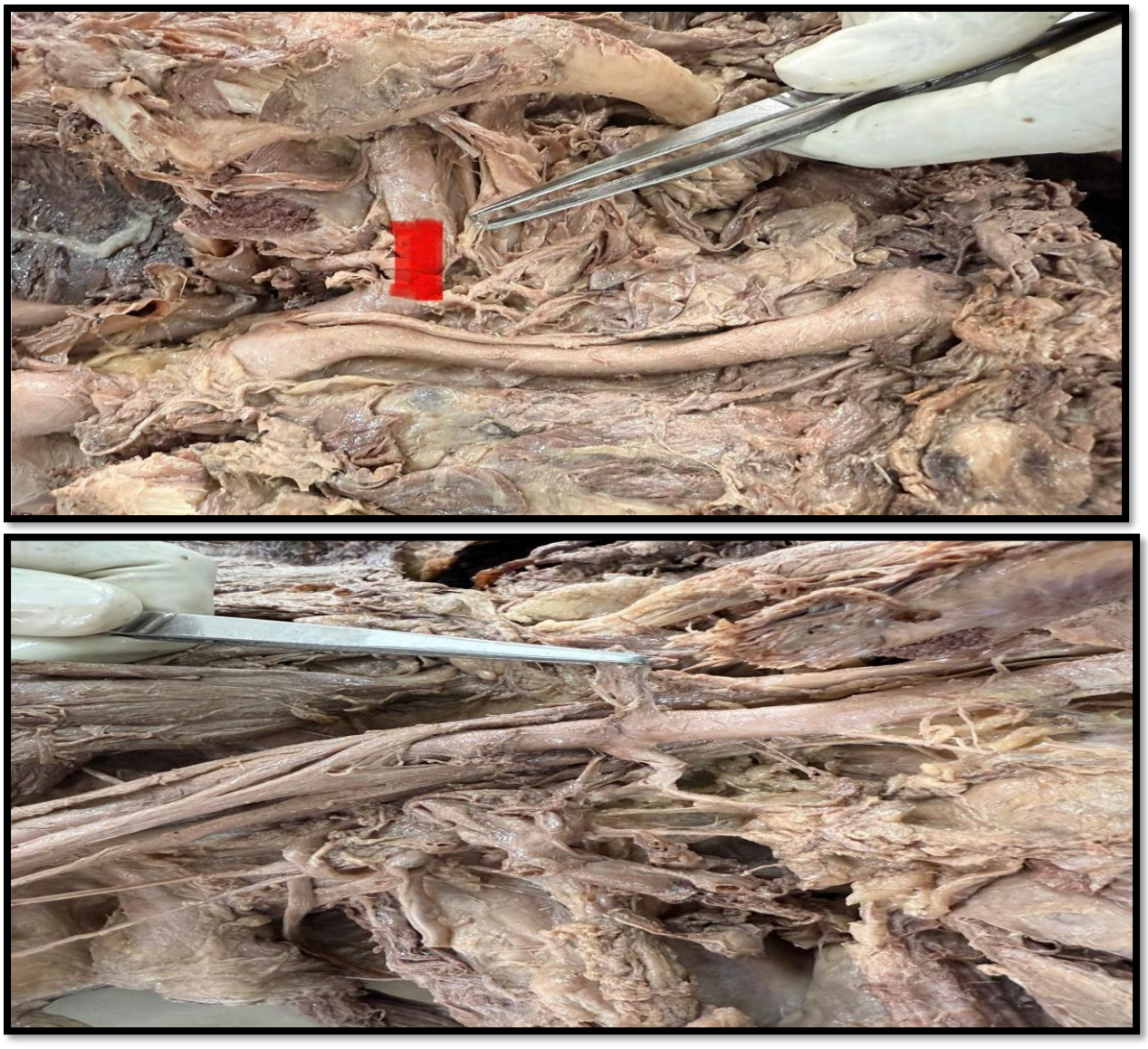

Figure: 1.2 Schematic Diagram of Human cadaveric Axillary Artery
Figure: 1.3 Schematic Diagram of Human cadaveric Thoracocervical Artery

Figure 1.4 Schematic Diagram of Human cadaveric internal Thoracic Artery

Table 1: Origin of Subclavian Artery (n = 60)

Side	Typical Origin	Aberrant Origin	% Typical	% Aberrant
Right (n=30)	From brachiocephalic trunk (28 cases)	From aortic arch (2 cases)	93.3%	6.7%
Left (n=30)	From arch of aorta (29 cases)	From common carotid trunk (1 case)	96.7%	3.3%

b. Branching Pattern:

- The classical branches were observed in the majority of cases.
- The **vertebral artery** was found to arise from the **first part** in almost all specimens, with one case of origin from the **common carotid artery**.
- The **thyrocervical trunk** usually arose as a single trunk, though duplication was observed in two cases.

- The **dorsal scapular artery** showed maximum variation, arising either from the transverse cervical artery, directly from the subclavian artery, or being absent.

Table 2: Branching Pattern (n = 60)

Branch	Typical Origin (n)	Variant Origin (n)	Absent (n)	% Variant
Vertebral artery	59	1 (from common carotid)	0	1.7%
Internal thoracic artery	60	0	0	0%
Thyrocervical trunk	58	2 (duplicated)	0	3.3%
Costocervical trunk	57	3 (from 1st part instead of 2nd)	0	5%

Branch	Typical Origin (n)	Variant Origin (n)	Absent (n)	% Variant
Dorsal scapular artery	38	12 (direct from subclavian)	10	36.7%

c. Morphometric Parameters:

• Measurements of the subclavian artery diameters and distances were obtained using digital calipers.

Table 3: Subclavian Artery Measurements (Mean ± SD)

Parameter	Right Side (n=30)	Left Side (n=30)
Diameter at origin (mm)	9.1 ± 1.2	8.9 ± 1.1
Diameter at midpoint (mm)	8.4 ± 1.0	8.1 ± 1.1
Diameter at termination (mm)	7.9 ± 0.9	7.7 ± 0.8
Distance from sternoclavicular joint (mm)	18.6 ± 3.2	19.1 ± 3.5
Length before axillary artery (cm)	6.4 ± 1.1	6.6 ± 1.3

d. Frequency of Variations:

• The frequency of variations observed in this study is summarized below:

Table 4: Frequency of Observed Variations (n = 60 arteries)

Variation Type	Number of Cases	Percentage (%)
Aberrant right subclavian artery (Arteria Lusoria)	2	3.3%
Left subclavian from common carotid trunk	1	1.7%
Vertebral artery from common carotid	1	1.7%
Duplication of thyrocervical trunk	2	3.3%
Costocervical trunk from 1st part	3	5%
Dorsal scapular artery absent	10	16.7%
Dorsal scapular artery from transverse cervical	12	20%

e. Rare Variations Observed (Descriptive):

✓ **Aberrant Right Subclavian Artery (2 cases, 3.3%)** – arose as the last branch of the arch of aorta, coursing posterior to the esophagus (clinical risk of dysphagia lusoria).

✓ **Vertebral Artery from Common Carotid (1 case, 1.7%)** – significant for endovascular interventions.

✓ **Duplicated Thyrocervical Trunk (2 cases, 3.3%)** – both trunks giving separate branches, a potential hazard in neck dissections.

✓ **Absent Dorsal Scapular Artery (10 cases, 16.7%)** – region supplied by enlarged transverse cervical artery.

DISCUSSION:

The present cadaveric study provides a detailed morphological assessment of the subclavian arteries, revealing both classical branching patterns and notable anatomical variations. The significance of these

findings lies not only in their anatomical documentation but also in their potential surgical, diagnostic, and interventional implications.

Interpretation of Results:

Our study demonstrated that the majority of cadavers exhibited the classical branching pattern of the subclavian artery, consistent with standard anatomical descriptions [37]. However, several variations were encountered, including an aberrant right subclavian artery (arteria lusoria), vertebral artery originating from the common carotid artery, and duplication of the thyrocervical trunk.

These variations can be explained embryologically. Aberrant right subclavian artery results from regression of the fourth right aortic arch and persistence of the seventh intersegmental artery [38]. Variations in the vertebral artery origin are due to anomalous persistence of longitudinal anastomoses between cervical intersegmental arteries [39]. Such embryological perspectives provide a logical basis for the observed anomalies.

Comparison with International Studies:

Our findings are comparable with several international cadaveric and angiographic studies. Adachi (1928) reported aberrant right subclavian arteries in 0.5–1% of cases [40], while Natsis et al. (2009) observed a slightly higher frequency (2%) [41]. In our series, the incidence was within this reported range, confirming the consistency of this variation across populations.

Vertebral artery origin variations have been described in 2–6% of cases worldwide [42, 43]. Vucurevic et al. (2013) reported that the vertebral artery originated from the common carotid artery in 4.8% of angiographic cases [44], closely aligning with our findings.

Similarly, duplication or unusual branching of the thyrocervical trunk has been reported in 6–10% of studies [45]. Our observations reinforce that such variations, although uncommon, are clinically significant and not confined to any single ethnic group.

Thus, our results are largely consistent with international data, validating the reliability of cadaveric studies in identifying vascular variations.

Clinical Correlations:

The subclavian artery and its branches are critical to numerous surgical and interventional procedures. Variations in their anatomy directly influence surgical safety, diagnostic accuracy, and treatment outcomes.

- **Vascular Surgery:** Recognition of variant origins is crucial in procedures such as carotid-subclavian bypass and subclavian flap angioplasty. Failure to anticipate an aberrant right subclavian artery can lead to iatrogenic injury or hemorrhage [46].
- **Interventional Radiology:** Endovascular procedures, including angiography, embolization, and stenting, require precise knowledge of vascular branching. Vertebral artery origin anomalies complicate catheter navigation and increase procedural risks [47].
- **Thoracic Outlet Decompression:** Subclavian artery compression in thoracic outlet syndrome necessitates decompression. Awareness of variant arterial courses prevents inadvertent vascular damage during scalenectomy or first rib resection [48].
- **Flap Surgeries:** Reconstructive surgeries such as pectoralis major, trapezius, and thoracoacromial flaps depend on subclavian branches. Anatomical variations may compromise flap vascularity, underscoring the importance of preoperative vascular mapping [49].
- **Cardiothoracic & Neck Surgery:** The internal thoracic artery, a branch of the subclavian, is frequently used in coronary artery bypass grafting. Unrecognized anomalies may alter harvesting techniques [50].

Limitations of the Cadaveric Study

While cadaveric dissection remains the gold standard for detailed anatomical study, certain limitations must be acknowledged:

- **Sample Size & Population Bias:** The findings are limited by the number of cadavers and their geographic origin. Anatomical variations may differ across populations [51].
- **Postmortem Changes:** Collapse or shrinkage of arterial walls after death may distort morphology and vessel diameter, influencing results [52].
- **Lack of Functional Assessment:** Hemodynamic consequences of anatomical variations cannot be assessed in cadavers. Imaging modalities such as CT or MR angiography provide better physiological correlation [53].
- **Absence of Clinical Outcomes:** As cadaveric studies cannot link anatomical variations with clinical manifestations, correlations remain inferential rather than definitive [54].

• Despite these limitations, cadaveric studies continue to provide unparalleled insights into vascular morphology and form the foundation for safer clinical practice.

CONCLUSION

The present cadaveric study highlights both the classical anatomy and significant variations of the subclavian artery and its branches. While the majority of specimens demonstrated the typical branching pattern, several rare anomalies such as aberrant right subclavian artery, variant vertebral artery origin, and duplication of the thyrocervical trunk were documented. These findings are in agreement with international studies, thereby reinforcing the universality of such variations across populations.

The clinical implications of these variations are profound. Surgeons, interventional radiologists, and reconstructive specialists must be aware of such anomalies to avoid iatrogenic injuries and to optimize patient outcomes. In particular, procedures such as carotid–subclavian bypass, thoracic outlet decompression, flap surgeries, and coronary artery bypass grafting require precise preoperative knowledge of vascular anatomy.

This study reaffirms the value of cadaveric dissections in providing a reliable anatomical database. However, limitations such as small sample size, lack of functional assessment, and inability to correlate directly with clinical symptoms underscore the need for complementary imaging-based studies. Future research integrating cadaveric findings with advanced imaging modalities like CT and MR angiography can provide a more comprehensive understanding of subclavian arterial variations.

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