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Anatomical Variations of the Brachial Plexus Cords and Their Clinical Relevance to the Infraclavicular Block: A Literature Review

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Anatomical variations of the brachial plexus are frequently encountered during anatomical dissections and clinical procedures. Among its components, the cords represent a structurally complex and developmentally dynamic segment, making them particularly prone to morphological deviations. The present review summarizes and systematizes the anatomical variations of the lateral, medial, and posterior cords of the brachial plexus as reported in the literature from 1918 to 2025. Variations include alterations in cord formation, atypical contributions from roots and trunks, absence or fusion of cords, anomalous communications between cords, and variations in terminal branching patterns. Particular attention is given to deviations in the segmental composition and structural organization of the cords. Understanding these variations is essential for accurate anatomical interpretation and for preventing iatrogenic injury during surgical and anesthetic procedures involving the axillary region. This review aims to provide a morphological overview of cord variations and to contribute to the field of variation anatomy.

Key words: Brachial plexus; anatomical variations; lateral cord; medial cord; posterior cord

Introduction

Anatomical variability is a well-recognized phenomenon in human morphology. Although classical anatomical descriptions present a standardized structural pattern, numerous deviations from the classical configuration occur during embryological development. These anatomical variations are generally non-pathological and present at birth, yet they may significantly influence surgical approaches, regional anesthesia, and the interpretation of neurological deficits.

The brachial plexus is one of the most complex peripheral nerve networks in the human body. Due to its intricate developmental formation and segmental organization, it exhibits a broad spectrum of anatomical variations. While many studies have described variations of the roots and trunks, relatively less systematic attention has been directed specifically toward the cords of the brachial plexus.

The cords — lateral, medial, and posterior — represent the infraclavicular portion of the plexus and serve as the origin of the major terminal branches supplying the upper limb. Variations in their formation, fiber composition, and branching pattern may alter the classical anatomical relationships around the axillary artery.

A structured literature search was conducted using PubMed and Scopus databases covering the period from 1918 to 2025. The following keywords and combinations were used: “brachial plexus”, “cords”, “lateral cord”, “medial cord”, “posterior cord”, “anatomical variation”, “infraclavicular” and “infraclavicular block”.

Inclusion criteria comprised cadaveric studies and case reports describing variations of the brachial plexus cords. Studies focusing exclusively on roots, trunks, or divisions without cord-level analysis were excluded unless relevant to infraclavicular organization.

Additional sources were identified through manual screening of reference lists of selected articles.

The aim of the present review is to analyze and systematize the anatomical variations of the cords of the brachial plexus reported in the literature, with particular emphasis on their morphological patterns, structural classification, and clinical relevance to infraclavicular block.

Anatomical Variations

During embryological development, structural variations may arise in individual anatomical components. It has long been recognized in anatomical science that the human body exhibits a spectrum of morphological deviations from the most commonly described structural pattern, commonly referred to as anatomical variation [39]. An anatomical variation represents a normally developed body structure whose morphological characteristics differ from the classical description and from the configuration observed in the majority of individuals.

Such variations may involve a wide range of anatomical structures, including muscles, ligaments, vascular branches, and nerves, and may extend to entire neural networks such as the brachial plexus [3]. In most cases, these variations are congenital and present at birth. They are generally non-pathological and do not significantly impair function.

Despite their non-pathological nature, anatomical variations possess considerable clinical relevance. They may influence diagnostic interpretation, modify surgical landmarks, and necessitate adapted clinical approaches during interventional or anesthetic procedures [35]. For this reason, variation anatomy represents an important field within the morphological sciences, aiming to identify, document, and systematize deviations in human structural organization.

Variations are frequently encountered during surgical interventions and radiological examinations, where unexpected anatomical configurations may complicate clinical management. Therefore, knowledge of variation anatomy is essential not only for anatomists but also for clinicians. In a study conducted in 2015, Raikos and Smith [33] reported that clinicians encounter anatomical variations regularly in practice — monthly (39%), weekly (25%), and even daily (21%), underscoring their practical significance.

Normal Anatomy of the Brachial Plexus

The brachial plexus is a complex neural network responsible for the motor and sensory innervation of the upper limb [40]. It is classically formed by the ventral rami of the spinal nerves C5, C6, C7, C8, and T1 [5]. In certain cases, additional contribution from C4 results in a prefixed brachial plexus, whereas participation of T2 defines a postfixed brachial plexus [29].

The ventral rami unite to form three trunks: the superior, middle, and inferior trunks. The superior trunk is formed by the ventral rami of C5 and C6; the middle trunk represents the continuation of the ventral ramus of C7; and the inferior trunk is formed by the ventral rami of C8 and T1 [23, 40].

Each trunk divides into anterior and posterior divisions. These divisions reorganize in the infraclavicular region to form three cords, which are named according to their relationship to the axillary artery: the lateral cord, medial cord, and posterior cord [40].

The lateral cord is formed by the anterior divisions of the superior and middle trunks and typically contains fibers from C5–C7. The medial cord arises from the anterior division of the inferior trunk and contains fibers from C8–T1. The posterior cord is formed by the posterior divisions of all three trunks and therefore contains fibers from C5–T1 [30].

Topographically, the brachial plexus is divided into supraclavicular (roots and trunks) and infraclavicular (divisions and cords) parts. The cords are located in the infraclavicular region and surround the axillary artery [28].

The lateral cord gives rise to the lateral pectoral nerve, the musculocutaneous nerve, and the lateral root of the median nerve. The medial cord gives rise to the medial pectoral nerve, the medial cutaneous nerve of the arm, the medial cutaneous nerve of the forearm, the ulnar nerve, and the medial root of the median nerve. The posterior cord gives rise to the subscapular nerves, the thoracodorsal nerve, the axillary nerve, and the radial nerve.

The schematic representation of the normal anatomy of the brachial plexus is shown in **Figure 1**.

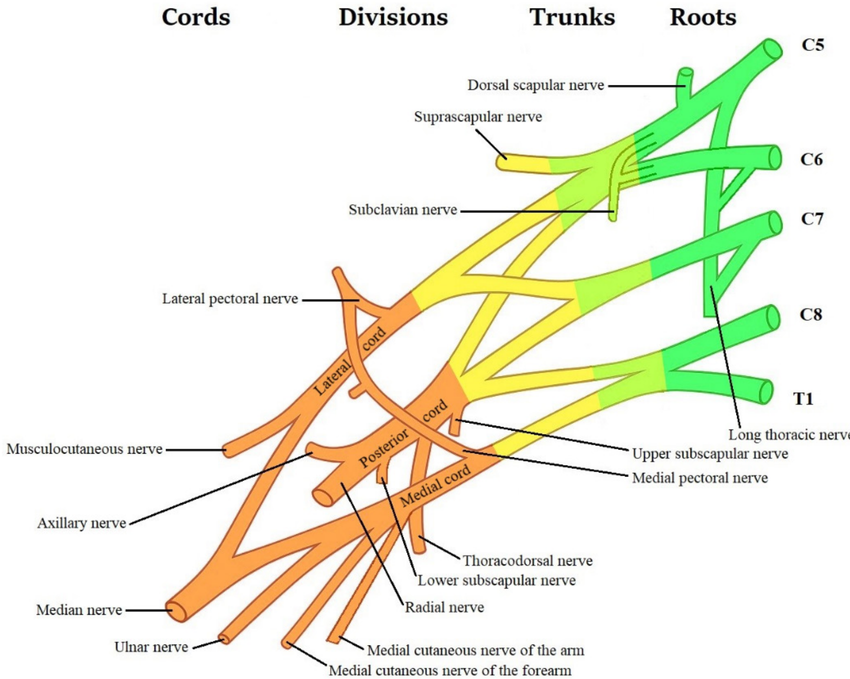

Fig. 1. Schematic representation of the normal anatomy of the brachial plexus. Modified from Wikimedia Commons, licensed under CC BY-SA 4.0.

Classification of Brachial Plexus Variations

The brachial plexus represents a hierarchically organized neural structure composed of roots, trunks, divisions, cords, and terminal branches. Variations may occur at any **level** of th**is** anatomical **organization**. From a structural perspective, brachial plexus variations can therefore be categorized into five principal groups:

(1) root variations;
(2) trunk variations;
(3) division variations;
(4) cord variations;
(5) terminal nerve variations.

While such a level-based classification provides a general anatomical framework, more detailed **classifications have** been proposed specifically for **patterns of cord formation.**

Cord-Level Classification According to Benes et al. (2021) **[6]**

A comprehensive meta-analysis conducted by Benes et al. (2021) identified six principal subtypes of variation in the formation of the brachial plexus cords from the anterior and posterior divisions of the trunks:

1. Standard cord formation pattern

• Classical configuration with three cords formed in the usual manner.

2. Rearranged merging of divisions

• Abnormal redistribution or splitting of anterior/posterior divisions leading to atypical cord composition. This includes:

• Splitting of the anterior division of the middle trunk with contributions to both lateral and medial cords.

• Absence of contribution of the anterior division of the middle trunk to the lateral cord.

• Absence of contribution of the posterior division of the inferior trunk to the posterior cord.

• Abnormal participation of the posterior division of the superior trunk in medial cord formation.

3. Variations in trunk number with preservation of three cords

• Altered number of trunks (two or four trunks) with subsequent formation of three anatomically recognizable cords.

4. Qualitative changes in cord configuration

• Structural reorganization such as:

• Single common cord,

• Two-cord configuration (anterior and posterior),

• Temporary fusion of cords with subsequent separation,

• Post-formation splitting of the posterior cord.

5. Absence of cord formation

• Partial or complete failure of cord development, with divisions continuing directly as terminal nerves.

6. Unclassified or rare patterns

• Variants not fitting into the above categories.

This meta-analytic classification provides a structured framework for understanding variability **in cord formation** and highlights the considerable morphological plasticity of the infraclavicular brachial plexus.

Scope of the Present Review

The present review focuses exclusively on cord-level variations, analyzing published cases in relation to:

• alterations in cord formation,

• **changes in** segmental composition,

• topographic deviations relative to the axillary artery,

• intercord communications, and

• variations in branching patterns.

By adopting a morphology-oriented analytical approach, this review aims to expand upon existing classifications and to integrate developmental and clinical perspectives into cord-level variations.

Embryological Basis of Variations of the Brachial Plexus

The development of the brachial plexus begins during the fourth week of embryogenesis, when motor axons emerging from the ventral horns of the spinal cord extend toward the developing upper limb bud. Shortly thereafter, sensory fibers from the dorsal root ganglia join these motor axons, forming the primitive neural network that later differentiates into the definitive brachial plexus [5, 10].

Plexus formation involves sequential processes of axonal growth, redistribution, fusion, and separation. Initially, ventral rami establish a primitive neural meshwork, directing fibers toward the dorsal and ventral muscle masses of the developing limb. From this early arrangement arise the anterior and posterior divisions of the trunks, followed by secondary reorganization into the three cords.

The patterning of this neural network is regulated by highly coordinated molecular signaling between mesenchymal cells and axonal growth cones. Axonal extension is guided by the expression of chemoattractant and chemorepellent molecules in a spatially and temporally controlled manner. Disruptions in these signaling pathways may alter axonal trajectory and fiber redistribution, resulting in variations in trunk division or cord formation [9, 34].

Following initial formation, selective apoptosis and remodeling of transient neural connections occur. Some early embryonic communications regress, whereas others persist. Persistence of such temporary connections may explain accessory roots of the median nerve, atypical intercord communications, or abnormal segmental participation within specific cords. Once established, these anatomical variations persist after birth [9].

Vascular development in the axillary region may further influence plexus organization. Variations in the formation of the axillary vessels can mechanically affect fusion patterns and spatial relationships between plexus components [40].

From an evolutionary perspective, the organization of the brachial plexus demonstrates considerable phylogenetic plasticity. Lower vertebrates lack a clearly defined trunk-and-cord arrangement, whereas primates exhibit progressive structural specialization. This evolutionary variability may partly account for the relatively high frequency of brachial plexus variations in humans.

Thus, variations in cord formation may be attributed to:

- Alterations in axonal migration and guidance signaling
- Persistence of transient embryonic neural connections
- Atypical trunk fusion or division
- Vascular developmental influences
- Evolutionary morphological variability.

The embryological complexity of this secondary reorganization stage explains why the cords of the brachial plexus demonstrate considerable morphological variability.

Anatomical Variations of the Brachial Plexus Cords

1. Variations of the Lateral Cord

The lateral cord demonstrates considerable variability in its formation, segmental composition, intercord communications, branching pattern, and topographic relations.

Early documentation of lateral cord anomalies dates back to Kerr (1918), who reported absence and atypical configurations of the lateral cord in his large anatomical series [19].

1.1. Variations in Formation

Altered formation of the lateral cord is among the most frequently described infraclavicular variations. Uysal et al. [41], in a fetal series, described cases in which the lateral cord was formed solely from the anterior division of the superior trunk, without contribution from the middle trunk. **This is presented in Figure 2.** Similar observations were reported by Wozniak et al. [44], who identified several plexuses in which the lateral cord was formed only by the anterior division of the superior trunk. In such cases, the typical C7 contribution through

the middle trunk is absent, resulting in altered segmental distribution to the musculocutaneous nerve and the lateral root of the median nerve.

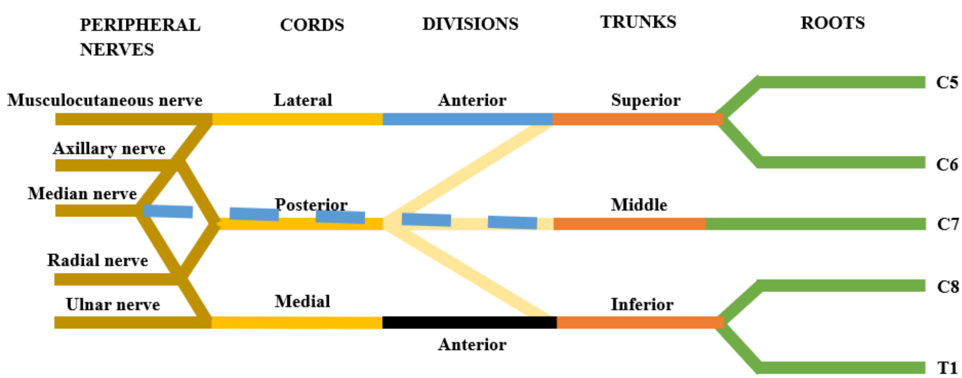

Fig. 2. Formation of the lateral cord from the anterior division of the superior trunk, without contribution from the anterior division of the middle trunk.

More complex rearrangements of cord formation have also been described. Uysal et al. [41] reported a case in which the inferior trunk divided into two anterior and two posterior branches; one anterior and one posterior branch united to form the medial cord, whereas the remaining anterior branch joined the lateral cord and the remaining posterior branch contributed to the posterior cord. This configuration illustrates marked redistribution of fibers between the cords and modification of the classical infraclavicular architecture. This is presented in **Figure 3**.

Failure of superior trunk formation may further alter lateral cord development. In two plexuses described by Uysal et al. [41], the ventral rami of C5 and C6 did not unite into a superior trunk; instead, they divided independently, with the posterior components contributing to the posterior cord and the anterior components joining to form the lateral cord. This arrangement bypasses the classical trunk–division–cord sequence while preserving the expected segmental origin of the fibers. **This is presented in Figure 4.**

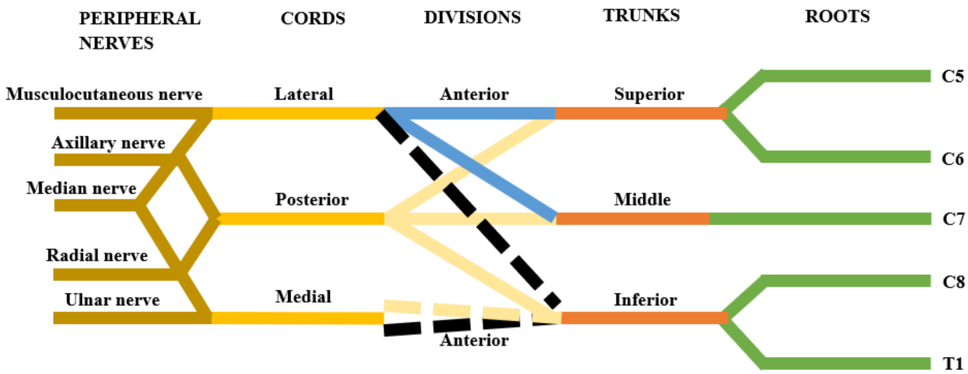

Fig. 3. Formation of the medial cord from one anterior and one posterior branch of the inferior trunk; lateral cord from the anterior branch and anterior divisions of the superior and middle trunks; posterior cord from the posterior branch of the inferior trunk and posterior divisions of the superior and middle trunks.

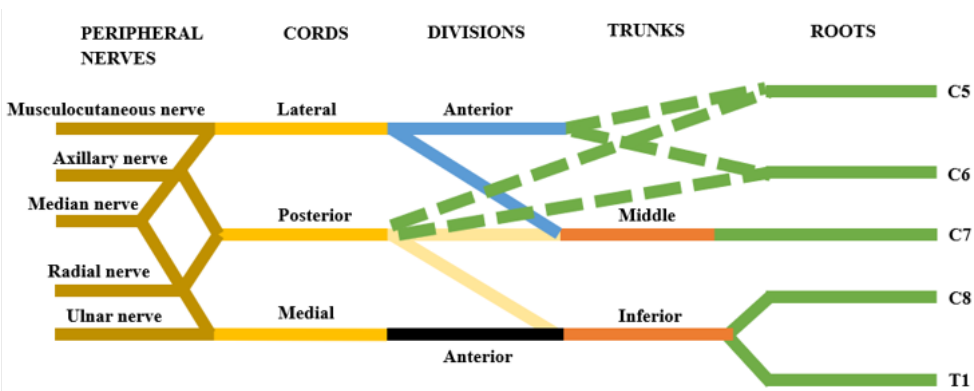

Fig. 4. Lateral cord formed by the anterior components of C5 and C6 ventral rami; posterior cord formed by the posterior components of C5 and C6. Superior trunk is absent.

Large cadaveric studies also support the variability of lateral cord formation. Pandey and Shukla [25], in a series of 172 brachial plexuses, documented abnormal cord formation and location in a notable proportion of specimens, reinforcing the morphological diversity of the infraclavicular plexus.

1.2. Variations in Segmental Contribution

Segmental alterations may significantly affect the fiber composition of the lateral cord. Proximal prefixation has been described, including direct participation of C4 in the superior trunk and subsequent contribution to the lateral cord. Uysal et al. [41] reported a rare case (0.5%) in which the superior trunk was formed by C4 and C5, while C6 divided independently and contributed directly to cord formation. **This is presented in**

Figure 5. Wozniak et al. [44] also described a plexus in which the lateral cord received fibers directly from C4.

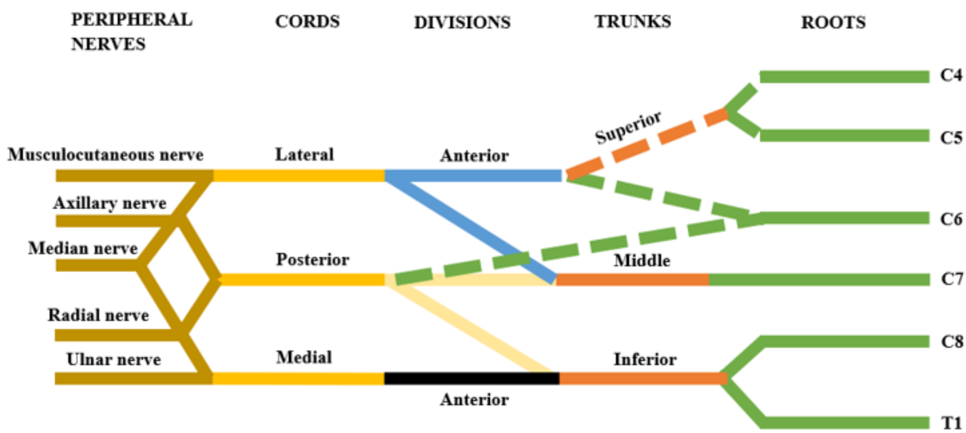

Fig. 5. Rare variant with superior trunk formed by C4–C5 and independent contribution of C6 to cord formation.

Distal postfixation and caudal fiber redistribution have likewise been documented. Prasad and Patel [31] described bilateral variations in which C8 failed to join T1 in the usual manner to form the inferior trunk; instead, C8 contributed to the anterior divisions of the superior and middle trunks, resulting in a lateral cord containing fibers from C5 to C8. **This is presented in Figure 6.** Comparable patterns were noted by Kerr [19], who reported lateral cords receiving fibers from C8 in two cases and from the inferior trunk in one case, as well as a lateral cord with fibers extending from C4 to C7. Fazan et al. [13] also noted segmental redistribution associated with atypical posterior cord formation. Such changes may alter the functional distribution of fibers within lateral cord derivatives and may influence the clinical presentation of plexus lesions.

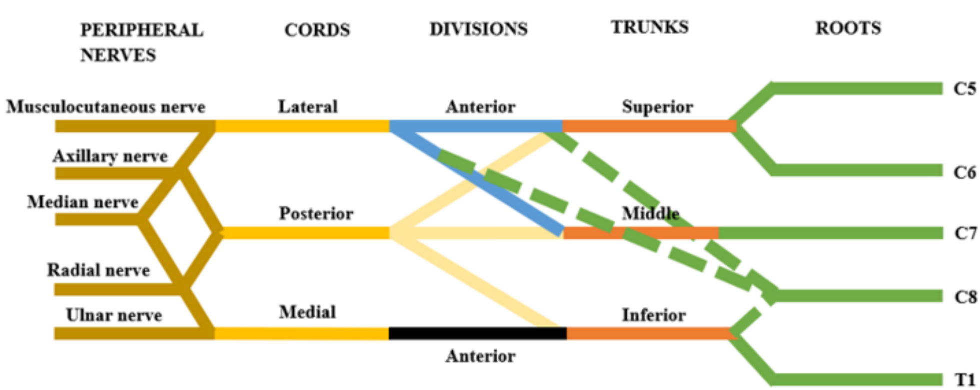

Fig. 6. Variation with C8 bypassing T1, contributing to anterior divisions of superior and middle trunks, forming a lateral cord containing C5–C8 fibers.

Additional rearrangement of middle trunk fibers has also been reported. Uysal et al. [41] described division of the middle trunk into two parts, with the superior portion joining the lateral root of the median nerve and the inferior portion contributing to the medial cord. Although this variant primarily affects median nerve formation, it also reflects redistribution of fibers that would normally contribute to the lateral cord system. **This is presented in Figure 7.**

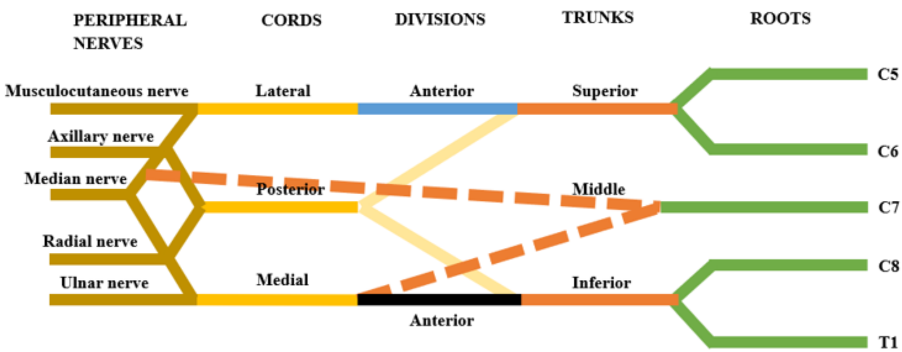

Fig. 7. Division of the middle trunk into superior and inferior portions: superior portion joins the lateral root of the median nerve, while inferior portion contributes to the medial cord, illustrating fiber redistribution that normally contributes to the lateral cord system.

1.3. Absence of the Lateral Cord

Complete absence of a morphologically distinct lateral cord has been documented. Kerr [19] reported seven cases in which the lateral cord was not observed as a separate structure. Wozniak et al. [44] described additional cases in which the anterior division of the superior trunk continued directly as the musculocutaneous nerve, effectively replacing the lateral cord as an anatomically recognizable cord. **This is presented in Figure 8.**

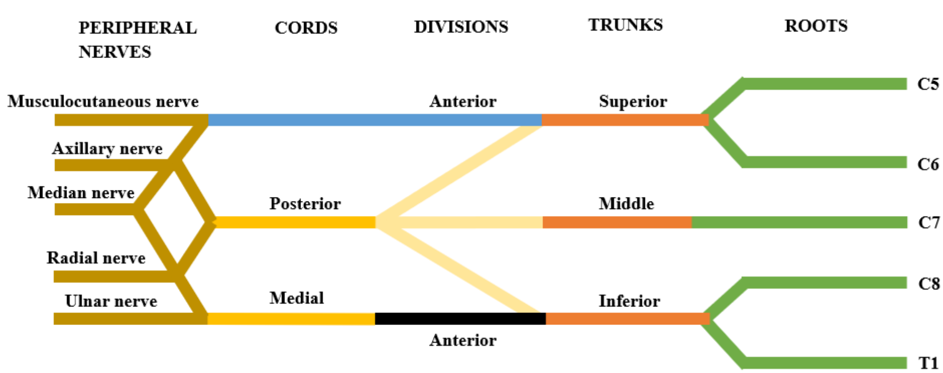

Fig. 8. Anterior division of the superior trunk continuing directly as the musculocutaneous nerve, effectively replacing the lateral cord as an anatomically distinct cord.

1.4. Intercord Communications

Intercord communications involving the lateral cord are among the most commonly reported infraclavicular variations. Wozniak et al. [44] identified the most frequent anomaly as an additional communicating branch between the lateral cord and the medial root of the median nerve, producing a double lateral root configuration; triple lateral contributions were also observed in one plexus. **This is presented in Figure 9.** Similar findings have been reported by Patel and Smit**h** [26], who described cases in which the median nerve was formed by two branches from the lateral cord and one branch from the medial cord, whereas the inverse configuration was rare.

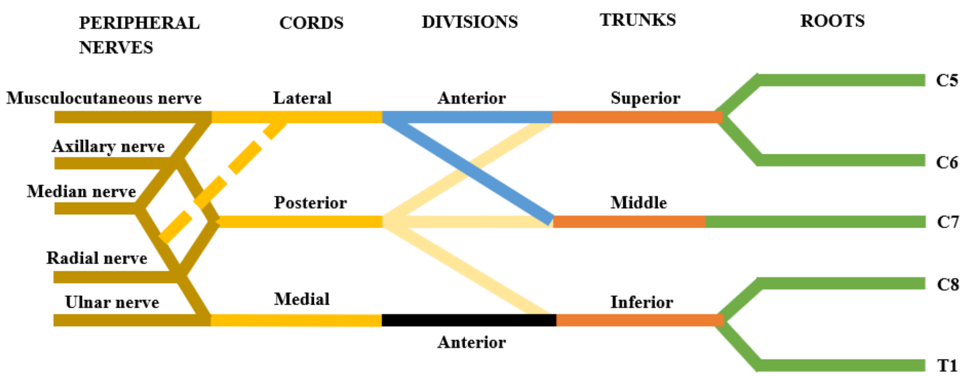

Fig. 9. Additional communicating branch between the lateral cord and the medial root of the median nerve, resulting in a double lateral root configuration.

Pattanshetti et al. [27] described accessory lateral roots of the median nerve in seven limbs (11.67%). Additional communicating branches from the lateral cord to the ulnar nerve or to the medial root of the median nerve have also been reported by Han et al. [15], who documented multiple cord-to-nerve communications in cadaveric material. Ajayi et al. [2] likewise reported a median nerve formed by two lateral roots and one medial root, further illustrating the tendency of the lateral cord to contribute accessory fibers to the median nerve.

Cross-communications and proximal fusion between the lateral and medial cords have also been documented. Malukar et Rathva [22] reported fusion of the lateral and medial cords anterior to the axillary artery, whereas Patel and Smith [26] described proximal cross-connections and fusion of the two cords before the formation of the classical "M". Such patterns modify the expected topography of the infraclavicular part of the brachial plexus and may complicate both dissection and regional anesthesia.

1.5. Variations in Branching Pattern

Terminal organization of the lateral cord may show substantial variation. Pattanshetti et al. [27] reported absence of the musculocutaneous nerve in four limbs (6.67%), as well as frequent accessory lateral roots of the median nerve. Gupta et al. [14] described a case in which the anterior division of the middle trunk gave rise to a branch to the coracobrachialis muscle together with an accessory lateral root of the median nerve, functionally approximating middle trunk fibers to lateral cord derivatives.

Han et al. [15] reported cases in which the medial root of the median nerve was absent. In those specimens, the lateral cord divided into the musculocutaneous nerve and a lateral root component, which fused with the medial cord and then bifurcated into the median and ulnar nerves. These patterns emphasize the close developmental relationship between lateral cord formation and median nerve organization.

1.6. Topographic Variations

Topographic deviations relative to the axillary artery have also been documented. Das et Paul [11] described anomalous branches of the lateral cord passing anterior to the axillary artery, a relationship of possible compressive and surgical significance. Malukar et Rathva [22] reported fusion of the lateral and medial cords located anterior to the artery, and in some cases all three cords were positioned lateral to the axillary artery. **This is presented in Figure 10.** Similar positional changes have been described in anomalous two-cord or fused-cord configurations [20].

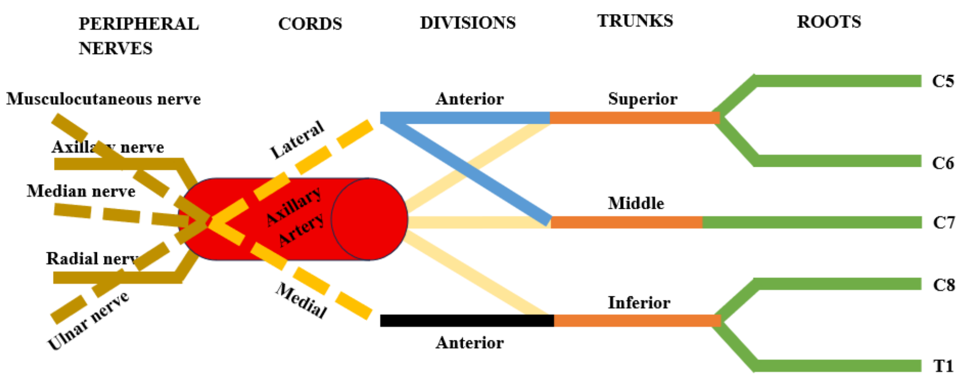

Fig. 10. Fusion of the lateral and medial cords located anterior to the axillary artery

Collectively, these findings indicate that the lateral cord demonstrates marked morphological plasticity, particularly in relation to its formation, segmental contribution, and communications with the medial cord.

2. Variations of the Medial Cord

The medial cord is traditionally described as the continuation of the anterior division of the inferior trunk and normally contains fibers from C8 and T1. Although it is generally considered to be more stable than the lateral and posterior cords, several structural deviations have been documented.

2.1. Variations in Formation

Alterations in the classical formation pattern of the medial cord have primarily been described in fetal and cadaveric series. Uysal et al. [41] reported cases in which a branch from the anterior division of the middle trunk contributed to the formation of the medial cord, thereby introducing C7-derived fibers into a cord that is classically formed by C8–T1. This atypical participation expands the segmental composition of the medial cord beyond its usual pattern. **This is presented in Figure 11.**

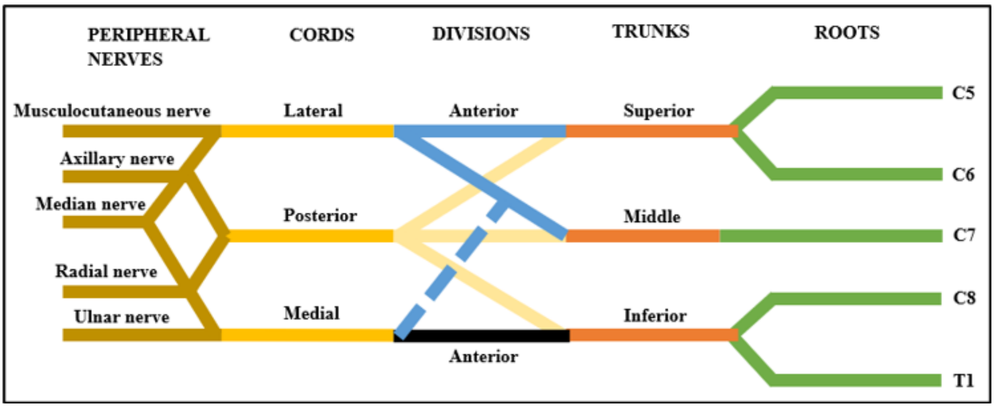

Fig. 11. Contribution of a branch from the anterior division of the middle trunk to the medial cord, introducing C7 fibers into a cord normally formed by C8–T1.

More complex rearrangements have also been described. In one fetal plexus reported by Uysal et al. [41], the inferior trunk divided into two anterior and two posterior branches; one anterior and one posterior branch united to form the medial cord, whereas the remaining anterior branch joined the lateral cord and the remaining posterior branch contributed to the posterior cord. This pattern reflects profound redistribution of fascicles between the cords and a substantial departure from the normal infraclavicular organization.

2.2. Variations Associated with Absence or Reorganization of the Inferior Trunk

Because the medial cord is classically derived from the anterior division of the inferior trunk, anomalies affecting inferior trunk formation directly alter medial cord morphology. Uysal et al. [41] described 18 plexuses (9%) in which the inferior trunk failed to form; under these conditions, the ventral ramus of C8 divided independently, with its posterior part joining the posterior cord and its anterior part uniting with T1 to form the medial cord. This represents a direct root-level reorganization of C8–T1 fibers without an intervening inferior trunk**. This is presented in Figure 12.**

Additional caudal rearrangements have also been documented. In a rare case described by Uysal et al. [41], the inferior trunk was formed by T1 and T2, whereas C8 divided and contributed separately to the medial and posterior cords. **This is presented in Figure 13.** Aragão et al. [4] likewise reported a four-trunk configuration in a fetal plexus in which the medial cord was formed by the anterior divisions of C8 and T1, while the posterior cord received fibers from all posterior divisions. These variants alter the segmental composition of the medial cord and may influence the clinical expression of lower plexus lesions.

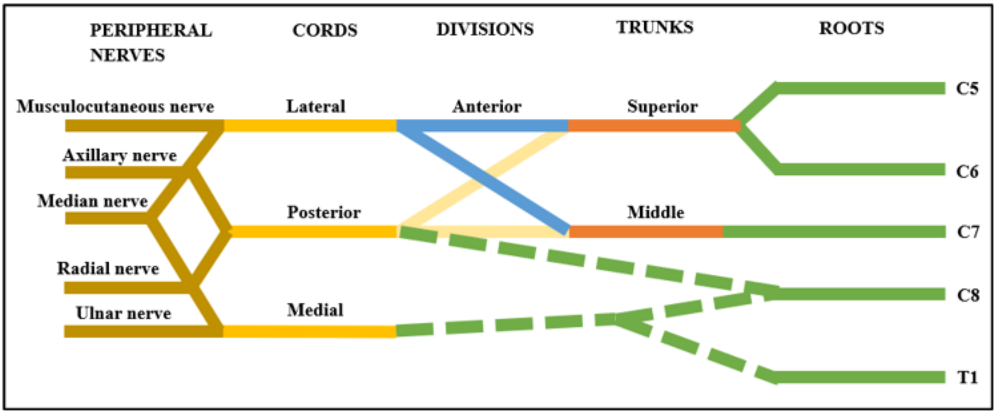

Fig. 12. Absence of the inferior trunk: C8 ventral ramus divides independently, with its posterior part joining the posterior cord and anterior part uniting with T1 to form the medial cord, representing direct root-level reorganization of C8–T1 fibers.

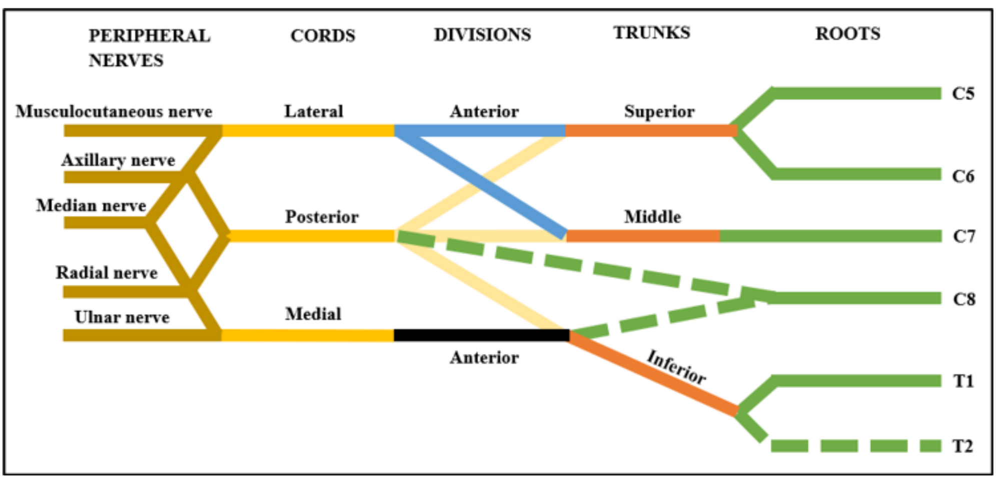

Fig. 13. Inferior trunk formed by T1 and T2, with C8 dividing independently to contribute to the medial and posterior cords.

Prasad and Patel [31] described a bilateral variation in which C8 did not join T1 in the usual manner. On one side, the medial cord was formed mainly by T1 with a minor contribution from C8, whereas on the opposite side T1 fibers passed directly into the medial cord without forming a conventional inferior trunk. Similar patterns were later described by Mchonde et al. [**24**], who reported bilateral multiple variations in which the inferior trunk was effectively represented by T1 alone and continued as the medial cord.

2.3. Redistribution of Middle Trunk Fibers

Uysal et al. [41] further described division of the middle trunk into two portions, with the superior portion joining the lateral root of the median nerve and the inferior portion contributing to the medial cord. This configuration demonstrates simultaneous fascicular and terminal reorganization and shows that fibers usually associated with the lateral cord system may be redistributed to the medial cord.

2.4. Stability and Prevalence

Despite these variants, the medial cord appears comparatively stable. In his extensive anatomical material, Kerr [19] reported that the medial cord was present in all examined plexuses and that in 99.46% of cases it was formed predominantly by the anterior division of the inferior trunk; only two cases showed additional contribution from another division.

Across major cadaveric series, anomalies of the medial cord are reported less frequently than posterior cord variations, reinforcing its relatively consistent anatomical pattern.

2.5. Variations in Relation to the Median Nerve

Terminal organization of the medial cord may also vary. Pattanshetti et al. [27] reported two limbs (3.33%) in which the medial root of the median nerve did not arise from the classical medial cord. Instead, it originated from the first part of the anterior division of fused middle and inferior trunks, whereas the second part functioned as the medial cord proper and gave rise to its remaining branches. **This is presented in Figure 14.**

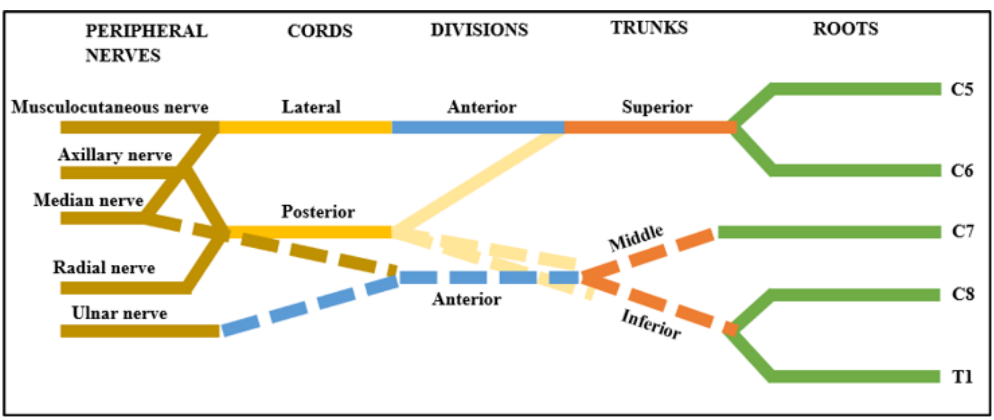

Fig. 14. Medial root of the median nerve originating from the anterior division of fused middle and inferior trunks, while the remaining portion functions as the medial cord proper, illustrating variation in terminal organization of the medial cord.

Han et al. [15] described cases in which the medial root of the median nerve was absent, and the lateral root component fused with the medial cord before dividing into the median and ulnar nerves. Patel and Smith [26] also reported rare cases in which the median nerve received two branches from the medial cord and only one from the lateral cord, further illustrating variability in the contribution of the medial cord to median nerve formation.

Overall, the medial cord demonstrates comparatively limited variability, with most deviations related to altered inferior trunk formation, redistribution of C8–T1 fibers, and variant participation in median nerve organization.

3. Variations of the Posterior Cord

The posterior cord represents one of the most frequently involved components in infraclavicular variations of the brachial plexus. Most anomalies involve altered contributions of posterior divisions, absence of inferior trunk participation, proximal displacement of branches, duplication or splitting patterns, or reduction of the posterior cord as a distinct morphological entity.

3.1. Variations in Formation

Historical observations by Kerr [19] demonstrated that in 36 of 175 plexuses (20.57%), a true posterior cord was not clearly identifiable unless the radial nerve was regarded as its representative. This early finding illustrates reduction or indistinct formation of the posterior cord as a separate anatomical structure.

A recurring pattern reported in multiple studies is formation of the posterior cord solely from the posterior divisions of the superior and middle trunks, without contribution from the inferior trunk. **This is presented in Figure 15.** Wozniak et al. [44] described this arrangement in four plexuses, and Fazan et al. [13] reported the same configuration in five plexuses (9%), all from male Black cadavers. Singh et al. (2019) [36] likewise observed five plexuses in which the posterior cord was formed by the posterior divisions of the superior and middle trunks alone. Similar configurations were also noted by Priya et al. and by Mchonde et al. [32, 24], in whom the inferior trunk continued as the medial cord without contributing to the posterior cord.

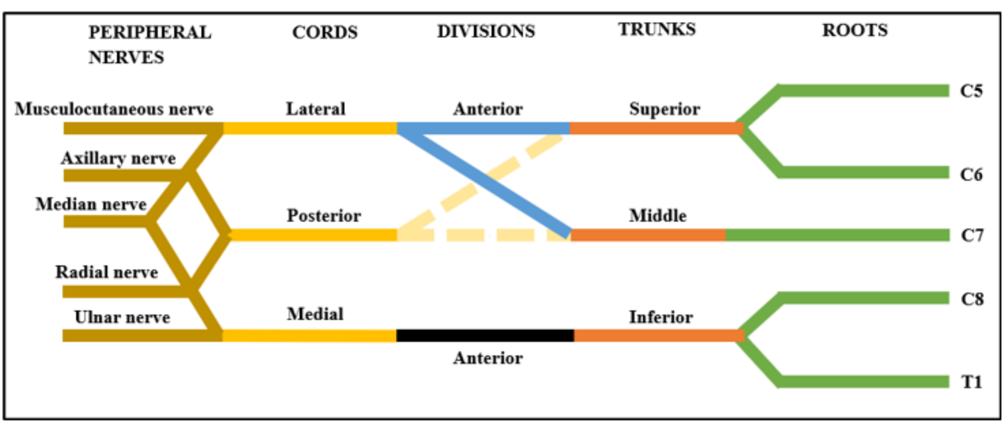

Fig. 15. Posterior cord formed solely from the posterior divisions of the superior and middle trunks, without contribution from the inferior trunk.

Failure or reorganization of trunk formation may further modify posterior cord assembly. Uysal et al. [41] described 18 plexuses in which the inferior trunk did not form; in these cases, the posterior part of C8 joined the posterior cord directly. In additional cases, failure of superior trunk formation led to independent division of C5 and C6, with their posterior components contributing to the posterior cord. Uysal et al. [41] also reported a rare prefixation pattern in which the superior trunk was formed by C4 and C5, while the posterior division of C6 contributed directly to the posterior cord.

More complex rearrangements of trunk organization have also been described. Singh [37] reported cases in which the superior and middle trunks fused into a common trunk that later divided into lateral and posterior cords, whereas the inferior trunk continued as the medial cord. **This is presented in Figure 16.** In related cases, the inferior trunk failed to divide into anterior and posterior divisions and continued directly as the medial cord, leaving the posterior cord to be formed only by posterior divisions of the superior and middle trunks [20, 37]. Cash et al. [8] described a two-trunk variation in which the posterior cord was formed by the posterior divisions of the superior and inferior trunks, reflecting the altered architecture of a two-trunk brachial plexus.

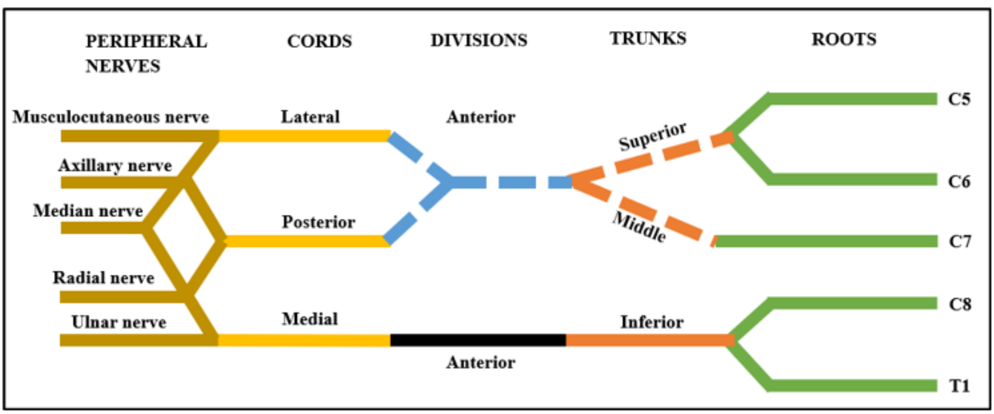

Fig. 16. Fusion of the superior and middle trunks into a common trunk, which divides into lateral and posterior cords, while the inferior trunk continues as the medial cord.

Four-trunk configurations further expand the spectrum of posterior cord variation. Aragão et al. [4] reported a fetal case in which C4–C5, C7, C8, and T1 formed four trunks, and the posterior cord was assembled from the posterior divisions of all participating trunks. Han et al. [15] likewise described several four-trunk patterns, including cases in which the posterior cord was formed by the posterior divisions of three trunks and others in which all four trunks contributed to it.

An extreme variant was reported by Elzawawy [12], in which the posterior cord was effectively replaced by the posterior division of the superior trunk; this branch gave rise to the axillary and upper subscapular nerves and continued as the radial nerve. This represents near-complete proximal substitution of the posterior cord. **This is presented in Figure 17.**

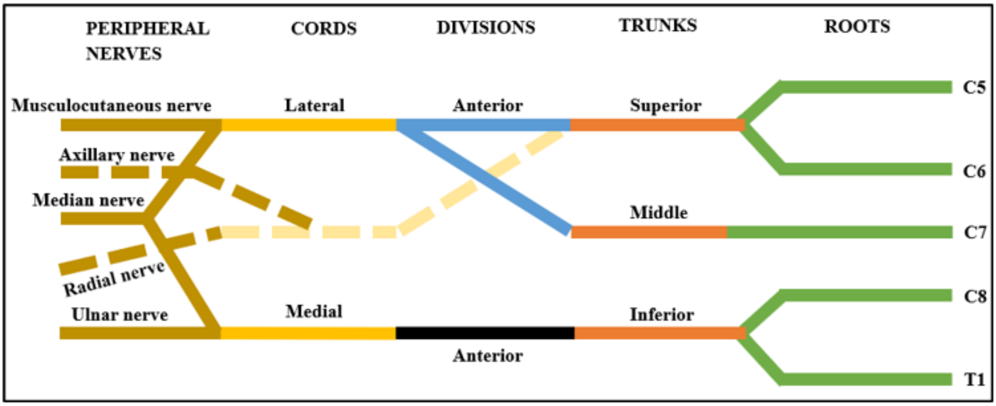

Fig. 17. Posterior cord effectively replaced by the posterior division of the superior trunk, giving rise to the axillary and upper subscapular nerves and continuing as the radial nerve, representing near-complete proximal substitution of the posterior cord.

3.2. Split or Duplicated Posterior Cord Patterns

A distinct morphological variation involves splitting of the posterior cord into two roots that subsequently reunite to form the radial nerve. Bhat and Girijavallabhan (2008) [7] described such a configuration, in which the two roots compressed the subclavian artery before reuniting. **This is presented in Figure 18.** Pattanshetti et al. [28] observed a similar two-root radial origin pattern in one limb (1.67%). These variants are of potential surgical relevance because of their unusual relationship to neighboring vessels.

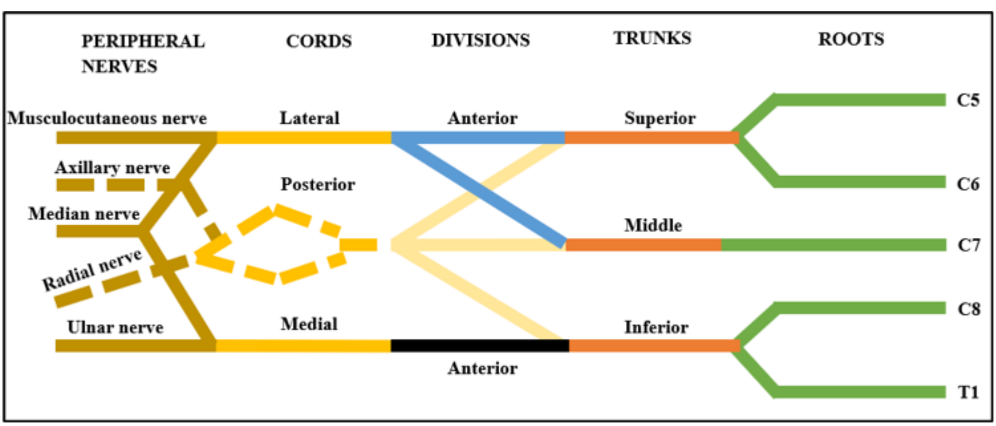

Fig. 18. Two roots of the posterior cord compressing the subclavian artery before reuniting, illustrating a split or duplicated posterior cord configuration.

3.3. Proximal Displacement of Posterior Cord Branches

Several reports describe branches that normally arise from the posterior cord as originating instead from the posterior division of the superior trunk. Kocabiyik et al. [21] reported a case in which the upper subscapular, thoracodorsal, and lower subscapular nerves arose from the posterior division of the superior trunk, after which the posterior cord continued as the axillary and radial nerves. A similar pattern was noted by Pattanshetti et al. [27], in whom the axillary nerve and subscapular branches occasionally arose proximally from a posterior division rather than from the fully formed posterior cord. Such findings may be interpreted as a proximal shift of posterior cord branches rather than complete absence of the cord.

3.4. Associated Branch Variations and Intercord Redistribution

Branch-level anomalies related to the posterior cord include duplication of the thoracodorsal nerve, as reported by Pattanshetti et al. [27] in two limbs (3.33%), and variations in the origin of the subscapular nerves [36]. In some plexuses, posterior cord fibers also contribute aberrantly to the roots of the median nerve. Wozniak et al. [44] described one case in which two branches from the posterior cord joined the medial and lateral roots of the median nerve. Patel and Smith [26] likewise reported a rare pattern in which fusion involving the medial and posterior cords caused the median nerve to receive fibers indirectly from all three cords. These observations highlight the possibility of intercord redistribution beyond the classical pattern.

3.5. Reduction to Two-Cord or Single-Cord Patterns

More radical reorganizations include reduction of the infraclavicular plexus to two cords or even a single common cord. Han et al. [15] described a case in which only anterior and posterior cords were present, both located lateral to the axillary artery; in that specimen, the anterior cord represented fusion of the lateral and medial cords. Havaldar et al. [17] also reported a two-cord configuration in a two-trunk brachial plexus, with a superior and an inferior cord located lateral to the axillary artery.

Single-cord configurations have been documented by several authors. Priya et al. [32] reported bilateral cases in which two trunks fused and continued as a single cord giving rise to all terminal branches. Similar single-cord patterns were described by Viswanathan et al., Aggarwal et al., Singh et al., and Hasan and Narayan [42, 1, 38, 16]. Although such cases affect the entire infraclavicular plexus rather than the posterior cord alone, they are relevant because they represent the most extreme loss of normal cord differentiation and therefore include functional replacement of the posterior cord within a common neural bundle.

Taken together, these findings show that posterior cord variations are frequently part of broader system-level reorganization rather than isolated anomalies. Among the three cords, the posterior cord appears to be the most susceptible to structural rearrangement.

Collectively, the reviewed studies demonstrate considerable morphological variability in the formation and organization of the brachial plexus cords. Variations most frequently involve the posterior cord, particularly alterations in trunk contributions and proximal displacement of branches. In contrast, the medial cord appears to demonstrate relatively greater structural stability, while the lateral cord commonly participates in intercord communications and variations related to the formation of the median nerve. These findings highlight the developmental plasticity of the infraclavicular brachial plexus.

The principal patterns of cord-level anatomical variations and their clinical implications are summarized in Table 1.

Clinical relevance: Implications for Infraclavicular Block

The cords of the brachial plexus represent the principal neural targets of the infraclavicular block, as they are arranged around the second part of the axillary artery in the infraclavicular region [43]. Classical anatomical descriptions assume a predictable relationship between the lateral, medial, and posterior cords and the axillary artery. However, multiple cadaveric studies demonstrate that this arrangement is subject to considerable variability.

Variations in cord formation, position, and intercord communications may significantly influence the success and safety of infraclavicular anesthesia.

Altered topographic relationships have been described, including:

1. Fusion of lateral and medial cords
2. All three cords positioned lateral to the axillary artery
3. Posterior cord formed only from posterior divisions of the superior and middle trunks
4. Absence or reduction of a morphologically distinct cord

Such variations may modify the expected triangular or circumferential distribution of the cords around the axillary artery under ultrasound guidance. As a result, anesthetic deposition based on classical anatomical assumptions may lead to incomplete blockade, particularly if one cord lies outside the anticipated spread of local anesthetic.

Intercord communications, especially additional connections between the lateral cord and the medial root of the median nerve, may further complicate the clinical picture by producing partial or asymmetric motor blockade.

Because infraclavicular block specifically targets the cords rather than trunks or terminal branches, detailed understanding of cord-level anatomical variability is essential for optimizing needle placement, ensuring adequate anesthetic spread, and minimizing vascular or neural injury.

Conclusion

The cords of the brachial plexus demonstrate considerable anatomical variability. Reported variations include atypical formation from trunks and divisions, altered segmental contributions, absence or fusion of cords, anomalous communications between cords, and deviations in terminal branching patterns. Among the three cords, the posterior cord appears to be most frequently involved in structural rearrangements, followed by the lateral cord, while the medial cord demonstrates relatively greater stability.

These morphological deviations reflect the developmental complexity of the brachial plexus and underline the importance of variation anatomy in both

Table 1. Summary of the principal anatomical variations of the brachial plexus cords and their clinical relevance

Cord	Type of Variation	Morphological Pattern	Representative Sources	Clinical Relevance
Lateral cord	**Altered formation**	**Formation solely from the anterior division of the superior trunk (absence of middle trunk contribution)**	**Uysal et al.; Wozniak et al.**	**Altered C7 fiber distribution; possible incomplete block**
Lateral cord	**Segmental variation**	**Contribution from atypical roots (C4 or C8) due to prefixation or postfixation**	**Kerr; Prasad & Patel**	**Atypical motor and sensory distribution**
Lateral cord	**Absence**	**Direct continuation of anterior division as musculocutaneous nerve**	**Kerr; Wozniak et al.**	**Misidentification of cord structure; procedural difficulty**
Lateral cord	**Intercord communication**	**Additional lateral roots contributing to median nerve formation**	**Pattanshetti et al.; Patel & Smith**	**Partial or asymmetric median nerve blockade**
Lateral cord	**Fusion pattern**	**Fusion with medial cord forming a common anterior cord**	**Malukar & Rathva**	**Altered infraclavicular topography**
Medial cord	**Altered formation**	**Contribution from middle trunk (C7 fibers)**	**Uysal et al.**	**Expanded segmental composition**
Medial cord	**Inferior trunk variation**	**Absence or reorganization of inferior trunk affecting cord formation**	Uysal et al.; Mchonde et al.	**Altered C8–T1 distribution**
Medial cord	**Median nerve variation**	**Absence or atypical origin of medial root of median nerve**	**Han et al.; Pattanshetti et al.**	**Atypical nerve formation; anesthetic variability**

Table 1. Summary of the principal anatomical variations of the brachial plexus cords and their clinical relevance

Posterior cord	**Altered formation**	**Formation without contribution from posterior division of inferior trunk**	**Fazan et al.; Wozniak et al.; Singh et al.**	**Incomplete posterior cord blockade**
Posterior cord	**Reduction/ absence**	**Radial nerve replacing or representing posterior cord**	**Kerr; Elzawawy**	**Misinterpretation during surgery or dissection**
Posterior cord	**Split pattern**	**Division into two roots forming radial nerve**	**Bhat & Girijavallabhan**	**Risk of vascular compression; surgical relevance**
Posterior cord	**Proximal branching**	**Branches arising from posterior division of superior trunk**	**Kocabiyik et al.; Pattanshetti et al.**	**Altered surgical landmarks**
All cords	**Topographic variation**	**Atypical position relative to axillary artery (e.g., all cords lateral)**	**Das & Paul; Malukar & Rathva**	**Incomplete anesthetic spread; technical difficulty**
All cords	**Two-cord pattern**	**Fusion into anterior and posterior cords**	**Han et al.; Havaldar et al.**	**Modified anesthetic distribution**
All cords	**Single-cord pattern**	**Complete fusion into one common cord**	**Priya et al.; Aggarwal et al.**	**Major deviation from classical anatomy**

anatomical research and clinical practice. A thorough understanding of the possible cord configurations is essential for accurate interpretation of anatomical findings and for minimizing complications during surgical and interventional procedures in the infraclavicular region.

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