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A prefix brachial plexus with two trunks and one anterior cord

Running head: Brachial plexus variants

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ABSTRACT

The brachial plexus presents a great variability in formation, division and branching pattern. Its variants are of immense importance during axillary and arm surgery and nerve blockade. The current case highlights a unilateral atypical formation of brachial plexus, the so called prefix, in which the C_4 root contributed a large branch to the superior trunk and further anastomosis with the inferior trunk. Thus, the prefix or high brachial plexus consisted of a superior and inferior trunk and one anterior cord. Coexisted neural and arterial variations are also discussed in relation to the data literature.

Key words: brachial plexus, variation, cords, nerve roots, trunks, prefix, surgery

INTRODUCTION

The brachial plexus (BP) is a complex neural network typically formed by the union of the ventral rami of C_5, C_6, C_7, C_8 and T_1 nerves and supplies cutaneous, muscular

and sympathetic innervation to the upper limb. The ventral rami of C_5 and C_6 nerves unite to form the superior trunk (ST), the C_7 nerve courses as the middle trunk (MT) and C_8 and T_1 nerves unite to form the inferior trunk (IT). Infraclavicularly, each trunk bifurcates into anterior and posterior divisions. The ST and MT anterior divisions form the lateral cord (LC). The IT anterior division continues as the medial cord (MC). Posterior divisions of all trunks unite to form the posterior cord (PC). From the LC, MC and PC arise the terminal branches of BP including the musculocutaneous, median, ulnar, axillary and radial nerves (MCN, MN, UN, AN and RN) [22] (Fig. 1).

Almost 50% of the BP showed variability in their branching pattern [2]. Anomalies of the cords and terminal branches of BP have been well documented [25]; however anomalies of the roots and trunks are comparatively rare and have been reported in only a few cases [4, 11, 25]. BP variants are of immense importance during surgery of the axilla and arm region and during nerve blockade. BP may be damaged in open, closed or obstetrical injuries, it may be pressed upon by the cervical rib or through the atypical growth of the Struthers' ligament which presses the median nerve and Struthers arcades which cause the ulnar nerve compression [24] or it may be involved in a tumor [3, 16]. Understanding BP variants helps the clinicians explain some previously unexplained clinical symptoms, such as significant disability after injury.

The current case report highlights a case of unilateral abnormal formation of the BP, the so-called prefix or high BP, in which the C_4 root contributed to the ST formation and further anastomosis with the IT. The atypical left-sided prefix BP consisted of two trunks (ST and IT) and one anterior cord formed after the fusion of the ST and IT anterior divisions. Coexisted axillary artery (AA) variations and its relations to BP arrangement are described and the ontogeny and phylogeny of this variant entity are also discussed.

CASE REPORT

During routine dissection of the axilla and arm in a 76 year-old formalin embalmed female cadaver conducted for undergraduate medical students in the Department of Anatomy and Surgical Anatomy of the Medical School of the Aristotle University of Thessaloniki, a unilateral variation of the BP was observed at the roots, trunks' division and cords' formation, at the left side. Further dissection of the neck and pectoral region was performed to meticulously observe BP formation at the level of the roots, trunks, divisions,

cords and branching pattern. The AA was located posteromedial to both the anterior cord (AC) and PC. Two trunks (ST and IT) instead of three were identified. The ST was formed by the union of C_4, C_5 and C_6 roots. The special contribution of C_4 root characterizes the BP as prefix. The C_7 root, instead of continuing as the MT, joined with the C_8 and T_1 roots to form the IT. Anterior divisions of the ST and IT joined to form an AC and posterior divisions of the two trunks joined to form a PC instead of the three typical cords (LC, MC and PC) (Figs.2, 3). Both cords were located anterolateral to the AA. The suprascapular nerve only contained fibers from C_4 and C_5, but not C_6 root. The MCN, MN, UN and medial cutaneous brachial and antebrachial nerves originated from the AC by a common stem. The lateral pectoral nerve received fibers from C_4, C_5 and C_6 roots and from the anterior part of C_7 C_8 and T_1 and the medial pectoral nerve from the posterior part of C_7, C_8 and T_1. Both pectoral nerves formed an ansa pectoralis (Fig. 4). The point of AC formation was the level of thoracoacromial trunk origin from the AA. The superior subscapular nerve originated from the posterior divisions of C_4, C_5 and C_6 roots. The thoracodorsal nerve, the AN and RN arising at the same level from the PC. The AN, after its common origin with the inferior subscapular nerve, divided into an anterior and posterior branch (Fig. 4). The intercostobrachial nerve coursed anterior to the long thoracic nerve and posterior to the lateral thoracic artery. The MN originated from the AC. The anterior and posterior circumflex humeral arteries arising by a common trunk at the same level of origin with of subscapular artery which further divided into the circumflex scapular artery and the thoracodorsal artery. The posterior circumflex humeral artery accompanied the AN (Fig. 5). On the right side, a typical pattern of the BP was detected.

DISCUSSION

Embryological Development of the Brachial Plexus

In the 4^{th} developmental week, the first differentiation of the mesenchyme occurs. Primordia of the dorsal nerves end up at the height of the distal end of the humerus in the sheath of the forming primordia arm muscles. On 32^{th} day, nerves' extensions from C_5-T_1 are formed and on 33^{th} day, the nerves merge and BP formation begins. Between 39^{th} and 40^{th} day, the MN, RN and UN reach the hand. A similar arrangement and orientation of the BP to that in adults is observed on the 49^{th} and 50^{th} day [5]. As the embryonic somites migrate to form the extremities, they carry their neural supply, so that each dermatome and myotome

retains its original segmental innervation. Throughout somite migration, some nerves fuse in a particular pattern, forming a plexus early in fetal life [5, 7].

Prasada Rao and Chaudary [19] suggested that developmentally, the BP in humans appears as a single radicular cone in the upper limb bud. Initially, a plexus is formed by a connection between the spinal nerves and then it develops into a solid plate that finally divides into separate trunks and then, divisions. The posterior division supplies the extensor muscles and the anterior division the flexor ones [12]. Any alterations in the signaling between the mesenchymal cells and the neuronal growth cones or the circulatory factors at the time of BP cords' disruption, can lead to significant variations [6]. Ontogenically, the present variation may be due to a failure on the part of the radicular cone of the upper limb nerves to divide into different trunks.

BP variations are often accompanied by vessels' abnormalities [7, 12, 14]. The AA has an association to the cords' division [14]. During development, if the AA has abnormal relations to the BP, the cords' division would be modified by the presence of the abnormally placed artery [14, 17, 25]. Our case reinforces this view, since the AA is atypically located posteromedial to the AC and PC [14].

Variant cases of abnormal brachial plexus

A prefix pattern may be found in 10%-65% of the BP [17]. Uncommon trunk variations reported in the literature are the IT absence characterized by the nonunion of C_8 and T_1 [11, 25] and the MT absence [11, 18]. In cases of MT absence, the ST may be formed by the ventral rami of C_5, C_6, and C_7 roots [11, 18] or the IT may be formed by the ventral rami of C_7, C_8 and T_1 [11]. Unilateral ST variations have been reported [11, 25]. The ventral rami of C_5 and C_6 roots, without joining to form the ST, independently divided into anterior and posterior divisions which joined the LC and PC, respectively. Additionally, the atypical suprascapular nerve originated directly from C_5 root [1, 9, 26].

Formation of the IT of the BP by the C_7 and C_8 roots is very rare. Singla et al. [21] mentioned the MT absence, with the C_7 root joining C_5 and C_6 to form the UT; the LT being formed by C_8 and T_1. In our case, the two trunks were formed, but C_7 root joined C_8 and T_1.

Uysal et al. [25] supported that the ST absence was less common (1%) than the IT absence (9%).

Clinical significance

BP variations, such as the occurrence of a prefix pattern, may lead to deviation from the expected dermatome distribution or differences in the motor innervation of the upper limb muscles [17]. Clinical implications may appear in a cervical nerve root impingement. Thus, in individuals with a suprascapular nerve directly emerged from C_5 root, a C_5 root impingement may result in complete supraspinatus muscle paralysis [3, 13, 23].

The trunk variation presented in the current case did not result in abnormal terminal branches distal to the level of cords. Therefore, it is unlikely that the described variants would negatively affect the normal function of the upper limb, although this cannot be proven with certainty.

ST absence may increase the chance of nerve root avulsion due to BP traction injury. A downward traction force of the upper limb may cause a breaking strain expended on the BP from above and result in a C_5 root lesion [23]. Thus, a blow from above on the neck or shoulder may stress the integrated cord and the stress is transmitted to the sites of cord attachment. One of these risk sites is where the nerve roots meet the spinal cord. According to Stevens [23], the combination of five cords as one will withstand a greater amount of strain than the same cords divided**.** Thus, in a typical BP, a portion of the stress applied to a cord will be transferred back to the spinal cord where it would then be disseminated to the cervical roots by way of the trunk. This division of force decreases the strain on cervical roots and may prevent avulsion. Absence of a trunk results in the full force of strain being applied to the cervical nerve root [13].

CONCLUSIONS

Knowledge of the BP variants is of paramount importance for radiologists, anesthesiologists, neurosurgeons and orthopedic surgeons. Cervical spine procedures need a thorough knowledge of the typical and abnormal formation of BP, as well as knowledge of the surgical treatment of tumors of the nerve sheaths and non-neural tumors. A BP with two trunks, with the LT having a root value of C_7, C_8 and T_1 may give a confusing clinical picture if it is affected by Klumpke's paralysis. In such cases, the injury may not be restricted to C_8 only, but rather may extend to C_7. Moreover, the occurrence of BP variants may be used to explain unexpected clinical manifestations or nerve palsy syndromes and other vascular

dilemmas. Taking into consideration the abnormal anatomy would aid anesthesiologists to successfully blockade the infraclavicular nerves in order to approach the BP pathology [15, 20].

REFERENCES

1. Aktan ZA, Ozturk L, Bilge O, Ozer MA PY. A cadaveric study of the anatomic variations of the brachial plexus nerves in the axillar region and arm. Turk J Med Sci 2001;31:147–150.
2. Ballesteros L, Ramirez L. Variations of the origin of collateral branches emerging from the posterior aspect of the brachial plexus. J Brachial Plex Peripher Nerve Inj 2014;02(01):e22-e27.
3. Benjamin K. Part1. Injuries to the brachial plexus: mechanisms of injury and identification of risk factors. Adv. Neonatal Care 2005; 5(4):181-189
4. Chaudhary P, Singla R, Kalsey G, Arora K. A four trunked brachial plexus and a post fixed brachial plexus: A conjunction or a coincidence? Report of three cases. Clin Anat 2012; 25: 593–600
5. Goyal N, Harjeet, Gupta M. Bilateral variant contributions in the formation of median nerve. Surg Radiol Anat 2005;27(6):562-565
6. Harry WG, Bennett JDC, Guha SC. Scalene muscles and the brachial plexus: Anatomical variations and their clinical significance. Clin Anat. 1997;10(4):250-252
7. Hollinshead WH (William H. Anatomy for Surgeons. Harper & Row; 1982. https://openlibrary.org/books/OL4261216M/Anatomy_for_surgeons. Accessed January 29, 2019
8. Kerr AT. 1918. The brachial plexus of nerves in man, the variations in its formation and branches. Am J Anat 23: 285–395
9. Kocabiyik N, Yalcin B, Kilic C OH. Multiple anomalies of the brachial plexus: a case report. Neuroanatomy 2007;8:21–23
10. Lee HY, Chung IH, Sir WS, Kang HS, Lee HS, Ko JS, Lee MS, Park SS. 1992. Variations of the ventral rami of the brachial plexus. J Korean Med Sci 7: 19–24
11. Matejcik V. Aberrant formation and clinical picture of brachial plexus from the point of view of a neurosurgeon. Bratisl Lek Listy 2003;104(10):291-299

12. Miller RA. Observations upon the arrangement of the axillary artery and brachial plexus. Am J Anat. 1939;64(1):143-163
13. Mukund R. Thatte, Sonali Babhulkar, and Amita Hiremath, Brachial plexus injury in adults: Diagnosis and surgical treatment strategies, Ann Indian Acad Neurol. 2013; 16(1): 26–33
14. Nakatani T, Tanaka S, Mizukami S. Superficial brachial arteries observed in bilateral arms. Kaibogaku Zasshi 1996;71(4):308-312
15. Natsis K, Totlis T, Tsikaras P, Anastasopoulos N, Skandalakis P, Koebke J. Variations of the course of the upper trunk of the brachial plexus and their clinical significance for the thoracic outlet syndrome: a study on 93 cadavers. Am Surg. 2006;72(2):188-192
16. Pandey SK, Shukla VK. Anatomical variations of the cords of brachial plexus and the median nerve. Clin Anat 2007;20(2):150-156
17. Pellerin M, Kimball Z, Tubbs RS, Nguyen S, Matusz P, Cohen-Cadol AA, Loukas M. The prefixed and postfixed brachial plexus: a review with surgical implications. Surg Radiol Anat. 2010;32(3):251-260
18. Prabhu L V, Kumar J, Singh G. Brachial Plexus With Two Trunks and Double Axillary Veins: Applied Importance and Clinical Implications. www.firattipdergisi.com. Accessed January 29, 2019
19. Prasada Rao P V, Chaudhary SC. Communication of the musculocutaneous nerve with the median nerve. East Afr Med J 2000;77(9):498-503
20. Raphael DT, McIntee D, Tsuruda JS, Colletti P, Tatevossian R. Frontal slab composite magnetic resonance neurography of the brachial plexus: implications for infraclavicular block approaches. Anesthesiology 2005;103(6):1218-1224
21. Singla RK, Sharma RK, Shree B. A Two Trunked Brachial Plexus: A Case Report. J Clin Diagnostic Res. 2013;7(4):704-705
22. Standring S. Gray's Anatomy : The Anatomical Basis of Clinical Practice. 39th Ed. (Edinburgh E-CL, ed.). Elsevier Health Sciences UK; 2005
23. Stevens JH. Brachial plexus paralysis. By J.H. Stevens, M.D., 1934. Clin Orthop Relat Res. 1988;(237):4-8
24. Suranyi L. Median nerve compression by Struthers ligament. Journal of Neurology, Neurosurgery and Psychiatry 1983; 46: 1047-1049
25. Uysal II, Seker M, Karabulut AK, Büyükmumcu M, Ziylan T. Brachial plexus

variations in human fetuses. Neurosurgery 2003;53(3):676-684

26. Vilamere J, Goodwin S, Hincke M JA. A brachial plexus variation characterized by the absence of the superior trunk. Neuranatomy 2009;8:4-6.

FIGURE LEGENDS

Figure 1. The typical formation of the brachial plexus. The lateral, medial and posterior cords (LC, MC and PC) are depicted, AA- axillary artery is transected, MCN-musculocutaneous nerve, MN- median nerve, UN-ulnar nerve, RN-radial nerve, AN- axillary nerve and ICBN-intercostobrachial nerve

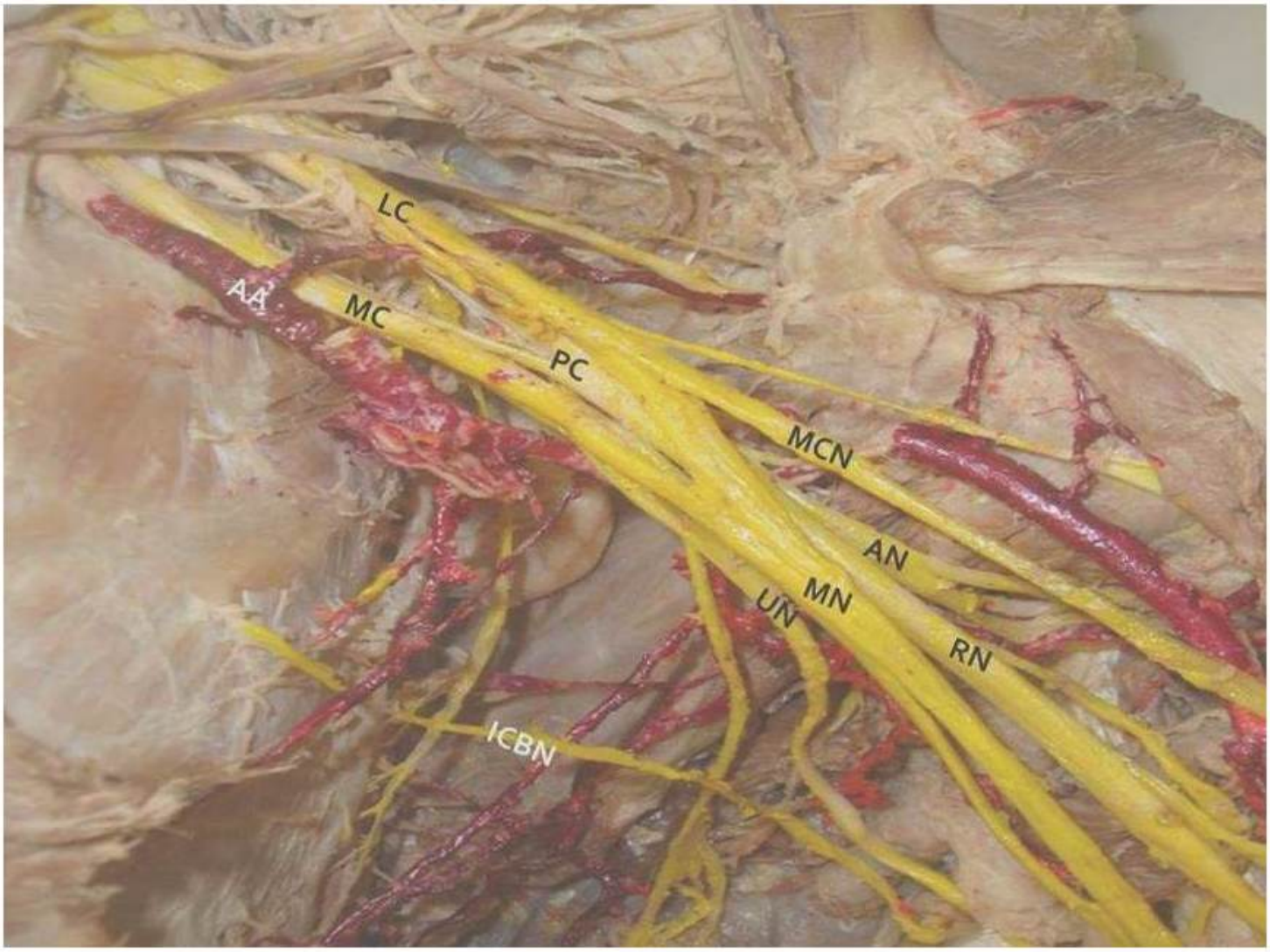
Figure 2. **A.** The atypical formation of the prefixed brachial plexus (contribution of C_4 root). **A, B**. C_4, C_5 and C_6 roots joined to form the superior trunk (ST) and C_7, C_8 and T_1 (**C**) to form the inferior trunk (IT). The anterior and posterior cords are depicted (AC and PC), AA-axillary artery, AS-anterior scalene muscle, CCT- costocervical trunk, RN-radial nerve, AN-axillary nerve, TDN-thoracodorsal nerve, MCN-musculocutaneous nerve, UN-ulnar nerve, MBCN-medial brachial cutaneous nerve and MN-median nerve

Figure 3. The atypical formation of the prefixed brachial plexus (contribution of C_4 root). C_4, C_5 and C_6 roots joined to form the superior trunk (ST) and C_7, C_8 and T_1 to form the inferior trunk (IT). The anterior and posterior cords are depicted (AC and PC), AA- axillary artery, AS-anterior scalene muscle, AP- ansa pectoralis, AN- axillary nerve, MCN-musculocutaneous nerve, UN-ulnar nerve, MBCN-medial brachial cutaneous nerve, MN-median nerve

Figure 4. A, B. The branching pattern of the posterior cord (PC), the radial nerve (RN), the thoracodorsal nerve (TDN) and the axillary nerve (AN) bifurcated into an anterior (1) and posterior branch (2), (3) the inferior subscapular nerve. SSBSN- superior subscapular nerve, AA - axillary artery posterior to the PC, MCN-musculocutaneous nerve, BA- brachial artery, LTN-long thoracic nerve, ICBN-intercostobrachial nerve, MCN-musculocutaneous nerve. **C.**

Ansa pectoralis (AP) formed after the interconnection of the lateral and medial pectoral nerves (LPN and MPN)

Figure 5. A. The axillary artery (AA) gave off at the same level a common trunk of the anterior and posterior circumflex humeral arteries (ACHA and PCHA) and the subscapular artery giving off the thoracodorsal artery (TDA). **B.** The AA continued as brachial artery (BA). The anterior cord (AC) gave off the median nerve (MN), the musculocutaneous nerve (MCN) and the ulnar nerve (UN). The posterior cord (PC) gave off the axillary nerve (AN), the radial nerve (RN), while the superior subscapular nerve (SSBSN) emerged from the superior trunk posterior divisions. SSN-suprascapular nerve, TDN-thoracodorsal nerve, TDA-thoracodorsal artery.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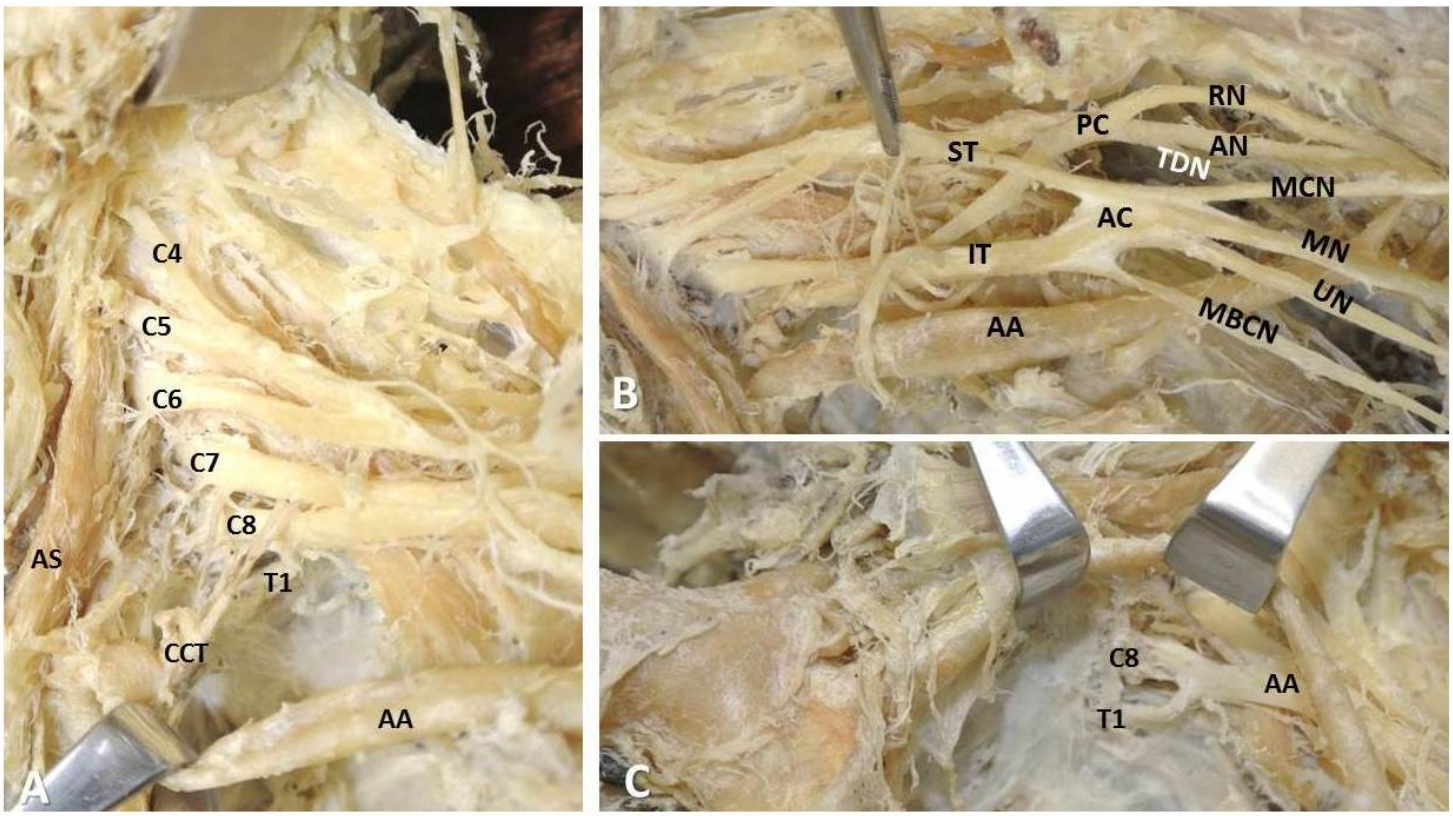
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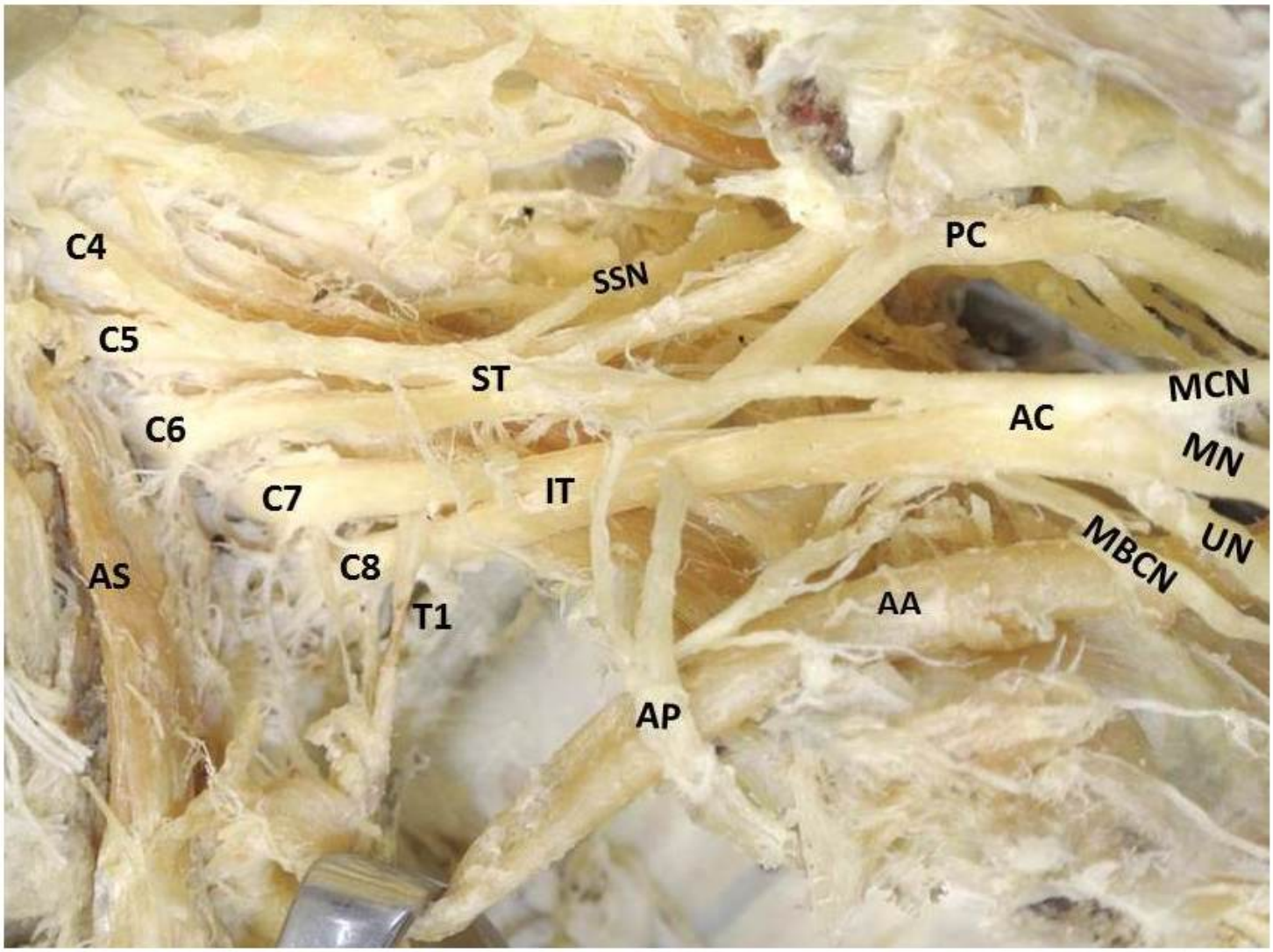
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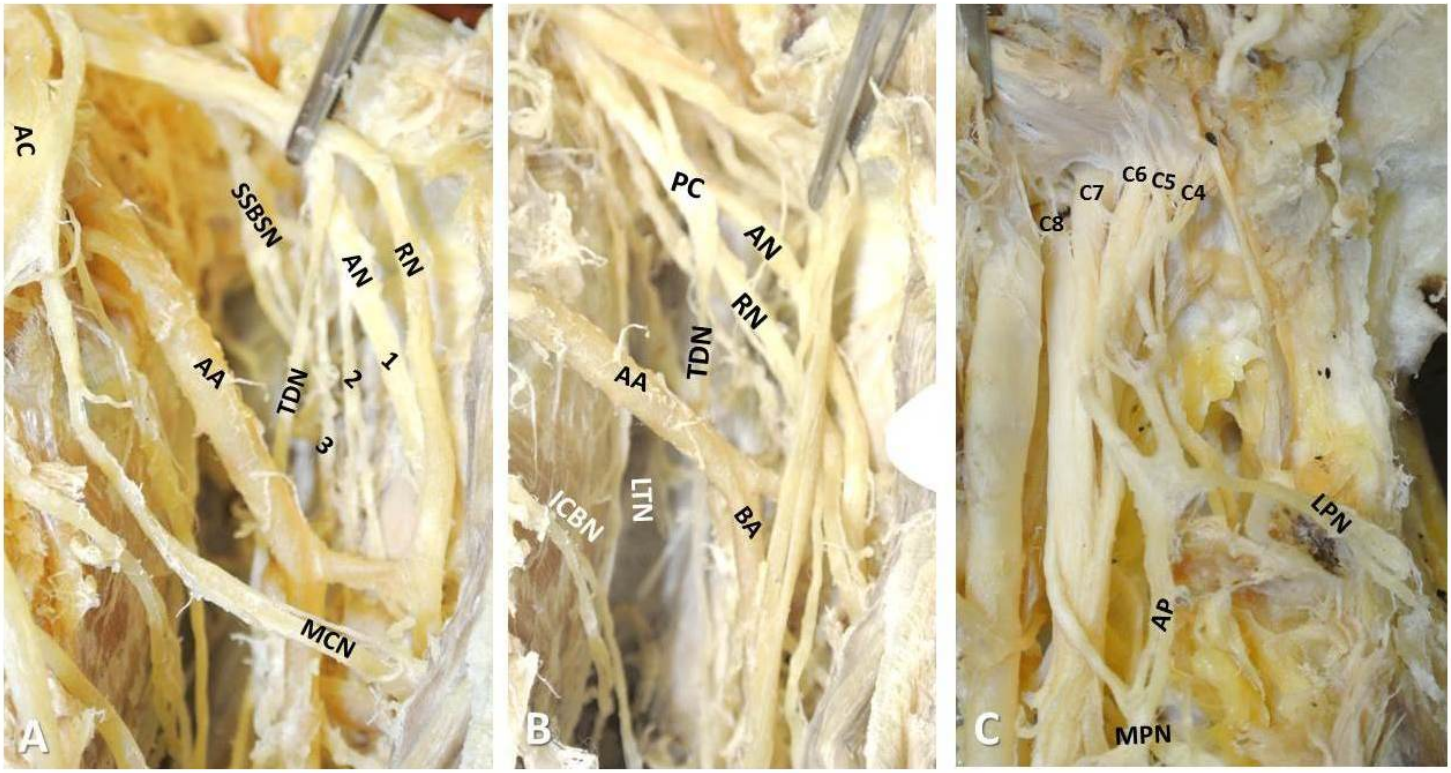
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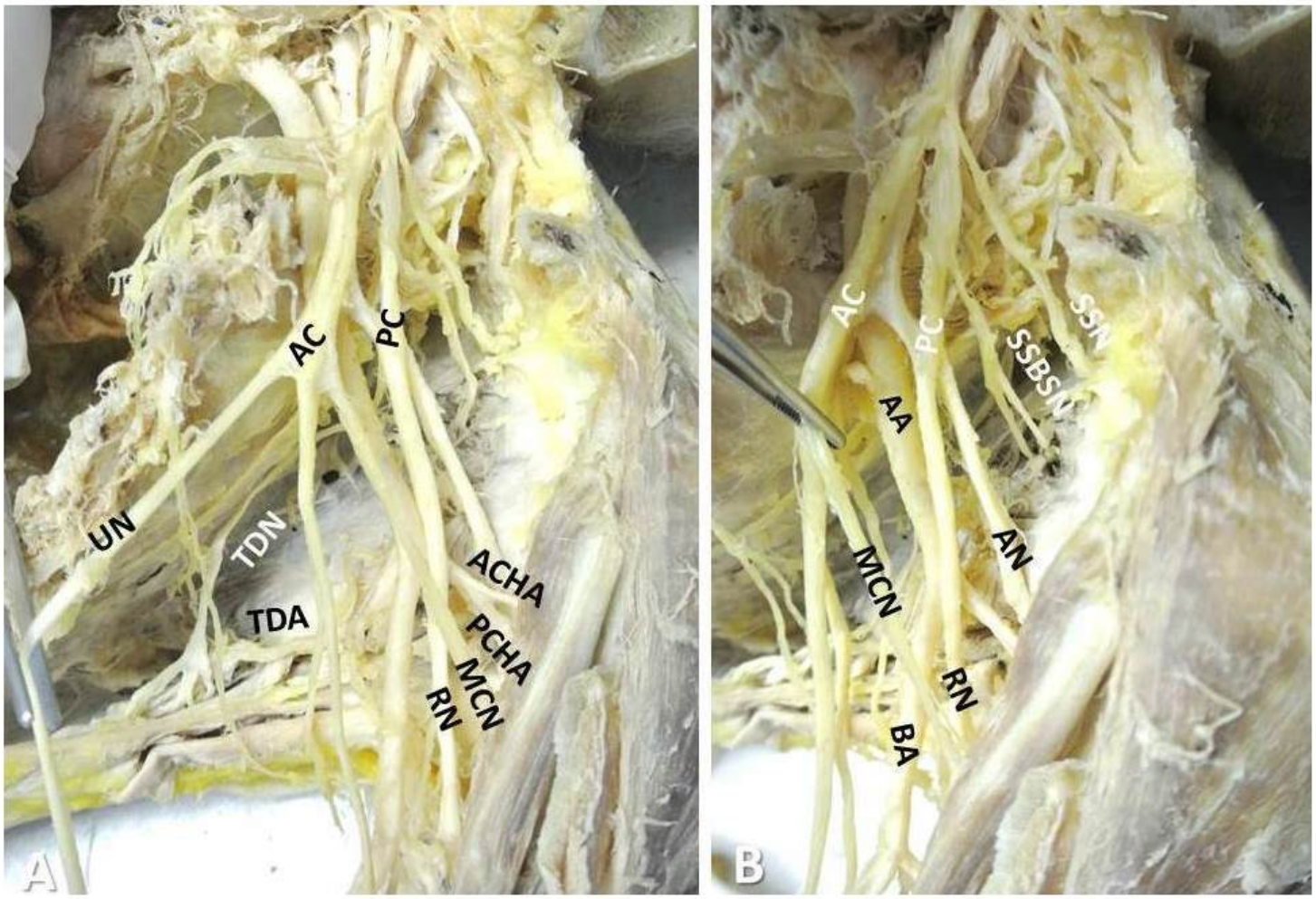
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