OPEN

PRS GLOBAL OPEN

ORIGINAL ARTICLE
Peripheral Nerve

Supraclavicular Approach to the Brachial Plexus

Steven E. Dawson,MD
Jeffrey N. Gross, MD
Jessica M. Berns, MD
Thomas Weinzerl, MA
Joshua M. Adkinson, MD
Gregory H. Borschel, MD

Background: The brachial plexus consists of an intricate array of nerves originating from the C5–T1 ventral rami of the spinal cord. Their course is complex and can be substantially distorted after injury. Thus, dissection of the brachial plexus can be difficult. Here, we present a practical approach to the supraclavicular dissection of the brachial plexus, with emphasis on relevant anatomy and surgical landmarks.
Methods: This anatomical review was prepared using intraoperative surgical imaging. In addition, illustrations are used to display the images in schematic form. We present a stepwise surgical approach to the supraclavicular dissection of the brachial plexus. We highlight the differences between pre- and postganglionic nerve root injuries, and also relevant anatomical variants of the brachial plexus.
Results: Eleven steps are recommended to facilitate the supraclavicular approach to the brachial plexus.
Conclusion: The supraclavicular dissection of the brachial plexus is reliable with consistent landmarks and can be carried out in a stepwise fashion. *(Plast Reconstr Surg Glob Open 2023; 11:e4771; doi: 10.1097/GOX.0000000000004771; Published online 23 January 2023.)*

INTRODUCTION

Humans typically have 31 pairs of spinal nerves, including eight cervical, 12 thoracic, five lumbar, five sacral, and one coccygeal. Spinal nerves are composed of nerve fibers from the dorsal and ventral roots of the spinal cord. From there, each spinal nerve branches into a dorsal and ventral ramus, carrying motor, sensory, and autonomic innervation. The brachial plexus (from Latin, "arm intricate braid"), a complex neural network serving as the primary source of innervation to the upper limb, is formed by the ventral rami of the fifth cervical nerve through the first thoracic spinal nerve (Fig. 1). Injuries to the brachial plexus can be devastating to the upper extremity function and activities of daily living.[1,2] Because the brachial plexus nerve roots originate at the cervical and thoracic level, surgeons may be faced with a unique and demanding anatomical setting for reconstruction. This article will describe the typical anatomy encountered during a supraclavicular approach to the brachial plexus.

From the Division of Plastic Surgery, Indiana University School of Medicine, Indianapolis, Ind.

Received for publication May 31, 2022; accepted November 18, 2022.

DOI: 10.1097/GOX.0000000000004771

BRACHIAL PLEXUS ANATOMY VIA A SUPRACLAVICULAR APPROACH

Nerve roots that contribute to the brachial plexus exit their respective intervertebral foramen and branch in a well-described pattern: roots, trunks, divisions, cords, terminal branches, and peripheral nerves. However, taking a two-dimensional image of the brachial plexus and translating it to the three-dimensional surgical dissection can be difficult. Here we describe the anatomy as seen through a supraclavicular approach.

1. The patient is placed on the operating table with the neck in extension and the head turned away from the side to be operated upon (Fig. 2). In bilateral cases (eg, bilateral injuries or in cases involving cross-C7 nerve root transfer), both sides should be prepared and draped. The endotracheal tube should be secured, preferably sutured to the nasal septum. Markings are made to identify the key landmarks of the sternocleidomastoid muscle, jugular notch, and mastoid process (Fig. 3). It is particularly helpful to place small children close to the edge of the bed for visualization.
2. This approach begins with a 4- to 6-cm incision made cephalad to the clavicle, depending on the size of the patient (Fig. 3).
3. The platysma is the first muscle encountered (Fig. 4). In children it is very thin. In adults it is slightly more substantial in thickness. The platysma may be divided with cautery (Fig. 5).
4. After dissection through the platysma, there will be a subplatysmal fat pad (of Brown), consisting of

Disclosure: *The authors have no conflicts of interest to declare in relation to the content of this article.*

adipolymphatic tissue, which can be dissected medially and cephalad (Fig. 6). Some surgeons may choose to raise a laterally-based flap that may be replaced after the dissection.

5. The omohyoid muscle should be visualized coursing from its origin at the upper border of the scapula toward the hyoid (Fig. 7). The muscle can be transected through its tendon with or without later repair. Some may choose to repair the omohyoid after dissection, as it serves as a landmark should reoperation be needed.
6. The next critical structure to locate is the phrenic nerve. It drapes over the anterior scalene muscle and can be distinguished as the only structure coursing lateral to medial (Fig. 8). Here, it can be seen contributing to the brachial plexus as it gives off a small interneural connection to the C5 nerve root.[3,4] This can also be recognized by comparing the smaller caliber of the phrenic nerve after its C5 branch point. The phrenic nerve may be electrically stimulated with a bipolar nerve stimulator, which should result in diaphragm contraction apparent on both palpation and on end-tidal CO_2 monitor tracing. Supraclavicular and transverse cervical nerve branches from the cervical plexus can serve as landmarks for orientation, as these branches can be followed retrograde to the C4 root/intervertebral foramen. Once located, the surgeon can dissect stepwise caudally and posteriorly to encounter the C5, C6, and C7 roots. The phrenic nerve should be placed under medial traction in a vessel loop for safety.
7. The transverse cervical vessels are then dissected and ligated (Fig. 9).
8. In posttraumatic cases, the scalene muscle may be scarred, sometimes initially obscuring the entire brachial plexus. Spreading with fine tenotomy scissors over the neuroma will reveal the neural elements (Figs. 10 and 11). In cases with severe scarring, the supraclavicular nerves are traced retrograde to identify the C4 root and then the surgeon may dissect distal and more posterior to locate the C5 root. The surgeon then dissects the C5 root and the upper trunk, locating the C6 root at the same time.
9. The upper trunk leads to three structures: the suprascapular nerve, the posterior division of the upper trunk (PDUT), and the anterior division of the upper

Takeaways

Question: Taking a two-dimensional image of the brachial plexus and translating it to the three-dimensional surgical dissection can be difficult.

Findings: We present a stepwise practical surgical approach to the brachial plexus and related anatomy.

Meaning: This article describes a safe, reliable, and reproducible supraclavicular approach to the brachial plexus.

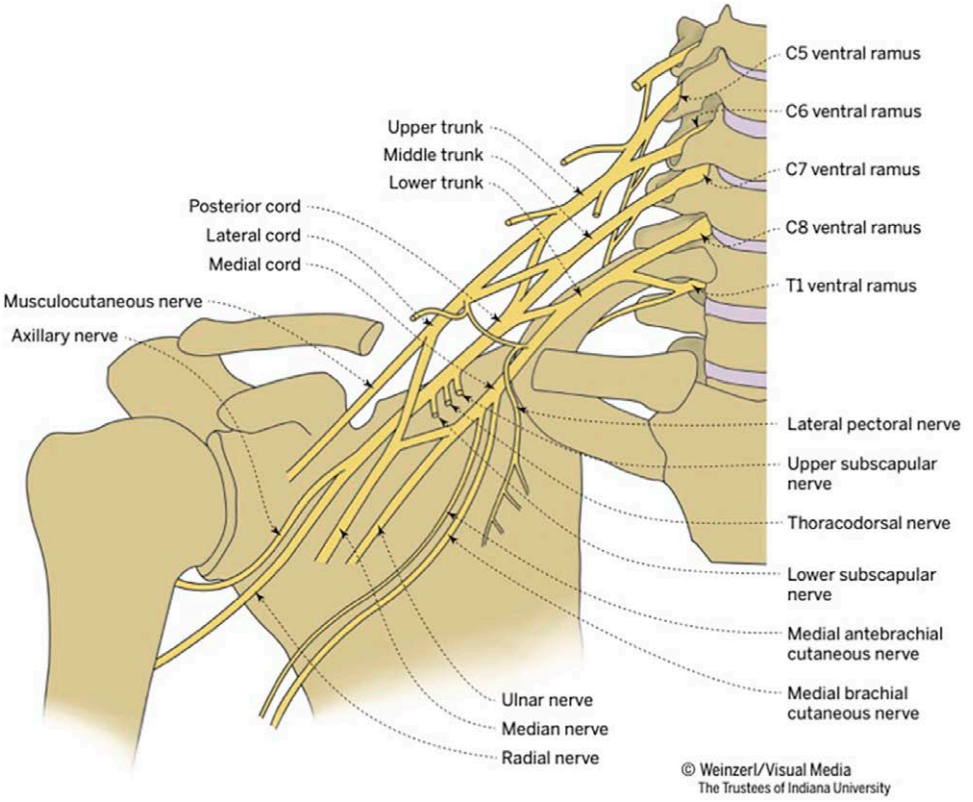

Fig. 1. Overview of the brachial plexus and its components.

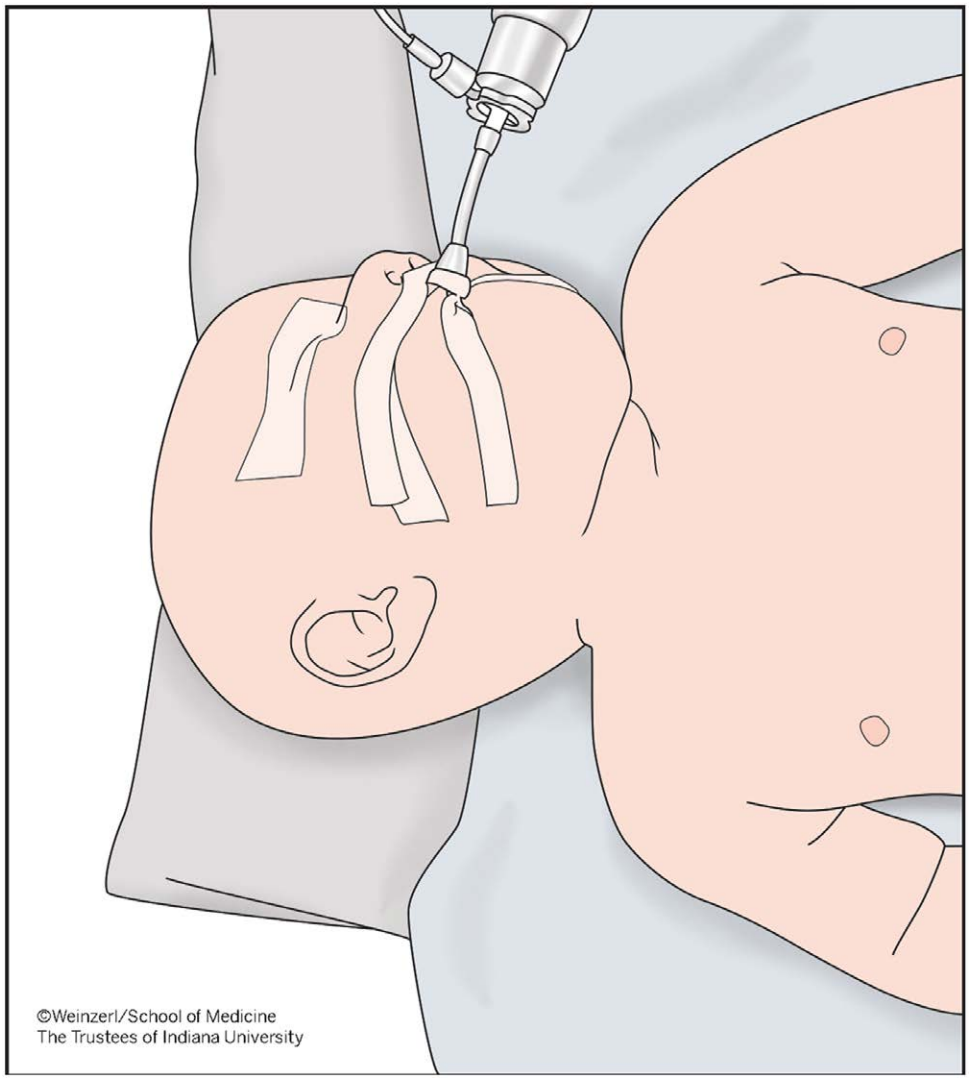

Fig. 2. Note the patient's position on the table, with neck in extension turned contralateral to the operative site. ET tube is well-secured.

trunk (Fig. 12). The suprascapular nerve, which is usually the most lateral structure at this level, lies next to the PDUT. Medial to the PDUT lies the anterior division of the upper trunk. Depending on the amount of distortion caused by scarring, the level of branching may vary.

10. The C7 root lies distal and posterior to the C6 root. The distance between the C5 and C6 roots is greater than that of the C6–C7 interval. The C7 root is typically the thickest in diameter.
11. Likewise, the C8 and T1 nerve roots lie more closely spaced and posterior. Where the C8 and T1 roots merge to form the lower trunk, the subclavian artery is visible and may be initially mistaken for a nerve root. To assist with visualization, a headlight (preferably loupe-mounted) is very useful, as is anterior retraction on the clavicle by an assistant. With this combination of maneuvers, clavicular osteotomy is rarely, if ever, required.

ANATOMIC PEARLS, BY LEVEL

Roots

As the C5–T1 ventral rami course through the neck between the anterior and middle scalene muscles, they coalesce in a predictable pattern to form the "roots" of the brachial plexus. The roots of the brachial plexus are synonymous with the ventral rami of C5–T1 spinal nerves. This is not to be confused with the dorsal and ventral roots (rami), which merge to form the spinal nerve proper. Exiting the intervertebral foramina, the C5–C7 roots course above their respectively named vertebrae, whereas the C8 root emerges below C7 vertebrae, and the T1 root below the T1 vertebrae. The roots proceed to give off three branches: the dorsal scapular nerve (C5), long thoracic nerve (C5–C7), and first intercostal nerve (T1).

The dorsal scapular nerve emerges from the C5 root, diving posterior to the brachial plexus to innervate the rhomboid major and minor muscles.[5] The long thoracic

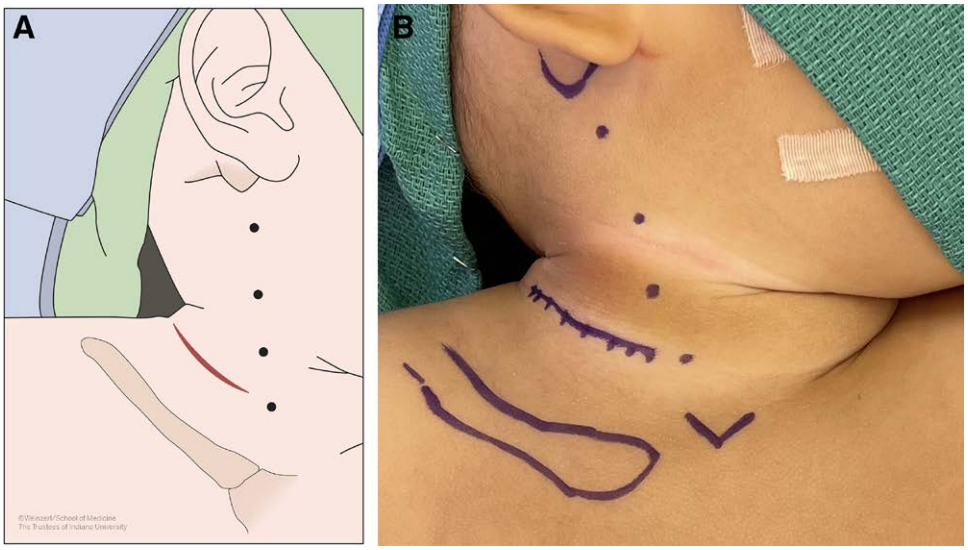

Fig. 3. The skin is widely prepared and draped and landmarks are drawn out, including sternocleidomastoid muscle, jugular notch, mastoid process, and the clavicle. Incision is marked out 4- to 6-cm long, just cephalad to the clavicle. A, Illustration. B, Intraoperative photograph.

Fig. 4. Incision is made with a 15-blade through the dermis down to the subcutaneous fat being careful not to violate platysma as it is superficial at this level.

nerve emerges from the C5–C7 roots, and passes through the cervicoaxillary canal before innervating the serratus anterior muscle.[5] A winged scapula, resulting from injury to the long thoracic nerve, can be indicative of a C5–C7 root avulsion. The first intercostal nerve is a branch of the T1 root, and innervates nearby intercostal muscles, as well as a portion of the thoracic wall and thoracic pleura.[6] The phrenic nerve originating from C4 travels lateral to medial in the region surrounding the roots. While descending over the anterior scalene muscle, it both gives and receives axons from C5 prior to entering the thorax.[3,4]

Root Injury

When there is concern regarding a root injury, it is important to determine if the injury is an avulsion or a rupture. Proximal lesions termed preganglionic avulsions or root avulsions occur proximal to the dorsal root ganglia. Direct surgical repair is not possible due to the absence of a proximal nerve stump recipient, and performing laminectomies for better exposure is not widely performed.[7] Distal lesions, termed postganglionic lesions or nerve ruptures, can be accessed via the supraclavicular approach and repaired directly, with nerve grafts, or addressed with nerve transfers. These postganglionic lesions may be total nerve ruptures, neuromas in continuity, or neuropraxia.[7] Identifying the type of lesion with a clinical workup is critical in determining if these patients are candidates for nerve reconstructive surgery, and can include physical examination, electromyography, computed tomography myelogram, or magnetic resonance imaging.

Anatomical Variations

Despite the standard description of the brachial plexus originating from the ventral rami of C5–T1, there are important anatomical variations. These include the pre-fixed and postfixed brachial plexus. The definition of pre-fixed and postfixed brachial plexus vary within the literature, but we find the following descriptions to be the most accurate: a pre-fixed brachial plexus receives contribution from C4 and has minimal contribution from T1.[8] A postfixed brachial plexus is one with little contribution from C5, but rather receives large contributions from T2.[8] There are innumerable other possible anatomical variations of the brachial plexus that surgeons may encounter during reconstruction.[9]

Trunks

Shortly after their origin, the brachial plexus nerve roots coalesce in the posterior triangle of the neck to

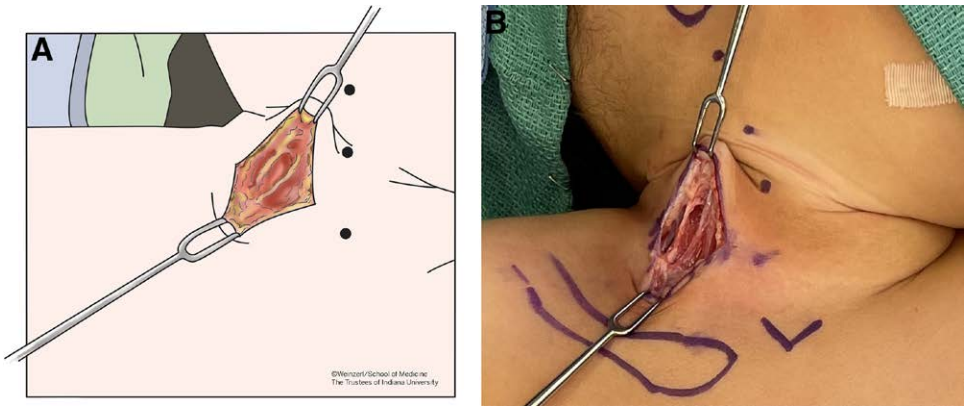

Fig. 5. Platysma is the first muscle encountered. We recommend dividing with fine tip cautery. Careful dissection is recommended because the muscle is rather thin. Here you also encounter branches of supraclavicular nerves. These can be used as graft material when the need for grafts exceeds that provided by the preferred sural nerves. A, Illustration. B, Intraoperative photograph.

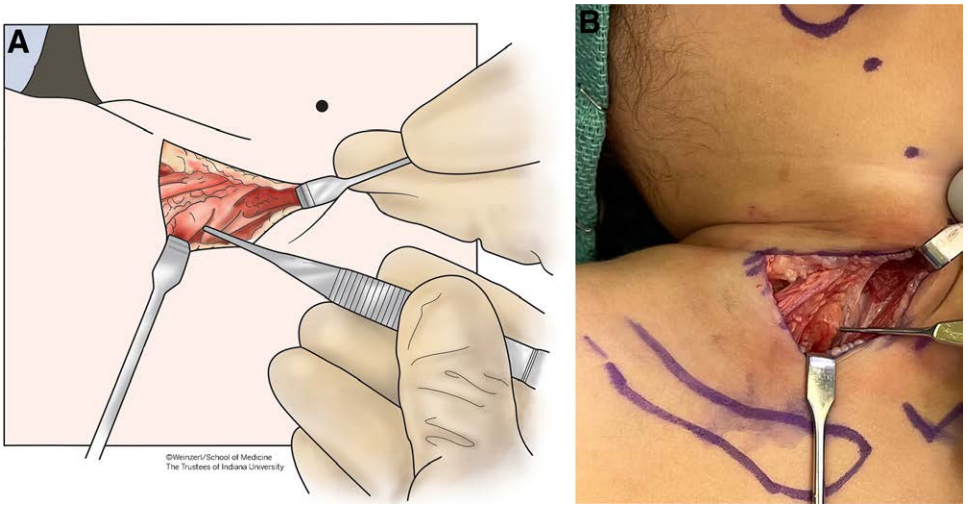

Fig. 6. Once through the platysma, the fat pad of Brown is encountered. We recommend raising a laterally-based flap of this adipolymphatic tissue, which can be replaced after the dissection. A, Illustration. B, Intraoperative photograph.

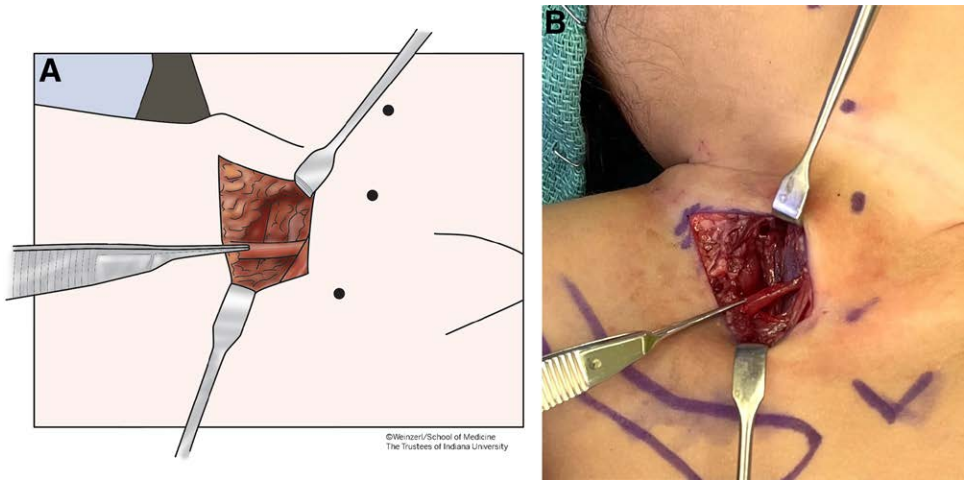

Fig. 7. The omohyoid is distinguished anatomically coursing from the scapula to hyoid. It can be transected at its mid-belly. Our group does not repair it after dissection, although some advocate repair because it may serve as a future surgical landmark. A, Illustration. B, Intraoperative photograph.

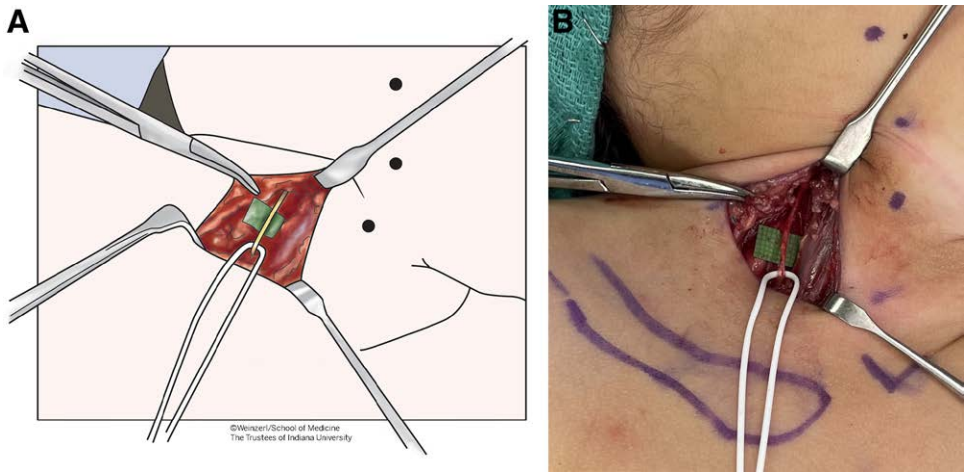

Fig. 8. The phrenic nerve will be encountered as the only structure coursing lateral to medial. Careful dissection and retraction medially will maintain it in a safe and viable position. A, Illustration. B, Intraoperative photograph.

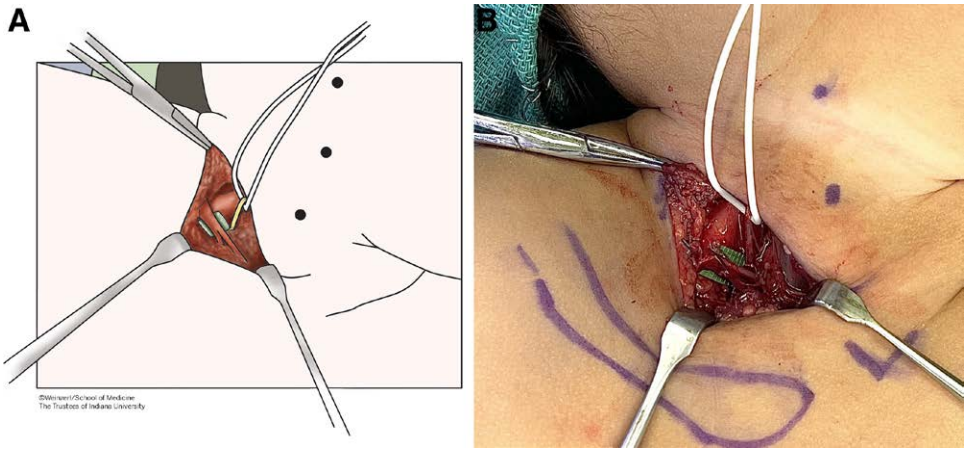

Fig. 9. Transverse cervical vessels (green background) are dissected and ligated to allow for full exposure of the roots and trunks. The phrenic nerve is retracted medially (white vessel loop). A, Illustration. B, Intraoperative photograph.

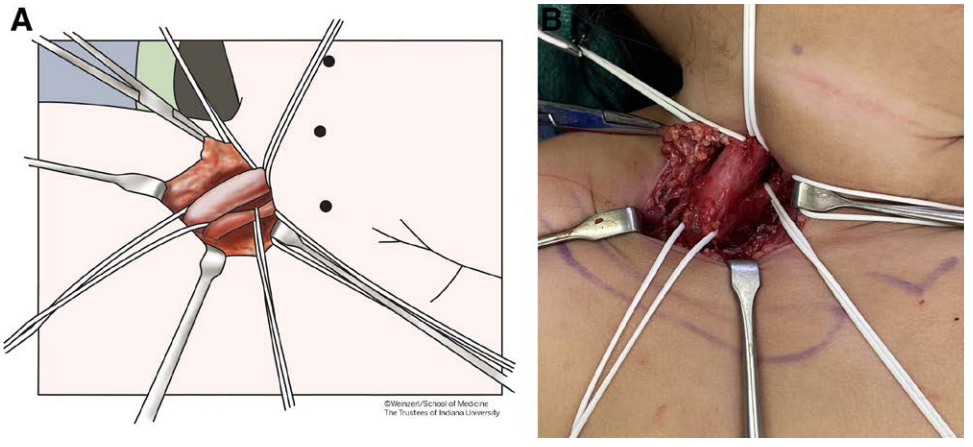

Fig. 10. Neuroma-in-continuity is dissected with full exposure of the trunks. Pictured here is a neuroma involving the upper and middle trunk. C5 and C6 roots have vessel loops most cephalad. C7 has a vessel loop most medial. Inferior vessel loop consists of neuroma of upper and middle trunk. A, Illustration. B, Intraoperative photograph.

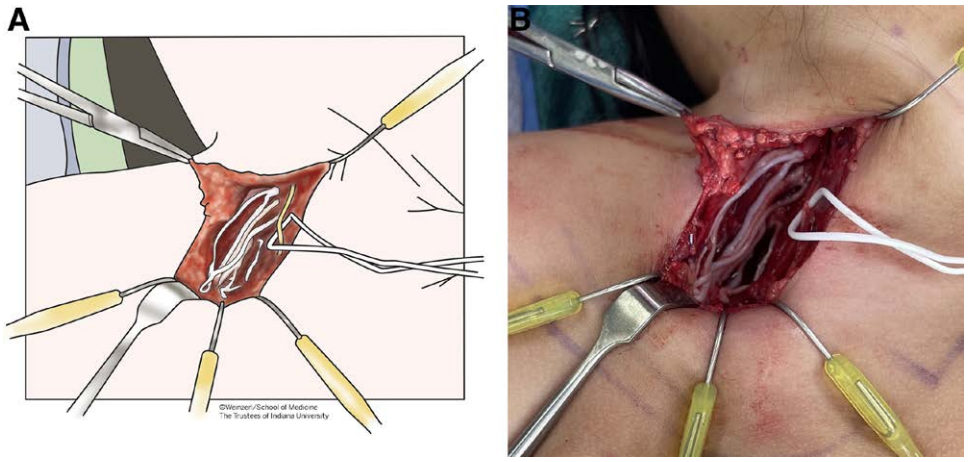

Fig. 11. Neuroma-in-continuity is excised and replaced with sural nerve grafts. A, Illustration. B, Intraoperative photograph.

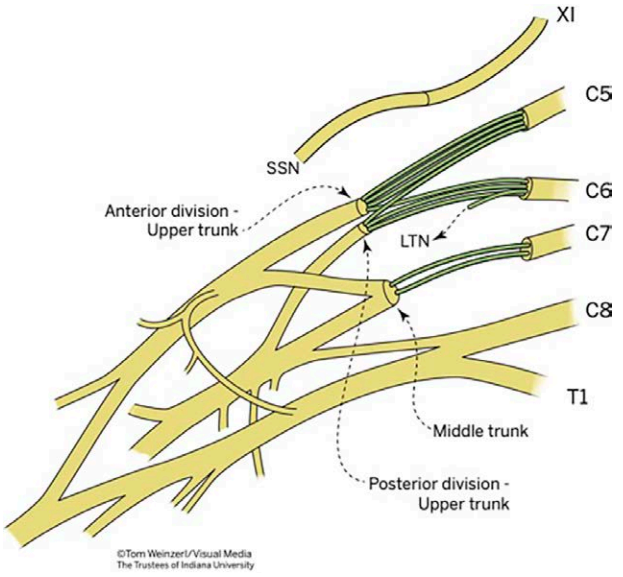

Fig. 12. This patient underwent CN11 to suprascapular nerve transfer followed by coaptations of sural nerve graft from C5/C6 roots to PDUT, anterior division of the upper trunk, long thoracic nerve, and C7 to middle trunk reconstruction.

form three "trunks": superior, middle, and inferior. The superior trunk, formed by the fusion of the C5 and C6 roots, gives off two branches, the subclavian nerve and the suprascapular nerve. The subclavian nerve innervates the subclavius muscle, and the suprascapular nerve innervates the supraspinatus and infraspinatus muscles. Neither the middle trunk or lower trunk give off any branches. The middle trunk is formed by a continuation of the C7 root only, whereas the lower trunk is formed via coalescence of the C8 and T1 roots.

Divisions

As the trunks course beneath the clavicle, each of the three trunks split into an anterior and posterior "division," yielding a total of six divisions. Although there are no branches associated with the divisions, the embryologic development of the brachial plexus is reflected by the muscles innervated by the divisions. During development, the limb buds contain a ventral and dorsal muscle mass. As the embryo develops, axons from the anterior divisions of the brachial plexus travel to the ventral muscle mass, whereas the posterior divisions send axons to the dorsal muscle mass. Consequently, nerve fibers from the anterior divisions innervate flexor muscles in the anterior compartment, whereas nerve fibers from the posterior divisions innervate extensor muscles in the posterior compartment.[10]

Cords

The divisions ultimately coalesce in the axilla posterior to the pectoralis minor to form the medial, lateral, and posterior "cords." The cords are anatomically named relative to the axillary artery. The medial cord is a continuation of the anterior division of the lower trunk, whereas the lateral cord is formed by merging of the anterior division of the superior and middle trunk. The posterior cord is formed by coalescence of all three posterior divisions, receiving input from C5 to T1. Each of the cords then gives off preterminal branches prior to ending as "branches."

Medial Cord

The medial cord is a continuation of the anterior division of the lower trunk. It therefore receives input from C8 and T1. Branches arising from the medial cord include the medial pectoral nerve, the medial brachial cutaneous nerve, and the medial antebrachial cutaneous nerve. The medial pectoral nerve (C8–T1) innervates the pectoralis major and minor muscles. The medial brachial cutaneous nerve of the arm (C8–T1) supplies the skin of the medial side of the arm, while the medial antebrachial cutaneous nerve of the forearm (C8–T1) supplies the skin of the medial aspects of the forearm. The medial cord terminates into the ulnar nerve (C8–T1) and the medial root of the median nerve (C5–T1). The ulnar nerve provides motor innervation to flexor muscles in the forearm and intrinsic hand muscles. Furthermore, it receives sensory input from

the ulnar aspect of the hand, as well as the small finger and ulnar half of the ring finger. The medial root of the median nerve will merge with the lateral root of the median nerve from the anterior division of the upper trunk to form the median nerve proper. The median nerve will serve as the main source of innervation to the forearm and hand flexors and is further described in the following section.

Lateral Cord

The lateral cord consists of the convergence of the anterior divisions of the upper and middle trunks. Therefore, it has contributions from C5 to C7. The lateral cord gives off the lateral pectoral nerve (C5–C7), before continuing as the musculocutaneous nerve (C5–C7) and the lateral root of the median nerve (C5–C7). The lateral pectoral nerve innervates the pectoralis major muscle. The musculocutaneous nerve provides innervation to the anterior arm musculature, including the coracobrachialis, biceps brachii, and the brachialis muscles. The musculocutaneous nerve also gives off the lateral antebrachial cutaneous nerve of the forearm, providing sensation to the lateral forearm. Lastly, the lateral root of the median nerve merges with the medial root of the median nerve from the medial cord to form the median nerve proper (C5–T1).

Generally speaking, the median nerve provides motor innervation to most of the flexor components of the forearm, as well as thenar and intrinsic hand muscles. As the median nerve reaches the elbow, it gives off motor branches. These branches innervate the pronator teres, flexor carpi radialis, palmaris longus, and flexor digitorum superficialis muscles. The median nerve also gives off the anterior interosseous nerve, which supplies the flexor pollicis longus, pronator quadratus, and the radial half of the flexor digitorum profundus. In addition, the recurrent branch, also known as the thenar motor branch, supplies the abductor pollicis brevis, flexor pollicis brevis, and opponens pollicis muscles.

The median nerve is a mixed motor/sensory nerve, and the palmar cutaneous branch of the median nerve receives sensation from the palm and thenar eminence. It also receives sensation from the volar surface of the radial 3 ½ digits, as well as the dorsal distal surfaces of the first 3 ½ digits, and digits via its palmar digital branches. These palmar digital branches provide motor innervation to the first two lumbricals as well.

Posterior Cord

The posterior cord consists of all three of the posterior divisions of the upper, middle, and lower trunks. It therefore has contributions from C5 to T1. The posterior cord gives off the upper subscapular nerve (C5–C6), thoracodorsal nerve (C6–C8), and lower subscapular nerve (C5–C6) before terminating as the radial nerve (C5–T1) and axillary nerve (C5–C6). The thoracodorsal nerve provides motor innervation to the latissimus dorsi muscle. The upper and lower subscapular nerves supply the subscapularis muscle, with the lower subscapular nerve also providing innervation to the teres major muscle. The axillary nerve serves as one of the terminal branches, providing motor innervation to the deltoid and teres minor muscles, as well as receiving sensory input from the skin overlying the deltoid. The radial nerve serves as the other terminal branch of the posterior cord. It provides motor innervation to the posterior compartment of the forearm and arm and receives sensory input from the dorsal surface of the radial hand and proximal dorsal surface of the radial 3 ½ digits.

The radial nerve directly innervates the triceps brachii, extensor carpi radialis longus, brachioradialis, and anconeus muscle. As it passes through the cubital fossa, the radial nerve gives off the deep branch of the radial nerve, which supplies the extensor carpi radialis brevis and supinator muscle before continuing as the posterior interosseous nerve. The posterior interosseous nerve supplies the abductor pollicis longus, extensor carpi ulnaris, extensor digit minimi, extensor digitorum communis, extensor indicis proprius, extensor pollicis brevis, and extensor pollicis longus.

CONCLUSIONS

Injuries of the brachial plexus can devastate upper extremity function.[1,2] Presented with the complex anatomy and often times scarred and neuroma-plagued brachial plexus components, the surgical team can be challenged with a difficult and possibly disorienting dissection. However, with a solid foundation of anatomy and understanding of the technical nuances of the supraclavicular approach to the brachial plexus, various reconstructive modalities can be successfully performed.

Gregory H. Borschel, MD
Indiana University School of Medicine
545 Barnhill Drive
Indianapolis, IN 46202
Email: gborsche@iu.edu

REFERENCES

1. Gray B. Quality of life following traumatic brachial plexus injury: a questionnaire study. *Int J Orthop Trauma Nurs.* 2016;22:29–35.
2. Hong TS, Tian A, Sachar R, et al. IndirEect cost of traumatic brachial plexus injuries in the United States. *J Bone Joint Surg Am.* 2019;101:e80.
3. Al-Qattan MM, El-Sayed AA. The use of the phrenic nerve communicating branch to the fifth cervical root for nerve transfer to the suprascapular nerve in infants with obstetric brachial plexus palsy. *Biomed Res Int.* 2014;2014:153182.
4. Marcus JR, Clarke HM. Management of obstetrical brachial plexus palsy evaluation, prognosis, and primary surgical treatment. *Clin Plast Surg.* 2003;30:289–306.
5. Williams AA, Smith HF. Anatomical entrapment of the dorsal scapular and long thoracic nerves, secondary to brachial plexus piercing variation. *Anat Sci Int.* 2020;95:67–75.
6. Ostrowska M, de Carvalho M. Chapter 34 – injuries of the nerves of the thorax. In: Tubbs RS, Rizk E, Shoja MM, et al, eds. *Nerves and Nerve Injuries.* Cambridge, MA: Academic Press; 2015:525–543.
7. Kattan AE, Borschel GH. Anatomy of the brachial plexus. *J Pediatr Rehabil Med.* 2011;4:107–111.
8. Pellerin M, Kimball Z, Tubbs RS, et al. The prefixed and postfixed brachial plexus: a review with surgical implications. *Surg Radiol Anat.* 2010;32:251–260.
9. Uysal II, Seker M, Karabulut AK, et al. Brachial plexus variations in human fetuses. *Neurosurgery.* 2003;53:676–684; discussion 684.
10. Thomas K, Sajjad H, Bordoni B. *Anatomy, Shoulder and Upper Limb, Medial Brachial Cutaneous Nerve.* Tampa, FL: StatPearls. StatPearls Publishing.