Acta Neurochirurgica (2019) 161:1937–1942
https://doi.org/10.1007/s00701-019-04009-w

ORIGINAL ARTICLE - NEUROSURGICAL ANATOMY

Avoidance of scapular winging while approaching tumors of the middle scalene region

Ross C. Puffer[1] · Jonathan Stone[1] · Robert J. Spinner[1]

Received: 19 June 2019 / Accepted: 5 July 2019 / Published online: 12 July 2019

Abstract

Background Large tumors arising from the middle scalene region can displace the middle scalene muscle and distort regional anatomy, placing nerves at risk. Understanding the surgical anatomy of these nerves is key to approaching pathology of the middle scalene muscle and avoiding damage to the dorsal scapular, long thoracic, and spinal accessory nerves, each of which can cause scapular winging and associated morbidity if injured.

Methods IRB approval was obtained for this study, allowing cases with relevant pathology to be reviewed and presented to highlight the relevant surgical technique. Anatomical depictions were created to correlate intraoperative images with known anatomical relationships.

Results Key to this approach is consideration of the regional anatomy in a standard supraclavicular approach, the superficial plane, containing the anterior scalene muscle and brachial plexus, and the oblique plane containing the middle scalene muscle, long thoracic, spinal accessory, and dorsal scapular nerves. Identification and mobilization of each of these structures prior to lesion removal can not only provide likely boundaries of the tumor, but also allow for protection of the nerves to avoid injury that may lead to scapular winging with associated morbidity and functional impairment of the upper extremity.

Conclusions Lesions of the middle scalene region often split two important anatomical planes, the superficial and deep, creating an advantageous surgical corridor through an anterolateral approach. Through early identification of known anatomy, these two planes can be developed, and a safe approach to the lesion of the middle scalene region can be exploited.

Keywords Scapular · Winging · Brachial · Plexus · Approach · Technique

Introduction

The middle scalene muscle is most commonly accessed for the surgical treatments of peripheral nerve sheath tumors, reconstructive brachial plexus surgery, and thoracic outlet syndrome. Surgical exposure of pathology near or within the middle scalene muscle may pose risk to three predominantly motor nerves, the dorsal scapular, long thoracic, and distal spinal accessory nerves, which can cause scapular winging and associated morbidity if injured. The scapula plays an important role in shoulder stabilization, mainly allowing for abduction, elevation, and rotation of the upper extremity [7, 8]. A winged scapula causes morbidity by decreasing the utility of the extremity in daily life as well as leading to notable asymmetry of the back. The two most common causes of scapular winging are injury to the long thoracic and spinal accessory nerves, causing lateral and medial scapular winging respectively [8, 9]. Large tumors arising in this region can displace the nerves and distort regional anatomy, further placing these small nerves at risk. Understanding the surgical anatomy of these nerves is key to approaching pathology of the middle scalene muscle and avoiding injury to the nerves resulting in postoperative winged scapula. Injury to the long thoracic nerve causing scapular winging during axillary lymph node dissections for breast cancer is a well-known complication [2, 14, 16]. Similarly, injury to the spinal accessory nerve during lymph node dissections along the accessory chain in the neck has also been widely reported [6, 15]. Injury to the spinal accessory nerve in these patients leads to shoulder dysfunction and scapular winging. While dorsal scapular

This article is part of the Topical Collection on *Neurosurgical Anatomy*

✉ Ross C. Puffer
puffer.ross@mayo.edu

[1] Department of Neurosurgery, Mayo Clinic, 200 1st St, SW, Rochester, MN 55905, USA

nerve lesions and/or injury are rare, they are an identifiable cause of medial scapular winging and morbidity [1, 3]. All three of these nerves can be encountered during exposure of tumors arising from the middle scalene region, and all three nerves, if injured, can cause scapular winging and significant shoulder dysfunction leading to postoperative morbidity, highlighting the importance of identification and protection of these nerves during exposure and resection of tumors arising from the middle scalene region.

The dorsal scapular nerve originates most commonly from the 4th and 5th cervical spinal nerves, coursing posteriorly, piercing the middle scalene muscle and ultimately innervating the rhomboids and levator scapulae muscles [5, 12]. The rhomboids (major and minor) insert on the medial aspect of the scapula and retract and elevate the medial scapula, working with the middle trapezius as stabilizing muscles [5, 7, 8]. The long thoracic nerve receives contributions from C5 to C7, descending posterior to the brachial plexus and along the chest wall, innervating the serratus anterior muscle [11]. The serratus anterior arises from the ribs and inserts on the medial aspect of the scapula, functioning to keep the medial aspect of the scapula against the chest wall and stabilizing it during upper extremity movements [8]. It works synergistically with the trapezius muscle in upward rotation, allowing for continued overhead arm function [11]. Weakness causes medial winging of the scapula.

The spinal accessory nerve is created by combination of cranial and spinal nerves and descends obliquely in the posterior triangle of the neck after exiting the jugular foramen [6]. It innervates the sternocleidomastoid (SCM) and trapezius muscles, responsible for contralateral head rotation in the case of SCM, and shoulder elevation/scapular stabilization via the trapezius muscle. Weakness causes lateral scapular winging. The brachial plexus (C5–T1) lies in the interscalene triangle and innervates the muscles of the shoulder, elbow, forearm, wrist, and hand. The phrenic nerve (which arises from C3 to C5, receiving most of its contribution from C4) descends along the anterior surface of the anterior scalene muscle [10]. The phrenic nerve travels through the thorax to innervate the diaphragm, and injury to the phrenic nerve can lead to hemidiaphragmatic elevation and loss of respiratory function, although this may remain clinically asymptomatic [13].

These nerves, their anatomic relationships, and functions are important to understand when surgically approaching the middle scalene muscle. When considered in a standard anterior supraclavicular approach, these structures make up two distinct planes, with the anterior scalene muscle and brachial plexus comprising the superficial plane, and the middle scalene, long thoracic, spinal accessory, and dorsal scapular nerves in the oblique plane, coursing from superficial at the origin from the plexus to deep targets on the chest wall or peri-scapular region. Pathology arising from the middle scalene separates these two planes creating an advantageous anterolateral surgical corridor. The order in which each nerve is identified may differ depending on tumor specifics and surgeon preference. We describe a technique for approaching and identifying these nerves and exploiting this anterolateral corridor to resect lesions of the middle scalene region while avoiding damage to nerves that would lead to postoperative scapular winging and associated morbidity. We present this technique with three illustrative case examples that were identified after IRB approval and patient consent at our institution.

Case illustrations

Case 1: A 48-year-old woman presented with a supraclavicular mass causing local pain and paresthesias down the right arm into the hand. Strength, sensation, and EMG were normal. MR imaging demonstrated 5 cm × 2 cm mass arising from within the middle scalene muscle (Fig. 1). A CT-guided biopsy demonstrated a solitary fibrous tumor. She was taken to surgery via a supraclavicular brachial plexus approach, and the dorsal scapular, phrenic, and long thoracic nerves were identified and protected prior to resection of the tumor (Fig. 1). At 1-year follow-up, she had no evidence of recurrent/residual disease and had complete resolution of her preoperative symptoms.

Case 2: A 46-year-old woman presented with right shoulder pain with radiation to the index finger and a palpable mass in the supraclavicular fossa. Strength, sensation, and EMG were normal. Imaging was consistent with a 5-cm lipoma centered over the middle scalene muscle. She was taken to surgery for resection; the tumor was adherent to the long thoracic nerve (Fig. 2). After complete resection of the lipoma, she was pain free with full shoulder abduction, external rotation, and elbow flexion and had no scapular winging.

Case 3: A 47-year-old woman noticed a large, right-sided neck mass and developed right hand paresthesias traveling into the middle finger. MRI demonstrated a 7 cm × 5 cm benign nerve sheath tumor arising from C7 and projecting posteriorly into the region of the middle scalene. Given its size, symptoms, and observed growth, the patient underwent surgical resection (Fig. 3). The large size of the tumor made exposure and identification of the nerves more difficult, but after initial identification of the upper trunk, the remaining nerves could be exposed around the margins of the tumor. The tumor was resected via in interfascicular technique, maintaining the true capsule of the tumor and completely excising it [17]. Pathology confirmed the mass to be a schwannoma. She had complete resolution of her preoperative symptoms, and imaging demonstrated no recurrence 10 years after surgery.

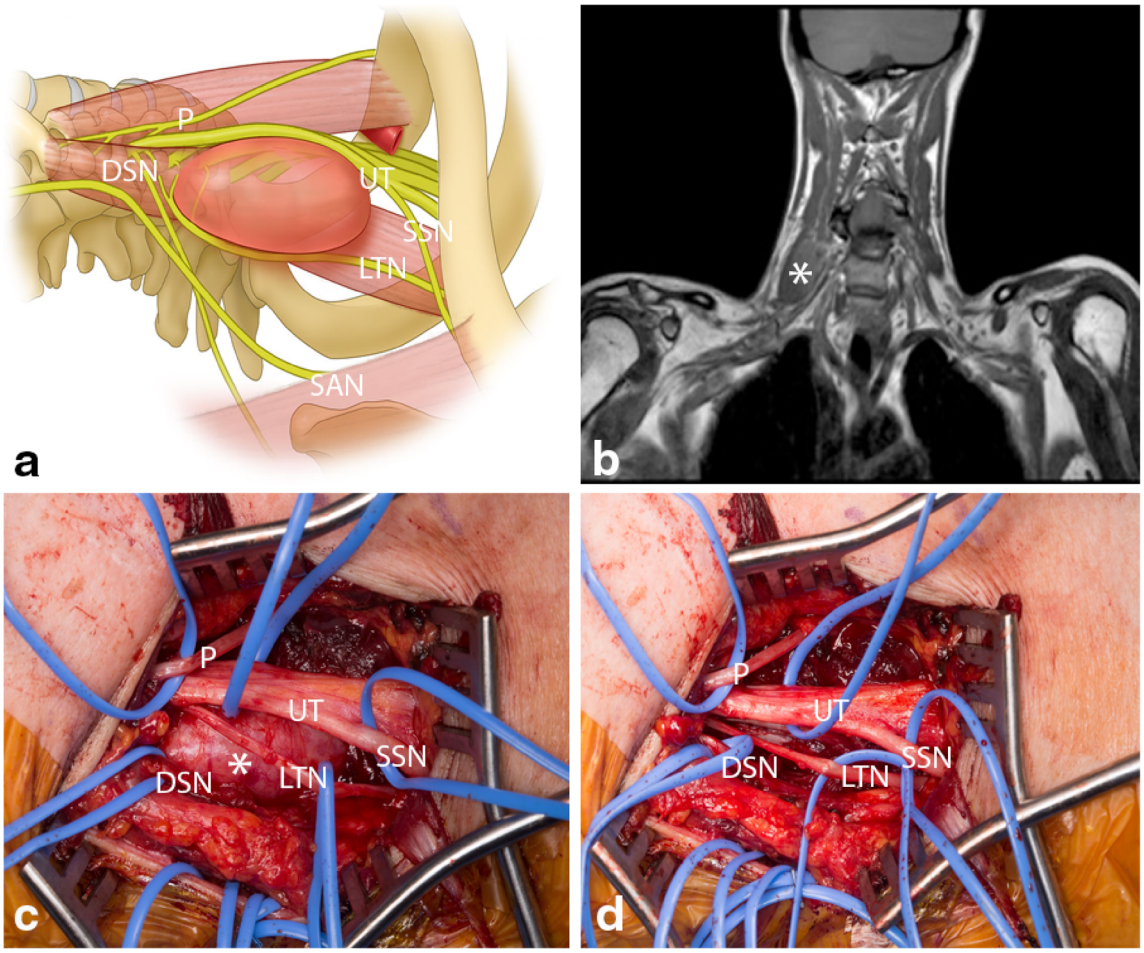

Fig. 1 **a** Depiction of relevant anatomy for middle scalene approach to a right-sided solitary fibrous tumor. **b** Coronal T1-weighted MRI demonstrates a mass (asterisk) displacing the brachial plexus. **c** Intraoperative photograph demonstrating a solitary fibrous tumor (asterisk) arising from within the middle scalene muscle displacing the brachial plexus and retroplexal nerves. **d** Intraoperative image after resection of the mass. PN, phrenic nerve; UT, upper trunk; SAN, spinal accessory nerve; SSN, suprascapular nerve; LTN, long thoracic nerve; DSN, dorsal scapular nerve

Surgical technique

A depiction of the surgical corridor created by masses in the region of the middle scalene is demonstrated in Fig. 4. Using a sequence of several steps, based on known anatomical landmarks, important large and small neural structures can be identified and protected, even in cases of large tumors distorting the regional anatomy.

Superficial plane

During the anterolateral approach to the middle scalene muscle, the upper trunk of the brachial plexus is identified first because it can be palpated beneath the supraclavicular fat pad in a consistent anatomical location. Prior to identifying the upper trunk, the omohyoid muscle, and depending on patient-specific anatomy, the transverse cervical vessels are identified, placed in vessel loops, and retracted. This creates a large corridor through which to identify the upper trunk. During this initial exposure, the goal is to identify the lateral border of the upper trunk and shoulder of the suprascapular nerve. This starting point is an ideal location to begin because there is little danger to the phrenic nerve or major vessels. Electrical stimulation can be used to confirm the upper trunk and suprascapular nerve. Dissecting proximally along the upper trunk will expose the C5 and C6 spinal nerves as well as the anterior scalene muscle. The phrenic nerve runs along the anterior surface of the anterior scalene muscle and can be identified by finding its C5 contribution. While there are several methods to find the phrenic nerve throughout its course along the anterior scalene muscle, we feel that the safest approach when dealing with distorted anatomy from neoplasm or scar tissue is to find its origin using the C5 root as a guide. It should be noted that contributions also come from C3–C4 and there may be a separate accessory phrenic nerve. As the dissection continues proximally, the C5 spinal nerve can be taken to the level of the

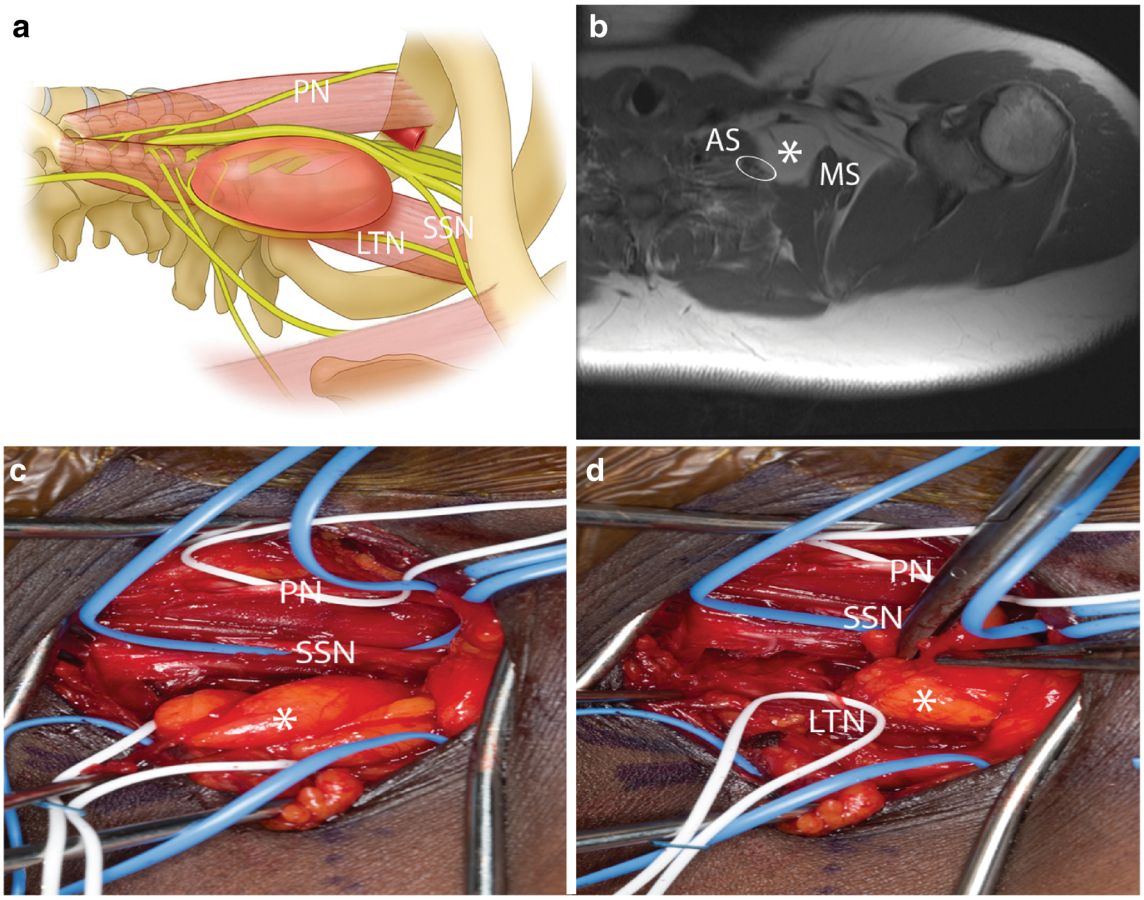

Fig. 2 **a** Depiction of relevant anatomy for middle scalene approach to a right-sided lipoma. **b** Axial T1-weighted MRI demonstrating a lipoma (asterisk) splitting the anterior (AS) and middle (MS) scalene muscles, which are displaced by the mass. Elements of the upper trunk (circle) of the brachial plexus can also be visualized. **c** Intraoperative image demonstrating initial exposure of the mass (asterisk), as well as localization of the suprascapular (SSN) and phrenic (PN) nerves. **d** Intraoperative image after further dissection of the borders of the mass, allowing for identification of the proximal long thoracic nerve (LTN)

foramen; however, this may require resection of the anterior scalene muscle to fully expose. Distally, the suprascapular nerve is identified branching off the upper trunk as it travels to the suprascapular notch.

Oblique plane

After identification of the superficial plane, but prior to engaging the tumor, attempts should be made to find the three at-risk nerves depending on the size and position of the lesion. The long thoracic nerve can be identified distally by dissecting deep to the suprascapular nerve [4]. When mobilized, it can be traced proximally to the middle scalene muscle, which it pierces. Different surgical windows can be opened by following superior and lateral paths to find the dorsal scapular and spinal accessory nerves, respectively. The dorsal scapular nerve can be visualized during proximal dissection of the C5 spinal nerve; however, its takeoff is very proximal, and it may be difficult to dissect along its entire course from a standard brachial plexus exposure. The spinal accessory nerve is easily identified on the medial border of the trapezius muscle several centimeters above the clavicle. It can be dissected proximally as far as necessary for treatment of the primary surgical lesion.

Discussion

Surgical approaches to the middle scalene muscle can be difficult and regional nerves can be displaced from their normal course, putting them at risk during tumor dissection. Injury to the three nerves in the oblique plane, the dorsal scapular, long thoracic, and spinal accessory nerves, can lead to postoperative scapular winging and significant functional impairment in upper extremity function. Early identification and protection of these nerves can make safe resection of the tumor easier. A step-by-

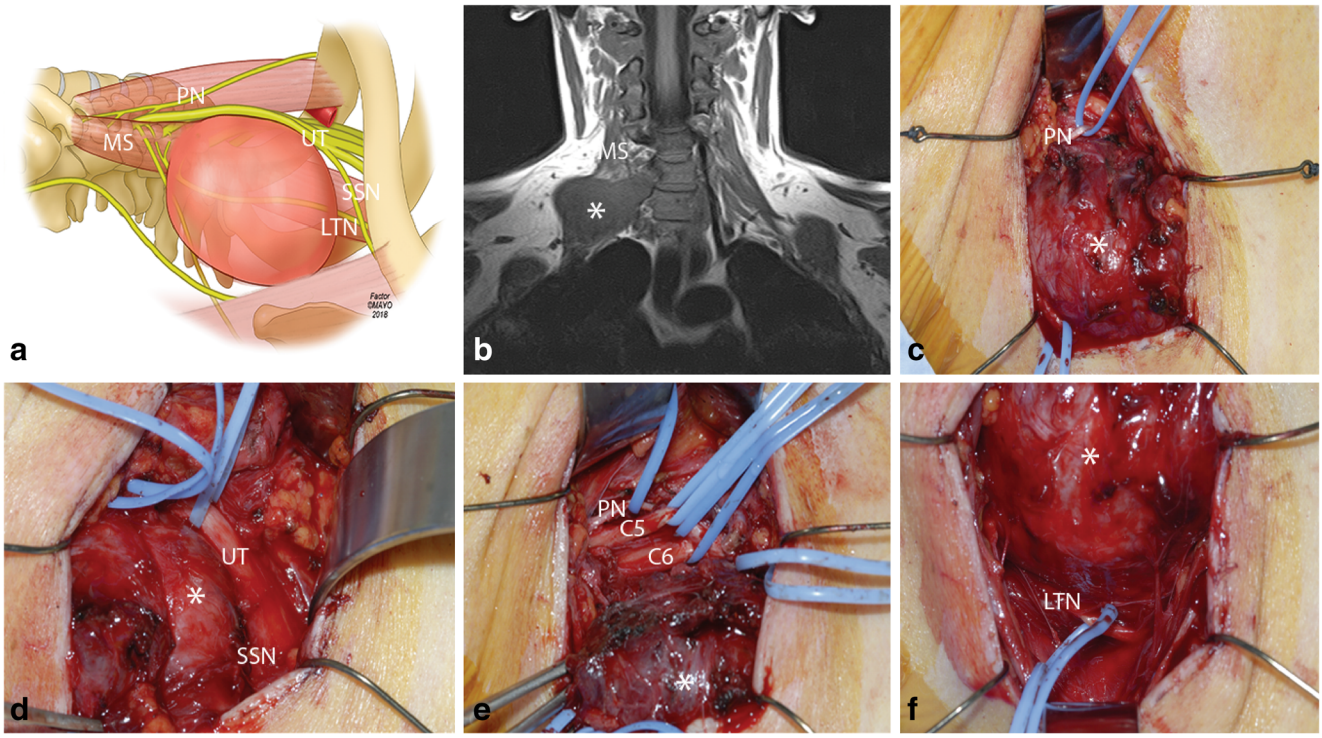

Fig. 3 **a** Depiction of relevant anatomy for middle scalene approach to a large right-sided C7 schwannoma. **b** Coronal T1-weighted MRI demonstrating a mass (asterisk) arising from C7 projecting just anterior to and displacing the middle scalene muscle (MS). **c** Intraoperative image during tumor exposure (asterisk) and early identification of the phrenic nerve (PN). **d** Dissection around the borders of the tumor (asterisk) allows for identification of the upper trunk (UT) and suprascapular nerve (SSN). **e** Proximal dissection along the upper trunk allows for better identification of the phrenic nerve (PN) as well as C5/C6 spinal nerves. **f** The suprascapular nerve can be traced around the border of the tumor to reach the superior border, where the long thoracic nerve (LTN) can be identified in the deep plane

step technique for identification of the nerves based from known anatomy may be beneficial to the surgeon approaching lesions of the middle scalene region. Key to this approach is consideration of the regional anatomy in a standard supraclavicular approach, the superficial plane, containing the anterior scalene muscle and brachial plexus, and the oblique plane containing the middle scalene muscle, long thoracic, spinal accessory, and dorsal scapular nerves. Identification and mobilization of each of these structures prior to lesion removal can not only provide likely boundaries of the tumor, but also allow for protection of the nerves to avoid injury.

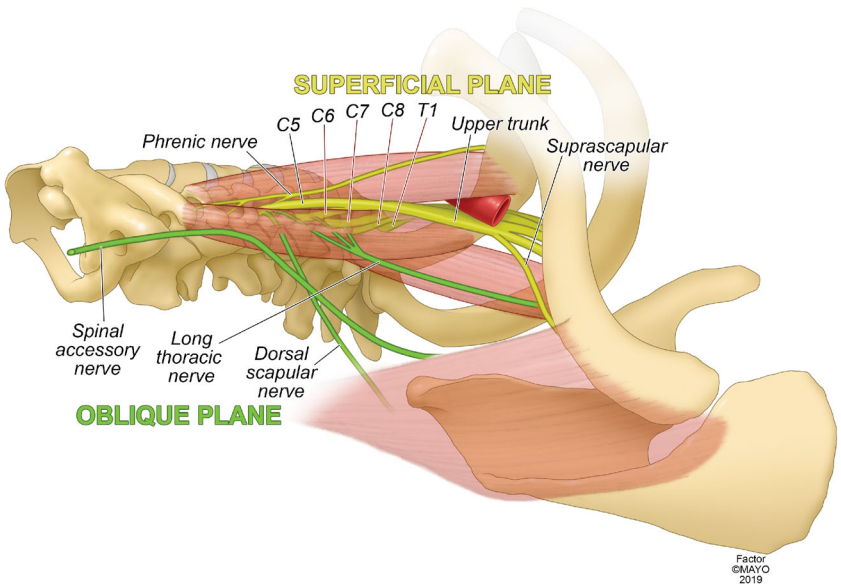

Fig. 4 Depiction of relevant anatomy for middle scalene approach and planes for the middle scalene approach. The superficial plane highlights the main brachial plexus elements, including the suprascapular and phrenic nerves. Initial anatomic identification begins with control of the brachial plexus prior to working with the middle scalene mass. The oblique plane highlights the dorsal scapular, long thoracic, and spinal accessory nerves that often are displaced posterior to the mass and must be identified and controlled to avoid scapular winging

Conclusion

Lesions of the middle scalene region often split two important anatomical planes, the superficial and oblique, creating an advantageous surgical corridor through an anterolateral approach. Through early identification of known anatomy, these two planes can be developed, and a safe approach to the lesion of the middle scalene region can be exploited.

Compliance with ethical standards The authors have been compliant with all applicable ethical standards in the publication of this manuscript.

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval IRB approval was obtained for this study. All patients included signed consent forms for the use of non-identifying medical information in medical research, including this study. For this type of study, formal consent is not required.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Akgun K, Aktas I, Terzi Y (2008) Winged scapula caused by a dorsal scapular nerve lesion: a case report. Arch Phys Med Rehabil 89:2017–2020. https://doi.org/10.1016/j.apmr.2008.03.015
2. Belmonte R, Monleon S, Bofill N, Alvarado ML, Espadaler J, Royo I (2015) Long thoracic nerve injury in breast cancer patients treated with axillary lymph node dissection. Support Care Cancer 23:169–175. https://doi.org/10.1007/s00520-014-2338-5
3. Benoit P, Deplante F (1994) Paralysis of the dorsal nerve of the scapula: an unusual cause of scapular displacement. Presse Med 23:348
4. Bertelli JA, Ghizoni MF (2005) Long thoracic nerve: anatomy and functional assessment. J Bone Joint Surg Am 87:993–998. https://doi.org/10.2106/JBJS.D.02383
5. Bishop KN, Varacallo M (2018) Anatomy, shoulder and upper limb, dorsal scapular nerve. In: StatPearls. Treasure Island (FL)
6. Cesmebasi A, Spinner RJ (2015) An anatomic-based approach to the iatrogenic spinal accessory nerve injury in the posterior cervical triangle: how to avoid and treat it. Clin Anat 28:761–766. https://doi.org/10.1002/ca.22555
7. Crowe MM, Elhassan BT (2016) Scapular and shoulder girdle muscular anatomy: its role in periscapular tendon transfers. J Hand Surg Am 41:306–314; quiz 315. doi:https://doi.org/10.1016/j.jhsa.2015.06.123
8. Didesch JT, Tang P (2019) Anatomy, etiology, and management of scapular winging. J Hand Surg Am 44:321–330. https://doi.org/10.1016/j.jhsa.2018.08.008
9. Fardin P, Negrin P, Dainese R (1978) The isolated paralysis of the serratus anterior muscle: clinical and electromyographical follow-up of 10 cases. Electromyogr Clin Neurophysiol 18:379–386
10. Leinberry CF, Wehbe MA (2004) Brachial plexus anatomy. Hand Clin 20:1–5
11. Lung K, Lui F (2018) Anatomy, thorax, long thoracic nerve. In: StatPearls. Treasure Island (FL),
12. Malessy MJ, Thomeer RT, Marani E (1993) The dorsoscapular nerve in traumatic brachial plexus lesions. Clin Neurol Neurosurg 95(Suppl):S17–S23
13. Mandoorah S, Mead T (2018) Phrenic nerve injury. In: StatPearls. Treasure Island (FL),
14. Nevola Teixeira LF, Lohsiriwat V, Schorr MC, Luini A, Galimberti V, Rietjens M, Garusi C, Gandini S, Sarian LO, Sandrin F, Simoncini MC, Veronesi P (2014) Incidence, predictive factors, and prognosis for winged scapula in breast cancer patients after axillary dissection. Support Care Cancer 22:1611–1617. https://doi.org/10.1007/s00520-014-2125-3
15. Restrepo CE, Tubbs RS, Spinner RJ (2015) Expanding what is known of the anatomy of the spinal accessory nerve. Clin Anat 28:467–471. https://doi.org/10.1002/ca.22492
16. Rizzi SK, Haddad CA, Giron PS, Pinheiro TL, Nazario AC, Facina G (2016) Winged scapula incidence and upper limb morbidity after surgery for breast cancer with axillary dissection. Support Care Cancer 24:2707–2715. https://doi.org/10.1007/s00520-016-3086-5
17. Stone J, Puffer RC, Spinner RJ (2019) Interfascicular resection of benign peripheral nerve sheath tumors. JBJS Essential Surgical Techniques 9

Comments The brachial plexus and associated pathology can be approached, exposed, and dealt with from different angles and planes. This article from the prolific group at the Mayo Clinic provides an excellent description of how to safely approach and remove tumors in the region of the middle scalene muscle while minimizing or preventing damage to functionally important nerves, especially those involved with stabilization of the scapula so as to prevent winging. The application of their approach is beautifully demonstrated and illustrated using preoperative imaging, intraoperative photographs, and schematic diagrams from three of their cases. Their concept of partitioning and visualizing structures involving upper and middle portions of the brachial plexus into a superficial and deep or oblique plane is useful. They show that masses arising in the region of the middle scalene muscle expand or split these planes apart, thereby providing an anterolateral surgical corridor through which the surgeon can safely identify and preserve early on the dorsal scapular, long thoracic, and spinal accessory nerves which are not always specifically exposed and identified. An advantage in taking this approach is that there is less need to resect the anterior scalene muscle upon which the phrenic nerve courses. Overall, this article provides a very useful conceptual framework for the surgeon that is likely to benefit patients with pathology in the region of the middle scalene muscle.

Michel Kliot
CA, USA