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SCIENTIFIC ARTICLE

Sonographically guided anesthetic injection of anterior scalene muscle for investigation of neurogenic thoracic outlet syndrome

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Abstract
Objective To describe the technique and complications of sonographically guided anesthetic injection of the anterior scalene muscle in patients being investigated for neurogenic thoracic outlet syndrome.
Material and methods Subjects were identified via a retrospective review of medical records. For the procedure a 25-gauge needle was introduced into the anterior scalene muscle under real-time ultrasound guidance followed by injection of local anesthetic. The procedures were evaluated for technical success, which was defined as satisfactory identification of anterior scalene muscle, intramuscular needle placement, and intramuscular delivery of medication. There was a short-term follow-up to determine procedure-related complications and rate of unintended brachial plexus (BP) block, manifested by upper extremity paresthesias and/or weakness.
Results Twenty-six subjects with suspected neurogenic thoracic outlet syndrome underwent 29 injections (three subjects received bilateral injections). Technical success was achieved in all procedures. The mean duration of the procedure was 30 min, and there were no cases of intravascular needle placement or neurogenic pain during the injection. No major complications occurred. Temporary symptoms of partial BP block occurred after nine injections (9/29, 31%), and a temporary complete BP block occurred after one injection (1/29, 3%).
Conclusion Sonographically guided anesthetic injection of the anterior scalene muscle is a safe and well-tolerated diagnostic test for patients being investigated for neurogenic thoracic outlet syndrome.

Keywords Thoracic outlet syndrome · Anterior scalene · Brachial plexus · Ultrasound · Percutaneous block

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Introduction

The definition of thoracic outlet syndrome (TOS) is "upper extremity symptoms due to neurovascular compression in the area of the neck above the first rib" [1]. The thoracic outlet has three anatomic compartments through which neurovascular structures must traverse to reach the upper extremity: the interscalene triangle, the costoclavicular, and the retropectoralis minor spaces [2]. While narrowing of these spaces may lead to vascular (arterial or venous) symptoms, over 95% of all TOS patients present with neurogenic TOS (NTOS) [1].

Clinical tests and electrodiagnostic studies are helpful to evaluate patients with suspected NTOS [1]. Scalene muscle blocks are especially useful to confirm a diagnosis of NTOS [3], with a good response being highly correlated with a good response to surgery [1, 4]. The aim of the procedure is to test if relaxing the anterior scalene muscle will lead to temporary relief of symptoms associated with

neurogenic compression. Based on the patient's response, management decisions and likely surgical outcome can be predicted [3].

Several techniques have been described to guide needle placement in the anterior scalene muscle, including the use of anatomical landmarks [3], and electromyography combined with sonography [5] or fluoroscopy [6]. However, the technical aspects and complications of a dedicated sonographic approach have not been described. We report our experience with sonographically guided anesthetic injections of the anterior scalene muscle in patients undergoing investigation for NTOS.

Materials and methods

This retrospective study was approved by the Institutional Review Board and complied with the guidelines of the Health Insurance Portability and Accountability Act ((HIPPA). We retrospectively reviewed the records of patients being evaluated for NTOS by a single thoracic surgeon. Between April and December 2008, patients were referred for sonographically guided anesthetic injections of the anterior scalene muscle, which is the procedure of choice for suspected NTOS in our institution. In all patients the indications for the procedure were varied degrees of pain in the neck, shoulder and upper extremity, with associated paresthesias of the hand. Patients with a history and clinical symptoms likely related to degenerative change of the cervical spine and to radiculopathy were not referred for anterior scalene blocks.

Available computed tomography and magnetic resonance imaging studies of the brachial plexus (BP) were evaluated prior to the procedure for preliminary assessment of neck soft tissues. There was no oral or intravenous administration of sedatives. Informed consent was obtained in the intervention suite and included a detailed explanation of the procedure, its benefits, risks and potential complications (allergic reactions, infection, bleeding, neurovascular injury and temporary BP block characterized by upper extremity paresthesias and/or weakness).

Patients with long hair were fitted with disposable surgical head caps. With the patient lying supine, a rolled towel was placed below the neck, and the head was rotated approximately 20° opposite to the injection site, exposing the region of sternocleidomastoid muscle. Using a General Electric Logiq 700 ultrasound unit (GE Healthcare, Waukesha, WI, USA) with a multi-frequency (7.5–12.0 MHz) linear transducer, a preliminary assessment determined the location of vascular structures, the anterior scalene muscle, and trunks of BP. Scanning was performed primarily in the transverse plane, with minor adjustments as needed. The selected frequency was 12 MHz, and there were 3 to 6 focal zones. The anterior scalene muscle was scanned along its craniocaudal extension and best visualized on images through its lower half. Once an adequate approach had been identified, a mark with indelible ink was made on the skin, adjacent to the lateral short axis of the transducer (Figs. 1 and 2). A lateral-to-medial needle approach was the preferred method in all cases, to decrease the likelihood of vascular injury. Patients undergoing bilateral injections were examined, and their skin was marked on the contralateral side. Color Doppler sonography was available but was not used, since the vascular structures were easily identified on gray-scale images. The skin surrounding the entry point mark was cleaned with betadine solution, and sterile drapes were placed. The ultrasound transducer was protected with a sterile cover containing a small amount of gel.

Approximately 1 ml of lidocaine 1% was injected subcutaneously at the previously marked site. A syringe containing 2 ml of bupivacaine 0.5% was connected to a 25-gauge 1.5-in. needle [4]. Using a free-hand technique, a radiologist oriented the needle–syringe set parallel to the transducer's imaging plane and angled it approximately 45° to the transducer's footprint. If needed, the angle of needle entry was adjusted to avoid superficial vessels such as the external jugular vein (Fig. 3). The needle was slowly advanced with intermittent back-and-forth movements to identify its tip, allowing adjustment of the entry angle. The

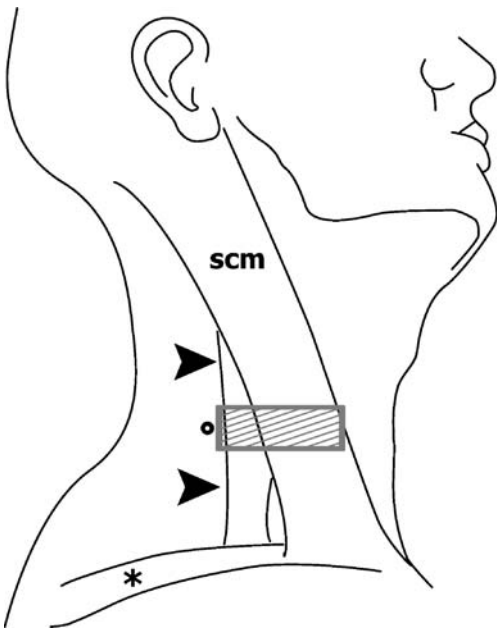

Fig. 1 Schematic adapted from [7] shows the approach for the sonographically guided injection of the right anterior scalene muscle. The lower half of the anterior scalene (*arrowheads*) is shown relative to the sternocleidomastoid muscle (*scm*). The needle entry point (*black circle*) is lateral to the ultrasound transducer footprint (*hatched rectangle*) and superior to the clavicle (*asterisk*)

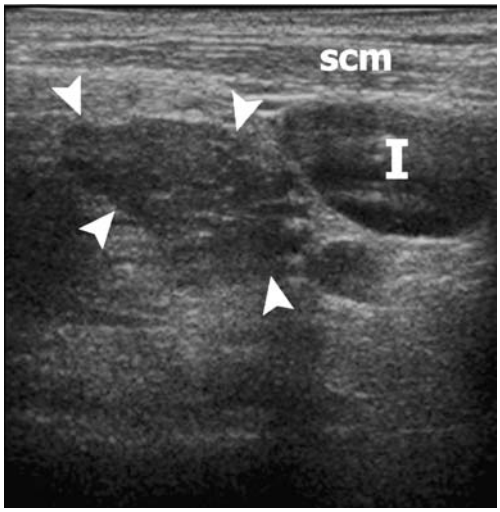

Fig. 2 Transverse sonographic image prior to needle placement, showing right anterior scalene muscle (delimited by *arrowheads*), internal jugular vein (*I*), and sternocleidomastoid muscle (*scm*)

entire needle was kept under sonographic visualization by rotary adjustment of the transducer's position (Fig. 4a). Once the needle tip was seen within the belly of the anterior scalene muscle, bupivacaine was slowly delivered under real-time monitoring (Fig. 4b). Adjustments in needle position during injection helped maximize the distribution of medication throughout the muscle cross-section. Constant communication with the patient during the injection helped the radiologist to adjust the injection rate to avoid any discomfort caused by expansion of the anterior scalene muscle. After the full volume had been injected, the needle

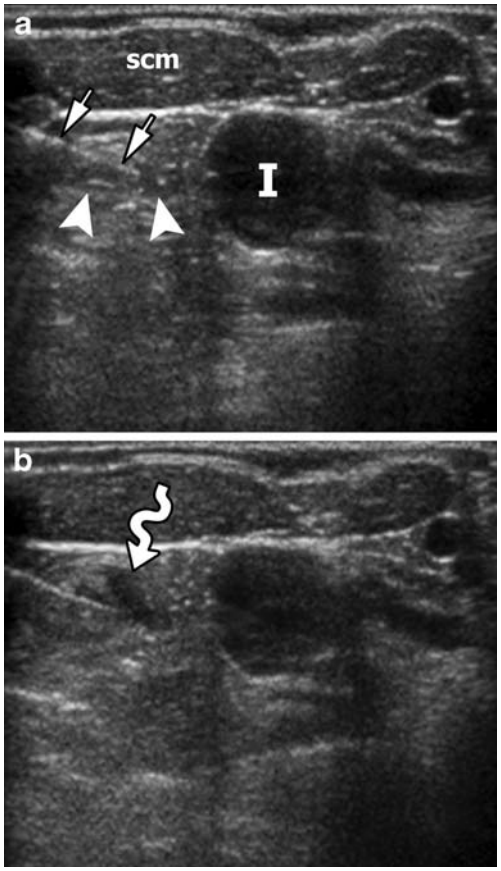

Fig. 4 **a**, **b** A 55-year-old woman with right-sided pain in the neck, shoulder and upper extremity. *arrowheads* delimit the posterior aspect of the right anterior scalene muscle. The needle (*arrows*) is seen within the muscle before (**a**) and after (**b**) injection of hypo-echoic local anesthetic (*wavy arrow*). *I* internal jugular vein, *scm* sternocleidomastoid muscle

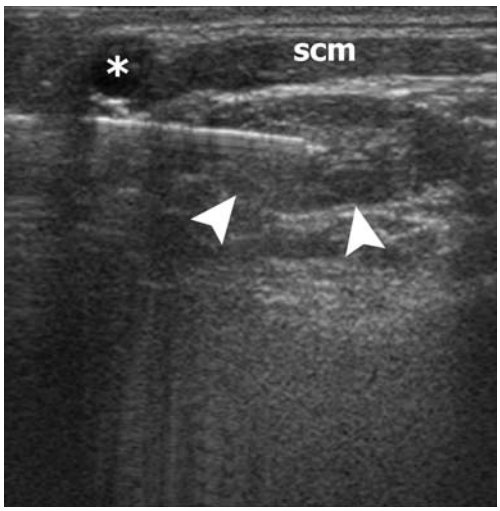

Fig. 3 A 19-year-old woman with right-sided pain in the neck, shoulder and upper extremity and symptoms of hand paresthesias. The needle was inserted into the anterior scalene muscle (*arrowheads*) with a shallow approach to avoid the external jugular vein (*asterisk*). *scm* sternocleidomastoid muscle

was removed. In bilateral injections the contralateral side was subsequently injected with a new needle–syringe set. After the skin had been cleaned, a sterile bandage was placed at the puncture site. The patient was discharged, with instructions on self-assessment for upper extremity symptoms. Short-term follow-up was carried out over the phone, for assessment of complications.

The procedures were evaluated for technical success, which was defined as satisfactory identification of anterior scalene muscle, intramuscular needle placement, and intramuscular delivery of medication. At a short-term follow-up, the patients were asked if their symptoms had improved or not, without the use of a detailed scale to assess the degree of improvement. Where there were symptoms of unintended BP block after the injections, classification was as follows: (A) partial block, in cases of mild to moderate paresthesia, numbness and/or weakness (focal if involving single trunk; diffuse if multiple trunks), and (B) complete block, in cases of severe diffuse numbness and/or motor deficit of the upper extremity.

Results

A total of 40 subjects was clinically examined for suspected NTOS between April and December 2008, of whom 26 (22 female and four male) aged between 19 and 69 years (mean 42 years) were referred for anterior scalene injection. The duration of symptoms prior to the initial examination was between 3 months and 10 years, being unilateral in 23 subjects and bilateral in three. The dominant symptoms were pain affecting the neck, shoulder and arm, associated with hand paresthesias.

A total of 29 sonographically guided anesthetic injections was performed, 12 on the right anterior scalene muscle and 17 on the left. Three subjects received bilateral injections. The anterior scalene muscle was reliably identified in all subjects. The mean duration of the procedure was 30 min (range 16–70 min). Technical success was achieved in 100% of cases. In all cases the tip of the needle was visualized within the anterior scalene muscle belly, which mildly expanded during the injection. No peri-muscular distribution of anesthetic was identified during the procedure. There were no cases of intravascular needle placement, and no subjects had neurogenic pain during the procedure. There were no instances of infection, abnormal bleeding, hematoma, or allergic reaction.

Same-day follow-up revealed improvement of symptoms after 11 procedures (11/29, 38%) and no change in symptoms after eight procedures (8/29, 28%). Symptoms of unintended BP block ipsilateral to the injection site were seen after ten procedures (34%, 10/29), of which nine were partial (9/10, 90%) and one complete (1/10, 10%). Partial block with focal involvement of C6 dermatome (thumb and/or index finger) occurred after four procedures, while diffuse involvement of C6 through C8 distribution (entire hand) occurred after two procedures. Details regarding the distribution of symptoms were not available for the remaining three subjects with partial blocks. One subject had severe diffuse weakness and numbness of the upper extremity, consistent with a complete BP block. In six subjects the duration of BP blocks was 6 h on average (range 5–7 h). This information was not available for the remaining subjects with BP blocks.

Discussion

The etiology of NTOS is most often related to prior neck trauma (86%), such as from a motor vehicle accident, fall, or work-related injury. The cause of NTOS may be unknown in 12% of cases and related to a cervical or anomalous first rib in 2% [1]. It is hypothesized that post-traumatic intrascalene muscle hemorrhage leads to scarring [1] and spasm that cause pressure on the BP. Subjects with cervical ribs, cervical bands, and congenitally narrow spaces between the anterior and middle scalene (scalene triangle) may be predisposed to developing NTOS symptoms after neck trauma. As seen in our cohort, NTOS affects predominantly women; however, the cause of this is unknown.

The diagnosis of NTOS is challenging, since most patients present with subjective complaints of positional or exertional arm pain, fatigue, and paresthesias affecting predominantly the fourth and fifth finger and ulnar forearm [1, 4]. In patients with NTOS, clinical examination may reveal tenderness over the scalene and trapezius muscles, a positive Tinel sign over the BP and a positive response to provocative maneuvers [1]. Electromyography and nerve conduction velocity studies are helpful to exclude other causes of symptoms; however, this can be limited by low sensitivity in mild cases and false negative results [1]. In the absence of well-defined anatomical abnormality (e.g., cervical rib), there are no well-defined criteria to establish the diagnosis of NTOS.

The scalene muscles arise from cervical transverse processes and insert on the first (anterior and middle scalene) and second (posterior scalene) ribs; they act as inspiratory muscles by elevating the ribs [7]. Injection into the anterior scalene muscle was first described as a diagnostic test for TOS in 1939, representing a useful technique to confirm the diagnosis of NTOS and the patient's potential response to surgery [1, 3, 4]. The aim of the procedure is to weaken the anterior scalene muscle temporarily, leading to temporary relief of symptoms associated with neurogenic compression. The simplest method for anterior scalene injection relies on anatomical landmarks: a needle is inserted approximately two finger breadths above the clavicle at the lateral edge of the sternocleidomastoid muscle [3]. A correctly placed needle will move synchronously with respiration. Potential complications of this method include vascular injury, needle proximity or entry into the BP trunks, and increased likelihood of BP block due to uncertainty of needle tip location.

In prior reports Jordan and colleagues [4–6] described alternative approaches to scalene block using electromyography combined with sonography or fluoroscopy. Although, by these techniques, no significant complications from the needle placement were reported, a dedicated sonographic approach was not described. In addition, there are no previously reported rates of unintended BP block after injection of anesthetic into the anterior scalene muscle. Our study demonstrated that sonographically guided injection of anesthetic into the anterior scalene muscle is safe and well tolerated. Sonography allowed precise depiction of anterior scalene muscle and intramuscular needle placement in all patients. Furthermore, real-time delivery of medication was

visualized, increasing the certainty of intramuscular delivery of the drug.

While no serious complications occurred in our series, temporary symptoms of BP block were seen in some patients. Despite the low injectate volume used in our study, it was possible that intramuscular anesthetic could have flowed back through the fascial puncture and come into contact with adjacent BP trunks. In this situation symptoms of multiple trunk involvement were more likely to have occurred (partial diffuse or complete blocks). However, the most frequent observation in our series was a partial focal BP block, which could result from anatomical variations in the trajectory of BP trunks. Prior studies in cadavers have shown that components of the upper trunk (C5 and C6 nerves) may pierce the anterior scalene in up to 34% of cases, as opposed to the expected intermuscular trajectory between anterior and middle scalene muscles [8, 9]. Therefore, it seems reasonable for one to hypothesize that intramuscular diffusion of anesthetic could affect nerves traveling through the anterior scalene muscle and cause symptoms such as transient paresthesias and numbness of thumb and index finger. The temporary nature of these blocks warrants the inclusion of this information in the consent procedure, as well as instruction to the patient to avoid potentially hazardous activities that involve the arm ipsilateral to the injection site (e.g., driving) for at least 7 h after the procedure. Considering the unique capability of sonography to demonstrate delivery of anesthetic within the muscle, we believe the BP blocks in our series would likely have occurred under other guidance methods. Nevertheless, our data cannot determine the etiology of these blocks. Although a lower volume of intramuscular anesthetic could decrease the frequency of BP blocks, the final effect in muscle relaxation may be compromised by lower dosage.

The patient's response to an anterior scalene anesthetic injection provides an indication of surgical success, with symptom improvement correlating with good response to surgery [1, 4]. The significance of improved symptoms after anterior scalene injection in our series is currently unknown and will be correlated with physical therapy and surgical outcome in future studies. In subjects with partial and complete BP blocks, responses were considered unreliable, since improvement of symptoms may be a function of transient anesthesia. In these cases, chemodenervation of the anterior scalene with botulinum toxin type A represents an alternative to anesthetic blocks, with the advantage of longer symptom relief and no potential BP block [5, 6]. The technique described in our study can be used for botulinum toxin injection into the anterior scalene muscle with no modification other than an appropriate consent procedure and drug selection.

In summary, our study demonstrated that sonographically guided anesthetic injections of the anterior scalene muscle are safe and well-tolerated, and that unintended BP blocks may occur in up to a third of the procedures. The technique described in this study can be employed for reliable intramuscular delivery of other medications, such as botulinum toxin type A.

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