Development and Validation of a New Technique for Ultrasound-Guided Stellate Ganglion Block

Michael Gofeld, MD,* Amuj Bhatia, MD,† Sherif Abbas, MD,‡ Sugantha Ganapathy, MD,§ and Marjorie Johnson, PhD||

Background and Objectives: Although the stellate ganglion is located anteriorly to the first rib, anesthetic block is routinely performed at the C6 level. Ultrasonography allegedly improves accuracy of needle placement and spread of injectate. The technique is relatively new, and the optimal approach has not been determined. Moreover, the location of the cervical sympathetic trunk relative to the prevertebral fascia is debatable.

Methods: Three-dimensional sonography was performed on 10 healthy volunteers, and image reconstruction was completed. On the basis of analysis of pertinent anatomy, a lateral trajectory for needle placement was simulated. Accuracy was tested by injection of methylene blue in cadavers. A clinical validation study was then conducted. A block needle was inserted according to the predetermined lateral path, and 5 mL of a mixture of bupivacaine and isosorbide was injected. Spread of the contrast agent was verified fluoroscopically.

Results: Image reconstruction revealed that the cervical sympathetic trunk is located postero-laterally to the prevertebral fascia on the surface of the longus colli muscle. The mean anteroposterior width of the muscle at the C6 level was 11 mm. The lateral approach does not interfere with any visceral or nerve structures. Anatomic dissection in cadavers confirmed entirely subfascial spread of the dye and staining of the sympathetic trunk. The contrast agent spread was seen in all patients between the C4 and T1 levels in a typical prevertebral pattern.

Conclusions: This study revealed that, at the C6 level, the cervical sympathetic trunk lies entirely subfascially. Subfascial injection via the lateral approach ensures reliable spread of a solution to the stellate ganglion.

(Reg Anesth Pain Med 2009;34: 475-479)

stellate ganglion block has been used since the mid-1930s. First implemented by Leriche and further refined by Findley and Patzer, this method has been practiced since then without significant modifications. It is a common intervention in the diagnosis and management of sympathetically mediated pain and vascular insufficiency of the upper extremities. In addition, this type of anesthetic block has been advocated for treatment of a variety of medical conditions, such as phantom pain, postherpetic neuralgia, cancer pain, cardiac arrhythmias, orofacial pain, and vascular headache.6

Although an inferior C7 approach to stellate ganglion block has been described, the anesthetic is routinely administered according to the following anatomic landmarks: prominent anterior tubercle of C6 vertebra (Chassaignac tubercle), cricoid cartilage, and carotid artery. This essentially "blind" injection is associated with a variety of adverse effects and complications, such as intravascular injection, formation of hematomas, temporary paralysis of the recurrent laryngeal nerve, and esophageal injury.6,9

Injection of anesthetic at the C6 level has a long history, but its reliability in achieving blockade of the sympathetic trunk and cervicothoracic (stellate) ganglion remains uncertain. In addition, the course of the cervical sympathetic trunk (CST) relative to the longus colli muscle and the prevertebral fascia continues to be in dispute. Although some anatomic and imaging studies indicate a subfascial position, others relate the path of the trunk to the superficial plane.12,13

A method of stellate ganglion blockade under ultrasound guidance was described in 1995 but has only recently gained popularity. Ultrasound guidance can reduce the volume of local anesthetic required to achieve reliable blockade and should also prevent unintentional puncture of blood vessels and the esophagus.5,9

The current study was undertaken to determine the sonoanatomy of the CST and to determine the feasibility of ultrasound-guided blockade. In addition, an attempt was made to develop a safe and reliable injection technique, which will be essential for clinical implementation and popularization. Finally, the ultrasound-guided injection method was validated against a standard imaging technique (fluoroscopy).

METHODS
Identification of Pertinent Anatomic Structures and Simulation of Injection

Sunnybrook Health Sciences Centre research ethics board waived their requirement for full application and approval of the volunteer part of the protocol. We performed bilateral ultrasonographic examination of the anterolateral neck (left and right sides) in 10 healthy volunteers, for a total of 20 examinations. We used a Voluson-i machine and RSP6-16-RS transducer (GE Medical Systems, Milwaukee, Wis). The transducer was initially placed at the level of the cricoid cartilage, above the sternocleidomastoid muscle. Short-axis ultrasonography revealed typical appearance of the C6 transverse process, with a prominent anterior tubercle, a shorter posterior tubercle, and the exiting C6 nerve root. The longus colli muscle was seen as an oval structure adjacent to the base of the transverse process and vertebral body. Sometimes the caudal portion of the longus capitis muscle could be seen as well (Fig. 1A). Scanning
FIGURE 1. Short-axis ultrasonography of the neck. A, C6 level. at indicates anterior tubercle; CA, carotid artery; IJV, internal jugular vein; LCo, longus colli muscle; LCp, longus capitis muscle; N, C6 nerve root; pt, posterior tubercle; PVF, prevertebral fascia; SCM, sternocleidomastoid muscle; B, C7 level. N indicates C7 nerve root; TP, transverse process.

caudally and slightly dorsally brought the C7 transverse process into the view. Unlike the C6 transverse process, the C7 transverse process has no anterior tubercle. The C7 nerve root was situated just anterior to the transverse process (Fig. 1B).

At the C6 level, a spindle-shaped structure was inconsistently localized on the short-axis view (the middle cervical ganglion). It was typically situated on the posterolateral surface of the longus colli muscle; if the ganglion could not be identified, some widening of the tissue plane below the prevertebral fascia could usually be appreciated. Once all of the mandatory anatomic structures (transverse process of C6, vertebral body, and longus colli muscle) had been visualized, 3-dimensional scanning was performed. After image reconstruction, the anatomic location of the sympathetic trunk was identified and its relationship to neighboring structures was studied.

After analyzing the images, a previously described ultrasound-guided anterior technique was deemed suboptimal. Although displacement of the carotid artery and thyroid may create a passage for needle placement (Fig. 2), this approach requires application of force to the tissues and yet does not prevent vascular and visceral damage. Therefore, an attempt to develop a safer technique was deemed necessary. To accomplish this, a simulated injection was performed in all volunteers. With the transducer placed as shown in Figure 3, only the anterior tubercle of the C6 transverse process was visible adjacent to the projected entry point of the needle, and no visceral or neural elements were situated on the line connecting the entry site and the lateral surface of the longus colli muscle. Occasionally, the internal jugular vein was seen within the projected needle track, but it could be collapsed readily under light transducer pressure. Typically, the simulated passage was entirely intramuscular, that is, through the sternocleidomastoid muscle or the anterior scalene muscle or both.

Verification of Subfascial Location of the Sympathetic Trunk (Cadaveric Study)

Dissection of a cadaver and publication of the images were approved by the Cadaveric Research Review Committee of the Department of Anatomy and Cell Biology, according to the ethical standards of the University of Western Ontario.

Two adult cadavers (1 male and 1 female) were used. The procedure was performed on the left side. The anatomic features of the C6 vertebra and the longus colli muscle were studied in the same fashion as in the healthy volunteers, but 3-dimensional imaging was not performed. The injections were administered via the lateral pathway determined in the initial phase of the study. The block needle was advanced using in-plane short-axis to the C6 vertebra technique and positioned immediately under the prevertebral fascia on the surface of the longus colli muscle. Methylene blue (0.2 mL) was injected, and the needle was withdrawn.

The heads were turned slightly to the right, and necks were positioned in extension. Dissections were performed anteriorly to the sternocleidomastoid muscle approximately 2 spinal segments above and below the injection level (C6). The sternocleidomastoid muscle was retracted together with carotid sheath. The deep fascia was exposed and dissected. The CST was identified and verified by an experienced anatomist (M.J.).

Imaging and Clinical Validation

The clinical phase of the study was approved by the Sunnybrook Health Sciences Centre Research Ethics Board, and the patients gave their written informed consent. We performed 10 sympathetic blocks in 7 patients at the level of the C6 vertebra, according to the knowledge of anatomy acquired through examination of volunteers and dissection of cadavers (described previously). Patients were placed in the lateral decubitus position, with the side to be treated uppermost. The skin was prepared and draped in a sterile fashion. The 13-6 MHz 38-mm broadband linear array (model HFL38; SonoSite, Inc, Bothel, Wash) was covered by a sterile adhesive bandage (Tegaderm, 3M Health Care, St. Paul, Minn). Ultrasonography was performed as previously described. A skin wheal was raised with 1 mL of 2% lidocaine applied immediately posterior to the ultrasound transducer. Under real-time ultrasound guidance, a 22-gauge spinal needle was inserted via the lateral pathway.

FIGURE 2. Anterior short-axis view of the neck structures at the C6 level, with application of pressure. The thyroid gland (Th) and the carotid artery (CA) are clearly separated, and the inferior thyroid artery (ITA) can be seen. VB indicates C6 vertebral body.
fluoroscopy was performed. Images of the cervical spine with shadows of the contrast agent were printed for documentation. All patients were closely monitored for at least 30 minutes after the injection. Signs of the sympathetic blockade as well as occurrence of adverse effects were recorded.

RESULTS
Identification of Pertinent Anatomic Structures and Simulation of Injection
The images obtained from healthy volunteers were analyzed by comparing the axial image with sagittal and coronal views; this was accomplished by digitally “slicing” the tissue planes starting just above the prevertebral fascia. In this way, we were able to identify the fascial planes, the sympathetic trunk, and the longus colli muscle. Image analysis showed that the CST is typically situated subfascially between the posterolateral surface of the longus colli muscle and the prevertebral fascia, posterior to the common carotid artery. Coronal imaging showed the oblique descending pathway of the CST from the C5 level to the C7 level (Fig. 5). The epimysium of the longus colli muscle appears as a soft hyperechoic nonsolid layer of connective tissue. The mean anteroposterior thickness of the muscle on C6 level was 11 mm (range, 9.1 ± 1.27 mm), and there were no significant differences between the left and right sides. In 3 volunteers, a distinct nodular structure was apparent, which we identified as the middle sympathetic cervical ganglion. Using the caliper tool, a line was extended from the skin (needle entry site) to the sympathetic trunk (lateral pathway for placement of the block needle). It consistently traversed the sternocleidomastoid and/or the anterior scalene muscle, without interfering with any visceral or nerve structures.

Verification of Subfascial Location of the Sympathetic Trunk (Cadaveric Study)
Deposition of methylene blue was carefully observed during dissection of the cadavers. No dye was found superficial to the prevertebral fascia (Fig. 6), and the sympathetic trunk was strongly stained at the level of injection (C6 vertebra). Even with

![Figure 3](image1.png)

**FIGURE 3.** When the linear transducer is held in the optimal position, only the anterior tubercle of C6 is seen posteriorly. Simulated pathway (white line) connects the entry site and the lateral surface of the longus colli muscle.

![Figure 4](image2.png)

**FIGURE 4.** Block needle (arrowheads) has been placed under the prevertebral fascia. Initial injection of 0.9% NaCl (asterisks) separates LCo from the fascia.

![Figure 5](image3.png)

**FIGURE 5.** Reconstruction of 3-dimensional image at C6. On the axial image navigating “dot” is positioned under the prevertebral fascia (upper left); coronal view (lower left) showed the cervical sympathetic trunk spread-eagled on the longus colli muscle. No solid fascial layer is seen between the trunk and the muscle.
a low-volume injection (0.2 mL), the CST in the target area was completely bathed in dye.

**Imaging and Clinical Validation**

The injectate spread between the C4 and T1 spinal vertebrae in all cases, with occasional extension to the C3 (n = 2) and the T2 levels (n = 1). The radiographic results were compatible with previous descriptions of the typical prevertebral radiopaque contrast agent deposit (Fig. 7). No intramuscular deposit pattern of the contrast was observed in all cases. All of the patients had 2 or more clinical signs of successful sympathetic blockade of the upper extremity, such as temperature elevation, venous engorgement, and vascular flushing. Some degree of Horner syndrome was evident in all patients. Despite the subjective feeling of a lump in the throat (reported by 2 patients), no cases of hoarseness were observed, and there were no other complications or adverse effects.

**DISCUSSION**

The aim of this study was to conduct in vivo verification of assumption that the CST is located subfasically in the prevertebral compartment and precise injection of relatively small (5 mL) volume will spread from the midcervical CST to the T1 level where the cervicothoracic (stellate) ganglion is located. Both research targets were accomplished. Three-dimensional ultrasonography provided the evidence of in vivo topographic anatomy, whereby cadaver dissection and clinical imaging delivered the answer regarding feasibility and accuracy of the injection technique. We had no intention to support or decline clinical efficacy of the stellate ganglion anesthetic blockade.

The anatomy and position of the stellate ganglion (also known as the cervicothoracic ganglion) have been confirmed by dissection, magnetic resonance imaging, and computed tomography. This ganglion is described as a structure 1 to 2.5 cm long, approximately 1 cm wide, and 0.5 cm thick. It is present in approximately 80% of the population, representing a fusion of the inferior cervical ganglion and the first thoracic ganglion. It is located just anterior to the transverse process of the C7 vertebra and superior or anterior to the neck of the first rib. Cephalad to it, at the level of C6, the middle cervical ganglion may be located anterolaterally to the belly of the longus colli muscle, or alternatively, only traversing fibers of the CST are apparent. The cervical prevertebral fascia is attached to the base of the skull and extends over the prevertebral muscles (longus capitis, rectus capitis, and longus colli muscles) to attach distally at the T4 vertebra, just beyond the longus colli muscle. This position of the fascia forms a plane along which the injected fluid can flow.

Given that only traversing sympathetic fibers or middle cervical ganglia can be found at the C6 level, the procedure should more accurately be called cervical sympathetic block. Several clinical and cadaver trials have been performed in an attempt to elucidate the pattern of spread when solutions are injected at the C6 level. The results of these studies have been conflicting. The results of a cadaver study suggested that only deposition of solution into the prevertebral interfascial space provides reliable spread to the stellate ganglion.

Having no agreement regarding radiologically controlled injections, routine blind technique is deemed even more ambiguous. It is typically performed using a so-called paraskeletal approach and placing the needle toward the lateral part of the C6 vertebra body. The needle is then to be withdrawn by 1 to 5 mm and a solution is to be injected. This maneuver was claimed to be sufficient to position the needle outside the longus colli muscle (ie, where the sympathetic trunk is believed to be situated). However, our results indicate that the actual size of the longus colli muscle is thicker than was previously suggested. As such, routine injection by the traditional method may lead to intra-muscular injection, and the CST will be anesthetized only by overflow or diffusion of the injectate.

Fluoroscopy-guided cervical sympathetic block has the advantages of allowing identification of the bony anatomy and reducing overall risk through prior injection of a contrast agent. However, the anatomic position of the CST is determined by surrounding soft tissues (the longus colli muscle, the thyroid,

---

**FIGURE 7.** Anteroposterior radiograph of the contrast spread. The dye is clearly seen at the level of T1 where the stellate ganglion is typically located.

© 2009 American Society of Regional Anesthesia and Pain Medicine
and the esophagus) rather than the cervical vertebrae. As such, fluoroscopic control cannot be used to ensure precise needle placement, and injection of a contrast agent is required; however, the contrast agent may show aberrant and inconsistent spread. Therefore, the success or failure of either blind or fluoroscopically-guided injection depends entirely on the thickness of the longus colli muscle and the anatomic location of the CST.

Ultrasound guidance was deemed the logical solution to ensure accurate injection when soft tissues are involved. Clear imaging of the muscles, fasciae, blood vessels, viscera, and bone surface makes ultrasonography superior to fluoroscopy for image-guided CST block. In 1995, Kapral et al. described a technique and published a case series. Compared with blind injection, these authors found that ultrasound-guided stellate ganglion block used a lower volume of local anesthetic (5 mL rather than 8 mL), was not associated with formation of hematomas (whereas 3 patients in the blind injection group had a hematoma), and was associated with more rapid onset of Horner syndrome. However, because tissue visualization was probably not feasible below the C7 level, these authors concluded that a local anesthetic depot was limited to the C4 to C7 levels and speculated that the upper extremity sympathetic blockade was not related to blockade of the stellate ganglion per se. Their findings agreed with those published by Hogan and Erickson, but these observations and conclusions have been challenged by results presented here, in which the contrast agent spread between the C4 and T1 levels in all 10 cases, occasionally reaching T2 level.

Shibata et al. suggested that subfascial injection would result in better spread of the injectate and more reliable sympathetic blockade. The published image is ambiguous, and it is not clear whether subfascial or intramuscular injection was actually performed. Such deposition of the injectate can be a limiting factor in the onset and spread of blockade. In the present study, injection of 5 mL of local anesthetic subfascially but externally to the longus colli muscle ensured reliable spread of the solution to the stellate ganglion.

Narouze et al. further emphasized the risks of a blind approach, pointing out that blind injection at the C6 level on the left side may cause unintentional esophageal puncture; in addition, the needle invariably traverses the thyroid gland. Hematoma formation is likely related to damage to the inferior thyroid artery. These observations are important, but to date, no practical solution to the problem has been recommended. Using the anterior approach, the needle is inserted through the thyroid gland, adjacent to the carotid artery and close to the inferior thyroid artery and the recurrent laryngeal nerve. In addition, this approach requires the application of pressure to the anterior neck, which is troubling for most patients.

In the study reported here, we attempted to find a pathway for needle placement, away from vital neck structures. This method has been previously published but required experimental validation. We performed scanning and simulated injection using volunteers, confirmed these initial results in 2 cadavers and in a small clinical study. Three-dimensional reconstruction and image analysis supported our conclusion that the CST is located below the prevertebral fascia, on the surface of the longus colli muscle. The longus colli muscle is thicker than can be inferred from the literature. Therefore, we conclude that routine blind injection may result in intramuscular deposition of the injectate. Visualization of the soft tissue, vessels, and cervical sympathetic ganglia may make ultrasound imaging guidance superior to fluoroscopy. Subfascial injection of 5 mL of local anesthetic reliably spread to the midneck CST and the stellate ganglion. Ultrasound guidance may prevent complications and adverse outcomes associated with either blind or fluoroscopically-guided techniques, but a larger clinical study will be required to prove this assertion.

REFERENCES