



Evaluation of sonoanatomy relevant to performing stellate ganglion blocks using anterior and lateral simulated approaches: an observational study

Évaluation de l'écho-anatomie pour la réalisation d'un bloc du ganglion stellaire avec une simulation des abords antérieur et latéral : étude observationnelle

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Abstract

Purpose *Stellate (cervicothoracic) ganglion block (SGB) can be associated with serious complications, such as esophageal and vascular injury. The objective of this study was to evaluate the potential for vascular and esophageal injury in healthy subjects by examining the sonoanatomy of the neck relevant to the SGB at the sixth (C6) and seventh (C7) cervical vertebral levels and determining the incidence of blood vessels and esophagi in the simulated path of needle insertion in the conventional and two different ultrasound-guided approaches used to perform a SGB.*

Methods *Ultrasound scanning of the neck at the C6 and C7 cervical vertebral levels was performed in 100 adult subjects, and the following measurements were obtained: the degree of deviation of the esophagus relative to the larynx/trachea; the likelihood of encountering a vessel in*

the simulated path of needle insertion in the two different approaches to SGB; the incidence of the vertebral artery being situated outside the foramen transversarium at the C6 level; and the distance of the simulated path of needle insertion in the anterior and lateral approaches to SGB at the C6 level.

Results *The position of the esophagus was found to be variable but lateral to the airway in 50% and 74% of the subjects at C6 and C7, respectively. The esophagus covered more than half of the distance between the airway and the carotid artery in 14% and 44% of the subjects at the C6 and C7 levels, respectively. With the anterior approach, a major vessel was observed in up to 29% and 43% of patients at the C6 and C7 levels, respectively. The vertebral artery was outside the foramen transversarium in 7% of subjects at the C6 level.*

Conclusion *Major blood vessels and the esophagus are in close proximity to needle pathways during the anterior approach to SGB performed with either anatomic landmarking or fluoroscopic guidance. An ultrasound-guided lateral approach at the C6 level may possibly confer a greater margin of safety for performing SGB.*

This study was conducted with written informed consent from the study subjects.

This report describes an observational clinical study, and it adheres to the STROBE guidelines.

Author contributions *Anuj Bhatia, David Flamer, and Philip W.H. Peng have seen the original study data and reviewed the analysis of the data. Anuj Bhatia is the author responsible for archiving the study files.*

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Résumé

Objectif *Le bloc du ganglion stellaire (cervicothoracique) (BGS) peut être associé à des complications graves, telles que des lésions œsophagiennes et vasculaires. Les objectifs de l'étude étaient les suivants : étudier l'écho-anatomie du cou pertinente pour le BGS au niveau des 6^e et 7^e vertèbres cervicales (C6 et C7) chez des patients en bonne santé, évaluer le risque de lésion vasculaire et œsophagienne en enregistrant l'incidence des vaisseaux sanguins et de*

l'œsophage, respectivement, sur le trajet simulé d'une aiguille dans le cas d'un abord conventionnel et de deux abords guidés par échographie pour un BGS.

Méthodes L'étude échographique du cou a été réalisée chez 100 sujets adultes au niveau des vertèbres cervicales C6 et C7. Les mesures suivantes ont été obtenues : le degré de déviation de l'œsophage par rapport au larynx et à la trachée, la probabilité de croiser un vaisseau sanguin sur le trajet simulé de l'aiguille avec deux abords différents pour un BGS, l'incidence de l'artère vertébrale en dehors du trou transversaire au niveau C6, et la longueur du trajet simulé pour un abord antérieur ou latéral pour un BGS au niveau C6.

Résultats Il a été constaté que la position de l'œsophage est variable, mais externe par rapport à la voie aérienne chez 50 % et 74 % des sujets aux niveaux C6 et C7, respectivement. L'œsophage couvrait plus de la moitié de la distance séparant la voie aérienne de l'artère carotide chez 14 % et 44 % des sujets aux niveaux C6 et C7, respectivement. La présence d'un grand vaisseau était observée chez jusqu'à 29 % et 43 % des patients aux niveaux C6 et C7, respectivement avec l'abord antérieur. L'artère vertébrale était en dehors du trou transversaire chez 7 % des sujets au niveau C6.

Conclusion Des grands vaisseaux sanguins et l'œsophage sont à proximité immédiate des trajets de l'aiguille dans le cas d'un abord antérieur pour BGS réalisé avec un repérage anatomique ou sous guidage par fluoroscopie. Un abord latéral guidé par échographie au niveau C6 pourrait procurer une plus grande marge de sécurité pour la réalisation d'un BGS.

The stellate (cervicothoracic) ganglion block (SGB) is an accepted intervention for the treatment of a variety of pain conditions of the head and neck regions as well as the upper limbs.¹ In addition, this procedure has been performed increasingly for non-painful conditions.²⁻⁴ The common techniques for SGB are the paratracheal approaches performed at the level of the transverse process of the sixth (C6) or the seventh cervical vertebra (C7).^{5,6} These techniques are conventionally guided by the use of anatomic landmarks and/or fluoroscopy,^{4,7} but both of these techniques can be associated with complications. There are many important soft-tissue structures that can be inadvertently pierced at these levels during needle placement for SGB,⁸⁻¹⁰ including the trachea, thyroid gland, esophagus, arteries (carotid, vertebral, inferior thyroidal, deep and ascending cervical), cervical nerve roots, and external jugular vein. Puncture of the esophagus and blood vessels can result in serious complications, such as esophagitis, mediastinitis, and hematoma, and injection of local

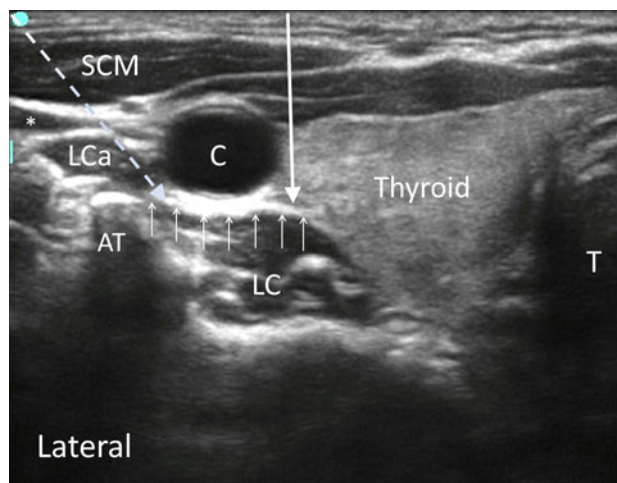


Fig. 1 Ultrasound image of the neck at the sixth cervical vertebral level. C6 = sixth cervical vertebra; C = carotid artery; * = Internal jugular vein (compressed); SCM = sternocleidomastoid muscle; LC = longus colli muscle; LCa = longus capitis muscle; T = airway; AT = anterior tubercle. The prevertebral fascia is marked by small solid arrows. The needle paths of the anterior and lateral approaches are marked by long solid and dotted arrows, respectively

anesthetic into a vertebral artery can precipitate seizures. This is more likely at the C7 level because this vessel is extraforaminal and exposed at this level.

Ultrasound is being used increasingly in pain management interventions.⁸ Use of ultrasound can help to identify and potentially avoid penetration of vessels, nerves, and soft tissue structures that cannot be reliably avoided when using an anatomic landmarking technique or fluoroscopy for procedural guidance.^{11,12} There is a 25% incidence of hematoma formation with the landmark-based approach for SGB.¹³ Although the vast majority of hematoma is asymptomatic, retropharyngeal hematoma formation can result in catastrophic complications.¹⁴

Two different needle approaches for ultrasound-guided SGB have been described. The first is the “out-of-plane” anterior approach (similar to the paratracheal approach) and the other is the “in-plane” lateral approach (Fig. 1).^{8,10,13} In a recently published study, it was suggested that the ultrasound-guided anterior approach for SGB may avoid penetration of the esophagus and blood vessels¹⁵; however, this study estimated the potential for vascular and esophageal puncture with conventional (non-image-guided) paratracheal approaches at the C6 and C7 levels, and risk with the lateral approach was not evaluated.

There were two objectives in this study. The first objective was to examine the sonoanatomy of the neck relevant to the SGB at the C6 and C7 levels in adult subjects. The second objective was to evaluate the anatomic margins relative to potential for vascular and esophageal puncture with simulated needle paths for conventional

SGB and ultrasound-guided SGB using the anterior or the lateral approach. We hypothesized that the ultrasound-guided lateral approach at the C6 level would confer a greater distance between the simulated path of the needle and the great vessels of the neck and the esophagus.

Methods

General description

Following approval of the Research Ethics Board of the University Health Network and after obtaining written informed consent, one hundred healthy volunteers aged 18-70 yr were recruited for this study during March to September, 2011. The study was advertised through posters in the University of Toronto and e-mails to all employees of the hospital. Subjects were excluded from the study if they were unable to provide informed consent or if they had undergone either surgery or trauma to the neck.

Scanning procedure

Each volunteer was positioned supine with her/his head in the neutral position during ultrasound scanning performed by one of the investigators (D.F.). A SonoSite M-Turbo® Ultrasound System (Seattle, USA) with a 6-13 MHz resolution linear transducer was used to scan over two cervical vertebral levels - C6 and C7.

The ultrasound probe was initially placed at the level of the cricoid cartilage, and the C6 transverse process was identified by the prominent anterior tubercle. The level of C6 was further confirmed by moving the ultrasound probe caudally to reveal the C7 transverse process with a single (posterior) tubercle. A typical sonographic appearance at the C6 level included the transverse process and anterior tubercle of C6, longus colli muscle (LC), longus capitis muscle, carotid artery, and thyroid gland (Fig. 1). At the C7 level, the vertebral artery was visualized as a pulsating structure with an arterial Doppler signal that could be followed in a cranial direction where it entered the foramen transversarium (Fig. 2).

Three lines were defined as the reference lines for measurements (Fig. 3). Line X was the line drawn anteroposteriorly from the lateral border of the cricoid or trachea at the C6 and C7 levels, respectively. Line Y was the line drawn anteroposteriorly from the medial border of the carotid artery. The area between line X and line Y was defined as the “anterior zone” that encompassed the needle path for anterior approaches to SGB, with or without image-guidance (fluoroscopy or ultrasound). The area lateral to line Y and anteromedial to the transverse process of the cervical vertebrae (anterior tubercle at C6 level,

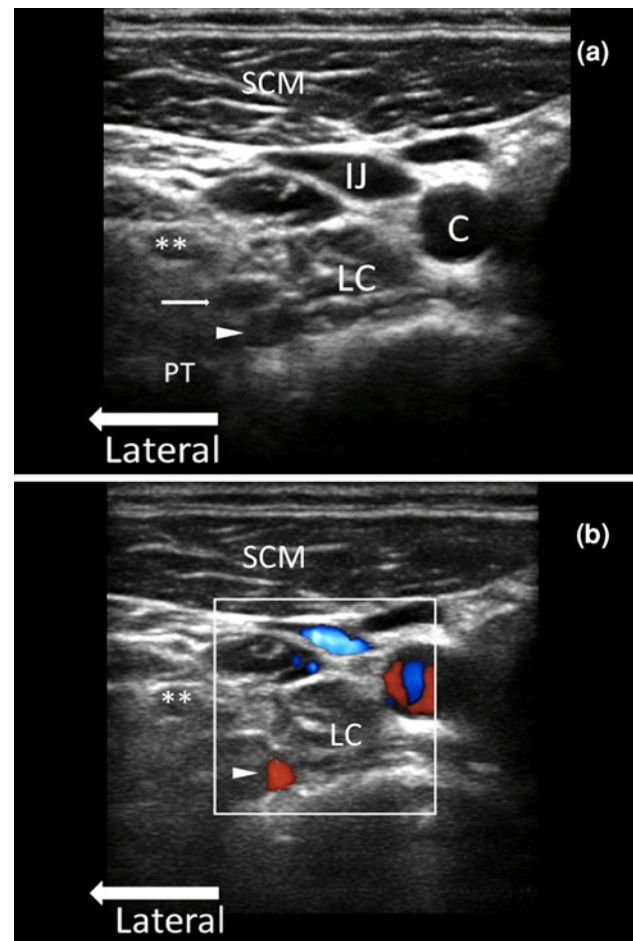


Fig. 2 a. Ultrasonographic image of neck at seventh cervical vertebral level (C7). b. Ultrasonographic image of neck at the same level with Doppler imaging. Arrow head = vertebral artery; line arrow = vertebral vein; ** = C7 nerve root; C = carotid artery; LC = longus colli muscle; IJ = internal jugular vein; SCM = sternocleidomastoid muscle; PT = posterior tubercle. Reproduced with permission from USRA (<http://www.usra.ca>)

posterior tubercle at C7 level) was defined as the “lateral zone” that embraced the needle path for the lateral ultrasound-guided approach.

The esophagus was defined as an oval structure with a lumen located dorsolaterally to the trachea (Fig. 4), and its identity was confirmed by observing movement of its wall on swallowing. Line Z was drawn anteroposteriorly at the lateral border of the esophagus. To characterize the risk of esophageal puncture, the esophageal deviation was divided into two groups: the esophagus covering greater than (“high-risk”) or less than 50% of the anterior zone. Multiple measurements were performed at the C6 and C7 levels (Fig. 3), including distance “a” from line Y to line Z, distance “b” from the skin to the anterior surface of the LC just medial to the carotid artery, and the thickness “c” of the LC measured just medial to the carotid artery. The measurement “a” was a measure of the “safe zone” in which the needle could be

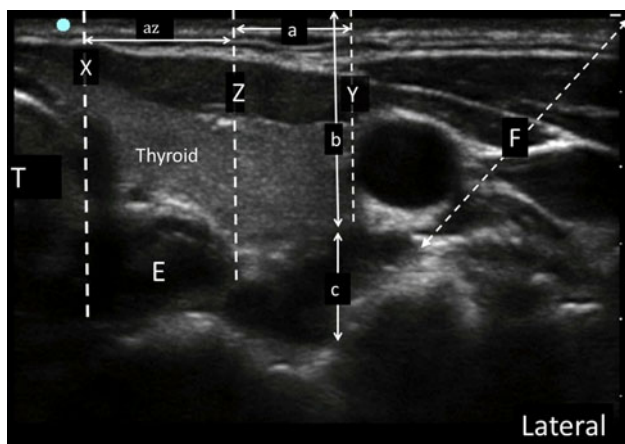


Fig. 3 Ultrasound image of the neck at the C6 level on the left side with reference lines and measurements. Line X = line drawn anteroposteriorly on the lateral border of the airway; Line Y = line drawn anteroposteriorly on the medial border of the carotid artery. Line Z = line drawn anteroposteriorly on the lateral border of the esophagus. Line F = line drawn to bisect the shortest distance between the medial border of the carotid artery and the anterior tubercle, from the skin to the prevertebral fascia; az = anterior zone; a = distance between lines Y and Z; b = distance from skin to prevertebral fascia; c = thickness of longus colli muscle; AT = anterior tubercle of C6; C = carotid artery; E = esophagus; LC = longus colli muscle; T = airway

placed for the anterior approach without penetrating the esophagus. The measurement “b” approximated the length of the simulated path of the needle for the ultrasound-guided anterior approach. The distance “d” (“b” + “c”) was the distance between the skin to the anterior surface of the transverse process, and this approximated the length of the needle path for the landmark-based or fluoroscopy-guided approach for SGB. Another line, F, was drawn from the skin to the anterior surface of the LC to simulate the lateral in-plane approach at the C6 level.^{8,10} This line bisected the shortest distance between the medial surface of the carotid artery and the anterior tubercle of the C6 vertebra. The length of line F approximated the needle path for the lateral ultrasound-guided approach at the C6 level.

The presence of aberrant arteries, other than the carotid and vertebral arteries in the anterior and lateral zones, was recorded, and we noted the course of the vessels in the short-axis view of the neck (Fig. 5a). A vessel in high-risk configuration (HRC) was defined as an artery that appeared in long-axis or crossing the anterior or lateral zone (Fig. 5b). This configuration implied a higher probability of puncture from a needle introduced for SGB. All scan images were saved and the measurements were rechecked by the other two investigators.

Statistical considerations

The sample size ($n = 100$) was chosen as a convenient sample for the purpose of this study. We used descriptive

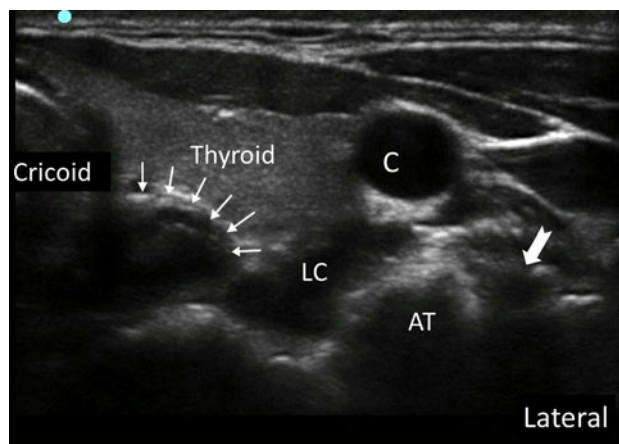


Fig. 4 Ultrasound image of the neck at the C6 level on the left side showing the esophagus (line arrows) and nerve root (bold arrow)

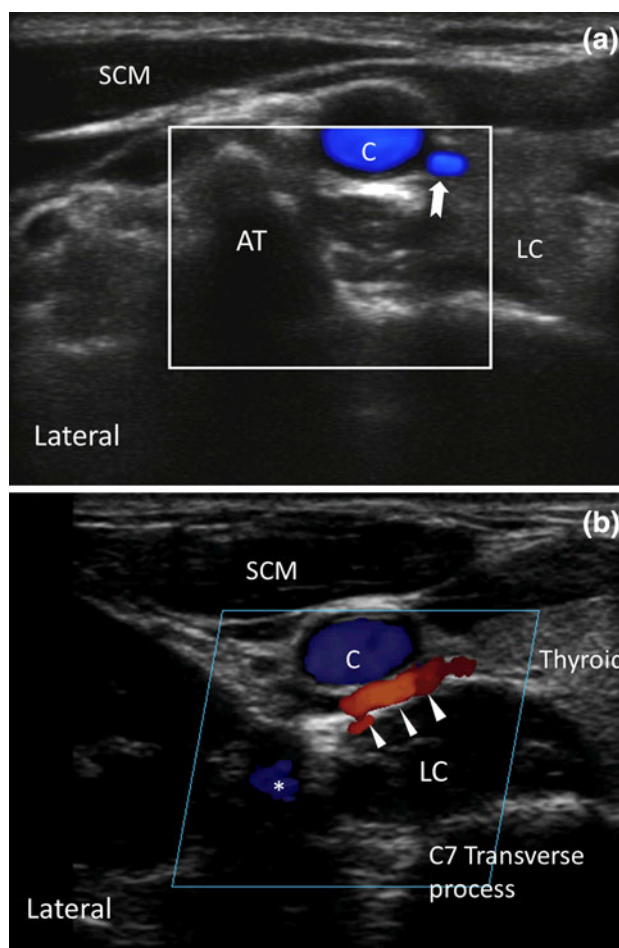


Fig. 5 a. Ultrasound image of the neck at the C6 level on the right side showing a vessel in the short axis (bold arrow). **b.** Ultrasound image of the neck at the C7 level on the right side showing the inferior thyroidal artery (arrow heads) in the long axis (high-risk configuration), crossing ventral to the prevertebral fascia. AT = anterior tubercle; C = carotid artery; LC = longus colli muscle; SCM = sternocleidomastoid muscle; * = vertebral artery

statistics for the presentation of data, and we expressed the presence of blood vessels within the needle path (anterior and lateral approaches) and ultrasound visualization of the esophagus in accordance with the number of subjects investigated. Otherwise, data are shown as mean (standard deviation). Differences in the incidence of aberrant blood vessels or a deviated esophagus at the C6 and C7 levels were compared using a Chi square test. A *P* value of ≤ 0.05 was considered significant.

Results

One hundred volunteers, 52 male and 48 female, were enrolled in this study. The mean (standard deviation) age of this cohort was 34 (8.7) yr, and the mean body mass index was 23.5 (3.3) $\text{kg}\cdot\text{m}^{-2}$. The volunteers represented a variety of ethnic groups, including Caucasian (40%), African-American (5%), Middle-eastern (10%), South Asian (10%), and East Asian (35%).

Visualization of esophagus

The esophagus appeared lateral to the airway in 50% and 74% of the subjects at the C6 and C7 levels, respectively (Table 1). All esophagi were found to be deviated to the left side. The incidence of esophageal deviation, where the esophagus covered $> 50\%$ of the anterior zone, was higher at the C7 level than at the C6 level, 44% vs 14%, respectively.

Vessels at risk in the needle path

The incidence of a major vessel appearing in the anterior and lateral zones is shown in Table 2. In the anterior zone, HRC vessels were found on the left side in 7% (C6 level) and 16% (C7 level) of patients and on the right side in 2% (C6 level) and 14% (C7 level) of patients. No HRC vessels appeared in the lateral zone. The vertebral artery was found

Table 1 Variations in the position of the esophagus at the sixth and seventh cervical vertebral levels

Extent of esophagus deviation	C6 level % of subjects	C7 level % of subjects
Covering $< 50\%$ in the anterior zone	36	30
Covering $\geq 50\%$ in the anterior zone	14	44*
Covering the anterior zone	50	74

The degree of esophageal deviation was measured by the extent of coverage in the anterior zone (from the lateral border of cricoid/trachea to the medial border of the carotid artery): $< 50\%$ or $\geq 50\%$ of this distance. **P* < 0.05

Table 2 Incidence of aberrant blood vessels at the sixth and seventh cervical vertebral level

	Anterior zone	Lateral zone
C6		
Left	29	2
Right	23	3
HRC- left/right	7/2*	0 [†]
C7		
Left	43	1
Right	43	1
HRC- left/right	16/14	0 [†]

Anterior zone = from the lateral border of the cricoid/trachea to the medial border of the carotid artery; Lateral zone = lateral to the medial border of the carotid artery and anteromedial to the transverse processes of the cervical vertebra (anterior tubercle at C6 level, posterior tubercle at C7 level)

The data are presented as the actual number of subjects with aberrant vessels on the left and right side at different levels. High-risk configuration (HRC) referred to finding an aberrant vessel in the long axis covering most of the anterior or lateral zone. The incidence of HRC vessels at C6 was lower than that at the C7 level (*P* < 0.05)* and lower in the lateral zone than in the anterior zone at both levels (*P* < 0.001)[†]

outside the foramen transversarium bilaterally at the C6 level in 7% of subjects.

Distance of the simulated needle path

The mean distance “*a*” between the esophagus and carotid artery (lines Y and Z) was < 1 cm at the C6 level [0.9 (0.4) cm]. The distances “*b*” and “*f*” that were measured for the simulated path of the needle for the anterior and lateral ultrasound-guided approaches were 1.8 (0.3) cm and 2.5 (0.4) cm, respectively, on the left side and 1.8 (0.4) cm and 2.6 (0.4) cm, respectively, on the right side. The distance “*d*” approximating the needle path for the conventional anterior approach was 2.2 (0.6) cm and 2.3 (0.6) cm on the left and right sides, respectively.

Discussion

Using two different (anterior and lateral) approaches in 100 adult volunteers, we examined the sonoanatomy of the neck and evaluated the distances between the esophagus and the major vessels relative to the simulated needle paths for the conventional and ultrasound-guided SGB. Our findings suggest that an ultrasound-guided lateral approach at C6 level may be a safer approach because it is less likely to penetrate blood vessels and the esophagus.

In our view, these results are applicable to the general adult population. The mean age of subjects enrolled in this

study was closer to the age of patients requiring stellate ganglion blockade¹³ than the mean age of patients in another study where ultrasound with a simulated anterior approach was used to estimate the risk of injury in fewer subjects of a younger age group.¹⁵

For the anterior approach, we estimated the risk of esophageal puncture based on the distance that was occupied by the esophagus between the lateral border of the trachea and the medial border of the carotid artery. We found that the esophagus occupied this zone in one of two subjects at the C6 level and three of four subjects at the C7 level. In these subjects, there would be a potential for esophageal puncture by a needle introduced for SGB using conventional approaches that do not allow visualization of this structure (anatomical landmarks or fluoroscopy). Furthermore, the esophagus was a prominent structure (covering at least 50% of the anterior zone) in 14% and 44% of individuals at the C6 and C7 levels, respectively. Patients with similar anatomy would be at an even higher risk of esophageal puncture during SGB.

Previous studies^{16,17} suggest that the esophagus is displaced laterally to the cricoid in 52% of individuals; however, the sample size was small in these studies, and the area of interest was restricted to the C6 level. In these studies, the degree of esophageal deviation from the cricoid was examined, while interventional pain specialists who perform SGB using anatomic landmarks or fluoroscopy for guidance will be more interested in knowing the extent of the anterior zone covered by the esophagus. Moreover, the potential for esophageal puncture is even higher with the needle directed more medially as in the modified fluoroscopic approach.⁷ The consequences of puncturing the esophagus can be serious and can result in significant morbidity and mortality (mediastinitis, abscess formation, and death).¹⁸ The risk of injury is increased if the patient has a pharyngoesophageal diverticulum. The reported prevalence of pharyngoesophageal diverticulum (Zenker's diverticulum) is 0.01-0.11%, and they are usually asymptomatic and detected incidentally.^{19,20} Puncture of the esophagus can lead to a foreign body sensation, which patients have often described following a SGB; however, this sensation is usually attributed to blockade of the recurrent laryngeal nerve.²¹ The incidence of undetected (subclinical) esophageal perforation during SGB is unknown.

The ultrasound-guided anterior approach targets the fascial plane on the surface of the LC (thereby restricting the depth of needle insertion to a plane superficial to the esophagus) in a more lateral position and allows visualization of the esophagus.⁸ This should facilitate a substantial reduction in the risk of esophageal damage. The ultrasound-guided lateral approach obviates this risk altogether.

This study examined the incidence of the vertebral artery in an extraforaminal location at the C6 level and the

presence of other vessels in the simulated path of a needle introduced in the anterior or lateral approach. The vertebral artery originates from the subclavian artery at the inferior border of the thyroid gland and lies at the anterior zone at the C7 level. In 7% of the subjects in our study, the vertebral artery was found in an extraforaminal location in the lateral zone at the C6 level. This incidence is similar to that reported in the literature.^{15,22,23} In 23-43% of the individuals, we found arteries other than carotid or vertebral (ascending cervical, deep cervical, and inferior thyroid artery) in the anterior zone at the C6 and C7 levels, but the incidence was < 3% in the lateral zone. These vessels can be at risk of needle puncture during SGB.²⁴ Furthermore, the inferior thyroid artery is notorious for its variable course,²⁵ and its course in the anterior zone has been described as "serpentine".²²

We classified vessels visualized in the long-axis at high risk of puncture from a needle introduced for SGB (HRC). Vessels visualized in long-axis occupy a greater proportion of the area in the injection field than those visualized in short-axis, and such vessels are more likely to be penetrated by a needle inserted without ultrasound imaging. The chances of encountering a HRC vessel in the anterior zone varied from 2-16% at the C6 and C7 levels, with a higher incidence at the C7 level. None of the HRC vessels appeared in the lateral zone. These data suggest that SGB performed at the C6 level using an ultrasound-guided lateral approach has the least potential for vascular puncture and its attendant complications (hematoma causing airway compression, seizures, arrhythmias, death).

Possible complications of vascular injury and/or intravascular injection of local anesthetic include formation of hematoma with airway compromise, seizures, cardiac arrest, and ischemic injury to spinal cord. Although the frequency of retropharyngeal hematoma with resulting airway compromise and obstruction after SGB is reported to approximate one in 100,000 cases,¹⁴ asymptomatic hematoma is very common after the anterior approach.¹³ In a small study of 12 patients comparing SGB using landmark-based and ultrasound-guided techniques, Kapral *et al.* reported that the blind technique resulted in asymptomatic hematoma formation in 25% of patients, while no hematoma occurred with an ultrasound-guided technique.¹³ Thus, there is a potential risk in performing SGB using anatomic landmarks or fluoroscopy as these techniques cannot identify blood vessels in the needle path. Our study highlights the potential advantage of visualizing (and avoiding) blood vessels by using ultrasound for performing SGB.

Although fluoroscopy with contrast injection avoids the injection of local anesthetic into the vertebral artery, it does not "prevent" it from being punctured. A pre-procedure ultrasound scan of the cervical region can help to avoid this complication because the interventional pain specialist can

choose an approach or level that avoids the vertebral artery. The results of our study suggest that the lateral approach at the C6 level has a low probability of encountering a vessel, and there is no vessel with a high-risk configuration across the needle path. Ultrasound guidance is mandatory for the lateral approach, and the needle can be directed towards the fascial plane that contains the cervical sympathetic chain.

Though results of this study may help inform and guide clinical practice, we emphasize that this is an observational study of neck sonoanatomy. The results of this study provide only circumstantial evidence for the risk of puncture of the esophagus or major vessels during SGB and the potential for their reduction with the use of ultrasound. The enhanced safety of performing SGB with ultrasound guidance can be evaluated only in a clinical trial that is powered adequately to compare complications of this block. A randomized controlled trial comparing the incidence of complications due to esophageal and vascular puncture using the three techniques for SGB (anatomic landmarks, fluoroscopy, and ultrasound) may provide data on accuracy, efficacy, and complications to facilitate choosing between the various approaches. It would be difficult to perform such a trial because the sample size would need to be large (a few thousands subjects). In the absence of these data, our results may assist the individual practitioner in adopting an approach that may potentially reduce or prevent complications of SGB, such as esophageal injury, mediastinitis, seizures, retropharyngeal hematoma, and cardiorespiratory arrest.

It is important to be aware of the definite learning curve involved in using ultrasound to perform interventional pain procedures.²⁶ Knowledge of sonoanatomy and the application of principles of ultrasound-guided procedures (using an in-plane technique, visualizing the needle tip at all times, hydro-dissection, and use of Doppler imaging) should enhance safety for interventionalists who are new to this imaging technique.^{27,28}

In conclusion, our findings suggest that the ultrasound-guided lateral approach at the C6 level can be a potentially safer approach for SGB because the needle targets the lateral zone where the esophagus is absent, and there is a relatively low chance of encountering the vertebral artery or an aberrant vessel in the lateral zone at this level. A pre-procedure ultrasound scan is suggested that can allow the interventional pain specialist to choose the appropriate approach and needle path.

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Competing interests None declared.

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