Ultrasound-guided selective C5 nerve root blocks have been described in several case reports as a safe and effective means to anesthetize the distal clavicle while maintaining innervation of the upper extremity and preserving diaphragmatic function. In this study, cadavers were injected with 5 mL of 0.5% methylene blue dye under ultrasound guidance to investigate possible proximal and distal spread of injectate along the brachial plexus, if any. Following the injections, the specimens were dissected and examined to determine the distribution of dye and the structures affected. One injection revealed dye extended proximally into the epidural space, which penetrated the dura mater and was present on the spinal cord and brainstem. Dye was noted distally to the divisions in 3 injections. The anterior scalene muscle and phrenic nerve were stained in all 4 injections. It appears unlikely that local anesthetic spread is limited to the nerve root following an ultrasound-guided selective C5 nerve root injection. Under certain conditions, intrathecal spread also appears possible, which has major patient safety implications. Additional safety measures, such as injection pressure monitoring, should be incorporated into this block, or approaches that are more distal should be considered for the acute pain management of distal clavicle fractures.

Keywords: Brachial plexus, clavicle fracture, intrathecal injection, selective C5 nerve block, ultrasound guidance.

Aneesthesia to the distal clavicle presents a unique challenge because it receives nerve innervation from the cervical and brachial plexuses. However, only the C5 root of the brachial plexus contributes to this innervation.¹ Ultrasound-guided selective C5 root block performed in combination with a superficial cervical plexus block has been described in several case reports in the last few years as a safe and effective approach for providing anesthesia to the distal clavicle and proximal shoulder while maintaining innervation to the remainder of the upper extremity.²³ Additionally, authors have demonstrated that common side effects such as phrenic nerve blockade can be avoided.²

Technically advanced peripheral nerve blocks such as the selective C5 root block would not be possible without the incorporation of ultrasound into these procedures. Ultrasound guidance provides 3 advantages over the landmark technique in the performance of peripheral nerve blocks: (1) identification of anatomic structures beneath the skin, (2) visualization of needle movements in real-time, and (3) observation of local anesthetic spread. Reviews of randomized controlled trials show these advantages translate into decreased procedure times, fewer needle passes, decreased incidence of vascular puncture, faster block onset, and lower volumes of local anesthetic to achieve the same effect.⁴⁻⁵

Although real-time needle movements and local anesthetic spread are visualized with ultrasound, it is only possible to see this in two dimensions. Given the compact nature of the brachial plexus, proximal and distal spread of local anesthetic from the injection site is plausible. Since dural sleeves can extend to the spinal roots, intrathecal spread resulting in high spinal anesthesia could occur. Distal clavicle isolation also seems unlikely because the C5 nerve root contributes to the innervation of the diaphragm as well as sensory and motor components to various areas of the upper extremity.¹

Methods

The institutional review board at East Tennessee State University, Johnson City, Tennessee, waived the need for review. Human cadavers with unknown medical histories obtained from the university’s Anatomical Gift Program and scheduled for dissection were injected bilaterally at the C5 cervical nerve root under ultrasound guidance with 5 mL of 0.5% methylene blue.

An M-Turbo ultrasound system (SonoSite) with an HFL 13-6 MHz, high-frequency ultrasound transducer was used to identify the brachial plexus. Starting in the
midclavicular fossa, the trunks/divisions of the brachial plexus were identified at the supraclavicular level lateral to the subclavian artery, then followed cephalad to where cervical roots C5, C6, and C7 are sandwiched between the anterior and middle scalene muscles. Continuing cephalad, each cervical root was identified as it exited the transverse process of the cervical vertebrae. The ultrasound characteristics of the anterior and posterior tubercles of the transverse processes were used to determine the location of C5 (Figure 1A).

A 5-cm, B-bevel, stimulating block needle (B Braun) was inserted in-plane, lateral to medial, under ultrasound guidance adjacent and deep to the C5 nerve root between the anterior and posterior tubercles (Figure 1B). A total of 5 mL of 0.5% methylene blue was injected under ultrasound observation.

Following the injections, the plexuses were dissected from the roots to the terminal branches. Proximal and distal spread of injection was determined through gross visualization of dye. Gross dissection of the spinal column was performed for evidence of dye in the epidural space and spinal cord.

**Results**

The C5 nerve root was detected with ultrasound for all 4 injections, and visualization of the block needle was possible between the anterior and posterior tubercles adjacent to the nerve root. No injection was more technically difficult than the others. The same investigator performed all injections to reduce operator variability. The Table lists the injection site, the volume injected, and the spread of dye.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Injection site</th>
<th>Proximal spread</th>
<th>Distal spread</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Left C5</td>
<td>C5 nerve root</td>
<td>Divisions of BP</td>
</tr>
<tr>
<td>1</td>
<td>Right C5</td>
<td>C5 nerve root</td>
<td>Divisions of BP</td>
</tr>
<tr>
<td>2</td>
<td>Left C5</td>
<td>C5 nerve root</td>
<td>Divisions of BP</td>
</tr>
<tr>
<td>2</td>
<td>Right C5</td>
<td>Epidural space</td>
<td>Trunks of BP</td>
</tr>
</tbody>
</table>

There was proximal spread of injectate into the epidural space following 1 of the 4 injections, with dye extending distally to the level of T10. An additional laminectomy, craniotomy, and brain dissection revealed that dye had penetrated the dura and stained the spinal cord, brainstem, and midbrain (Figure 2).

Dye was visualized distally to the trunks following all 4 injections and extended to the anterior and posterior divisions of the plexus in 3 of the 4 injections. Additionally, dye was evident on the ventral surface of the anterior scalene muscle and phrenic nerve in all 4 injections (Figure 3).

**Discussion**

In this cadaver study, ultrasound-guided selective C5 root injections using 5 mL of dye resulted in the spread of injectate proximally and distally along the brachial plexus. Orebaugh et al performed a similar study with ultrasound-guided selective C5 injection using 5 mL of particulate dye with local anesthetic. These injections were placed directly in the neural tissue using an auto-
mated pump and pressure monitor. The high pressures (mean peak, 48.9 psi) were suggestive of intrafascicular injection. However, unlike the study by Orebaugh and colleagues, dye discovered in the epidural space penetrated the dura, staining parts of the spinal cord, brainstem, and midbrain. In addition, the anterior scalene muscle and phrenic nerve were affected in all 4 injections.

Accomplishing a selective C5 root block requires isolation of the nerve root from the rest of the brachial plexus. Chan et al described a method for determining the cervical level with ultrasound by identifying the area where the nerve root passes between the anterior and posterior tubercles of the transverse process. Although they noted it was “important to avoid local anesthetic injection immediately adjacent to the transverse process and nerve root emerging from the neural foramen because of the risk of unintentional epidural or spinal anesthesia,” this is the first study, to our knowledge, to demonstrate this occurrence.

Kline first described selective C5 nerve blockade with catheter placement for inadequate pain coverage of a superficial cervical plexus block following the surgical repair of a distal clavicle fracture. The author guided a 10-cm stimulating Tuohy needle in-plane to the superficial...
surface of the C5 nerve root and injected 8 mL of 2% lidocaine. Circumferential spread was noted around the root. A catheter was then placed deep to the C5 root. Follow-up assessment in the postoperative area revealed continued complete analgesia with intact distal motor function.

Shanthanna described 2 cases in which selective C5 root blockade was used for surgical repair of distal clavicle fractures in high-risk patients. With use of an in-plane technique, a 50-mm echogenic needle was passed under the nerve root between the anterior and posterior tubercles, and 2 mL of 0.5% ropivacaine was injected. Postoperative follow-up revealed minimal pain scores on an analog scale (< 2 of 10). However, motor function was not evaluated. Chest x-ray films revealed no incidence of diaphragmatic paralysis, and both patients were discharged with no apparent complications.

Both Kline and Shanthanna used reduced volumes (8 mL and 2 mL, respectively) of surgical concentrations of local anesthetics. Both authors noted circumferential spread around the nerve root. However, this spread was visualized only in 2 dimensions, and it is not known whether proximal or distal spread occurred. Adequate pain management to the distal clavicle and proximal shoulder without involvement to the remainder of the upper extremity was noted in both articles. Shanthanna also reported no incidence of hemidiaphragmatic paresis in either of his cases. Possible explanations for this are the mantle effect and differential blockade. Mantle fibers of a nerve bundle typically innervate the more proximal areas of an extremity, reflecting the somatotropic organization of the nerves. Smaller C and A delta sensory fibers are also more likely to be blocked first. Because functional assessments did not occur following discharge from the postoperative care area, long-term outcomes from the procedures are not known. This is important because the amount of local anesthetic required to achieve sufficient analgesia varies from patient to patient and long-term pain management strategies using catheters have been shown to change the spread of local anesthetic. Renes et al conducted a study to determine the minimum volume of 0.75% ropivacaine required for shoulder analgesia with an ultrasound-guided selective C7 root block. The minimum effective anesthetic volume (MEAV) was noted to be 2.9 mL (95% confidence interval [CI], 2.4-3.5 mL), and the 95% effective dose (ED50) was 3.6 mL (95% CI, 3.3-6.2 mL). There was not a reduction in ventilatory function or hemidiaphragmatic movement for 2 hours following surgery. However, following a continuous infusion of 0.2% ropivacaine at 6 mL/h for postoperative pain management, 100% of the study participants experienced hemidiaphragmatic paresis by 24 hours. Future studies involving selective C5 root blockade should include both sensory and motor examination extending past discharge from the postoperative care unit to determine the long-term effects of this block.

Plante et al described proximal C5 interscalene block injections that provide many of the same benefits as a selective C5 nerve root block with less risk of proximal spread because the block is more distal to the transverse process. They demonstrated that injections directed at the C5 root during an interscalene block provided adequate analgesia following shoulder surgery, but with less involvement of the radial, ulnar, and median nerves, despite the injection of large volumes (30 mL) of local anesthetic. Plante et al acknowledged that the large volume of injectate used in their study increased the risk for phrenic nerve blockade. However, even when small volumes of local anesthetic are used in performing ultrasound-guided interscalene blocks, as many as 45% of patients may experience hemidiaphragmatic paresis.

This study has several limitations. First, all injections were performed by the same investigator, and there was no blinding to the injection technique or the volume of dye used. Postmortem changes in cadaveric tissue could have altered the spread pattern of the injectate. Additionally, the spread of dye to specific anatomic structures does not automatically translate into local anesthetic effect. Finally, the small number of injections and limited data on this subject make it difficult to apply external validity to these findings. However, this study demonstrates, under certain conditions, it is possible for injectate to reach the spinal cord following an ultrasound-guided selective C5 nerve root block. This finding has major patient safety implications.

**Conclusion**

Recent case studies have described C5 selective nerve root blocks as a safe and effective means to provide anesthesia to the distal clavicle while maintaining innervation to the remainder of the upper extremity and preserving diaphragmatic function. In this cadaveric investigation, selective C5 nerve root injections were performed using ultrasound guidance as described in previous case reports. Despite direct needle visualization and observation of injectate spread, dye extended distally along the brachial plexus and was evident on the anterior scalene muscle and phrenic nerve in all injections. One injection resulted in proximal spread into the epidural space that penetrated the dura, staining the spinal cord and brainstem. This finding has obvious patient safety implications.

Additional safety measures, such as injection pressure monitoring, should be considered when one performs this block. Practitioners may also choose more distal approaches that have been shown to provide comparable anesthesia with a reduced risk of intrathecal spread.

Finally, future studies must include outcomes data extending beyond the immediate postoperative period so the long-term effects of this procedure can be fully known.
REFERENCES

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DISCLOSURES
The authors have declared they have no financial relationships with any commercial interest related to the content of this activity. The authors did not discuss off-label use within the article.