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Comparison of tissue distribution, phrenic nerve involvement, and epidural spread in standard- *vs* low-volume ultrasound-guided interscalene plexus block using contrast magnetic resonance imaging: a randomized, controlled trial†

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Abstract

Background: Ultrasound guidance allows for the use of much lower volumes of local anaesthetics for nerve blocks, which may be associated with less aberrant spread and fewer complications. This randomized, controlled study used contrast magnetic resonance imaging to view the differential-volume local anaesthetic distribution, and compared analgesic efficacy and respiratory impairment.

Methods: Thirty patients undergoing shoulder surgery were randomized to receive ultrasound-guided interscalene block by a single, blinded operator with injection of ropivacaine 0.75% (either 20 or 5 ml) plus the contrast dye gadopentetate dimeglumine, followed by magnetic resonance imaging. The primary outcome was epidural spread. Secondary outcomes were central non-epidural spread, contralateral epidural spread, spread to the phrenic nerve, spirometry, ultrasound investigation of the diaphragm, block duration, pain scores during the first 24 h, time to first analgesic consumption, and total analgesic consumption.

Results: All blocks provided fast onset and adequate intra- and postoperative analgesia, with no significant differences in pain scores at any time point. Epidural spread occurred in two subjects of each group (13.3%); however, spread to the intervertebral foramen and phrenic nerve and extensive i.m. local anaesthetic deposition were significantly more frequent in the 20 ml group. Diaphragmatic paralysis occurred twice as frequently (n=8 *vs* 4), and changes from baseline peak respiratory flow rate were larger [Δ=−2.66 (1.99 SD) *vs* −1.69 (2.0 SD) l min^{-1}] in the 20 ml group.

Conclusions: This study demonstrates that interscalene block is associated with epidural spread irrespective of injection volume; however, less central (foraminal) and aberrant spread after low-volume injection may be associated with a more favourable risk profile.

† Preliminary results of this study were presented as an abstract during the annual conference of the American Society of Regional Anesthesia (ASRA) in Las Vegas, NV, USA on May 15–16, 2015.

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Clinical trial registration: This study was registered with the European Medicines Agency (Eudra-CT number 2013-004219-36) and with the US National Institutes' of Health registry and results base, clinicaltrials.gov (identifier NCT02175069).

Key words: anaesthetics, local; brachial plexus block; injections; intramuscular; magnetic resonance imaging; phrenic nerve

Editor's key points

- The interscalene approach to the brachial plexus can affect the phrenic nerve and may result in a total spinal block.
- Ultrasound can provide real-time confirmation of correct block placement and may reduce the volume of local anaesthetic required.
- Central spread of local anaesthetic after interscalene block might be reduced with a low-volume injection.
- Central spread was associated with a short transaxial neck distance at the level of the glottis.

Interscalene plexus block (ISB) is among the most frequent regional anaesthetic techniques for surgery of the upper limb. Its efficacy in providing pain control is superior to other modes of analgesia.[1] However, critical structures are located in close proximity to the injection site, including neck muscles and tendons, blood vessels, the phrenic and recurrent laryngeal nerves, and structures of the spinal cord. Phrenic nerve block was once considered an unavoidable consequence of ISB.[2] Other potential complications of ISB include i.m. deposition of local anaesthetic, with potential for subsequent myotoxicity.[3 4] Moreover, there are reports of contralateral block and total spinal anaesthesia after ISB, presumably invoked through epidural and intrathecal spread of local anaesthetics, respectively.[5–7]

The widespread use of ultrasound for peripheral nerve blocks provides an opportunity to reduce the volume of local anaesthetic required to perform a successful block, and this should reduce the risk for adverse events. However, little is known about the pattern of local anaesthetic distribution after ISB and how smaller injection volumes impact on it. Our group previously performed a cadaveric study of ISB followed by computed tomography to assess epidural spread using progressively higher volumes of contrast dye.[8] Higher volumes were associated with a significantly higher incidence of ipsilateral and contralateral epidural spread.

The present randomized, controlled trial was designed to test the hypothesis that a standard volume (20 ml)[9] of local anaesthetic for ultrasound-guided ISB (US-ISB) in patients undergoing shoulder surgery would cause more central (epidural) spread when compared with a lower volume (5 ml) as seen with contrast magnetic resonance imaging (cMRI). The primary outcome was the incidence of spread of local anaesthetics to the epidural space. Secondary outcomes were central non-epidural spread (to the transverse process or intervertebral foramen), contralateral epidural spread, spread of local anaesthetic to the phrenic nerve on the anterior scalene muscle, bedside spirometry, ultrasound assessment of diaphragmatic function, self-reported block duration, pain scores during the first 24 h, time to first analgesic consumption, and total analgesic consumption.

Methods

This study was approved as an investigational pharmacological study by the ethics committee of the county of Salzburg, Austria (file number 415-E/1691/9-2014) and the Austrian Federal Office for Safety in Healthcare, Vienna, Austria. It was registered with the European Medicines Agency (Eudra-CT number 2013-004219-36) and with the US National Institutes' of Health registry and results database, clinicaltrials.gov (identifier NCT02175069). A mandatory patient insurance contract was arranged with HDI Insurance Company, Vienna, Austria (contract no. 01645847). The reporting of this study follows the Consolidated Standards of Reporting Trials guidelines.[10]

A total of 30 patients undergoing shoulder surgery were included. Eligible patients were identified and approached consecutively during their presurgical evaluation in the anaesthesia clinic 1 day before surgery, informed about the study, and if they agreed to participate, were asked to provide written consent. Inclusion criteria were as follows: planned shoulder surgery, age between 18 and 75 yr, and ASA physical score I, II, or III.[11] Exclusion criteria included the following: language barrier, hearing impairments, or other conditions impeding study participation; serious cardiac or pulmonary disease; hepatic or renal impairment; hypersensitivity to ropivacaine or gadopentetate dimeglumine (contrast dye); contraindications for peripheral nerve blocks or MRI; chronic use of opioids or adjunctive pain medications; psychiatric disorders; neuropathy; and pregnancy. Patients were randomly assigned to the Standard-volume Group (20 ml) or Low-volume Group (5 ml). Randomization was achieved through computer-generated lists.[12] Allocation information was prepared in sealed, opaque envelopes by an otherwise uninvolved third person. The de-randomization key was accessible only after study completion or in the event of an emergency. An envelope was added to each participant's chart in a consecutive order. On the day of surgery, a non-blinded anaesthesia nurse not otherwise involved in the study prepared the study medication according to the randomization result in the envelope, supervised by a pharmacy consultant.

Baseline neurological and pain assessments were carried out immediately preceding ISB. Patients received either ropivacaine 0.75% (Naropin®, 20 ml; AstraZeneca Austria GmbH, Vienna, Austria) mixed with 0.05 mmol of the contrast dye, gadopentetate dimeglumine (Magnevist®, 0.5 mmol ml^{-1}; Bayer Vital GmbH, Leverkusen, Germany) or ropivacaine 0.75% (5 ml) mixed with gadopentetate dimeglumine (0.0125 mmol) for ultrasound-guided ISB. All blocks were performed in the MRI scanner anteroom, by a blinded single practitioner (G.F.) with many years of experience in regional anaesthesia. Routine monitoring consisted of ECG, pulse oximetry, and non-invasive blood pressure monitoring. Mild sedation with midazolam (1–2 mg) and fentanyl (0.05 mg) was administered. After skin disinfection and sterile draping of the injection site, structures of the fifth and sixth cervical root (C5 and C6) were identified using a sterile-wrapped ultrasound probe (Sonosite™ M-Turbo, 13 MHz linear probe; Sonosite Corp., Bothell, WA, USA). A skin wheal was placed at the designated injection site [1 ml lidocaine 1% (Xylocain); AstraZeneca Austria GmbH, Vienna, Austria). The ISB was then performed using an in-plane technique, moving the needle (PlexoLong® Nano Line™ Facet Set, 19 gauge, 50 mm; Pajunk Corp., Geisingen, Germany) from lateral through the middle scalene muscle close