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ORIGINAL ARTICLE

Ultrasound-guided interscalene blocks: understanding where to inject the local anaesthetic

B. C. Spence,[1] M. L. Beach,[2] J. D. Gallagher[3] and B. D. Sites[4]

1 Assistant Professor of Anaesthesiology, 2 Professor of Anaesthesiology and Community & Family Medicine, 3 Professor of Anaesthesiology, 4 Associate Professor of Anaesthesiology and Orthopedics, Director Regional Anaesthesiology, Dartmouth Medical School, Hanover, New Hampshire, USA

Summary

Although ultrasound-guided regional anaesthesia has gained in popularity, few data exist describing the optimal location(s) to inject local anaesthetic. Our objective was to compare, for interscalene blocks, the effectiveness of an injection between the middle scalene muscle and brachial plexus sheath (peri-plexus) with an injection within the brachial plexus sheath (intra-plexus). We enrolled 170 patients undergoing shoulder surgery with general anaesthesia and interscalene block in this randomised, controlled trial. Our primary outcome variable was loss of shoulder abduction. Block quality was also measured and defined by an evaluation of onset time, sensory and motor loss and duration. There was no difference between the two groups in block onset times or block quality. After adjusting for sex, age and volume injected, intra-plexus blocks lasted a mean of 2.6 h (16%) longer (95% CI 0.25–5.01, p = 0.03) than peri-plexus blocks.

Correspondence to: Dr Brian C. Spence
Email: brian.c.spence@hitchcock.org
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Characterising the different distributions of spread of local anaesthetic that predict success while enhancing safety is paramount to advancing the widespread acceptance of ultrasound-guided regional anaesthesia. Each nerve and plexus may have one or more effective morphological distributions of local anaesthetic solution. There are currently no evidence-based patterns of spread of local anaesthetic that can be recommended [1]. This leaves practitioners unsure whether a new needle position is needed following a test injection. This is in contrast to nerve stimulation, where the end point for injection is a motor response to nerve stimulation at currents between 0.2 and 0.5 mA.

Traditionally, the placement of local anaesthetic around the nerve structure, or 'doughnut sign', has been considered the gold standard [2]. This concept of circumferential spread may be necessary or appropriate for some nerve blocks. Our clinical experience, however, suggests that it is not true for single injection interscalene block. Injection in the potential space between the middle scalene muscle and the brachial plexus sheath (peri-sheath) has seemed equally efficacious in our practice. Indeed, demanding an aggressive circumferential spread may result in more needle-to-nerve trauma, more repositioning and the induction of unnecessary dysaesthesias [3]. Our hypothesis in this investigation was that there is an equally effective method of placing the local anaesthetic immediately lateral to the plexus, without the need to penetrate into the plexus itself. In essence, we aimed to compare the block efficacy between a conservative injection in the peri-plexus location with that of a more traditional and aggressive intra-plexus injection technique.

Methods

Approval for the study was obtained from the Committee for the Protection of Human Subjects at Dartmouth Medical School and informed consent was obtained from each participant on the day of surgery. All adults (≥ 18-year-old) undergoing primary shoulder arthroscopy were identified for possible inclusion

in the study. Patients unable to consent for their anaesthetic, patients having a repeat shoulder arthroscopy, patients having a total shoulder replacement or hemiarthroplasty, patients on chronic opioid therapy, patients who were pregnant, employees of our institution and their family members, medical students and patients who refused to participate were not studied.

Patients were randomly assigned to either an 'aggressive' intra-plexus injection or a 'conservative' peri-plexus injection. Computer-generated group codes were sealed in an envelope and opened following the signing of informed consent. The regional anaesthesia nurse, data collection nurse and the operative team were blinded to the group assignment. Baseline measurements of sensation and motor function were obtained from the operative limb and recorded. Patients were given a combination of midazolam 0–2 mg and fentanyl 0–50 μg intravenously for the block placement. After an aseptic preparation and draping of the patient, the skin was anaesthetised with 5 ml lidocaine 1% using a 25-G needle. Next, an ultrasound-guided, in-plane, and single injection interscalene block was performed using a 22-G 50-mm blunted bevel needle (B Braun, Melsungen, Germany). The site of the all injections was at the level of roots to trunks as defined using ultrasound. The needle was directed from lateral to medial through the middle scalene muscle. In the intra-plexus group, the needle was advanced into the brachial plexus sheath by passing between the two most superficial large hypoechoic circles. This sheath penetration corresponded to a physical and visual popping sensation. The injection commenced and local anaesthetic was then expected to fill from within and expand the tissue layers surrounding the brachial plexus (Fig. 1 and Video S1; see Supporting Information details given at the end of this paper). If the local anaesthetic did not appear to be surrounding all of the identified neural structures, then the needle was repositioned to assure complete spread of the local anaesthetic. In the peri-plexus group, the needle was advanced and stopped at the junction of the outer hyperechoic fascial layer of the plexus and the fascial layer covering the middle scalene muscle. The injection commenced and was expected to result in the plexus being pushed medially with the local anaesthetic spread adjacent to the plexus (Fig. 2 and Video S2; see Supporting Information details given at the end of this paper). If an intramuscular injection was noted with the first 2 ml of local anaesthetic, then the needle was advanced closer to the plexus, but not through the fascial layer covering the plexus.

The first 15 patients enrolled (seven peri-plexus and eight intra-plexus) received 30 ml bupivacaine 0.5% for their interscalene blocks. The protocol was changed, with permission from the Committee for the Protection of Human Subjects, to 0.25 ml.kg^{-1} (with a maximum of 30 ml) because of the potential for systemic toxicity in patients with low body weight. All traditional techniques for insuring safety were utilised, including assessing patient feedback, monitoring resistance to injection with an in-line pressure monitor (B-Smart; Macosta, Mirandola, Italy) and frequent aspiration during the injection. Injection pressures were kept below 103 kPa (15 psi).

Following block completion, a research nurse blinded to the treatment group, performed the block assessment. Sensory and motor examinations were performed at 5-min intervals for 30 min. Loss of

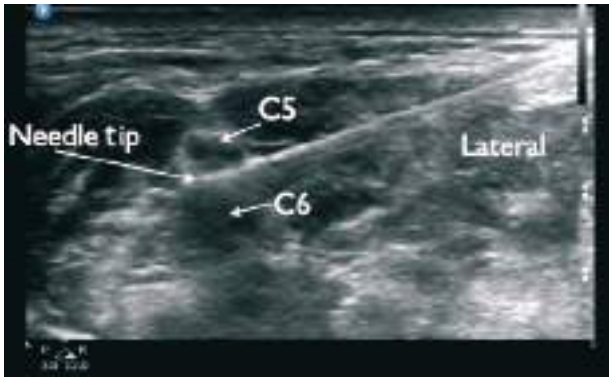

Figure 1 Needle placement for the intra-plexus group. The needle tip is demarcated in the image by an arrow. C5 and C6 are the nerve roots of the brachial plexus.

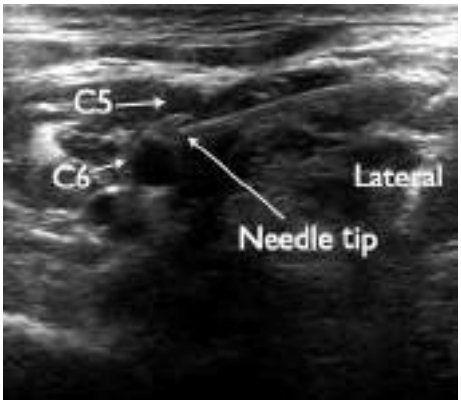

Figure 2 Needle placement for the peri-plexus group. The needle tip is demarcated in the image by an arrow. C5 and C6 are the nerve roots of the brachial plexus.

sensation and loss of motor function were assessed using the system that Kapral et al. established [4]. Sensory dermatomes from C5 to C8 in the blocked arm were compared with similar dermatomes in the contralateral arm using pinprick (with a 21-G blunted needle) and a scale with 100% being normal sensation and 0% being insensate. Motor block was evaluated by thumb abduction (radial nerve), thumb adduction (ulnar nerve), thumb opposition (median nerve), forearm supination or pronation (radial and median nerves) and shoulder abduction (axillary nerve). Motor function was evaluated using a seven-point scale developed by Kapral et al., where '6' is normal muscle force, '5' is slightly reduced muscle force, '4' is greatly reduced muscle force, '3' is slightly impaired mobility, '2' is greatly impaired mobility, '1' is near complete paralysis and '0' is complete paralysis [4].

All patients received a standardised general anaesthetic performed in the operating room after block placement. Anaesthesia was induced with up to 5 $ml.kg^{-1}$ propofol with either rocuronium or vecuronium used to facilitate tracheal intubation and to maintain neuromuscular blockade. All patients were placed in the 'beach-chair' position. Anaesthesia was maintained with desflurane or sevoflurane. Patients were allowed up to 3 $\mu g.kg^{-1}$ fentanyl intra-operatively to maintain heart rate and blood pressure within 20% of pre-induction levels.

Patients were contacted by telephone on the day following surgery and were asked about block resolution, defined as the time when the patient perceived that the block had resolved due to the return of normal sensation and motor strength and an increase in perceived discomfort. Patients whose block had not resolved by the time of the initial phone call were contacted again the following day to assure block resolution and to confirm that there were no persistent sensory or motor deficits.

The primary binary outcome was an evaluation of the development of a complete motor block of shoulder abduction using a Kapral score of 2 or less. Secondary outcomes included significant motor weakness across other muscle groups as defined by a Kapral score of 2 or less, complications, sensory evaluation at 30 min, block duration and intra-operative opioid consumption.

This was an equivalence study in which we hypothesised that the efficacy of the intra-plexus block was equivalent to the peri-plexus blocks. We assumed that the standard intra-plexus technique results in a successful block approximately 95% of the time, and that the two techniques were essentially equivalent if the difference between the success rates was no greater than 7.5%. Assuming 80% power and a type-1 error rate of 0.05, we needed to assign randomly 208 patients, with 104 to each group. Randomisation was computer generated and blocked in groups of eight to minimise time effects and maintain balance. Standard univariate techniques were used for binary and continuous variables. Multivariate logistic regression and least squares regression models with transformations as needed were used for binary and continuous variables, respectively. We report 95% confidence intervals and considered a p value of ≤ 0.05 to indicate statistical significance. Because there was only one comparison of primary interest (the development of a complete motor block), no adjustment was made for multiple comparisons for that outcome. We considered a p value of 0.01 to indicate statistical significance based on a Bonferroni correction to allow for five comparisons of secondary interest.

Results

During the period of enrolment, our practice evolved, to favour a block-only (awake) technique rather than a block combined with general anaesthesia. As the number of eligible patients decreased, enrolment was discontinued after 170 patients. One patient was not studied because of the addition of nalbuphine to the block solution and another patient who received more than 40 ml local anaesthetic solution (0.36 $ml.kg^{-1}$ in this patient) was also not studied. The final analysis includes 84 patients in both groups. As described above, the first 15 patients enrolled received 30 ml bupivacaine 0.5% for their interscalene block, before the protocol was changed to a weight-based volume determination.

All blocks were performed by an anaesthesiology resident supervised by a staff anaesthesiologist. There were no inadvertent conversions from the peri-plexus to intra-plexus group. There were no complications such as intravascular injection, vascular trauma, seizure, persistent paraesthesia, persistent motor loss or persistent sensory loss.

Patient characteristics and a summary of the operative procedures are provided in Table 1. There was no difference in fentanyl dosage administered during surgery between the two groups (151.2 and 155.8 μg for the intra-plexus and peri-plexus groups, respectively; difference in means −4.6, 95% CI −33.6 to 24.4) μg. Tables 2 and 3 provide summary data for

Table 1 Patients' characteristics and operative details. Values are mean (SD) or number (proportion).

	Intra-plexus group (n = 84)	Peri-plexus group (n = 84)
Age; years	53.6 (13.6)	53.3 (11.1)
Height; cm	171 (11)	173 (10)
Weight; kg	89.7 (19.1)	94.2 (20.2)
BMI; $kg.m^{-2}$	30.6 (6.7)	31.5 (6.4)
Male	45 (54%)	59 (70%)
Procedure		
Clavicle resection	18 (21%)	14 (17%)
Biceps repair	26 (31%)	36 (43%)
Open shoulder procedure	2 (2%)	4 (5%)
Arthroscopy	82 (98%)	81 (96%)

block quality as demonstrated by the sensory and motor examinations.

The result of the multivariate regression model are presented in Table 4. In the unadjusted results, we did not find a difference in shoulder abduction at 30 min with success rates of 95% and 93% in the intra-plexus and peri-plexus groups, respectively, as defined by a Kapral score of 2 or less. Adjusting for sex, age and volume showed that intra-plexus blocks lasted, on average, 2.6 h (16%) longer (p = 0.03, 95% CI 0.25–5.01). The relationship between block duration and volume of injectate is shown in Fig. 3.

Discussion

There was no difference between the groups for the primary outcome. While we initially powered the study with 208 patients, the primary outcome was based on only 155 patients. Complete data on all 208 patients would not change the findings because the failure rate in remaining peri-plexus injection group would have to have been greater than 60%. Given the 93% observed success rate, this would be extremely unlikely. Thus, our results suggest that an equally effective sensory and motor block results from a less invasive peri-plexus interscalene block in comparison with an intra-plexus injection. This finding may help the practitioners avoid unnecessary needle-to-nerve contact and thus reduce nerve trauma. Given the relatively low incidence and complex aetiology of nerve injury, the ability to connect reductions in nerve trauma to meaningful reductions in morbidity will be challenging, if not impossible [5–9].

Anatomical literature suggests that a connective tissue sheath surrounds the brachial plexus as a thin membrane [9–12]. Franco et al. in a recent cadaver study of the brachial plexus sheath described the membrane as only 1- to 2-mm thick and observed that the sheath could be easily detached from the surrounding muscle bed [10]. Our results suggest that local anaesthetic solution readily diffuses across this membrane, as both groups were equivalent in terms of onset of the sensory and motor block. Tables 2 and 3 demonstrate the different dermatomes and nerve roots tested. These results are interesting as they show that there is no benefit from the more aggressive needle placement compared with the peri-plexus technique in terms of block-onset. It is likely that once the surrounding nerve sheath is contacted, it is the properties of the local anaesthetic (concentration, lipid solubility and pKa) and not the

Table 2 Sensory block at cervical dermatomes, 10 and 30 min after interscalene block using the scale devised by Kapral et al. [4]; 100 is normal sensation and 0 is insensate. Values are mean (SD) or difference in means (95% CI).

	Intra-plexus group (n = 83)	Peri-plexus group (n = 83)	Difference in means	p value
10 min				
C5	62 (32)	65 (35)	−3.8 (−14.1 to 6.6)	NS
C6	65 (31)	71 (29)	−6.0 (−15.2 to 3.2)	NS
C7	77 (29)	82 (25)	−4.8 (−13.0 to 3.4)	NS
C8	80 (27)	83 (22)	−3.0 (−10.7 to 4.7)	NS
Deltoid	46 (36)	56 (35)	−10.1 (−21.0 to 0.9)	NS
	(n = 76)	(n = 76)		
30 min				
C5	30 (32)	27 (32)	2.7 (−7.4 to 12.8)	NS
C6	30 (32)	36 (34)	−6.0 (−16.5 to 4.6)	NS
C7	50 (35)	52 (37)	−1.4 (−12.9 to 10.1)	NS
C8	53 (36)	57 (37)	−4.2 (−15.8 to 7.4)	NS
Deltoid	11 (21)	19 (27)	−7.5 (−15.2 to 0.3)	NS

Table 3 Motor block at 10 and 30 min after interscalence block using assessment devised by Kapral et al. [4]. Values are proportion of patients who developed significant motor weakness (Kapral score of 2 or less), or odds ratio (95% CI).

	Intra-plexus (n = 84)	Peri-plexus (n = 84)	Odds ratio (95% CI)	p value
10 min				
Thumb abduction	11%	5%	2.40 (0.63–11.08)	NS
Thumb adduction	10%	4%	2.84 (0.65–17.16)	NS
Thumb opposition	8%	1%	7.55 (0.93–344.39)	NS
Forearm supination	30%	22%	1.56 (0.73–3.36)	NS
Forearm pronation	25%	19%	1.42 (0.64–3.19)	NS
Shoulder abduction	62%	60%	1.09 (0.55–2.13)	NS
	(n = 79)	(n = 76)		
30 min				
Thumb abduction	43%	50%	0.76 (0.38–1.49)	NS
Thumb adduction	42%	46%	0.84 (0.42–1.67)	NS
Thumb opposition	46%	48%	0.88 (0.45–1.74)	NS
Forearm supination	77%	87%	0.51 (0.20–1.29)	NS
Forearm pronation	70%	84%	0.43 (0.18–1.00)	NS
Shoulder abduction	95%	93%	1.32 (0.27–6.92)	NS

Table 4 Added duration of intra-plexus injection, when compared with peri-plexus injection, using a multivariate regression model and adjusting for sex, age and volume of local anaesthetic solution.

	Co-efficient	95% CI	p value
Unadjusted added duration; h	2.03	(−0.34 to 4.40)	NS
Adjusted added duration; h	2.63	(0.25 to 5.01)	0.03

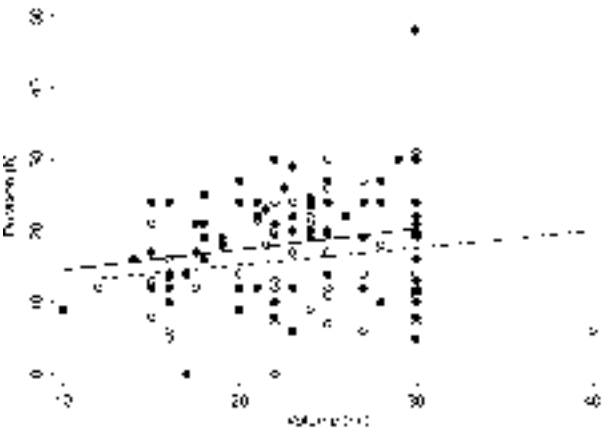

Figure 3 Regression analysis demonstrating patient perceived block (motor of sensory) duration vs volume of injectate after intra-plexus (•) and peri-plexus interscalene (○) block. The solid line represents the relationship between block duration and volume of local anaesthetic for the intra-plexus group and the dashed line represents the same relationship for the peri-plexus group.

exact needle placement that determines the block onset. Another interesting finding was the prolongation of the sensory block in the intra-plexus group compared with the peri-plexus group. One possible explanation is that there was less systemic uptake of local anaesthetic in the intra-plexus group due to more anaesthetic's being contained within the brachial plexus sheath, increasing the reservoir volume of local anaesthetic solution within the brachial plexus sheath. Franco et al. described the interior of the sheath surrounding the neuronal tissue as a combination of loose connective tissue and fat, with veins running along the exterior of the sheath [10]. These observations could also help explain our results, as there may have been increased systemic absorption in the peri-plexus group due to the increased vascularity on the outside of the sheath. The prolongation of the block in the intra-plexus group should be interpreted with some caution, given that it was a secondary outcome variable and identified using multivariate analysis.

An additional weakness of our study is that duration of block was elicited from patients' perception of block resolution, which is a subjective data point. Originally, we considered defining the duration as the time to the first postoperative opioid. However, all of our 'block' patients are asked to take oxycodone or similar prescribed oral analgesic before going to sleep the night after surgery, regardless of whether or not they have discomfort. This is to minimise rebound pain during block resolution.

In conclusion, intra-plexus and peri-plexus needle tip placement for single injection interscalene blocks are associated with similar onset times in both the motor and sensory distributions of the brachial plexus.

The intra-plexus technique has a slightly longer duration than the peri-plexus, although the clinical significance of this difference is yet to be determined.

Competing interests

No external funding and no competing interests declared.

References

1 Sites BD, Brull R. Ultrasound guidance in peripheral regional anesthesia: philosophy, evidence-based medicine and techniques. *Current Opinions in Anaesthesiology* 2006; **19**: 630–9.
2 Ootaki C, Hayashi H, Amano M. Ultrasound guided infraclavicular brachial plexus block: an alternative technique to anatomical landmark-guided approaches. *Regional Anesthesia and Pain Medicine* 2000; **25**: 600–4.
3 Neal JM, Hebl JR, Gerancher JC, Hogan QH. Brachial plexus anesthesia: essentials of our current understanding. *Regional Anesthesia and Pain Medicine* 2002; **27**: 402–28.
4 Kapral S, Greher M, Huber G, et al. Ultrasonographic guidance improves the success rate of interscalene brachial plexus blockade. *Regional Anesthesia and Pain Medicine* 2008; **33**: 253–8.
5 Bigeleisen P. Nerve puncture and apparent intraneural injection during ultrasound-guided axillary block does not invariably result in neurologic injury. *Anesthesiology* 2006; **105**: 779–83.
6 Chan V, Brull R, McCartney CJL, et al. An ultrasonographic and histological study of intraneural injection and electrical stimulation in pigs. *Anesthesia and Analgesia* 2007; **104**: 1281–4.
7 MacDonald KS, Sites BD. Electron microscopy evaluation of block needle-related trauma to the tibial nerve. *Acta Anaesthesiologica Scandinavica* 2010; **54**: 426–9.
8 Brull R, McCartney CJL, Chan VWS, El-Beheiry H. Neurological complications after regional anesthesia: contemporary estimates of risk. *Anesthesia and Analgesia* 2007; **104**: 965–74.
9 Auroy Y, Narchi P, Messiah A, et al. Serious complications related to regional anesthesia: results of a prospective survey in France. *Anesthesiology* 1997; **87**: 479–86.
10 Franco CD, Rahman A, Voronov G, et al. Gross anatomy of the brachial plexus sheath in human cadavers. *Regional Anesthesia and Pain Medicine* 2008; **33**: 64–9.
11 Winnie A, Radonjic R, Akkineni SR, Durrani Z. Factors influencing distribution of local anesthetic injected into the brachial plexus sheath. *Anesthesia and Analgesia* 1979; **58**: 225–34.
12 Thompson GE, Rorie DK. Functional anatomy of the brachial plexus sheaths. *Anesthesiology* 1983; **59**: 117–22.

Supporting information

Additional information may be found in the online version of this article at doi:10.1111/j.1365-2044.2011.06712.x

Video S1 Intra-plexus injection sequence. The needle enters the brachial plexus sheath between the C5 and C6 nerve roots with resulting circumferential spread of local anaesthetic solution.

Video S2 Peri-plexus injection sequence. The needle contacts the brachial plexus sheath, but does not penetrate it. The local anaesthetic solution is adjacent to the plexus.

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