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REVIEW ARTICLE

Postoperative analgesia for shoulder surgery: a critical appraisal and review of current techniques

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Summary

Shoulder surgery is well recognised as having the potential to cause severe postoperative pain. The aim of this review is to assess critically the evidence relating to the effectiveness of regional anaesthesia techniques commonly used for postoperative analgesia following shoulder surgery. Subacromial/intra-articular local anaesthetic infiltration appears to perform only marginally better than placebo, and because the technique has been associated with catastrophic chondrolysis, it can no longer be recommended. All single injection nerve blocks are limited by a short effective duration. Suprascapular nerve block reduces postoperative pain and opioid consumption following arthroscopic surgery, but provides inferior analgesia compared with single injection interscalene block. Continuous interscalene block incorporating a basal local anaesthetic infusion and patient controlled boluses is the most effective analgesic technique following both major and minor shoulder surgery. However, interscalene nerve block is an invasive procedure with potentially serious complications and should therefore only be performed by practitioners with appropriate experience.

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Shoulder procedures are associated with a level of postoperative pain that may necessitate opioid use for several days [1–3]. The opioid requirement may be similar to that following gastrectomy or thoracotomy [4, 5], and opioid-only analgesic techniques for shoulder surgery are commonly associated with opioid-related adverse effects such as nausea and vomiting, pruritus, sleep disturbance and constipation [2]. 'Multi-modal' analgesic approaches incorporating paracetamol, non-steroidal anti-inflammatory drugs and tramadol can reduce opioid requirements; however, opioid consumption remains significant, particularly after rotator cuff surgery [6, 7]. Recently, further evidence has emerged of the adverse effects of both poorly treated acute postoperative pain [8] and acute postoperative opioid use [9]. These adverse effects include nociception-induced central sensitisation and opioid-induced secondary hyperalgesia. Both mechanisms may be involved in the pathogenesis of persistent post-surgical pain, an entity that can occur following many shoulder procedures [8].

The late 1990s witnessed an increase in the popularity of minimally invasive arthroscopic techniques for shoulder surgery. Although it is commonly claimed that these techniques can reduce early postoperative pain, these benefits are typically only seen after the first few days [10]. Consequently, analgesic requirements during the first 24–48 h are often similar to those after open surgery; following arthroscopic shoulder surgery, one third of patients will report severe pain on the first postoperative day, despite multimodal analgesia [3]. This situation has led to the search for opioid-sparing techniques. These include:

- Subacromial (bursal) or intra-articular infiltration of local anaesthetic (SBB).
- Suprascapular with or without axillary (circumflex) nerve block.

- Single-injection ('single-shot') interscalene nerve block (SSISB).
- Continuous interscalene nerve block (CISB).

Subacromial (bursal)/intra-articular infiltration analgesia

This is usually performed by the surgeon at the end of the surgical procedure just before wound closure. The joint space and/or subacromial space is filled with 20–50 ml local anaesthetic and this may be followed by placement of a catheter [11]. The technique gained popularity during the early part of the current decade, because it was seen as a simple and effective alternative to interscalene analgesia, but without the risks.

Suprascapular and/or axillary (circumflex) nerve block

The shoulder joint is innervated predominantly by the suprascapular nerve and to a lesser extent the axillary (circumflex) and lateral pectoral nerves. The suprascapular nerve provides sensory contributions to 70% of the joint capsule in addition to the subacromial bursa, the acromioclavicular joint and the coracoclavicular ligament. The nerve is readily blocked in the suprascapular fossa either with a landmark-only based technique or with the assistance of a nerve stimulator or ultrasound device. Concomitant blockade of the axillary (circumflex) nerve has been recently used to provide more complete perioperative shoulder joint analgesia [12, 13].

Single-injection ('single-shot') interscalene block

This may be the most commonly used technique for postoperative analgesia following shoulder surgery. Blockade of the brachial plexus is at the level of the sixth cervical vertebra [14]: the root/trunk level of the brachial plexus. Analgesia for shoulder surgery requires blockade of the C5-6 nerve roots or superior trunk, which give rise to the suprascapular, axillary (circumflex) and lateral pectoral (with small contribution from C7) nerves innervating the shoulder. Single-shot interscalene block may not provide a sufficient duration of potent analgesia following shoulder surgery and is therefore often combined with a continuous infusion.

Continuous interscalene block

Before the turn of the century, prolonging nerve blockade through the use of continuous techniques was barely feasible because of the limitations of the equipment available at the time and limited understanding of the approaches required for successful catheter placement. Of all the peripheral nerve block techniques, the interscalene approach is possibly the most suited to a continuous technique. This is because of the prolonged severe pain associated with shoulder surgery, the anatomical advantage that a single catheter can be used to block the shoulder joint, and the fact that any resulting motor block is generally well tolerated.

The aim of this review is systematically to search and assess the evidence for effectiveness of the commonly used regional anaesthesia techniques for postoperative analgesia following shoulder surgery. On the basis of this evidence, recommendations are made for management. Logistical and procedural aspects of the effective treatments are also discussed.

Methods

Two independent investigators (S.K, C.C) systematically searched the MEDLINE, EMBASE, Google Scholar and the Cochrane Central Register of Controlled Trials databases for relevant articles relating to pain, regional anaesthetic interventions and shoulder surgery published between January 1, 1990 and October 1, 2009. Keywords included shoulder, rotator cuff repair, acromioplasty, subacromial decompression and analgesia/intra-articular, suprascapular, interscalene, subacromial and cervical paravertebral. The reference lists of eligible articles were also searched. Only prospective randomised controlled trials that included objective measures of postoperative pain (visual analogue or numerical rating scales) were used for the assessment of analgesic effectiveness. For trials involving both shoulder and non-shoulder surgery, there had to be a defined shoulder surgery group, which could be analysed independently of the non-shoulder group. Non-English language reports were excluded.

The methodological quality of the selected trials was rated using the scoring system advocated by Jadad et al. [15]. This system consists of a 5-point scale determined by three factors. Randomisation attracts one point. An additional point is given if the method of randomisation is described and appropriate, while a point is deducted if randomisation is inappropriate. Likewise, a point is given if the study is double-blind, with an additional point given if the blinding procedure is described and appropriate; one point is deducted if blinding is inappropriate. A further additional point is given if the numbers and reasons for withdrawals are described. Each investigator independently assessed each trial and where disagreement occurred, these were resolved by round table discussion.

Studies were stratified according to the specific regional anaesthetic method compared (subacromial bursal/intra-articular, suprascapular, interscalene) and whether these were single-injection or catheter based techniques (intermittent bolus and/or continuous infusion). Pain score data recorded on different scales were converted to a 0–100 scale so that they could be compared directly with

a score on a visual analogue scale (VAS, 0–100 mm). Studies were evaluated qualitatively by assessment of the overall pattern of effectiveness reported in each individual study, and in addition, for each stratified comparative group, we planned to perform a meta-analysis if that group contained three studies reporting mean (SD) VAS data at *specific* time points.

Non-randomised controlled trials were included in this review if they were relevant to the resulting recommendations for each treatment (most commonly complications or safety issues); however, they were not used when assessing the relative effectiveness of each technique.

Results

Thirty-six studies fulfilled the inclusion criteria and all were included regardless of methodological quality (Table 1). For each stratified group, there were at most, two studies reporting mean (SD) VAS data at specific time points. Therefore, meta-analysis was not conducted.

Subacromial (bursal)/intra-articular infiltration analgesia

Three studies compared single-injection SBB with controls; all failed to show any clinically significant reduction in postoperative pain [17–19]. Eight studies compared continuous SBB with controls [6, 20–26]. The four earliest studies (n = 206) [21, 24–26], demonstrated a reduction in pain of 7–20 points in the continuous SBB groups. The subsequent four studies (n = 444) (including a recent study involving 158 patients and having the maximum Jadad score of 5) [6] failed to demonstrate any clinically significant reduction in pain compared with controls. Two additional studies compared continuous SBB with controls, with both groups first receiving a SSISB; one showing clinical benefit with continuous SBB [27], the other showing no benefit [28].

Of the four studies (n = 206) demonstrating a clinical benefit from continuous SBB over controls, none involved open procedures and only one study included rotator cuff repair. Conversely, of the four studies (n = 444) failing to show clinical benefit from continuous SBB over controls, three involved open procedures and four included rotator cuff repair. The two groups of five studies (effective vs ineffective) did not significantly differ with respect to the dose and volume of local anaesthetic administered.

Suprascapular and/or axillary (circumflex) nerve block

Compared with placebo, suprascapular nerve block reduces postoperative pain, morphine consumption and nausea following arthroscopic shoulder surgery [5]. Suprascapular nerve block also provides better postoperative analgesia compared with intra-articular infiltration, but inferior analgesia compared with SSISB [19]. Suprascapular nerve block adds little clinical benefit when added to a general anaesthesia–interscalene block technique [29].

Single-injection ('single-shot') interscalene block

Four studies compared SSISB with controls; all showed reduced pain in the SSISB groups, albeit only up to 24 postoperative hours. Only one of these studies had a Jadad score of more than 2 [30–33]. Three studies compared SSISB with single injection SBB, but all had low Jadad scores [17, 19, 34]. Two of these favoured SSISB, while one showed comparable pain scores with each technique. Two studies compared SSISB with continuous SBB, one study showing improved analgesia in the SSISB group [35], while the other showed no difference between techniques [36]. Two studies evaluated the effect of adding a continuous SBB to a SSISB; one demonstrated improved analgesia with continuous SBB [27], while the other failed to show any benefit from continuous SBB once the SSISB had worn off [28].

Continuous interscalene block

Two studies compared CISB with controls; both demonstrated reduced pain with CISB [37, 38]. Three studies compared CISB with continuous SBB [39–41]; two demonstrated reduced pain in the CISB group [40–41] while the other study (Jadad score = 2) showed no difference [39], although the latter study was actually a comparison of single injection techniques via catheters removed one hour after surgery. Nine studies compared CISB with SSISB and all demonstrated a clinically significant reduction in pain in the CISB group [1, 2, 42–48]. In six of these studies, the treatment effect continued for the 48 h of follow-up (in two studies, pain scores were only measured for 24 h). More importantly, in all but one of these nine studies, the Jadad scores were 4 or more.

Discussion

Subacromial/intra-articular infiltration analgesia

The discrepancy in the findings between the early studies of this technique and the more recent studies could be explained, as stated, by the surgical procedures included in each study. The initial studies demonstrating clinical benefit from continuous SBB tended to be simple, arthroscopic, non-rotator cuff procedures. However, the lower number of patients included in these earlier 'positive' studies always raises the possibility of publication bias. On balance, it appears that at best, the technique is only effective for arthroscopic non-rotator

Table 1 Randomised controlled trials evaluating acute postoperative pain according to regional anaesthetic technique.

Authors	Surgical procedures	*n*	Results	Pain scores	Jadad score (max = 5)	Complications
SSSBB vs Control						
Muittari et al. [18] (1999)	Neer acromioplasty ± RCR	Enrolled = 42 SSSBB (bupivacaine) = 14 SSSBB (oxycodone) = 14 Control (im or iv opioid) = 14	Pain scores were lowest in the bupivacaine group and highest in the control group, but the differences did not reach statistical significance at any time point. Peri-operative opioid consumption was higher in the control group.	VAS mean (SEM) at 6 h/24 h Intrabursal bupivacaine 40 (40–48)/31 (31–35) Intrabursal oxycodone 32 (25–32)/32 (32–42) Intramuscular oxycodone 41 (35–41)/29 (24–29)	4	None reported
CSBB vs Control						
Boss et al. [22] (2004)	RCR Acromioplasty	Enrolled = 50 CSBB = 20 Control = 22 Eliminated = 7 Excluded = 1	There was no statistically significant difference either in total cumulative morphine consumption or in subjective pain perception between the two groups.	VAS mean (SD) in the first 48 h (time not specified). Rest: CSBB 32 (14) Control 31(15) Movement: CSBB 39 (16) Control 41 (30)	4	None reported
Eroglu et al. [23] (2006)	Acromioplasty	Enrolled = 48 CSBB (ropivacaine) = 16 CSBB (fentanyl) = 16 PCA (fentanyl) = 16	The postoperative pain scores at 2, 4, 6 and 12 h were higher in the Group CSBB (fentanyl) compared with the other 2 groups. However, the pain scores at the other time points were similar between the three groups. PCA subacromial fentanyl was not as effective as either subacromial ropivacaine or iv fentanyl.	VAS mean (SD) at 12 h/24 h/48 h CSBB (ropivacaine) 40 (20)/30 (20)/10 (10) CSBB (fentanyl) 20 (10)/10 (10)/10 (0) PCA fentanyl 10 (10)/10 (10)/10 (0)	4	None reported
Savoie et al. [25] (2000)	ASD	Enrolled = 62 CSBB = 31 Control = 31	There was a statistically significant difference in pain in all parameters tested in the CSBB group compared with the control group.	VAS mean (SD not reported) at 24 h/48 h CSBB 32/36 Control 39/49	3	None reported
Harvey et al. [24] (2004)	ASD Arthroscopic RCR Distal clavicle resection	Enrolled = 24 CSBB = 10 Control = 9 Excluded = 5	Subacromial infusion of ropivacaine was associated with an overall 34% reduction in pain scores (46% on day 1 and 22% on day 2). Opioid consumption similar between groups.		5	None reported
Barber et al. [21] (2002)	Arthroscopic surgery	Enrolled = 50 CSBB + glenuhumeral = 25 Control = 25	Lower pain scores were observed in the CSBB group at all recorded times throughout the 7 days of data collection.	VAS mean (SD not reported) at 24 h/48 h CSBB 23/46 Control 43/68	5	None reported
Banerjee et al. [20] (2008)	Arthroscopic RCR	Enrolled = 60 CSBB (2 ml group) = 20 CSBB (5 ml group) = 20 Control = 20	Little difference in pain or opioid consumption between groups.	VAS mean (SD not reported) 12 h/24 h/48 h CSBB (2 ml group) 20/22/21 CSBB (5 ml group) 34/32/26 Control 34/36/12	4	None reported

Table 1 (*Continued*).

Authors	Surgical procedures	*n*	Results	Pain scores	Jadad score (max = 5)	Complications
Coghlan et al. [6] (2009)	RCR (A) ASD (B)	Enrolled = 158 CSBB (A) = 35 (ropivacaine) CSBB (B) = 45 (ropivacaine) SSSBB (A) = 35 (Control) SSSBB (B) = 43 (Control)	Continuous subacromial ropivacaine infusion resulted in a significant, but clinically unimportant, improvement in average pain in the first 12 h following both ASD and RCR, a pooled difference between groups of 6.1.	VAS mean (SD) 12 h/24 h CSBB (A) (ropivacaine) 21.2 (10.7)/20.4 (17.4) CSBB (B) (ropivacaine) 16.2 (11.4)/13.4 (11.9) SSSBB (A) (control) 28.2 (17.2)/25.0 (17.2) SSSBB (B) (control) 21.6 (10.8)/15.8 (10.3)	5	Slightly greater proportion of patients with nausea and vomiting in the ropivacaine arm
Axelsson et al. [26] (2003)	ASD	Enrolled = 30 (3 groups of 10): 1. Prilocaine pre-operatively and ropivacaine infusion postoperatively (PR) 2. Saline + adrenaline pre-operatively and ropivacaine infusion postoperatively (SR) 3. Saline + adrenaline pre-operatively and saline infusion postoperatively (SS)	Postoperative pain at rest was significantly lower in group PR than in group SS during the first 30 min postoperatively. After 1 h the pain decreased in all three groups, so that from the 4th postoperative hour, the VAS was between 10 and 20 in all groups. The intensity of pain was significantly less after the infusion of ropivacaine (groups PR and SR) than after infusion of saline.	VAS median (IQR) at 12 h/24 h/48 h Rest: PR = 5 (0–35)/10 (0–25)/10 (0–20). SR = 20 (0–35)/5 (0–20)/5 (0–25) SS = 20 (0–45)/10 (0–25)/0 (0–10) Movement: PR = 50 (0–100)/40 (0–70)/40 (0–80) SR = 50 (0–80)/30 (0–50)/50 (0–90) SS = 60 (0–85)/60 (0–75)/60 (0–95)	5	Three patients had a positive isolated culture of coagulase negative staphylococcus. None developed infection
SSISB vs Control						
Bain et al. [31] (2001)	Digitally assisted acromioplasty	Enrolled = 40 SSISB = 20 Control = 20	Shoulder pain was significantly less in the SSISB group on day 1. The difference in pain scores between the block and non-block groups was not significant beyond day 1.	VAS presumed mean (nil SD reported) at 24 h/48 h SSISB 25/30 Control 55/38	1	None reported
Al-Kaisy et al. [30] (1998)	ASD Arthroscopic stabilisation, RCR, capsular shift	Enrolled = 30 SSISB = 15 Control = 15	VAS scores were significantly less in the SSISB group compared with control at 20, 30, 60 and 120 min. Reduced opioid consumption (and side effects) with SSISB.	VAS mean (SD) at 0.5 h/1 h/2 h SSISB 34 (20)/25 (13)/22 (10) Control 68 (7)/50 (12)/36 (12)	4	None reported
Hadzic et al. [32] (2005)	RCR	Enrolled = 55 SSISB = 25 GA + infiltration = 25 Dropouts = 4	Moderate/severe pain (VAS 30) was not reported by any of the SSISB patients, whereas 80% of all GA patients requested treatment with analgesics in the PACU. No significant difference between groups in pain scores at 24, 48 and 72 h.	VAS mean/median (SD/IQR) not reported	2	None reported

Table 1 (*Continued*).

Authors	Surgical procedures	*n*	Results	Pain scores	Jadad score (max = 5)	Complications
Kinnard et al. [33] (1994)	Acromioplasty	Enrolled = 30 SSISB = 15 Control = 15	Highly significant difference in pain scores during the first postoperative day between the two groups in favour of the SSISB group.	VAS mean (SD) at 24 h SSISB 18 (23) Control 35 (28)	2	None reported
SSISB vs SSSBB						
Singelyn et al. [19] (2004)	ASD	Enrolled = 120 SSISB = 30 SBB = 30 SSB = 30 Control = 30	Groups SSB and SSISB had significantly lower pain scores at rest at 4 h compared to SBB and controls. No significant difference was observed between the SBB and control groups.	VAS mean (SD) at 4 h/24 h Rest: SSISB 7 (14)/16 (14) SBB 40 (20)/30 (24) SSB 19 (18)/11 (13) Control 34 (20)/25 (16) Movement: SSISB 13 (24)/33 (22) SBB 54 (23)/61 (23) SSB 35 (25)/35 (19) Control 55 (21)/53 (19)	2	Sedation (more in control group), local tenderness (no difference between the three block groups), nausea and vomiting (more in the control group).
Nisar et al. [34] (2008)	ASD ± Mumford procedure Co-planing	Enrolled = 60 SSISB = 19 SBB = 19 Control = 15 Not included = 7	No significant differences in pain between the SBB and SSISB groups during the first 12 h postoperatively, although the values for the SSISB and SBB groups were significantly lower than those in the control group.	At 12 h/24 h SSISB 12/8 SBB 15/12 Control 25/15	3	None reported
Laurila et al. [17] (2002)	ASD Arthroscopic RCR, stabilisation	Enrolled = 45 SSISB = 15 SBB = 15 Control = 15 Not included = 6	Pain scores during the first 4 h at rest and during the first 6 h on movement were lower in the SSISB group compared with the SBB and control groups. No statistical difference was found in the pain scores at rest or on movement between the SBB and control groups at any measurement point	VAS median (IQR) at 6 h/8 h/20 h Rest: SSISB 10 (0–15)/10 (0–20)/12 (12–30) SBB 10 (0–20)/10 (10–20)/12 (0–22) Control 20 (20–35)/20 (10–30)/12(10–22) Movement: SSISB 10 (0–20)/10 (0–30)/30 (20–40) SBB 20 (15–30)/30 (20–40)/40 (20–60) Control 40 (30–65)/40 (30–50)/30 (15–50)	3	Respiratory rate less than 10 (three patients in control group and one patient in SBB group) The lowest measured oxygen saturation was 89 in the ISB group (two patients), 93 in the SBB group, and 90 in the control group
SSISB vs CSBB						
Chao et al. [35] (2006)	ASD	Enrolled = 41	No difference in pain or analgesic consumption between group.	VAS mean (SD) at 24 h/48 h Daytime: SSISB 43 (19)/47 (20) CSBB 58 (27)/64 (25) Night: SSISB 41 (21)/47 (25) CSBB 57 (27)/58 (26)	1	

Table 1 (*Continued*).

Authors	Surgical procedures	*n*	Results	Pain scores	Jadad score (max = 5)	Complications
Klein et al. [27] (2001)	Shoulder arthroscopy	Enrolled = 40 SSISB + CSBB = 20 SSISB = 20	The mean VAS scores at rest for SSISB + CSBB group at 12, 24 and 48 h were significantly lower than the SSISB	VAS mean (SD) at 12 h/24 h/48 h Rest: SSISB + CSBB 25 (30)/20 (22)/15 (20) SSISB 45 (37)/50 (30)/35 (17) Movement: SSISB + CSBB 29 (31)/29 (30)/20 (25) SSISB 48 (37)/56 (26)/36 (19)	5	None reported
Webb et al. [36] (2007)	All shoulder procedures	Enrolled = 56 CSBB = 24 SSISB = 29 Excluded = 3	No statistically significant differences were identified between the two groups with regard to visual analog scale pain scores	VAS mean (no SD reported) at 12 h/24 h/48 h SSISB 51/49/47 CSBB 46/49/44	3	None reported
Ciccone et al. [28] (2008)	ASD ± RCR	Enrolled = 128 SSISB only = 20 CSBB only = 19 SSISB + CSSB = 19 SSISB + Control = 18 Excluded = 52	CSBB-only group had significantly higher scores than all other groups for the first 2 h. The percentage of patients who required oral opioid or iv pain medication was significantly higher for the CSBB-only group than for the other groups	VAS mean (SD not always reported) at 24 h/48 h SSISB only 48/45 CSBB only 42 (26)/34 (24) SSISB + CSBB 42/40 SSISB + Control 48 (32)/38 (33)	3	None reported
CISB vs Control						
Hofmann-Kiefer et al. [37] (2008)	RCR Acromio-clavicular procedures	Enrolled = 87 CISB = 36 PCA = 34 Excluded = 17	In the CISB group, pain scores were significantly lower at rest at 6, 24, 72 h and during physiotherapy on day 2	VAS median (IQR) at 6 h/24 h/48 h CISB 10 (0–25)/20 (10–35)/20 (10–40) PCA 35 (30–50)/30 (20–45)/30 (20–42)	3	Mild dyspnoea, Horner's syndrome, catheter dislodgement (all CISB group)
Lehtipalo et al. [38] (1999)	Acromioplasty	Enrolled = 30 CISB = 7 PCA = 10 im or iv morphine = 10 Excluded = 3	Pain scores in the CISB group were significantly lower than in groups with im Morphine and PCA	VAS mean (SEM) at 12 h/24 h CISB 10 (5)/9 (7) PCA 35 (8)/30 (7) im/iv Morphine 55 (7)/35 (3)	2	Respiratory depression in one patient in PCA group CISB group patients – ptosis (5), Horners syndrome (4), haematoma (1)
CISB vs CSBB						
Beaudet et al. [39] (2008)	All shoulder procedures	Enrolled = 60 CISB = 29 IA = 30 Excluded = 1	Pain scores when patients arrived in the PACU were significantly lower in group CISB	VAS mean (SD) at 24 h CISB 57 (25) IA 50 (25)	2	One patient in group IA reported persistent paraesthesia in the first, second, and fifth fingers of the operated limb, which had diminished in intensity after 9 months of follow-up but not completely resolved.

Table 1 (*Continued*).

Authors	Surgical procedures	*n*	Results	Pain scores	Jadad score (max = 5)	Complications
Delaunay et al. [40] (2005)	Arthroscopic RCR	Enrolled = 30 CISB = 14 CSBB = 15 No follow up = 1	Pain in PACU, oral morphine and local anaesthetic consumption at 24 h was lower in the CISB group	VAS median (IQR) at 24 h/48 h Rest: CISB 0 (0–25)/0 (0–30) CSBB 20 (0–80)/10 (0–40) Movement: CISB 10 (0–60)/15 (0–60) CSBB 45 (20–100)/30 (0–60)	3	Three patients in the interscalene group experienced a Horner's syndrome
Winkler et al. [41] (2009)	ASD	Enrolled = 40 CISB = 20 CSBB = 20	The CISB patients had significantly lower pain levels at rest and movement at 8 and 12 h. Night pain was reported in 22.2% of the CISB group vs 60% in the CSBB group	VAS mean (SD) at 12 h/24 h Rest: CISB 25 (25)/20 (15) CSBB 40 (30)/30 (20) Movement: CISB 30 (10)/40 (15) CSBB = 60(25)/50 (10)	3	None reported
CISB vs SSISB						
Mariano et al. [47] (2009)	Arthroscopic and open shoulder surgery	Enrolled 32, CISB = 15 Control = 15. Not included = 2	Ropivacaine group had significantly less pain, less opioid consumption and less sleep disturbance than the control group	'Average' VAS median(IQR) at 24 h/48 h CISB 2 (0–30)/0 (0–20) Control 50 (30–65)/40 (20–50).	5	Mild dyspnoea (CISB), catheter site pain (saline), catheter dislodgement
Ilfeld et al. [2] (2003)	Arthroscopic and open shoulder surgery	Enrolled = 25 CISB = 10 Control = 10 Not included = 5	Pain reduced in CISB group. 80% of patients receiving CISB required ≤ 1 opioid tablet per day during their infusion vs ≥ 4 opioid tablets in controls	'Average' VAS median (IQR) at 24 h/48 h CISB 0 (0–20)/15 (0–20) Control 45 (40–50)/40 (35–50)	5	Catheter dislodgement
Kean et al. [43] (2006)	All shoulder procedures	Enrolled = 16 CISB = 8 SSISB = 8	The CISB group had lower pain scores at each assessment. Morphine consumption was also lower in the CISB group	VAS mean (range) at 12 h/24 h CISB 1.3 (0–10)/17 (0–60) SSISB = 27 (0–70)/41 (0–80)	5	None reported
Borgeat et al. [1] (1997)	Shoulder arthroplasty RCR	Enrolled = 43 PCIA = 20 SSISB + PCA = 20 Excluded = 3	Pain scores were similar in both groups when PCIA and PCA were started (t = 0) and 6 h later (t = 6) . Significantly better pain control was observed in the PCIA group at 12 and 18 h. At 24, 30, 36, 42, and 48 h, no significant difference in pain score between the two groups was observed	VAS mean (SD) at 12 h/24 h/48 h PCIA 2.5 (6)/19 (17)/11 (19) SSISB+PCA = 24 (26)/32 (26)/16 (19)	3	None reported

Table 1 (*Continued*).

Authors	Surgical procedures	*n*	Results	Pain scores	Jadad score (max = 5)	Complications
Borgeat et al. [43] (1998)	Shoulder arthroplasty RCR	Enrolled = 65 CISB = 30 SSISB + IV PCA = 30 Excluded = 5	Except for 42 h after surgery, pain was less in the CISB group at all times		3	None reported
Capdevila et al. [44] (2006)	Acromioplasty	Enrolled = 40 (subgroup) CISB = 15 Bolus + PCIA = 15 PCA = 10	The morphine group had higher pain scores and higher consumption of morphine and ketoprofen compared with both ropivacaine groups		3	None reported
Tamosiunas et al. [48] (2004)	ASD	Enrolled = 80 CISB = 35 Control = 38 Not included = 7	The CISB group had less pain at rest and on movement than the control group ($p < 0.0001$). The requirement for supplemental analgesia was also lower	VAS median (IQR) at 12 h/24 h/48 h Rest: CISB 4 (0–30)/6 (0–27)/4 (0–31) Control 21 (2–42)/35 (17–44)/31 (19–42) Movement: CISB 8 (0–45)/13 (4–51)/10 (2–52) Control 29 (3–70)/47 (38–75)/47 (30–75)	5	None reported
Klein et al. [46] (2000)	Open RCR, biceps tenodesis	Enrolled = 40 CISB = 22 SSISB = 18	Reduced pain in CISB group	VAS mean (SD) at 12 h/24 h CISB 10 (5)/15 (5) SSISB 34 (7)/28 (7)	5	Mild dyspnoea, catheter site pain, catheter dislodgement (all ropivacaine)
Borgeat et al. [42] (2000)	Shoulder arthroplasty RCR	Enrolled = 35 PCIA = 18 SSISB+PCA = 15 Excluded = 2	Pain scores were similar in both groups when PCIA and PCA were started (6 h after the ISB). Significantly better pain control was observed in the PCIA group at 12 and 24 h	VAS median (IQR) at 12 h/24 h/48 h PCIA 6 (0–15)/4.5 (0–10)/0 (0–5) SSISB 30 (0–40)/20 (0–29)/0 (0–22.5)	3	None reported
Multiple comparisons between all groups vs control						
Fontana [16] (2009)	Acromioplasty RCR	Enrolled = 120 IA = 19 SBB = 21 IA + SBB = 23 SSISB = 20 Control = 20 Excluded = 17	Patients in SSISB, IA + SBB and SBB groups had less pain than those of the control group at all time points. Pain in IA + SBB group was statistically comparable with those in SSISB and SBB groups at each time interval	VAS (area under the curve) mean (SD) at 24 h IA = 118 (5.6) SBB = 87 (4.6) IA + SBB = 63 (3) SSISB = 37 (2.6) Control = 147 (6.5)	3	Four cases of mild dyspnoea and two occurrences of dysphonia were observed in the SSISB group

ASD, arthroscopic subacromial decompression; CISB, continuous interscalene block; CSBB, continuous subacromial bursa block; GA, general anaesthesia; IA, intra-articular; ISB, interscalene block; PACU, post anaesthetic care unit; PCA, patient controlled analgesia; PCIA, patient controlled interscalene analgesia; PR, prilocaine-ropivacaine; RCR, rotator cuff repair; SBB, subacromial bursa block; SR, saline-ropivacaine; SS, saline-saline; SSB, suprascapular nerve block; SSISB, single-shot interscalene block; SSSBB, single shot-acromial bursa block; VAS, visual analogue pain score

cuff procedures; for open and/or rotator cuff (and other major) procedures it appears to perform only marginally better that placebo. Consequently, the use of this technique has declined over the last 5 years as a result of this uncertainty over effectiveness and a rise in popularity of peripheral nerve blockade.

Adverse effects

More recently, concern has been raised over the possibility of iatrogenic chondrolysis associated with intra-articular local anaesthetic [49]. These concerns were highlighted in a recent editorial [50]. Essentially, there is convincing animal evidence for local anaesthetic induced chondrotoxicity, especially for bupivacaine when used in high doses. These data have coincided with several reports of catastrophic glenohumeral chondrolysis occurring in healthy young patients, all having received high and prolonged doses of intra-articular bupivacaine. The condition had been rarely reported before the introduction of intra-articular local anaesthetic infusions. Consequently, some ambulatory pump manufacturers are now actively advising against the use of their pumps for the intra-articular route of administration [51].

Recommendation

Because of substantive evidence showing that this treatment modality provides little, if any, clinically important benefit in terms of reduced postoperative pain (especially for open and/or rotator cuff procedures), and may be associated with irreversible chondrotoxicity, this treatment modality can no longer be recommended.

Suprascapular and/or axillary (circumflex) nerve block

On its own, suprascapular nerve block provides clinically significant improvements in postoperative pain control compared with placebo but provides inferior analgesia compared with interscalene block [19]. When combined with an axillary (circumflex) nerve block, prospective observational data suggest that it will often achieve complete shoulder joint analgesia [12, 13]. The main advantage of this approach over brachial plexus blockade is the avoidance of motor block to those parts of the upper limb innervated by the more inferior roots of the brachial plexus (C8-T1). It also theoretically eliminates the risk of phrenic nerve blockade. Thus, patients with moderate-to-severe respiratory disease who might be expected to be intolerant of both ipsilateral phrenic nerve block (associated with interscalene block) and high doses of perioperative opioid represent prime candidates for this technique. The disadvantage of this approach for perioperative analgesia is the requirement for two separate nerve block procedures, incomplete blockade of all nerves innervating the shoulder joint (in particular the lateral pectoral nerves), and a limited duration of action. Placing perineural catheters adjacent to the suprascapular and/or axillary (circumflex) nerves are theoretically possible, but little data exist to support this practice [51].

Adverse effects

Experience with both of these blocks is still relatively limited; therefore, data concerning safety issues are also limited. Theoretically, both procedures carry a risk of nerve damage and intravascular injection while suprascapular nerve block also carries a risk of pneumothorax [53].

Recommendation

There is insufficient evidence from randomised trials, at present, to support the addition of axillary (circumflex) nerve block to suprascapular nerve block; however, prospective observational data exist to support its use. Suprascapular nerve block with or without a concomitant axillary (circumflex) nerve block may be the preferred technique when an interscalene block is contra-indicated (e.g. moderate-to-severe respiratory disease) or when the absolute avoidance of distal extremity motor block is important. The addition of a suprascapular nerve block to a SSISB cannot be recommended.

Single-injection interscalene block

The block is traditionally performed by palpation of the sternomastoid muscle and then more posteriorly the groove between the anterior and middle scalene muscles. The interscalene brachial plexus lies between these two muscles. The original description recommended the elicitation of a 'paraesthesia' around the area of the shoulder joint as an endpoint for appropriate needle tip placement [14], but peripheral nerve stimulation has became an attractive alternative for correctly identifying appropriate proximity between the needle tip and plexus [54, 55]. The most commonly accepted motor responses for correct needle tip position at this level are a deltoid, lateral pectoralis, biceps or triceps response [56].

The posterior approach to the brachial plexus was first described by Pippa and more recently popularised by Boezaart [57]. It has been claimed that more selective sensory-motor differential blockade can be achieved with this approach compared with the anterior approach, as blockade occurs proximal to the point of fusion of the sensory and motor fibres. Despite these claims, data supporting reduced motor block with this approach are lacking.

The main limitation of both anterior and posterior needle approach SSISB is the limited duration of action, which for most shoulder surgery is shorter than the requirement for potent postoperative analgesia [2]. Many

practitioners have tried to address this by way of combining the block with subacromial infusions of local anaesthetic, but these approaches have been limited in their effectiveness [11, 27, 28, 36]. Following more major procedures, SSISB provides better analgesia and reduced opioid-related side effects relative to local anaesthetic infiltration techniques [11, 17, 19, 34, 35].

Despite the limited duration of potent analgesia provided by SSISB, it is still a very useful technique, particularly when the expertise and logistics required for continuous interscalene analgesia are unavailable. Arguably, SSISB provides a sufficient duration of potent analgesia following minor arthroscopic surgery [58].

Adverse effects

In addition to the common risks associated with peripheral nerve blocks (nerve damage, local anaesthetic toxicity), interscalene block is also associated with a risk of pleural puncture. More importantly, it has been associated with central neuraxial needle placement, cervical spinal cord damage and permanent paralysis [59]. To prevent this potentially devastating complication, it is essential to limit needle depth and maintain the needle in a caudad direction, thereby minimising the risk of entering an intervertebral foramen [60, 61]. Finally, of note, needle placement in the spinal cord can occur with the posterior approach to the interscalene brachial plexus [62].

Recommendation

Interscalene analgesia is the preferred technique for postoperative analgesia following most shoulder procedures; however, it is an invasive procedure that may lead to serious complications. It should therefore be performed by practitioners with appropriate experience. Where possible, it should be combined with a continuous infusion and/or patient controlled boluses of local anaesthetic.

Continuous interscalene block

Borgeat and colleagues showed, in a prospective randomised trial involving patients having rotator cuff surgery, that when compared to single-shot interscalene block, CISB provides better analgesia, improves patient satisfaction and reduces opioid-related side effects [1]. Other workers confirmed these findings for acromioplasty [38], and in the ambulatory setting [2, 46]. Inevitably, the technique was compared with the other commonly used technique at the time, intra-articular local anaesthetic infiltration, and was shown to provide more effective analgesia [40, 41].

Of all the techniques assessed in this review, the strongest evidence for effectiveness exists for CISB. Therefore, the technique will be discussed in detail.

Evolution of continuous interscalene block

Continuous interscalene block was first described in 1987 [4], using an approach similar to that described by Winnie [14] for interscalene block; however, these early reports were associated with failure rates as high as 25%. Between 1990 and 1997, reports of the technique were infrequent but improvements in equipment and a description of a new approach by Meier et al. [63] resulted in a rise in its popularity and with it, increasing reports of its effectiveness. The technique is similar to SSISB, but with the essential modification that the needle insertion point is at a point cephalad of the C6 level. This enables the needle to approach the interscalene brachial plexus along its long axis, which theoretically promotes catheter threading in close proximity to it and enables the placement of sufficient catheter beneath the skin, thereby facilitating catheter fixation. Early descriptions of the technique involved non-stimulating catheters, threaded at least 5 cm beyond the needle tip. 'Secondary' catheter failure rates were high, resulting in editorial commentary sceptical of the technique [64]. As late as 2002 these went so far as to state that 'interscalene catheters will never become routine because of high failure rates and long insertion times' [65]. Subsequent reports described progressively less catheter advancement beyond the needle tip and were associated with lower failure rates [66]. The technique originally described by Meier et al. underwent a very minor modification by Borgeat and colleagues who termed it a 'lateral' approach, even though the needle is essentially directed in a caudad/medial direction. Electrical catheter stimulation was promoted as a way of precisely confirming appropriate catheter positioning and therefore of reducing the previously reported high secondary failure rates [67]. However, subsequent prospective randomised studies have failed to demonstrate any superiority over non-stimulating catheters [68–70]. This, however, does assume that non-stimulating catheters are advanced no further than 3 cm beyond the target needle tip position. Finally, interscalene catheter placement, utilising a posterior approach analogous to that used for posterior approach SSISB, has been shown to be an effective analgesic technique following painful shoulder surgery [67]. To date, this approach has not been formally compared with the anterolateral approach.

Ultrasound guidance for interscalene catheter placement

The neurostimulation technique for plexus localisation specific for interscalene catheter placement has been shown to be associated with a false negative motor response rate of over 50%, and this is higher than that reported for single-injection techniques [71]. This high false negative motor response rate was the likely reason for the finding in subsequent studies that substitution of a

neurostimulation needle endpoint for an ultrasound endpoint results in a reduction in both needling and procedural pain [72]. Furthermore, the incorporation of ultrasound guidance for this procedure, by facilitating catheter positioning adjacent to the most appropriate elements of the brachial plexus (C5-6 roots/superior trunk), has been recently shown to improve indices of interscalene catheter performance, in particular local anaesthetic and supplemental oral analgesic adjuvant consumption [73]. However, a subset of patients exists in whom the use of nerve stimulation is essential for accurate catheter placement [71]. The size of this subset is dependent on the operator's level of experience with ultrasound.

The choice of out-of-plane vs in-plane techniques for ultrasound guided perineural catheterisation remains controversial [74]. The out-of-plane approach has been the most frequently described [71–73, 75, 76] and is popular for a number of reasons. Many anaesthetists are already familiar with this approach for venous cannulation. Second, out-of-plane needle-probe alignment places the needle and therefore the catheter along the long axis of the plexus, potentially promoting catheter advancement along it. Finally, and arguably most importantly, orientation of a short bevelled or Tuohy tipped needle along the long axis of a nerve or plexus virtually eliminates the possibility of intraneural needle placement. Intraneural needle placement has yet to be reported with a Tuohy needle and this needle-to-nerve orientation. Theoretically, by allowing observation of the needle tip, in-plane needle-probe alignment might facilitate catheter positioning adjacent to the most appropriate roots and/or trunks [47, 77, 78]. However, the main drawback of the in-plane approach is that the needle can deviate from the ultrasound beam, and thus be lost from view [79]. This can place the nerve at risk of impalement. In-plane needle-probe alignment, with consequent orientation of the needle perpendicular to the plexus, renders the catheter-past-needle distance more critical with respect to the resultant proximity of catheter and plexus. Therefore, when using the in-plane short-axis technique (needle perpendicular to nerve/plexus) it is probably prudent to limit the advancement of a non-stimulating interscalene catheter no further than 1–2 cm past the needle tip.

Other technical aspects of interscalene catheter placement

Catheter threading in the interscalene area can be challenging [75]. Expanding the perineural space with injectate has been shown to facilitate catheter advancement [80]. Local anaesthetic, normal saline and dextrose 5% have all been used, but dextrose has advantages over both saline and local anaesthetic because an evoked muscle response is typically maintained after injection through the stimulating needle [81]. With a neurostimulation-assisted technique, this is advantageous if catheter threading proves difficult, as the needle can be manipulated in an attempt to facilitate threading, often without losing the muscle response [81, 82]. Placing all local anaesthetic via the catheter provides a simple (if not gross) method of confirming the functional proximity of catheter and plexus [10, 56, 71–73, 83].

Catheter fixation in this area can be difficult because of the mobile nature of the surrounding area and adjacent hair follicles. Attention to this often-overlooked detail is crucial for effective management of continuous interscalene techniques, especially in the ambulatory setting. Two or three drops of topical medical cyanoacrylate (e.g. Dermabond®, Ethicon, Berkshire, UK or Glustitch®, Delta, BC, Canada) at the catheter entry site can reduce problematic postoperative catheter leakage to an acceptable 1% of patients [75]. Catheter tunnelling is popular in many centres but is not essential for effective fixation. An effective non-tunnelled catheter fixation technique that facilitates both catheter retention and patient self-removal has involved the use of a simple epidural catheter securing device (Lockit-Plus®, Portex, Hythe, UK) combined with a clear occlusive dressing (e.g. Tegaderm®, 3M, St Paul, MN, US.A) and non-woven fabric (e.g. Hypafix®, Smith & Nephew, Auckland, New Zealand). This system is efficient and well tolerated [75].

Despite the profound analgesia provided by CISB, tramadol and/or opioid supplementation is generally still required, particularly in the ambulatory setting where the technique is limited by the use of low volume infusion pumps, which necessitate low background infusions in order to provide more than 1–2 days of blockade [2, 83].

Ambulatory management

Ambulatory application of CISB was first described in 2000 [46], followed 3 years later by a small placebo controlled trial [2]. A small feasibility study [84] and later a large prospective study involving over 300 consecutive patients, performed by a single operator, confirmed that the technique could also be safely and effectively applied in the private practice/community environment [75]. The technique has also been shown to be feasible when performed by a mixed group of anaesthetists [11, 76]. However, successful and safe ambulatory management of this treatment, like all perineural catheters, requires careful patient selection, substantial pre-operative education [85] and close postoperative supervision. Pre-operative education typically starts when the patient is booked for surgery. Postoperative instructions are ideally accompanied by explicit written instructions, which must provide a clear point of contact in the event of catheter-related problems including inadequate

analgesia. This typically involves either the primary anaesthetist (e.g. private practice setting) [75] or acute pain service (e.g. teaching hospital) [76].

Pharmacology

The optimum combination of both volume and concentration for interscalene infusions is largely unknown. Initial reports of the technique used infusion rates as high as 10 $ml.h^{-1}$ [46]; however, subsequent reports have been characterised by progressively lower background infusions and the incorporation of patient controlled boluses [86–88]. Lower background infusions have been adopted because of an appreciation that high rates were not necessary, that high doses may increase unwanted motor block, because ambulatory pumps have limited reservoir volumes, and possibly because interscalene catheter placement has become more precise. Ropivacaine 0.2% was shown to provide similar analgesia to bupivacaine 0.15% but with reduced motor block [89], and has subsequently remained the most common local anaesthetic drug studied. Ilfeld et al. [86] showed that ropivacaine 0.2% at 8 $ml.h^{-1}$ with a 2-ml hourly bolus capability provided superior baseline analgesia compared to the same drug administered at 4 $ml.h^{-1}$ with 6-ml boluses. Le and colleagues, using a neurostimulation catheter placement technique that necessitated a biceps or deltoid motor response, compared ropivacaine 0.2% and 0.4% administered at a constant total dose (8 $ml.h^{-1}$ infusion/4-ml bolus vs 4 $ml.h^{-1}$ infusion/2-ml bolus) [87]. The secondary outcome of postoperative pain was reduced in the high volume/low concentration group. Compared with 0.25%, ropivacaine 0.4% was associated with both reduced ropivacaine bolus demands and reduced supplemental ketoprofen administration [88]. With ropivacaine 0.2% administered at 2 $ml.h^{-1}$ by continuous infusion supplemented with on-demand patient controlled 5-ml boluses, rotator cuff surgery and arthroplasty are associated with generally acceptable pain control but a significant proportion of patients experiencing moderate-to-severe breakthrough pain, which is not improved by increasing the concentration to 0.4% [83]. These studies suggest that a background infusion of at least 4 $ml.h^{-1}$ is required for optimal analgesia, but equally important is the bolus dose [91–93], the optimal volume of which appears to be at least 4 ml. There appears to be little benefit in administering concentrations of ropivacaine > 0.2%. These relatively high basal and bolus volumes will be difficult to administer in the ambulatory setting where the duration of treatment is restricted by limited volume pumps [83]. However, the small subset of patients who require more than 72 h of potent analgesia can be safely and effectively managed by having their elastomeric pump refilled in order to provide extended brachial plexus blockade [94].

Surgical indications

Early prospective randomised trials comparing CISB with SSISB demonstrated profound analgesia following major shoulder surgery including rotator cuff repair and open procedures [1, 2, 43]. More recently, an ultrasound guided placement technique targeting the C5-C6 roots and/or superior/middle trunks has also been shown to improve analgesia and reduce supplemental oral analgesic adjuvant consumption following minor arthroscopic procedures [10].

Training issues

Interscalene catheter placement has long been recognised as technically challenging [64], and this factor has been a likely reason for the slow uptake in the utilisation of the technique. Over the last decade, improvements have been made in the design features of the commonly available catheter kits. These improvements have been accompanied by a steady increase in the availability in the operating theatre of portable ultrasound equipment. There is some evidence to suggest that ultrasound guidance may accelerate proficiency with peripheral nerve block procedures [95]; however, it remains to be seen whether this modality will affect the rates of perineural catheter utilisation. It is possible that the only solution to the current low utilisation rates will be the adoption of minimum training requirements and minimum levels of ongoing case exposure similar to that often seen with the cardiac, paediatric and obstetric anaesthesia subspecialties.

Adverse effects

Side effects are similar to those of SSISB, although those side-effects likely to be volume/dose related should theoretically be less frequent with a lower 'primary' local anaesthetic dose, as is often used when incorporating a continuous infusion. The most common side effects reported with the technique include mild dyspnoea (7%), hoarseness (4%) and Horner's syndrome (7%) [75]. More significant adverse effects include pneumothorax, intravascular injection (all approximately 0.2%) and local inflammation/infection (0.3–0.8%) [56, 75]. Transient postoperative neurological symptoms associated with the technique are relatively frequent (8%) at day 10, but are infrequent (2–4%) after 1 month [56, 96]. Differentiating transient symptoms arising as a result of the block from other causes is difficult; however, block-related neurological sequelae lasting more than 6 months are exceedingly rare [56, 96].

Recommendation

Continuous interscalene block represents the gold standard for postoperative analgesia following both major and minor, open and arthroscopic shoulder surgery. It

provides better analgesia than SSISB (which in turn provides better analgesia than both suprascapular nerve block and subacromial (bursal)/intra-articular infiltration). However, like its single injection counterpart, it remains an invasive procedure as a result of its association with serious procedure related complications. Despite advances in the methods used to facilitate catheter placement, it remains a technically challenging procedure. It should, therefore, be used by practitioners who have the appropriate training and/or experience.

Superficial cervical plexus block

The superficial cervical plexus innervates the skin on the side of the neck and shoulder joint principally via the supraclavicular nerves. Consequently, an isolated block of the brachial plexus or its terminal nerves will not provide cutaneous anaesthesia for shoulder surgery. It has been suggested that a conventional interscalene block will result in local anaesthetic spread to the cervical plexus and therefore eliminate the requirement for a separate injection, but this notion is not supported by definitive data. Because CISB often involves large calibre needles (e.g. 18-G Tuohy), it is likely that interscalene catheter placement involves greater procedural pain than single-injection techniques that utilise smaller calibre needles (e.g. 22-G short bevelled). The superficial cervical plexus block therefore represents an attractive anaesthetic technique to facilitate interscalene catheter placement, with the added advantage of ensuring blockade of the cutaneous nerves innervating the skin of the shoulder. It does, however, involve an additional procedure, which, at least theoretically, carries a small risk of trauma to the nerves of the cervical plexus.

Conclusion

In conclusion, the last 5 years have seen significant advances in the management of pain after shoulder surgery. Recent large, high quality placebo controlled trials of subacromial/intra-articular infiltration of local anaesthetic have shown that the technique provides little if any clinical benefit. Because the technique may be a factor in the aetiology of catastrophic chondrolysis, it can therefore no longer be recommended. While single injection nerve blocks have an important place in the management of pain after shoulder surgery, they are nevertheless limited by a short effective duration of action, that is often shorter than the duration of moderate-to-severe postoperative pain. Continuous interscalene block represents the gold standard for analgesia after this surgery; however, it remains an invasive technique, is technically challenging and is consequently under-utilised. The most urgent areas for future study, therefore, are the identification of barriers to CISB as an analgesic modality, and the subsequent evaluation of strategies aimed at promoting its uptake.

Competing interests

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