Current Concepts in Anaesthesia for Shoulder Surgery

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Abstract: There has been an exponential growth in the volume of shoulder surgery in the last 2 decades and a very wide variety of anaesthetic techniques have emerged to provide anaesthesia and post-operative analgesia. In this article we examine current opinion, risks, benefits and practicalities of anaesthetic practice and the provision of post-operative analgesia for shoulder surgery.

Keywords: interscalene block, local anaesthetics, regional anaesthesia, shoulder surgery.

INTRODUCTION

There is considerable diversity in the manner in which anaesthetists approach the provision of shoulder surgery. Patients may be awake or asleep, sitting or lateral and have systemic, peri-neural or intra-articular analgesia, or indeed or a combination of all three. Advances in minimally invasive techniques are extending the benefits of shoulder surgery to ever more frail patients with greater co-morbidity who would normally be regarded as very high risk for general anaesthesia.

The increasing confidence of anaesthetists in their use of regional anaesthesia for shoulder surgery is allowing sicker patients access to shoulder surgery, improving the quality of post-operative care, and permitting a wider choice for patients in how they have their surgery.

AIRWAY MANAGEMENT

Patients undergoing arthroscopic shoulder surgery may be awake, undergo conscious, unconscious sedation or general anaesthesia with either a supraglottic airway or tracheal tube and practice varies widely from country to country as well as between institutions.

Extravasation of irrigation fluid in shoulder arthroscopy is common [1], particularly during subacromial procedures because the subacromial space is not enclosed within a capsule [2]. The exact incidence is unknown, although in a case series of 141 patients Berjano *et al*. [3] identified 4 cases of severe oedema affecting the cervical region, of which one developed airway problems. There are multiple case reports in the literature of airway obstruction due to tracheal compression and laryngeal oedema from extravasated fluid [4, 5]. Massive tissue oedema may cause major difficulties in airway rescue, even necessitating an emergency surgical airway [6]. This is a life-threatening problem regardless of the mode of anaesthesia though it may not be recognised in intubated patients until extubation. A common theme running through nearly all reported cases is prolonged surgery >2hrs [4, 5, 6]. Other identified risk factors include lateral decubitus positioning exacerbating gravitational accumulation, high pump pressures and subacromial bursoscopy [4-6].

GENERAL ANAESTHESIA *VS* REGIONAL ANAESTHESIA:

Pain following shoulder surgery may be severe, require strong opioids, and may last days to weeks [7]. There are several methods of delivering regional anaesthesia to alleviate this phenomenon using local anaesthetics (LA), and this ability to attenuate pain in the short term has brought arthroscopic shoulder surgery firmly into the arena of day case surgery [8].

On a population basis modern day general anaesthesia is extremely safe with expected mortality rates of 1 in 300,000 [9] however in candidates with severe co-morbidity this figure is undoubtedly higher. No regional anaesthetic technique has a 100% success rate and even with a successful nerve block the risk of inadequate analgesia necessitating conversion to general anaesthesia persist, with conversion rates upto 8.7-13% in some series [10, 11].

In awake shoulder surgery patient selection is vital and pre-operative psychological preparation should start long before the day of surgery. There are many obstacles to overcome ranging from perceptions of regional anaesthesia [12] in the general population to practical issues such as proximity of the patient's face to the surgical site and consequent claustrophobia due to drapes.

General anaesthesia alone has multiple disadvantages including higher pain scores in recovery, more readmissions and late discharge [10, 13] and hence nearly all patients undergoing general anaesthesia will have some form of additional regional anaesthesia. Options include intra-articular (IA) LA +/- opiates, suprascapular nerve block (SSNB) +/- axillary nerve block (ANB), single shot interscalene block (SSISB) or continuous interscalene block (CISB).

ANALGESIA FOR SHOULDER PROCEDURES

Opioid requirements following surgery may approximate to that following thoracotomy [14]. Poorly controlled post-operative pain and acute post-operative opioid use may

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1874-3250/13 2013 Bentham Open

contribute to persistent post-surgical pain [15]. While minimally invasive shoulder surgery may reduce post-operative pain these benefits are often not apparent for the first few days and for the first 48 hours analgesic requirements in the absence of regional anaesthesia may equate to those following open surgery [7].

INTRA-ARTICULAR ANALGESIA:

This technique, usually undertaken by surgeons, involves injecting LA +/- opiates into the joint space at the end of the surgical procedure. It may also involve placement of an epidural-type catheter for continuous LA infusion. Opiates, typically morphine or diamorphine, may be added to the LA mix.

There does seem to be an effect from IA LA and comparisons with saline result in a reduced analgesic requirement in the IA LA groups. However the extent of this effect seems relatively small [16]. Nisar *et al.* reported comparable analgesia from IA LA in comparison with SSISB involving 60 patients split between 3 groups, however this study excluded cuff repairs and found reduced morphine consumption in the interscalene group (14.0mg) compared with the IA LA group (22.3mg) and control group (32.3mg) [17]. Singelyn *et al.* found SSISB to provide superior analgesia to IA LA which in turn was similar to the control group [18]. Similarly Laurila and co-workers found SSISB to relieve early post-operative pain more effectively than IA LA (oxycodone use in first 6 hrs: 6 mg *vs* 24.1mg) with no significant difference between IA LA and placebo). IA LA mixed with opiates seem to work better than either alone [19] though numerous studies have reported mixed results and LA alone seems more effective than IA opiates alone. Scoggin *et al.* found IA opiate alone for knee arthroscopy to be no better than placebo [20]. Eroglu found IA fentanyl was less effective than either IV fentanyl or IA ropivicaine [21]. Tetzlaff *et al.* found IA bupivicaine + morphine provided better pain relief than IA bupivacaine alone after SSISB with mepivacaine [22]. Using a hybrid technique, Klein *et al.* found SSISB with short-acting LA followed by an IA LA infusion provided better analgesia over 48 hrs than SSISB with long-acting LA alone [23]. There is very little data comparing IA LA and long acting opiate with SSISB. In a study from a Spanish group, Contreras-Dominguez *et al.* found that single shot IA LA and morphine provided equivalent analgesia to CISB with a weak O.O625% bupivacaine solution for 12 hours but poorer analgesia and patient satisfaction in the subsequent 36 hours with higher nausea scores and lower patient satisfaction in the IA group [24].

Results from studies of IA LA are very mixed and show a biphasic pattern with earlier studies showing more benefit than more recent studies, perhaps because the limited effect of the technique is exposed by the trend towards more extensive surgery involving cuff repair rather than sub-acromial decompression alone [8]. Nevertheless, while perhaps not the gold standard of analgesia, single shot IA LA particularly in combination with IA morphine provides a simple, useful and low risk route of providing a degree of analgesia after less painful shoulder surgery in the immediate post-operative period.

Some concerns have been raised regarding the the possibility of amide LA induced chondrotoxicity manifesting as devastating post-arthroscopic glenohumeral chondrolysis (PAGCL) and there does seem to be *in vitro* evidence to this effect [25], more pronounced for lignocaine than bupivacaine [26]. *In vivo* chondrotoxicity has been linked to IA infusions of bupivacaine [27] and through animal models to a dose related chondrotoxic effect [28]. There is little evidence to suggest that there is any significant chondrotoxic effect of single shot IA LA in humans though there is some animal data showing reduced chondrocyte density in sacrificed rats at 6 months [29]. In the face of growing evidence of a time and concentration dependent negative effect of prolonged LA infusions [30] alternative strategies may seem more attractive though clearly no technique is without risk.

SSISB +/- ADJUVANTS

Several studies have compared SSISB with controls with all showing reduced pain in the treatment group but with a limited duration of analgesia upto 24hrs [31]. Singelyn and colleagues in a seminal paper showed SSISB provides superior analgesia to either singleshot IA LA or suprascapular nerve block [18]. One hundred and twenty patients undergoing arthroscopic shoulder acromioplasty were divided into 4 groups of 30 and given in conjunction with general anaesthesia either IA LA, SSNB, SSISB or placebo. There was no difference between the control and IA LA groups whereas groups receiving SSNB and SSISB had significantly lower pain scores. At 4 hours follow up better pain scores on movement were noted in the SSISB group. When compared with controls a significant reduction in pain scores, nausea rates and improved satisfaction was noted in the SSISB group only.

Pain after block resolution is a significant problem to which anaesthetists are sometimes oblivious, as the patient may have been discharged by this stage. Wilson *et al.* [8], in a telephone survey, found very high levels of severe pain with 20% recording a maximum pain score following discharge, with few patients taking regular oral analgesia as prescribed. Clearly patient preparation and reinforcement of advice is as much a part of successful regional anaesthesia as block administration.

A number of strategies may be undertaken in order to minimise this problem. One such strategy is prolonging the block with the use of adjuvant drugs. A number of drugs have been tried in this regard including epinephrine, clonidine, ketamine, midazolam with some success. Perhaps the most promising is dexamethasone which appears to be effective in prolonging analgesia in a recent large scale clinical trial [32]. Cummings III *et al.* found the addition of 8mg dexamethasone prolonged time to first opiod consumption from 11.8 hours to 22.2 hours for ropivicaine and from 14.8 hours to 22.4 hours for bupivacaine. The exact mechanism by which this works is unclear but it may be that dexamethasone acts *via* glucocorticoid receptors to increase the activity of inhibitory potassium channels on nocioceptive C-fibres [33], though it is also possible that this effect occurs *via* systemic absorption. However there is little data to suggest that this systemic route extends analgesia to the same degree as the perineural route. In a comparison with epinephrine, Kim *et al.* found that perineural dexamethasone with SSISB provided lower pain scores with an effect extending up to 48 hours [34]. A note of caution should be added in that dexamethasone does not have a license for perineural administration though epidural dexamethasone administration has been common practice for many years. While some experimental studies have shown dexamethasone to demonstrate a degree of neurotoxicity, this was less than that shown by ropivicaine [35]. Though we are still in the early phases of understanding the effects of perineural dexamethasone, several randomised studies have been published with large numbers of patients without any evidence of adverse effects *in vivo* [32, 34, 36].

LOW VOLUME SSISB

The advent of ultrasound has enabled practitioners to visualise LA spread and adjust LA administration accordingly rather than dosing all patients with a standard volume which must therefore incorporate a generous margin of error to ensure adequate analgesia. Fredrickson *et al.* conducted a study to estimate the volume and concentration of ropivicaine required to avoid pain in recovery after shoulder surgery under general anaesthesia [37] and found no difference between 20ml 0.375% and 30 ml 0.5% ropivicaine in pain scores or grip strength, though satisfaction was higher with the lower dose. Riazi *et al.* randomized 40 patients to receive either 5 or 20 ml of 0.5% ropivicaine by ultrasound-guided SSISB [38]. There were no differences in pain score or morphine consumption over the first 24 hours but phrenic nerve block was less frequent in the low-volume group (45% *vs* 100%) and oxygen saturation was higher in the low-volume group (-1.5 *vs* -5.85). Interestingly, in the low-volume group even those who developed a phrenic nerve block had a statistically significant smaller reduction in FEV1 (-0.62 *vs* -1.23 l), FVC (-0.84 *vs* -1.59 l) and oxygen saturation (-2.2 *vs* -5.85) than in the high volume group. However, there was substantial overlap between the data points for these two groups and it is difficult to predict if a low volume SSIB will adequately preserve respiratory function for an individual patient with diminished respiratory reserve.

Studies involving intermediate volumes report mixed results. Renes *et al.* conducted a study on 30 patients randomized to receive 10 ml 0.75% ropivicaine either by ultrasound guidance or nerve stimulation at a low C7 level SSISB [39]. There was a much lower incidence of phrenic nerve block in the ultrasound group (13% *vs* 93%) whereas Sinha *et al.* studied 30 patients randomized to receive 10 or 20 ml of 0.5% ropivicaine by ultrasound guidance at the cricoid level with both groups experiencing a 93% incidence of phrenic nerve block.

NERVE STIMULATION *VS* ULTRASOUND GUIDANCE

The use of ultrasound has infiltrated nearly every aspect of anaesthetic practice. The ability to visualise needle and nerve has seduced many anaesthetists away from nerve stimulation with its long track record of safety and success, and at the same time exposed some of the unrecognised weaknesses of nerve stimulation. In particular, the high false negative rate associated with seeking neurostimulation endpoints [40].

Beach and colleagues retrospectively examined supra clavicular block records performed with dual guidance (ultrasound and nerve stimulation together) [41]. They found that out of 74 patients in whom adequate ultrasound images were obtained, 64 had a positive motor response and these patients had an 88% success rate as compared with a 90% success rate in the 10 patients who had no motor response. The authors concluded that nerve stimulation added little benefit if an adequate ultrasound image was obtained.

Liu and colleagues undertook a prospective randomised trial comparing nerve stimulation and ultrasound guidance for SSISB in 219 patients [42]. They found that ultrasound reduced the number of needle passes (1 *vs* 3), enhanced motor block at 5 min but did not decrease block performance time (5 min). No patient required conversion to general anaesthesia and patient satisfaction was similar in both groups (92% ultrasound *vs* 96% nerve stimulation). The incidence of postoperative neurological symptoms was similar at 1 week (8% *vs* 11%) and at 4-6 weeks (6% *vs* 7%).

Kapral and co-workers randomized 180 patients having a SSISB for trauma related upper arm surgery to either nerve stimulation or ultrasound guidance [43]. Surgical anaesthesia was achieved in a significantly higher proportion of patients in the ultrasound group (99% *vs* 91%). The extent of sensory / motor block was better in the ultrasound group.

False negative neurostimulation endpoints are more common in interscalene catheter placement when compared to SSISB [40], and substitution for an ultrasound endpoint results in less needling time (78s *vs* 108s) and procedural pain [44] with equivalent quality of analgesia.

SUPRASCAPULAR +/- AXILLARY (CIRCUMFLEX) NERVE BLOCK

The suprascapular nerve provides approximately 70% of the sensory supply to the shoulder joint with the remainder largely from the axillary and lateral pectoral nerves. Suprascapular nerve block (SSNB) reduces morphine consumption by 31% compared with placebo, reduces nausea and vomiting rates and allows earlier discharge [45]. SSNB alone provides analgesia superior to IA LA but inferior to SSISB [18]. As a supplemental technique in addition to SSISB, SSNB prolongs time to first analgesic requirement (594 *vs* 375 mins) but did not change supplemental analgesic requirements or pain assessment at 24hrs and so adds little clinical benefit [46].

When SSNB is used in conjunction with axillary (circumflex) nerve block (ANB) observational data suggests it is possible to achieve total shoulder joint analgesia [47, 48] though some intra-operative opiate may still be necessary due to joint capsule stretching and unblocked sensory supply from the lateral pectoral nerves, but this is usually a short lived phenomenon [49]. In a case series of 20 patients undergoing arthroscopic shoulder surgery Checcucci *et al.* describe using SSNB plus ANB and port infiltration as a sole technique without failure [50] and with a negligible requirement for postoperative opiates in the first 24 hours. The advantage of this technique over an SSISB are the absence of phrenic nerve block for those patients who have limited respiratory reserve as well as the absence of unwanted motor block to the lower half of the upper limb. The disadvantages are the requirement for two separate, deep injections, incomplete blockade of the shoulder joint and if a continuous infusion is required then the unappealing prospect of two separate perineural catheters.

Whilst there is limited experience with this technique, and a paucity of trial data to support its use, there is however substantial prospective observational data of its efficacy. The technique is likely to grow in popularity and may well become the technique of choice in those with impaired respiratory reserve.

SUPRACLAVICULAR NERVE BLOCK

The supraclavicular block has not been generally seen as the technique of choice for shoulder surgery because of concerns that the proximal nerve branches arising from the upper roots of the brachial plexus will be missed, particularly the origin of the suprascapular nerve at the proximal superior trunk. However as the block is undertaken above the clavicle, it is possible to achieve entire shoulder anaesthesia though this may depend partly on LA tracking up into the interscalene groove.

There is very little randomized trial data comparing these two techniques but a substantial body of prospective [51, 52] data supporting the efficacy of the supraclavicular technique exists. Liu *et al.* [51] recorded data for 1169 patients undergoing ultrasound guided interscalene (n=515, success rate 100%) and supraclavicular (n=654, success rate 99.7%) blocks for ambulatory shoulder surgery. The incidence of hoarseness was significantly lower for supraclavicular blocks at 22% *vs* 31%, while the incidence of dyspnea was similar (7% *vs* 10%). There was no clinically apparent pneumothorax and a low rate of post-operative neurological symptoms (0.4%) and a 0% rate of permanent nerve injury. DiMeo *et al.* [52] in a small, randomized trial achieved a 100% success rate with both supraclavicular and SSISB but noted a reduced rate of phrenic nerve block in the supraclavicular block group (40.6% *vs* 76%), a reduced rate of voice hoarseness (46.7% *vs* 56%) and a reduced incidence of Horner's syndrome (21.9% *vs* 32%).

While perhaps anatomically not the location of choice, supraclavicular block does seem to be an effective technique for analgesia for arthroscopic shoulder surgery. However it is likely to lead to a greater degree of motor block to the entire upper limb which may have an effect on patient satisfaction [53].

CONTINUOUS INTERSCALENE INFUSIONS

By far the strongest evidence for effective analgesia lies with CISB. Fredrickson and colleagues studied 61 patients undergoing minor arthroscopic surgery all of whom received 0.5% ropivicaine *via* an ultrasound-guided interscalene catheter which was randomly assigned to be removed in 30 patients following completion of surgery. The remaining 31 patients continued to receive 0.2% ropivicaine *via* an elastomeric infusion pump at 2ml/hr with a 5ml bolus option. The continuous infusion group had lower worst pain scores both at rest (1 *vs* 2) and with movement (2 *vs* 4), a lower tramadol intake for the first 24 hours but a higher rate of arm numbness [54]. Pain scores were however similar on the second day.

Mariano *et al.* randomized 30 patients undergoing major shoulder surgery to an interscalene catheter [55] with a bolus of 40 ml of 0.5 % ropivicaine followed by either an infusion of either 0.2% ropivicaine or normal saline. The ropivacaine infusion group had better analgesia, sleep quality, patient satisfaction and lower opioid consumption.

Kean *et al.* compare CISB with SSISB for open shoulder surgery in a small, randomized trial of 16 patients and found reduced pain scores at all time points upto 24 hours, reduced morphine consumption and increased satisfaction in the CISB group [56].

Ilfeld *et al.* undertook a retrospective case-control study of total shoulder arthroplasty matching 25 patients with CISB to those without and comparing achievement of joint motion targets. Patients with CISB achieved a substantially greater range of motion on their first postoperative though this observation did not persist to the second postoperative day [57]. Several successful models of ambulatory day case surgery for total shoulder arthroplasty have been reported [58] and while these models require investment, they may provide a route to overall cost savings.

However, CISB is not without its problems. CISB may not always provide adequate analgesia. Klein *et al.* reported logistical problems and inadequate analgesia in 47-70% of patients in their study group of ambulatory interscalene analgesia following open rotator cuff repair [59]. In a survey of 172 patients who had undergone CISB almost 10% complained of dyspnea [60]. Readmission for lower lobe collapse has been reported [61], as have infectious complications such as cellulitis and mediastinitis [62]. CISB is a technically difficult procedure relative to SSISB, and not suited to the occasional practitioner. The catheters themselves are difficult to secure and easily dislodged, may leak at the site of insertion [59] and the requirement of equipment and infrastructure to support the service is substantial [58].

RISKS OF REGIONAL ANAESTHESIA

There are undoubtedly risks associated with interscalene analgesia particularly in the hands of the occasional practitioner. There are in excess of 20 case reports documenting epidural or intrathecal injections and permanent neurological deficits resulting from both SSISBs and interscalene catheters.

Auroy *et al.* reported prospectively on the complications from over 250, 000 nerve blocks and found an overall incidence of nerve damage of 1:5000 however this was 1:3500 for interscalene analgesia [63]. The interscalene block is by definition close to the neuraxis where the relative lack of connective tissue [64] and immobility promote the likelihood of impalement and consequent neural injury.

Particular risk factors include medial angulation of needle with depth >2.0 cm [65] and catheter advancement of >5 cm [66] beyond the needle tip which brings with it the risk of catheter knotting leading to brachial plexus avulsion injuries on removal [66] as well as catastrophic catheter misplacement [67].

All analgesic systems including opiod analgesia carry the risk of potentially fatal complications but careful attention to detail, awareness of the pitfalls and careful post-operative management can substantially mitigate but never completely eliminate the risks associated with effective regional anaesthesia [65].

SUMMARY

The capacity for more extensive shoulder surgery on frailer patients requires anaesthetists to constantly reassess the techniques they use to provide adequate conditions for surgery and appropriate post-operative analgesia. There is little data to suggest that regional anaesthesia is safer than general anaesthesia but for a small subsection of the high risk population regional anaesthesia continues to have an enduring appeal.

Shoulder surgery without an element of regional anaesthesia results in poor post-operative analgesia and high opioid consumption. The interscalene block remains the cornerstone of analgesia for shoulder surgery. For less painful procedures, single shot IA LA with opiate may be adequate though for more painful procedures SSISB or CISB is preferable. IA LA infusions cannot be recommended due to the risk of devastating chondrotoxicity. Interscalene analgesia has become much more accessible and simpler since the advent of ultrasound in anaesthetic practice. SSNB alone has limited value, adds little to a SSISB but in conjunction with ANB provides an acceptable alternative and in time may grow in popularity to become the first choice for patients with severe respiratory disease but at the present is beyond the technical ability of most anaesthetists.

CISB provides the most effective analgesia for more painful procedures yet there remain questions over its practicality and complications. CISB requires a support network and infrastructure found in only a few specialist centres at present. But as pressure mounts to reduce the duration of inpatient stay the technique may yet find a fertile ground to expand.

ABBREVIATIONS

ANB	=	Axillary nerve block
CISB	=	Continuous interscalene block
FEV1	=	Forced expiratory volume in 1 second
GA	=	General anaesthesia
IA	=	Intra-articular
LA	=	Local anaesthesia
PAGCL	=	Post-arthrosopic glenohumeral chondrolysis
SSISB	=	Single shot interscalene block
SSNB	=	Suprascapular nerve block

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

I would like to acknowledge the great contribution of Drs Fredrickson, Hadzic and Harrop-Griffiths to the field of anaesthesia for shoulder surgery from whose work I have learnt so much.

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Received: September 8, 2012 Revised: October 6, 2012 Accepted: November 24, 2012