Regional Anesthesia Procedures for Shoulder and Upper Arm Surgery Upper Extremity Update—2005 to Present

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Introduction

Common shoulder surgical procedures include hemiarthroplasty, total shoulder arthroplasty, shoulder arthroscopy, subacromial (SA) decompression, shoulder instability procedures including rotator cuff repair and frozen shoulder procedures. These procedures are performed with general anesthesia (GA), regional anesthesia (RA), or combined GA and RA. Postoperative pain after shoulder surgery in many patients is severe and may be exacerbated by movement during rehabilitation.[1] RA has been increasing in popularity, especially for ambulatory shoulder surgery, as RA can provide both anesthesia and postoperative analgesia.[2] RA techniques have been developed to help manage the dynamic pain of shoulder surgery.

Although the structure and innervation of the arm, shoulder, and lateral clavicular area is complex, ultrasound (US) imaging allows for identification of accurate location of the brachial plexus and its branches, thereby making upper limb blocks achievable. Commonly used techniques for shoulder surgery are the interscalene block (ISB), cervical paravertebral block (CPVB), suprascapular nerve block (SSNB),

supraclavicular nerve block (SCB), SA block, and intra-articular (IA) injections. In addition to ultrasound-guided (USG) blocks, the use of perineural infusions has increased in the outpatient setting. This chapter will review the literature for RA for shoulder surgery published since 2004.

■ Shoulder Anatomy and Nerve Innervation

The humerus, scapula, and clavicle provide the framework for the shoulder girdle that consists of the 3 main shoulder joints, the sternoclavicular, acromioclavicular, and glenohumeral joint. There is one often overlooked shoulder joint—the scapulothoracic joint. Static shoulder stability is provided by the labrum, capsule, and glenohumeral ligament, whereas dynamic stability is provided by the rotator cuff, long head of the biceps tendon, and periscapular muscles.[3] The brachial plexus supplies all the motor and most of sensory functions of the shoulder, except the cephalad cutaneous areas of the shoulder, which are innervated by the supraclavicular nerves, originating from the superficial cervical plexus (C3-C4).[1] Effective control of postoperative shoulder pain requires blockade of the nerve supply to the synovium, capsule, articular surfaces, periosteum, ligaments, and muscles of the shoulder joint.[1,4]

The suprascapular nerve (SSN) originates from the C5 to C6 nerve roots of the superior trunk of the brachial plexus, and possibly C4. The superior trunk supplies 70% of the sensory nerve supply to the shoulder joint, the capsule, SA bursa, coracoclavicular ligament, and makes variable innervation contributions to the overlying skin.[5] The axillary nerve originates from the C5 to C6 nerve roots, with occasional contribution from C4. It is derived from the posterior cord of the brachial plexus. The posterior branch of the axillary nerve terminates as the superior lateral brachial cutaneous nerve, which supplies the cutaneous innervation to the skin overlying the deltoid muscle. The anterior trunk supplies the motor innervation to the middle and anterior deltoid muscle.

■ RA For Shoulder Surgery

GA Versus RA

Both GA and RA techniques have been used for shoulder surgery. ISB is the most successfully used RA technique, which can provide complete analgesia for shoulder surgery, and has been used as the sole anesthetic.

RA provides several advantages over GA such as rapid recovery, adequate analgesia, a significantly lower incidence of postoperative nausea and vomiting (PONV), and timely same-day discharge.[6] Observational

studies indicate even less PONV after ISB (without GA) when multimodal antiemetic prophylaxis is employed.[7] For outpatient rotator cuff surgery, ISB use without GA is associated with majority of patients (i) bypassing the phase-1 postanesthesia care unit (PACU), (ii) reporting less pain, (iii) achieving earlier ambulation, (iv) having fewer unplanned admissions, (v) achieving faster time to discharge, and (vi) reporting improved patient satisfaction.[6] In a study by Hadzic et al,[6] none of the patients treated with ISB required additional analgesics before the discharge to home, whereas 80% of patients in the GA group required pain management despite wound infiltration and single-injection IA instillation of local anesthetic (LA) by the surgeon.[6] The development of chondrolysis with IA infusions has brought into question the safety of this technique, and is discussed later.

On the other hand, there are reasons to avoid GA in outpatients and older patients because of short-term cognitive impairment, PONV, and delayed recovery. Problems associated with airway management could be avoided using RA. However, we must caution that when performing RA, one must always be prepared to instrument the airway regardless of RA being the primary anesthetic plan. In addition, postoperative pain can interfere with rehabilitation.[1] Opioid analgesics are commonly used for analgesia when nerve blocks are not used. Opioids are effective in relieving postoperative pain at rest, but are known to increase PONV, somnolence, constipation, urinary retention, respiratory depression, and sleep disturbances.

Some perceived disadvantages of ISB versus GA include the additional time required to perform the block, the possibility of block failure, and the potential that patients undergoing blocks ultimately may have more pain when the blocks wear off. Anesthesia-controlled time for emergence (time from end of the application of surgical dressing until operating room exit) has been reported to be shorter after RA versus GA.[8,9] USG is well documented to reduce the time taken for block placement, and has also improved success rates in many settings. Rebound pain[10] has not been addressed after ISB, to our knowledge. Another perceived disadvantage of ISB versus GA is the potential for peripheral nerve injury, which has not been attenuated by USG [vs. nerve stimulation (NS) technique], and is likely related to myriad interrelated pathogenic factors, a complex issue remaining unresolved.[11] We do know that when the block is combined with GA, larger doses and/or higher concentrations of LA are not needed.

A. Interscalene Brachial Plexus Blocks

The ISB is the most commonly used block, and is considered the gold standard RA technique for shoulder procedures. The block is useful for procedures involving the shoulder including the lateral two

thirds of the clavicle, proximal humerus, and shoulder joint.[1] Ulnar sparing (C8 nerve root) is often seen with this block, which limits the usefulness of ISB for distal procedures. The ISB can be performed as a single injection or continuous nerve block. The block can be performed using paresthesia, NS, USG, or the combination of NS and USG.[12]

ISB is widely used as the primary anesthetic and as an adjuvant to regional pain therapy in patients undergoing major shoulder surgery. ISB has proven its effectiveness, and is accepted with respect to postoperative pain reduction and opioid-sparing effect. An ISB for ambulatory arthroscopic shoulder surgery has been shown to be more cost-effective than GA in one study (when excluding staffing costs).[13] Minor complications occur with ISB, but most do not produce long-term injury. ISB is an invasive procedure with serious complications if not performed carefully, and should be performed by or under the instruction of trained practitioners using appropriate equipment.[14]

Anterior approach ISB   The classic approach of Winnie (anterior approach) is still commonly performed, especially for single-injection blocks. Winnie identified a paresthesia as the endpoint for injection; however, today most clinicians use NS, US, or a combination of both to determine the endpoint for injection.[15] The Winnie technique was modified by Meier et al[16] to reduce complications and facilitate catheter placement. Meier et al[16] and Borgeat and Ekatodramis[1] used the same landmarks as Winnie, along with NS as their endpoint for injections; these are considered lateral approaches to the ISB.[1,16] Chan[17] used US to directly visualize the nerve roots of the brachial plexus in the interscalene groove at the level of cricoid. The needle can either be inserted using an in-plane technique (alignment with the long axis of the probe) or an out-of-plane technique (alignment with the short axis of the probe).[17] Although the in-plane technique allows better visualization of the needle, the out-of-plane technique provides a shorter path to target tissues.

US Guidance Versus NS   Since the advent of USG to perform peripheral nerve blocks, there has been the question of superiority between USG and NS. USG allows real-time identification of relevant anatomy and needle position when performing regional techniques. USG increases the quality of sensory and motor blockade, and by reducing the incidence of paresthesia, may confer greater safety, but this is yet unproven.[18] However, ISB with NS is acknowledged to have a high success rate and safety profile in experienced hands.

Kapral et al[19] evaluated the success rate of USG versus NS in randomized patients. Surgical anesthesia was achieved in 99% of patients in the USG compared with 91% of patients in the NS group. Furthermore, sensory, motor, and extent of blockade was significantly better in the USG group than the NS group, showing that the use of

USG for needle placement and monitoring the spread of LA improves the success rate of ISB. In another prospective study comparing USG to NS-guided ISB, Liu et al[20] reported the reduced number of needle passes to perform the ISB, and enhanced motor block using USG. There were no significant differences in block failures, patient satisfaction, or incidence and severity of postoperative neurological symptoms (PONS). In another study by Fredrickson et al[21] comparing USG to NS-guided interscalene catheter placement, the USG group had less needle underneath the skin time and improved numerical rating pain scores on the first day, but no difference on the second day. Untoward events such as paresthesia and PONS were lower (1%) with USG compared with existing data with NS (14%). The overall rate of transient neurologic deficits, for NS and paresthesia techniques, has been shown to be 2.8%.[22] Patients with continuous ISB (CISB) showed higher incidence of arm numbness.[23] USG can be successfully used as a ''stand alone'' method to perform ISB, rather than an adjunct to NS techniques.[23] However, NS is still an excellent alternative; a patient undergoing shoulder surgery is likely to have a significantly higher quality outcome with NS block versus no block at all.

Paresthesia Versus NS   Even though USG is gaining popularity, NS is still an extremely common method used to perform ISB and paresthesia is less commonly used at present. In a randomized study, patients underwent shoulder surgery under ISB using either NS or paresthesia techniques. The incidence of PONS was 10%, with no difference between NS and paresthesia techniques. PONS lasted a median duration of 2 months, and symptoms resolved within 12 months in all patients. The success rate, onset time, and patient satisfaction were also comparable between groups.[24]

Single-Shot Versus Continuous Catheter   Advances in recent technology and equipment have led to the increased use of peripheral nerve catheters for primary anesthesia and for management of acute post-operative pain. USG single-injection ISB for surgical anesthesia and continuous infusion ISB are both effective for pain control.[25]

Several studies have suggested that use of RA may produce a preemptive effect in reducing sensitization of nerve endings after surgical incision, potentially reducing postoperative pain. In one prospective study, a bolus of ropivacaine was given through an USG-stimulating catheter, placed using a posterior approach. Postoperatively, the patients were discharged with oral analgesics and a portable infusion device, containing either ropivacaine or normal saline (control group), to be used for 2 days. Compared with the group receiving a single-injection ISB, the group of a 2-day continuous posterior ISB obtained greater pain relief, minimized opioid requirements, improved sleep quality, and increased

patient satisfaction after painful outpatient shoulder surgery.[26] ISB decreases the time to discharge readiness after total shoulder arthroplasty,[27] and the addition of a continuous interscalene LA infusion to a single-injection ISB reduces pain, especially with movement. Continuous interscalene infusion of LA is an effective method of postoperative analgesia after major shoulder surgery. Inpatient stays may be shortened with use of continuous ISB, by providing adequate analgesia with reduction in use of opioids and improved shoulder mobilization.[23,25,28]

In an orthopedic study of analgesic requirements during the 5 days following surgery after ISB for shoulder arthroscopy, Trompeter et al[29] concluded that the complexity and costs of continuous LA infusions may not be justified for "moderately painful" and/or "moderately invasive" surgeries. Single-injection ISB was shown to provide good initial analgesia. As pain could be controlled with simple oral analgesics in the majority of cases, long-term continuous infusions are less likely to be required. Ninety-seven percent of the patients were satisfied with their postoperative oral analgesia. In the minority who experience severe pain, rescue analgesics should be considered for postoperative analgesia. It would not be surprising if our surgical colleagues tended to overlook opioid-induced side effects when categorizing "rescue analgesics" as a simple maneuver.

In summary, minor shoulder procedures may be managed with a single-injection nerve block; however, major shoulder procedures such as rotator cuff repair and total shoulder arthroplasty that produce intense pain lasting for days should be treated with a perineural catheter. Advantages of continuous peripheral nerve block techniques include continuous analgesia, accelerated rehabilitation, reduced use and side effects of opioids, improved patient satisfaction, and faster discharge from the hospital.

Prolonging the duration of LA-based nerve blocks through non-neurotoxic perineural additives may help further eliminate any controversy between single injection and CISB for minor or moderate shoulder procedures. Clonidine and buprenorphine are safe as adjuvants at clinical concentrations. Midazolam should not be combined in any perineural mixture with LA.[30] Williams et al[30] suggest that attention should be directed toward exploring the time dependent and concentration-dependent basis for neurotoxicity associated with dexamethasone combined with ropivacaine.

Volume and Concentration Studies   Advantages of USG nerve blockade is to place and observe the spread of LA while visualizing the brachial plexus. This allows for real-time adjustment for LA location, and can theoretically reduce LA volumes to an amount that would decrease the risk of LA systemic toxicity.[31] A study to estimate the volume and concentration of LA used for ISB showed that increasing LA

concentration increased grip weakness but not block duration.[32] ISB requires a threshold volume and concentration, with concentration primarily determining motor block. When combined with continuous blockade, suprathreshold doses do not significantly prolong block duration.[32]

In a randomized study, McNaught et al[33] compared USG to NS to determine the minimum effective analgesic volumes (MEAV) of LA needed for a successful ISB for postoperative analgesia. Sequential up-down dosing was used to evaluate the MEAV. All patients received GA with opioid, and were followed for only 3 hours after operation. The US group had a lower number of needling attempts, smaller LA volume, and less postoperative pain; MEAV was significantly lower than in the NS group. In the study, 40 patients were randomized to receive USG single-injection ISB with either 5 or 20 mL bolus dose of 0.5% ropivacaine; GA was standardized. There were no significant differences in pain scores, sleep quality, and total morphine consumption up to 24 hours after surgery. The use of low-volume USG ISB was associated with fewer respiratory and other complications, with no change in post-operative analgesia when using only 0.5% ropivacaine.[34] However, this study is not valid in clinical or psychometric reality, in that this study did not study rebound pain scores, did not consider preoperative baseline pain scores, and did not factor preoperative sleep quality into postoperative sleep quality. In summary, lower LA volumes can produce an effective USG ISB when combined with GA, but studies of analgesic duration, rebound pain after the block effects wear off,[10] and sleep quality[35] have yet to be properly studied.

Comparison of Outcomes When comparing the same concentration of different LA (0.25% bupivacaine vs levobupivacaine) for shoulder surgery under single-injection ISB, one study showed similar motor and sensory block onset times, block quality, and extent of analgesia.[36] On the other hand, the use of continuous infusions of higher concentration of the same LA (eg, ropivacaine 0.2% vs. 0.3%,[37] or ropivacaine 0.25% vs. 0.4%[38]) provided a significant reduction of morphine consumption and a better sleep quality without increasing the intensity of motor block or side effects.[37,38] A study of the onset time of a single-injection ISB using a combination of chloroprocaine-bupivacaine versus lidocaine-bupivacaine demonstrated that a successful block was more rapid with chloroprocaine and bupivacaine.[39]

Cost Comparison In a retrospective review, the three commonly employed analgesic techniques were compared: (i) CISB; (ii) Single-injection ISB with postoperative intermittent IA LA infiltration; and (iii) intermittent IA-only LA infiltration. The outcomes were for total opioid/tramadol and antiemetic consumption, and monetary cost after

rotator cuff repair. Only a CISB was associated with reduced total opioid/tramadol and antiemetic consumption. CISB did not lead to a significant increase in the monetary cost.[40] A comparative study of USG ISB versus GA for arthroscopic surgery showed USG ISB as a cost-effective and preferable method for arthroscopic shoulder surgery.[13] Total costs were lower for patients with ISB than those who received GA. Anesthesia-related workflow (ready for surgical preparation, OR emergence time, anesthesia control time, and PACU time) was improved in the ISB group when compared with the GA group.[13] Conversely, in a comparative study of single-injection ISB and a continuous SA infusion in patients undergoing arthroscopic surgery under GA, no statistical differences between pain scores, complication rate, medication intake, or cost were seen.[41]

Posterior approach ISB/CPVB   The posterior approach to the ISB has gained renewed interest. A posterior approach to the brachial plexus was first performed by Pippa et al[42] using the loss-of-resistance technique and surface landmarks. Boezaart et al[43] modified this technique by passing the needle between the levator scapulae and the trapezius muscles to avoid somatic pain resulting from the needle traversing the neck extensor musculature. Using the Pippa landmarks, van Geffen et al[44] described USG of stimulating needles to the brachial plexus through the posterior approach to perform a single-injection nerve block; this study showed achievement of complete block in 95% of patients, with no punctures of the carotid artery. Feasibility of inserting a catheter for continuous brachial plexus block using posterior approach has been demonstrated in patients undergoing shoulder surgery. However, efficacy and safety of USG posterior approach requires further evaluation.[45,46]

Advantages of continuous posterior ISB include avoidance of the external jugular vein, a greater distance between the catheter entry site and the surgical field, and a lower incidence of catheter migration. The catheters are perhaps anchored in the posterior approach in a better way because the catheter passes through multiple layers of muscle, and additionally (theoretically) there would be a decreased risk of injuring vital structures.

Posterior approach to ISB has potential disadvantages. Advancing the needle through the muscles of the neck can be painful for the patient. The needle generally has to pass through the middle scalene muscle, which contains 2 proximal branches of the brachial plexus—the long thoracic and dorsal scapular nerves; either of these may be injured. Inserting the needle deep into the neck may be difficult for novices to maintain full needle visibility when using a USG in-plane technique. If the needle is not well visualized with US, there is a risk that the needle may be inadvertently inserted toward the cervical spine, potentially causing a high spinal, epidural block, or even creating a syrinx from

direct injection into the spinal cord (described below). This same issue can occur when using NS technique if not careful.

Complications of ISB (Both Anterior and Posterior Approaches)

Spinal cord damage: Direct injection into the spinal cord after ISB can cause permanent loss of cervical spinal cord function.[47] Voermans et al[48] reported such a case associated with the posterior approach to ISB using surface anatomy and NS technique with a B-bevel block needle; loss of cord function was thought to be due to intrathecal and intramedullary injection of LA. This catastrophic occurrence questions the safety of the posterior approach. Cases of permanent loss of superior trunk of brachial plexus, quadriplegia, and spinal cord injury have been reported.[26,46] Severe and permanent nerve injuries may be avoided by understanding spinal and peripheral nerve microanatomy, using appropriate equipment such as blunt Tuohy-style needles when working near the spine and dural sleeves, careful catheter placement, and subsequent removal only after recovery of full sensation to the limb.[49] When using blind landmark techniques near nerve roots, we recommend using a Tuohy-style needle. This is because thinner and relatively sharper short-bevel or B-bevel block needles have a higher potential for dural puncture, thus more easily breaching the dura mater.

Phrenic block. When using standard LA volumes, ISB results in 100% incidence of phrenic nerve blockade[50] with resultant hemidiaphragmatic paresis, reduced pulmonary function, and potential blockade of the recurrent laryngeal nerve with resultant vocal cord paresis.[51,52]

Patients undergoing USG ISB reported a 3% incidence of dyspnea and 11% of hoarseness after PACU discharge that lasted a mean of 2 days. It is possible that symptoms were due to prolonged block of the phrenic and recurrent laryngeal nerves.[53] Other complications such as pleural effusion and atelectasis during CISB have also been reported.[54]

By scanning the neck in posterior cervical triangle of volunteers with US, the phrenic nerve was identified in 93.5% of scans. The phrenic nerve was indistinguishable from the C5 ventral ramus at the level of the cricoid cartilage.[55] This close anatomic relationship explains the high incidence of ipsilateral phrenic nerve block after ISB. In a study comparing USG ISB using either 5 mL or 20 mL of 0.5% ropivacaine, the incidence of diaphragmatic paralysis was significantly lower in the low-volume group compared with the standard-volume group (45% vs. 100%). The use of low-volume USG ISB is also associated with fewer respiratory and other complications.[34] In patients in whom diaphragmatic paralysis was a concern, postoperative respiratory parameters indicated successful RA without evidence of phrenic nerve blockade with use of low-volume ISB. Even though reports demonstrate that USG may allow performance of low-volume ISB while avoiding phrenic nerve

blockade, further studies are needed for verification.[56] In either case, 45% incidence of phrenic block is still, effectively, a "coin toss." Using low volumes does not guarantee the same block duration either.

Continuous CPVB is a relatively new modality for postoperative pain control after major surgery to the upper limb. Epidural spread is a recognized complication and has been demonstrated with contrast injection under fluoroscopy.[57] Continuous CPVB has a 4% incidence of epidural spread.[58] Hence, meticulous attention to the direction of the needle bevel and early recognition and management of adverse events are recommended.[57] Continuous cervical paravertebral catheter knot (with no imaging-based evidence of entanglement of nerve or vascular structures) has been reported.[59] Dysphonia, Horner syndrome, difficulty in breathing, minor paresthesiae, and cervical pain were reported complications.[45] ISB and associated perineural catheters do have complications, but most of these are minor and resolve without sequelae.[41,60,61] However, the possibility of catastrophic complications exists especially because the ISB brings the needle so close to neuraxial structures.

In summary, studies show that performing shoulder surgeries under RA only using ISB (without GA) have better outcomes and highest level of patient satisfaction. Other regional techniques can be useful as rescue or backup techniques, for patients who cannot undergo ISB for pain management.

B. Suprascapular Nerve Blocks

The SSNB combined with an axillary block may provide an efficacious alternative to the ISB for shoulder analgesia when combined with GA. The majority of the nerve supply to the shoulder joint is provided by the SSN and axillary nerve. When these nerves are blocked, there are fewer complications and side effects than the traditional ISB.[4,5] The phrenic nerve is not blocked; therefore, these blocks can be used for patients who are not candidates for an ISB, for example, severe chronic obstructive pulmonary disease. This technique may also be used as a rescue block for unsuccessful ISB. SSNB is helpful to relieve the shoulder pain, but does not always provide complete analgesia.

Techniques: For the SSNB, the ideal approach should ensure blockade of the more proximal branches to the acromion and the SA region to maximize coverage. This may be achieved by blocking the nerve in the suprascapular notch; however, this location is associated with a small risk of pneumothorax.[4,31] Price[4] described a technique for this block that was adopted from Meier.[16] Price describes placing both suprascapular and axillary (circumflex) nerve blocks for postoperative pain control, while surgery is performed under GA. The blocks were performed with the patient in the sitting position with the shoulder fully adducted.[4,62] Checcucci et al[5] also described techniques for blocking the

suprascapular and axillary nerves in a lateral decubitus position. Interestingly, SSNB and an axillary nerve block in combination have been shown to be effective and safe technique for intraoperative anesthesia and postoperative analgesia for certain arthroscopic shoulder procedures. Matsumoto et al[63] developed a new technique for performing the SSNB based on cadaveric anatomy, and evaluated its effectiveness by recording visual analog scale scores in patients experiencing severe pain after rotator cuff repair. They found that 2 or 3 sensory branches pass the scapular notch. Their method to block SSN is safe and effective, and can be considered for pain control in patients after open cuff repair. Finally, Harmon and Hearty[64] described an USG technique for blocking the SSN. USG facilitates blockade of the SSN, seen as a round hyperechoic structure at a depth of 4 cm beneath the transverse scapular ligament in the scapular notch. USG helps to direct injection and visualize LA spread in the scapular notch.

Outcomes and Comparison to ISB: At present, there are no published studies comparing the combination of a SSNB and axillary nerve block to an ISB. Price[4] performed SSNB and axillary nerve blocks in 40 patients undergoing shoulder arthroscopies done under GA. No morphine was required in 57% and 83% of patients in the recovery room and during the first night, respectively. The average morphine consumption for all study patients was 3 mg in the recovery room and 2 mg during the first night. This block may not be appropriate as a surgical anesthetic if extensive arthroscopic work is planned. In a study with 20 patients undergoing simple diagnostic arthroscopic procedures, the patients only had SSNB and axillary nerve blocks as their primary anesthetic.[5] Patients did not require opioid analgesics or rescue GA for the procedure, and patient satisfaction was 100%.[5] Jerosch et al[65] performed a randomized trial with 260 patients scheduled for shoulder operations of moderate to severe pain under GA. The patients either had a SSNB or no block. The results showed the SSNB group had statistically better pain scores that were not necessarily clinically significant.

Volume Comparison: Price[4] and Checcucci[5] each recommended 15 mL of LA for the SSNB. Jerosch et al[65] showed that 10 mL of LA was adequate, whereas Feigl et al,[62] using a lateral technique to block the SSN in cadavers, showed that as little as 5 mL of LA could be sufficient. However, the latter study needs clinical correlation, as the quality and duration of the block may be adversely affected by this small volume.

Complications: In the last 5 years, there have been no reported major complications of the SSNB or the axillary nerve block. However, the basic risks for any peripheral nerve block still exist, and SSNB does have a small risk of a pneumothorax.

Summary: A combination of SSNB and axillary nerve blocks are suitable as an intraoperative anesthetic and postoperative analgesic for patients undergoing simple arthroscopic procedures. Although

SSNB and axillary nerve blocks are not suitable for the sole intraoperative anesthetic in shoulder operations generating moderate to severe pain, they may be effective and can be considered for postoperative pain control after simple diagnostic arthroscopies, and may prove to be quite useful in patients who cannot tolerate any risk of phrenic nerve block.

C. Supraclavicular Nerve Blocks

SCB create a brachial plexus conduction block at the level of the plexus divisions, between the anterior and middle scalene muscles at the first rib. The popularity of this approach was limited in the past because of the risk of pneumothorax.[66,67] However, US has rejuvenated interest in this block by providing real-time visualization of the target tissues and surrounding structures, reducing complications such as pneumothorax and nerve injury.[68,69] Further, studies in experienced hands have demonstrated a series of 1001 blocks without one case of clinically evident pneumothorax.[70]

Approaches: SCB can be performed by either the classic approach or "plumb-bob" approach.[66] Both the techniques use either paresthesia or NS as an endpoint. USG uses a linear array transducer near the clavicle to produce a transverse image of the brachial plexus as it passes just posterolateral to the subclavian artery.[68] USG facilitates nerve localization and needle placement near the brachial plexus. The visualization of LA spread and facilitation of catheter-based brachial plexus anesthesia has the potential to reduce complications.[68] USG was used to modify the traditional plumb-bob approach by advancing the needle in a posterolateral direction from the more anterior sternocleidomastoid-clavicle junction, within the imaging plane of a high frequency linear US transducer. This provides a safer needle trajectory when needle tip visibility is suboptimal and subsequent spread of LA is observed.[71]

From the anatomical point of view, the block performed between the scalene muscles just like the ISB, raises an interesting question—are SCBs in fact ISBs? Although it may be a low interscalene block, it remains a brachial plexus block at the level of the divisions. There is a distinctive covering over the nerves, which is the prevertebral fascia of the neck that forms the floor of the posterior triangle of the neck and covers the scalene muscles. This fascia acts to contain the LA.[72] SCBs were not being used for shoulder surgery because of concern that the block is too distal from the cervical nerve trunks and roots to provide satisfactory shoulder anesthesia. However, anatomic studies with US and computed tomographic scanning demonstrate that LA injected at a SCB travels cephalad between the anterior and medial scalene muscles, and can function as a more caudad approach to spread LA cephalad onto the trunks and roots within the prevertebral fascial covering.[53]

Outcomes and Comparison to ISB: Liu et al[53] conducted a study on 1169 patients who underwent shoulder surgery and had either an ISB (n = 515) or SCB (n = 654) performed at the discretion of the clinical team. Success rate was excellent for both blocks: ISB (99.8%) and SCB (99.4%). The incidence of hoarseness in the PACU was statistically less for the SCB group (22%) compared with ISB group (31%); the clinical significance of this difference is difficult to discern. The incidence of dyspnea was similar: ISB (10%) and SCB (7%). There was no evidence of pneumothorax and the incidence of PONS was 0.4%. The investigators concluded that USG ISB and SCB are both effective and safe for shoulder arthroscopy. Several studies failed to support the concept of rapid-onset successful SCB through a simple USG LA injection.[73] Studies have not shown any advantage of low volumes of LA required for USG SCB from those of the conventional non-US-based SCBs.[74]

NS: An evoked motor response when using only a peripheral NS and surface anatomy technique is considered essential for a successful block. The failure rate in NS-assisted SCB varies from 1.2% to 12%.[70,75] A study of minimal required stimulation threshold to elicit a motor response during USG SCB was stimulation current $\leq 0.2\,mA$, which reliably detected intraneural placement of the needle, whereas stimulation currents of >0.2 but $<0.5\,mA$ could not rule out intraneural position. Significantly higher thresholds were observed in patients with diabetes.[76] One study showed that use of a NS did not improve the efficacy of USG SCBs. In addition, the high false-negative rate suggests the blocks to be effective, even in the absence of a motor response.[69]

Complications: Owing to the proximity of the pleura to the brachial plexus, pneumothorax is a complication from SCB, and its incidence has been reported to be 0.6% to 6.1%.[77] However, no incidence of pneumothorax was reported in a recent large survey of 510 US expert-guided SCB.[77] The ability to visualize the first rib and pleura during SCB may minimize the risk of pneumothorax.[53] Other complications include vascular punctures, unintended intravascular injection with resulting LA systemic toxicity, Horner syndrome, recurrent laryngeal nerve blockade, brachial plexus injury, and phrenic nerve blockade with transient hemidiaphragmatic paresis.[53,77]

Summary: USG SCB are effective and safe for shoulder surgery and arthroscopy with a low incidence of complications.[65] The use of a NS does not seem to improve the efficacy of USG SCBs.

D. Subacromial Block/Intra-articular Injections

SA/IA LA infiltrations perform marginally. Concern has been recently raised over the possibility of iatrogenic chondrolysis or the rapid destruction of articular cartilage. Chondrolysis is a noninfectious entity associated with IA LA injections.[78] It is a devastating complication

in a young patient and is difficult to manage.[79] These concerns were highlighted in a recent editorial.[80] There is convincing evidence for LA-induced chondrotoxicity in animal studies,[81] especially when bupivacaine is used in high doses. Using a rabbit shoulder model, Gomoll et al[81] demonstrated that bupivacaine given by continuous infusion over 48 hours caused a significant decrease in sulfate uptake, cell viability, and histologic scores. The first clinical report of postarthroscopic glenohumeral chondrolysis (PAGCL) implicated radiofrequency ablation and an IA pain pump infusing 0.5% bupivacaine with epinephrine.[82]

These data have coincided with several reports of catastrophic PAGCL occurring in healthy young patients, all having received high and prolonged doses of IA bupivacaine.[79] The condition had been rarely reported before the introduction of IA LA infusions. Infusion devices for pain management after shoulder surgery have recently come under scrutiny due to concern for IA use and the association with chondrolysis. Consequently, some ambulatory pump manufacturers (eg, I-Flow Corporation) are now actively advising against the use of their pumps for the IA route of administration. Awareness of the risk factors is important for preventing this complication; it is both devastating and difficult to treat in young patients.[79]

The SA block is generally used for arthroscopic shoulder procedures including SA decompression and rotator cuff repair. Single injection or continuous infusions are employed depending on the anticipated intensity of pain.[83,84] Busfield et al[83] followed up patients for a month after having received SA continuous infusion. Without describing the amount of bupivacaine delivered to the shoulder, their study did not validate analgesic efficacy. As PAGCL can take longer to develop, a 1-month follow-up may not be sufficient to detect PAGCL.

Outcomes and Comparison to ISB: In a randomized trial with patients undergoing either arthroscopic SA decompression or rotator cuff repair, there was minimal evidence to support the use of SA infusion of ropivacaine after rotator cuff surgery in the setting of a preemptive ropivacaine SA injection and intraoperative parecoxib. There was no observable benefit seen with respect to pain, reduction in opioid or oral analgesia use, duration of hospital stay, or the proportion with a postoperative stiff painful shoulder. These findings imply that the continued use of a SA ropivacaine infusion is not worth the substantial additional costs.[84] Delaunay et al[85] showed that ISB provides better pain control than SA infusion for controlling pain after rotator cuff repair. Recent FDA case reports pointed out adverse events after continuous direct LA infusion into surgical wounds.[86] Necrosis, surgical wound infection, cellulitis, and infection in patients with IA/SA blocks have been reported.[86] Winkler et al[87] showed a significant reduction of postoperative pain after arthroscopic acromioplasty in the CISB group versus the continuous SA infusion group both at rest and during exercise.

One of the most sensitive parameters of pain control after shoulder surgery is night pain, which can be seen as a bimodal parameter because it also affects both sleep and well-being the next day.[88] There was higher incidence of this indicator in the SA group indicating better pain management achieved with continuous ISB.[87,89,90] However, after arthroscopic rotator cuff repair, either continuous SA infusion or combination of IA and SA infiltration provides less analgesia compared with continuous ISB.[85,91]

Subacromial bursa block (SBB) is a simple analgesic supplemented with good "take-home" analgesia in some patients, when ISB is contra-indicated or expertize for its administration is not available. Studies comparing single-injection SBB with controls failed to demonstrate any clinically significant reduction in postoperative pain compared with controls.[84,92] Two additional studies compared continuous SBB with controls, one showing clinical benefit with continuous SBB, and the other showing no benefit.[93,94] Of the studies showing a clinical benefit from continuous SBB over controls, none involved open procedures and only one study included rotator cuff repair, whereas studies failing to show clinical benefit from continuous SBB over controls, 3 were open procedures and 4 included rotator cuff repair.[14]

Summary: There is substantial evidence showing that SA and IA infusions provide little, if any, clinically important benefit in terms of reduced postoperative pain, especially for open andor rotator cuff procedures. These infusions seem to be associated with irreversible chondrotoxicity and, therefore, these infusions can no longer be recommended.[14]

Management of Nonsurgical Shoulder Pain

There have been reports of the use of SSNB to reduce pain in nonsurgical situations, such as treatment to improve upper limb function in patients with shoulder pain after the stroke.[95] USG ISB was used for reduction of shoulder dislocations in emergency depart-ment to achieve pain control and muscle relaxation without airway compromise.[96] Manipulation of idiopathic unilateral frozen shoulder under SSNB and single-injection IA LA has been reported. It is a safe, cost effective, and minimally invasive procedure for shortening the course of a self-limiting disease while rapidly improving shoulder function and symptoms.[97]

■ Summary

This review of the literature since 2005 assesses developments of RA techniques commonly used for shoulder surgery, and their effectiveness for postoperative analgesia. Advantages of regional techniques include

site-specific anesthesia and decreased postoperative opioid use. For shoulder surgeries, the ISB provides effective analgesia with minimal complications, whereas the impacts of IA single-injections remain unclear. When combined with GA, ISB can be used in lower volumes and reducing the complications for shoulder and proximal upper extremity. USG ISB and SCB are both effective and safe for shoulder surgery with a low incidence of complications, especially PONS.[53] When compared with intravenous patient-controlled opioid analgesia, a perineural LA infusion using a disposable pump with patient-controlled LA bolus function has led to better pain relief and functional recovery while decreasing the need for rescue analgesics and the number of adverse events after ambulatory orthopedic surgery.[98]

The most remarkable advance in RA in the past 5 years is the increased usage of USG. Although there are no large-scale prospective studies to show the safety, efficacy, and success and complication rates for USG blocks, USG RA theoretically could have less risk for neurologic symptoms, except for those induced by LA (less likely perineurally, much more likely intraneurally). The next "quantum leap" lies in reducing LA concentrations and augmenting anesthetic-analgesic effects with perineural additives (including clonidine, buprenorphine, and likely low-dose dexamethasone).[30]

Since 2005, perineural catheters have been an analgesic option that offers improved pain relief among other benefits, and are now being used at home.[99] It is clear that patients benefit greatly from a single injection and continuous nerve block for postoperative pain management, but the financial and logistical aspects need to be resolved, not to mention the phrenic hemiparesis coin toss. Whether combined perineural analgesic adjuvants prolong low-concentration LA nerve blocks sufficiently to render brachial plexus catheters as unnecessary would certainly represent another quantum leap.

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