4 Regional and General Anesthesia, Pain, and Bleeding Control in Shoulder Arthroscopy and Upper Limb Procedures

Paolo Grossi, Emilio Grilli, and Simone Repaci

4.1 Introduction

Shoulder arthroscopic surgery has spread worldwide due to its possibility to treat a huge scenario of pathologies.

Arthroscopy and visualization are the same from a surgical point of view. Thus, it is mandatory to have a perfect control of bleeding, and this is only possible in joints like the shoulder if an anesthesia with blood pressure control is obtained.

Another important issue in shoulder arthroscopy is to control the postoperative pain, thus allowing this surgery in an outpatient facility as mostly done in Western countries.

In this chapter the author focuses on all the strategies to perform an optimal anesthesia, thus controlling pain and reducing bleeding, helping both patients and surgeons.

P. Grossi, MD (✉)
U.O. Anestesia Loco-Regionale e Terapia del Dolore, IRCCS Policlinico San Donato, Milan, Italy
e-mail: pagrossi@libero.it

E. Grilli, MD
Servizio Anestesia Ospedale Beato Matteo, Vigevano, Italy

S. Repaci, MD
Servizio Anestesia Ospedale Maggiore, Bologna, Italy

4.2 Beach Chair Position

The beach chair position was described for the first time in 1988 [37]. It was invented with the aim to avoid neuropathies that may develop during arthroscopy in the lateral decubitus position. To attain the beach chair position, the patient is placed supine on a standard operative table or on the operating table beach chair equipped with a removable posterior portion. The patient is placed in 15° Trendelenburg position, with hips flexed to 45–60° and knees flexed to 30° with a pillow placed under them to protect neurovascular structures at the popliteus groove. The table is then adjusted progressively, raising the trunk and chest, creating an angle of 60° with respect to the pelvis. The head is fixed with a head plate and placed in neutral position, while the chest is secured with straps; the nonoperative arm is placed on a sling; the operative arm can be attached to the Spider [35–46]. The positioning in beach chair takes more time than in lateral decubitus because you have to correctly position the head, neck, and chest; it is possible to reposition the patient during surgery; also it needs at least one assistant washed to keep the arm to operate and to keep the traction if the Spider is not used. Regarding the ease of transition, the beach chair position is faster and easier to be carried out because it does not need repositioning, it having rifar the operative field [35–45]. As regards the effect that the position has on

P. Randelli et al. (eds.), *Arthroscopy: Basic to Advanced*, DOI 10.1007/978-3-662-49376-2_4

anesthesia, surgeons who prefer the beach chair state that this position may be used without distinction between regional anesthesia with the patient awake and general anesthesia, since the sitting position is tolerated better than lateral decubitus. There is easy access to the airway, when intubation is necessary, in the beach chair position with respect to the lateral decubitus [34–47], although in the lateral decubitus position, a laryngeal mask can be easily placed. The costs for the beach chair are higher than the lateral decubitus, because it requires a dedicated table, a head plate, and the Spider. With respect to orientation, accessibility, and operative visualization, the supporters of the beach chair reported that the sitting position allows the anatomy of the arthroscopic shoulder to be more easily understood [37, 41–45]. The supporters of the sitting position claimed not to have any operative visualization difficulties and were able to work in all portions of the glenohumeral joint and subacromial space using various trocar access. The beach chair position allows to better stabilize the scapula allowing improved diagnostic arthroscopic examination under anesthesia compared to the lateral decubitus [41]. It has been argued that the beach chair is the best position for anterior stabilization and the release and repair of the rotator cuff [41]. Access to the anterior region of the shoulder is easier, and the anterior trocar allows the insertion of anchors at the level of the neck of the glenoid below the 4 o'clock position [37, 41–45]; also the lateral translation of the humerus gives an excellent access to the front-lower portion of the capsule and the axillary region. The beach chair position provides surgeons a better upper limb mobility by ensuring better working dynamic view of the cuff and allows them to treat some minor disorders such as subluxation and the subacromial impingement [34–45].

	Lateral decubitus	Beach chair
Advantages	1. Traction increases space in joint and subacromial space	1. Upright, anatomic position
	2. Traction accentuates labral tears	2. Ease of exam under anesthesia
	3. Operating room table/patient's head not in the way of posterior and superior shoulder	3. Arm not hanging in the way of anterior portal
	4. Cautery bubbles move laterally out of view	4. No need to reposition or redrape to convert to open procedure
	5. No increased risk of hypotension/ bradycardia; better cerebral perfusion	5. Can use regional anesthesia
		6. Mobility of operative arm
Disadvantages	1. Nonanatomic orientation	1. Potential mechanical blocks to use of scope in posterior or superior portals
	2. Must reach around arm for anterior portal	2. Increased risk of hypotension/bradycardia causing cardiovascular complications
	3. Must reposition and redrape to convert to open procedure	3. Cautery bubbles obscure view in subacromil space
	4. Patients do not tolerate regional anesthesia	4. Fluid can fog camera
	5. Traction can cause neurovascular and soft tissue injury	5. Theoretically increased risk of air embolus
	6. increased risk of injury to axillary and musculocutaneous nerves when placing anteroinferior portal	6. Expensive equipment if using beach chair attachment with or without mechanical arm holder

The main risks linked to the beach chair position are attributable to the incorrect alignment of the head relative to axis of the body and to the occurrence of bradycardia/hypotension episodes and cerebral hypoperfusion. Various complications have been reported concerning the correct head positioning in the beach chair, ranging from neuropraxia of cutaneous nerves of the cervical plexus up to the very rare cases of midcervical quadriplegia [48, 49]. Park and Kim [50] have identified three cases of neuropraxia of cutaneous branches of the cervical plexus after arthroscopy in the beach chair position; nerves affected were the small occipital nerve and the great auricular nerve that is thought to have been damaged directly by headrest compression. Mullins [51] and Rhee [52] reported cases of paralysis of the hypoglossal nerve after shoulder arthroscopy in the beach chair position, whose etiology is thought to be due to a change in the position of the neck during the procedure, and so the nerve was compressed to below the angle of the mandible. Haisa and Nitta [48, 49] reported the occurrence of stroke and spinal midcervical quadriplegia after neurosurgical procedures performed in a sitting position. The authors and Wilder [53] have proposed that the extreme flexion of the neck and the stretching of the spinal cord may be sufficient, together with the loss of self-regulating mechanisms induced by drugs of general anesthesia in a sitting position, to compromise the self-regulation of the flow and encourage a spinal cord ischemia.

One of the most common complications that develop in the beach chair position is represented by the appearance of bradycardia/hypotension episodes (BHE), which if not recognized and treated can lead to very serious consequences. The incidence of BHE is about 13–30 % [54–56] of patients who submit to shoulder arthroscopy in the beach chair position with interscalene block. The BHE were defined as a reduction of at least 30 beats/min within 5 min from positioning, or a rate <50 beats/min, and a reduction in systolic BP of more than 30 mmHg in 5 min or a reduction of PAs <90 mmHg. The etiology of BHE is still not well defined, but it is thought that the most common mechanism is the activation of the Bezold-Jarisch reflex [54, 55].This is a cardioinhibitory reflex that originated in cardiac receptors with unmyelinated vagal C fibers, representing the afferent arm of the reflex. The activation of this reflex starts from an empty hypercontractile ventricle, which causes stimulation of mechanoreceptors (C fiber), producing a sudden interruption of the sympathetic stimulation and thus creating a vagal overtone. D'Alessio [54] reported that during beach chair positioning, increased accumulation and stagnation of blood to the extremities due to the bending of the legs involves an initial sympathetic hyperstimulation that, associated with a reduced cardiac preload, involves a ventricular hypercontractility which triggers the activation of mechanoreceptors, thus mediating vagal fibers, and interruption of sympathetic stimulation. However, Campagna and Carter [57] say that the incidence of BHE in shoulder arthroscopy is not attributed to the activation of the Bezold-Jarisch reflex. There is a bit of discrepancy on the use of epinephrine in the mixture of local anesthetic as a cofactor of BHE. Sia [56] postulated that the use of epinephrine in the anesthetic mixture for interscalenic block increases the incidence of BHE by 25 %, while the study of K Chuo Seo [58] showed no difference in the incidence of BHE between the mixture with adrenaline and that without. The hypothetical mechanism is that adrenaline, when used with a local anesthetic mixture for a regional block, is absorbed slowly into the circulation and so could increase cardiac contractility and heart rate and cause peripheral vasodilation and pooling (decreased afterload), creating ventricular hypovolemia with hypercontractions that predispose patients to BHE. One factor that could contribute to the development of BHE is the site of interscalene block. In fact, in the study of K Chuo Seo [58], it showed that the patients who received a right interscalene block in 92 % of cases experience BHE. The authors think that the blockade of the stellate ganglion caused by right interscalene block may be involved in the etiology of BHE, because the right interscalene block prevents the compensatory response of hemodynamic changes induced by the sitting position due to loss of sympathetic stimulation. Other studies support the hypothesis that the side of the block can be a determining factor in the occurrence of BHE [59–61].

Other studies suggest that the association between general anesthesia and the sitting position can predispose the incidence of BHE, since drugs of general anesthesia can depress the reflex sympathetic response triggered by the supine position, helping to reduce vascular resistance, MAP, and cardiac output [62]. Liguori et al. [63] have developed a protocol of prophylaxis with metoprolol and glycopyrrolate to prevent the development of BHE, since metoprolol can prevent hypercontraction-induced ventricular activation from the sitting position and reduce the Bezold-Jarisch reflex, while glycopyrrolate blocks the Bezold-Jarisch reflex in the effector arm. Their study showed that incidence of BHE was 28 % in the placebo group, 22 % in the glycopyrrolate group, and 5% in the metoprolol group. However, the protection offered by the prior administration of b-blockers in the onset of BHE was not confirmed by the study of Kahn-Hargett [55].

Another complication associated with the beach chair position is the occurrence of cerebral ischemic events, which can occur especially if the technique of controlled hypotension is used. Controlled hypotension is a technique well validated and used in orthopedic surgery, especially for arthroscopic techniques and in the absence of tourniquet, since it permits an improvement of the operating field, increases the speed of the procedure, and reduces intraoperative bleeding [64]. In normal subjects, the cerebral blood flow is maintained constant at mean arterial pressure values between 60 and 140 mmHg, and outside these values, the cerebral blood flow becomes dependent on mean arterial pressure. Since there is a lack of a specific limit pressure safety for controlled hypotension [65] applicable for all patients, the need to monitor indirectly cerebral perfusion using NIRS technology is suggested. NIRS makes possible to estimate the cerebral tissue oxygenation [66] considering both oxyhemoglobin and deoxyhemoglobin concentrations in the brain, thus allowing to detect episodes of cerebral desaturation. The NIRS values are influenced by deep anesthesia, by the type of anesthetics used, by the levels of $PaCO_2$ from FiO_2 administered, and by the blood pressure. In the study by J. YaDeau [67], the relationship between hypotension and cerebral desaturation was assessed in patients undergoing shoulder surgery anesthetized with interscalene block plus intraoperative sedation with spontaneous breathing. The results of the study [68] showed that hypotension in the sitting position was present in 76 % of patients, while cerebral desaturation, defined as a 20 % reduction in the rSO_2 baseline, was only present in 10 % of patients. Risk factors of correlation between cerebral desaturation and hypotension were represented by hypertension, hyperlipidemia, coronary artery disease, and diabetes. This low value of cerebral desaturation despite the more frequent incidence of hypotension in this study can be explained by the use of regional anesthesia technique in combination or not with sedation associated with spontaneous breathing. In fact, in a recent study, Murphy [68] reported an 80 % incidence of cerebral desaturation in patients in the beach chair position under general anesthesia, while there were no reported events in patients in lateral decubitus under general anesthesia. There are important differences between general anesthesia and regional anesthesia. Volatile anesthetics alter the regulation of the cerebral blood flow unlike propofol [69], even if they have a protective effect on cerebral ischemia; furthermore, mechanical ventilation associated with general anesthesia reduces venous return and cardiac output, causing a right ventricular dysfunction and obstructing the cerebral venous return, thus favoring a reduction in cerebral perfusion [70]. In the awake but sedated patient spontaneously breathing, spontaneous ventilation does not alter the venous return and the distensibility of the left ventricle, while the sympathetic system is active and can prevent the collapse of vascular resistance induced by the sitting position. Despite the high frequency of cerebral desaturation in the study of Murphy [68], there were no recorded neurological events upon awakening and in the succeeding hours. The low incidence of neurological events is related to both the brevity of surgery and to the short duration of cerebral desaturation episodes. In fact, both the severity and the duration of ischemia are critical determinants of brain tissue damage. A data analysis of NIRS conducted in patients undergoing coronary bypass [71] reported a threshold of cerebral desaturation time of 50 min with the occurrence of neurological decline upon awakening and a prolonged hospital stay. In Murphy's study [68], although he did not report any neurological events upon awakening, he found a strong correlation between cerebral desaturation episodes and PONV, which are the result of short episodes of hypoxygenation and cerebral hypoperfusion [72]. The study by Lee [73] found that although the MAP always decreased after induction of anesthesia without any cerebral desaturation, the rSO2 decreases significantly only after placement in the beach chair position. Papadonikolakis [47] in his review focused on the correct interpretation of blood pressure in the sitting position. Because the cerebral perfusion pressure is the difference between average pressure and intracranial pressure, pressure measurement in the sitting position should be made at the level of the brain, because cerebral autoregulation would occur in the intracranial arterioles and capillaries. In the sitting position, there is a hydrostatic pressure gradient between the brain and the normal detection site of Pa. In fact when the MAP is measured from sites other than the brain, it is necessary to apply a correction arithmetic of 1 mmHg for every 1.35 cm difference in height between the brain and the measurement site [74].

4.3 Analgesia for Shoulder Surgery

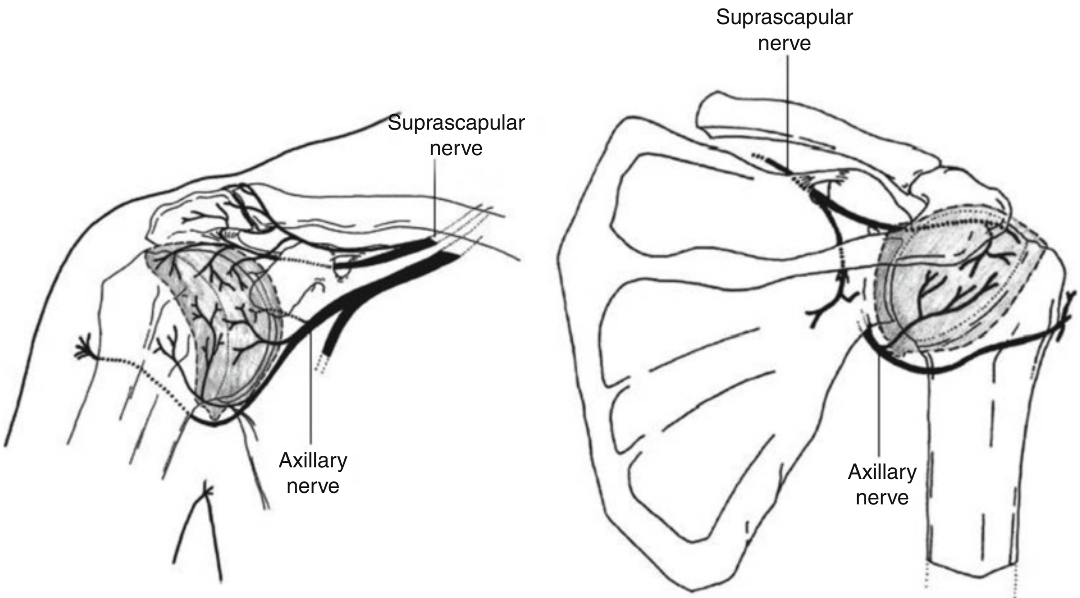
Shoulder surgery is associated with a high level of intense postoperative pain which may require the use of opioids even for many days [75, 76], sometimes similar to pain treatment for laparotomy and minithoracotomy [77, 78].Therefore, nowadays, opioid-based analgesic technique is no longer feasible due to either the many side effects associated with its use, such as nausea, vomiting, constipation, delirium, pruritus, and light-headedness, or the new findings about the high use of opioids in the perioperative period, as nociception-induced central sensitization and hyperalgesia secondary to the use of opioids [79], both mechanisms that may be involved in the pathogenesis of pain after surgery. The multimodal analgesia approach [80] prevents postoperative pain and is based on the administration of opioid and non-opioid techniques as well as opioid-sparing techniques, as local regional anesthesia techniques, TENS, physical therapy, and acupuncture that act on different parts of the central and peripheral nervous system to reduce the process of central sensitization and chronic pain [81]. In the outpatient surgery, the multimodal analgesia approach allowed faster discharge of patients; reduced the effects of constipation, urinary retention, nausea, and vomiting; and permitted a more rapid recovery of the patient's functions and psychomotor performance, reducing the costs of hospital stay and the management of side effects. The introduction and diffusion of arthroscopic techniques in orthopedic surgery have reduced hospital stay and the costs of prolonged hospitalization and allowed a quick postoperative course although the pain in the first 24–48 h may be similar in intensity as that of open surgery. For this, different techniques of regional anesthesia have been developed with the intent to spare opioids that you can integrate with or replace general anesthesia.

4.3.1 Intra-articular Analgesia

This technique is the administration by the surgeon at the end of the procedure of a variable volume of 25–50 ml of anesthetic solution or local anesthetics and opioids in the joint space or into the subacromial space to which the positioning of a catheter for continuous infusion follows. There are many conflicting opinions in the literature about the real benefit of this analgesic technique. Nisar [82] in a study involving 60 patients, in which rotator cuff repair was a majority, found that this technique can be an alternative to interscalene block in reducing the consumption of postoperative morphine to provide better postoperative pain control. However, other studies as Singelyn [83] and Laurila [84] et al. found a clear superiority of the interscalene block than the intra-articular analgesia that proved only slightly better than placebo. Several studies [85–87] suggest that the combination of local anesthetic + opioid analgesia in intra-articular space provides better analgesic coverage compared to that provided by only using local anesthetic. The initial enthusiasm of this technique, in recent years, has seen poor results especially in extensive arthroscopic shoulder procedures; the use of this technique has been greatly reduced and is limited to minor arthroscopic procedures that do not involve rotator cuff repair, preferring a technical single injection with a mixture of local plus long-acting opioid such as morphine. Besides the limited analgesic coverage, the disuse of this technique can be explained by the increasing emerging concern of damage of chondrotoxicity with chondrolysis induced directly by local anesthetic. In fact, it has been reported in several studies [80, 88, 89] of post-arthroscopic glenohumeral chondrolysis; this was particularly evident with continuous systems of intra-articular infusions, but it appears that the single injection may be associated to a reduced density of chondrocytes at 6 months [89].

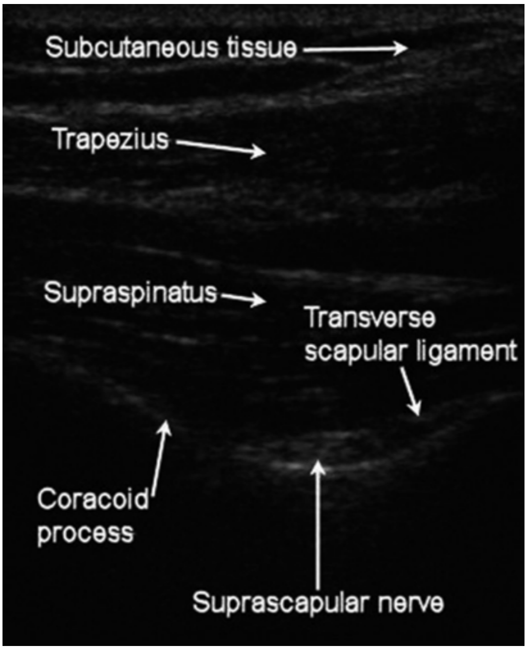
4.4 Suprascapular Nerve Block and Circumflex Nerve Block

The suprascapular nerve is a mixed nerve, both sensory and motor, which originates from the roots of C5 and C6 and receives a small contribution from C4 in 50 % of cases. It crosses the posterior triangle of the neck and enters the suprascapular incisure below the superior transverse ligament of the scapula and then continues its descent through the spinoglenoid notch and the inferior transverse ligament of the scapula, ending in the infraspinatus fossa [90]. The motor component innervates the supraspinatus and infraspinatus muscles, with its sensory innervation providing about 70 % of the sensitivity of the shoulder joint, because it innervates the upper and posterior parts of the capsule of the shoulder, acromioclavicular joint, the subacromial bursa, and the coracoclavicular ligament. The circumflex or axillary nerve is a mixed nerve that originates from the secondary posterior trunk of the brachial plexus and, from the axilla, exits at the posterior and across the quadrilateral space of Velpeau and then, after surrounding the neck of the humerus, terminates at the posterior loggia of the arm; its motor component innervates the teres minor and deltoid, while the sensory component supplies the anterior and lateral part of the shoulder [91].

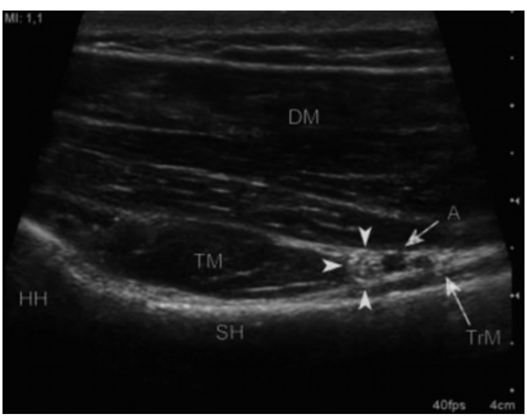


The suprascapular nerve block can be performed with either the peripheral nerve stimulator technique or the ultrasound-guided technique [92]. The ideal approach involves blocking the branches of the nerve proximal to the acromion and subacromial region to ensure better analgesic coverage. Therefore, the best point to perform the block would be at the suprascapular notch, although there is the risk of pneumothorax. Price [93] has described a technique at the level of the supraspinatus fossa, and Checcucci [94] described his block technique by positioning the needle 2 cm medial to the medial border of the acromion and 2 cm cephalad to superior margins of the scapular spine evoking, with nerve stimulation, the abduction and external rotation of the arm (supra- and infraspinatus muscle movements).

For the ultrasound-guided technique [95], the patient is placed in the sitting position; it will use a linear probe placed parallel to the spine of the scapula, scanning in depth the skin, subcutaneous tissue, trapezius muscle, supraspinatus muscle, and suprascapular notch. The location of the suprascapular artery will be identified with the Doppler; the nerve usually lies medial to the pulsation of the circumflex artery over the scapula under the transverse scapular ligament. Eichember and Curatolo [96] described in 2012 a supraclavicular approach for suprascapular nerve block that, according them, ensures a more simple and frequent view of the nerve than the standard approach.



The circumflex nerve block can be done with either the electrical nerve stimulation (ENS) technique or the ultrasound-guided technique. With the ENS technique, the best-known landmarks are those of Price [93] and Checcucci [94]. For the ultrasound-guided technique [97], the ultrasound probe is placed in long axis, about 1.5 cm to 2 cm, below the angle of the acromion parallel to the loggia of the posterior muscles of the arm or the humerus. So you locate, with the Doppler, the pulsation of the circumflex artery in which the nerve is always adjacent, while other landmarks are the deltoid and the teres minor muscles.



In the study of Ritchie [98], the suprascapular nerve block reduces morphine consumption, by 31 % compared to placebo, and the incidence of nausea and vomiting and allows the patient to be discharged earlier. The study of Singelyn [83] compared three analgesic techniques for post-arthroscopic pain shoulder and showed that the suprascapular nerve block alone has better pain control than intra-articular infiltration/subacromial local anesthetic, but provides an analgesic coverage lower than the interscalene block, requiring therefore an integration systemically. Moreover, it is seen that the use of a suprascapular nerve block in addition to a single injection interscalene block prolongs the request for the first administration of analgesic, but does not change the subsequent requests and intensity of pain at 24 h, adding so little benefit compared to interscalene block [99]. When the suprascapular nerve block is used in combination with circumflex nerve block, Price's studies [93–100] suggest that it is possible to obtain a total shoulder analgesia during intra-op, although during surgery opiates or sedative drugs should be used to control pain that could result from stretching of the joint capsule and at the sensitive region of the lateral pectoral nerve that is not blocked by those nerve blocks. In a small number of cases, Checcucci [94] described, as the only anesthetic technique for arthroscopic shoulder, the success of the combined use of suprascapular nerve block, circumflex nerve block, and infiltration of access portals of the trocar without any intraoperative sedation. In the study by Lee [101], different analgesic protocols, such as PCA technique + general anesthesia, PCA plus interscalene block, and PCA plus suprascapular nerve block and circumflex nerve block, were compared. The study showed that in the first 8 h after surgery, the best analgesic coverage was provided by the interscalene block, with mean values of VAS recorded in the recovery room of 1.5 for the interscalene group, 3.6 for the suprascapular nerve block + circumflex nerve block, and 7 for the group of general anesthesia alone. After 8 h from the end of surgery, there has been a rebound pain effect in the interscalene group with a mean VAS of 5.2, while VAS in the double block group was 3.9, and the group

General anesthesia was 5. Even pain control at 16 h–24 h showed a better analgesic and constant coverage in the double block group than in the interscalene group. Lee's study [101] concluded that in the first 8 h, interscalene block is the best postoperative analgesic technique, but suprascapular nerve block plus circumflex nerve block provides analgesic coverage similar if not superior to interscalene block without creating a rebound pain effect that lasts for the first 24 h. The advantages of this combination are that it avoids blocking the motor and sensory function for those parts of the upper limb innervated by the lower roots of the brachial plexus (C7–C8–T1), thus leaving full control of the lower half of the upper limb, and especially avoids paralysis of the phrenic nerve which presents at different degrees, depending on the volume of anesthetic used and on the site of the injection level (C5–C6, C6–C7), especially for those patients who have breathing problems, such as severe COPD and pleural effusion contralateral to the block, patients with one lung, and patients with decreased respiratory reserve contralateral to the block. The disadvantage of this analgesic-anesthetic approach is the need to perform two separate blocking techniques, to have an incomplete block of the shoulder, since it leaves uncovered the lateral pectoral nerve, which may require intraoperative sedation or intraoperative opioid and postoperatively could need integration systemically. Because the single injection nerve block have a limited duration, a continuous infusion is necessary, but for good analgesic coverage, you must use a dual-catheter continuous infusion pump, both for the suprascapular nerve and the circumflex nerve, with some risk of local anesthetic overdose.

4.4.1 Interscalene Single Injection Block

The interscalene single injection block is the procedure most used in shoulder surgery both for open surgery and arthroscopic procedure, since it provides excellent anesthetic and analgesic coverage during the intraoperative period and for the first 12 h postoperatively. It can be used as the only anesthetic technique especially in arthroscopic procedures or in combination with intraoperative sedation with spontaneous breathing or general anesthesia. Hadzic [102] compared interscalene block (ISB) to general anesthesia. Patients in the ISB group have better analgesic coverage, a more rapid recovery of ambulation, and less hospital stay and, more frequently, bypass phase 1 of the PACU without having any unplanned hospital readmission. However, the study of Hadzic [102] also assessed the duration of the analgesic coverage between interscalene block and general anesthesia; upon 24 h, 48 h, and 72 h follow-up, Hadzic did not find any benefit in opiate consumption; and there were no changes in pain intensity after 24 h between the two groups. A similar observation was also made by McCartney [103]. Singelyn's study [83], comparing different analgesic techniques for arthroscopic shoulder, showed a better quality of analgesic coverage for interscalene block, with respect to intra-articular infiltration, and suprascapular nerve block in the first 10–12 h of the postoperative period. Several approaches have been proposed to interscalene block, and its main advantage is that, with a single puncture performed with either the ENS technique or the ultrasound-guided technique, you can get a complete blockage of the shoulder, because the block was performed at the roots of C5–C6, covering, thus, the suprascapular nerve, circumflex nerve, and lateral pectoral nerve and the intra-articular parts. In the ENS technique, the success of research and nerve localization is based on anatomical knowledge through which you can make blocks in different places, limiting complications.

According to some anatomical observations (P. Grossi 2001), it is possible to provide an important aid to ensure the efficiency of the anesthetic block technique, by identifying cutaneous anatomical landmarks that may be some distance from and not directly involved in the area of the block, but lie over the path of the nerve structure and represent an alignment with it in what is a theoretical "anesthetic line."

The concept of an "anesthetic line" reflects only an anatomical virtual observation of the craniocaudal longitudinal course of the nerve structure, which, when a patient assumes a certain position aimed at identifying various anatomical landmarks, allows to show the nerve structure in a straight manner and therefore in a pattern more accessible from the outside with a needle, allowing it to remain at a greater distance from other structures, such as vessels or organs; this is in order to improve the success of the block through an improved criterion approach thus reducing the time and repeated attempts of punctures, not well tolerated by the patient.

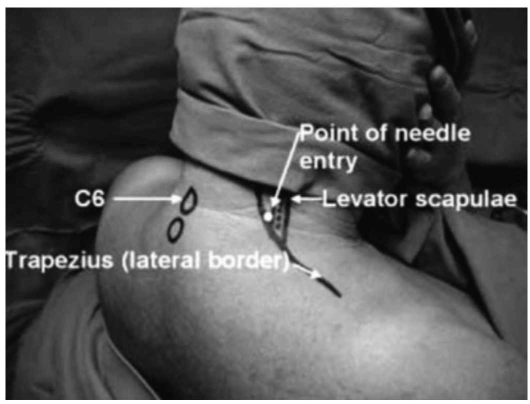
4.4.1.1 Anesthetic Line for the Upper Limb

The patient is placed in the supine position, head turned to the opposite side and the upper limb adducted at 45° to the trunk. Thus, you have a common starting position for all blocks of the upper limb, which allows an excellent visualization of the following landmarks:

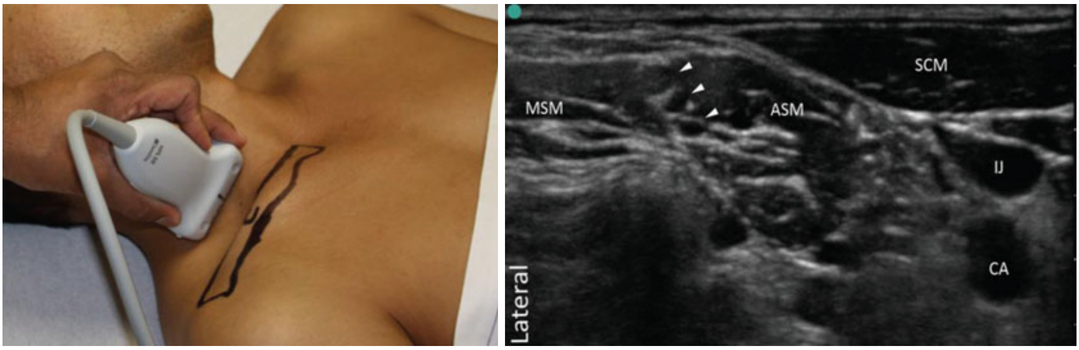
- The apex of the scalene triangle (Chassaignac tubercle)
- The midpoint of the clavicle
- Deltoid-pectoral groove, focusing on the coracoid and the profile of the rib cage
- Point of pulsation of the axillary artery at the axilla
- The medial epicondyle of the elbow (in this case the forearm is flexed at 90° on the arm)

In this situation, we can see that the various cutaneous anatomical landmarks are spread along a line running from the apex of the scalene triangle until the point where the axillary artery is palpated. This line extends up to the medial epicondyle of the elbow and is utilized in the case of blocks at mid-humeral level.

The classic approach of Winnie [104] allows the identification of the interscalene groove, at the level of the cricoid cartilage (C6) with the needle directed medially, slightly caudal, and slightly posterior; Meier [105] changed the approach of Winnie to reduce the risk of complications and to facilitate placement of catheter for continuous infusion; Meier's [105] approach enters the skin at 30° at 2–2.5 cm cephalad to the Winnie approach; Borgeat's [106] lateral approach has a needle insertion 0.5 cm below the level of the cricoid, with a needle orientation of 45–60°. The posterior approach of Pippa [107], an old paracervical approach to the brachial plexus, was recently revisited by Boazaard [108], whose technique involves passing the needle between the levator scapulae and trapezius muscle, thus limiting neck pain and incidence of epidural injection (ref [13] Art Review of blocks and shoulder). Also Boazaard [108] postulated that with this approach, it is possible to have a more selective differential sensory-motor block than the anterior approach, because the block occurs more proximal to the point of fusion of the sensory fibers and motor fibers [109].



The use of ultrasound has enabled us to optimize and improve the block techniques, making them safer and increasing their success rate, through direct visualization of nerve structures and adjacent structures, assessing the progress of the needle and the spread of the anesthetic, and visualizing intravascular and intraneural injections. Liu [110] et al., in a prospective study in which they compared ultrasound with ENS, found that the use of ultrasound reduces the number of needle punctures, increases the speed of block onset and, in expert hands, can reduce the speed of execution of the block, and improve the success rate of the block. Chan [111], in his ultrasound-guided technique, used both in-plane and out-of-plane approaches to identify the brachial plexus at the interscalene groove, with the difference being that in the in-plane approach, you can display the needle in its entirety and pathway, while the out-of-plane approach provides a shorter path to the target tissue with the needle visualized in the transverse plane [111].



The use of ultrasound permits direct visualization of the spread of anesthetic, allowing to optimize the dose and the volume of anesthetic infusion and minimizing the negative effects of excessive anesthetic volume. Fredrickson [112] conducted a study to estimate the volume and concentration of ropivacaine required to avoid pain in recovery after shoulder surgery. His study found no difference in pain scores between a volume of 20 ml 0.375 % ropivacaine and a volume of 30 ml 0.5 % ropivacaine, but satisfaction was greater in the lower dose group for the shortest effect of motor block. Riazi [113] evaluated the effects of the volume on the phrenic nerve paralysis by comparing a volume of 5 mL of 0.5 % ropivacaine to a volume of 20 mL of 0.5 % ropivacaine during execution of ultrasound interscalene nerve block. He [113] found no difference in pain scores and morphine use between the two groups in the first 24 h, but found a lower incidence of phrenic nerve paralysis (45 % versus 100 %) and better levels of oxygenation and less impairment of FEV1 in the lower-volume group. However, the study of Sinha [114] evaluating intermediate volumes of 10 ml versus 20 ml of 0.5 % ropivacaine using ultrasound-guided technique at the level of the cricoid cartilage (C6) found an incidence of phrenic nerve paralysis in 93 % of patients with no difference between the two groups with different volumes.

Recently Van Geffen [115] and Antonakakis [116] using the ultrasound-guided technique revisited Pippa's posterior approach [107], which, according to them, is very useful in the long-term positioning of the catheter for continuous infusion, thanks to greater stability and better anchorage to the various muscle planes (especially the levator scapulae and trapezius muscle), avoids damage to vascular structures that you may encounter at anterior approach. The major disadvantage of the posterior technique is the increased distance the needle must travel from the entry point to the target nerve; another rare complication is the damage which could be done to the long thoracic and dorsal scapular nerves as the needle has to pass through the middle scalene muscle. The main disadvantage of the single injection interscalene block is its limited duration of action compared to that used during shoulder surgery. Various strategies to minimize this problem have been taken into consideration. One of these is the use of adjuvant drugs with the intent of extending the motor and sensory block. Adjuvant drugs such as adrenaline, clonidine, ketamine, and dexamethasone were used with varying success. The most promising seems to be the use of dexamethasone. Cummings [117] in his study has found that the use of 8 mg dexamethasone extends the time for the first request of opioids of about 11 h. The specific mechanism of action is not clear but may be related to the glucocorticoid receptor channel activity that would increase K inhibitors on the C fibers [118], although it is possible that this mechanism is mediated by systemic. However, Shaikh [119] et al. think that dexamethasone could have a local action after perineural administration secondary to its action on C fibers, mediated via membrane-associated glucocorticoid receptors and the upregulation of the K channels. Abdallah [120] found that the perineural and intravenous administration of 8 mg dexamethasone has similar effectiveness on time extension of analgesia after supraclavicular single injection block. Recent research by Alemanno et al. [121] found a role of vitamin B1 as an adjuvant drug for time extension after single nerve block. It could be that vitamin B1, at perineural level, ensures the level of synthesis and storage of acetylcholine at presynaptic level thus potentiating analgesia. In his study, the analgesia extension of 1,5–2 ml/kg vitamin B1 was similar with analgesia prolongation offered by buprenorphine after a middle single injection interscalene block.

4.4.2 Continuous Interscalene Nerve Block

Continuous interscalene nerve block was described for the first time in 1987 by Tuominen [77], who had used a similar approach to that described by Winnie, for the single injection block, with a failure rate over 25 %. In 1997, thanks to improved medical devices, Meier [105] revived the continuous technique, with improved effectiveness. In Meier's technique [105], the needle's insertion point is placed slightly higher than at the classic level of C6. This allows to approach the brachial plexus at the interscalene groove along its long axis, supporting that the catheter with its holes be placed to lie more in the vicinity of the roots, thus promoting a greater fixation. Meier's technique is followed then by the lateral technique of Borgeat [106], the posterior approach of Pippa [107], and the modified posterior approach of Antonakakis [116] and Boezaart [109], which favors a greater fixation for the long-term positioning of the catheter. Boezaart [122] used the electrostimulation-guided technique to better confirm the exact location of catheter insertion, prevent malposition, and reduce high failure rate. However, subsequent randomized trials have shown no significant differences between electrostimulation with a stimulating catheter and electrostimulation with a nonstimulating catheter in avoiding second failure and malposition [123–125]. For interscalene catheter placement using a nonstimulating catheter, it is recommended not to insert more than 3 cm from the tip of the catheter once the correct electromotive target is identified. The specific technique for interscalene catheter placement has been associated with a false-negative motor response rate of over 50 % [126]. This high percentage of false-negative motor response was the reason to replace the neurostimulation technique with the ultrasound-guided technique that showed exactly where the catheter was placed and the spread of the anesthetic around surrounding tissues [127].

The ultrasound-guided technique sped up the procedure, improved effectiveness of the block, had a greater opioid-sparing effect, and encouraged a more rapid onset of rehabilitation. The choice between the out-of-plane approach and the in-plane approach remains controversial [128]. Most described is the out-of-plane approach [129], mainly used for cannulation of the internal jugular vein. This approach allows the alignment of the needle and catheter to the long axis of the nerve, promoting catheter advancement. Some authors argue that the orientation of a Tuohy needle bevel along the long axis of the nerve reduces the risk of intraneural positioning. The in-plane approach allows visualization of the entire progress of the needle, thus favoring a better alignment with respect to the long axis of the plexus; nevertheless, the risk of a leak of the injected solution is possible when the tip of the needle is not correctly identified, with the real tip migrating elsewhere or in the intraneural position [130]. Proper placement of interscalene catheter is a real challenge. The expansion of the perineural space with injected solution can facilitate catheter progression [131]. The solution may be physiological, 5 % dextrose, or local anesthetic; among these, 5 % dextrose is preferred because it allows to maintain the motor response during stimulation and to reposition the catheter in the most appropriate location during its progression, if the electrostimulation-guided technique is used [132, 133]. Catheter fixation in this area can be a problem especially for the anterior and lateral approach, due to the mobile nature of the surrounding tissues and the presence of hair. In addition to the technique of using tunneled catheter, nowadays securing devices are used such as LockIt Plus that allow to assemble properly the catheter and encourage some small retraction in case of malfunction or kinking. The effectiveness and superiority of continuous interscalene block has been shown by several studies. Borgeat [75], in a randomized study on patients undergoing rotator cuff repair, compared the single injection block with the continuous block showing superiority in the quality and duration of analgesia and greater opioid-sparing effect in patients with catheter. Mariano [134] conducted a randomized trial with 30 patients undergoing major surgery of the shoulder comparing continuous infusion of 0.2 % ropivacaine with normal saline, after intraoperative bolus of 40 mL 0.5 % ropivacaine. The study showed better analgesia, better sleep quality, low demand for opioids, and improved satisfaction. Even Fredrickson [135] in his study showed the superiority of continuous infusion, compared to control without continuous infusion, in the control of postoperative pain both at rest and during movement, with the continuous infusion group requiring less use of tramadol, but experiencing a greater feeling of heaviness and numbness of the arm. Also Kean [136] and Ilfeld [137] showed a greater superiority of the continuous block compared to single injection block. The right combination of volume and concentration for interscalenic infusion is still not well defined. Klein [138] used high-speed infusions of about 10 ml/h; thereafter it was seen that this dose was not necessary for high-speed infusions because there were always a different degree of motor block, possible reabsorption phenomena, and related risks to intoxication by local anesthetics. With improvement of technology and more accurate placement of the catheter at the site of the block, the volume and concentration of drugs are reduced: Borgeat [139] compared 0.2 % ropivacaine with 0.15 % bupivacaine via PCA showing a comparable analgesic efficacy between the two types of anesthetics, but low impact motor block offered by ropivacaine. Ilfeld [140] showed that 0,2 % ropivacaine 8 ml/h with bolus injection of 2 ml/h provides better analgesic coverage compared to the same drug administered in a speed of 4 ml/h with bolus injection of 6 ml/h; also the study of Le [141] confirmed that a better analgesic coverage is obtained with a continuous higher volume and lower concentration, compared to a lower volume with higher concentration (0.2 % ropivacaine 8 ml/h versus 0.4 % ropivacaine 4 ml/h). The study of Fredrickson [142] showed that there is good pain control for patients administered with 0.2 % ropivacaine at 2 ml/h with boluses of 5 ml/h by means of PCA at the interscalene level after rotator cuff repair procedures and arthroplasty but that a large proportion of the patients experienced a moderate to severe breakthrough pain, which did not subside with increasing concentrations of 0.4 % ropivacaine. These studies suggest that to provide adequate analgesia, at least one infusion is needed with a minimum of 4–5 ml/h, which, however, must be associated with an optimal bolus dose of about 4–5 ml/h [143, 144].

The main complications of interscalene block include ipsilateral phrenic nerve paralysis that is always present when the volume injected is above 8–10 ml with different impact on lung function according to the patient's comorbidities, Horner's syndrome, recurrent laryngeal nerve block with dysphonia, hoarseness of voice, accidental puncture of the carotid artery and internal jugular vein. Rare but serious complications are puncture or administration of anesthetic at the level of the intervertebral artery, pneumothorax, subdural injection, intervertebral foramina injection resulting in total spinal anesthesia, cardiovascular shock, and nerve damage of the nerve roots coming out of the foramina, infection at the catheter's point of entry, malposition of the catheter, catheter migration, and transient neurological symptoms.

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