Anesthesia in Shoulder Arthroscopy

9

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Introduction

Surgical procedures in shoulder arthroscopy can be performed under regional blockade, general anesthesia, or a combination of the two techniques. The anesthesiologist's preoperative assessment is crucial to the formulation and execution of the anesthetic plan. The patients must be evaluated for coexisting medical problems, potential airway management difficulties, and considerations related to intraoperative positioning. This evaluation together with an understanding of the surgeon's need is used to formulate the anesthetic plan.

Hypertension is the prevalent medical problem observed in elderly patients undergoing shoulder surgery. Hypertensive patients will experience wider fluctuations in blood pressure intraoperatively than normotensive individuals, especially in the beach-chair position. Noxious stimuli will lead to exaggerated hypertensive responses. Conversely, since hypertensive patients tend to be intravascularly depleted, once general anesthesia is induced, hypotension may occur. In general, hypertensive patients should continue their antihypertensive therapy perioperatively. Some patients undergoing shoulder arthroscopy have rheumatoid arthritis. This disease could involve lungs, heart, and musculoskeletal system. Rheumatoid involvement of the cervical spine may result in limited neck range of motion, which interferes with airway management.

Shoulder arthroscopy can be performed with the patient in either the lateral decubitus or the sitting position. The sitting position offers an excellent intra-articular visualization for all types of arthroscopic shoulder procedures, less intraoperative blood loss, a lower incidence of traction neuropathy, and ease of conversion to an open approach if needed [1]. Position during shoulder arthroscopy may influence the choice of anesthetic plan since regional anesthesia is poorly tolerated in patients in the lateral decubitus position. A combination of regional and general anesthesia is recommended in the lateral decubitus, offering patients the advantages of long-acting local anesthetics (ropivacaine, levobupivacaine) in postoperative pain control and ensuring deep hypnosis for the uncomfortable position with ultrashort-acting modern medications (remifentanil, propofol, desflurane). However, like in the beach-chair position, unconsciousness due to general anesthesia could favor neurological and vascular lesions due to patient's positioning. Especially in the upright position, maintaining a safe position for the head during shoulder surgery under general anesthesia can be challenging. Reported complications attributed to an incorrect head position during surgery in the sitting asset have ranged in severity from cutaneous neurapraxias to complete midcervical quadriplegia [2–4]. In the lateral position cerebral hypoperfusion events are uncommon, and hypotension due to general anesthesia is less worrisome than in the upright one [5]. Shoulder surgery in the beach-chair position under general anesthesia is associated with significant reductions in cerebral oxygenation and subsequently with higher risk of neurological damage like visual loss and ischemic brain and/or spinal cord injury [6, 7].

Actually, regional anesthesia has several advantages for patients undergoing shoulder surgery: excellent anesthesia, reduction in both intraoperative and postoperative doses of opiates, delay of the onset of postoperative pain, a shortened postanesthesia stay, rapid discharge from the hospital, improved outcome, and increased patient satisfaction [8]. Furthermore, brachial plexus blockade is a cost-effective method for arthroscopic shoulder surgery [9].

During the last few years, ultrasonographic guidance has become a widely used technique for regional anesthesia, with safer procedures and faster onset time [10, 11]. Direct view of needle and anatomic structures reduces approximately to zero the incidence of intravascular injection, systemic

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local anesthetic toxicity, block failure, pneumothorax, and incidence of permanent nerve injury. Postoperative neurological symptoms are uncommon. Furthermore, ultrasound guidance allows shorter procedure time, fewer needle punctures, and reduced local anesthetic volume and postoperative pain when compared to neurostimulation technique for interscalene block [12–14].

Hypotensive Bradycardic Events During Shoulder Arthroscopy

When operating in the sitting position, one of the major concerns for anesthesiologists is cardiovascular instability during the shoulder procedure [15]. Hypotensive and bradycardic events (HBEs) have been reported in 13–28 % of patients. A HBE was defined, according to Liguori et al. [16], as a decrease in heart rate of >30 bpm in <5 min or any decrease <50 bpm and/or a systolic blood pressure decrease of >30 mmHg in <5 min or any decrease <90 mmHg. This event must have been accompanied by intraoperative treatment by the attending anesthesiologist. Light-headedness, nausea, and sweating were recorded but were not necessary in defining a HBE. Onset time of these transient but considerable events is 40–80 min after the plexus block or 25–45 min from the sitting position [17–19]. Most HBEs appear to be transient occurrences without complications such as brain hypoperfusion injury, but few severe cases of HBE have been reported, including asystolic cardiac arrest [20]. Underlying mechanisms responsible for the cardiovascular adverse effects are not completely understood. Several causes have been suggested: vasovagal syncope, carotid sinus hypersensitivity, orthostatic syncope, stellate ganglion block, drugs administration, and Bezold-Jarisch reflex [21]. The last one is a cardioinhibitory reflex. It is triggered by an empty hypercontractile ventricle, which causes activation of intramyocardial mechanoreceptors (C fibers) and results in a sudden reduction of sympathetic outflow, increasing vagal tone and thus causing bradycardia and hypotension. Some authors thought that the mechanism of the reflex was due to a reduced venous blood return induced by the beachchair position and to a hyperexcitable heart caused by the βadrenergic effects of endogenous and exogenous epinephrine. These mechanisms result in an arterial vasodilation induced by activation of the parasympathetic nervous system and a subsequent vagally mediated bradycardia [17, 18]. Nevertheless, Seo et al. [22] suggested that the exogenous epinephrine does not augment the incidence of hypotensive-bradycardic events and that increased contractility due to epinephrine used in local anesthetic mixtures for nerve blocks is not certainly documented [23]. More studies are necessary to demonstrate the exact role of epinephrine. At the present time, there is no certain data in the literature to support the role of central volume depletion and hypercontractile empty ventricle for the activation of the Bezold-Jarisch reflex in the shoulder arthroscopy in the sitting position [24].

HBEs are only observed in awake conditions under isolated interscalene brachial plexus blockade. In awake settings, several stimuli may trigger the vasovagal reflex: fear, pain, prolonged sitting position, heat exposure, exertion, and coughing may lead to inhibition of the sympathetic system and to activation of the parasympathetic system, causing respectively hypotension and bradycardia. The afferent neural signals are probably derived from organ receptors, like cardiac mechanoreceptors, which respond to mechanical or chemical stimuli. Vagal triggering and sympathetic inhibition should be activated also by stimulation of carotid sinus. In the shoulder arthroscopy associated to brachial plexus block, sinus stimulation should be activated by denervation of sternocleidomastoid muscle due to block of fibers of C2–C4 spinal nerves. In fact, sternocleidomastoid proprioceptive information seems to have an important role in the regulation of baroreflex arc of the carotid sinus [25].

Stellate ganglion block occurs in 75 % of patients undergoing interscalene block with the Winnie's approach [26]. The symptoms after stellate ganglion block may be caused by baroreflex mechanism failure because of impairment of both cardiac sympathetic nerves and vagal afferents, including aortic depressor nerves [27].

Considering all these concerns, anesthesiologists should perform the brachial plexus block reducing the risk of local anesthetic diffusion toward medial structures, trying to avoid the block of the sympathetic chain and stellate ganglion, phrenic and laryngeal recurrent nerves, vagal nerve, and C2–C4 spinal nerves. Laterally directed needle [28] and lower local anesthetic volume could help obtain a safer technique. The patient's position should be very well executed avoiding abdominal and thoracic compression and maintaining a neutral and comfortable head position. Any neck stretching or stress could induce HBE directly stimulating carotid sinus, and uncomfortable sitting could augment patient's anxiety and start a vasovagal reflex. Furthermore, the anesthesiologist should consider the patient's medical history. Patient with a syncopal history and/or with a major anxious-depressive syndrome may not be candidate to isolated brachial plexus block. Although good sedation is necessary to perform both regional anesthesia and surgical procedure, the anesthesiologist should avoid opioids administration to patients, preferring the use of benzodiazepine. Opioids induce bradycardia and reduction in blood pressure. Fentanyl inhibits GABAergic transmission to cardiac vagal neurons in the nucleus ambiguous [29], inducing bradycardia. Song et al. demonstrated that the incidence of HBE is increased in patients receiving an intravenous bolus administration with 100 mcg of fentanyl (27.5 %) compared with the saline group (10 %) [30].

Therapy of HBE should be obtained with fluid and ephedrine administration. When a profound and dangerous reflex occurs, the first, and often the only, therapy is to lay down the patient.

Ultrasound-Guided Brachial Plexus Block

The brachial plexus is composed of the ventral roots of spinal nerves C5–T1, and sometimes it contains small fibers from C4 to T2. The roots exit the lateral foraminal spaces and pass between the anterior and the middle scalene muscles to innervate the upper limb. In the interscalene space, the roots coalesce to form the superior (C5–C6), middle (C7), and inferior (C8–T1) trunks that proceed laterally and inferiorly toward the space between the clavicle and first rib and then into the axilla. Several important branches are released from the brachial plexus at this level, including the suprascapular nerve, the dorsal scapular nerve, and the long thoracic nerve. When the trunks meet the first rib, they lie dorsolateral to the subclavian artery and superior to the rib. The brachial plexus and the artery are enclosed in a connective vagina. At the root level, the fascicles are surrounded by dura/perineurium. Within the perineurium there is little or no stroma, and care must be taken not to position the needle within the nerve root itself.

The anesthesiologists need a variety of supplies to perform ultrasound-guided brachial plexus block. Usually blocks are conducted in the preoperative holding area or in the operating room itself. Patients should have an intravenous catheter initiated, monitors placed, and supplement oxygen delivered prior to the block. The induction of regional anesthesia has risks that are similar to those of general anesthesia. For this reason, the practitioners should arrange a block cart containing both equipment for regional anesthesia and equipment and drugs for resuscitation [31]. Patients should be prepared with sedation and analgesia to remove anxiety and stress but still able to cooperate and without precluding feedback to the anesthesiologist.

The skin is prepared in sterile manner, and subcutaneous local anesthetic solution is injected at the site in which the block needle is to be inserted. The ultrasound probe is covered with a sterile, transparent membrane for single-shot blocks, while the anesthesiologist wears sterile gloves. It is controversial which is the best block needle to use. Most authors recommend the use of short-beveled needles, as it appears to be more difficult to penetrate the perineurium with this type of needle [32], although clinical outcome data is lacking. The choice of local anesthetic solution depends on the anesthesiologist's intent. Blocks intended for rapid onset and short duration may be conducted with mepivacaine or lidocaine, whereas longer-acting blocks will require ropivacaine or levobupivacaine. Mixture probably adds little to speed onset while significantly reducing the duration of long-acting agents. The ultrasound system should be portable with high definition and the probe linear and high frequency (10–13 MHz) to allow imaging of superficial nerves.

On performing the interscalene brachial plexus block under ultrasound guidance, the anesthesiologist should start identifying a reliable landmark at the base of the neck that consists of the subclavian artery and the brachial plexus, which lies dorsolateral to the artery and superior to the first rib. This requires placement of the ultrasound transducer in the supraclavicular fossa with a sagittal oblique orientation. At this level, the plexus appears as a cluster of grapes (Fig. 9.1). Keeping in the middle of the monitor the nerves, focusing on them, moving the probe slowly cranially, and titling the transducer more horizontally, the practitioner will appreciate the appearance of the anterior and middle scalene muscles with the plexus between them. Approximately at C6 level the anesthesiologist may display roots or trunks or a combination of the two aligning vertically like a traffic light. In 13 % of plexuses, variation from the typical relationship of the scalene muscles and nerve roots were present, the most common being the C5 nerve root running anterior to or directly through the anterior scalene muscle [33]. These anomalies may be responsible for occasional incomplete blocks. The sternocleidomastoid muscle at this level is visible like a triangular blanket lying superficial to the plexus and the scalene muscles.

The roots and trunks appear as hypoechoic nodules [34]. In fact, in most cases, the closer the nerve lies to the spine, the more likely it is to be hypoechoic. The hypoechoic aspect is due to cerebrospinal fluid that intersperses axons. At this level, nerves are surrounded by perineurium, which appears hyperechoic, but little or no stroma and fat is present. The peripheral nerves, instead, have hyperechoic stroma and fat outside the perineurium and assume the typical honeycomb aspect. In most patients, C5, C6, and C7 are easily visible in the same image. In some patients, also C7 and C8 are visible with this approach. The nerves lie at a mean depth of 5.5 mm from the skin surface [35]. Vascular structures of interest in this region are carotid artery and internal jugular vein, separated from the plexus by the anterior scalene muscle, the transverse cervical artery and associated vein, crossing transversely the interscalene space, and the external jugular vein, just beneath the skin. Fortunately, these vessels are seldom in the path of the blocking needle.

The brachial plexus can be approached in several ways. The most common is the interscalene block, although the posterior, the parascalene, and the supraclavicular techniques are well described. Performing the interscalene block, the patient should be positioned in the supine position with the head turned contralateral to the surgical site. The ultrasound transducer orientation should be transverse over the sternocleidomastoid muscle at the level of C6,

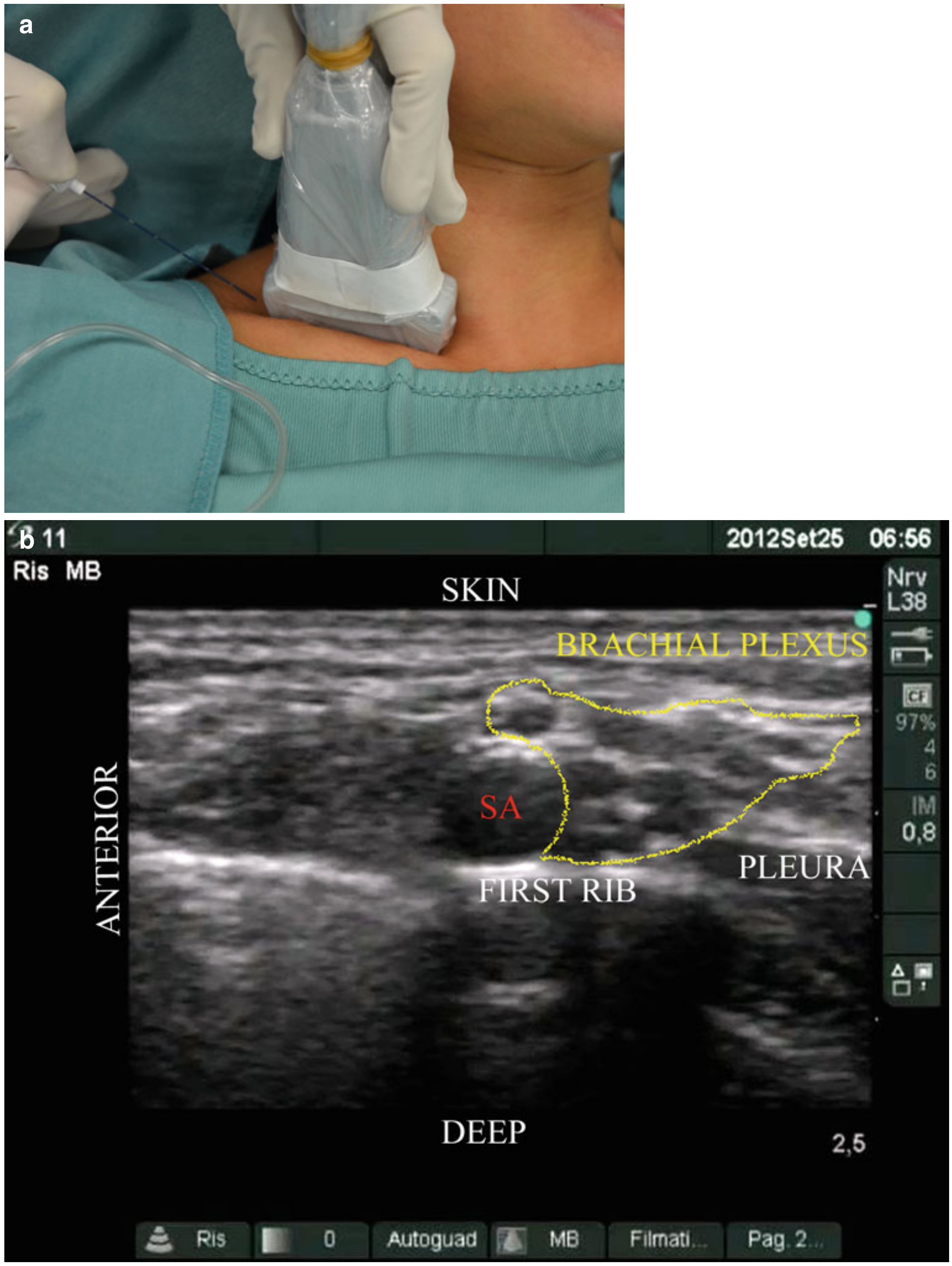

Fig. 9.1 (**a**) Placement of the ultrasound transducer in the supraclavicular fossa. (**b**) The brachial plexus at the supraclavicular level. *SA* subclavian artery

moving the probe until C5, C6, and C7 spine roots are well visible (Fig. 9.2). The ultrasound beam may be refracted as it passes through tissues. Fat globules below the skin, in the muscles, and around nerves serve as scattering and diffraction sites for the incident and reflected ultrasound beam and cause a spotted appearance in the image (this phenomenon is called "speculation"). For these reasons, obese patients can be very difficult to image. The image formed by ultrasounds is very sensitive to the angle of insonation, which is the angle of incidence of the beam relative to the nerve. Sometimes, changing the angle of insonation by only a few degrees can bring the nerve into focus. In obese patients, a light pressure of the tissue may improve the quality of the image. Once the optimal ultrasound image is obtained, it should be centered on the screen by sliding the probe on the patient's skin.

The needle may be inserted either posterior or anterior to the transducer, although a medial to lateral direction is preferable, for reasons exposed in the HBE paragraph. The in-plane approach offers the advantage of a perfect visualization of the entire needle and especially of the tip, and that is of fundamental importance to perform a successful and safe block (Fig. 9.3). After establishing the appropriate approach and the right image of the nerve root, the skin is anesthetized

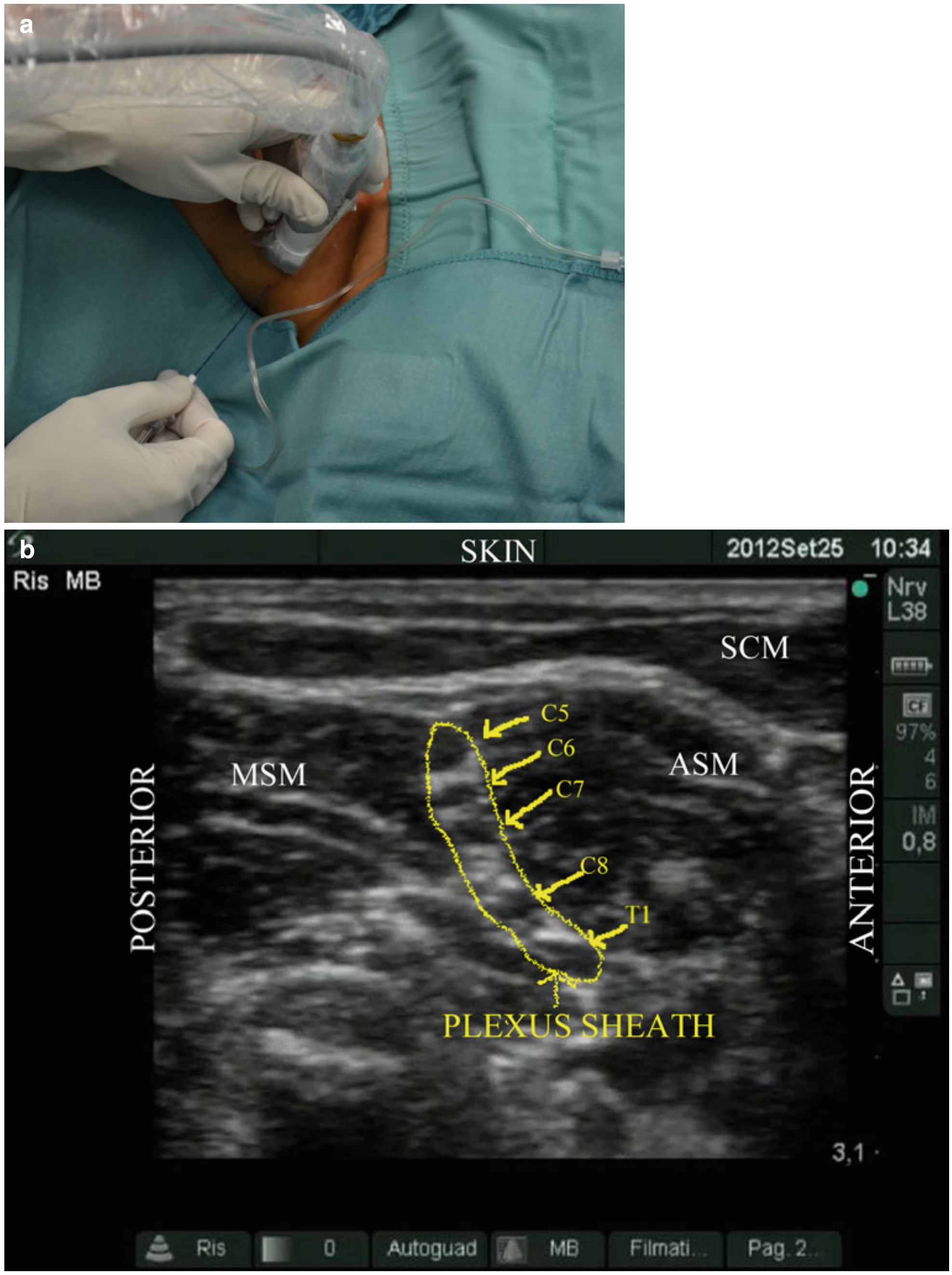

Fig. 9.2 (**a**) Placement of the ultrasound transducer for interscalene block. (**b**) The interscalene brachial plexus. *ASM* anterior scalene muscle, *MSM* middle scalene muscle, *SCM* sternocleidomastoid muscle. In this patient C8 and T1 are also visible

and the block needle introduced toward the goal. Little probe adjustments may be necessary to maintain a good visualization of both nerves and needle. Once the nerves are reached, the local anesthetic solution, usually 10–20 mL, is injected to surround the nerve elements. Local anesthetic should be injected between scalene muscles and brachial plexus sheath (peri-plexus), or within the brachial plexus sheath (intra-plexus) (Fig. 9.4). Intra-plexus block has longer duration then peri-plexus [36].

Complications in performing interscalene brachial plexus block under ultrasound guidance are uncommon. However, practitioners must be aware of the potential difficulties to prevent, recognize, and treat both light adverse effects and catastrophic complication. Vascular puncture, which may lead to systemic local anesthetics toxicity, can be easily avoided with a clear imaging and well needle-tip positioning. Aspiration before injection is always a necessary practice. Intravascular administration of local anesthetics may be responsible of neurological signs and symptoms, from mild tongue dysesthesias and speech difficulties to seizures and coma, depending on the plasmatic concentration of the anesthetic, and cardiovascular complications, including arrhythmias and cardiac arrest. The therapy consists in fluid and oxygen administration, supporting vital function, and

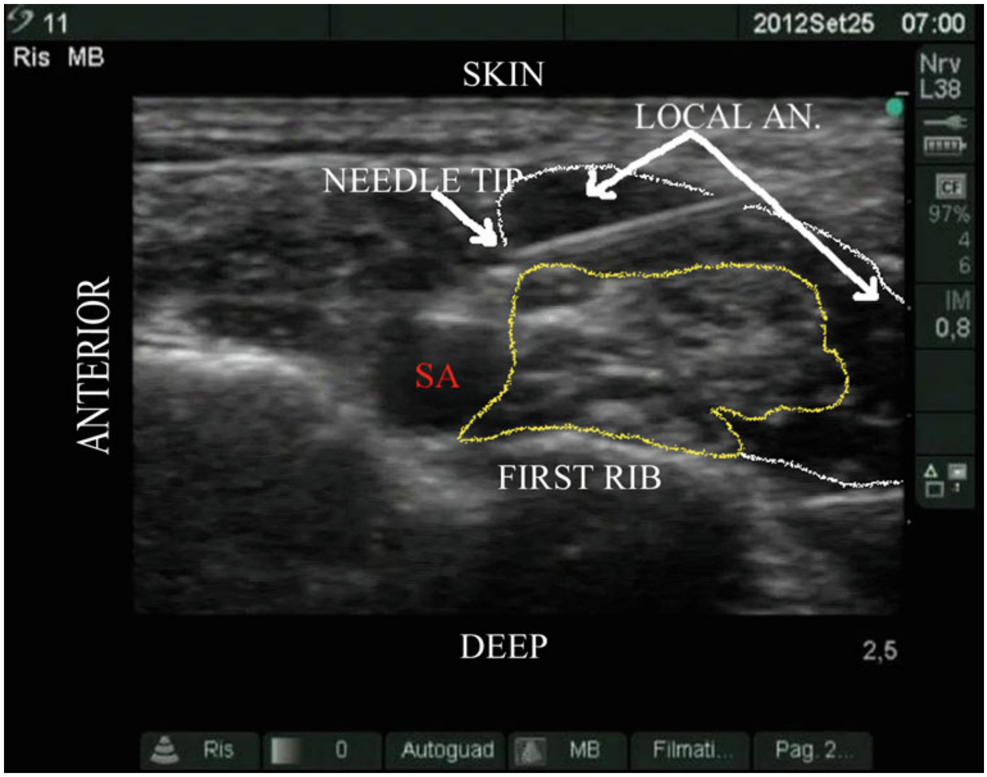

Fig. 9.3 Local anesthetic surrounding supraclavicular brachial plexus. With the in-plane technique, the needle and its point are well visible. *SA* subclavian artery

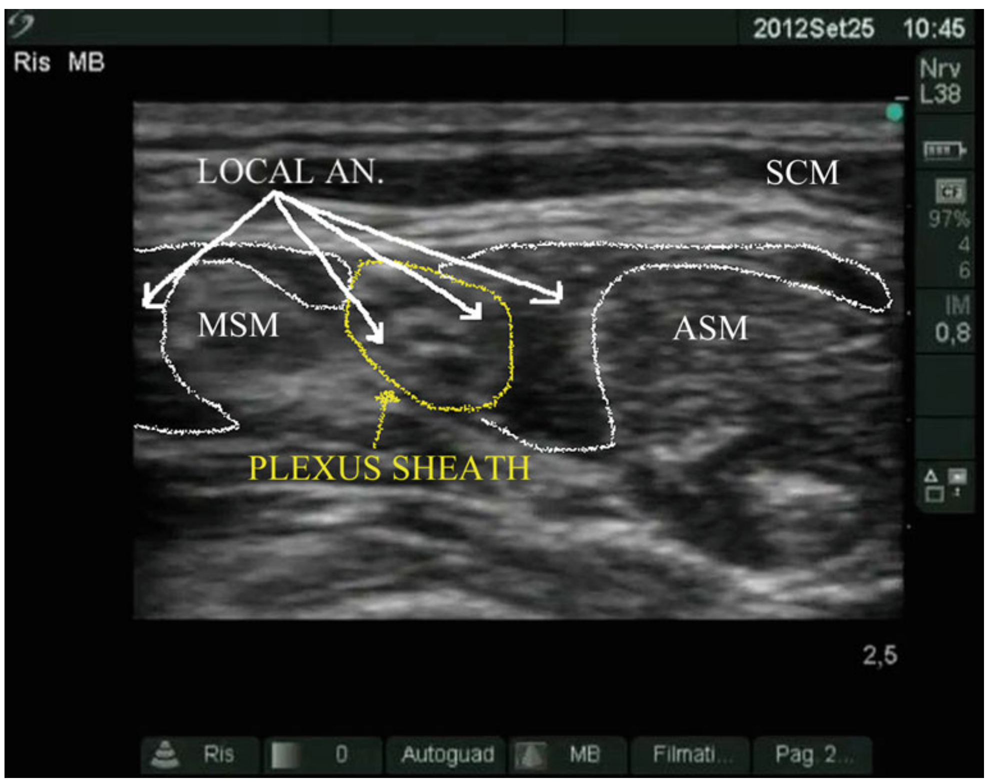

Fig. 9.4 Local anesthetic surrounding brachial plexus (peri-plexus) and intra-plexus (plexus swelling). *MSM* middle scalene muscle, *ASM* anterior scalene muscle, *SCM* sternocleidomastoid muscle

administration of antiepileptic drugs and lipid emulsion [37]. Lipid rescue has led to a reduction in fatalities associated with severe systemic toxicity. The underlying mechanisms of the lipid resuscitation may be a combination of a lipid catching and metabolic effect, but continued research is necessary for a better mechanistic understanding.

Phrenic nerve and laryngeal nerve block, generally, do not need of any intervention. However, being them common side effects of the interscalene nerve block, the block is strictly contraindicated in patients affected by paralysis of contralateral phrenic nerve or laryngeal nerve, and, also, the anesthesiologist should carefully evaluate patients with respiratory diseases.

Like intravascular injection, pneumothorax is uncommon under a well-executed ultrasound-guided block. Extreme care must be adopted when the supraclavicular approach is chosen.

Catastrophic events were described in association with interscalene plexus block, like permanent loss of spinal cord function or total spinal anesthesia [38, 39]. Although these complications happened without ultrasound guidance and under general anesthesia, anesthesiologist must reflect on the opportunity to avoid intra-roots or intrafascicular injection as well as keep the needlepoint under strict vision.

After shoulder arthroscopy, patients may complain of neurological symptoms. It is improbable that they depend directly on a well-executed ultrasound-guided nerve block. In case of persistent paresthesia, dysesthesia, or pain not related to surgery after interscalene block, sulcus ulnaris syndrome, carpal tunnel syndrome, or complex regional pain syndrome should be excluded since specific treatment may be required [40].

Bleeding and Clear Surgical Field

The use of hypotensive anesthesia during orthopedic procedures performed on patients in the supine or decubitus position has been shown to be a safe and effective technique for reducing operative blood losses and helping maintain a clear surgical field [41, 42]. This said, in the beach-chair position, major complications have been reported under the use of hypotensive anesthesia. Pohl and Cullen reported four cases of ischemic brain and spinal cord injury after both open and arthroscopic procedures performed on patients in the sitting position under a hypotensive controlled anesthesia. Although the ideal perfusion pressure varies among patients, there exists a critical cerebral perfusion pressure below which cerebral blood flow will be compromised. Cerebral perfusion pressure is defined as mean arterial pressure less intracranial pressure (5–10 mmHg). When the patient is in the sitting position, there is a significant hydrostatic gradient between the brain and the site of blood pressure measurement, usually the contralateral arm to the surgical site. The difference is approximately 25–30 mmHg. When we measure a mean arterial systemic pressure of 80 mmHg, it could be not enough to guarantee an adequate cerebral perfusion pressure. Deliberate hypotension and errors in blood pressure reference point can be catastrophic [43]. Blood pressure should be maintained stable and near baseline parameters. Only hypertension should be mildly treated obtaining no more than 20 % decrement of preoperative resting values.

Since the 90s, surgeons investigated characteristics of fluid irrigation to augment visualization during shoulder arthroscopy and to prevent intraoperative and postoperative complications. They evaluated the temperature of the irrigation fluid and its influence on core body temperature, the way to administer it, and the possibility of diluting it with some vasoactive agents. The use of warm irrigation fluid during arthroscopic shoulder surgery decreases perioperative hypothermia, especially in elderly patients [44]. Surely, the thermic homeostasis is important to preserve patient's comfort and stability and favor hemostatic mechanisms. Anesthesiologists could contribute to this aim warming saline solutions and using forced air warming. In 2001 Jensen et al. [45] randomized 44 patients that underwent routine arthroscopic shoulder surgery into a prospective, double-blinded, placebo-controlled study to determine whether diluted epinephrine saline irrigation (0.33 mg/L) significantly reduces intraoperative bleeding. A pressure-controlled pump delivered the irrigation fluid. The study also evaluates potential adverse cardiovascular reactions of adding epinephrine to the irrigation fluid. Intraoperatively, intra-articular bleeding was estimated by multiplying the total volume of the irrigation fluid used by the hemoglobin concentration of the irrigation fluid. The clarity of visualization during the procedure was assessed asking the surgeon to quantify it by a visual analogy scale. In the treatment group the intraoperative bleeding was significantly reduced ($P = 0.008$), and the clarity of the visual field was significantly better ($P = 0.0007$) compared to the control group. No cardiovascular adverse events were observed administrating the intra-articular epinephrine.

Postoperative Pain Control

Arthroscopic shoulder surgery performed under general anesthesia is associated with severe postoperative pain requiring large doses of opioids. Nausea, vomiting, sedation, and lack of complete pain control are often associated with intravenous opioids analgesia [46, 47]. The interscalene brachial plexus block offers a valid postoperative analgesia, reducing both the request of rescue medications and consequently side effects. In the single-shot setting, the duration of analgesia is up to 13 h [48]. Addiction of adjuvants to the local anesthetic, like buprenorphine or tramadol, may prolong analgesic time up to more hours [49, 50]. Continuous peripheral nerve blocks provide optimal analgesia, prolong brachial plexus local anesthetic delivery in the outpatient setting, have minimal side effects, and avoid premature regression of an analgesic block. Furthermore, an improvement in patients' health-related quality of life and outcome has been demonstrated [51]. Continuous intra-articular infusion of local anesthetics should be avoided because of the risks of chondrotoxicity. Continuous intra-articular infusion of bupivacaine with or without epinephrine led to significant histopathologic and metabolic changes in articular cartilage [52].

References

1. Peruto CM, Ciccotti MG, Cohen SB. Shoulder arthroscopy positioning: lateral decubitus versus beach chair. Arthroscopy. 2009;25:891–6.
2. Mullins RC, Drez Jr D, Cooper J. Hypoglossal nerve palsy after arthroscopy of the shoulder and open operation with the patient in the beach-chair position. A case report. J Bone Joint Surg. 1992;74A:137–9.
3. Park TS, Kim YS. Neuropraxia of the cutaneous nerve of the cervical plexus after shoulder arthroscopy. Arthroscopy. 2005;21:631.
4. Wilder BL. Hypothesis: the etiology of midcervical quadriplegia after operation with the patient in the sitting position. Neurosurgery. 1982;11:530–1.
5. Murphy GS, Szokol JW, Marymont JH, Greenberg SB, Avram MJ, Vender JS, et al. Cerebral oxygen desaturation events assessed by near-infrared spectroscopy during shoulder arthroscopy in the beach chair and lateral decubitus positions. Anesth Analg. 2010;111:496–505.
6. Bhatti MT, Enneking FK. Visual loss and ophthalmoplegia after shoulder surgery. Anesth Analg. 2003;96:899–902.
7. Pohl A, Cullen DJ. Cerebral ischemia during shoulder surgery in the upright position: a case series. J Clin Anesth. 2005;17:463–9.
8. Bishop JY, Sprague M, Gelber J, Krol M, Rosenblatt MA, Gladstone J, et al. Interscalene regional anesthesia for shoulder surgery. J Bone Joint Surg. 2005;87A:974–9.
9. Gonano G, Kettner SC, Ernstbrunner M, Schebesta K, Chiari A, Marhofer P. Comparison of economic aspects of interscalene brachial plexus blockade and general anesthesia for arthroscopic shoulder surgery. Br J Anaesth. 2009;103:428–33.
10. Liu SS, Gordon MA, Shaw PM, Wilfred S, Shetty T, YaDeau JT. A prospective clinical registry of ultrasound-guided regional anesthesia for ambulatory shoulder surgery. Anesth Analg. 2010;111:617–23.
11. Abrahams MS, Aziz MF, Fu RF, Horn JL. Ultrasound guidance compared with electrical neurostimulation for peripheral nerve block: a systematic review and meta-analysis of randomized controlled trials. Br J Anaesth. 2009;102:408–17.
12. McNaught A, Shastri U, Carmichael N, Awad IT, Columb M, Cheung J, et al. Ultrasound reduces the minimum effective local anesthetic volume compared with peripheral nerve stimulation for interscalene block. Br J Anaesth. 2011;106:124–30.
13. Danelli G, Bonarelli S, Tognú A, Ghisi D, Fanelli A, Biondini S, et al. Prospective randomized comparison of ultrasound-guided and neurostimulation techniques for continuous interscalene brachial plexus block in patients undergoing coracoacromial ligament repair. Br J Anaesth. 2012;108:1006–10.
14. Kapral S, Greher M, Huber G, Willschke H, Kettner S, Kdolsky R, et al. Ultrasonographic guidance improves the success rate of interscalene brachial plexus blockade. Reg Anesth Pain Med. 2008;33:253–8.
15. Gelber PE, Reina F, Caceres E, Monllau JC. A comparison of risk between the lateral decubitus and the beachchair position when establishing an anteroinferior shoulder portal: a cadaveric study. Arthroscopy. 2007;23:522–8.
16. Liguori GA, Kahn RL, Gordon J, Gordon MA, Urban MK. The use of metoprolol and glycopyrrolate to prevent hypotensive/bradycardic events during shoulder arthroscopy in the sitting position under interscalene block. Anesth Analg. 1998;87:1320–5.
17. D'Alessio JG, Weller RS, Rosenblum M. Activation of the Bezold-Jarisch reflex in the sitting position for shoulder arthroscopy using interscalene block. Anesth Analg. 1995;80:1158–62.
18. Sia S, Sarro F, Lepri A, Bartoli M. The effect of exogenous epinephrine on the incidence of hypotensive/bradycardic events during shoulder surgery in the sitting position during interscalene block. Anesth Analg. 2003;97:583–8.
19. Kahn RL, Hargett MJ. Betaadrenergic blockers and vasovagal episodes during shoulder surgery in the sitting position under interscalene block. Anesth Analg. 1999;88:378–81.
20. Turker G, Demirag B, Ozturk C, Uckunkaya N. Cardiac arrest after interscalene brachial plexus block in the sitting position for shoulder arthroscopy: a case report. Acta Orthop Belg. 2004;70:84–6.
21. Song SY, Roh WS. Hypotensive bradycardic events during shoulder arthroscopic surgery under interscalene brachial plexus blocks. Korean J Anesthesiol. 2012;62:209–19.
22. Seo KC, Park JS, Roh WS. Factors contributing to episodes of bradycardia hypotension during shoulder arthroscopic surgery in the sitting position after interscalene block. Korean J Anesthesiol. 2010;58:38–44.
23. Bonica JJ, Akamatsu TJ, Berges PU, Morikawa K, Kennedy Jr WF. Circulatory effects of peridural block. II. Effects of epinephrine. Anesthesiology. 1971;34:514–22.
24. Campagna JA, Carter C. Clinical relevance of the Bezold-Jarisch reflex. Anesthesiology. 2003;98:1250–60.
25. Tea SH, Mansourati J, L'Heveder G, Mabin D, Blanc JJ. New insights into the pathophysiology of carotid sinus syndrome. Circulation. 1996;93:1411–6.
26. Brull R, McCartney CJL, Sawyer RJ, von Schroeder HP. The indications and applications of interscalene brachial plexus block for surgery about the shoulder. Acute Pain. 2004;6:57–77.
27. Ikeda T, Iwase S, Sugiyama Y, Matsukawa T, Mano T, Doi M, et al. Stellate ganglion block is associated with increased tibial nerve muscle sympathetic activity in humans. Anesthesiology. 1996;84:843–50.
28. Feigl G, Fuchs A, Gries M, Hogan QH, Weninger B, Rosmarin W. A supraomohyoidal plexus block designed to avoid complications. Surg Radiol Anat. 2006;28:403–8.
29. Griffioen KJ, Venkatesan P, Huang ZG, Wang X, Bouairi E, Evans C, et al. Fentanyl inhibits GABAergic neurotransmission to cardiac vagal neurons in the nucleus ambiguus. Brain Res. 2004;1007:109–15.
30. Song SY, Son SH, Kim SO, Roh WS. Intravenous fentanyl during shoulder arthroscopic surgery in the sitting position after inter scalene block increases the incidence of episodes of bradycardia hypotension. Korean J Anesthesiol. 2011;60:344–50.
31. Tucker MS, Nielsen KC, Steele SM. Nerve block induction rooms-physical plant setup, monitoring equipment, block cart, and resuscitation cart. Int Anesthesiol Clin. 2005;43:55–68.
32. Selander D, Dhuner KG, Lundborg G. Peripheral nerve injury due to injection needles used for regional anesthesia. An experimental study of the acute effects of needle point trauma. Acta Anesthesiol Scand. 1977;21:182–8.
33. Kesseler J, Gray AT. Sonography of scalene muscles anomalies for brachial plexus block. Reg Anesth Pain Med. 2007;32:172–3.
34. Perlas A, Chan VW, Simons M. Brachial plexus examination and localization using ultrasound and electrical stimulation. Anesthesiology. 2003;99:429–35.
35. Yang WT, Chui PT, Metreweli C. Anatomy of the normal brachial plexus revealed by sonography and the role of sonography guidance in anesthesia of the brachial plexus. Am J Roentgenol. 1998;171:1631–6.
36. Spence BC, Beach ML, Gallagher JD, Sites BD. Ultrasound-guided interscalene blocks: understanding where to inject the local anesthetic. Anesthesia. 2011;66:509–14.
37. Weinberg GL, VadeBoncouer T, Ramaraju GA, Garcia-Amaro MF, Cwik MJ. Pretreatment or resuscitation with a lipid infusion shifts

the dose–response to bupivacaine-induced asystole in rats. Anesthesiology. 1998;88:1071–5.
38. Benumof JL. Permanent loss of cervical spinal cord function associated with interscalene block performed under general anesthesia. Anesthesiology. 2000;93:1541–4.
39. Dutton R, Eckhardt WF, Sunder N. Total spinal anesthesia after interscalene blockade of the brachial plexus. Anesthesiology. 1994;80:939–41.
40. Borgeat A, Ekatodramis G, Kalberer F, Benz C. Acute and nonacute complications associated with interscalene block and shoulder surgery. Anesthesiology. 2001;95:875–80.
41. Thompson GE, Miller RD, Stevens WC, Murray WR. Hypotensive anesthesia for total hip arthroplasty: a study of blood loss and organ function (brain, heart, liver, and kidney). Anesthesiology. 1978;48:91–6.
42. Tuncali B, Karci A, Bacakoglu AK, Tuncali BE, Ekin A. Controlled hypotension and minimal inflation pressure: a new approach for pneumatic tourniquet application in upper limb surgery. Anesth Analg. 2003;97:1529–32.
43. Papadonikolakis A, Wiesler ER, Olympio MA, Poehling GG. Avoiding catastrophic complications of stroke and death related to shoulder surgery in the sitting position. Arthroscopy. 2008;24:481–2.
44. Kim YS, Lee JY, Yang SC, Song JH, Koh HS, Park WK. Comparative study of the influence of room-temperature and warmed fluid irrigation on body temperature in arthroscopic shoulder surgery. Arthroscopy. 2009;25:24–9.
45. Jensen KH, Werther K, Stryger V, Schultz K, Falkenberg B. Arthroscopic shoulder surgery with epinephrine saline irrigation. Arthroscopy. 2001;17:578–81.
46. D'Alessio J, Rosenblum M, Shea K, Freitas D. A retrospective comparison of interscalene block and general anesthesia for ambulatory shoulder surgery. Reg Anesth Pain Med. 1995;20:62–8.
47. Brown AR, Weiss R, Greenberg C, Flatow EL, Bigliani LU. Interscalene block for shoulder surgery: comparison with general anesthesia. Arthroscopy. 1993;9:295–300.
48. Gautier P, Vandepitte C, Ramquet C, DeCoopman M, Xu D, Hadzic A. The minimum effective anesthetic volume of 0.75% ropivacaine in ultrasound-guided interscalene brachial plexus block. Anesth Analg. 2011;113:951–5.
49. Alemanno F, Ghisi D, Fanelli A, Faliva A, Pergolotti B, Bizzarri F, et al. Tramadol and 0.5% levobupivacaine for single-shot interscalene block: effects on postoperative analgesia in patients undergoing shoulder arthroplasty. Minerva Anestesiol. 2012;78:291–6.
50. Behr A, Freo U, Ori C, Westermann B, Alemanno F. Buprenorphine added to levobupivacaine enhances postoperative analgesia of middle interscalene brachial plexus block. J Anesth. 2012;26:746–51.
51. Capdevila X, Ponrouch M, Choquet O. Continuous peripheral nerve blocks in clinical practice. Curr Opin Anaesthesiol. 2008;21:619–23.
52. Gomoll AH, Kang RW, Williams JM, Bach BR, Cole BJ. Chondrolysis after continuous intra-articular bupivacaine infusion: an experimental model investigating chondrotoxicity in the rabbit shoulder. Arthroscopy. 2006;22:813–9.