



Review

# Evolution of Anesthetic Techniques for Shoulder Surgery: A Narrative Review

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**Abstract:** Shoulder surgery has radically evolved within the last 70 years, from a marginal orthopedic sub-specialty to an area of great research and advancement; consequently, anesthetic techniques have undergone important development. In fact, a wide variety of anesthetic strategies have emerged, to provide anesthesia and post-operative analgesia: general anesthesia (GA), regional anesthesia (RA), or combined GA and RA. A literature review on online databases was carried out about the different anesthetic approaches for shoulder surgery and their evolution through the years, taking in consideration papers from 1929 to 2021. A comprehensive preoperative assessment of patients undergoing shoulder surgery allows to identify and modify potential risk factors and complications of general anesthesia. Moreover, the use of ultrasound-guided regional blocks could improve the effectiveness of these techniques and bring better postoperative outcomes. Anesthetic management for shoulder surgery has progressed drastically during the last century. More studies are needed to finally standardize anesthetic techniques for specific procedure.



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## 1. Introduction

Shoulder surgery has radically evolved within the last 70 years, from a less important orthopedic field to an area of great research and progress. Success primarily is based on progress of biomedical technology, considering the well-known complexity of the joint [1].

Although the exact number of total shoulder procedures performed each year is unknown, it is evident that the amount is very relevant [2]; moreover, there is a wide variety of patients who are candidates for shoulder surgery, from the healthy, strong patient affected by sports injury requiring a stabilization procedure, to the weak, aged patients with arthritic complications and trauma [3], who requires joint decompression or arthroplasty [4].

At present, common shoulder surgical procedures include hemiarthroplasty, total shoulder arthroplasty, shoulder arthroscopy, subacromial (SA) decompression and shoulder instability procedures, such as rotator cuff repair and frozen shoulder procedures [5].

With improvements in technology and equipment, arthroscopy has become the main treatment modality for many shoulder disorders; arthroscopy has imposed itself as one of the greatest orthopedic enhancements of the last century [1].

In comparison with open surgery techniques, arthroscopy enables making smaller incisions and is associated with lower risk of deltoid muscle damage, better intra-articular visualization, less postoperative pain and potential quicker recovery from surgery [6].

In the same way, anesthetic techniques have undergone important developments over the past decades.

In fact, a large variety of anesthetic strategies have emerged, to provide anesthesia and post-operative analgesia: general anesthesia (GA), regional anesthesia (RA), or combined GA and RA [7].

Until 70's almost all the operations for shoulder surgery were carried out under general anesthesia. In the second half of the past century, interscalene brachial plexus block (ISB) has been firstly proposed as a different but valid anesthetic technique. In fact, the brachial plexus innervates the shoulder, the arm and the hand; a single injection close to the plexus, considering anatomic landmarks, gives the possibility of a satisfying anesthesia and analgesia for the shoulder [8].

Several techniques have been developed to approach the brachial plexus; from obtaining a paranesthesia below the level of the shoulder, to using a peripheral nerve stimulator to ascertain needle tip location [9], to the most recent ultrasound (US) imaging which allows the identification of the exact location of the brachial plexus and its branches [5].

Moreover, a series of other nerve blocks have been discovered throughout the years, aiming to become more and more selective [8].

Current regional anesthetic techniques permit to effectively control pain after shoulder surgery, to decrease the muscle spasm and to make possible an earlier movement, fasting physiotherapy treatment in the postoperative period, and finally improving both patient recovery and outcome [4].

The aim of this narrative review is to analyze and understand the evolution of different anesthetic techniques for shoulder surgery.

## 2. Methods

A literature review on online databases was carried out, searching for the different anesthetic approaches for shoulder surgery and their evolution through the years. Articles were extracted mainly from PubMed, Google Scholar, MEDLINE, UpToDate, Embase and Web of Science, using the terms 'Shoulder surgery anaesthesia', 'anaesthetic techniques for shoulder surgery', 'regional anaesthesia for shoulder surgery' and 'general anaesthesia for shoulder surgery' as keywords for the research. Searches have been restricted by English language and human studies. Non-English language studies were excluded. Scientific publications were included from 1929 to 2021. Only papers focusing on anesthetic techniques for shoulder surgery and their evolution were included. All reference lists of pertinent studies were then checked to identify any missing publications.

The search and the study selection were realized by two investigators working independently. Incongruities have been identified and resolved through discussion and consensus. Papers selected were then retrieved for full-text review.

## 3. Results

### 3.1. *The Evolution from General Anesthesia (AG) to Regional Anesthesia (RA)*

An initial and complete pre-operative anesthetic evaluation is essential to choose the most suitable anesthetic technique depending on the type of surgery and patients.

Notably, shoulder surgery has been performed under both GA and RA techniques over past and current years [5].

The anesthetic choice depends essentially on several factors: the wishes of the patient, the desires of the surgeon, the skill of the anesthesiologist and patient's characteristics [2], without forgetting surgical factors. In fact, minor surgical procedures can usually be performed using regional anesthesia alone, while a combination of general and regional anesthesia is considered more suitable in the case of longer duration surgery [4].

General anesthesia has always been the most common form of anesthesia [10] and it consists of a reversible state of unconsciousness that allows patients to undergo surgery in a safe way. GA ensures intraoperative amnesia, resulting with a decreased patient awareness and recall [11]. During GA, anesthetic drugs can be continuously administered during surgery. The effects of GA can be easily monitored, thus allowing appropriate changes in depth and duration during procedures [10]. Despite these advantages, however, some

risks and complications need to be considered, especially in older and sicker patients. General anesthesia morbidities go from minor side effects such as nausea and vomiting, to more severe complications with long-term repercussions, such as permanent disability. Cardiovascular and respiratory complications are the most recorded. Myocardial infarction, interference with lung functioning and worsening of pre-existing pathological states can also happen. Other serious side effects include acute renal impairment and the development of long-term postoperative cognitive dysfunction [12]. Minor but also meaningful complications of GA are postoperative nausea and vomiting, sore throat, and dental damage [13]. In addition, it is necessary for the anesthetist to monitor at a more advanced level patient's vital signs and ensure the correct position of an endotracheal device in order to control breathing, since GA suppresses physiological autonomic functions, including cardiac and respiratory responses [14].

Previous authors have noticed that cerebral hypoperfusion is potentiated by inhalational anesthetic drugs used in GA [15], and a clinical trial by Koh et al. proved that cerebral deoxygenation events were substantially more likely with GA rather than RA alone, also due to a particular operating position: the beach-chair position (BCP), often used for shoulder arthroscopy [16]. Moreover, in the awake, upright patient, the sympathetic nervous system is activated with the result of increasing vascular resistance and mean arterial pressure (MAP) in response to a decreased cardiac output. This autonomic response is essential to preserve cerebral perfusion. Under general anesthesia, however, the sympathetic nervous system cannot efficiently face the upright position, which causes a relative decrease in vascular resistance, a reduction in MAP and a greater reduction in cardiac output and cerebral perfusion pressure (CPP) [17]. All these complications can lead to a prolonged hospital stay and costs, due to their high impact on patients.

A comprehensive preoperative assessment of patients undergoing shoulder surgery allows to identify and modify potential risk factors and complications of general anesthesia, with the possibility to use other anesthetic techniques, as RA [13].

During the last years, the regional anesthetic approach to shoulder surgery has revealed some unquestionable strengths compared with general anesthesia, particularly in outpatients and older patients. Application of RA can be traced as early as the late 1800s and its utilization has reported by Strode since 1929 in the treatment of upper extremity fractures [18]. The benefits of RA include: reducing of general anesthesia side effects, decreasing of blood loss [19,20], ensuring an excellent muscle relaxation (necessary for efficient surgery) [8], reducing the impact of anesthetic agents on cardiac and pulmonary function, shortening permanence in the Post-Anesthesia Care Unit (PACU) [21] with rapid recovery, lowering concentrations of analgesic drugs needed to control postoperative pain that can block the rehabilitation after surgery [5], lowering incidence of postoperative nausea and vomiting (PONV), reducing hospital re-admission rates and reducing postoperative opioid analgesics [22] prescriptions.

In this regard, it is reasonable to assume that the goal of the best anesthetic technique is to guarantee the most optimal conditions for patients concerning peri- and post-operative pain control, optimizing surgical conditions and at the same time promoting an early and efficient rehabilitation [8].

On the other hand, regional anesthesia techniques could be associated with potentially serious complications which cannot be underestimated [23]. ISB can compromise an adequate spontaneous ventilation because of the high incidence of ipsilateral hemidiaphragmatic paralysis [24].

It is worth mentioning other ISB complications, which are: Horner's syndrome if stellate ganglion is blockaded, hoarseness if recurrent laryngeal nerve or cervical sympathetic are blockaded, systemic and local anesthetic toxicity, phrenic nerve palsy with hemi-diaphragmatic paresis and nerve injuries [21], quadriplegia, apnea, brainstem and spinal cord toxicity if occurs high epidural, total spinal or subdural injection. In addition, hematoma, pneumothorax, venous air embolism, subcutaneous emphysema and pneumomediastinum [8] could eventually occur. Lastly, it has to be mentioned the possibility of

block failure and the potential for increased pain when the effectiveness of the blocks wears off [5].

It has been speculated that the use of regional anesthesia can add more time to the procedure than general anesthesia, thus also influencing the cost-effectiveness of the technique. In this regard, Brown et al. [14] demonstrate that there is no difference on the average time from the start of administration of anesthetic to the incision among general anesthesia and interscalene block. It is possible to minimize the waiting time through positioning and draping the patient while the block is setting. At the end of the procedure conducted under regional anesthesia, the patient is awake enough to leave the operating room immediately; this does not always happen after general anesthesia, when delays can occur due to slow patient's awakening, slow reversal of neuromuscular blockers, and patient extubating time [8].

### 3.2. The Interscalene Brachial Plexus Block (ISB)

The interscalene brachial plexus block (ISB) is one of the most successfully RA technique, which can provide a complete analgesia for shoulder surgery and can be used as the only anesthetic technique, especially for procedure which interest mainly the deltoid area [5].

In 1925, July Etienne reported the successful blockade of the brachial plexus by inserting a needle halfway between the lateral border of the sternocleidomastoid muscle and the anterior border of the trapezius muscle at the level of the cricothyroid membrane, performing a single injection in the area around the scalene muscles. This approach was most likely the first clinically successful interscalene block technique [9].

The percutaneous technique of palpating and injecting local anesthetic into the groove between the anterior and middle scalene muscles at the level of the cricoid cartilage and the sixth cervical vertebra was reported by Alon Winnie, in 1970. This was an effective, technically simple, and safe way of anesthetizing the brachial plexus. Then, interscalene brachial plexus block become more and more popular [2].

Before the advent of the ultrasound, a modified Winnie's technique has remained the most popular approach to the brachial plexus in the interscalene region [4].

This approach can block the brachial plexus at the level of nerve root or trunk. Local anesthetic is directed toward C5–C6 nerve roots or the superior trunk. Based on the volume of local anesthetic used, C7 and even C8 nerve roots may also be blocked. The block is especially suitable for surgical procedures involving the shoulder, particularly the lateral two-thirds of the clavicle, proximal humerus, and shoulder joint [25].

It is possible to mention other historical approaches to the interscalene brachial plexus block, as the posterior approach of Pippa [26], where the point of needle insertion corresponds to the upper edge of the transverse process of the seventh cervical vertebra, approximately 3 cm lateral to the interspinous line C6 and C7 [25]; the lateral modified technique of Meier, in which the landmarks are the same of Winnie's technique, but the point of needle insertion is displaced by 2–3 cm cranially from the cricoid cartilage. A nerve stimulator can help to place the needle rightly into the interscalene space. Another technique, the modified lateral technique of Borgeat, represent a modification of the classical Winnie's technique [25].

As just mentioned above, the brachial plexus is a quite superficial anatomical structure in the interscalene region, and many techniques can be used to localize it [27]. Anyway, 'blind' nerve blocks that are exclusively based on anatomical landmarks and/or fascia clicks can produce serious complications [28]. For this reason, blind blocks have been almost completely abandoned and most clinicians prefer to use nerve stimulator-guided ISB (NS-ISB) [29], ultrasound-guided ISB (US-ISB) [30–32], or a combination [33] of them in order to determine the correct injection point, with the minimum number of side effects. For a long time, nerve stimulation has been recommended as the gold standard technique for nerve identification in regional anesthesia [27]. Since the introduction of ultrasound, the superiority of this approach over NS-ISB to perform ISB has been discussed. NS-

ISB demonstrated to have a similar effectiveness, chance of success, and postoperative neurological symptoms compared to US-ISB according to experts [34] but on the other hand, NS-IBS is unable to ensure an equal level of nerve block and carries the risk of inflicting damage to nerve structures through direct injection into them.

Over the past few years, US-ISB demonstrates several potential advantages. The evidence of the benefit of the ultrasound in regional anesthesia is growing, especially with a recently updated Cochrane Review, which suggest that it reduces block performance time, improves sensory and motor block and decreases the need for block supplementation [35]. Ultrasound guided block allows the clinician to visualize the plexus at different levels in the neck area, and allows to verify precisely where the needle tip is located and how the local anesthetic distributes around the nerves. Furthermore, ultrasound can prove whether the size or shape of the nerve change during scanning along the path of nerves, and it is also possible to differentiate whether the nerve is normal or pathological by measuring its cross-sectional area. Moreover, the ultrasound is able to identify not only the nerve itself, but also musculoskeletal structures surrounding nerves in the same scanning window, with the possibility of accurately target several desired structures with the same single needle injection [36].

Kapral et al. [37] have demonstrated that the ultrasound-guided interscalene block (ISB) has a faster onset time and longer duration than the block made with nerve-stimulation technique, and it produces surgical anesthesia more reliably when the same volume of local anesthetic is used. McNaught et al. assume that lower volumes of local anesthetic are required for an effective ultrasound-guided nerve block compared with a block obtained with peripheral stimulation [38]. In addition, an ultrasound-guided technique can potentially reduce the number of complications, such as intraneural and intravascular injection [27]; it can also decrease the incidence of hemi-diaphragmatic paresis [39].

Last but not least, a periplexus approach to the ultrasound-guided ISB, with deposition of local anesthetic in the virtual space between middle scalene (MS) muscle and brachial plexus sheath, brings to the same quality of block as the classic intraplexus approach (where the needle tip is located between nerve roots) [40,41], thus reducing the risk of nerve damage [42].

Beyond the technique of nerve stimulation and the ultrasound-guided technique, it is possible to consider a third level of control of peripheral nerve block: the monitoring of opening injection pressure (OIP) [43,44]. It can help to distinguish needle-tip location in the perineural tissue versus the needle-nerve contact or intrafascicular needle placement (i.e., perineural vs. intraneural-intrafascicular). This is possible thanks to a transducer which accurately measures the pressure applied over the syringe to start the injection of local anesthetic. Results from several studies suggest that high-pressure injection (>20 psi) into the intraneural space, even with small volumes, can be a major contributor to mechanical injury of neurological tissue during peripheral nerve blocks. The rationale and basis for nerve damage from high-pressure injection are likely a combination of mechanical injury from breaching the perineurium, leading to interference with endoneural microcirculation, and chemical injury from neurotoxicity of local anesthetics [45].

### 3.3. The Supraclavicular Brachial Plexus Block (SCB)

Supraclavicular block provides the most substantial and efficient anesthesia of all upper extremity when compared to other brachial plexus techniques. The supraclavicular level is an ideal site to achieve anesthesia of the entire upper extremity just distal to the shoulder; at this level the plexus is relatively tightly packed, producing a rapid and high-quality block after the injection of local anesthetic. For this reason, it is often informally known as the “spinal of the arm” [46]. Similar to the interscalene nerve block, this block is carried out between the anterior and middle scalene muscles, but in the immediate supraclavicular area, over the first rib and next to the subclavian artery [5].

Kulenkampf [47] described the first percutaneous supraclavicular brachial plexus block in the early 1900s. However, the popularity of this approach was limited in the

past, due to the risk of pneumothorax, when using landmark-based techniques [48]. The advent of ultrasound has refreshed interest in SBC, allowing real-time visualization of the target tissues and surrounding structures and potentially reducing complications such as pneumothorax, nerve injury and vascular puncture [49].

Peripheral nerve stimulation (PNS) is another way to confirm nerve location. However, studies demonstrate that combining PNS and ultrasound-guided regional anesthesia techniques does not add value to ultrasound guidance alone. Block success is not improved when a motor response is present rather than unobtainable during needle placement for SBC [50].

SBC is frequently performed for elbow, forearm, wrist, and hand surgery and since it is carried out above the clavicle, it can ensure shoulder analgesia and anesthesia. The main problem with using this block for shoulder surgery is that proximal nerves and nerve branches, such as the axillary and the suprascapular nerves, may be missed.

For what concern the ultrasound-guided supraclavicular block, it is important targeting the inferio-medial area of the brachial plexus, lateral to the subclavian artery and superior to the first rib; this area is commonly known as the 'corner pocket' [51].

Furthermore, the supraclavicular brachial plexus block has potentially less anatomic risk for neurological injury and less risk of phrenic nerve paresis compared to ISB (67% [46] for SCB vs. almost 100% for ISB), because it is performed at a more distal site.

#### 3.4. *The Suprascapular Nerve Block (SSNB) +/- the Axillary Nerve Block*

Although it was first described in 1941 by Wertheim and Rovenstine [52], there has been renewed interest in the suprascapular nerve block (SSNB) for analgesia of the shoulder. Most of the shoulder innervation is guaranteed by the suprascapular and axillary nerves. The suprascapular nerve provides 70% of the sensory input to the glenohumeral joint and innervates the infraspinatus and supraspinatus muscles [53]. The axillary nerve supplies the motor innervation to the deltoid muscle, the skin over the shoulder and part of the glenohumeral joint [54].

When these nerves are blocked separately, there may be fewer complications and side effects if compared to the traditional interscalene block [55,56].

Karatas and Meray [57] have reported that nerve blocks close to the nerve with electromyography (EMG) guidance is more effective than blind injection in the suprascapular fossa. Thus, techniques that target the nerve more selectively are potentially advantageous [58].

Only in 2007 was described for the first time through a case-report, the visualization of the suprascapular nerve with ultrasound and real-time guidance of the injection [59].

The most common complication of SSNB is a transient nerve palsy [23] but it is essential to underline that the phrenic nerve is never blocked; therefore, these blocks may be used for patients that are not perfect candidates for an interscalene block; for example, patients with severe chronic obstructive pulmonary disease, bronchial asthma, restrictive lung disease, contralateral phrenic nerve palsy or high body mass index [60].

The suprascapular nerve block combined with an axillary nerve block may provide an effective alternative to the interscalene nerve block for shoulder anesthesia [61] and this technique may also be used as a rescue block for unsuccessful interscalene blocks.

## 4. Discussion

In the recent years, shoulder surgery has become one of the most performed orthopedic procedure [62]. In the fast-track surgery era, the never-ending evolution of surgical and anesthetic techniques has allowed to drastically reduce the complications and improve the outcomes in most of the patients.

Anyway, there is still lack of clarity on what should be the best "anaesthetic standard" for shoulder procedures; in fact, the technique applied is strongly dependent on the hospital standards of care and the anesthetist's preferences. The definition of a "gold standard", also depending on the specific procedure and on the patient, universally approved, and focused

on regional anesthesia techniques, will surely harmonize the standards and outcomes between different centers.

In this narrative review we have analyzed the different anesthetic approaches proposed for this kind of surgery, from the first brachial plexus block performed with anatomic landmarks, to general anesthesia, to modern more selective and peripheral nerve blocks, now possible thanks to the advent of the US guidance and more accurate human anatomy knowledge. A summary of the principal studies regarding anesthetic techniques for shoulder surgery is showed in Table S1.

Surely, the less and less invasiveness of modern surgery and anesthesiology practice has permitted to reach important outcomes that were once not possible. The advent of regional anesthesia, applied alone or associated to GA, to perform shoulder surgery, has permitted to greatly reduce systemic drugs dosage, especially of strong painkillers such as opiates, which have well known adverse effects.

Even if also brachial plexus anesthetic techniques have some possible adverse effects, according to Yuan JM et al. [63], thanks to the US guidance is possible to injectate the LA in the very proximity of the nerves, reducing drastically the dosage and volume of drug used, and limiting the incidence of phrenic nerve paralysis. Anyway, as stated by Abrahams and colleagues in their review [64], larger studies are needed to understand to what extent the US diminish the incidence of complications when compared to ENS alone.

Surely, adding the ENS and the OIP controls to the US imaging, makes possible to further reduce approximately to zero the eventuality of nerve damage [44,65].

The possibility to totally avoid general anesthesia, and consequently extremely limiting the impact on body homeostasis, has allowed to perform shoulder orthopedic procedures also in the elderly or in people with multiple cardiac and respiratory morbidities. Moreover, diminishing the days of hospitalization, has reduced to minimum the risk of postoperative complication, such as hospital pneumonia, which could be devastating especially in older patients. In fact, according to the recent review written by Corcoran et al. [66], choosing regional anesthesia in the elderly guarantee faster recovery and lower incidence of side effects.

Thanks to the US, finally, is now possible to anteriorly approach the suprascapular and the axillary nerves and complete the anesthesia of the surgical area, even in patients with contraindication to the ISB [67]. This US approach is more than useful in all the respiratory patients who would suffer badly from an accidentally paralysis of the phrenic nerve during an ISB. Anyway, it is important to say that execution of these more advanced blocks is not always easy, and required high level of experience and training, especially when compared to the easier ISB. Moreover, according to Dhir Shalini et al., SSNB combined with axillary block provides better pain relief at 24 h, but lower analgesia in the immediate postoperative period when compared to ISB [68].

However, this review has some limitations. Firstly, the studies taken in consideration were heterogenic and regarded different types of surgical approaches, from arthroscopic tendon repair to open prosthesis implantation. Secondly, also the patients were different in age and comorbidities. Lastly, different purpose of the studies could have made the global analysis difficult.

Surely, larger studies focused on standardize anesthetic management in shoulder surgery are needed, giving priority to limit invasiveness and impact on patient homeostasis, to minimize complications and hospitalization length.

## 5. Conclusions

Anesthetic management for shoulder surgery has progressed drastically during the last century. The evolution of the techniques and technologies has permitted to reduce anesthetic and surgical impact on the patients, reducing complications and drugs consumption. More studies are needed to finally standardize anesthetic technique for specific procedure.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/osteology2010006/s1>, Table S1: Summary of the principal studies regarding anesthetic techniques for shoulder surgery.

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