Visualization and Anesthesia in Shoulder Arthroscopy: How to Overcome Bleeding and Poor Exposure

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5.1 Introduction

The evolution of surgical techniques for the treatment of shoulder injuries has made significant progress with the development of arthroscopic techniques. This evolution is supported by improvements in materials and expanding surgeons' experience, which results in an increasing number of indications for arthroscopy for both diagnostic and therapeutic purposes.

A correct performance of a shoulder arthroscopy requires an appropriate visualization using a variety of technical equipment. Among the many factors that can negatively impact the quality of the arthroscopic surgery, poor visualization due to swelling and bleeding is probably the most common avoidable cause. Shoulder arthroscopy, more than arthroscopy of any other joint, requires active measures for control of bleeding to enhance visualization.

During a shoulder arthroscopy, particularly procedures involving the subacromial space, bleeding is a frequent complication that limits the surgeon's field of view and affects the operative technique. Additionally, the duration of surgery can be greatly increased as a result of such a complication.

Visual clarity is essential to perform a safe and successful arthroscopic procedure [1]. The mixing of blood with the irrigation fluid during arthroscopic procedures is the most common factor influencing visual clarity.

The use of specific equipment such as thermal electrocautery devices and pressurized irrigation systems to control bleeding has shown a positive effect on visual clarity. Some studies have found that the use of epinephrine reduces bleeding and increases visual clarity.

In this chapter we describe some general essential parameters for shoulder arthroscopy to avoid obscured visualization and decrease the problem of bleeding. We divide these factors in four sections:

1. Technical equipment
2. Patient positioning
3. Surgical technique
4. Management of anesthesia

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5.2 State-of-the-Art Treatment

5.2.1 Technical Equipment

5.2.1.1 Fluid Management

We recommend the following issues for fluid management:

- Saline bag. The addition of epinephrine (0.33 mg/L) to the irrigation fluid significantly improves visual clarity in the most common types of therapeutic shoulder arthroscopy. A significant reduction in total operating time and use of irrigation fluid was observed [2, 3].
- Inflow tubing systems.
- A specialized automated pump (so-called dual-wave pump, controlling both inflow and outflow) [4, 5].
- Outflow tubing with or without pressure-sensing feedback to an automated pump.

Pump systems used for arthroscopic surgery have evolved over the years to provide improved intraoperative visualization [6].

Advantages of mechanical fluid irrigation system over gravity irrigation are:

- Consistent flow
- Greater and more reproducible degree of joint distention
- Improved visualization, especially when motorized operative instruments are used
- A tamponade effect on bleeding
- Decreased operative time

Disadvantages include the need for additional equipment with increased cost and maintenance, initial learning curve for the surgical team, and possible extraarticular fluid dissection leading to soft tissue swelling [7].

Although significant advances have been made in arthroscopic equipment, few investigations exist that compare different pump systems. Even though improvements in visualization have been noted with dual systems, more research is necessary to determine the exact clinical significance.

5.2.1.2 Radiofrequency Devices

Bleeding from smaller vessels during arthroscopic procedures of the shoulder joint is often unavoidable, especially while working in extra-articular (e.g., subacromial) space and in case of inflammatory tissue reaction. The use of thermal coagulation electrode (radiofrequency devices) devices is indispensable because it enables direct coagulation of bleeding vessels and tissue dissection with concomitant vessel ablation.

Most reconstructive arthroscopic procedures such as a rotator cuff repair (especially complex tears) are only possible using these thermal devices.

Several highly effective systems are available and offered as single-use devices by the industry. We recommend the following parameters:

- Bipolar electrode using rather low temperatures at the tip of the probe inside the shoulder (<65°)
- Plasma layer creating probe
- Slow profile probe with ablation angle of 90° related to instrument shaft
- Highly effective outflow tubing to evacuate air/gas bubbles
- Metal proximity detection feature to avoid damage to scope or other instruments
- Foot switch control

5.3 Patient Positioning

Any successful surgical procedure begins with correct positioning of the patient. In shoulder arthroscopy, two different options of patient positioning exist (Figs. 5.1 and 5.2):

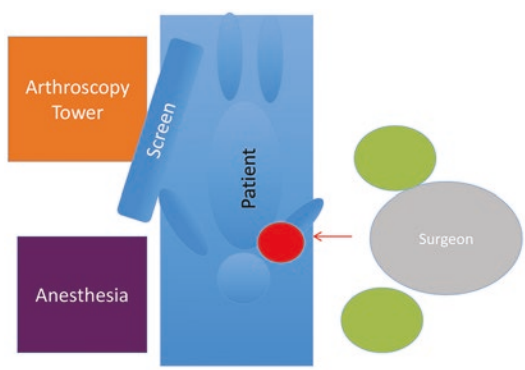

Fig. 5.1 Operation theater setup for shoulder arthroscopy: the arthroscopy tower and the screen are set up at the opposite side of the patient, facilitating access to the shoulder from a posterior, lateral, and anterior direction and leaving working space for the surgeon and assistants

Fig. 5.2 Operation theater setup for lateral decubitus position

– Lateral decubitus position
– The beach chair position

Whether one or the other is chosen is usually based on the surgeon's preference or in many centers a question related to the specific procedure, because each positioning offers specific advantages and disadvantages.

Special equipments such as positioning devices including arm holders are required for both types of positioning (Figs. 5.3, 5.4, 5.5, and 5.6).

Beach chair positioning is associated with the danger of cerebral oxygen desaturation and potential neurological complications. This is why regional cerebral oximetry should be utilized during shoulder arthroscopy in this position. In terms of potential neurological injury, the lateral decubitus position seems to be a safer option because cerebral blood flow is not compromised by the upright position of the head under general anesthesia (see also below).

However, in our experience, the majority of arthroscopic procedures are facilitated by the use of the beach chair position, including posterosuperior (supra- and infraspinatus) and anterior (subscapularis) tendon repairs. More complex extra-articular procedures such as the arthroscopic Latarjet procedure or plexus release require extensive anterior extra-articular shoulder dissection and access to the medial anterior shoulder, which is much easier to achieve in the beach chair position.

Fig. 5.3 Arthroscopy tower including video chain, automated pump, and radiofrequency console

The exact way to position the arm in the beach chair position is crucial to have adequate access to the subacromial space, e.g., during cuff repair.

Fig. 5.4 Dual-wave pump, specifically suitable for shoulder arthroscopy. These pumps control both in- and outflow, thus minimizing turbulent flow

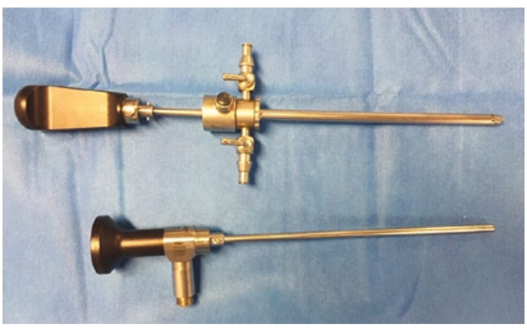

Fig. 5.5 High-flow arthroscopy shaft

We recommend putting the shoulder into a slight forward flexion (approximately 20°) and slight abduction while simultaneously applying slight (1–2 kg) traction of the upper arm parallel to the thorax. This will allow the subacromial space to open up and slightly move the humeral head backward and away from the narrow anterior part of the subacromial space. Usually, this allows excellent and wide access to the humeral and cuff

Fig. 5.6 Bipolar radiofrequency device (ArthroCare®)

Fig. 5.7 (Left) Wrong position of the arm in the beach chair. (Right) Correct position of the arm in slight flexion and abduction, which leads to subacromial opening and improved joint access

(Fig. 5.7). Moreover, in the beach chair position, rotational maneuvers of the arm can be made to facilitate access and entrance for implants and instruments using different portals.

The lateral decubitus position (Fig. 5.8) allows for excellent visualization for intra-articular glenohumeral reconstruction such as instability repair. The use of double arm traction both distalizes and lateralizes the humeral space giving easier access to the inferior and posterior part of the labrum and capsule during instability repair. It seems that this is a reason why the lateral decubitus positioning is related to lower recurrence rates after arthroscopic Bankart repair than beach chair positioning.

Fig. 5.8 Double arm traction for lateral decubitus position

5.4 Surgical Technique

A careful surgical arthroscopic technique is another decisive factor to improve visualization during the procedure.

A very important principle is to minimize outflow of the irrigation fluid from the portals. This can be achieved by cannula placement or simply the assistant closing the portals with the fingers, thus eliminating outflow. Uncontrolled outflow will lead to turbulent flow inside the shoulder (Bernoulli effect), which opens small lacerated arterial vessels [8]. This will lead to bleeding and obscured vision.

We do not routinely place cannulas in each portal, so we often have several potential foci for the Bernoulli effect, which leads to its accompanying clouding of the arthroscopic field. We routinely have our surgical technician apply digital pressure over each of the non-cannulated portals, plugging the stream at each site. This simple maneuver (Fig. 5.9) can dramatically improve visualization, leaving the surgeon free to proceed with his operation instead of needlessly wasting valuable time "chasing bleeders" and uttering epithets. Recognizing and neutralizing the Bernoulli effect (Fig. 5.10) have helped us immensely to perform demanding subacromial techniques such as the repair of large and massive rotator cuff tears more rapidly and efficiently (Fig. 5.11).

We recommend some general arthroscopic principles in surgical technique:

- Reduce blood pressure if medical condition allows, to maintain systolic pressure of less than 90 mmHg (see below in detail).
- Incise the skin only and avoid deeper muscle laceration.
- Use a blunted conical trocar for penetration of the muscle, joint, and subacromial space.
- Avoid debridement of anterior medial acromion and the undersurface of the AC joint for as long as possible.
- Direct control of bleeding points by:
  - Thermal electrocautery devices (both monopolar and bipolar). Use them immediately when significant bleeders are encountered.
  - Locally infused vasoconstrictors (addition of epinephrine to the arthroscopy irrigation fluid).
- Indirect control of bleeding by:
  - Minimizing the fluid pressure differential between the patient's blood pressure and the pressure of the infused irrigation fluid [9]. This is done by a combination of lowering the patient's blood pressure if possible (hypotensive anesthesia; see below) and raising the pressure of the irrigation fluid.
  - The relation between subacromial pressure, blood pressure, and visual clarity during arthroscopic subacromial decompression was studied by Morrison et al. [7]. They concluded that a pressure of 49 mmHg is sufficient to prevent bleeding during surgery. In our experience, using a pump pressure between 40 and 45 mmHg, positioning the patient in the deckchair position, and using a saline/epinephrine solution, combined with sound knowledge of the vascular anatomy of the subacromial space, are sufficient to perform most interventions without difficulties. In the event of cumbersome bleeding, transient increase in the pump pressure may be necessary to identify and cauterize the offending vessels.

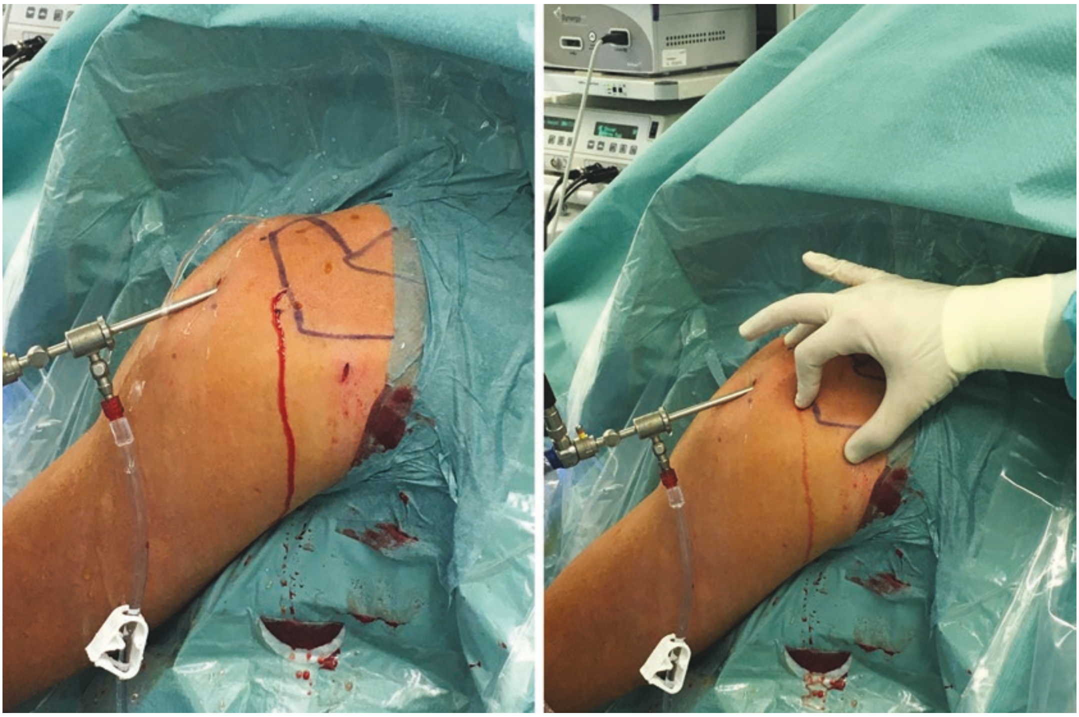

Fig. 5.9 (Left) Outflow of irrigation fluid leading to turbulent flow and bleeding (Bernoulli effect). By closing the portals with the fingers of the assistant (right), this can easily be avoided

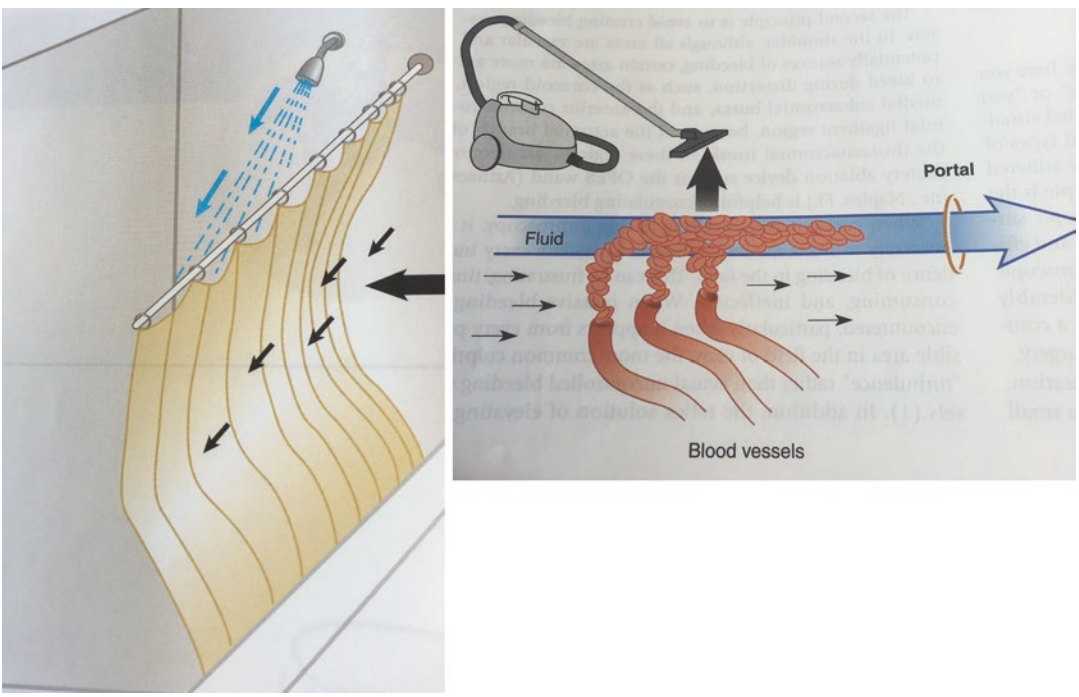

Fig. 5.10 Bernoulli effect: the uncontrolled outflow of fluid leading to turbulent flow will “suck” out the blood from small vessels and obscure the field (right)

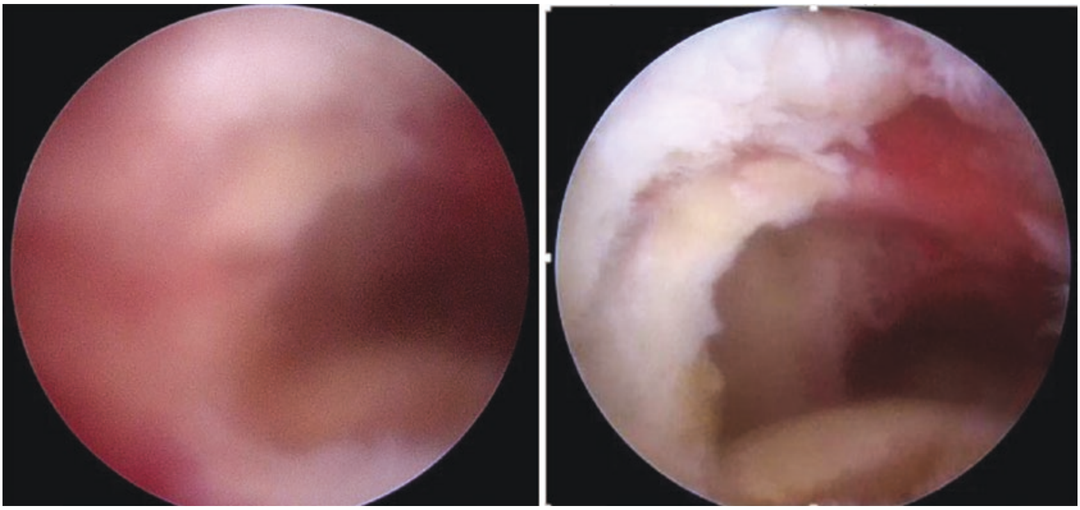

Fig. 5.11 (Left) Obscured vision during arthroscopic rotator cuff repair by turbulent flow. By closing the portals and eliminating outflow (right), the vision becomes clear

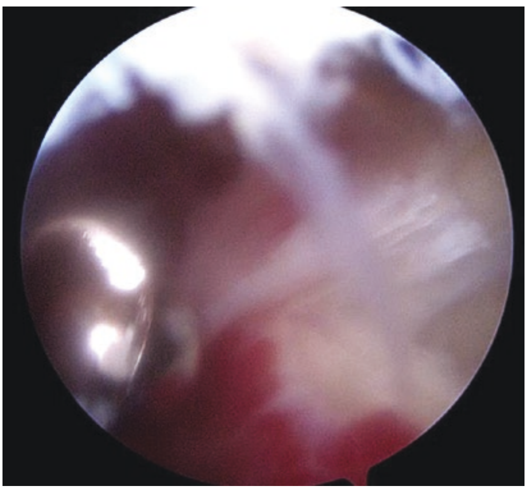

Fig. 5.12 Foresightful dissection: in inflammatory tissue, careful and slow preparation with a minimum of shaving is helpful

- Foresightful dissection technique [10]: depending on the case, careful and slow preparation of the tissue is mandatory. For example, it is clear that in case of highly inflammatory tissue reactions (bursitis, capsulitis), aggressive shaving of the tissue will lead to more bleeding and problems than in uninflamed tissues (Fig. 5.12). So in these cases, dissection with the radiofrequency (RF) probe is recommended. It is important to anticipate the risk of bleeding during tissue dissection and adapt the technique to the anatomic area and the degree of inflammation.

5.5 Anesthesia

Over the last few years, arthroscopic shoulder surgery has been increasingly performed by surgeons in a sitting position, thereby creating new challenges for anesthesiologists [11].

On the one hand, the surgeon's legitimate wish is for good visual conditions and thus low blood pressure. On the other hand, the anesthetist has to be aware of the redistribution of the blood volume due to gravity resulting from general anesthesia. This takes place at the normal measuring points of blood pressure measurement (NIBP) at the upper arm, which can therefore no longer be considered accurate.

The brain is a very ischemic-intolerant organ and particularly threatened by cerebral hypoperfusion. There are findings in literature of rare cases of cerebral damage, with partially fatal outcome because of permissive hypotonia and cerebral hypoperfusion [12].

Thus, we have developed so-called standard operating procedures (SOP) for shoulder arthroscopy, which enable safe and controlled hypotonic blood pressure values.

In a sitting position, an average vertical distance from the upper arm blood pressure cuff (NIBP) to the auditory canal or cranial base is 30–35 cm, resulting in a pressure difference of 20–25 mmHg. This difference will have to be subtracted from the measured NIBP values (Fig. 5.13).

It should be noted that the hydrostatic pressure gradient and a normally safe lower limit of 60 mmHg pressure (MAD) could lead to cerebral desaturation, while the conventional oxygen saturation (SaO_2) still denotes normal values at the finger clip [13].

The anesthesia often commences intravenously with propofol, opiate, and muscle relaxant, and then the patient is intubated and placed in an upright position.

A high incidence of 70–80% hypotonia below the known safe limits can be observed.

It has been shown that the hypnotics, such as propofol or sevoflurane alone, influence the redistribution phenomenon in a dose-dependent manner: in higher doses the usage of propofol has a characteristic "on-off effect" and may lead to increased awareness. At low doses, however, and used in combination with inhalational anesthetics, this characteristic is absent (Figs. 5.14 and 5.15).

Therefore, anesthesia continuation after introduction should be done with sevoflurane, which is associated with significantly less cerebral desaturation. Low doses of inhaled anesthetics disrupt cerebral autoregulation to a lesser extent [14].

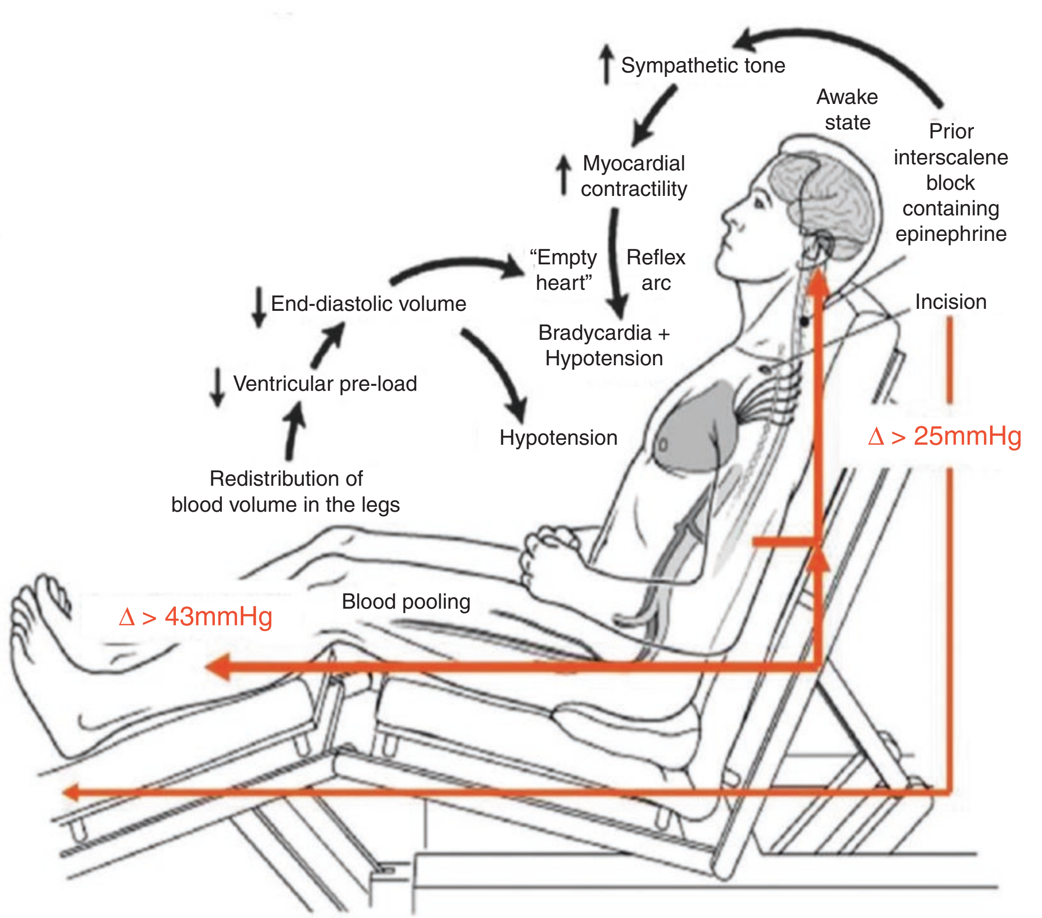

Fig. 5.13 Hydrostatic pressure difference (RR cuff at upper arm to cranial base) of 20–25 mmHg (30 cm H_2O = 22 mmHg) should be noted

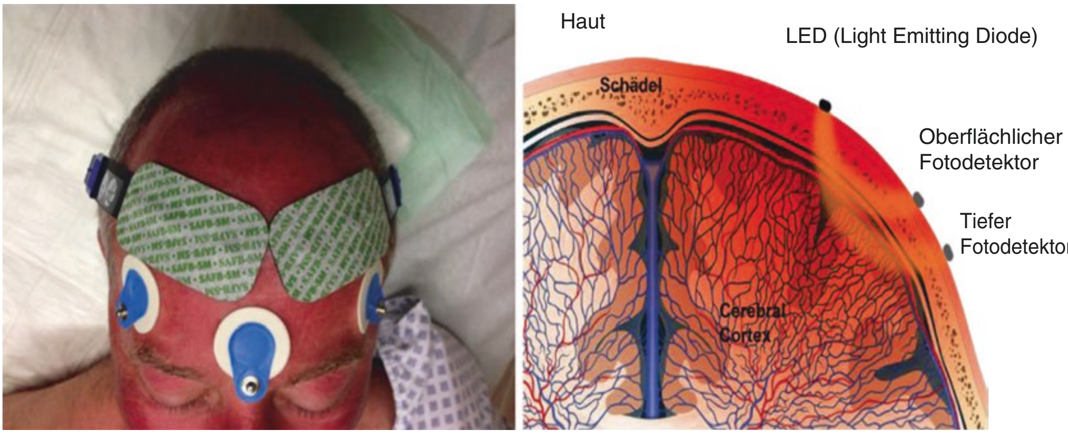

Fig. 5.14 Regulation of cerebral blood flow (CBF) as a function of inhalation anesthetics in different doses. In high doses, the autoregulation is abolished, and the CBF passively follows the perfusion pressure

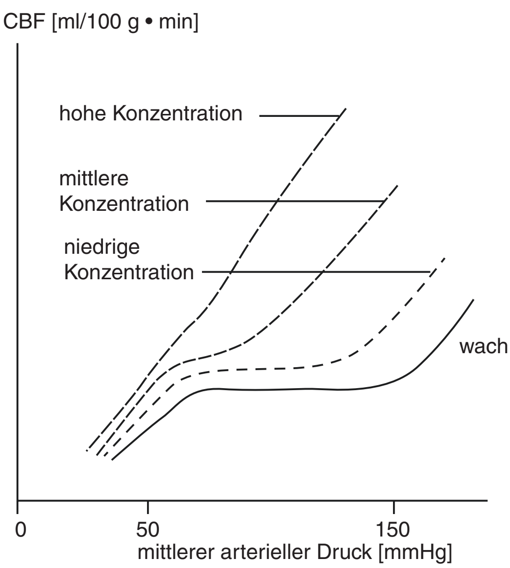

Fig. 5.15 Influence of MAP, CO_2, and O_2 on cerebral blood flow (CBF)

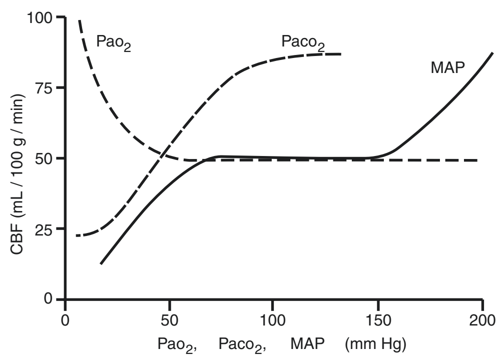

Fig. 5.16 Measurement of cerebral brain oxygenation (NIRS). (Left) *NIRS and Narcotrend electrodes*. (Right) NIRS function scheme

A moderate hypercapnia during ventilation denotes a notable effect and leads to a vasodilation with increase of the intracerebral blood volume and higher $rcSO_2$ values (regional cerebral oxygen saturation). Never hyperventilate with subsequent hypocapnia and cerebral hypoperfusion [15].

The cerebral blood flow (CBF) is affected by MAP, CO_2, and O_2. $rcSO_2$ using NIRS (near-infrared spectroscopy; Fig. 5.16) [16]. It should be measured before induction of the general anesthesia with the patient in sitting position which yields a baseline for each individual patient. Further the $rcSO_2$ should be continuously monitored throughout the whole surgical case so that critical drops of the saturation below the baseline can be early recognized and counteracted.

A so-called controlled hypotension (goal MAP of 60 mmHg) should be attained by utilizing all these measurements with adequate brain oxygen saturation being secured ($rcSO_2$ measurements) throughout the case (Fig. 5.17).

Fig. 5.17 Example of "ideal" conditions for shoulder arthroscopy using the setup mentioned in the text: systolic arterial pressure is very low; however NIRS indicated sufficient brain oxygenation at the same time

Checkbox with recommendations for anesthesia for shoulder arthroscopy:

Preop
Always regional anesthesia (interscalene block or catheter), decreasing pain and sympathotonus during the surgery [17]
Infusion bolus of approx. 500 mL crystalloids (electrolyte solution)
Sympathomimetics during anesthesia initiation (Akrinor® or ephedrine)
Antithrombosis prophylaxis with NMH the previous evening

Intra-op
If necessary sympathicomimetics during anesthesia
Always *low inhalational anesthesia* (*sevoflurane*) with end-tidal ca. 0.7% (age appropriate)
Moderately high end-expiratory CO_2 (EtCO_2) of 40–50 mmHg
Ventilation with 100% O_2
Cerebral oxygen saturation monitoring (NIRS)
NIBP interval 3 min for higher continuity, instead of arterial cannula

It has been shown that the consequent application of this neuroprotective procedure results in high safety as well as low hypotonic blood pressure.

5.6 Take-Home Message

Poor visualization continues to be a frustrating aspect in the field of arthroscopic shoulder surgery.

In this chapter we offer a concept (surgical equipment, patient positioning, surgical technique, anesthesia), which in our hands has tremendously helped to improve visualization by the decrease of intraoperative bleeding.

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