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Improving visualization in shoulder arthroscopy

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Arthroscopic shoulder procedures are one of the most common procedures used to restore function through minimally invasive techniques. With the demand for shoulder arthroscopic procedures comes the need for safe, effective, and efficient surgery that maximizes patient outcomes while minimizing complications. Many variables contribute to visualization in shoulder arthroscopy including vascular anatomy, blood pressure control, arthroscopic pump systems, turbulence control, epinephrine, and tranexamic acid. Furthermore, patient positioning can have a dramatic effect on visualization with both the beach chair position and lateral decubitus positioning having various strengths and weaknesses depending on the intended procedure being performed. The purpose of this review is to examine the benefits and complications reported in the literature for improving visualization in shoulder arthroscopy.

Keywords: Shoulder; Arthroscopy; Visualization; Surgery; Review

INTRODUCTION

Arthroscopic shoulder procedures are one of the most common procedures used to restore function through minimally invasive techniques. The 2006 National Survey of Ambulatory Surgery estimated that 529,689 rotator cuff repairs and shoulder arthroscopic procedures were performed that year [1,2]. A more recent study examined this number by geographic location and determined the rates of shoulder arthroscopy and arthroscopic rotator cuff repair to be 64.96– 623.6 per 100,000 persons [2]. With the demand for shoulder arthroscopic procedures comes the need for safe, effective, and efficient surgery that maximizes patient outcomes while minimizing complications.

Visualization in shoulder arthroscopy is crucial to efficiency, effectiveness, and safe surgery. Poor visualization can lead to surgeon frustration and unintended complications. Increased operative time can lead to a larger amount of fluid extravasation, neck swelling, chest-wall swelling, and respiratory distress [3]. Many variables contribute to visualization quality during shoulder arthroscopy including vascular anatomy, patient positioning, blood-pressure control, arthroscopic pump systems, turbulence control, epinephrine (EPI), and tranexamic acid (TXA). In particular, patient positioning, including the beach chair position (BCP) and lateral decubitus position (LDP), can have a dramatic effect on visualization, and the positions have various strengths and weaknesses depending on the procedure being performed [4].

Visualization is hard to define but encompasses the clarity necessary during surgery to perform the procedure in a safe, effective manner. Historically, most studies utilized a subjective visualization scoring, but recent efforts have aimed to establish an objective measurement tool to assess visual clarity during shoulder arthroscopy. The visual analog scale, graded 0–10, and the Shoulder Arthroscopy Grading Scale, graded 1–4, have been proposed as objective tools, with one study noting strong-to-ex-

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cellent interobserver reliability [5]. The purpose of this review is to examine the benefits and complications reported in the literature for improving visualization in shoulder arthroscopy.

ANATOMY

Knowledge of normal and abnormal shoulder anatomy is critical when performing arthroscopic shoulder surgery. Understanding the reported vascular anatomy in the shoulder allows the surgeon to avoid potential bleeding and improve visualization during shoulder arthroscopy [6]. Anatomical understanding is also paramount in portal placement to avoid iatrogenic injury. The posterior viewing portal is often established on the posterolateral corner of the acromion in the raphe of the infraspinatus and may vary according to patient size, positioning, and intended procedure [7,8]. Structures at risk in posterior portal placement include the infraspinatus and teres minor muscles, suprascapular artery, and axillary and suprascapular nerves [9]. A standard anterior rotator interval portal is commonly used and is typically established using needle localization just lateral to the coracoid process and is created under direct visualization [8]. Cadaveric dissection of standard shoulder arthroscopic portals revealed that the most at risk structure in anterior portal placement is the cephalic vein; while still at risk, the axillary artery and nerve are further away [9].

Yepes et al. [6] performed a cadaveric study to identify the arteries in the subacromial space as well as their corresponding landmarks. They examined the vascular patterns through the use of gross inspection, angiograms, and photographs. The authors found a constant vascularity pattern in 60% of the shoulders. They found that heavy bleeding can be expected if the coracoacromial ligament is transected and the inferior deltoid fascia is exposed, injuring the acromial branch of the thoracoacromial artery. During arthroscopic distal clavicle resection, Yepes et al. [6] suggest avoiding capsular damage to prevent bleeding from the anterior and posterior vessels of the acromioclavicular joint. Light bleeding may be expected from the coracoacromial arterioles during acromioplasty and rarely presents a major issue. They also found that the suprascapular artery runs over the neck of the glenoid and is at risk of injury when instrumentation advanced beyond 20 mm from the glenoid rim [6]. Understanding these vascular areas of the subacromial space can help a surgeon minimize bleeding and improve visualization during arthroscopic shoulder surgery.

POSITIONING

Patient positioning during shoulder arthroscopy can affect visualization. Both BCP and LDP are commonly used in shoulder arthroscopy and are often chosen based on a combination of factors including surgeon and comfort level and type of surgery being performed. Each position has advantages regarding pathology and visualization. For example, the authors utilize the LDP position for cases with shoulder instability but prefer BCP for rotator-cuff pathology. The current authors prefer LDP for cases of stability and BCP for rotator cuff, biceps, and subacromial pathology.

The BCP is commonly used due to its standard anatomic relationship and ease of access to the patient's airway [4]. Another reported benefit of this position is that it allows easier visualization for rotator cuff repairs and open surgical procedures due to its more anatomic orientation. Proponents of this position claim that BCP affords easier portal placement due to better palpation of external anatomic landmarks, and they report no difficulty with visualization of the glenohumeral or subacromial spaces [10]. The BCP also allows manipulation of the arm in various directions to improve visualization of the intended structure. For example, forward flexion can aid in posterior portal placement while internal and external rotation can aid in visualizing the respective posterior and anterior aspects of the shoulder from a posterior viewing portal. This position also allows for easy conversion to an open procedure if required, without additional repositioning or instrumentation.

BCP setup uses an operating-room table in conjunction with a padded articulating headrest. Additionally, there are several commercially available seated positioners. Once in the seated position, the contralateral arm of the patient is placed in an arm holder or tucked and padded to protect the ulnar nerve as well as the common peroneal nerve in the lower extremities. The hips are typically flexed to 45°–60° with the knees flexed to 30° to relieve tension on the sciatic nerve. A mechanical arm holder can be used to hold the operative extremity and typically does not involve traction [4,10-12]. It is crucial that the head remain neutral with regard to extension and rotation to maintain vertebral artery blood flow [4,12].

Potential complications of the BCP include cerebral hypoperfusion and ischemia, cerebral desaturation events, stroke, vision loss, nerve injury, and even death [4,12-14]. These complications are commonly seen during the initial positioning and can be minimized through more gradual movement from a supine to seated position [8]. There is no reported increased risk of mortality for this position [14]. A systolic blood pressure > 90 mmHg and the maximum reduction of both systolic blood pressure and mean arterial pressure within < 20% of baseline is typically recommended for BCP to decrease the incidence of cerebral hy-

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poperfusion while maximizing visualization [12,13].

LDP offers improved visualization and access to the inferior glenoid with less risk of cerebral hypoperfusion and cerebral desaturation events [12,13]. This is the favored position of some surgeons to address cases with instability because of the glenoid access it permits and the ability to manipulate the humeral head out of the surgical field. Increased axial traction of the arm can aid in instability procedures by increasing the distance between the glenoid and humerus. Surgeons that favor the LDP argue that there is increased visualization of the glenohumeral joint, and that the surgeon can operate with the patient's arms at their side as opposed to the abducted BCP position. Positioning the glenoid parallel to the floor affords an anatomic reference point for orientation, and electrocautery bubbles escape laterally, out of the field of view, improving visualization [15].

Contrary to BCP, LDP can be performed with most operating-room tables with the addition of a beanbag or rigid post configuration. The peroneal nerve is carefully padded, and an axillary roll is used to prevent nerve-related complications. The surgical extremity is placed into traction with the use of a sling and weights. The amount of weight needed for appropriate visualization should be carefully considered to avoid a neurovascular traction injury. The balanced traction devices vary from pulley systems to pneumatic or mechanical devices [12,15].

Disadvantages of the LDP include neurovascular injuries related to portal placement and traction on peripheral nerves and the brachial plexus, the potential need for general endotracheal anesthesia, the possible need to re-prep and drape the patient should a conversion to an open procedure be necessary, and the need to reach around the patient for the anterior portal [4,10,15]. In their systematic review, Memon et al. [3] found that fluid extravasation is more prevalent in the LDP.

BLOOD PRESSURE CONTROL

Blood pressure control remains a concern in shoulder arthroscopy. These concerns are more often associated with BCP as it has been associated with neurologic complications, stroke, and death [8,12,16]. There remains controversy regarding the parameters for controlled hypotension to avoid cerebral hypoperfusion. Anesthesia literature currently cites that a reduction in systolic blood pressure to no lower than 90 mmHg is adequate for cerebral perfusion [17]. Papadonikolakis et al. [18] suggest that blood pressure be carefully monitored at the heart level. The pressure gradient between the calf and heart blood pressure readings proved to be high, and reliance on calf blood pressure can result in an overaggressive decrease in blood pressure.

Studies have been performed to evaluate the effect of permissive hypotension in shoulder arthroscopy. Through accurate hypodynamic monitoring, the literature notes that patients may be able to tolerate a reduction in blood pressure in a safe and controlled manner without neurologic injury [16-18]. This permissive hypotension can be maintained through a combination of BCP, interscalene block, inhaled anesthetics, and IV medication to include beta-blockers [17]. Interscalene brachial plexus block (ISBPB) is effective in providing anesthesia for shoulder procedures, including arthroplasty and fracture work, with excellent results. The block has been shown to reduce perioperative opioid consumption, increase patient satisfaction, and decrease postoperative stay. This block, while effective in BCP, is poorly tolerated in the LDP [19].

Hypotensive bradycardic events (HBEs) and the associated hypotension are also a concern with BCP. Song and Roh [19] conducted a review to examine HBEs in shoulder arthroscopy when combined with ISBPB. They reported an incidence of HBEs under ISBPB around 13%–28%, and most events tended to be transient in nature, occurring without complications. The causative mechanisms for HBEs are not fully understood but may include carotid sinus hypersensitivity and orthostatic syncope. Treatment includes administration of alpha-agonist vasoconstrictors or ephedrine when the HBE is of unknown origin. The authors argue that preventing these events remains a challenge, and that studies aimed at ultrasonography-guided ISBPB might be promising.

ARTHROSCOPIC PUMP SYSTEMS

There are varying types of commercially available pump systems for arthroscopy. This includes gravity systems, pressure-driven pumps, and pressure- and flow-controlled pumps. A gravity system involves hanging bags of saline several feet above the operative site, with the pressure in the joint ranging from 50–120 mmHg depending on the outflow in the system [20]. Pressure, or single-roller, pumps and pressure-and-flow, or double-roller, pumps both are commercially available to provide intra-articular pressure either by regulating the pressure alone or by regulating the pressure and flow in the system [21,22].

One of the first studies to discuss the use of infusion pumps in arthroscopy was by Bergstrom and Gillquist [23] in 1986. The study examined fluid inflow and outflow as well as postoperative circumference as means of measuring fluid extravasation in patients undergoing knee arthroscopy. They concluded that the use of an arthroscopy pump allowed controlled, higher intra-articular pressures and greater joint distention to achieve better visualization and a more useful tool for arthroscopy.

In their 1995 paper, Ogilvie-Harris et al. [22] prospectively compared two pump systems. One pump allowed for pressure control but not flow, while the other allowed for control of both pressure and flow. One of the two pumps was utilized in cases of knee, ankle, or shoulder arthroscopy. Visualization and fluid extravasation were measured with a subjective scoring system. The study concluded that the pump with both pressure and flow control independently led to significantly improved visualization.

The advantage of a pump system is the ability to achieve a higher, constant, intra-articular pressure that could theoretically improve visualization [23,24]. Some systems only control pressure, while others, known as dual-roller pumps, control both pressure and fluid flow. These dual-roller pumps can decrease bleeding, decrease operative time, and improve visualization [24-26]. Complications of these systems include joint damage, fluid extravasation, increased postoperative pain, and risk of compartment syndrome [24,27]. Studies on both gravity and fluid pump systems suggest that both are safe and effective for use in arthroscopy [20,21,24].

Gravity and automated fluid pump systems are commercially available and widely used in arthroscopy. Some studies note that gravity systems are lower cost, effective, reliable, and do not deform the joint capsule with excess pressure [24,27]. Proponents of gravity systems suggest that they are safer because they are not expected to reach high intra-articular pressures and avoid excess fluid extravasation. The disadvantage is that the pressure is determined by bag height and will not yield as high intra-articular pressures as other systems and could inhibit visualization [24].

Careful understanding of automated pump systems is required to ensure safe surgery. Taha et al. [28] compared three arthroscopic pump systems and compared intraoperative pump pressures with an intra-articular spinal needle pressure measurement. Actual intra-articular pressure was significantly higher than the set pressure in all three pump machines. The authors suggested using the intra-articular spinal needle pressure measurement as a tool to calibrate commercially available pumps to allow more accurate pressure readings and to minimize the risk of intraoperative complications. The current authors utilize a pressure and flow automated fluid management system that is typically set to 35 mmHg for shoulder arthroscopy.

TURBULENCE CONTROL

In their paper on turbulence control, Burkhart et al. [29] discuss the Bernoulli effect. According to Bernoulli's principle, a fluid stream will create a perpendicular force against itself. The moving arthroscopy fluid leaking through the anterior portal creates a suction effect on the surrounding blood vessels, resulting in mixture of blood and turbulence that obscures visualization. The authors posit that a simple cannula or digital pressure stops this pressure gradient, diminishes the Bernoulli effect, and improves visualization. Furthermore, any turbulence will decrease visualization, and steps should be taken to decrease fluid leakage and the pressure gradient. Surgical techniques that limit fluid leaking and extravasation can help increase local pressure and diminish turbulence, leading to improved visualization.

EPINEPHRINE

Intra-articular bleeding is a major cause of decreased visualization. Conventionally, cold irrigation fluid, electrocautery, and permissive hypotension have been used to improve visual clarity by reducing bleeding because tourniquets are not technically possible in shoulder arthroscopy [30]. EPI is used as an alternative to these techniques. EPI is a vasoconstrictor that, when administered into the shoulder, acts locally to constrict blood vessels that cause bleeding in shoulder arthroscopy [30]. The addition of EPI to arthroscopy fluid to reduce bleeding and improve clarity remains a topic of interest [30-34].

Two studies found significantly increased visual clarity when comparing EPI injected into arthroscopic fluid with that into standard saline. The EPI dosage in these papers was 0.33 mg/L, though they comment that more research is needed to establish the optimal concentration. Neither study reported adverse reactions in either group [30,31].

In their systematic review and meta-analysis, Kuo et al. [32] evaluated three randomized control trials with 238 participants. They found that the use of EPI in arthroscopy fluid provided significantly better visual clarity and reduced the need for increased pump pressure compared with the group with standard saline fluid. This review also found no records of adverse events.

Another study found improved visualization but did not find a difference in operative time or volume of irrigation fluid used, prompting the question of the clinical significance of this technique [33]. Cost has also been a concern in the use of EPI, with one 30-mL bottle costing $237 in 2019. Stetson et al. [35] highlight this expenditure in their article and note that foregoing EPI lead to about $900 in cost savings per shoulder arthroscopy case. While addition of EPI to arthroscopy fluid has demonstrated promise, it is not without theoretical risk. Due to the different effects on adrenergic receptors, Chierichini et al. [36] sought to compare norepinephrine with EPI for patients in the BCP for improving visual clarity while lowering the risk of cardiovascular

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instability. They found that continuous administration of 0.66 mg/L norepinephrine in arthroscopic fluid reduced HBE incidence and similarly improved visual clarity.

Use of EPI in shoulder arthroscopy has also been associated with cardiomyopathy [37], arrhythmias [38], and encephalopathy [39], though these instances are rare. Knowledge of these potential complications is crucial for surgical and anesthesia teams to properly respond in the event of a life-threatening situation. For improved visualization, the current authors use 1mg/mL of EPI in 3 L of normal saline as arthroscopic fluid in both BCP and LDP. One author injects 10 mL of 1% lidocaine with EPI into the subacromial space prior to surgery for cases performed in the BCP.

TRANEXAMIC ACID

TXA is an analog of the amino acid lysine and inhibits fibrinolysis by acting as a competitive inhibitor to the binding site on plasminogen [40]. It has been shown to reduce blood loss and need for transfusion [40,41]. Orthopedic literature has explored the use of TXA in trauma [42], arthroplasty [43], and spine surgery [44] and confirms promising results. TXA has been associated with reduced blood loss [43,45] and decreased hematoma formation [43] and is now being investigated for improving visualization in shoulder arthroscopy [40,46]. In shoulder arthroscopy procedures, TXA has been shown to improve visual clarity, lower postoperative hemarthrosis incidence, and decrease postoperative pain when administered via IV [40,46,47]. No significant difference was found between intra-articular and IV administration of TXA in a study on knee arthroscopy outcomes [48], though studies on shoulder arthroscopy cases are needed.

Despite being shown to be effective in different orthopedic subspecialties, TXA use remains controversial. Cited concerns for TXA use include thromboembolic events [49], myocardial infarction [50], visual disturbances [49], and chondrotoxicity [51]. However, multiple studies evaluating the safety of this drug have not found an increase in thromboembolic events regardless of administration route [43,52]. To improve visualization, the current authors administer 1 g of IV TXA after antibiotics at the start of surgery for BCP cases.

EPI VERSUS TRANEXAMIC ACID

TXA and EPI both offer promising results when applied to shoulder arthroscopy and improved visualization. In a comparison of the two, there was no significant difference in visual clarity as determined by visual analog scale, and no adverse events were recorded in either group. The current authors conclude that the addition of TXA to irrigation fluid may provide similar visual effects as EPI [53].

CONCLUSIONS

Shoulder arthroscopy is a common procedure that requires visual clarity for safe and effective surgery. There are many factors that may impact visualization during arthroscopic shoulder surgery, including vascular anatomy, positioning, blood pressure control, fluid flow in the joint, and adjuncts to arthroscopic irrigation fluid. Orthopedic surgeons should understand the risks and benefits of these factors as well as patient health and pathology to improve visualization during arthroscopic shoulder surgery. Understanding the anatomy, positioning, blood-pressure control, fluid flow in the joint, and adjuncts to arthroscopic irrigation fluid can all lend themselves to a more uniform, reproducible experience.

NOTES

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