

Cost Effective Technique of Shoulder Arthroscopy Without the Use of Epinephrine in Irrigation Solution



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Abstract: Arthroscopic surgery of the shoulder joint and the subacromial space requires adequate visualization to be effectively performed. Visual clarity is essential to perform a safe and successful arthroscopic procedure. The major determinants to provide visualization in the subacromial space and the glenohumeral joint include adequate inflow (dependent on the dimension of the inflow cannula), flow rate versus pressure, pump system versus gravity, the use of electrocautery and radiofrequency devices, blood pressure control and hypotensive anesthesia, and the type of irrigation solution used with or without the use of epinephrine. In 2012, the cost of a 30-mL (30-mg) vial of epinephrine was \$6 (adrenalin/epinephrine injection, USP, Par Pharmaceuticals), and approximately 3 to 4 bottles would be used on average for a single shoulder arthroscopy. In 2019, the same 30-mL bottle of epinephrine cost \$237, a nearly 40-fold increase. The purpose of our study is to describe the various factors and techniques that can be used to maintain visual clarity in shoulder arthroscopy without the use of epinephrine in the irrigation solution and the cost savings associated without the use of epinephrine.

Arthroscopic surgery of the shoulder joint and the subacromial space requires adequate visualization to be effectively performed.¹ Visual clarity is essential to perform a safe and successful arthroscopic procedure.² In particular, bleeding in the subacromial space is an annoying but ever-present impediment to visualization during arthroscopic subacromial procedures.³

Technique (With Video Illustration)

The major determinants to provide visualization in the subacromial space and the glenohumeral joint have been incompletely studied. Significant factors include adequate inflow (dependent on the dimension of the

inflow cannula), flow rate versus pressure, a pump system versus gravity inflow, the use of electrocautery and radiofrequency devices, blood pressure control and hypotensive anesthesia, and the type of irrigation solution used with or without the use of epinephrine (Video 1). All of these are important factors in providing adequate visualization during shoulder arthroscopy and will be discussed in detail. However, first and foremost, the role of epinephrine will be discussed and whether or not it is truly necessary or cost effective in shoulder arthroscopy.

In knee and shoulder arthroscopy, epinephrine is frequently added to the irrigation solution in an attempt to reduce intraoperative articular and subacromial space bleeding, and thereby improve visualization. However, the specific effect has not been sufficiently quantified or studied extensively. The vasoconstrictive effect of locally administered epinephrine in arthroscopic shoulder surgery is based primarily on anecdotal observation.⁴

In 2012, the cost of a 30-mL (30-mg) vial of epinephrine was \$6 (adrenalin/epinephrine injection, USP, Par Pharmaceuticals), and approximately 3 to 4 bottles would be used on average for a single shoulder arthroscopy procedure. In 2019, the same 30-mL bottle of epinephrine cost \$237, a nearly 390% increase.

Because of the sudden rise in the cost of epinephrine, we have discontinued the use of epinephrine in our

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irrigation solution for shoulder arthroscopy in our outpatient surgery center, saving on average of over \$900 per case, sometimes more depending on the length of the procedure.

The purpose of our study is to describe the various factors and techniques that can be used to maintain visual clarity in shoulder arthroscopy without the use of epinephrine in the irrigation solution and the cost savings associated without its use.

Surgical Equipment and Setup

Attention to detail in all aspects of the surgical procedure are key in maintaining visual clarity for shoulder arthroscopy. From the operating room setup, equipment use, patient positioning, anesthesia consideration, and surgical technique, are all important factors in providing adequate visualization (Table 1).

Operating Room Setup and Personnel

As simple as it may sound, the operating room setup is the first and most important component for a successful shoulder arthroscopy. All equipment is placed in front of the surgeon and on the opposite side of the operating table. Whether one performs shoulder arthroscopy in the beach chair or lateral decubitus position, the video monitor arthroscopic tower, shaving equipment, arthroscopic pumps, and radiofrequency device should be visible to the surgeon so that if there is a visualization problem, the surgeon can take a quick look at all the equipment to make sure it is operating properly (Fig 1). This also includes the patient's vital signs, including blood pressure, as hypotensive anesthesia is also key to adequate visualization. This is similar to an airline pilot in the cockpit of an airplane with all monitors and gauges in front of him.

It is also very important to have experienced staff members working with the surgeon (Table 1). This includes an experienced surgical technician/scrub tech who knows the surgical setup and routine of the operating surgeon. We typically operate with only one assistant who is an experienced technician and who knows the techniques and maneuvers of the surgeon for these complex arthroscopic shoulder procedures. An experienced circulating nurse is also important to make sure all equipment is readily available and to make sure the irrigation fluids do not run out during the procedure, introducing air into the system and into the patient's systemic vasculature. Finally, an experienced anesthesiologist who is experienced in hypotensive anesthesia techniques is critical for the success of the procedure.

Positioning

Shoulder arthroscopy is generally performed when the patient is in either the beach chair or the lateral decubitus position (Table 1). To allow greater visual

Table 1. Proper Operating Room Setup and Personnel

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- Lateral decubitus preferred over beach chair positioning
 - Equipment set up in front of the surgeon for easily visualization
 - Experienced surgical technician/scrub tech, circulating nurse, and anesthesiologist
-

exposure in the glenohumeral joint, the senior author (W.B.S.) prefers the lateral decubitus position for not only stability cases but for all shoulder arthroscopy cases, including arthroscopic rotator cuff repairs. While in the lateral decubitus position, lateral and axial traction is applied to the operative arm, which maintains arthroscopic visualization of the glenohumeral joint (Fig 2).⁵ With the use of hypotensive anesthesia, which is critical for adequate visualization, blood pressure can be easily monitored with no risk of cerebral desaturation (Table 2). Murphy et al.⁶ reported a significantly higher incidence of cerebral desaturation events during arthroscopic shoulder surgery in the beach chair position than with the lateral decubitus position. A more recent study found the incidence much lower but still present.⁷ We therefore strongly recommend the lateral decubitus position.

Anesthesia Considerations

An experienced anesthesiologist is key to safely perform shoulder arthroscopy using hypotensive anesthesia techniques (Table 2). We prefer and recommend general endotracheal intubation and anesthesia for shoulder arthroscopy. We believe it is safer and easier to control not only the airway but also the blood pressure, which is key for adequate visualization (Table 3).

Hypotensive anesthesia is key to maintain visual clarity during shoulder arthroscopy. Maintaining systolic blood pressure of 90 mm Hg and a pump pressure of 40 mm Hg is the ideal situation for visualization, especially for the subacromial space (Table 3). Morrison et al.¹ found that the average differences between systolic blood pressure and the subacromial space pressure at which bleeding from cancellous bone and surrounding soft tissue ceased was 49.2 mm Hg \pm 9.0 mm Hg. Therefore a pump pressure of 40 mm Hg and a systolic blood pressure of approximately 90 mm Hg is the ideal situation for adequate visualization not only in the subacromial space but also in the glenohumeral joint.

We also recommend a suprascapular nerve block, and we do not use, nor do we recommend, an interscalene block as the risk of complications is too high for an elective procedure.⁸

Equipment

Shoulder arthroscopy is typically performed with a 30° arthroscope. In arthroscopy "good exposure"

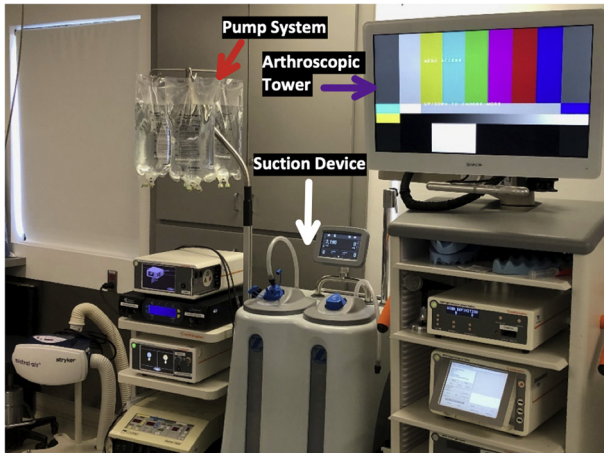


Fig 1. From right to left: the arthroscopic tower (purple arrow), the suction device (white arrow), and the pump system with irrigation fluid (red arrow) are situated in front of the surgeon so they are easily visible, and the surgeon can attend to any malfunctioning devices if visualization is decreased.

translates into obtaining and maintaining good visualization throughout the procedure. Good visualization, in turn, requires a properly functioning optical system of an arthroscopic lens, arthroscopic camera, and video equipment (Table 4). Adequate joint distention is maintained by a pump system that delivers and maintains an optically clear medium into the joint. Proper distention of the joint by a pump system facilitates accurate visualization, as well as safe and efficient manipulation of the arthroscope and surgical instrumentation.⁹ Although we have used gravity inflow in the past, we do not recommend it as we believe it does not provide enough joint distention and hydrostatic pressure to decrease bleeding and allow for adequate visualization for complex shoulder arthroscopy procedures. A pump pressure of 40 mm Hg is recommended as long as the systolic blood pressure is near 90 mm Hg, which provides adequate hydrostatic pressure on the capillaries to decrease bleeding.

The proper arthroscopic cannula system is also key for shoulder arthroscopy (Table 4). We recommend a 5.5-mm × 8.5-cm “J-lock” metal cannula system (Smith and Nephew/Dyonics). The 5.5-mm cannula provides an adequate inflow and flow rate through the arthroscope for adequate joint distention (Video 1). We also recommend that the cannula be 8.5 cm in length and not the longer cannula as the shorter cannula is easier to maneuver within the glenohumeral joint (Fig 3).

A radiofrequency/thermal electrocautery device (either monopolar or bipolar) is also a critical piece of equipment to have to control bleeding (Table 4). The use of thermal electrocautery devices and pressurized irrigation systems to control bleeding has shown a positive effect in visual clarity in previous studies.^{3,10-12}

Arthroscopic Pump Pressure and Flow Rate

Maintenance of a clean field for shoulder arthroscopy is dependent on both the flow rate and pressure of the irrigation fluid. High flow rates keep an operative field free of blood but have the detrimental effects of fluid extravasation into the surrounding tissues and may cause excessive turbulence, possibly interfering with visualization.¹

Pressure manipulation within the glenohumeral joint and subacromial space enhances visualization by tamponading capillary blood vessels. The goal is to obtain sufficient glenohumeral and subacromial pressure to decrease blood flow while at the same time minimizing fluid extravasation.¹ To obtain the ideal situation, the glenohumeral joint pressure and the systolic blood pressure must be controlled and same is true for the subacromial space pressure. Raising irrigation pressure via the arthroscopic pump has been shown to increase joint distention, reduce intra-articular bleeding, and improve visualization.¹ However, excessive pump pressure can lead to excessive fluid extravasation into the surrounding soft tissues causing significant soft tissue edema in the postoperative period.

Arteriolar and capillary pressure average 25 mm Hg less than the measured systolic blood pressure.¹³ Therefore the blood vessels feeding the subacromial space, which are small arterioles and capillaries, have less pressure in them than the patient’s systolic blood pressure.¹ An arthroscopic pump system with a pressure set to 40 mm Hg is usually adequate for joint distention and visual clarity as long as the patient’s systolic blood pressure is maintained at approximately 90 mm Hg.



Fig 2. This is a left shoulder with the patient in the lateral decubitus position with the left shoulder wrapped in a sterile sleeve (Arthrex). The lateral decubitus position is preferred, as previous studies have shown significantly higher incidence of cerebral desaturation events during arthroscopic shoulder surgery in the beach chair position than with the lateral decubitus position.^{6,7}

Table 2. Risks and/or Limitations of this Procedure

- Use of hypotensive anesthesia increases the risk of cerebral desaturation
- Significantly reduced in the lateral decubitus position
- Inexperienced anesthesiologist allows too many fluctuations in blood pressure, hindering visualization
- Inadequate equipment will also hinder visualization

In arthroscopy in general, joint distension is accomplished by pressurizing the joint with a liquid medium such as saline or Ringer's lactate solution (Table 4). In arthroscopy, resistance to flow is a function of the diameter of the inflow system. The greater the diameter of the inflow system, the greater the flow. For this reason, a large 9-mm diameter inflow tubing from the irrigation solution to the arthroscope commonly used for urologic endoscopy is recommended for arthroscopy.⁹

Flow rate is measured in meters cubed per second (m^3/sec) or liters per second (L/sec). Flow rates can measure mass flow rate or volume flow rates. For shoulder arthroscopy, we are interested in volume flow rates, which is the measurement of how much fluid is flowing past a selected point over a length of time. It is calculated by multiplying the average velocity of the fluid by the cross-sectional area of the pipe or tube in which it flows (volume flow rate = average velocity \times cross-sectional area). The cross-sectional area is calculated using the square of the diameter (d squared) of the pipe or tubing multiplied by n ($n = 3.142$) divided 4:

$$\text{Cross-section area (CSA)} = [n \times (\text{diameter})^2] / 4$$

Hence the importance of the diameter of the inflow cannula used in shoulder arthroscopy is critical for adequate inflow and pressure. The volume flow rate for a 4.5-mm cannula is 31.8 L/sec, whereas the volume flow rate for a 5.5-mm cannula is 47.6 L/sec, a 50% greater flow rate. Using a 5.5-mm arthroscopic cannula delivers a 50% greater flow rate, which aids in pressure manipulation, joint distention, enhancing the tamponade effect on capillary blood vessels, and enhancing visualization. It has been the senior author's (W.B.S.) experience that a 4.5-mm arthroscopic cannula does not provide enough fluid pressure for fluid adequate joint distension, compromising visualization because of joint capsule collapse with turbidity from bleeding.

Type of Arthroscopic Fluid

Normal saline solution is commonly used in large quantities as an irrigation solution for shoulder arthroscopy. However, normal saline solution is in fact not physiologic and it has been shown to inhibit normal synthesis of proteoglycans by the chondrocytes.¹⁰ Data show that neither normal saline nor phosphate-buffered saline supports metabolic activity as well as Ringer's lactate or acetate.¹⁰

Articular cartilage is a metabolically complex and active tissue that is entirely dependent for nutrition on the fluids that bathe its surface.¹⁰ It has been recommended that normal saline solution be abandoned as an irrigation solution during shoulder arthroscopic procedures and that lactated or acetated Ringer's solution be used.¹⁰

Epinephrine Versus No Epinephrine

In shoulder arthroscopy, adding epinephrine to the irrigation fluid has shown potential benefits by reducing intra-articular bleeding and surgeon rated visualization.⁴ Anecdotal observations of arthroscopic shoulder and knee surgery suggest that intraoperative bleeding is minimized when dilute epinephrine irrigation solution is used during the surgery. However, there are very few studies in the literature that have actually proven this hypothesis.⁴ We have used epinephrine in our irrigation solution for over 20 years based on arthroscopic surgical training during residency and fellowship.

The vasoconstrictive effect of locally and/or intra-articularly administered epinephrine was shown in early animal studies.¹⁴ Adding epinephrine to irrigation fluid leads to contraction of the smooth muscle lining of the arterioles.² These early animal studies showed less bleeding and a positive effect in visual clarity when performing arthroscopy.^{15,16}

A recent study by Van Montfort et al.² of patients undergoing shoulder arthroscopy showed that visual clarity was significantly better and total operating time significantly shorter in the epinephrine group. Total irrigation fluid was also significantly lower in the epinephrine group with no adverse effects on blood pressure or heart rate. This study found the addition of epinephrine (0.33 mg/L) to the irrigation fluid significantly improved visual clarity in the most common types of therapeutic shoulder arthroscopy procedures.² Similarly, in a prospective randomized double-blind controlled study, Jensen et al.⁴ reported a reduction in intra-articular bleeding in shoulder arthroscopic procedures. However, neither study mentions other factors that may play a role in maintaining visual clarity, including blood pressure monitoring, use of a pump and the pump pressure or flow rate or other factors.

Cost of Epinephrine

Until recently, we used epinephrine in our irrigation solution for shoulder arthroscopy for many of the

Table 3. Anesthesia Considerations

- Experienced anesthesiologist
- General anesthesia with endotracheal intubation
- Hypotensive anesthesia—systolic blood pressure at 90 mm Hg
- Suprascapular nerve block preferred over an interscalene block

Table 4. Operating Room Equipment

-
- 30° arthroscope
 - 5.5-mm × 8.5-cm “J-lock” metal cannula system (Smith and Nephew/Dyonics)
 - Arthroscopic pump—pump pressure set at 40 mm Hg
 - Radiofrequency/thermal electrocautery device (either monopolar or bipolar)
 - Arthroscopic shaving system
 - Lactated Ringer’s solution—without the use of epinephrine
-

reasons outlined here. However, approximately 9 months ago it was brought to the senior author’s (W.B.S.) attention that the cost of a single 30-mL bottle of epinephrine had increased from \$6 per bottle to over \$235 a bottle. This dramatic increase started approximately 7 years ago, and since then the price has risen steadily to almost 40x the original price (Table 5). Because of this high price of epinephrine, we immediately stopped using it and then had to refine our technique of shoulder arthroscopy so that adequate visualization could be obtained without the use of epinephrine in the irrigation solution (Table 5).

We found that attention to the details of the surgical equipment and techniques described here now allows us to perform shoulder arthroscopy safely and efficiently without the use of epinephrine. We also save on average over \$900 per case.

Surgical Procedure

The patient is brought into the operating room and placed supine on the operating room table and general endotracheal anesthesia is induced. The patient is then placed in the lateral decubitus position with an axillary roll placed and all bony prominences are padded. The operative shoulder is prepped and draped in the usual sterile manner, and the arm is placed in the shoulder holder (Arthrex) in balanced suspension at approximately 70° of abduction and 15° of forward flexion. The bony landmarks are then outlined with a sterile marking pen and a posterior portal is established 2 cm medial and 2 cm inferior from the posterolateral aspect of the acromion, and a 5.5-mm × 8.5-cm “J-lock” metal cannula (Smith and Nephew/Dyonics) is introduced into the shoulder joint. Multiple attempts or “poke” holes are discouraged to enter the joint as this can lead to early fluid extravasation, and less fluid pressure into the glenohumeral joint, which can decrease visualization.

Once the glenohumeral joint is entered into, an anterior-superior portal is established using either an outside-in or inside-out technique. The outflow for the anterior-superior portal is by gravity and controlled by a clamp, which is only opened to “clear the picture” when the visualization becomes cloudy.

Once the portals are established, a 15-point glenohumeral examination described by Snyder¹⁷ is performed on all patients, with the first 10 points viewing

from the posterior portal and the remaining 5 from the anterior superior portal. The arthroscopic pump pressure is maintained at 40 mm Hg, and the systolic blood pressure is maintained at 90 mm Hg.

It is of utmost importance that the anesthesiologist carefully monitors the patient’s blood pressure throughout the entire procedure. He or she is not allowed to use their cellphones for personal use of “surfing the internet,” “texting friends,” or “checking the latest posts” on Facebook. Cellphones are not allowed in our operating room as they can be a distraction for not only the anesthesiologist but also the nursing staff, taking away from care of the patient.

If there is adequate joint distension, adequate pump pressure and flow rate, and adequate hypotensive anesthesia, excellent visualization can be obtained in the glenohumeral joint without the use of epinephrine in the irrigation solution, or the use of a radiofrequency device for hemostasis.

Once the work is completed in the glenohumeral joint, the arthroscope is removed, and attention is then turned to the subacromial space. The arm position is changed from abduction to approximately 20° of adduction by placing the weight on a different point of the suspension device.

Using the same incision for the posterior portal, the arthroscopic cannula with the blunt obturator is placed just under the posterior aspect of the acromion into the subacromial space. The blunt obturator is removed, and a smooth switching stick is introduced through the cannula exiting out the anterior incision previously used for the anterior-superior portal for the glenohumeral joint. A second 5.5-mm × 8.5-cm “J-lock” metal cannula is then introduced anteriorly over the switching stick so that there is one cannula posterior and one cannula anterior and the 2 ends are touching each other. There is a two-thirds to one-third rule for this as the posterior cannula should be two-thirds of the way into the subacromial space to get past the posterior bursal curtain, and the anterior cannula is one-third of the way into the subacromial space. The surgical assistant or technician then holds both cannulas close together or “end-to-end” as the surgeon removes the switching stick (Fig 4). With the assistant still holding the 2 metal cannulas together, the surgeon carefully places the arthroscope through the posterior cannula, locks it into place, and then turns the irrigation fluid on. The anterior cannula should be visible at the end of the arthroscope, and then the surgeon carefully places a 4.0-mm arthroscopic shaver through the anterior cannula so that the tip of the shaver is visible at the end of the arthroscope. The arthroscopic shaver is then locked in by sliding back the cannula to the base of the shaver while still maintaining the tip of the shaver near the end of the arthroscope. The surgeon then has one hand on the arthroscope and one hand on the shaver and he

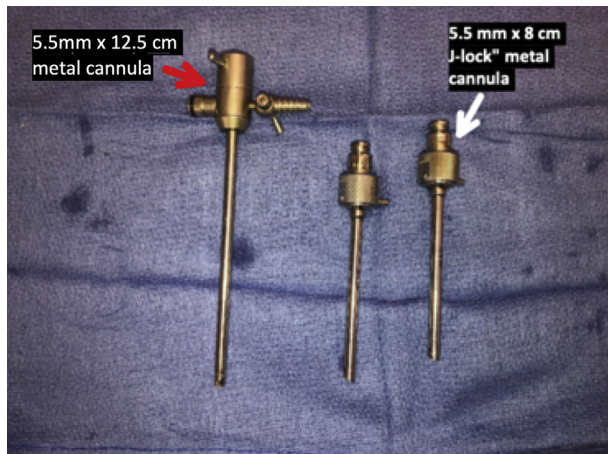


Fig 3. The proper arthroscopic cannula system is also key for shoulder arthroscopy. We recommend a 5.5 mm × 8.5 cm “J-lock” metal cannula system (Smith and Nephew/Dyonics) pictured on the right (white arrow). The 5.5-mm cannula provides an adequate inflow and flow rate through the arthroscope for adequate joint distention. We also recommend the cannula be 8.5 cm in length and not the longer cannula pictured on the left (red arrow), as the shorter cannula is easier to maneuver within the glenohumeral joint.

or she then creates “a room with a view” by carefully debriding the bursal tissue within the subacromial space until the coracoacromial ligament and the undersurface of the acromion are visible (Fig 5). Once this view is established, typically within 15 to 20 seconds, a third portal is created 2 finger-breadths from the lateral aspect of the acromion in line with the posterior aspect of the acromioclavicular joint.

A 4.5-mm × 8-cm plastic cannula (Arthrex) is then inserted through the lateral portal and the arthroscopic shaver is typically then inserted to debride more bursal tissue. This portal can also be used for a radiofrequency device to clear off the undersurface of the acromion in preparation for an acromioplasty and can also be used for a viewing portal or for a working portal for rotator cuff repairs.

Once the lateral portal is established, there is often no cannula placed in the anterior portal. This can sometimes lead to fluid outflow through this portal leading to “bubbles” or loss of visualization because of the previously described “Bernoulli Effect” by Burkhart et al.³ Burkhart et al.³ described having the assistant place his finger over the portal, however, we recommend placing either a plastic or metal obturator into the portal, which will also reduce or eliminate this effect and improve visualization.

Adequate visualization in the subacromial space can be obtained using similar principles used for the glenohumeral joint. This includes an adequate diameter cannula that delivers an adequate flow rate, pump pressure of 40 mm Hg, hypotensive anesthesia (systolic

blood pressure of 90 mm Hg), and minimizing the use of a shaver to clear bursal tissues, which tend to be hypervascular. Early use of a radiofrequency device (Arthrocare Wand, Smith and Nephew) will also help reduce or eliminate bleeding and aid in visualization.

Discussion

In knee and shoulder arthroscopy, epinephrine is frequently added to the irrigation solution in an attempt to reduce intraoperative articular and subacromial space bleeding, and thereby improve visualization. However, the specific effect has not been sufficiently quantified or studied extensively.⁴ The vasoconstrictive effect of locally administered epinephrine in arthroscopic shoulder surgery is based primarily on anecdotal observation.⁴

In 2012, the cost of a 30-mL (30-mg) vial of epinephrine was \$6 (adrenalin/epinephrine injection, USP, Par Pharmaceuticals), and approximately 3 to 4 bottles would be used on average for a single shoulder arthroscopy. In 2019, the same 30-mL bottle of epinephrine cost \$237, a nearly 40-fold increase in price (Table 5).

Because of the sudden rise in cost of epinephrine, we have discontinued the use of epinephrine in our irrigation solution for shoulder arthroscopy in our outpatient surgery center, saving on average of over \$900 per case, sometimes more depending on the length of the procedure (Table 5). Using the techniques described, we have found no problems with adequate visualization in the glenohumeral joint or the subacromial space without the use of epinephrine. Attention to detail in all aspects of the surgical procedure are key in maintaining visual clarity for shoulder arthroscopy. From the operating room setup, equipment uses, patient positioning, anesthesia consideration, and surgical technique, are all important factors in providing adequate visualization.

Hypotensive anesthesia is key to maintain visual clarity during shoulder arthroscopy. Maintaining systolic blood pressure of 90 mm Hg and a pump pressure of 40 mm Hg is the ideal situation for visualization, especially for the subacromial space. Morrison et al.¹ found that the average differences between systolic blood pressure and the subacromial space pressure at which bleeding from cancellous bone and surrounding soft tissue ceased was 49.2 mm Hg ± 9.0 mm Hg.

Table 5. Key Points

- Cost of epinephrine has dramatically increased almost 4000% in the last 7 years
- Lactated Ringer’s solution used without epinephrine provides adequate visualization and can save over \$900 per case
- Hypotensive anesthesia (systolic blood pressure at 90 mm Hg)
- Adequate pump pressure (40 mm Hg)
- Adequate flow rate (5.5-mm diameter inflow cannula)
- Experienced surgical team

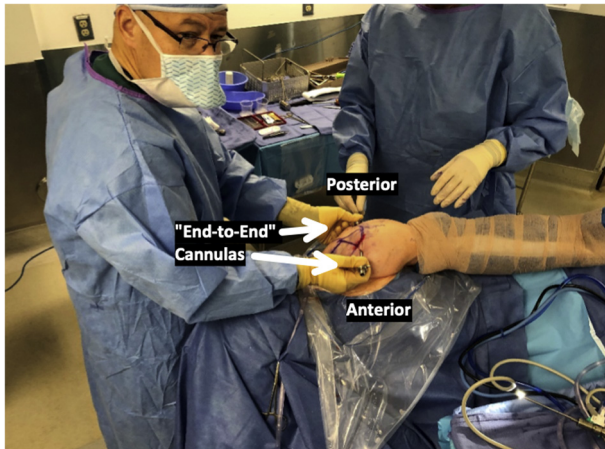


Fig 4. This is a left shoulder of a patient in the lateral decubitus position with the anterior aspect of the shoulder in front. While in the subacromial space, the surgical assistant or technician holds both cannulas close together or “end-to-end” as the surgeon removes the switching stick (white arrows).

Therefore a pump pressure of 40 mm Hg and a systolic blood pressure of approximately 90 mm Hg is the ideal situation for adequate visualization not only in the subacromial space but also in the glenohumeral joint.

The importance of the diameter of the inflow cannula used in shoulder arthroscopy is critical for adequate inflow and pressure. The volume flow rate for a 4.5-mm cannula is 31.8 L/sec, whereas the volume flow rate for a 5.5-mm cannula is 47.6 L/sec, a 50% greater flow rate. Using a 5.5-mm arthroscopic cannula delivers a 50% greater flow rate, which aids in pressure manipulation, joint distention, enhancing the tamponade effect on capillary blood vessels, and enhancing visualization. It has been the senior author’s (W.B.S.) experience that a 4.5-mm arthroscopic cannula does not provide enough fluid pressure for fluid adequate joint distension, compromising visualization because of joint capsule collapse with turbidity from bleeding.

In shoulder arthroscopy, adding epinephrine to the irrigation fluid has shown potential benefits by reducing intra-articular bleeding and surgeon rated visualization.⁴ Anecdotal observations of arthroscopic shoulder and knee surgery suggest that intraoperative bleeding is minimized when dilute epinephrine irrigation solution is used during the surgery. However, there are very few studies in the literature that have actually proven this hypothesis.⁴

The vasoconstrictive effect of locally and/or intra-articularly administered epinephrine was shown in early animal studies.¹⁴ Adding epinephrine to irrigation fluid leads to contraction of the smooth muscle lining of the arterioles.² These early animal studies showed less bleeding and a positive effect in visual clarity when performing arthroscopy.^{15,16}

A recent study by Van Montfort et al.² of patients undergoing shoulder arthroscopy showed that visual

clarity was significantly better and total operating time significantly shorter in the epinephrine group. Total irrigation fluid was also significantly lower in the epinephrine group with no adverse effects on blood pressure or heart rate. This study found the addition of epinephrine (0.33 mg/L) to the irrigation fluid significantly improved visual clarity in the most common types of therapeutic shoulder arthroscopy procedures.² Similarly, in a prospective randomized double-blind controlled study, Jensen et al.⁴ reported a reduction in intra-articular bleeding in shoulder arthroscopic procedures.

However, in each of these studies there is no mention of other factors that can improve visualization, such as hypotensive anesthesia, use of a pump and its pressure, the diameter of the cannula, and the resultant flow rate. These are all important factors that are not addressed in these 2 studies and which play an important role in visualization.

We have used epinephrine in our irrigation solution for over 20 years based on arthroscopic surgical training during residency and fellowship. However, we have now abandoned its use because of its cost, and with the techniques described we have had no problems with visualization. We maintain that adequate visualization can be maintained without the use of epinephrine-infused



Fig 5. This is a left shoulder of a patient in the lateral decubitus position with the anterior aspect of the shoulder in front. With the assistant still holding the 2 metal cannulas together, the surgeon will carefully place the arthroscope through the posterior cannula, lock it into place, and then insert the shaver through the anterior portal so that the tip of the shaver will be visible with the arthroscope. The arthroscope (blue arrow) is in the posterior portal (white arrow) and the arthroscopic shaver (red arrow) is in the anterior portal (black arrow) in the subacromial space. The surgeon has one hand on the arthroscope and one hand on the shaver and he or she then creates “a room with a view” by carefully debriding the bursal tissue within the subacromial space until the coracoacromial ligament and the undersurface of the acromion are visible.

irrigation solution if the steps outlined in our techniques are followed.

It is of utmost importance that the anesthesiologist carefully monitors the patient's blood pressure throughout the entire procedure. He or she is not allowed to use their cellphones for personal use of "surfing the internet," "texting friends," or "checking the latest posts" on Facebook. Cellphones are not allowed in our operating room as they can be a distraction for not only the anesthesiologist but also the nursing staff, taking away from care of the patient.

Adequate visualization in the subacromial space can also be obtained using similar principles used for the glenohumeral joint. This includes an adequate diameter cannula that delivers an adequate flow rate, pump pressure of 40 mm Hg, hypotensive anesthesia (systolic blood pressure of 90 mm Hg), and minimizing the use of a shaver to clear bursal tissues, which tend to be hypervascular. Early use of a radiofrequency device (Arthrocare Wand, Smith and Nephew) will help reduce or eliminate bleeding and aid in visualization. Viewing from the posterior portal and with a cannula through the lateral portal with no cannula placed in the anterior portal, this can sometimes lead to the "Bernoulli Effect" as described by Burkhart et al.³ with bubbles or loss of visualization. If this occurs, we recommend placing a metal or plastic obturator into the portal, which will reduce or eliminate the bubbles and improve visualization.

Summary and Conclusions

Over the last 7 years, the cost of a 30-mL bottle of epinephrine has skyrocketed almost 40-fold. This has led us to refine our arthroscopic shoulder surgical techniques as we have described, and we therefore have been able to eliminate its use without any problems in maintaining adequate visualization not only in the glenohumeral joint but also in the subacromial space. This has saved our outpatient surgery center over \$900 per case. We recommend the discontinuation of epinephrine in the irrigation solution used for shoulder arthroscopy, which can then save a significant amount of money for any hospital or outpatient surgery center.

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