

Fluid Management Systems for Arthroscopy – A Clinical Perspective

a report by

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Introduction

Arthroscopy has become a valuable tool in the armamentarium of the orthopaedic surgeon. The anatomic space of concern is expanded by arthroscopy fluid and a camera is inserted within it for visualisation. The typical modern orthopaedic surgeon uses arthroscopy for the treatment of many different knee and shoulder pathologies. According to recent data from the American Board of Orthopedic Surgeons, four of the 10 most frequently performed orthopaedic surgical procedures are knee and shoulder arthroscopies. In order to perform these surgeries successfully, the orthopaedic surgeon must learn the essential skill of triangulation. This is the ability to move the arthroscopy camera around the joint to visualise the structure or structures in question, while simultaneously moving other instruments in and out of the joint to those same structures. This seemingly easy task can be very challenging, as it is made difficult by limited space and bleeding. Fluid management systems are paramount in the manipulation of these two factors and, quite simply, can mean the difference between success and failure in arthroscopic surgery.

Space Available

The space available in any joint is a potential space that must be manipulated to the advantage of the surgeon in order to make arthroscopy possible. It is obviously highly dependent upon the particular joint in question and the size of the patient. Other factors that are idiosyncratic to particular joints also play a role.

The glenohumeral joint of the shoulder is one of the first joints that the orthopaedic surgeon learns to navigate. It is a large joint with thick capsule and no intra-articular bursa to encroach upon the available space. The typical volume of fluid within the shoulder is less than 3ml or 4ml. With approximately 50ml of mercury pressure, the joint can be easily expanded to a volume of 60ml, allowing easy visualisation of the structures within the joint.

The subacromial area of the shoulder joint is very different and much more of a challenge. The space

available is far less for several reasons. Unlike the diarthrodial joint space of the glenohumeral joint, the subacromial space is non-articular and is therefore not ordinarily a fluid-filled space. Instead, the space is lined with a subacromial bursa that sits between the rotator cuff and the adjacent acromion and attached deltoid muscle. In order to adequately expand this space, a pressure of 60mm to 80mm of mercury is required. In addition, the highly vascular bursal tissue must be excised. This creates bleeding tissue that must be controlled – this will be discussed in due course.

The knee joint is very similar to the shoulder joint. It is a large diarthrodial joint encapsulated by thick tissue that is easy to expand at 50mm to 60mm of mercury pressure. From time to time, the intercondylar notch can have a sizeable fat pad that interferes with visualisation. This may require partial excision in order to increase the visible space in the notch. The fat pad is less vascular than the subacromial bursa, but, nonetheless, can produce unwanted bleeding that will also need to be controlled.

Bleeding

Bleeding is a fact of life that cannot be ignored by the arthroscopist. Just a few drops of blood are enough to create cloudy and murky fluid, making it impossible to visualise desired structures. Fortunately, it can usually be controlled in order to allow for visualisation within the desired space.

It is obvious that the first line of defence is to keep the patient's blood pressure as low as possible, meaning within the realm of what is safe for appropriate perfusion of the patient's vital organs. This is labelled 'controlled hypotension'. In most individuals, this safe zone is within 100mm to 110mm of mercury systolic blood pressure. Epinephrine can be added to arthroscopy fluid to help constrict vessels within the working space, but may have the paradoxical effect of increasing pressure through the systemic effects of epinephrine. When epinephrine is used, the concentration should not exceed a dilution of one to one million.

The second line of defence is to have an outflow portal that will allow fresh clear fluid to replace an egress of murky bloody fluid. This is similar to the natural cleanliness of a moving stream when compared with a stagnate pond. However, the source of fluid must be able to keep up with the outflow via adequate pressure and flow in order to keep the space open for business.

The third line of defence is dependent upon the space that the surgeon is working within. In the glenohumeral joint and knee, the joint capsule is lined with synovium that may bleed, especially when hypertrophied or inflamed, such as occurs with rheumatoid arthritis. The bleeding must be controlled by a combination of cauterisation of the bleeding vessels and elevated fluid pressure within the space. Larger vessels are easily and quickly cauterised. Increased fluid pressure is often a better tactic in this scenario because of the large number of microscopic vessels that bleed but are nearly impossible to cauterise individually. In this situation, the increased pressure allows for vessel tamponade and clotting of the multitude of small microscopic bleeders.

The same situation exists in the subacromial space. However, the number of vessels, large and microscopic, is more numerous and demanding. In order to work efficiently in this space, in procedures such as rotator cuff repairs, the pressure often needs to exceed that of the systolic blood pressure for quick and sustained tamponade of the many bleeding vessels. This means maintaining a working pressure of approximately 110mm to 120mm of mercury, while allowing appropriate egress of fluid through an outflow portal or suction of unwanted debris.

Debris

Another element that interferes with visualisation in various anatomic spaces is floating debris. The debris takes on an assortment of colours and shapes such as bone particles in the case of arthroscopic subacromial decompression or notchplasty and rice bodies or cartilage particles in the case of rheumatoid arthritis. The debris must be removed via the outflow canula or through additional suction with a mechanical rotating tool such as a tissue shaver. Additional suction is most often required due to the sheer volume of debris that is produced and requires removal. In order to maintain adequate space for visualisation, the flow of fluid must be able to keep up with the added egress of fluid created by the suction of unwanted debris.

Systems

Fluid management systems can be divided into two basic types – gravity versus mechanical pump. Gravity

systems usually consist of 2–3l fluid bags that are suspended at various heights from the anatomic site of arthroscopy. The ability to maintain adequate pressure and flow as previously described is dependent on the number of bags, the height of the bags and the tubing and scopes utilised. Obviously, this is different for each operating room. Unfortunately, each operating room must take the equipment used and make pressure measurements at various bag heights with the tubing and scopes specific to that operating room, if they want to know what pressures they are using and how the height of their bags influences the desired pressure. Very few operating rooms ever make these measurements, which means that most of gravity system users are not aware of the pressure under which they are working.

The advantage of a gravity system is that it is simple, readily available and applies a constant flow without erratic surges of pressure. Besides the common lack of knowledge about working pressure, other disadvantages include the lack of ability to instantaneously change the pressure. The bags would need to be raised or lowered in order to make a change.

On the other hand, mechanical pumps have the ability to measure pressure instantaneously and adjust pump output to maintain desired pressure levels. Relative disadvantages compared with gravity would include their more complex mechanical nature and their cost.

Pump Systems

Several pump systems have been introduced by a variety of manufacturers. Orthopaedic surgeons with expertise in arthroscopy have identified several positive attributes that make a pump system successful. Firstly, the pump system should provide a steady pressure with as little fluctuation as possible within the anatomic space of interest. Systems that do not maintain a steady pressure may play ‘catch-up’ by providing surges in pressure, followed by a drop in pressure that is lower than the desired pressure. This in turn requires another pressure surge and the cycle continues. In this type of system, the average pressure may be the desired pressure. However, the surges in pressure are responsible for extensive fluid extravasation into the surrounding tissues and, thereby, extensive swelling.

Secondly, the pump system should be able to maintain a steady pressure, while at the same time allowing a change in the outflow through the outflow portal, or in combination with suction devices. The combined outflow should be constantly measured by the pump system and simultaneously replaced by the pump system to avoid surges.

Thirdly, the system should be cost-saving by allowing unused fluid from one bag to be used on the next patient of the day. This requires a check valve and/or filter to be placed at the pump, downstream from the arthroscopy fluid bag. The tubing on the other side, which communicates with the arthroscopy space, will require changing without having to change the unused portion of the arthroscopy fluid bag and the tubing that connects it to the pump system.

Lastly, the pump system should allow the surgeon to quickly change the desired pressure and flow up or down to account for a changing arthroscopy environment. These attributes of the current, state-of-the-art pump systems, such as the Future Medical Systems arthroscopy pump system, make it possible to perform more technically demanding procedures such as arthroscopic rotator cuff repairs. Without a pump system with these attributes, it would be extremely difficult to perform this type of surgery. Most shoulder arthroscopists list this particular type of pump system as a prerequisite for success in arthroscopic rotator cuff repairs.

Potential Complications

The pump systems have one other distinct disadvantage when compared with gravity systems. The pressure can be set high enough for long enough to allow for significant swelling in surrounding tissues. Studies have shown that the tissue pressure subsides to normal levels very quickly after the pump system is shut down. However, the surgeon needs to be cognizant of the magnitude of the pressure being

used and the period of time that it remains at that level. For instance, after 60 to 90 minutes of a subacromial pressure of more than 100mm of mercury, fluid may extravasate to a patient's neck and result in enough pressure against the softer portions of the upper airway to result in reduced air flow. The anaesthesia staff need to constantly monitor the patient's neck when using these higher pressures. If swelling results in a concern for increased pressure on the airway, acute intubation must be performed. The swelling must subside prior to extubation.

In the knee, pressures of that magnitude are rarely required. However, a very long procedure at lower pressures could result in enough extravasation, (especially in cases with a pre-existing Baker's cyst), to result in compartment syndrome of the leg. This situation needs to be monitored by the surgeon personally.

Summary

In closing, current pump systems such as the Future Medical Systems arthroscopy pump system provide all the attributes that are necessary to perform the demanding technical aspects of modern arthroscopic surgeries such as rotator cuff repair. Without them, the surgeon would have to use more invasive non-arthroscopic techniques. Due to the fact that the pump systems are very powerful, the patient must be closely monitored. When properly used, these current state-of-the-art-systems are safe, effective and have several distinct advantages over the use of gravity. ■