Arthroscopic Knot tying

by

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Introduction:
Surgical knot tying has been a basic surgical skill for centuries. Over 1400 different knots have been described throughout the centuries of which most have their roots in fishing and sailing. Orthopaedic knot tying used to be less of a technical difficulty than in other general surgery subspecialties, however, with the advent of minimally invasive techniques, arthroscopic surgery of the shoulder in particular, the need for simple but effective knot tying in tight spaces has become a crucial issue for the success of the surgical procedure. Particularly in the shoulder the difficulty arises from the need to deliver an effective knot through soft tissue tunnels or cannulas over a distance. The knot can not be tied until delivered through the soft tissues and has to be tied effectively with the use of finger extenders.

Despite the vast array of different knot options there are only few knots that are suited for the use in arthroscopic surgeries. The knots have to meet two major criteria: (1) the knot must be easily tightened and locked once it has been delivered to the target tissue and (2) the knot may not slide once it has been tied.

The major difficulty with arthroscopic knot tying arises out of the need to tie the knot across a distance through a soft tissue envelope. During the process of knot tying the tension of the knot has to be maintained without incorporating distant tissues into the suture loop.

The purpose of this chapter is to introduce the reader briefly to the basic background of arthroscopic knot tying and guide him through the basic steps that may cause problems during the knot tying process. Finally we will provide our technique of basic arthroscopic knot tying in a step-by-step fashion providing a simple guide to the reader.

Basic Nomenclature / Definitions:
Any suture passing through tissue will end up with two separate limbs. The one limb will be held tight and serves as the post around which the knot will be tied. The other limb stays loose and will be looped around the post creating the knot. This limb is called the non-post or wrapping suture. The post limb defines where the knot is going to be placed in the tissue since the thrown knot will glide along the post down towards the
tissue. Although the post and the non-post can be arbitrarily chosen by the surgeon it is important to consider the placement of the final knot. For labral repairs or SLAP repairs for example, one would not like to have the knot sit directly on the glenoid surface but rather on the labral surface where the knot is less likely to interfere with joint mechanics. It is therefore important to choose the suture limb penetrating the labrum (or farthest from the joint) as the post in order to guide the knot down onto the labral surface away from the glenoid cartilage. In rotator cuff repair fixation, the post is the limb that passes through the tendon.

Furthermore it is important for knot security to understand the concept of switching the post. When switching the post the surgeon alternates the post for each successive loop. Another important concept is that of tying alternating over- and underhanded knots. This refers to the direction in which the loop passes around the post and refers to the free suture limb passing over or under the post when the knot is thrown.

Basic Knots:

Arthroscopic surgeons encounter two basic suture configurations that require fundamentally different knot tying techniques. The suture from an anchor that has been passed through soft tissue can either be sliding free through the tissue or eyelet of the anchor or, it can be tethered at the anchor or within the tissue itself. If the suture is sliding free the surgeon has the option to either tie a sliding or a non-sliding knot. If the suture is tethered only a non-sliding knot can be tied. Since any suture can end up being tethered at the anchor eyelet or inside the tissue the surgeon is well advised to have at least one sliding and one non-sliding knot in his armament.

Sliding knots:

Sliding knots can only be used with sutures that are free gliding through soft tissues and/or the suture anchor eyelet. Before a sliding knot is utilized it is imperative that the free passage of both suture limbs is verified.
The basic principle of a sliding knot is that the knot is assembled entirely outside the cannula or joint around the post limb of the suture. The knot typically is dressed and tightened around the post. Once the knot is dressed it slides down the post limb by pulling on the post limb until the sliding knot sits directly on top of the soft tissue. Sliding knots have a better ability to maintain their tension than non-sliding knots and are therefore preferentially used in situations where tissue needs to be tied under tension. Multiple different sliding knots have been described, such as the “Duncan loop”(1), the “Tennessee Slider”, the “Roeder”(2), the “SMC” (3), the “Weston”(4) knot and others (5). At this point we will not describe these knots individually. At the end of this chapter we will describe our preferred sliding knot. Any of the above mentioned sliding knots will be appropriate if tied correctly. It is therefore important for the arthroscopic surgeon to be able to tie at least one of these knots well and reproducibly.

Sliding knots can further be subdivided into locking and non-locking knots. A nonlocking sliding knot can be delivered to the tissue and can be initially tensioned. It will, however, not maintain its initial tension unless it is secured by alternating half hitches that need to be tied subsequently. An example of a nonlocking sliding knot is the “Duncan loop”.

Locking sliding knots have the advantage that they can be delivered to the tissue and can be tensioned in situ without having to add additional half hitches for knot security. The sequence to allow for the knot locking involves usually a reversal of the post such that the loop captures the post. Once this maneuver has been performed the knot can not be tightened further. Also the knot will loose some of its initial tension due to the fact that the post / nonpost reversal will allow the knot to fold back onto itself and therefore increase the size of the initial suture loop minimally.

A third group of knots are sliding knots that can only be advanced in one direction along the post. These so called ratchet knots have the advantage of a sliding knot that locks once the soft tissue pressure acts against it. These knots, however, still require a set of alternating half hitches for adequate knot security. An example of the ratchet knot is “Nicky’s knot”(6) or the “Giant knot”(7).
Non-Sliding Knots:

If the suture limbs do not readily pass through the tissue or suture anchor, a non-sliding knot has to be used. Non-sliding knots are tied outside the cannula as single over or underhanded loops and then sequentially passed through the cannula to the tissue. The difficulty with these knots is that they have to be tensioned carefully at the tissue and the tension has to be maintained while the next loop is being passed down through the cannula. One example of a non-sliding knot is the simple “square knot”. It is the most difficult knot to tie arthroscopically, since it requires equal tension on both limbs to prevent the knot from converting into a stack of half hitches that will not maintain its tension. It is therefore rarely used. Another example of a non-sliding knot is the “Revo knot”(8).

Knot and Loop security:

The two basic principles in knot tying are knot and loop security.

Loop security can be defined as the ability of the suture loop holding the tissue to maintain the initial tension and length as the knot is tied and tightened. Loop security is obviously greatest when the knot is initially tightened, and it is important not to loose knot security during the process of completing the knot. Loop security can be influenced by the mechanical property of the suture used and by the initial tension that was applied while tightening the knot.

Knot security can be defined as the ability of the knot to withstand slippage and hold its initial tension. It is important to understand that loop security and knot security play their role together. If the knot is not secure the loop will not be able to stay secure. If the loop is not tensioned securely initially, the knot will not create soft tissue fixation alone.

Biomechanical experiments on knot security have shown that there is a significant difference between different suture materials in terms of their knot security. Loutzenheiser et al. showed that braided sutures (Ethibond) had 10%-50% greater holding strengths and 50% less knot slippage than non-braided (PDS) knots. His groups also showed that complex knots (Duncan loop and Revo knot) where 50% stronger than
the overhand throw knot when tied with a braided suture (9) Burkhart et al. found that non-braided sutures may provide better knot security when tied on non-alternating posts (10), however, Loutzenheiser could show clearly that half hitches along alternating posts have a much higher knot security than half hitches along the same post (9). The overall strength that a knot may need to withstand is not known. However, Burkhart could show that cyclic loading of suture repairs leads to failure through the suture-soft tissue junction, and not necessarily through the knot or the loop. The cyclic loading therefore may not have such a great impact on the loop and knot security. It is estimated that that sudden loading through muscular contracture may stress the individual suture up to 60N (10). According to Loutzenheiser the alternating posts with a braided suture would technically be able to withstand this force as would the Duncan loop tied with PDS (9). These forces can be lowered by utilizing double armed anchors and distributing more than one suture per centimeter. In this case the maximum load can be reduced to approximately 37N (10). All tested knot configurations where able to withstand this load without knot slippage or loss of loop security.

Suture Management:

Suture Material:

A vast variety of suture material is available to the orthopaedic surgeon. Principally suture material can be divided according to its absorbability, whether they are braided or monofilament and if they are reinforced through ultrabraiding (MaxBraid, Arthrotek, Warsaw, IN) or additional core material such as kevlar (Fiberwire, Arthrex, Naples, FL).

Most arthroscopic surgeons prefer non-resorbable sutures for their repairs since absorbable sutures, either braided (i.e. Panacryl, Ethicon,Somerville, NJ) or monofilament (Polydioxanone [PDS]) have a lower tensile strength and are designed to loose strength over time. While this is a desired property for soft tissue repairs near the skin or in muscle, it may not be desirable for tendon or cartilage to bone repairs.

Non-absorbable sutures have been popular among arthroscopic surgeons for their high initial tensile strength. The most popular suture material has traditionally been
braided polyester. The use of #2 polyester sutures (i.e. Ethibond, Ethicon, Somerville, NJ) used to be the standard suture used for rotator cuff repairs and labral refixation. Recently, reinforced braided polyester sutures have been introduced that provide significantly higher tensile strengths and are close to “unbreakable” during the knot tying process. These suture materials are reinforced by an ultrabraiding process (MaxBraid, Arthrotek) or by co weaving of metallic filaments such as kevlar (Fiberwire, Arthrex, Naples, FL).

Suture material has its main impact during the process of knot tying. This is where its handling characteristics can play a crucial role. While monofilament sutures are stiffer, more ductile and tend to slide better they also have a memory and recoil making maintenance of knot security difficult. Braided suture material generally is less stiff, leads to more friction during the knot tying process and is more pliable, making maintenance of knot security easier, although it may be slightly more difficult to slide the knot into place.

The newer “unbreakable” sutures are not all the same. MaxBraid is a braided polyethylene suture with a hollow core. It has enhanced lubricity, meaning it slides very well while tying knots. Because the core is hollow, as the knot is tied, the suture material deforms. This enhances knot security and prevents loss of loop security. The number of throws needed to create a “locked” secure knot is not increased. This is different and better than the characteristics of the most popular Kevlar core “unbreakable” suture, which does not deform, has high lubricity, but requires potentially more half hitches to prevent slippage and create the necessary knot security.

The ultimate tensile strength of braided polyester sutures exceeds the required force that has been calculated to act on a single suture in a rotator cuff repair (10). Hence, many surgeons continue to use just simple braided polyester sutures for their repairs because they feel that the suture has slightly less friction than the new reinforced polyester sutures and therefore may be easier to tie. Others prefer the security that the reinforced polyester sutures provide during the knot tying process and will accept the slightly higher friction. Ultimately it depends on the individual surgeons’ preference which suture material is used. As a general rule, one should know the advantages and disadvantages of the suture material used, in order to anticipate problems during the knot tying process.
The other knot tying issue the surgeon should have knowledge of is the characteristics of the chosen anchors’ eyelet. Early metallic anchors had edges on the eyelets that could fatigue and wear suture material. This led to suture breakage during the knot tying process. Repetitive cycling the suture material through the eyelet was shown to weaken the suture material. This led to re-design of eyelets with smoother edges. The non-metallic anchors (plastic and bio-absorbable) evolved with more suture friendly eyelets. Suture eyelet orientation is important to consider, depending upon what type of repair, and what type to stitch configuration is being used. In general terms the surgeon should try to align the eyelet so that it is facing the direction the suture is traveling to and through the tissue and will be tied. This will prevent kinking at the anchor eyelet, allow suture sliding, and allow the loop to be tightened efficiently.

Arthroscopic Cannulas:
As a general rule, cannula placement is the single most critical aspect of knot tying and anchor placement in shoulder surgery. It is not the goal of this chapter to explain the different concepts of cannula placement for the different procedures since this will be done in great detail in the following chapters. However, there are some general aspects about arthroscopic cannulas that we would like to address at this stage.
The arthroscopic cannula is designed to help with the knot delivery, increase knot tying visualization and help avoid tanglement of sutures during the knot tying process. Arthroscopic cannulas can generally be divided into clear and not-clear cannulas. Not clear cannulas are usually of smaller diameter (5-6mm) and are designed to be primarily outflow cannulas for fluid management, they usually accommodate a small shaver blade or an arthroscopic probe, they are not designed to accommodate larger instruments or knot tying. Larger cannulas (6 – 8.25mm) that are designed for larger instruments and knot tying are usually clear cannulas. These cannulas improve visualization of the suture material inside the joint as well as outside the joint. This helps to avoid tangles. Many larger cannulas have threads that prevent dislodgement during the knot tying or anchor placement process. In order for cannulas to help during the knot tying process they have to be deliver in a straight line to the area of interest. This can become a challenge in very
muscular or large individuals. For those cases it may be advisable to have extra long arthroscopic cannulas available.

Use of a knot pusher:

Once the knot has been tied it has to be advanced into the joint. This generally requires a knot pusher. If a sliding knot is utilized the knot pusher is placed on the post limb of the suture in order to gently push the assembled sliding knot down the post to its destination. This does generally not require much pressure since the sliding knot is simultaneously pulled down the post. Once the knot is delivered to the tissue the knot pusher should be used to tightly position the knot on the tissue with gentle pressure. This process ensures initial knot and loop security.

The knot pusher is used differently when half hitches are tied. During the process of tying half hitches the surgeon alternates over and underhanded half hitches and also switches posts in order to provide excellent knot security. Since the half hitch is a loose loop tied around the post several problems can arise during the process of pushing the half hitch along the post. The pusher can easily be pushed passed the knot and simply not deliver the knot down the post at all. If an overhand loop is thrown around the post and knot pusher is advanced along the post it will lead to a “jerky” advancement and requires alternating tension on the post and non-post that can lead to fraying of the suture and eventual breakage. Chan and Burkhart advised the arthroscopic surgeon to utilize the knot pusher to “pull” an overhand loop of the non-post limb down the post limb. This is done by having the knot pusher on the non-post limb and leading the half hitch down the post limb. Thus the knot pusher “pulls” the half hitch behind it into the joint and then tightens the throw with the “past pointing” position. This will lead to a smooth delivery of the half hitch avoiding suture fraying. Once the knot has been delivered to the tissue it can either be past-pointed to 180° or the tension can be switched from the post to the non-post flipping the knot and thus allow for tying of half hitches around alternating posts without the need to move the knot pusher to the non-post limb (11).

There are different types of knot pushers available. Single looped knot pushers can be either straight barreled with a small oblique opening at the tip through which the suture is passed or they can be shaped like a small shoe with a ring at the end through
which the suture is passed. Any of the single-hole knot pushers can be utilized to tie any sliding or non-sliding knot proficiently. A thumb hole is an accepted feature that all knot pushers incorporate. Double diameter knot pushers have been introduced in order to help with the initial loop security while the knot is being finished. The inner diameter knot pusher will hold the knot in place while the securing half hitch is advanced by the outer diameter pusher. This is an excellent tool to improve initial loop security.

Our Technique:

We feel that an arthroscopic surgeon has to have at least one sliding and one non-sliding knot or knot arrangement in the armamentarium in order to safely and successfully manage suture repairs. While much has been talked about which knot is most secure and new knots or variations of knots appear at every meeting we feel that the most important aspect is to know the knot that you are using and be able to tie it reliably under difficult conditions. In the following we will describe our preferred sliding knot as well as our preferred non-sliding knot followed by some tips and tricks that may be helpful.

Our preferred sliding knot:

In our practice we utilize “Nicky’s knot” (taut line hitch). This is a sliding “ratchet” knot that has an excellent initial locking ability while being a non-locked sliding knot. We tie Nicky’s knot as initially described by DeBeer et al. (6). After the suture is past through the tissue, both suture limbs are brought out the same cannula. The post limb is confirmed and a suture manipulator/grasper is run down the limb to confirm that there are no tangles. Then the ability of the suture to slide through the tissue and the anchor is confirmed. Then and only then, is the sliding knot tied. The post limb is shortened. A right handed tie starts with an overhand half hitch around the post, but the hitch is not tightened around the post, preserving the hitch loop. Then the free suture is passed overhand again around the post, but through the same half hitch loop formed by the first throw. A third overhand half hitch is now thrown, but through its own hitch loop and behind the previous two throws on the post (Fig. 1a-c, Fig 2-3). The knot is lightly dressed. The knot pusher is placed on the post limb. The knot is easily advanced in only
one direction by pulling on the post. The post limb is pulled, “pulling” the knot into the joint with the knot pusher “chasing” the knot but not pushing it. Once the knot is down onto the tissue, the knot pusher pushes the knot down while still pulling on the post limb. Once the Nicky knot is set it will stay, but loop security can be enhanced by now tensioning the loop limb to “lock” the knot. This then allows the surgeon to secure the knot completely with three individual half hitches. We then secure the knot with three alternating half hitches, also alternating the post. It is a fast, easy knot to tie. It has excellent loop and knot security characteristic and can be used in almost every repair application is shoulder surgery where a sliding knot is appropriate (Figure 4+5).

Our preferred non-sliding knot:

We utilize five alternating half hitches switching the post twice. This knot is also called the “Revo knot” (8). The initial two half hitches are tied over handed down the same post. Even though it is a non-sliding knot, there is usually the ability to tension and tighten the knot by pulling on the non-post limb as the throws are brought down and past pointing is done to tighten them. The third half hitch is an underhand throw down the same post. The fourth hitch is again an overhand hitch down the same post. Then the post is switched and alternated with the finishing two half hitches. Thus the first four throws are down the same post and can be thought of as: hitch A, A, B, A. This non-sliding knot can be tensioned easily due to the initial two half hitches that are thrown in the same direction. Loop security can be maintained easily.

Tips / Tricks

Finally we would like to point out a couple of little details that can help tremendously during the knot tying process.

By far the most annoying and frequent problem during the process of knot tying is tanglement of sutures. In order to avoid tanglement one should try to place the cannula directly over the area that is going to be tied. The cannula should not come out of the joint during this process since it may re-enter through a different pass and the suture may be caught in soft tissues that will be incorporated into the knot before it has reached its
destination. In addition it is advisable to only store the suture limbs of the suture being tied in the working cannula. All other sutures should be stored in a different portal. Suture should ideally pass straight through the tissue that is going to be tied together. When using anchors the eyelet should be facing the direction of suture travel to and through the tissue. This helps prevent that the suture does not get kinked in the eyelet. This may create false loop security (the loop is not actually as tight as you think it looks). Suture abrasion at the eyelet is minimized with proper eyelet orientation. Finally one should always run a knot pusher down the individual suture limbs in order to assure that there is no tangle inside the cannula. Free passage of the knot pusher down the post limb will assure this. Follow you knot with your eyes (and the arthroscope). If the knot is tied and it appears to be tangled it is important not to tighten the knot down since at this stage it may still be reversed or untangled using a hooked probe. If a knot is tied down and appears loose one may try to untangle the knot with a hooked probe. If all fails it is better to remove the suture and start over.

Conclusion:

In this chapter we have provided a concise introduction to the art of arthroscopic knot tying. By providing the necessary basics of knot tying we helped establish the background. As so many skills in orthopaedic surgery, knot tying is dependent upon repetition, experience and meticulous attention to detail. Our preferred technique may act as a guideline along this process but requires each individuals practice in order to become a successful arthroscopic surgeon.

References:


11. Chan KC, Burkhart SS. How to switch posts without rethreading when tying half hitches. Arthroscopy 15: 444-450; 1999
Captions for Illustrations

Fig:
1A [Nicky knot 1st overhand throw]: To tie Nicky’s Knot (taut-lint hitch) a sliding locking knot, the post limb is shortened (stippled limb). The loop limb (plain limb) is past in an overhand hitch.

1B: [Nicky Knot 2nd overhand throw] The loop limb is passed again in an overhand throw around the post limb, but past through the same suture loop formed by the first throw.
1C: [Nicky knot 3rd overhand behind in separate loop] The loop limb is now passed as a third overhand throw around the post, but through a separate suture loop behind the first two throws.

Fig 2: [nicky dressed ready to slide]: The knot is *lightly* dressed and the loop limb left free. The knot will pulled into the joint by pulling on the post limb. A knot pusher is placed on the post limb and “chases” the knot into the joint.
Fig 3: [Nicky tight closure] When the Nicky knot is pulled into the joint, it will tighten around the soft tissue with excellent loop security. The ratchet character of the knot will not allow it to slide backwards.

Fig 4: [Nicky knot L RCR onto cuff] A sliding, locking knot almost down to the rotator cuff in a left shoulder. Note the knot pusher just behind the knot. When the knot gets down onto the cuff, the knot pusher will push the knot down, the post limb will be pulled and the loop limb can be tensioned to “lock” the knot even more securely.
Fig 5: [Nicky knot coming down cannula] A second Nicky knot is seen being pulled down the clear cannula in this left arthroscopic rotator cuff repair. Note the knot configuration and that it “travels” down the post limb onto the soft tissues. The knot is secured with three alternating half hitches with alternating posts.