



Course Notes

Core Surgical Skills: Knot Tying with Instruments and Hands

Introduction to Knot Tying

SUTURE STRANDS

There are two basic types of sutures available to surgeons, those with needles attached to a suture strand and those without needles. A suture without a needle is often called a “free tie”. Free ties are useful when ligating vessels and pedicles. Sutures with needles are frequently used when the surgeon must bring the edges of tissue into apposition or during the placement of “stay” sutures to hold tissue in position during surgery.

Suture strands with needles have three main components. The junction where a needle is fused to the suture strand is termed the “swage”. The portion of the strand opposite the end connected to the needle is called the “free” or working strand. The portion of the strand on the end connected to the needle is termed the “fixed” or nonworking strand.

It is important to understand these terms, because proper suture strand set-up is crucial to safe and consistent knot creation. When a knot is placed, the free/working end (without the needle), rather than the fixed/nonworking end (with a needle), is drawn through the suture loop. If possible, the fixed or nonworking strand connected to the needle should not be pulled through the loop when creating a throw, since this action can inflict injury to the surgeon or the patient.

THROWS AND KNOTS

Throw: a term used to describe a complete twist of the two opposing strands of suture. A completed throw forms an enclosed loop. A completed “knot” usually consists of at least two tight throws, laid one on top of the other in a specific configuration.

Suture Loop: the part of the stitch or ligature that contains tissue. The suture loop, completed by the knot, maintains approximation of divided wound edges or provides occlusion of a vascular structure. The orientation of the suture loop is important to understand, particularly when applying tension to the two strands to complete a knot. Ideally, for most knots performed in surgery, the surgeon pulls the strands in opposite directions and in-line or parallel with the orientation of the suture loop.

Square Knot: the most commonly used knot in surgery because it is one of the least complex and most secure knots a surgeon can make. On the first throw of a square knot, the surgeon is merely twisting one strand of suture around the other, with the suture ends exiting in opposite directions of the loop. On the next throw, the surgeon reverses the cross of the strands, with the suture ends positioned in the opposite direction, to create the square knot.

Knot Ear: when a knot is completed, the suture ends are cut with scissors, creating what is referred to as knot ears. The length of the knot ear is an important factor in secure knot creation. Ears that are cut too short tend to unravel. However, ears that are left too long tend to induce tissue reaction. The term “stiff ears” is sometimes used to describe knot ears that produce significant friction-induced inflammation, as the loose tissue moves across the ends of the prickly knot. Stiff ears are a function the type of suture, its gauge, and the length of the ears. The surgeon must keep these factors in mind when deciding what length to cut the knot ears.

Intrinsic Suture Tension: a stitch is created when a bite of tissue is taken with a needle through one side of a wound to the other, and the loop is tightened to appose the cut edges. A ligature is when suture material is passed around a structure to provide occlusion or intentional crushing of the structure. The amount of tension created in the tissue gathered within this loop is termed the “intrinsic suture tension”. The intrinsic suture tension will vary depending on the needs of the surgeon. For example, a ligature designed to crush down an ovarian pedicle to achieve hemostasis during ovariectomy should have high intrinsic suture tension to prevent blood leakage. However, sutures designed to gently appose skin or delicate viscera have relatively low intrinsic suture tension. It is important to understand that it is the surgeon’s knot tying technique that ultimately dictates the intrinsic suture tension within the suture loop required to appose tissue edges or control bleeding in a vascular pedicle.

THE THREE BASIC STEPS OF KNOT CONSTRUCTION

Step 1: The first step in making a surgical knot is to create the suture loop. This is achieved by pulling on the strands of a throw in opposite directions to create the appropriate intrinsic suture tension. Once the throw contacts the wound or vessel, the surgeon will have a preview of the ultimate apposition of the wound edges or tightness of the ligature. In the

case of organ or skin closure, ideally, the suture loop should approximate the divided wound edges without strangulating the encircled tissue. If there still is some separation of wound edges, the throw can be advanced further to reduce the size of the suture loop and, thereby, to bring the wound edges closer and more firmly together. For ligation, however, the suture loop should crush with the first throw and tightly bind the occluded vessel.

Step 2: The second step in the procedure serves to lock the knot in place. This usually involves creating a set of square throws, snugged on top of each other, over the initial throw.

Step 3: The third step required to create a surgical knot involves cutting the knot ears. It is important to cut the ears at the appropriate length, as this length of suture extending from the knot helps to prevent the knot from unraveling.

BASIC KNOT TYING RULES

There are eight important rules that surgeons should follow when tying and securing knots.

Rule #1: The primary objective in knot tying is to ensure knot security with the least number of throws. The square knot is almost exclusively used in surgery since it is the simplest and most secure knot.

Rule #2: When creating a knot, always select the appropriate suture gauge to ensure that the knot will be as small as possible. Knots made using smaller-sized material are generally more secure and their knot ears cause less mechanical irritation to surrounding tissues. Additionally, if smaller knots are compressed down between the wound edges, these knots do not separate tissue edges as much as bulkier knots.

Rule #3: It is important to avoid creating friction between the suture strands as the knot throws are being tightened. Attempt to tighten throws by pulling in opposite directions in a horizontal plane while slowly pushing down toward the tissue plane with similar rate and tension.

Rule #4: While tying a knot, do not crush or kink the suture with surgical instruments or your hands, because this will compromise the strength of the suture. Instead, grasp the suture with needle holders only on the portion that will be cut and discarded.

Rule #5: For sutures intended for tissue approximation, avoid creating excessive intrinsic suture tension. Minimizing suture tension will help to reduce tissue cutting, tissue ischemia, and resultant postoperative pain.

Rule #6: Avoid cutting knot ears too short, particularly with suture material that has known knot security issues. If ears are left too long, however, irritation from the suture ends can create unwanted tissue inflammation.

Rule #7: When tying a knot, try not to cross your hands or arms, since doing so will obstruct your line of vision. Instead, adjust your body position whenever necessary to facilitate tying toward and away from your body.

Rule #8: It is important to ALWAYS setup for your knot tying the same way each and every time you attempt a manual or instrument tie. Repetition and consistency allows the surgeon to develop a “muscle memory” of the physical motions necessary to create a knot correctly.

KNOT SECURITY

Length of Knot Ears

Generally speaking, the length of knot ear required to form a secure knot is related to the inherent “memory” or stiffness of the suture. For most synthetic sutures used in surgery today, leaving 3 mm ears on knots is recommended. If knot ears are cut more flush with the knot, an additional throw is required to maintain knot security. For chromic catgut, adding an additional 1 to 2 mm of length to the standard knot ear length (i.e., a total of 4 to 5 mm) is recommended, since catgut suture swells as it absorbs body fluid, and this might cause the last throw on the knot to untie, particularly when the ears are cut short.

Monofilament Sutures

Monofilament suture materials possess greater memory (i.e., suture tendency to retain its shape after it is manufactured) than multifilament suture. Monofilament also has a lower coefficient of friction (i.e., more slippery) than multifilament materials. These characteristics have a direct impact on knot security. The security of the knot made with monofilament materials is associated with how it is formed (e.g., square versus granny) and also with how the round suture shape changes as it is tensioned. This change in shape is called “plastic deformation”. The round shape becomes somewhat flattened and creased when deformed, locking the suture strands together, which resists untying or loosening. To lock monofilament sutures, they must be snugged down and pulled tightly together to deform the shape of the suture within the knot. The

surgeon will know that the knot has undergone plastic deformation and is secure when there is no tendency for the spaces between the throws to open after tension on the strands is released. Therefore, when using monofilament suture, surgeons should strive to see no “daylight” between the throws of their knots.

Keep in mind that the stiffer the suture and the larger the size of monofilament suture, the more tension is required on the strands to adequately deform the suture and secure the knot. This plastic deformation is similar to what happens to a plastic water container when it is crushed rather than being squeezed. The original shape of the container is maintained when it is gently squeezed, but it is permanently misshapen when it is crushed. Similarly, the thicker the suture, the harder it is to plastically deform, in much the same way as plastic gallon milk containers are much more difficult to permanently deform when compared to thin plastic water bottles.

Multifilament Sutures

Multifilament suture such as silk, polyester, and chromic catgut possess a higher coefficient of friction on their surfaces than monofilament suture. Multifilament sutures generally tie and handle better than their monofilament counterparts due to their supple, flexible character.

Friction is the main mechanism responsible for knot security with multi-stranded suture materials. In some cases, a coating is applied to braided suture materials to facilitate its passage through tissue and to improve handling properties. However, the slippery nature of the coating often worsens the suture's knot security. To compensate for this characteristic, coated polyglycolic acid or polyglactin 910 (both commonly used braided synthetic absorbable sutures) require 4 to 5 throws to form secure knots, whereas these same sutures supplied without coating can require fewer throws. However, not all suture coatings reduce knot security; some absorbable coatings dissolve quickly and reveal the underlying rough substrate surface, which enhances friction between the strands.

As a general rule, multifilament sutures become secure with considerably less tension applied to the strands when compared to monofilament sutures. However, all sutures must be knotted snugly and squarely to be confidently secure.

NUMBER OF THROWS TO CREATE A SECURE KNOT

Knots Made with Multifilament

Most multifilament suture materials should have three interlocking square knots, made with four squarely created throws. In actuality, only three throws are required for security. However, if one of the three throws is incorrectly formed, the knot could lose security. For this reason, most surgeons like to add an extra fourth throw for peace of mind.

Knots Made with Monofilament

With monofilament suture materials, particularly when used on critical lines (e.g., simple interrupted abdominal fascia closure or crucial ligations), 5 square throws are recommended on “single strand to single strand” knots. Again, 4 tight and squarely formed throws are considered secure, but one extra throw is added for confidence.

Knotting a Penultimate Loop

When placing a continuous suture line, special consideration must be given to knot security. In a continuous suture pattern, a knot is placed at the beginning of the line and a knot at the end of the line (called the penultimate loop because the surgeon must create a doubled stranded “loop” to provide an opposite strand end for knotting). Thus, the security of an entire continuous suture line depends on only two square knots. If one of these crucial knots unravels, catastrophic failure of the line will occur with potentially life-threatening results. Therefore, when using continuous suture patterns on tough tissues under tension or on body wall closures, most surgeons recommend adding an additional throw to the beginning knot (i.e., a total of 6 throws) on top of what they would normally tie on interrupted lines. Similarly, it is recommended to add two additional square throws for knotting the penultimate loop (i.e., a total of 7 throws).

Getting Started

HAND AND FINGER POSITION TERMINOLOGY

Proximal/Distal: In this module, the terms proximal and distal are used to indicate toward or away from the body. For example, the distal aspect of the thumb is the tip of the thumb, whereas the proximal portion is the first phalanx.

Palmar/Dorsal: The term palmar refers to the front or palm of the hand, while the term dorsal refers to the back of the hand.

Flexion/Extension: The term flexion refers to the act of bending a joint, while the term extension refers to the act of straightening a joint.

Supination/Pronation: The terms supination and pronation refer to hand/wrist rotations. With your hands pointing away from you in a neutral position, as if you were to extend your hand for a handshake, supination refers to the act of rotating the palmar surface of the hand upward. Pronation is the opposite wrist motion and refers to rotation of the palmar surface of the hand downward. Some students use a mnemonic to help them remember the difference between supination and pronation. Picture the direction of your hand and wrist motion when scooping soup from a bowl and use the word soup to remind you that this motion is called supination.

LEARNING TO UNCOUPLE YOUR FINGERS

During manual knot tying, you will notice that surgeons rarely lose control of the suture strands. Maintaining control of the strands at all times during knot tying allows for rapid knotting, and it controls tension between strands, resulting in uniform consistent square knots. Most hand ties utilize the thumb and index finger and occasionally the middle finger for the majority of the finger manipulations. This leaves the ring and little fingers available for grasping and holding the fixed strand.

To gain the dexterity required to perform manual knot tying, you will need to practice “uncoupling” your fingers. Using your practice rope, hold onto the rope strand with your ring and little fingers, and manipulate the free end with your thumb, index, and middle fingers. Practice these manipulations until you are comfortable independently moving your two sets of fingers.

ADOPTING A CONSISTENT SET-UP FOR KNOT TYING

When creating any suture, surgeons must “declare” their position relative to the incision being sutured or the structure being ligated. The adoption of a consistent set-up, wherein the surgeon’s arms and hands move in the same manner each and every time a knot is created, allows the surgeon to develop a “muscle memory” for how to tie a proper knot. Using a consistent set-up is particularly important for novice surgeons who must learn to “feel” when a knot is formed correctly and when it is formed incorrectly.

Novice surgeons often struggle to master the consistent set-up, particularly when the body and arm positions must be adjusted to accommodate the various tissue planes within a surgical field. To help you master this technique, learn how to commit your body position when knot tying so that your hands always move comfortably toward and away from your body during knot tying. Remember the suture loop should be positioned perpendicular to the tie plane of the structure you are closing or ligating. Your arm direction should run parallel to your intended suture loop plane. That way, your body and hand position will always feel the same when tying knots, regardless of the tissue orientation that you encounter. Once you have reached the appropriate perspective for arm movement and suture loop position, commit yourself to this perspective, and do not change these until all throws on the knot have been completed.

Practical Knot Tying Techniques

LEARNING TO GATHER AND SLIDE SUTURE

When tying knots using the instrument or hand tie techniques, surgeons must be able to lengthen or shorten suture strands in order to achieve the proper working distance to a knot. Gathering and sliding maneuvers are finger movements used to adjust the length of the suture strands. Both gathering and sliding can be combined to achieve the perfect working distance when tying knots.

Length of Suture: When tying knots, it is important to grasp the suture at a comfortable working distance from the knot. To ensure that you have a sufficient length of suture to work with, follow these guidelines.

- For instrument ties, the fixed suture strand should be held 3 to 4 inches (8–10 cm) from the knot, and the free strand should be around 1 to 2 inches (3–5 cm) from the knot.
- For most hand tie applications, 4 to 6 inches (10–16 cm) of suture strand on both the fixed and free ends should be available to establish a comfortable working distance to the knot.
- When using the rope to practice instrument ties, you might find it easier to work with the rope if you add a few more inches to your strands.

To achieve these optimal working distances, the surgeon will need to use a combination of gathering and sliding maneuvers to adjust the working distance to the knot.

Gathering: “Gathering” is a term used to describe the finger maneuver used to shorten the working distance from a knot. To gather suture, grasp the suture strand that needs to be adjusted between the tips of the thumb and index finger. Use only your fingertips so that the strands can be handled delicately. Supinate your hand and regrip the suture with your three free digits. Note that the index finger and thumb hike up on the suture, and the middle, ring, and little fingers hold on to the bulk of the suture. If you need to reduce the working distance further, release the suture held in your three fingers and pronate your hand to regrip the strand closer to the knot. This maneuver can be repeated as many times as necessary to achieve the desired working distance from the knot. Note that each regrip of the suture shortens the working distance by one hand-width.

Sliding: “Sliding” is a term used to describe the finger maneuver used to fine-tune the working distance to the knot. To slide suture, firmly grasp the suture strand with your non-dominant hand. Then lightly grasp the suture between the thumb and index finger. Slide your hand up and away from the knot, slipping the strand between your fingers to increase the working distance. Sliding can also be accomplished at the end of the gathering maneuver, without releasing the suture from your three fingers, by allowing the suture to slide slightly through the hand.

INSTRUMENT TIE TECHNIQUES

Creating Square Knots with an Instrument Tie: The square knot is the simplest and most secure knot available to surgeons; hence, it is the most common knot used in operating rooms. Watch a video demonstration: <http://bit.ly/2bh30IJ>

Avoiding Granny Knots During Instrument Ties: It is important for novice surgeons to be able to identify secure square knots and to recognize the less secure granny knots. Surgeons must understand how granny knots are formed so that these knots can be avoided. When practicing knot tying, look carefully at the formed knot to identify when it has been incorrectly performed, and carefully examine your technique to understand why a granny knot developed.

When attempting to tie a square knot, there are three mistakes that a surgeon can make, resulting in a granny knot. The first scenario occurs when the surgeon fails to place the needle holders from the same side horizontally into the formed loop. The second scenario occurs when the needle holders are placed below the long strand as it is wrapped around the needle holders. The third scenario results from a failure to alternate the direction of tension on the strands for each throw.

Granny knots produce a non-secure stitch or ligature, so you should know how to avoid creating this knot and how to identify it. To evaluate a completed knot to ensure it is square, conceptualize the knot as a “circle” with two strands coming out from the “circle” on each side. If the paired strands end on different sides, it is a square knot. If the paired strands end on the same side of the circle, it is a granny knot. You might not always be able to see whether the knot configuration is square, particularly with thinner suture materials. Therefore, it is critical to practice knot tying using the same technique and perspective. Consistency creates a psychomotor “memory” of the exercise, so when a throw is not performed correctly, this automatically signals to the surgeon that the throw was wrong, and corrective measures can be taken to make the knot secure.

Avoiding Slip Knots During Instrument Ties: It is important for novice surgeons to be able to identify secure square knots and to recognize a less secure slip knot. Surgeons must understand how slip knots are formed so that these knots can be avoided. When practicing knot tying, look carefully at the formed knot to identify when it has been incorrectly performed, and carefully examine your technique to understand why a slip knot developed. A slip knot occurs when unequal tension is applied on one end of the strand, which can occur on either the fixed or working side of the suture strand. As mentioned previously, advanced knot-tying techniques may purposefully include slip knots; however, these should be avoided if the objective is to create a secure square knot.

Surgeon’s Knot: The surgeon’s knot is similar to the instrument square-knot technique. The main difference is that, on the first throw, the fixed strand is looped around the needle holder not once, but twice. The surgeon’s knot has specific limitations and indications, and it should not be used as a routine method of suturing or ligating tissue. Watch a video demonstration: <http://bit.ly/2bh30IJ>

HAND TIE TECHNIQUES

Two-hand Technique: During the two-hand technique, the surgeon handles both ends of the suture strand to form the knot, and both hands are actively involved in knot formation. The main advantage of the two-hand tie is that the surgeon can readily apply continuous and equal horizontal tension to the suture ends until a secure knot is formed. This allows the creation of a more reliable square knot. The two-hand knot-tying technique also tends to be easier for the novice surgeon to learn than the one-hand technique. Watch a video demonstration: <http://bit.ly/2bh30IJ>

One-hand Technique: During the one-hand technique, the surgeon grasps and manipulates the suture strand using either their right or left hand. Only one hand is actively involved with knot formation. With the one-hand method, it is often difficult to maintain equal tension on the suture ends during the formation of the knot. Consequently, slippage (i.e., half hitching) of the first or second throws might be encountered, especially by the inexperienced surgeon. The one-hand hand tie also generally requires more suture material to comfortably tie a knot than the two-hand technique. With the one-hand technique, however, there is less arm motion during knot tying, so the tie can be completed in restricted areas. Alternatively, the throws can be formed first and then pushed down with one finger and tightened over the structure. We recommend that the novice surgeon first master the construction of square knots with two hands and then move on to the one-hand technique if desired. Watch a video demonstration: <http://bit.ly/2bh30IJ>

Tips for One-handed Ties

1. Keep the loop you have created with each throw open until the transfer of the short strand is complete and you begin your horizontal tension on the two strands to tighten the loop.
2. Never pull up or away from the knot as you tension the knot.
3. It must be emphasized that the directions the hands travel must be reversed and kept low from one throw to the next to ensure that the knot formed will be flat and square. Otherwise, insecure half hitches inevitably result. This is the main reason novice surgeons learn two-hand knot tying first, because it is easier to maintain equal tension on both strands during and between the creation of each throw.
4. If you want more throws on top of a one-hand square knot, repeat the sequence described previously.

Combined Instrument and Two-Hand Tie: In some surgical situations, the free end of the suture is either too short or too slippery to grasp with the hand. Instead of using your dominant hand in this situation, a surgical instrument can be used as a substitute to grasp the free suture strand securely. Watch a video demonstration: <http://bit.ly/2bh30IJ>

Deep Two-Hand Tie: Tying deep in a body cavity or recess can be difficult. To avoid tearing tissue or avulsing a blood vessel while tying, the surgeon must practice forming knots without creating tension away from the tissue plane. This is best done with a two-handed tie technique. In this technique, the index fingers are used to push the throw down to the tissue plane, to help avoid creating dangerous tension.

With this technique, it is very useful to use the gathering and sliding finger and hand movements to fine-tune the amount of working space, so that your index fingers can push the throw down to form the knot. Watch a video demonstration: <http://bit.ly/2bh30IJ>

CLINICAL CONSIDERATIONS FOR KNOT TYING

Instrument versus Hand Tie

INSTRUMENT TIES	HAND TIES
Pros	
Rapid placement of sutures	Suture strands are always controlled
Conserves suture material	Offers good control (sense) of suture tension
Does not require long strands for tying	
Cons	
Free strand is not controlled during knotting	Requires ample suture material
Difficult to maintain consistent tension	
Applications	
Closing wounds under minimal tension	Pre-placement sutures
Microsurgical procedures	Deep recessed with large approaches
Deep recesses with small approaches	
General soft tissue approximation	

Instrument Ties: When tying knots with an instrument, it is difficult to control the strands during tying. The non-fixed or working end lies free between the creation of the throws, and, therefore, it is not controlled at all times. Because of this, it is tough to apply continuous tension to the suture ends as you knot tie. Consequently, widening or loosening of the suture loop due to slippage is frequently encountered during instrument tying in wounds subjected to strong tension. The instrument technique, however, is ideally suited for closing a wound that is subjected to minimal tension. In this circumstance, instrument ties can usually be accomplished more rapidly than hand ties, while conserving considerably more suture. By using instruments instead of hands, the thrifty surgeon can complete 10 or more interrupted knotted stitches using one suture strand measuring 18 inches (45 cm) in length. This feat would be impossible if the knots had been tied by hand, where a surgeon would be lucky to achieve 3 or 4 hand ties with this length of suture. The value of instrument ties is readily apparent in special situations in which hand ties are impractical or impossible. In microsurgical procedures, an instrument tie provides the most reliable and easiest method of knot construction. Instruments are also useful for forming knots in tight spaces such as deep in the mouth, in the rectum or vagina, or in endoscopic surgery.

Hand Ties: Manual knot ties also have their advantages and disadvantages. Tying knots by hand allows the surgeon to “feel” how much intrinsic suture tension has been achieved. It also allows a better gauge of the tension applied on both strands during tying. Hand ties are particularly useful when the knot is pushed (i.e., “run down” with a deep tie technique) in confined or hard to reach areas, such as in a dorsal diaphragmatic hernia. Hand ties are also useful when sutures have been preplaced. For example, individual sutures are often preplaced around the ribs in a lateral thoracotomy approach and are tagged or clamped with hemostats without tying until the series of sutures are placed along the entire length of the opened intercostal space. While the assistant crosses adjacent preplaced sutures to help draw the ribs in apposition, the surgeon can then hand knot tie more easily using one of the “friction knots”. Hand ties are also useful when working in remote areas, such as deep in body cavities. Sometimes it is difficult to manipulate instruments in remote areas, and hand throws can be created in more superficial areas of the wound first, and then the throw can be pushed (“run down”) and tightened down more easily using the fingertips. Despite the many advantages of hand ties, keep in mind that they do require more length of suture strands than instrument ties. Additionally, the longer ends have to be cut off once the hand tie is completed, which wastes suture material.

ONE-HAND VERSUS TWO-HAND TECHNIQUE

There are several important factors to consider when selecting a manual knot-tying technique. Here are some guidelines to consider when deciding whether to use a one-hand or two-hand tie.

Tip #1: Recall that the set-up for a one- or two-hand tie has the fixed strand held in opposite hands. Therefore, depending on which hand the fixed or free end is held in, the surgeon should choose the hand-tie technique that works best with that hand position. To demonstrate this concept, position your hands on each side of and parallel to the suture loop, with the strand under the structure to be secured. Next, grasp the appropriate suture ends and form the suture loop, without exchanging suture ends between the hands. If the fixed strand is in your dominant hand, you should select a one-hand technique because the suture is set-up that way. Likewise, if the fixed strand is in the non-dominant hand, a two-hand technique should be chosen. Although exchanging suture ends between the hands can be done, it is an unnecessary step that wastes valuable time. Selecting the correct technique also allows the surgeon to pass the free suture end, rather than the fixed suture end, with the needle through the suture loop. The remaining throws are formed as you have practiced; reverse the position of the hands after each additional throw.

Tip #2: If the suture strands are uncomfortably short for the creation of a one-hand tie, a two-hand tie is more easily performed. Generally speaking, a shorter suture strand is required to form a knot with the two-hand technique when compared to the one-hand technique.

Tip #3: If a knot is required within a confined body cavity, the one-hand technique is often the best choice. When there is little space for tying a knot, the one-hand knot is easier to create than a two-hand knot.

Tip #4: Both the one- and two-hand technique can be used to push throws down to form knots within deep cavities. However, most surgeons favor the two-hand technique under these circumstances.

INDICATIONS AND PRECAUTIONS FOR THE SURGEON'S KNOT

Indications: Some surgeons opt to place a surgeon's knot when wound edges are not well apposed. Under these circumstances, mild wound tension causes the first throw of the intended knot to pull apart before it is locked in with a second square throw. The additional friction created from the double suture pass of a surgeon's knot helps to keep the stitch at the appropriate intrinsic suture tension until the second throw locks the knot in place. Otherwise, if tension causes unwanted tissue loosening after the first throw is placed, and the second throw locks the knot in place, the stitch might be too loose to allow apposition of the edges. When this occurs, the stitch must be replaced.

Precautions: Surgeon's knots take slightly longer to tie than conventional square knots. More importantly, the knots are larger, which can increase suture-induced inflammation and separate tissue planes. Therefore, surgeon's knots should not be used routinely and are not recommended when tissue edges are tension-free and remain in apposition after the first square throw is completed.

A surgeon's knot is also contraindicated when tying chromic catgut suture, because increased friction between the double-wrapped strands tends to fray and significantly weaken the suture material and the knot.

In general, it is advisable to avoid a surgeon's knot during pedicle ligation, because the only practical method to determine if a ligature is tight on a thick pedicle (such as a fat filled ovarian pedicle where the suture becomes buried as it is tightened and the knot is no longer exposed) is to "feel" that there is no more "give" in the suture when tensioning the strands, indicating that the first throw is sufficiently tight. However, when a surgeon's throw is used on a pedicle, as the throw is being "snugged down", the friction in the double twisted throw might "lock" the throw prematurely, and it might "feel" as if it is tightly applied when, in fact, it is not. This is particularly true when using multifilament suture material. This problem can lead to fatal hemorrhage after surgery.

Special Considerations: Notice that when a surgeon's double twist throw is completed and the second square throw is tightened, the first throw bunches up, and the enclosed suture loop becomes tighter than the original formed loop. In other words, the intrinsic suture tension increases when the second throw is fully tightened. This tightening is not from the first throw slipping down, but rather from the "bunching up" of the double twist on the first throw. It is important to keep this in mind when using a surgeon's knot, particularly during skin suturing when the skin edges are under some tension. To address this problem, the surgeon must intentionally pull the surgeon's throw down incompletely, anticipating that the second throw will pull the tissue closer together (further tightening the intrinsic suture tension) as the double twisted throw tightens the loop during tensioning of the second throw. Otherwise, the surgeon will unintentionally create skin stitches with excessive intrinsic suture tension.

SLIPPAGE DURING KNOT TYING

When tying knots, monofilament and multifilament suture have some important differences that you must be aware of. Recall the procedure for creating a square knot. The first throw on a stitch or ligature is pulled to the appropriate intrinsic suture tension, and the second throw is tensioned to lock the suture knot in place. Subsequent throws are made to be sure the knot stays firmly fastened and secure.

Tip #1: When using multifilament suture to create a square knot, the intrinsic suture tension of the first throw is usually not expected to change when the second throw is pulled firmly, due to the friction developed between the strands within the knot. However, monofilament sutures have minimal friction and, therefore, need to be pulled firmly to plastically deform the suture shape within the knot.

Monofilament sutures tend to slip down, or cinch, and increase intrinsic suture tension on the second throw. This tends to tighten the tissue within the stitch when the suture is pulled hard enough to cause plastic deformation. Therefore, when it is important not to crush tissue, such as skin or intestine, within the tissue bite of a monofilament stitch, avoid excessively tightening the second throw. Instead, tighten the throw down just enough to achieve tissue apposition with the first throw. Don't begin firm tightening and deforming until the third and subsequent throws. Lastly, remember that the slippery nature of monofilament suture does not allow it to "lock up" into a firm knot until the third throw has been fully tightened.

Tip #2: Unlike the multifilaments, monofilament sutures, when placed in square fashion, will still "cinch down" when pulled tightly on the second throw, but not on the third. If you notice that your third throw on a monofilament knot slips down and increases the intrinsic suture tension, then at least one of your three throws was not created squarely, and the suture must be replaced.

Tip #3: The slippery nature of monofilaments is desirable when creating knots that will be pushed down into deep cavities.

Tip #4: When using monofilament sutures, some "fine tuning" can be done with the second throw during knotting. If the first throw loosens somewhat after being placed, the second throw is pulled slowly and carefully until the desired intrinsic suture tension is developed. When attempting this maneuver, be sure to "hike up" on the strands. In other words, hold the suture strands within one or two inches of the knot before fine-tuning the second throw. This will allow the surgeon a better feel of the knot slipping and tissue loop tightening.

Multifilament sutures often "lock up" during the second throw, when the strands are pulled tightly. These sutures will not allow the same fine-tuning of the tissue loop as their counterparts, but they also take much less strand tension to create a secure knot.

Surgeons use fine-tuning during skin suturing, since the goal is to precisely control intrinsic suture tension to avoid suture-related tissue ischemia and inflammation. If, for example, the first square throw is not as tight as desired and the skin edges gape, simply pulling slowly and evenly on each strand during the second throw will tighten that suture loop to the desired intrinsic suture tension. Of course, the third and fourth throws must be firmly tensioned to create “plastic deformation” and a secure knot.

REFERENCES

Edlich RF, Long WB. Covidien Knot Tying Manual. 3rd ed., www.covidien.com.

Giddings FD. Surgical knots and suturing techniques. 3rd ed., Fort Collins, Colorado: Giddings Studio Publishing; 2009.

Knot Tying Manual. Ethicon Products Worldwide. www.ethicon.com, 2005.

Anderson RM, Romfh RF. Surgical knot tying manual. Appleton-Century-Crofts, New York, 1981.

Stott P, Lionel R, Lavelle M. The ultimate Aberdeen knot. *Ann R Coll Surg Engl* 2007; 89:713–717.

Shaw A, Duthie G. A simple assessment of surgical sutures and knots. *J R Coll Surg Edinb* 1995; 40:388–391.

Taylor FW. Surgical knots. *Ann Surg* 1938; 107:458–468.

Thacker JG, Rodeheaver G, Kurtz L, Edgerton MT, Edlich RF. Mechanical Performance of sutures in surgery. *Am J Surg* 1977; 133:713–715.

Kim E, Chern H, Huang E, Palmer B. How To Teach Knot Tying: A Kinesthetic Approach. MedEdPORTAL (www.mededportal.org/publication/9328), 2013.

Daniel D. Smeak, DVM, Diplomate ACVS
Professor and Chief, Small Animal Surgery
College of Veterinary Medicine and Biomedical Sciences
Colorado State University

Lawrence N. Hill, DVM, Diplomate ABVP
(Canine and Feline)
Professor - Clinical
Department of Veterinary Clinical Sciences
Hospital for Companion Animals
College of Veterinary Medicine
The Ohio State University

All content in the Knot Tying course, including videos, images, text, graphics, and audio, is the property of Texas A&M University, Colorado State University, and The Ohio State University. Redistribution or commercial use without the expressed, written permission of these institutions is prohibited. For information on usage rights, contact The Center for Educational Technologies at Texas A&M University, College of Veterinary Medicine & Biomedical Sciences, 979-458-8450.