

Laparoscopic Tissue Approximation Techniques

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INTRODUCTION

Knots are used since the time of primitive man for trapping animals and making weapons. Today's laparoscopic knots are basically a modification of knots used by Seamen, Fishermen, Weavers, or Hangmen. In much of the literature on laparoscopic surgery, the learning curve for performing the technique is described as steep. In fact, laparoscopy is more than a new technique; it is a completely different way of operating as far as tissue approximation is concerned. The visualization is different, the instruments are different, and the tactile aspects are very different. Laparoscopic suturing and knotting is a skill that requires a great deal of practice: "As a young surgeon in training, you sit up all night, night after night, and tying knots over and over again until you become perfect".

There are many ways of laparoscopic tissue approximation, but most commonly used one are:

- Laparoscopic extracorporeal and intracorporeal knots
- Surgical glues which act as a tissue adhesive
- Laparoscopic clips
- Laparoscopic staplers
- Laser welding.

LAPAROSCOPIC SUTURING AND KNOTTING

It is important to remember that knot is either exactly right or is hopelessly wrong and never nearly right.

There are three steps of knot tying:

- 1. Configuration (tying)
- 2. Shaping (drawing)
- 3. Securing (locking or snuggling).

Choice of Suture Material

Ideal Suture Characteristics

The choice of suture material influences wound healing. Ideal suture characteristics include:

- Good knot security
- Adequate tensile strength
- Flexibility and ease of handling
- Inertness and nonallergenic nature
- Resistance to infection

- Smooth passage through tissue
- Absorbability, when desirable.

Surgeons should choose sutures that they are comfortable with and that are suited to the intended application. This choice should be based on the duration of tensile strength. For internal sutures, least number of knots should be used to ensure knot security and avoid an excessive knot burden and consequent foreign body reaction.

Types of Sutures

Sutures traditionally have been classified into natural (i.e., naturally occurring) and synthetic (man-made). The use of natural sutures is declining for a number of reasons such as tissue reaction, infection, and weak knots. Examples of natural sutures include catgut and silk. Suture material is also classified into absorbable and nonabsorbable.

Absorbable Sutures

The natural absorbable (catgut) tend to have unpredictable rates of absorption and tissue reaction. For the most part, these sutures have short half-lives, so they are not good for wound closure where strength is desirable. Their use is being discontinued.

The synthetic absorbable are broken down by hydrolyzation. They generally have a longer half-life, less tissue reaction, and a more consistent breakdown rate. The synthetic absorbable, polyglycolic acid (Dexon[®]) or polyglactin 910 (Vicryl[®]), has decreased tissue reaction compared to the natural absorbable. Knot security is fair and can be used for extracorporeal knotting.

Polyglactin 910 (Vicryl[®]) keeps 75% of its tensile strength for about 2 weeks and 50% by 3 weeks. The coated sutures decrease the drag through tissue, so it is easier to use, but there are variable rates of absorption. Polyglactin 910 is a good suture material for intracorporeal suturing.

Poliglecaprone 25 (Monocryl[®]) is a monofilament product that has easy passage through tissue, good handling, and is inert. It keeps tensile strength for only a week, but stays in the wound for almost 4 months. It is good for anastomosis, gynecologic work, and small vessel ligation and epithelial approximation. This material can be used for both extra- and intracorporeal suturing. The delayed absorbable monofilament sutures such as polydioxanone (PDS[®]) and polyglyconate (Maxon[®]), used for abdominal wound closure, have good tensile strength and low tissue reaction, but the knots are not as strong. PDS is considered as ideal material for extracorporeal knotting by many surgeons and gynecologists.

Polydioxanone is also good for contaminated fields because it has a low affinity for bacteria. It is good for general use, tissue approximation, biliary work, anastomosis, fascial closures, heart surgery, and orthopedics.

Panacryl[®] is a braided synthetic absorbable suture. It has good tensile strength, low tissue reaction, and fairly good knot security. It maintains 60% of its tensile strength at 6 months. It may be a good substitute for a nonabsorbable suture because it has complete absorption in 2.5 years. It is good for fascial closures, closing tissues under tension, and it might have a role in the compromised patient where you presume that there is going to be inadequate or delayed wound healing.

Nonabsorbable Sutures

The natural nonabsorbables, cotton and silk, should be relegated to the past. Even though they have good knot security and are easy to tie, they provoke a lot of tissue reaction. Synthetic nonabsorbable sutures in common use include nylon, polyester, and stainless steel. The role of this material in laparoscopic surgery is very limited and can be used if the other materials are not available.

Suture Size

The narrower the suture, the lower is its tensile strength. Narrower sutures cause less scarring. In addition, a narrower suture will harbor fewer bacteria.

Surgeons should use the smallest suture that they are comfortable with and that will give optimal security of wound closure with minimal wound tension.

Usually, 2/0 or 3/0 is used in most of the minimal access surgical procedure with the exception of the fallopian tube, where 6/0 may be preferred.

Knots

The knot is the most important part of the suture closure *in vivo*; the knot is the determining factor in suture strength in 95% of sutures tested. Complex knots have twice the security of simple knots.

However, increasing complexity of the knot simply leads to the suture strength being the weak link. The size of the knot is also important. If you use the same suture and increase from three to five throws, the foreign body volume is increased by 50%.

LAPAROSCOPIC NEEDLE

In general surgery, needles are either straight or curved. With increasing proficiency, curved needle can also be used



Figs. 1A and B: (A) Endoski needle; (B) Bhandarkar Knot Pusher.

but in laparoscopic surgery most intuitive needle is Endoski needle. Endoski needle has advantage of both straight and curved needle (**Fig. 1A**).

Endoski Needle

The distal end is tapered half circle and proximal shaft of the needle is straight. The shaft of the needle is 1.5 times the length of curved portion of Endoski needle.

In our day-to-day practice, we can convert half-circled needle into Endoski-shaped needle by making proximal half of the needle straight.

LAPAROSCOPIC SUTURE MATERIAL

Although it is a personal preference and varies surgeon to surgeon but considering handicap of laparoscopic setting following is recommended:

- For extracorporeal suturing of small tubular structure such as cystic duct and small blood vessels—dry chromic catgut
- For extracorporeal suturing of thick tubular structure such as appendix and large blood vessels—PDS
- For intracorporeal continuous or interrupted suturing—Vicryl[®]
- For intracorporeal interrupted suturing in the repair of hernia, fundoplication, and rectopexy—dacron (polyester) or silk.

Types of Laparoscopic Surgical Knots

- Extracorporeal (tied outside the body and then slipped inside using a push rod):
 - Roeder's knot
 - Meltzer's knot
 - Tayside knot
- Intracorporeal (tied with the help of needle holder within the body cavity):
 - Square knot
 - Surgeon's knot
 - Tumble square knot
 - Dundee jamming knot
 - Aberdeen termination.

A long length of ligature is required (90 cm) for extracorporeal suturing. It must be long enough to have the knot pusher threaded onto it, to be passed into the abdomen, round the structure to be ligated and to be brought out again, and still have sufficient length for the surgeon to tie his/her knot effectively. The type of extracorporeal knot chosen to complete the loop depends on the clinical situation and the material used.

Roeder's Knot (Figs. 2A to L)

Roeder's knot is one of the most used extracorporeal knot. Bhandarkar Knot Pusher is ideal to tie extracorporeal all the knots including Roeder's knot **(Fig. 1B)**. The index finger of the assistant may be used to make extracorporeal knot. The left hand should be used to hold the short limb and the right hand should be used to hold the long limb of thread. The short limb of the thread is crossed over the long limb. The intersection point of thread should be pinched by left hand index finger and thumb. At the time of making intersection, surgeon should keep sufficient length of short limb to make it comfortably. It is important to remember that left hand is used only to hold the intersection point while the right hand will make the necessary hitches and loops.

Properly configured Roeder's knot loop diameter should be approximately 4 cm. Large size loop is difficult to manipulate inside the abdominal cavity and very short loop



Figs. 2A to H



Figs. 2I to L

Figs. 2A to L: (A and B) First hitch; (C and D) First wind; (E and F) Second wind; (G and H) Third wind; (I and J) The last lock (half knot); and (K and L) Roeder's knot applied on the appendix.

is difficult to reach up to the base of the structure which is to • be tied.

Roeder's knot can be remembered as 1:3:1.

- One hitch
- Three winds
- One locking hitch.

The steps below describe how to tie Roeder's knot:

- The length of suture used in the extracorporeal knot for free structure is 90 cm.
- Take the Bhandarkar Knot Pusher in left hand and pass 2 cm suture through the eye in the tail end of the Bhandarkar Knot Pusher by right hand.
- The knot pusher is now reversely feed in the 3 mm reducer. Reverse feeding is important.
- Once the reducer is feeded, the thread is pulled out from the eye of the tail of knot pusher. The job of the eye in the tail is just to pass the suture safely from the reducer.
- Now the other end of the suture is passed through the eye of the head end using right hand.
- Ask the assistant for a finger and the extracorporeal slip knot is tied.
- The configuration of Roeder's knot is 1-3-1 in which the first 1 stands for the single hitch, 3 stand for three winds, and 1 stands for single lock at the end.
- After making the knot, make the diameter of loop 6 cm by sliding the loop by right hand finger and thumb.
- After that, hide the knot and its loop under the reducer.
- Now the knot pusher and the reducer are introduced through the 5-mm or 10-mm port. If it is introduced through the 10-mm port, additional 5 mm reducer should be introduced over 3 mm reducer to prevent the leakage of the gas.

- An atraumatic grasper should also be introduced from the contralateral port.
- The loop of the knot should go near the free structure.
- The atraumatic grasper should have introduced in the loop and after that it should hold the tip of the free structure over which you want to tie.
- Now the knot pusher should go to feed the loop behind the structure. The same way like our hands goes behind when we put garland on someone's neck.
- The knot now can be slide to the desire place where you want to tie the knot by stabilizing the knot pusher with left hand and pulling the suture with right hand.
- It should be done in such a fashion that structure should not know that it is getting tied. Any traction of pulling and pushing should never be exerted over the tubular structure which you are ligating.
- After tightening the knot consecutively three times, the knot pusher and 3 mm reducer are pulled and hook scissors are introduced from the same port and the suture is cut leaving 1 cm tail.
- The extracorporeal Roeder's knot is very strong knot and one knot is sufficient to tie any tubular structure like appendix, fallopian tube, a piece of omentum, small pedunculated myoma, or paraovarian simple cyst.

Meltzer's Slip Knot (Figs. 3A to U)

This modification of the Roeder's knot was described in 1991 by Meltzer for use with PDS and has now superseded the use of Roeder's knot. It has components:

- Two hitches
- Three winds
- Two half locking hitches. Meltzer's knot can be remembered as 2:3:2.

Tying a Meltzer's knot: Following are the steps to tie • extracorporeal Meltzer's knot:

- The length of suture used in the extracorporeal knot for free structure should be 90 cm or 120 cm.
- Take the Bhandarkar Knot Pusher in left hand and pass 2 cm suture through the eye in the tail end of the Bhandarkar Knot Pusher by right hand.
- The knot pusher is now reversely feed in the 3 mm reducer. Reverse feeding is important.





Figs. 3K to U

Figs. 3A to U: (A and B) Shorter thread (suture) over the longer thread; (C and D) First hitch; (E and F) Second hitch; (G) Both the hitch; (H and I) First wind; (J and K) Second wind; (L and M) Third wind; (N and O) First lock (first half knot); (P and Q) Second lock (second half knot); (R) Completion of Meltzer's knot; (S) Complete Meltzer's knot ready to slide; and (T and U) Meltzer's knot tied to the appendix.

- Once the reducer is feeded, the thread is pulled out from the eye of the tail of knot pusher. The job of the eye in the tail is just to pass the suture safely from the reducer.
- Now the other end of the suture is passed through the eye of the head end using right hand.
- Ask the assistant for a finger and the extracorporeal slip knot is tied. You always start tying the knot putting the shorter end of the suture over the longer.
- There are three types of extracorporeal knot: (1) Roeder's knot, (2) Meltzer's knot, and (3) Mishra's knot. Meltzer's knot is ideal for monofilament suture materials.
- The configuration of Meltzer's knot is 2:3:2 in which the 2 stand for two hitches.
- The 3 stand for three consecutive winds.
- The last 2 stand for two locks (half knot). This knot is secure up to 12 mm tubular structure.
- Make the diameter of loop 6 cm by sliding the loop by right hand finger and thumb.
- After that, hide the knot and its loop under the reducer.
- Now the knot pusher and the reducer are introduced through the 5-mm or 10-mm port. If it is introduced through the 10-mm port, additional 5 mm reducer should be introduced over 3 mm reducer to prevent the leakage of the gas.
- An atraumatic grasper should also be introduced from the contralateral port.
- The loop of the knot should go near the free structure.
- The atraumatic grasper should have introduced in the loop and after that it should hold the tip of the free structure over which you want to tie.
- Now the knot pusher should go to feed the loop behind the structure. The same way like our hands goes behind when we put garland on someone's neck.
- The knot now can be slide to the desire place where you want to tie the knot by stabilizing the knot pusher with left hand and pulling the suture with right hand.

- It should be done in such a fashion that structure should not know that it is getting tied. Any traction of pulling and pushing should never be exerted over the tubular structure which you are ligating.
- After tightening the knot consecutively three times, the knot pusher and 3 mm reducer are pulled and hook scissors are introduced from the same port and the suture is cut leaving 1 cm tail.
- The extracorporeal Meltzer's knot is extraordinarily strong knot and one knot is sufficient to tie any tubular structures such as appendix, fallopian tube, a piece of omentum, small pedunculated myoma, or paraovarian simple cyst.

Applications: The Meltzer's knot is now used by most of the surgeons instead of the Roeder's knot to tie the medial end of the cystic duct during cholecystectomy and to fix the cystic duct drainage cannula after transcystic clearance of ductal stones, as catgut is no longer available (**Figs. 4A to C**). PDS is the suture material of choice for Meltzer's knot.

Tayside Knot (Figs. 5A to O)

The Tayside knot is safe for use with any braided material. It supplies a degree of resistance to reverse slippage equivalent to a surgeon's knot.

- *Step 1*: A single hitch is taken first just as Roeder's knot.
- *Step 2*: Four and half rounds are taken approximately 1 cm below the first hitch over long limb of thread.
- *Step 3*: A locking hitch is made by passing tail through the second and third loop.
- *Step 4*: Finally the first hitch is brought closer to the locking hitch by spreading the first loop.
- *Step 5*: The knot is stacked properly and the extra tail (if any) is cut. Once the knot is configured properly, it should be checked by sliding over the long thread.



Figs. 4A to C: Steps of Meltzer's slip knot.

Applications: The Tayside knot is suitable for use with all braided sutures (2/0 or stronger) as well as Dacron. It is used with Dacron for ligation of vessels such as the azygous vein, splenic artery/vein, or the inferior mesenteric artery/vein.

Using a Pretied Loop (Fig. 6)

- The loop is drawn up into the metal sleeve.
- The tube is then introduced through an abdominal port.
- Once inside the abdomen, the loop is advanced using the push rod.
- A grasping forceps are placed through the loop and used to grasp the tissue to be ligated.
- The loop is delivered over the tissue and the knot and push rod is positioned at the base of the tissue.

- The loop is then tightened around the tissue by tensioning the long end and applying pressure to the knot via the push rod causing it to slide.
- The knot is locked firmly in place.
- The graspers are removed and replaced by suture scissors to divide the long end prior to removal.

Pretied loops are available commercially. They are packaged with the following items, assembled ready for use:

- A push rod
- A pretied loop
- A metal or silicon introducer tube.

The pretied loop has one long tail of suture material, which is threaded through the plastic push rod and encapsulated by the end. The region at the end of the push rod is designed to be broken, so the thread may be pulled



Figs. 5A to F



Figs. 5G to O Figs. 5A to O: Various steps of Tayside knot.



Fig. 6: Roeder's loop.

through the remainder of the rod. The push rod is passed through the metal introducer tube.

Clinical uses: Preformed loops are used to ligate tissue, e.g., the base of the appendix, lung bullae, and a hole in the gallbladder during cholecystectomy. If multiple loops

are required, the push rod and introducer can be reloaded with a length of ligature and additional loops fashioned by a surgeon with knowledge of external slip knots.

A preformed loop can also be used to secure a divided vessel after it has been isolated by a grasper. A slight modification of this technique allows it to be used to secure smaller identified vessels. One end is clipped and the other is controlled by a grasper, which has already been passed through a loop. The vessel is divided and the loop slides into place and tightened before the grasper releases the vessel.

Endoloops are also useful for sealing a perforated organ if this is to be removed, e.g., perforation of the gallbladder during laparoscopic cholecystectomy where closure is necessary to prevent escape of gallstones into the peritoneal cavity.

On no account endoloops can be used to close a perforation in any organ that is not going to be resected and removed, as the tissue included in the closed endoloop will slough off a few days later, because of ischemia, resulting in peritonitis.

EXTRACORPOREAL KNOT FOR CONTINUOUS STRUCTURE

- A push rod is threaded onto a length of ligature material approximately 1.5 m long.
- A knot is tied at the end of the thread as it emerges from the straight end of the rod.
- The end of the ligature emerging from the tapered end is grasped by atraumatic endoscopic grasper.
- The grasper and catgut are then passed into an introducer tube.
- The introducer tube is then passed through an 11 mm cannula.
- The grasper and ligature are extended into the cavity and passed to one side and behind the structure to be ligated.
- A second grasper is introduced through a second port to grasp the ligature from the other side of the structure.
- The first grasper releases the ligature and then takes it back from the second in front of the structure.
- The first grasper and ligature are withdrawn from the abdomen through the introducer tube while the second is used to protect the structure from the suture.
- An external slip knot is tied externally. The knot tied is determined by the size of vessel to be controlled and the material in use.
- The knot is pushed into the abdomen by the push rod and positioned prior to tightening.
- The rod is withdrawn a little and scissors introduced to cut the thread leaving a reasonably long end.

Clipping

Titanium clip is most widely used tissue approximation technique used by general laparoscopic surgeon.

- Choose the correct size of clip for the structure.
- Double clip should be applied over important structures (Fig. 7).
- Always confirm the dumbbell effect after clipping.

- Dumbbell effect after clipping confirms the tension on tissue (Fig. 8).
- Do not clip fatty pedicles.
- Check positioning of jaws, the tips, and content before clipping.
- Beware of cross-clipping (Fig. 9).

CAT EYE STONE

Sometimes clip applied on cystic duct may internalize and it may act as foreign body. In rare cases, cat eye stone has been reported with the use of titanium clips. After many years, it stimulates stone formation by deposition of bile. It is called cat eye stone because after taking a cross-section of these stone, the titanium clips look like pupil of a cat seen in dark.

LAPAROSCOPIC INTERNAL SUTURING

One of the most challenging aspects of laparoscopic surgery is intracorporeal suturing and knot tying. A loss of depth perception and tactile sense and visual obstruction make placing accurate and well-tied knots a difficult and timeconsuming task. The technique for suturing needs to be modified depending on the instrumentation in use. A lot of work is currently being carried out on designs for new needle holders and automatic suturing.



Fig. 8: Dumbbell formation.



Fig. 7: Titanium clip.



Fig. 9: Clip should be kept pressed for 3 seconds.

INSTRUMENTATION

Needle

Endoski Needle

Although conventional open surgical needles (half circle) can be used endoscopically, the Endoski needle developed in Dundee is designed specifically for endoscopic use and is a hybrid of the straight and half circle needle. It carries an atraumatic suture and has a straight shaft and a terminal tapering curve (that corresponds to one-fourth of a circle), giving it the shape of a miniature ski. The shaft is a modified rectangle, which becomes more and more rounded toward the tip so that the curved portion of the needle is round bodied. This combination allows for an easier grip of the shaft by the jaws of the needle holder and smooth passage of the curved portion of the needle through the tissues.

Needle Holders

The most commonly used is 5 mm Cuschieri needle holders. These have single action tapered jaws. The handles are spring loaded and the most recent versions have diamond coating for gripping the suture material without damage. A relaxed "open hand" grip is strongly recommended for these instruments. Please note that there are a wide variety of needle holders (or drivers). In practice, it is vital for each surgeon to become accustomed to a particular type and use that pair all the time. This is crucial for efficient and safe suturing.

Needle Control

Introduction into the Body Cavity

We recommend the use of the introducer tube to protect all ligatures and sutures from the cannula valve mechanisms.

The suture material on the Endoski needle is trimmed to a suitable length. For a continuous suture, this will be approximately 15–20 cm **(Fig. 10)**. The suture length must never exceed 20 cm as this will result in very difficult intracorporeal suturing since the length is magnified (2.5 times) by the imaging system.

The needle holder is first passed through an introducer tube. The tail of the suture is held next to the tip of the needle and the suture is picked up by the needle holder at its midpoint. It is then withdrawn into the introducer tube until neither the needle nor the tail is visible. The introducer tube can then be passed through a port and the needle is extruded from the tube. The suture is watched into the abdomen and placed on a convenient surface, e.g., the flat, smooth anterior surface of the stomach.

To Insert the Needle

- Pass the needle holder through the reducing tube.
- Pick up the suture material with the needle holder at a point midway from the tip of the needle and the tail of the thread.
- Withdraw the suture and needle inside the tube so that it is completely out of sight.
- Insert the tube through an appropriate port.
- Extrude the needle and suture from the tube by advancing the needle holder and position on a safe surface, e.g., the anterior surface of the stomach.

Manipulation

- A trailing needle is a safe needle.
- A held needle should always be in view.
- Tips of the two needle holders must always be in view.
- Two needle holders must never cross each other by moving parallel to each other from one side to the other.

The ability to maneuver the needle into the desired position in the needle holder jaw is one of the first skills you must acquire. It is well-worth practicing the techniques for this as it will make all subsequent tasks much easier. This task causes much frustration until it can be achieved at will.



Fig. 10: The length of suture should not be more than 20 cm.

The first step is to arrange the needle to the required orientation on the tissues (preferably on a serosal surface and not fatty tissue). Recommended techniques to get the needle in the right attitude on the tissues include the "nudge", the "push", and the "twist" techniques. This maneuver should be better demonstrated for learning.

Position

The needle must next be positioned correctly in the jaws of the needle holder. Ideally the needle is grasped in the right orientation by the tips of the jaws. It is a mistake to grasp the needle by the back of the jaws as this impairs precision needle driving through the tissues and also reduces the grasping force so that needle swivel is more likely.

For a right-handed surgeon in a straightforward situation, the needle is held in the right hand (RH) needle holder with the tip pointing to the left. The tip of the needle points upward and the shaft of the needle should make an obtuse angle with the shaft of the holder.

The key elements in achieving this are:

- The needle position on the tissues
- The angle of approach of the holder
- The pickup actions.

Adjustments to the angle can be made using:

- Other needle holder
- Surrounding tissue
- Tensioned suture material.

Passage through the Tissues

Position the needle appropriately in the needle holder and identify the position of the first entry point. Place the tip of the needle at this position so that the sharp tip enters the tissue at right angles.

When approximately half of the curve of the needle has entered the tissue (corresponding to 2.0 mm), the wrist is supinated and lifted slightly to passage the curved section of the needle through the tissue. When the point of the needle is seen to emerge at the exit point, the grasp is maintained and the needle end (not tip) is grasped by the other (assisting) needle holder before it is released by the dominant needle holder. For the second bite (in other tissue edge), the dominant needle holder can retrieve the needle directly from the assisting needle holder provided the needle is in a favorable position for direct transfer. Otherwise, it is more ergonomic to drop the needle and pick it up by the dominant holder. Once the two edges have been passaged, the needle is dropped and the suture is pulled to the desired point by an instrument-to-instrument technique through the tissues. A trailing needle does less harm than one that is held rigid in the holder. A grasped needle must always be in view.

Tensioning

A continuous suture is initially tensioned by pulling through the suture material. Further tightening can be achieved by use of the dominant needle holder although one must be careful not to fray or damage the suture. The open jaws of needle holder are placed on the side of the suture as it exits from the tissues. They can then be used to apply counterpressure on the tissues as the suture is pulled tight by the assisting needle driver. Tension in a suture line is then maintained by occasional locking sutures and the appropriate use of an assistant. In clinical practice, tension on the suture line is kept by the assistant using a special suture holder that does not damage the suture which has rounded jaws.

Microsurgical Tying

This is a precise choreographed set of actions. Each maneuver is designed to help make the whole process smooth and reproducible with economy of movement and structured choreography, so that suturing is efficient with minimum of wasted time. Note the following important points:

- The passive and active role of the holders
- The formation of the initial "C"
- Its relation to the tail of the suture
- The conscious assessment of position
- The use of the natural bias of the thread
- Appropriate rotations of the needle active and passive needle holder that must be manipulated in consort
- Note the importance of keeping the ends of the two needle holders in the operative field
- Note the importance of two-handedness for efficient suturing.

Steps of Surgeon's Knot (Figs. 11A to H)

- A "C" loop is made.
- The instrument of the side of "C" should be kept above the "C" and two winds are taken with the help of right instrument.
- Winds are slipped in the line of left instrument.
- Knot is tightened with the help of both the instruments.
- First knot of surgeon's knot is complete.
- A reverse "C" is made and single wind is taken over the right instrument with the help of left instrument.
- Again "C" loop is made and single winds are taken to complete surgeon's knot.
- Surgeon's knot contains double wrap on the first throw, followed by two opposing, alternating single throws.

Tumble Square Knot (Figs. 12A to G)

This is a simple square knot which can be changed to slipping configuration by tightening of a same side of thread.

- A square knot is tied.
- Same side of thread should be straightened with the help of two Maryland or needle holders.



Figs. 11A to H: Various steps of surgeon's knot.

- After straightening of same side of thread, it is ready to slide.
- Closed jaw of Maryland forceps will slide the knot.
- After tightening, the knot is locked again by pulling both the thread.
- One more knot is tied to prevent slipping of Tumble square knot.

CONTINUOUS SUTURING

It is common practice to start a continuous suture with a Dundee Jamming slip knot. An equally acceptable alternative is an internal tied knot if the surgeon is proficient. A continuous suture can be finished in a number of ways. We recommend the Aberdeen termination, an internal tie to a convenient tail or a slipping loop tied to itself.

Dundee Jamming Slip Knot

This is a recommended way of starting a continuous suture. This knot has an external component but is completed, once inside the body cavity, after the first bite of tissue has been taken.

The external component has following steps:

- A simple slipping loop
- Passage of the tail through the first loop



Figs. 12A to G: Various steps of Tumble square knot.

- Creating a second loop
- Tensioning of the second loop.

The second loop should slip only from the tail, the knot should not be tightened at this stage, and the length of both the loop and of the tail should be at least 1 cm.

Once inside, the knot is locked by passage of the standing part of the suture through the loop, which is then slipped to lock the knot.

Starting a Continuous Suture

- Tie the external component of the Dundee Jamming slip knot at the end of an atraumatic suture or start with an intracorporeal surgeon's knot.
- Pass an atraumatic grasper through an introducer tube.
- Pick up the suture at a point midway from the tail of the suture to the needle tip.

- Draw suture and needle completely inside the introducer tube, being careful not to slip the Dundee Jamming slip knot.
- Pass the introducer through the 11 mm cannula.
- Extrude the suture and deposit it on a safe surface (e.g., the anterior surface of the stomach).
- Pick up the needle and take the first bite of the tissue or tissues to be sutured.
- Pull the thread through until the Dundee Jamming slip knot just impinges on the tissue.
- Pass the needle holder carefully through the loop of the Dundee Jamming slip knot and pick up the thread attached to the needle at a point near to its exit from the tissues.
- Pull the needle holder and thread with the trailing needle back through the loop.

- Next take hold of the tail of the loop and the standing part of the thread and pull first on the tail and then on the standing part, locking the knot.
- Trim the tail. You are now ready to start your continuous suture.

Applications

It is used in any continuous suture, e.g., closure of viscerotomies following stapled anastomosis, sutured anastomosis such as cholecystojejunostomy, gastrojejunostomy, etc. It can also be used as an interrupted suture, when additional one or two hitches are advised for security (in our practice, an internally tied knot would be used in preference for an interrupted suture).

Aberdeen Termination

This is an adaptation of a termination commonly used in abdominal closure following open surgery. The continuous suture is finished by the formation of three interlocking loops. In order to simplify the maintenance of tension in the suture line, the penultimate stitch can be locked. A further bite is then taken and the suture pulled through, though not completely. A small loop of suture is left, enough that the needle holder can be passed through it to pick up the standing part of the suture. A loop of this is then drawn through the first loop, which is tightened down onto the tissues. The needle holder is then passed through the new loop to repeat the maneuver three times.

It is important that each loop can be tightened as you proceed. To do this, tension must be applied to the leg of the loop, which exits, from the tissues or the preceding loop. The standing part and needle are delivered completely through the last loop. The standing part is held up and the suture is tensioned with counterpressure from the jaws of the needle holder placed on either side of the suture. The suture is cutoff leaving a reasonable length (approximately 1 cm).

EXTRACORPOREAL MISHRA'S KNOT

Mishra's knot is very string extracorporeal knot which can ligate any tubular structure up to 18 mm. Bhandarkar Knot Pusher is ideal to tie extracorporeal Mishra's knot. The index finger of the assistant is used to make extracorporeal Mishra's knot. The left hand should be used to hold the short limb and the right hand should be used to hold the long limb of thread. The short limb of the thread is crossed over the long limb. The intersection point of thread should be pinched by left hand index finger and thumb. At the time of making intersection, surgeon should keep sufficient length of short limb to make it comfortably. It is important to remember that left hand is used only to hold the intersection point while the right hand will make the necessary hitches and loops. All the movement of right hand is from below up. Properly configured Mishra's knot loop diameter should be approximately 6 cm. Large size loop is difficult to manipulate inside the abdominal cavity and very short loop is difficult to reach up to the base of the structure which is to be tied.

Mishra's knot can be remembered as 1:1:1:1:1:1.

- One hitch
- One wind
- One lock
- Second wind
- Second lock
- Third wind
- Third lock.

The steps below describe how to tie Mishra's knot (Figs. 13A to R):

- The length of suture used in the extracorporeal Mishra's knot is 90 cm.
- Take the Bhandarkar Knot Pusher in left hand and pass 2 cm suture through the eye in the tail end of the Bhandarkar Knot Pusher by right hand.
- The knot pusher is now reversely feed in the 3 mm reducer. Reverse feeding is important.
- Once the reducer is feeded, the thread is pulled out from the eye of the tail of knot pusher. The job of the eye in the tail is just to pass the suture safely from the reducer.
- Now the other end of the suture is passed through the eye of the head end using right hand.
- Ask the assistant for a finger and the extracorporeal slip knot is tied. You always start tying the knot putting the shorter end of the suture over the longer.
- There are three types of popular extracorporeal knot: (1) Roeder's knot, (2) Meltzer's knot, and (3) Mishra's knot. All the knots have different configuration.
- The configuration of Mishra's knot is 1:1:1:1:1:1. The first three 1 stands for one hitch, one wind, and one lock.
- The fourth and fifth 1 stand for second wind and second lock.
- The sixth and seventh 1 stand for third wind and the final lock. It is the most secure knot among the three for the structure up to 18 mm tubular structure.
- Make the diameter of loop 6 cm by sliding the loop by right hand finger and thumb.
- After that, hide the knot and its loop under the reducer.
- Now the knot pusher and the reducer are introduced through the 5-mm or 10-mm port. If it is introduced through the 10-mm port, additional 5 mm reducer should be introduced over 3 mm reducer to prevent the leakage of the gas.
- An atraumatic grasper should also be introduced from the contralateral port.
- The loop of the knot should go near the free structure.
- The atraumatic grasper should have introduced in the loop and after that it should hold the tip of the free structure over which you want to tie.

142 SECTION 1: Essentials of Laparoscopy

- Now the knot pusher should go to feed the loop behind the structure. The same way like our hands goes behind when we put garland on someone's neck.
- The knot now can be slide to the desire place where you want to tie the knot by stabilizing the knot pusher with left hand and pulling the suture with right hand.



Figs. 13A to J





Figs. 13A to R: (A and B) Shorter left limb is over longer right limb; (C and D) First hitch of Mishra's knot; (E and F) First wind of Mishra's knot; (G and H) First lock half knot of Mishra's knot; (I and J) Second wind of Mishra's knot; (K and L) Second lock half knot of Mishra's knot; (M and N) Third wind of Mishra's knot; (O and P) Third lock half knot of Mishra's knot; (Q) Complete Mishra's knot; and (R) Mishra's knot applied in the uterine artery.

- It should be done in such a fashion that structure should not know that it is getting tied. Any traction of pulling and pushing should never be exerted over the tubular structure which you are ligating.
- After tightening the knot consecutively three times, the knot pusher and 3 mm reducer are pulled and hook scissors are introduced from the same port and the suture is cut leaving 1 cm tail.
- The extracorporeal knot is very strong knot and one knot is sufficient to tie any tubular structures such as appendix, fallopian tube, a piece of omentum, small pedunculated myoma, or paraovarian simple cyst. This knot can also be used to do in mass ligation of cholecystectomy or partial cholecystectomy, ligation of uterine artery, splenic vessels, and renal vessels.

EXTRACORPOREAL WESTON KNOT

Weston knot is an extracorporeal knot which was first started by arthroscopic surgeons but now it is more used by gynecologist. This knot has advantage that there is no need of knot pusher. Another advantage of this knot is that many knots can be applied by only one 9 cm suture. This knot is used to close vaginal vault with needle or to do muffing of gastric band or can also be used for crural approximation in fundoplication.

- Taking suture 790 cm or preferably 150 cm with Endoski needle which is proximal two-thirds straight and distal one-third curved.
- Insert Maryland in the reducer.
- Hold the suture with Maryland at the tail end and pull it out through the reducer and then hold it near the needle and hide it in the reducer.
- Insert the Maryland with the reducer into the abdomen.
- Drop the needle over the tissue in such a way that the tip should be in the left and the tail in the right side.
- Align the needle by the following three techniques:
 - 1. Pressing the needle by the upper jaw of the needle holder at the junction of one-third and two-thirds.

- 2. Holding the needle by the left hand at the curvature and pulling the suture up near the needle by the right hand.
- 3. Hang the needle by the left hand like a pendulum and go with the open jaw of the needle holder keeping the moving jaw to the left and dragging it to the right.
- Stabilize the tissue by the left hand and take a bite by keeping the needle at 90° angle to the tissue and rotating the tip of the needle to bring it to the other side.
- Bring the tip of the needle one-third out and catch it with the left instrument, keeping the convex end toward the tissue.
- Guard the tissue by the needle holder, keeping the concave part of the instrument toward the tissue and pulling the needle by the left hand instrument.
- Feed the suture four times.
- Hold the suture by the needle holder as soon as the needle is out.
- The configuration of Weston knot is 1-1-1.
- Weston knot is a self-locking sliding knot, which has one hitch, one reverse hitch, and one final wrap and lock. The steps of Weston knot are (Figs. 14A to 0):



Figs. 14A to F



Figs. 14G to O

Figs. 14A to O: (A and B) Shorter thread (suture) over the longer one; (C and D) First hitch; (E and F) Thread placed toward the left side; (G and H) The thread passed between the two limbs to make a reverse hitch; (I and J) Encircling of both the limbs from below upward; (K and L) Encircling both the limbs and locking it in the first hitch; (M) Stacking the Weston knot; (N) Completed Weston knot; and (O) Weston knot applied in the vault closure.

- *Step 1*: The index finger of the assistant may be used to make Weston knot. The left hand should be used to hold the short limb and the right hand should be used to hold the long limb of thread.
- *Step 2*: The short limb of the thread is crossed over the long limb.
- *Step 3*: The intersection point of thread should be pinched by left hand index finger and thumb. At the time of making intersection, surgeon should keep sufficient length of short limb to make it comfortably. It is important to remember that left hand is used only to hold the intersection point while the right hand will make the necessary hitches and loops.
- *Step 4*: The short limb is passed between the thread upward.
- *Step 5*: The short limb should be pulled from up by right hand to make first hitch.
- *Step 6*: The short limb is placed toward the left side and is passed between the two limbs upward to make a reverse hitch.
- *Step 7*: The short limb should encircle the thread from below upward and should be put in the first loop to lock it.
- Now hide the knot in the reducer with or without Maryland and push the knot sliding downward to the desired place where you want to tie by keeping the suture in the left hand and pulling the suture with the right hand.
- After tightening the knot, you can take a final square knot to secure.
- Introduce the scissors from the right port and cut the suture.
- You can again reuse the same suture needle to tie another knot.
- Weston knot is used in gynecological surgeries and also in arthroscopic surgeries. It can be used in situations where suture slides smoothly and freely through tissue and the anchoring device.
- Advantages of Weston knot are:
 - It is a relatively easy knot which can be tied outside, can slip easily into place, and tightly secured
 - It locks readily and is not bulky
 - No knot pusher needed
 - Can be used with the needle to take a bite
 - The suture needle is maintained, so it can be reused for taking another bite.

INTERRUPTED SUTURES

Interrupted Knots

Dundee Jamming loop knot is used to create interrupted sutures. For additional safety, a further hitch or two is recommended if it is to be used as an interrupted suture. More commonly interrupted intracorporeal sutures are made by the use of the surgeon's or the Tumble square knots.

Applications of Interrupted Sutures

Interrupted sutures have a multitude of uses. Simple examples are closure of the common bile duct after exploration and fundoplication.

Stapled Anastomosis

The use of disposable stapling guns has simplified a number of endoscopic procedures such as the division of vascular pedicles and gut anastomosis.

The following important points are emphasized:

- Port positions for stapling
- Stay sutures for tensioning
- Enterotomy positioning and size
- Positioning and angulations of the instrument prior to closure
- Checking suture line
- Complete closure of residual opening
- End-to-end anastomosis can also be carried out by stapling closed bowel ends side by side.

Clinical Applications

An anterior or posterior, side-to-side anastomosis of stomach and jejunum done laparoscopically can be a satisfactory palliative procedure. Likewise, a laparoscopic cholecystojejunostomy may be performed with stapler to relieve jaundice and itching in patients with inoperable pancreatic cancer.

Sutured Anastomosis

Sutured anastomosis can be carried out endoscopically, although the process is demanding in terms of skill and time. However, it is pertinent to note that staplers may not always be available, or appropriate, and even if a stapler is used, you require the skills to perform a sutured closure if the stapled anastomosis is not perfect.

Important points to remember are:

- Port positioning
- Use of communication with your assistant
- Positioning of sutures, especially at the corners
- Spacing the sutures (remember the magnification)
- Tensioning of sutures.

Direction of Suturing

It is important that you suture at the right height, ideally your elbows should be held adducted at right angles. Keep your wrists loose and remember that you have two hands that must manipulate to help each other. The choreography is as follows:

- The suturing line is started with a "starter knot" (surgeon's or Tumble square knot).
- The two needle holders must be kept in view and used in concert with each other.

- Passage from right to left through the tissue edges (bites consisting of entry and exit points) with dominant needle holder.
- The needle is picked up from the exit point by the passive needle holder (NH).
- It is transferred to dominant needle holder for the next bite if the orientation is correct. Otherwise, it is dropped and reorientated in the needle holder. Once the suture has passed through the two edges, the thread is pulled through, handing the suture one needle holder to the other.
- The distance between the suture bites must be approximately equal to the depth of the bites.

TECHNIQUES TO ASSIST IN CONTROL OF BLEEDING

Methods of Securing Hemostasis

Endoscopic surgery is controlled almost entirely by vision. Any loss of view will result in loss of control and a reduction in safety. Hemorrhage, even to a minor extent, tends to obscure the operative field and consequently to be avoided. This means that vessels of a size that in open surgery could be divided without particular attention need to be secured prior to division when working endoscopically. Dissection must be more meticulous to proceed smoothly and you must develop a disciplined approach.

Magnification of tissues by the endoscope may initially confuse an inexperienced endoscopic surgeon as to the severity of the bleeding. A moderate bleed can appear torrential but an inexperienced endoscopic surgeon is welladvised to convert if he have any doubt about his ability to control the situation quickly.

- Pressure on the area applied by grasping adjacent tissue and using this to overly and apply gentle pressure onto the area.
- Compression with pledget swab if the bleeding is not heavy until hemostasis is achieved by clipping or electrocoagulation and the sucker.
- Suction/irrigation to identify the bleeding point prior to securing it.
- Underrunning by suture if the bleeding point cannot be identified.
- Argon spray coagulation for raw bleeding areas.
- Occluding the vessel with graspers before clipping it.
- Application of fibrin and other glues or hemostatic agents.

Avoid Blind Coagulation

Control the initial bleeding and then take your time to identify the bleeding point. In anatomically crowded areas containing important structures, it may be advisable to allow time for the bleeding to stop by compression for 1 or 2 minutes. If bleeding cannot be controlled inside within 5 minutes, serious consideration should be given for conversion to open surgery. This period should be shorter if bleeding is massive or arterial.

Suction and Irrigation

The availability of suction and irrigation is as important for hemostasis in endoscopic surgery as gauze swabs are in open surgery. When bleeding does occur, irrigation can assist in visualization of the bleeding point and suction removes pooled blood and clears clots from the operative site. In addition, the irrigation activates Hageman factor and thus initiates spontaneous hemostasis.

Heparinized Hartmann's solution (1,000 units/500 mL bag) is ideal if clots are present. This solution is preferred to normal saline because of its lesser conductivity, an important consideration when using monopolar high frequency electrocautery. The heparin also reduces the stickiness of the instruments and thus improves handling, especially of suture and ligature materials. It also aids in removal of pooled blood. The bag of fluid is placed in a Fenwal pressure bag raised to 200 mm Hg and hung from a drip stand. As the contents of the bag are used, the pressure needs to be maintained. There are several pressurized irrigation systems available, some heat the irrigating fluid to body temperature, other provide pulse irrigation which is helpful from breaking up blood clots and cleaning the peritoneal gutters.

Suction and irrigation are also essential to deal with leakage from ultra-abdominal organs, e.g., bile leakage, bowel content, perforated ulcer, and appendicitis. In these acute emergency situations, laparoscopic abdominal lavage of the peritoneal quadrants is aided by shaking the patient from side to side and changing the position of the operating table (head up, head down, and sideways).

BIBLIOGRAPHY

- 1. Ali MR, Mowery Y, Kaplan B, DeMaria EJ. Training the novice in laparoscopy. Surg Endosc. 2002;16:1732-6.
- 2. Champion JK, Hunter J, Trus T, Laycock W. Teaching basic video skills as an aid in laparoscopic suturing. Surg Endosc. 1996;10:23-5.
- 3. Croce E, Olmi S. Intracorporeal knot-tying and suturing techniques in laparoscopic surgery: technical details. JSLS. 2000;4:17-22.
- De Beer JF, Van Rooyen K, Boezaart AP. Nicky's knot: a new slip knot for arthroscopic surgery. Arthroscopy. 1998;14:109-10.
- Derossis AM, Brothwell J, Sigman HH, Fried GM. The effect of practice on performance in a laparoscopic simulator. Surg Endosc. 1998;12:1117-20.
- Dunkin BJ, Li Y, Marks JM, Ponsky JL. The "Yenni" knot: a simpler method of intracorporeal laparoscopic knot tying. J Am Coll Surg. 1997;185:492-3.
- 7. Faulkner H, Regehr G, Martin J, Reznick R. Validation of an objective structured assessment of technical skill for surgical residents. Acad Med. 1996;71:1363-5.
- Figert PL, Park AE, Witzke DB, Schwartz RW. Transfer of training in acquiring laparoscopic skills. J Am Coll Surg. 2001;193:533-7.

- Gallagher AG, McClure N, McGuigan J, Crothers I, Browning J. Virtual reality training in laparoscopic surgery: a preliminary assessment of minimally invasive surgical trainer virtual reality (MIST VR). Endoscopy. 1999;31:310-3.
- 10. Gaur DD. Laparoscopic suturing and knot tying: the Indian rope crick. J Endourol. 1998;12:61-6.
- 11. Grantcharov TP, Kristiansen VB, Bendix J, Bardram L, Rosenberg J, Funch-Jensen P. Randomized clinical trial of virtual reality simulation for laparoscopic skills training. Br J Surg. 2004;91:146-50.
- Hamilton EC, Scott DJ, Fleming JB, Rege RV, Laycock R, Bergen PC, et al. Comparison of video trainer and virtual reality training systems on acquisition of laparoscopic skills. Surg Endosc. 2002;16:406-11.
- Harold KL, Matthews BD, Backus CL, Pratt BL, Heniford BT. Prospective randomized evaluation of surgical resident proficiency with laparoscopic suturing after course instruction. Surg Endosc. 2002;16:1729-31.
- 14. Hasson HM, Kumari NV, Eekhout J. Training simulator for developing laparoscopic skills. JSLS. 2001;5:255-65.
- Hay DL, Levine RL, Von Fraunhofer JA. Chromic gut pelviscopic loop ligature. Effect of the number of pulls on the tensile strength. J Reprod Med. 1990;5:260-2.
- Inoue H, Kumagai Y, Ami K, Nishikage T, Baba H, Yoshida T, et al. A simple technique of using novel thread-holding and knot-pushing forceps for extracorporeal knot-tying. Surg Today. 2000;30:27-31.
- Jones DB, Wu JS, Soper NJ. Laparoscopic Surgery, Principles and Procedures. St. Louis: Quality Medical Publishing; 1997. pp. 50-65.
- Kadirkamanathan SS, Shelton JC, Hepworth CC, Laufer JG, Swain CP. A comparison of the strength of knots tied by hand and at laparoscopy. J Am Coll Surg. 1996;182:46-54.
- 19. Madan AK, Frantizdes CT, Shervin N, Tebbit CL. Assessment of individual hand performance in box trainers compared to virtual reality trainers. Am Surg. 2003;69:1112-4.
- Madan AK, Frantzides CT. Substituting virtual reality trainers for inanimate box trainers does not decrease laparoscopic skill acquisition. JSLS. 2007;11:87-9.
- Madan AK, Frantzides CT, Park WC, Tebbit CL, Kumari NVA, O'Leary PJ. Predicting baseline laparoscopic surgery skills. Surg Endosc. 2005;19:101-3.
- 22. Madan AK, Frantzides CT, Sasso L. Laparoscopic baseline ability assessment by virtual reality. J Laparoendosc Adv Surg Tech A. 2005;15:13-7.
- Madan AK, Frantzides CT, Tebbit CL, Park WC, Kumari NVA, Shervin N. Evaluation of specialized laparoscopic suturing and tying devices. JSLS. 2004;8:191-3.
- 24. Madan AK, Frantzides CT, Tebbit CL, Quiros RM. Participant's opinions of laparoscopic trainers during basic laparoscopic training courses. Am J Surg. 2005;189:758-61.
- 25. Madan AK, Frantzides CT, Tebbit CL, Shervin N, Quiros R. Selfreported versus observed scores in laparoscopic skills training. Surg Endosc. 2005;19:670-2.
- Martin JA, Regehr G, Reznick R, MacRae H, Murnaghan J, Hutchison C, et al. Objective structured assessment of technical skill (OSATS) for surgical residents. Br J Surg. 1997; 84:273-8.
- 27. Meilahn JE. The need for improving laparoscopic suturing and knot-tying. J Laparoendosc Surg. 1992;2:267.
- 28. Mori T, Hatano N, Maruyama S, Atomi Y. Significance of "hands-on training" in laparoscopic surgery. Surg Endosc. 1998;12:256-60.
- 29. Munz Y, Kumar BD, Moorthy K, Bann S, Darzi A. Laparoscopic virtual reality and box trainers: is one superior to the other? Surg Endosc. 2004;18:485-94.

- 30. Nathanson LK, Nathanson PK, Cushieri AL. Safety of vessel ligation in laparoscopic surgery. Endoscopy. 1991;23:206-9.
- Keynes G, Pare A. The Apologies and Treatise of Ambroise Pare containing the Voyager Made into Divers Places with Many of his Writings Upon Surgery. London: Galcion Educational Books; 1951.
- 32. Pearson AM, Gallagher AG, Rosser JC, Satava RM. Evaluation of structured and quantitative training methods for teaching intracorporeal knot tying. Surg Endosc. 2002;16:130-7.
- 33. Pennings JL, Kenyon T, Swanstrom L. The knit stitch. An improved method of laparoscopic knot tying. Surg Endosc. 1995;9:537-40.
- 34. Peters JH, Fried GM, Swanstrom LL, Soper NJ, Sillin LF, Schirmer B, et al. Development and validation of a comprehensive program of education and assessment of the basic fundamentals of laparoscopic surgery. Surgery. 2004; 135:21-7.
- 35. Pietrafitta JJ. A technique of laparoscopic knot tying. J Laparoendosc Surg. 1992;2:273-5.
- Reznick R, Regehr G, MacRae H, Martin J, McCulloch W. Testing technical skills via an innovative "bench station" examination. Am J Surg. 1997;173:226-30.
- 37. Roeder H. Die Technik der Mandelgesundungs bestrebungen. Artzl Rundschau Munchen. 1918;57:169-71.
- Rosser JC, Murayama M, Gabriel NH. Minimally invasive surgical training solutions for the twenty-first century. Surg Clin North Am. 2000;80:1607-24.
- Rosser JC, Rosser LE, Savalgi RS. Skill acquisition and assessment for laparoscopic surgery. Arch Surg. 1997;132: 200-4.
- Rosser JC, Rosser LE, Savalgi RS. Objective evaluation of a laparoscopic surgical skill program for residents and senior surgeons. Arch Surg. 1998;133:657-61.
- Scott DJ, Bergen PC, Rege RV, Laycock R, Tesfay ST, Valentine RJ, et al. Laparoscopic training on bench models: better and most cost-effective than operating room experience? J Am Coll Surg. 2000;191:272-83.
- 42. Sedlack JD, Williams VM, DeSimone J, Page D, Ghosh BC. Laparoscopic knot security. Surg Laparosc Endosc. 1996;6:144-6.
- 43. Semm K. Operative Manual for Endoscopic Abdominal Surgery. Chicago: Year Book Medical Publishers; 1987.

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