Laparoscopic Tubotubal Anastomosis: Laparoscopic Microsurgery In Gynecology

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Tubotubal anastomosis technique dates back to the 1920's when large sutures were used to approximate proximal and distal ends of the fallopian tube. Direct vision, aided by overhead illumination, was used and stitches were placed superficially to avoid inclusion of the posterior wall. Delicate tissue handling was not stressed. No major breakthroughs in this area developed over the next half century. The 21%[1] success rate for the conventional technique was disappointingly low although a clear explanation has never been established. Presumably it was caused either by the failure to reconstruct a patent lumenal channel or by causing extensive postoperative adhesion formation.

To prevent inadvertent closure of the lumen, intraluminal stents were used during the suturing process. This may have given a false sense of security and actually may have caused more failures by careless suturing. The stents were left in place and removed two weeks after surgery, which may have caused mucosal irritation and foreign body reaction at the anastomotic site. It can be hypothesized that upon removal of the stent the raw surfaces collapsed on each other and adhesed, blocking the lumen.

In the last two decades Swolin,[2] Gomel,[3] and others[4] introduced the concept of delicate tissue handling and meticulous technique to improve the success rate. Since microsurgery was introduced to gynecology this success rate has dramatically increased to over 80% patency.[5] Undoubtedly the improvements in vision provided by use of the operating microscope, fine tip instruments, 7-0 to 9-0 suture materials, delicate tissue handling, and improved suturing technique afforded a high level of precision and security, thereby producing improved healing and functional restoration of the Fallopian tube. Better defined patient selection was also a factor in increasing the success rate.

The concept of laparoscopic tubal microsurgery was suggested to one of the authors (ZS) by Dr. M. Seitzinger who, while taking a course in open microsurgery, suggested that this surgery should be possible laparoscopically. The advantage would be to maintain the high success rate of microsurgical tubotubal anastomosis and add to it the benefits of the laparoscopic approach which is associated with reduced adhesion formation and quicker patient recovery.

At this point laparoscopy was used extensively for diagnostic purposes and the suturing technique practiced by Semm[6] was used for large scale tissue repairs, such as closure of the serosa following fibroid removal from the uterus. An occasional report surfaced concerning attempts at laparoscopic tubal reanastomosis but the pregnancy rate was not encouraging.[7] Hence the techniques and instrumentation available were not suitable for smaller scale or complex suturing tasks.

In order to realize the marriage between microsurgery and the laparoscopic surgical approach new suturing techniques and instrumentation were needed to be developed. At the same time suturing instruments were also in great demand by the general surgeons who were ready to progress beyond the laparoscopic cholecystectomy. Karl Storz Endoscopy, Tuttlingen, Germany, agreed to develop and manufacture a specific coaxial instrument set with cylindrical handles[8] reminiscent of the Castroviejo type needle holders. These instrument designs proved pivotal in enabling the development of advanced laparoscopic suturing techniques.

The initial testing and exploration into the clinical possibility of the laparoscopic tubal anastomosis was carried out with two gynecologic surgeons in the local area. The first clinical case, however, was performed at Candler Hospital in Savannah, Georgia under the direction of one of authors (EDB). To date, two cases have been performed with one patient having achieved intrauterine pregnancy.

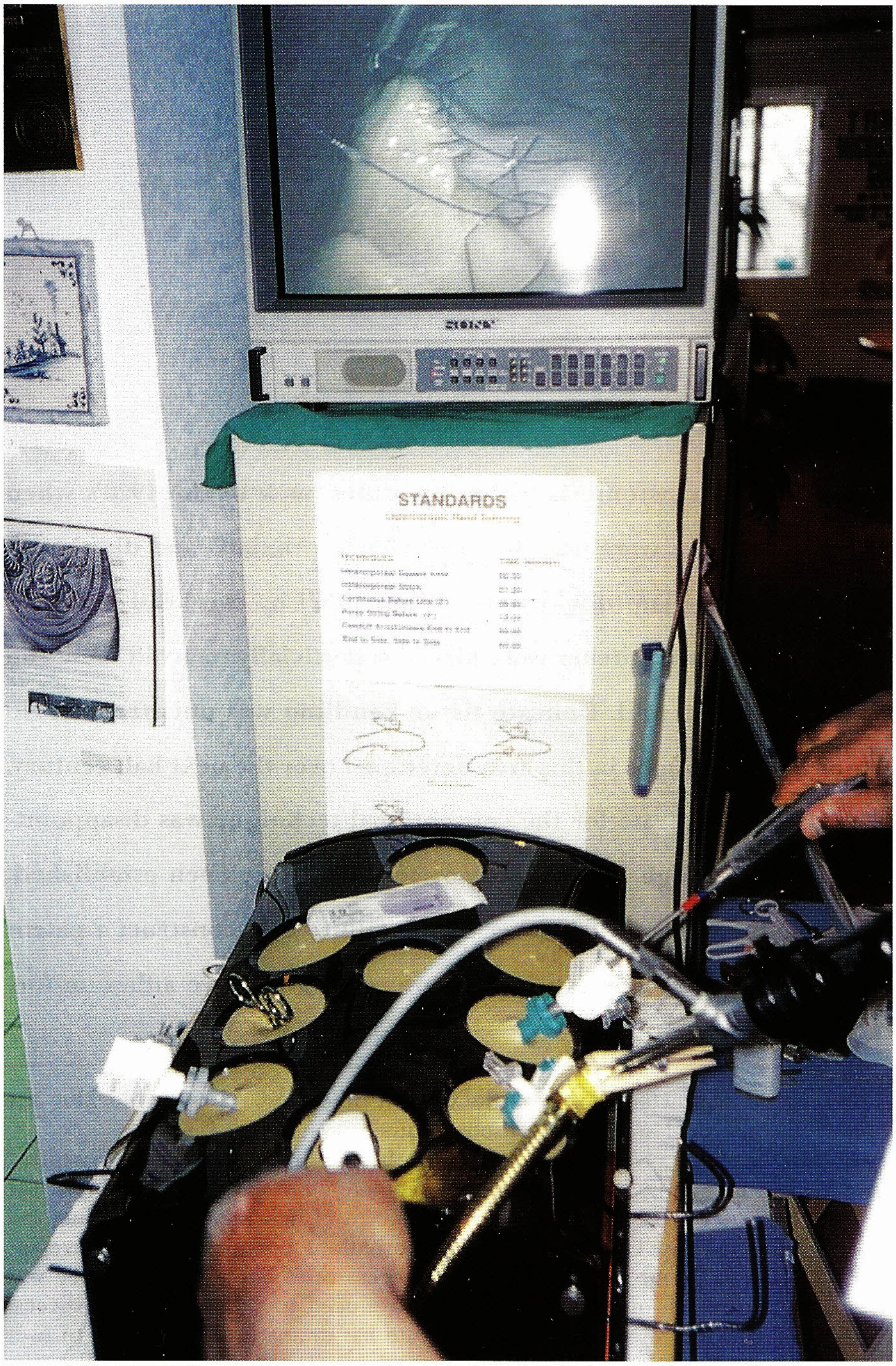

Figure 1. Training station and trainer box. Left hand instrument is in the umbilical port; right hand instrument is in the lateral suprapubic position and laparoscope is in between, creating the "center view triad" principle.

TRAINING FOR LAPAROSCOPIC MICROSURGERY

Suturing technique through the laparoscope is many times more difficult than in the open microsurgical setting,[9] however this substantial difficulty can be overcome with increased concentration, optimized setup and thorough training. In open microsurgery eye-hand coordination with precision instrument control is the main challenge. Hand tremor is also a major concern, requiring close hand positioning and support near the anastomotic site. Delicate handling of tissues and suture materials can be learned in one or two weeks (40-80 hours) in formal training courses, and with additional practice microsurgical skill could be honed to a high level.

When considering laparoscopic suturing, a number of similarities to microsurgery can be found. Both modalities share certain common features, including magnification, precision suturing technique, and delicate tissue handling in order to obtain improved surgical outcome. Significant differences also exist. Laparoscopy provides less magnification, and the long instrumentation dilutes tactile feedback and precision instrument control. The visual image using the microscope in laparotomy is stereoscopic (three dimensional) though it has a shallow depth of field; in laparoscopic surgery where viewing a closed circuit video image is standard, an image with poorer resolution and monocular view (two-dimensional) is the norm but it has a great depth of field. Overall laparoscopic suturing proved to be a considerably bigger challenge than open microsurgical anastomosis.

Training for laparoscopic suturing with intracorporeal knot tying is best accomplished in a 5-day, 40-hour formal program consisting of a structured program on magnified surgery, beginning with microsurgical technique and ending with laparoscopic suturing exercises on a live animal model. During the microsurgical phase meticulous open surgical technique is taught to establish the basic skills which are necessary before one can successfully complete a laparoscopic microsurgical tubal reanastomosis. The sutures used range from 7-0 to 10-0 with various needles for preparatory exercises. Depending on availability of time, the 40-hour program may be divided into two 20-hour sessions taken separately.

Choreographed techniques for needle handling, loading, driving and intracorporeal knot tying have been developed which require two-handed technique. Developing ambidexterity in the laparoscopic field is important for the gynecologist to evolve fully into a laparoscopic reconstructive surgeon. Once he has become facile in these techniques he should be able to accomplish tying a square knot in 30 seconds or less and precisely placing an interrupted in stitch and tying the square knot in 1.5 min. A laparoscopic tubal anastomosis should be accomplishable in 30 minutes per tube. These time standards approach those of open microsurgery but provide the benefits of the minimal access approach.

Training incorporates several facets, including maneuvering efficiently and safely in the magnified surgical environment, learning economy of motion principles, understanding the required mental framework and focused attention, and an overall flawless approach. For the gynecologist to be effective in laparoscopic suturing 90% of his or her effort should be expended on visual and mental activity, and only 10% of the effort on performing the physical task.[10] Therefore, laparoscopic suturing requires peak performance from the gynecologic surgeon to succeed.

During the laparoscopic phase of training both inanimate and animate models are used at specialized training stations[11] (Figure 1). Fresh animal tissue, specifically porcine uterine horn of an appropriate diameter, is used to develop and fine tune suturing skill using 5-0 to 8-0 suture material[12] (Figure 2a-d). Setup, port positions, hemostatic cutting, stenting and suturing techniques can be practiced on the bicornuate porcine uterine horn. After completion of the anastomosis the structure can be resected and examined

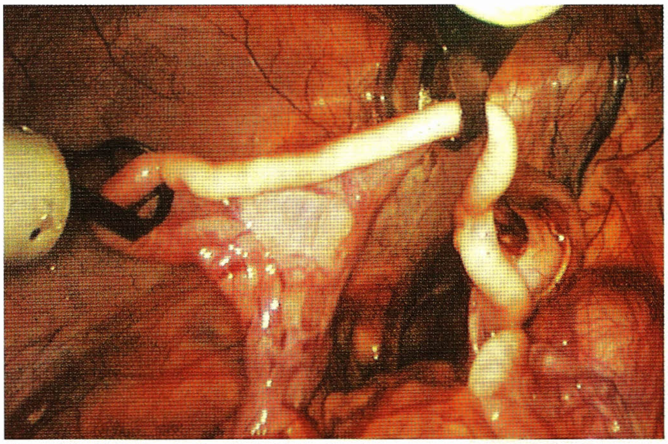

Figure 2a. Porcine uterine horn is displayed.

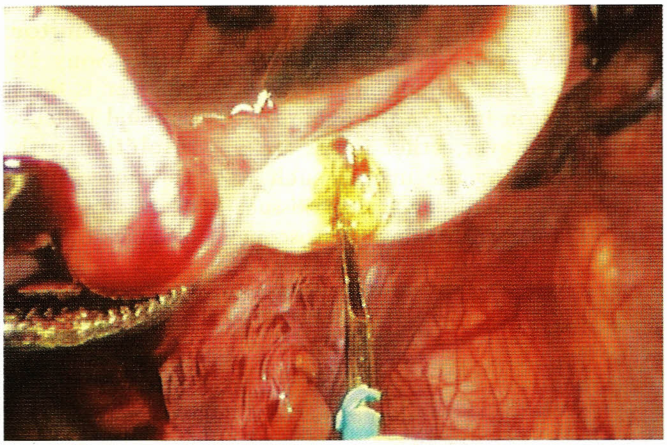

Figure 2b. Micromonopolar cutting.

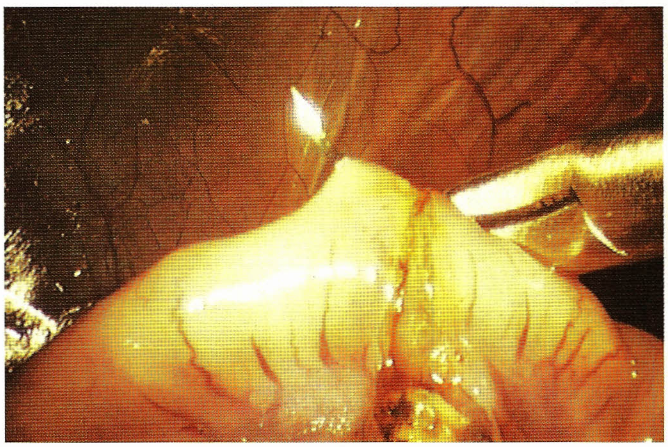

Figure 2c. Stitches are placed in a delicate manner to avoid trauma to the friable tissues.

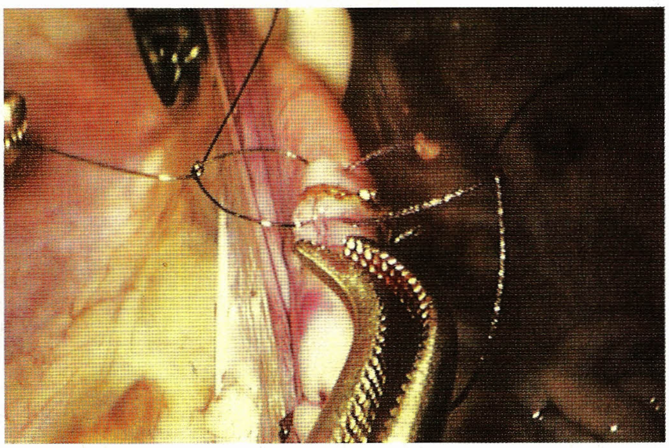

Figure 2d. Stitches are placed in a quadrangular fashion.

under the surgical microscope for correct suture placement and luminal reconstruction. Human hysterectomy specimens can also be used as they are of significant value for both microsurgical and laparoscopic anastomosis exercises (Figure 3). The final phase follows with live pig surgery (Figure 4) on an animal weighing approximately 60 lbs to provide a model similar to human surgery.

EQUIPMENT & INSTRUMENTATION

In laparoscopic microsurgery the role of equipment and instrumentation is greater than in traditional laparoscopic procedures and to this end important details are emphasized below.

In suturing small structures, considerable magnification is necessary (5 - 10X) to provide an optimal visual image, whether through the operating microscope or the laparoscope. Therefore, imaging equipment and instruments must be carefully selected and critically tweaked (fine-tuned).

Laparoscope

A little used 0° 10 mm laparoscope with a 20X ocular (Storz 26033 AP) can be used for a high quality, high magnification image to provide fine details. However, other issues are a factor affecting the image, such as monitor size and distance to the tissue. The 30° forward looking laparoscope is more versatile for general viewing and scanning of the pelvic and abdominal regions, but the image is slightly darker, and sharpness is best in the middle of the field.

4 mm laparoscopes could also be used since their image is nearly the same quality as the 10 mm laparoscope, yet the larger diameter is still preferred. An advantage in using the smaller laparoscope might be gained in enabling the use of smaller access ports, consequently minimizing the risk of herniation or adhesion formation but it comes at the cost of sacrificing image quality.

Video Camera

Three-chip cameras currently provide the highest resolution with good color representation. This is important in distinguishing the different tissue layers and visualization of the lumen and sutures. With this type of camera linked via RGB connectors to the monitor, 400 lines of displayed horizontal resolution is possible. However, the camera and monitor need to be sharply tuned for maximum image quality.

Video Monitor

The Sony 19 inch medical video monitor is the most frequently used unit and it delivers about 400 lines of resolution with good image clarity. This image quality is the current state-of-the-art, with the possible exception of special prototype or professional studio monitors carrying exorbitant price tags.

The 14 inch monitor is less frequently used and for good reason. The size of the display tube is part of the magnification, and the human eye seems to favor the larger monitor size with its greater magnification. The distance from which the monitor is viewed is approximately 6-7 feet. Although the smaller unit might have a sharper picture, hunting for details on the smaller screen causes significant stress in one's effort to perceive visual clues. Also, the 14 inch screen tends to produce a flatter picture, make depth perception even much more challenging.

Digital Enhancer

In the quest for a sharper and better overall image, a digital enhancer provides a good solution. It increases the sharpness of the image by digitally analyzing the video image and enhancing the contrast.

This unit is connected to the S-VHS output of the camera control unit, then inputs to the monitor. The enhancing effect can be increased or decreased, depending on the surgical field's characteristics. If the monitor is connected to both the RGB and S-VHS enhancer, with a push of a button, the image can be changed to take advantage of each system: color definition of the three chip camera system via RGB or edge definition with the enhanced S-VHS image.

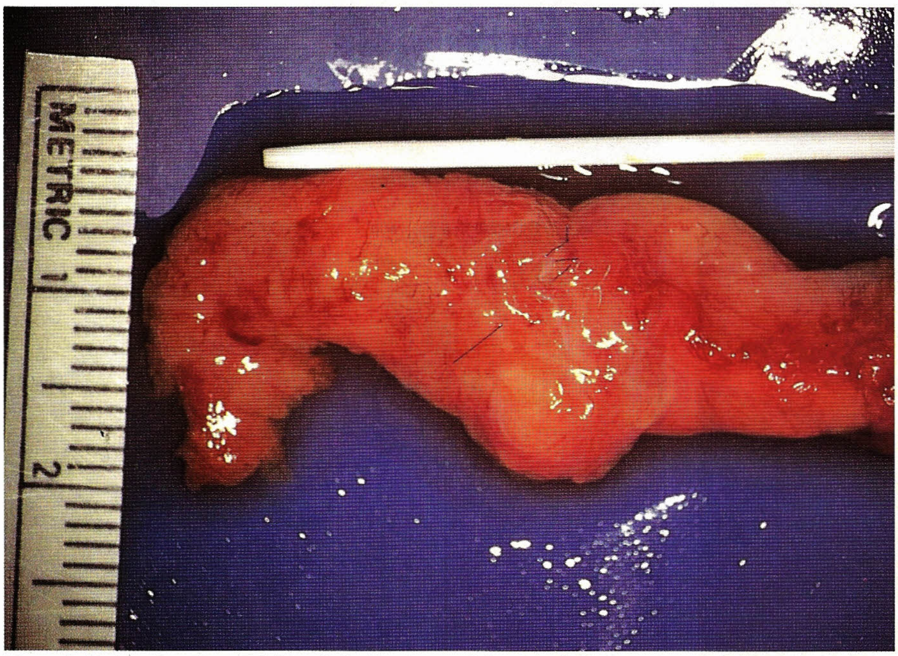

Figure 3. Various learning models, culminating in practicing on a fallopian tube surgical specimen, using 7-0 polypropylene suture.

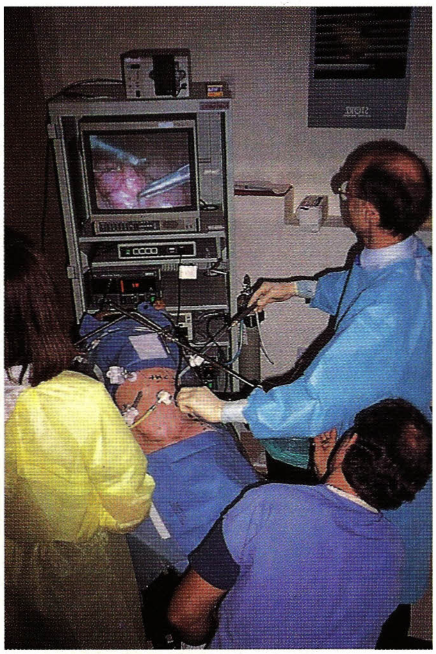

Figure 4. The live animal (pig) station.

Recording Media—Videotape

The best image is obtained by using the S-VHS enhancer and high quality S-VHS tape on standard speed. High-8 mm recordings also produce excellent quality images and are more compact than other videotapes.

Surgi-Slide Maker

Connected to the S-VHS output, the surgi-slide matter captures, stores, and permits quick exposure of up to four images at one time, then "prints" them out one after the other. As the images are printed and the memory buffer is freed, the 35mm film is automatically advanced, and subsequent images can then be captured.

The image quality is best when the unit is directly linked to the camera control unit and even better, to the digital enhancement output. The videoscopic image needs to be held steady, well-illuminated and composed. Movement, over or under lighting, smoke, and reflections will cause poor quality photographic images. Print film can also be used for creating enlargements of reasonable quality.

Photography

The 35 mm camera can be directly coupled to the laparoscope eyepiece in place of the video camera. A light source with flash ability and a synchronizing cord is necessary to complete the system. Although the images obtained in this manner are by far the best, it requires a high level of skill and careful composition of images to obtain a superior quality picture. Another disadvantage is the transition from the video to the photo mode causes the image from the video to be lost, with additional effort required to cover the camera with a sterilized wrap (bag).

Light Source and Cable

The video camera will automatically control the "iris" to allow the ideal amount of light to reach the video chip so having a light source that provide more illumination than the minimum necessary is practical. The Storz 615 xenon light source is suitable for general application; however for photography, a special xenon strobe unit is required, e.g. Storz 610, with the appropriate connections with the camera synchronizing cord.

The fiberoptic cables transmit light adequately, however, the longer the cable, the greater the loss of light. 180 cm and 250 cm cables are the most commonly used. With extended use, the fibers in the cable gradually break, particularly when it is roughly handled or bent in sharp angles. The result is diminished light transmitting capability. It is advisable to routinely check for increasing fiber breakage.

Liquid cables offer better light transmission ability but require even more care in handling.

O.R. Table

The surgeon should have a good overall position for comfort, and a narrow operating table (both surface and base) permits the surgeon to stand erect next to the patient. Anti-fatigue rubber floor mats covered with a surgical drape to minimize stress from standing on a concrete floor can be used (Figure 5a-b).

Laparoscope Holders

Since suturing with high magnification requires a steady image, a laparoscope holding device is recommended. They can be mechanical, pneumatic, or computer operating (foot switch controlled).[13]

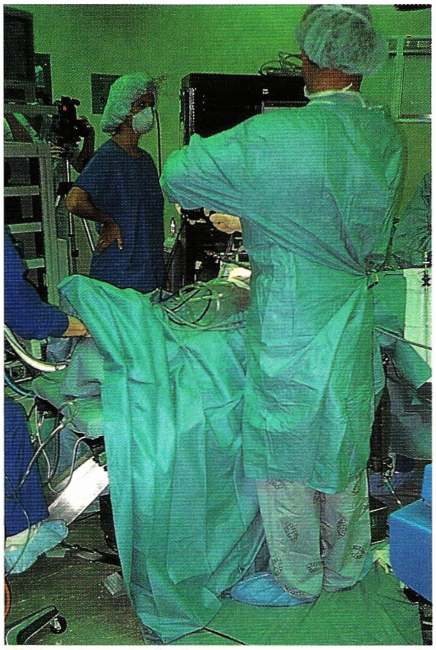

Figure 5a and 5b. Surgeon stands on an anti-fatigue mat covered with a surgical drape.

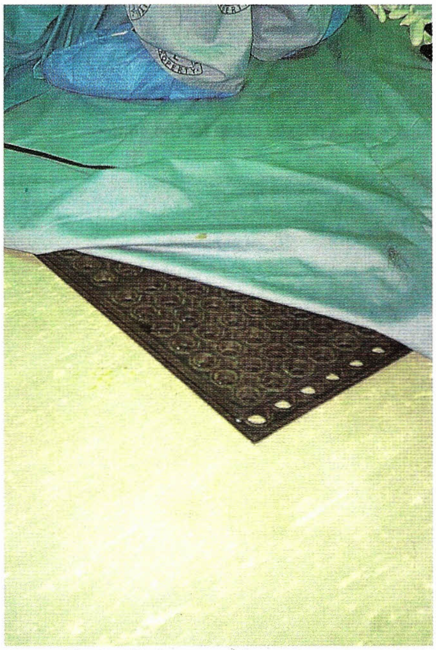

Figure 5b. Anti-fatigue mat shown.

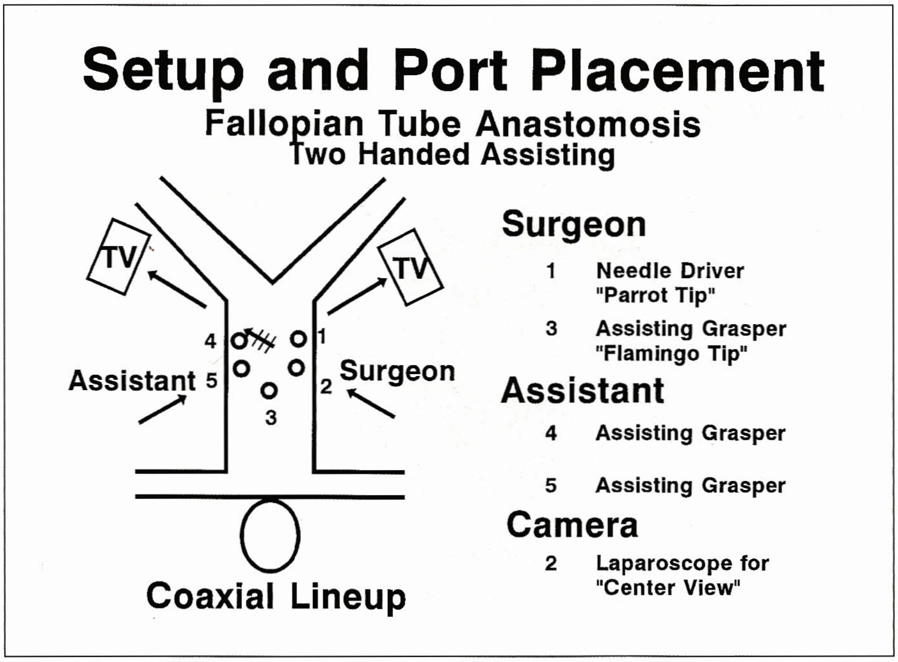

Figure 6. Coaxial setup diagram.

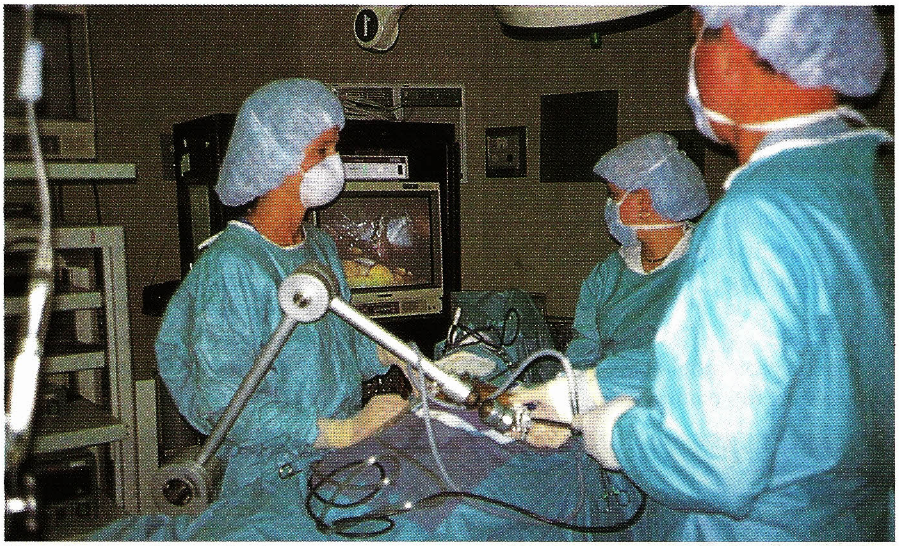

Figure 7a. A coaxial setup for the surgeon.

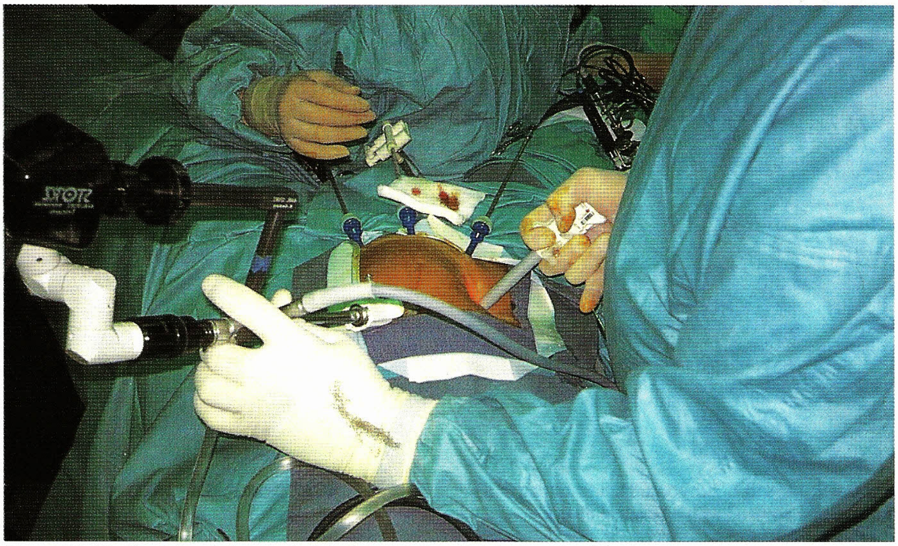

Figure 7b. Placing lateral view ports in between left and right suturing instrument ports.

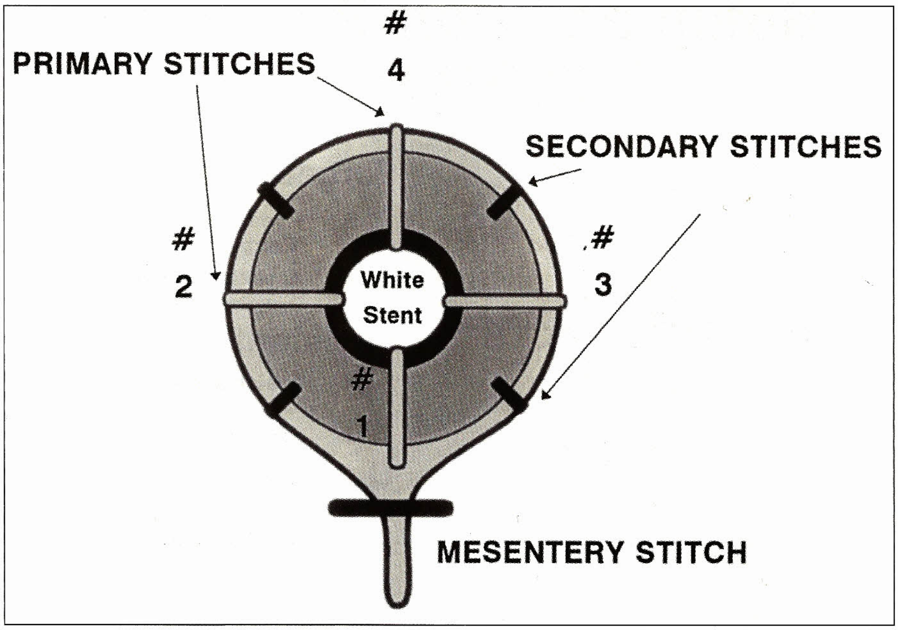

Figure 8. Sequence of stitch placement.

Suturing Instruments

Suturing was initially attempted mainly using straight tip instruments, including those with a bullet nose or a tapered tip,[6] and the angled Roman scissor grip. The movements possible with such instruments were significantly restricted and required modification of knot tying techniques. These knots were both time consuming and challenging to accomplish. The quality and security of the resulting knot was often questionable. The Szabo-Berci needle drivers (parrot needle driver and flamingo assisting grasper). Their complementary jaw design provide the surgeon with considerable mobility and flexibility.

O.R. SETUP AND PORT POSITIONS

Coaxial Setup

The surgeon, view port, instruments, suture line and monitor are to be arranged along a straight line (Figure 6.). This setup actually begins by first determining the proposed suture line. Accordingly, the view port is positioned so that the laparoscope will line up with the suture line.

Following the principles suturing port positioning, the left and right hand ports are placed on either side, creating the "center view triad" port positions (Figure 7a-b). An additional two assisting ports are placed so that the number of ports add up to the basic five principle.[14] This will allow the assisting instruments to be used simultaneously with the suturing instruments.

OPERATIVE APPROACH

Patient Selection

Since the level of technical difficulty is considerably greater in the laparoscopic method than in the open approach ideal tubal conditions are a prerequisite; that is, isthmic-isthmic anastomosis with at least a 3 cm length of proximal and distal segments without adhesions.

Instruments

The available instruments present a tremendous challenge for the surgeon, especially when 7-0 or 8-0 suture materials are needed. A microversion of the Szabo-Berci suturing set is needed.

Trimming of Stumps

Trimming is accomplished with either sharp dissection and pinpoint coagulation, or with a precisely calibrated micromonopolar needle cautery. First the proximal stump is trimmed, and identified with a solution of dye. The distal stump is opened in a similar manner but instead of dye, a stent of soft silicone tubing is used to identify the lumen.

Temporary Stent Placement

In order to visualize the lumen and aid in the suture placement a 2-3 cm length of soft silicone tubing is inserted after the mesentery stitch has been placed. This is removed before the final stitches are tightened to the appropriate tension.

Suture Placement (Figure 8)

The principles and techniques for laparoscopic suturing and knot tying[15] have been described in detail in the literature.[9 10 14 20]

The number and locations of stitches necessary for optimal tubal reconstruction is debatable. There is no scientific study in the literature that answers this question in a definitive manner.[16 17] The accepted standard is four primary stitches that includes the muscularis. The need for reperitonealization is an issue that is also unsettled but it would be logical to minimize raw surfaces.

Surgical Technique

One-handed Technique with an Assistant vs. Two-handed Technique

The traditional gynecologic operative laparoscopy technique is a one-handed approach that makes extensive use of the surgical assistant. One of the surgeon's hands (usually the dominant one) holds and guides the camera, while the other hand manipulates the tissue. The assistant stands near the hip of the patient or between the legs. As the surgeon sets up the tissue for cutting or other manipulation, he hands the grasping instrument to the assistant who will hold it in place. Then the surgeon introduces another instrument through a different operative port to continue or complete his maneuver.

If the target tissue needs to be repositioned, the surgeon will have to release his instrument, and actually grasp the assistant's hand and reposition it to relocate the tissue into the desired position. Then he must regrasp his original instrument and continue the task. The surgeon should be coaxially aligned with the view; however the assistant may be in a vastly different position to view the image and may have some difficulty anticipating the needs of the surgeon.

This method is suitable for simple procedures requiring a relatively small amount of tissue manipulation. For more complicated, suturing intensive tasks, this should be replaced by a two-handed surgeon and two-handed assistant setup. This permits immeasurably more efficient and complex procedures to be completed satisfactorily. This essentially duplicates the ideal microsurgical setup. Laparoscopically the two-handed active assistant should be either another skilled laparoscopic surgeon or a well-trained assistant.

Stitch Placement

The first stitch is placed into the mesenteric aspect taking a bite equal approximately to the wall thickness of the Fallopian tube. The bite should includes all layers, i.e., the serosa, muscularis, and mucosa then be tied tight. For this stitch a 5-0 or 6-0 Vicryl (Ethicon Inc., Somerville, NJ) suture can be used—the larger suture is preferred because of the tensile strength needed for this stitch and as well as its ease of handling.

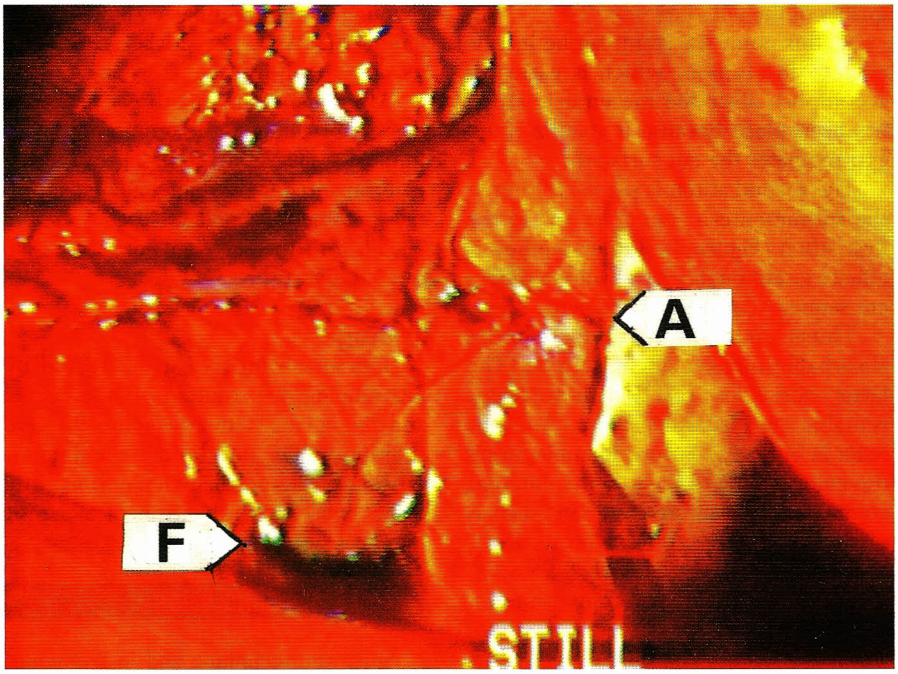

Figure 9. Beginning of the dye test.

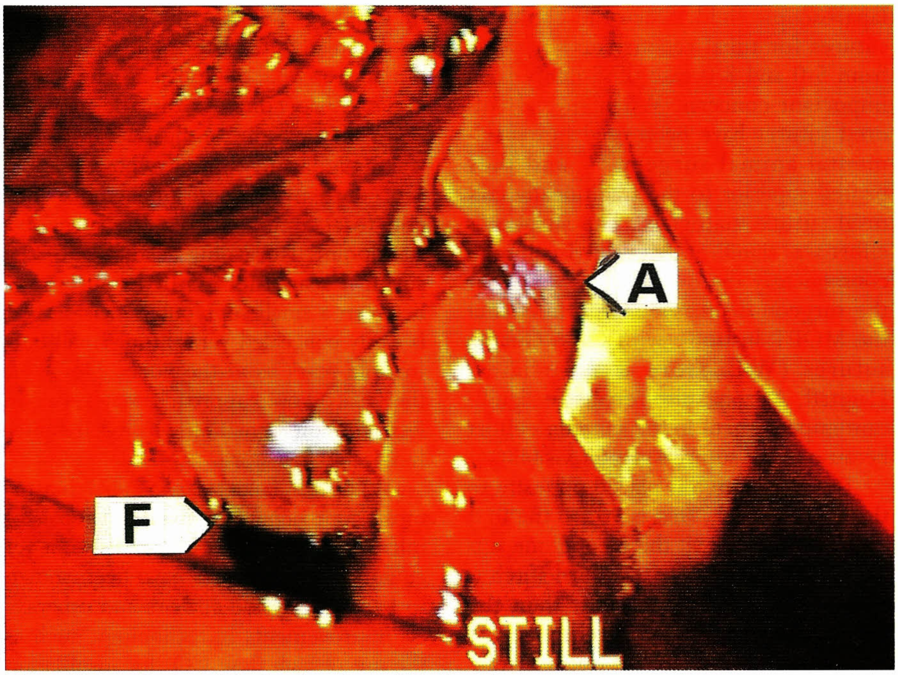

Figure 10. Free flowing of the dye through the Fallopian tube.

In the early days of microsurgical evolution, a near obsession developed concerning the use of the smallest possible suture. It was later realized that beyond a certain level, little or no patient benefit would be realized. On the other hand, such trends caused the surgeon substantially more effort so a balance was struck to equate the two factors concerning suture size and reasonable surgeon effort. Currently the pendulum swings in the opposing direction; i.e., the larger the suture the better, as long as there is no measurable loss or degradation in the quality of the outcome.

At this point the stent can be inserted into the lumen, which is easier to accomplish after the mesenteric stitch has been place because it stabilizes and approximates the cut surfaces.

The second stitch is placed, either at the antimesenteric aspect or 90° to the first stitch (Figure 8). Either method is effective, although they require a different sequence of stitch placement.

These primary stitches can be absorbable or permanent sutures. The latter causes less reaction, however, it remains encapsulated *in situ*. Another issue is visibility. Suture manufacturers use color coding to identify the different compositions of suture materials, such as violet for Vicryl (Ethicon Inc., Somerville, NJ) or Polysorb (U.S.S.C., Norwalk, CT), black for nylon, etc. Consequently if one needs a braided absorbable suture the only choice is the color purple or blue-green, both of which are difficult to visualize in the laparoscopic field. Since the choice of sutures for tubal reconstruction range from 5-0 and 8-0 ease of visibility is an important concern. When special colored sutures have been used in experimental animal surgery[18 19] and they proved superior to the traditionally colored suture materials. The surgeon's effort was significantly eased visually and consequently the overall stress level for the surgeon decreased. Experiments at the MOET Institute with CV-6 Gortex sutures (W.L. Gore & Associates, Flagstaff, Arizona) also revealed a significant improvement in the surgeon's effort because of the suture's greater visibility.

The third stitch is placed opposite to the second stitch, that is 90° to the first mesenteric stitch. If the second one was placed antimesenteric this third stitch is still placed in this location, then the fourth stitch is placed directly across from it, creating a precise quadrangulation technique.

Otherwise, the final fourth primary stitch is placed at the antimesenteric border. With the exception of the first stitch these stitches are tied in a precise square knot but left adequately loose in a suspension style[20] so that the cut edges and each of the tissue layers can be clearly identified for precision technique. It also permits removal of the soft silicone stent between the stitches. This suspension technique requires close familiarity with the slip knot technique[21] and if the suture end is left long enough, it could be brought out through the abdominal wall with a 16 gauge diameter thread retriever and used a stay suture.

After inspecting all the stitches for correct placement, the temporary intraluminal stent is extracted. Then the suspension stitches are tightened and suture tails trimmed. Secondary stitches may be placed into the serosa where excessive raw surfaces are present.

Testing

The anastomosis can be tested by introducing dye solution via the cervix and the cornual lumen (Figure 9). Dye solution spilling out through the fimbria, without leakage elsewhere along the tube, is a clear indication of a patent lumen (Figure 10).

CONCLUSION

Since the technique and instrumentation are still in the developmental stage, a large series of clinical cases with follow-up is not yet available, therefore it would be speculative to determine whether or not laparoscopic tubotubal anastomosis is a viable procedure. From the patient's point of view, the surgical access is less traumatic laparoscopically; however, the procedure itself is a great deal more difficult to accomplish from the surgeon's standpoint. Regarding aesthetics of the surgical scar, there is little difference between a small suprapubic incision that is easily concealed versus four small buttonhole scars from the ports. However, the laparoscopic approach may result in less adhesion formation which is definitely a desirable feature.

While the laparoscopic tubal anastomosis approaches the quality of repair of microsurgery via laparotomy, it is not yet equal. The techniques have been shown to be viable by the authors and others.[22] As improvements in technology, such as the use of high flow CO_2 for insufflation and the coupling of a camera to the laparoscope, have proved instrumental in the evolution of laparoscopic surgical techniques, technology again might provide the path for further development of laparoscopic microsurgery. Greater magnification with a longer focal distance in laparoscope design might prove practical, especially if it is incorporated into the newly designed 4 mm laparoscopes with high quality image. Instrumentation that incorporate the important features found in the suturing instruments available for suturing of larger structures will be refined for easier handling of the smaller sutures. With improvement such as these, laparoscopic microsurgical tubotubal anastomosis as well as other precision procedures can be expected to be adopted more widely. STI

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