LAPAROSCOPIC SURGERY FOR ADHESIOLYSIS

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INTRODUCTION

Postoperative adhesions occur after almost every abdominal surgery and are the leading cause of intestinal obstruction. In one study, 93% of patients who had undergone at least one previous abdominal operation had postsurgical adhesions. This was not considered surprising, given the extreme delicacy of the peritoneum and the fact that apposition of two injured surfaces nearly always results in adhesion formation.[1]

Fatal sequelae of intraabdominal adhesions were reported as early as 1872 after removal of an ovarian tumor resulted in intestinal obstruction.[2] Adhesions are the most common cause of bowel obstruction and most likely result from gynecologic procedures, trauma, appendectomies and other intestinal operations.[3] Adhesions have also been proposed to cause infertility and abdominal and pelvic pain. Although nerve fibers have been confirmed in pelvic adhesions, their presence is not increased in those patients with pelvic pain.[4] In addition, there does not appear to be an association between the severity of adhesions and complaint of pain. It is generally accepted that adhesions may impair organ motility resulting in visceral pain transmitted by peritoneal innervation.[5] Many patients experience resolution of their symptoms after adhesiolysis.[6-9] This may be complicated by placebo effect as demonstrated by one study that showed no difference in pain scores between patients who were randomized to adhesiolysis versus expectant management.[10]

In 1994, adhesiolysis procedures resulted in 303,836 hospitalizations, 846,415 days of inpatient care, and $1.3 billion in health care expenditures. Forty-seven percent of these hospitalizations were for adhesiolysis of the female reproductive system, the primary site for these procedures. In comparison to similar data from 1988, the cost of adhesiolysis hospitalizations is down. One significant influence on this trend is the increased use of minimally invasive surgical techniques resulting in fewer days of inpatient care.[11]

This chapter reviews the pathophysiology of adhesion formation, equipment and technique for adhesiolysis, and methods for adhesion prevention.

PATHOPHYSIOLOGY OF ADHESION FORMATION

Adhesion formation is initiated by peritoneal trauma. Its morphogenesis was described in detail by diZerega.[12] Within hours at the site of injury, polymorphonuclear leukocytes appear in large numbers meshed in fibrin strands. At 24-36 hours, macrophages appear in large numbers and are responsible for regulating fibroblast and mesothelial cell activities. By day 2, the wound surface is covered by macrophages, islands of primitive mesenchymal cells and mesothelial cells. By day four the islands of primitive mesenchymal cells have now come into contact with each other. Fibroblasts and collagen are now present and increasing. By day five, an organized fibrin interconnection is now seen composed of collagen, fibroblasts, mast cells, and vascular channels containing endothelial cells. The adhesion continues to mature as collagen fibrils organize into bands covered by mesothelium and containing blood vessels and connective tissue fiber.[12]

EQUIPMENT

A review of standard equipment such as light sources and video systems is beyond the scope of this chapter. Equipment useful for advanced procedures and energy sources is included. However, the main technique for adhesiolysis with the least possibility for reformation can simply be described as "cold scissors dissection with bipolar backup."

Laparoscopes

Four different laparoscopes should be available for adhesiolysis: a 10-mm 0° straight viewing laparoscope; a 10-mm operative laparoscope with 5-mm operating channel; a 5-mm straight viewing laparoscope for introduction through 5-mm trocar sleeves; and an oblique-angle laparoscope (30-45°) for upper abdominal and pelvic procedures.

Scissors

Scissors are the preferred instrument to cut adhesions, especially avascular and/or congenital adhesions. Using the magnification afforded by the laparoscope, most anterior abdominal wall, pelvic, and bowel adhesions can be carefully inspected and divided with minimal bleeding, rarely requiring microbipolar coagulation. Loose fibrous or areolar tissue is separated by inserting a closed scissors and withdrawing it in the open position. Pushing tissue with the partially open blunt scissors tip is used to develop natural planes.

Reusable 5 mm blunt-tipped sawtooth scissors and curved scissors cut well without cautery. Blunt or rounded-tip 5mm scissors with one stable blade and one moveable blade are used to divide thin and thick bowel adhesions sharply. Sharp dissection is the primary technique used for adhesiolysis to diminish the potential for adhesion formation; electrification and laser are usually reserved for hemostatic dissection of adhesions where anatomic planes are not evident or vascular adherences are anticipated. Thermal energy sources must be avoided as much as possible to reduce adhesion recurrence. Blunt-tipped, sawtooth scissors, with or without a curve, cut well (Richard Wolf Medical Instruments, Vernon Hills, IL and Karl Storz Endoscopy, Culver City, CA). Many disposable scissors depend greatly on electrification for cutting. Hook-scissors are not very useful for adhesiolysis. I use them only to cut suture.

Surgeons should select scissors that feel comfortable. To facilitate direction changes, the scissors should not be too long or encumbered by an electrical cord. This author prefers to make rapid instrument exchanges between scissors and microbipolar forceps through the same portal to control bleeding, instead of applying electrification via scissors.

Electrosurgery

When discussing electrosurgery, the term "cautery" should be abandoned as it is not electrosurgery. Cautery, thermocoagulation, or endocoagulation refer to the passive transfer of heat from a hot instrument to tissue. The hot instrument is usually heated by electrical current. The temperature rises within the tissue until cell proteins begin to denature and coagulate with resultant cell death. Electrical current does not pass through the patient's body!

Monopolar *cutting* current can be used safely, as the voltage is too low to arc to organs even 1 mm away. *Cutting current* is used to both cut and/or coagulate (desiccate) depending on the portion of the electrode in contact with the tissue. The tip cuts, while the wider body tamponades and coagulates.

Monopolar *coagulation current* which uses voltages over 10 times that of cutting current can arc 1 to 2 mm and is used in close proximity to tissue, but not in contact, to fulgurate diffuse venous and arteriolar

bleeders. It takes 30% more power to spark or arc in CO_2 pneumoperitoneum than in room air; thus, at the same electrosurgical power setting, less arcing occurs at laparoscopy than at laparotomy.

Monopolar electrosurgery should be avoided when working on the bowel unless the surgeon is well versed in this modality. The expert laparoscopic surgeon can use monopolar electrosurgery safely to cut or fulgurate tissue, but desiccation (coagulation) on bowel should be performed with bipolar techniques.[13,14]

Electrosurgical injury to the bowel can occur beyond the surgeon's field of view during laparoscopic procedures from electrode insulation defects or capacitive coupling. While the surgeon views the tip of the electrode, electrical discharge may occur from its body (insulation failure) or from metal trocar cannulas surrounding the electrode if they are separated from the skin by plastic retention sleeves. These problems are eliminated by active electrode monitoring using the Electroshield EM-1 monitor system (Encision, Boulder, CO). This consists of a sheath surrounding the electrode and a sheath monitor (EM-1) to detect any insulation faults and shield against capacitive coupling.

Bipolar desiccation using cutting current between two closely opposed electrodes is safe and efficient for large vessel hemostasis.[15,16] Large blood vessels are compressed and bipolar *cutting* current passed until complete desiccation is achieved, i.e., the current depletes the tissue fluid and electrolytes and fuses the vessel wall. Coagulating current is not used as it may rapidly desiccate the outer layers of the tissue, producing superficial resistance thereby preventing deeper penetration.

Small vessel hemostasis necessary for adhesiolysis is best achieved by using microbipolar forceps after precisely identifying the vessel with electrolyte solution irrigation. Microbipolar forceps (Richard Wolf Medical Instruments, Vernon Hills, IL) with an irrigation channel work best for precise tissue desiccation with minimal thermal spread.

Harmonic Scalpel

The use of Harmonic Scalpel (Ethicon Endosurgery, Cincinnati, Ohio) for laparoscopic adhesiolysis is gaining popularity. Although it has its limitations, the benefit of this multifunctional instrument far outweighs any disadvantage. Many factors can be attributed to its progressive acceptance. The lack of electrical energy used to coagulate vessels and the smaller (2mm) lateral energy spread make it more attractive than conventional electrosurgical instruments by potentially reducing the percentage of delayed post-operative bowel injuries (caused by electrical burns.) This is not to say however, that injury cannot occur. As with standard electrosurgical instruments, the Harmonic Scalpel, specifically the jaws, can become hot and cause tissue injury if not used in a prudent manner. Although Harmonic Scalpel has the ability to grasp, cut, and cauterize simultaneously, making it a useful instrument for a judicious operator (requiring fewer instrument changes in and out of port sites), the inability to cut without applying energy assures the need for a sharp pair of conventional scissors in laparoscopic adhesiolysis.

Rectal and Vaginal Probes

A sponge on a ring forceps is inserted into the vagina or the posterior vaginal fornix, and an 81-French probe is placed in the rectum to define the rectum and posterior vagina for lysis of pelvic adhesions and/or excision of endometriosis when there is a significant degree of cul-de-sac obliteration. Whenever rectal location is in doubt, it is identified by insertion of the rectal probe.

CO2 laser

The CO2 laser, with its 0.1 mm depth of penetration and inability to traverse through water, allows the surgeon some security when lysing adhesions especially in the pelvis. The Coherent 5000L laser (Palo Alto, CA), by using a 11.1 *u*m wavelength beam, maintains a 1.5mm spot size at all power settings allowing for more precision than most standard 10.6 *u*m wavelength CO2 lasers.

Aquadissection

Aquadissection is the use of hydraulic energy from pressurized fluid to aid in the performance of surgical procedures. The force vector is multidirectional within the volume of expansion of the uncompressible fluid; the force applied with a blunt probe is unidirectional. Instillation of fluid under pressure displaces tissue, creating cleavage planes in the least resistant spaces. Aquadissection into closed spaces behind peritoneum or adhesions produces edematous, distended tissue on tension with loss of elasticity, making further division easy and safe using blunt dissection, scissors dissection, laser, or electrosurgery.

Suction-irrigators with the ability to dissect using pressurized fluid should have a single channel to maximize suctioning and irrigating capacity. This allows the surgeon to perform atraumatic suction-traction-retraction, irrigate directly, and develop surgical planes (aquadissection). The distal tip should not have side holes as they impede these actions, spray the surgical field without purpose, and cause unnecessary tissue trauma when omentum, epiploic appendices, and adhesions become caught. The shaft should have a dull finish to prevent CO2 laser beam reflection, allowing it to be used as a backstop. The market is crowded with many aquadissection devices.

Plume Eliminator

Smoke evacuation during electrosurgery or CO2 laser laparoscopy is expedited using a Clear View EBS ICM 350 smoke evacuator (I.C. Medical, Phoenix, AZ).

Gasless laparoscopy (abdominal wall retractors)

Abdominal wall subcutaneous emphysema occurs frequently during anterior abdominal wall adhesiolysis as peritoneal defects result in free communication with the rectus sheath. This compromises peritoneal cavity operating space. A useful technique is to insert an anterior abdominal wall retractor (AbdaLift, Storz, CA) once the umbilicus has been cleared of adhesions.

LAPAROSCOPIC PERITONEAL CAVITY ADHESIOLYSIS

Adhesiolysis by laparoscopy and laparotomy can be very time-consuming and technically difficult and is best performed by an expert surgeon. However, despite lengthy laparoscopic procedures (two to four hours), most patients are discharged on the day of the procedure, avoid large abdominal incisions, experience minimal complications, and return to full activity within one week of surgery.

In this section, general adhesiolysis, pelvic adhesiolysis, ovariolysis, salpingo-ovariolysis, and salpingostomy are described. The laparoscopic treatment of acute adhesions has not been included. However, the best treatment for sexually transmitted disease adhesive sequelae may be prevention through early laparoscopic diagnosis and treatment of acute pelvic infection, including abscesses. Acute adhesiolysis will often prevent chronic adhesion formation.[17-19]

Classification

Extensive peritoneal cavity adhesion procedures need a classification system that relates to their degree of severity and the surgical expertise necessary for adhesiolysis. The single best indicator of the degree of severity and expertise necessary for adhesiolysis is the number of previous laparotomies. The frequency of small bowel obstruction symptoms indicates the need for surgery.

Peritoneal adhesiolysis is classified into enterolysis including omentolysis and female reproductive reconstruction (salpingo-ovariolysis and cul-de-sac dissection with excision of deep fibrotic endometriosis). Bowel adhesions are divided into upper abdominal, lower abdominal, pelvic, and combinations. Adhesions surrounding the umbilicus are upper abdominal as they require an upper abdominal laparoscopic view for division. The extent, thickness, and vascularity of adhesions vary widely. Intricate adhesive patterns exist with fusion to parietal peritoneum or various meshes.

Extensive small bowel adhesions are not a frequent finding at laparoscopy for pelvic pain or infertility. In these cases, the fallopian tube is adhered to the ovary, the ovary is adhered to the pelvic sidewall, and the rectosigmoid may cover both. Rarely, the omentum and small bowel are involved. Adhesions may be the result of an episode of pelvic inflammatory disease or endometriosis, but most commonly are caused by previous surgery. Adhesions cause pain by entrapment of the organs they surround. The surgical management of extensive pelvic adhesions is one of the most difficult problems facing surgeons today.

Surgical plan for extensive enterolysis

A well-defined strategy is important for small bowel enterolysis. For simplification, this is divided into three parts:

1. *Division of all adhesions to the anterior abdominal wall parietal peritoneum.* Small bowel loops encountered during this process are separated using their anterior attachment for countertraction instead of waiting until the last portion of the procedure (running of the bowel).

2. *Division of all small bowel and omental adhesions in the pelvis*. Rectosigmoid, cecum, and appendix often require some separation during this part of the procedure.

3. *Running of the bowel* Using atraumatic grasping forceps and usually a suction-irrigator for suction traction, the bowel is run. Starting at the cecum and terminal ileum, loops and significant kinks are freed into the high upper abdomen to the ligament of Treitz.

4.(Optional) Finally tubo-ovarian pathology is treated if indicated.

Time frequently dictates that all adhesions cannot be lysed. From the history, the surgeon should conceptualize the adhesions most likely to be causing the pain, i.e., upper or lower abdomen, left or right, and clear these areas of adhesions.

Preoperative preparation

Patients are informed preoperatively of the high risk for bowel injury during laparoscopic procedures when extensive cul-de-sac involvement with endometriosis or adhesions is suspected. They are encouraged to hydrate and eat lightly for 24 hours before admission. A mechanical bowel preparation (GoLYTELY or Colyte) is administered orally the afternoon before surgery to induce brisk, self-limiting diarrhea to cleanse the bowel without disrupting the electrolyte balance.[20] The patient is usually admitted on the day of surgery. Lower abdominal, pubic, and perineal hair is not shaved. Patients are encouraged to void on call to the OR, and a Foley catheter is inserted only if the bladder is distended or a long operation anticipated. A catheter is inserted during near the end of the operation and removed in the recovery room when the patient is aware of its presence, to prevent bladder distension. Antibiotics (usually cefoxitin) are administered in all cases lasting over two hours, at the two-hour mark.

Patient Positioning

All laparoscopic surgical procedures are done under general anesthesia with endotracheal intubation. An orogastric tube is placed routinely to diminish the possibility of a trocar injury to the stomach and to reduce small bowel distention. The patient's arms should be tucked on both sides so that the surgeon's position is comfortable and not limited. The patient's position is flat (0°) during umbilical trocar sleeve insertion and anterior abdominal wall adhesiolysis but a steep Trendelenburg position (30 degrees), reverse Trendelenburg position, and side-to-side rotation are used when necessary. Lithotomy position, with the hip extended (thigh parallel to abdomen) is obtained with Allen stirrups (Edgewater Medical Systems, Mayfield Heights, OH) or knee braces, which are adjusted individually to each patient before she is anesthetized. Anesthesia examination is performed prior to prepping the patient.

Incisions

In the absence of suspected periumbilical adhesions, an intraumbilical vertical incision is made through the skin of the inferior umbilical fossa extending to and just beyond its lowest point. A Verres needle is placed through this low point while pulling the umbilicus towards the pubic symphysis and insufflation with CO2 is continued until an intraabdominal pressure of 25-30mm Hg is obtained.

The palmed short trocar is positioned at a 90^{o} angle inside the deep funnel shaped portion of the umbilical fossa where fascia and peritoneum meet and inserted through this into the peritoneal cavity at a 45^{o} angle in one continuous thrusting motion, with wrist rotation. This is performed without lifting the anterior abdominal wall as the high intraabdominal pressure provides counterpressure against the parietal peritoneum to lift it above the large vessels below. The result is a parietal peritoneal puncture directly beneath the umbilicus. Once the trocar is in place within the abdominal cavity, the intra-abdominal pressure is lowered to 12-15 mm Hg to diminish the development of vena caval compression and subcutaneous emphysema.

Special alternate entry sites and techniques are used when there is a high suspicion for periumbilical adhesions in patients who have undergone multiple laparotomies, have lower abdominal incisions traversing the umbilicus, or who have extensive adhesions either clinically or from a previous operative record. Open laparoscopy at the umbilicus carries the same risk for bowel laceration if the bowel is fused to the umbilical undersurface.

One alternate site is in the left ninth intercostal space, anterior axillary line. Adhesions are rare in this area, and the peritoneum is tethered to the undersurface of the ribs, making peritoneal tenting away from the needle unusual. A 5-mm skin incision is made over the lowest intercostal space (the 9^{th}) in the anterior axillary line. The Veress needle is grasped near its tip, like a dart, between thumb and forefinger, while the other index finger spreads this intercostal space. The needle tip is inserted at a right angle to the skin (a 45^{o} angle to the horizontal) between the ninth and tenth ribs. A single pop is felt on penetration of the peritoneum. Pneumoperitoneum to a pressure of 30 mmHg is obtained. A 5 mm trocar is then inserted through this same incision that has migrated downward below the left costal margin because of the pneumoperitoneum.

Another alternate entry site is Palmer's point[21] located 3 cm inferior to the subcostal arch in the left medioclavicular line.[22] Also, if the uterus is present and thought to be free of adhesions, the surgeon may consider inserting a long Veress needle transvaginally through the uterus.[23]

When unexpected extensive adhesions are encountered initially surrounding the umbilical puncture, the surgeon should immediately seek a higher site. Thereafter, the adhesions can be freed down to and just beneath the umbilicus, and the surrounding bowel inspected for perforations. The umbilical portal can then be reestablished safely for further work.

Other laparoscopic puncture sites are placed as needed, usually lateral to the rectus abdominis muscles and always under direct laparoscopic vision. When the anterior abdominal wall parietal peritoneum is thickened from previous surgery or obesity, the position of these muscles is judged by palpating and depressing the anterior abdominal wall with the back of the scalpel; the wall will appear thicker where rectus muscle is enclosed, and the incision site is made lateral to this area near the anterior superior iliac spine.

If an umbilical insertion is possible and extensive adhesions are present close to but below the umbilicus, the operating laparoscope with scissors in the operating channel is the first instrument used. If a left upper quadrant 5 mm incision is necessary, there is usually room for another puncture site to do initial adhesiolysis with scissors.

Abdominal Adhesiolysis

Anterior abdominal wall adhesions involve the parietal peritoneum stuck to the omentum, transverse colon, and small bowel with varying degrees of fibrosis and vascularity. Adhesions may be filmy and avascular, filmy and vascular, or dense, fibrous and vascular. All of these adhesions to the anterior abdominal wall are released. If adhesions extend from above the level of the laparoscope in the umbilicus, another trocar is inserted above the level of the highest adhesion and the laparoscope is inserted there. Adhesions are easier to divide when working above them, instead of within them, as gravity helps to delineate the plane for separation after which the CO2 pneumoperitoneum can disperse into the dissection plane.

Adhesiolysis is done using scissors alone if possible. Rarely, electrosurgery, CO2 laser, and the Harmonic Scalpel can be are used. In most cases, the initial adhesiolysis is performed with scissors. CO_2 laser through the laparoscope on adhesions close to the trocar insertion often results in reflection with loss of precision. Electrosurgery (cutting current) is used only when there is little chance that small bowel is involved in the adhesion.

Initially, blunt-tipped scissors in the operating channel of an operating laparoscope are inserted into the interface between the anterior abdominal wall parietal peritoneum and the omentum. Rotating the laparoscope so that the scissors exit at 12 o'clock instead of 3 o'clock facilitates early adhesiolysis. Blunt dissection is performed by inserting the scissors at the interface, opening, and withdrawing them. This maneuver is repeated many times to delineate the thin avascular adhesions from thicker vascular fibrotic attachments that are individually coagulated and divided. Frequently, adhesions can be bluntly divided by grasping the adhesion in the partially closed scissors and gently pushing the tissue. If the plane of adhesions cannot be reached with the tip of the scissors, the abdominal wall can be pressed from above with the finger to make it accessible to the scissors.

After initial adhesiolysis, visualization is improved allowing better access and exposure for further adhesiolysis. Secondary trocar sites can now be placed safely. After their insertion, the remainder of the adhesions can now be lysed using scissors with microbipolar backup for rare arteriolar bleeders. Small venule bleeders are left alone. On occasion, in operations in which symptomatic bowel adhesions are not the main problem, an electrosurgical spoon or knife is used to divide the remaining omental adhesions if bowel is not involved. If bowel is involved, dissection proceeds with scissors, without electrosurgery, through the second puncture site, aided by traction on the bowel from an opposite placed puncture site. Rarely, the CO2 laser may be used through the operating channel of the operating laparoscope. When using the CO2 laser for adhesiolysis, aquadissection is performed to distend the adhesive surface with fluid before vaporizing the individual adhesive layers. The suction-irrigator can also be used for suction traction, instead of a laparoscopic Babcock, and as a backstop to prevent thermal damage to other structures. The suction irrigator is also used to clean the laparoscopic optic which is then wiped on the

bowel serosa before continuing. Denuded areas of bowel muscularis are repaired transversely using a 3-0 or 4-0 Vicryl seromuscular stitch. Denuded peritoneum is left alone. Minimal oozing should be observed and not desiccated unless this bleeding hinders the next adhesiolysis step or persists towards the end of the operation. With perseverance, all anterior abdominal wall parietal peritoneum adhesions can be released.

The Harmonic Scalpel is also useful for adhesiolysis. It bears repeating, the Harmonic Scalpel is *not* a scissor. This instrument works by coagulating tissue in between the blades and allowing it to be "pressed apart" after full coagulation of the tissue between the active blade and the compressing surface. Tissue is first grasped between the blades of the Harmonic Scalpel, steadily compressed, and the blade is activated allowing the tissue to separate once it is fully coagulated. Any tissue between the blades of the Harmonic Scalpel will be heated and then be allowed to fall apart. This includes all blood vessels up to 3mm in diameter incorporated in the tissue between the blades. As stated before, the Harmonic Scalpel can be used to grasp tissue in a general manner when the blades are not active. However, prior to grasping any tissue, the operator must allow the active blade to cool sufficiently so it will not burn any tissue it may come in contact with. The operator must remember that a Harmonic Scalpel does not replace the scissor, especially when dealing with bowel in the same proximity to an adhesion plane. Harmonic Scalpel comes in 5- and 10-mm size instrumentation with active jaws as well as adaptable adjuncts to the instrument such as a spatula type dissector, "ball" type dissector and hook dissector. All of these type instruments can be used in the same location as you would normally use a monopolar electrode; bear in mind once again that the lateral energy spread is only just 2mm with the Harmonic Scalpel.

Pelvic Adhesiolysis

The next step is to free all bowel loops in the pelvis. Small bowel attached to the vesicouterine peritoneal fold, uterus or vaginal cuff, and the rectum is liberated. There are three key points when performing bowel adhesiolysis within the pelvis: scissors dissection without electrosurgery, countertraction and blunt dissection. The bowel is gently held with an atraumatic grasper and lifted away from the structure to which it is adhered, exposing the plane of dissection. When adhesive interfaces are obvious, scissors are used. The blunt-tipped scissors are used to sharply dissect the adhesions in small, successive cuts taking care not to damage the bowel serosa. Countertraction will further expose the plane of dissection and ultimately free the attachment. Electrosurgery and laser are generally not used for adhesiolysis involving the bowel due to the risk of recurrent adhesions from thermal damage. However, when adhesive aggregates blend into each other, initial incision is made very superficially with laser, and aquadissection distends the layers of the adhesions, facilitating identification of the involved structures. Division of adhesions continues with laser at 10-20 W in pulsed mode. The aquadissector and injected fluid from it are used as a backstop behind adhesive bands that are divided with the CO_2 laser.

The rectosigmoid can be adhered to the left pelvic sidewall obscuring visualization of the left adnexa. Dissection starts well out of the pelvis in the left iliac fossa. Scissors are used to develop the space between the sigmoid colon and the psoas muscle to the iliac vessels, and the rectosigmoid reflected toward the midline. Thereafter, with the rectosigmoid placed on traction, rectosigmoid and rectal adhesions to the left pelvic sidewall are divided starting cephalad and continuing caudad.

Cul-de-sac adhesions can cause partial or complete cul-de-sac obliteration from fibrosis between the anterior rectum, posterior vagina, cervix, and the uterosacral ligaments. The technique of freeing the anterior rectum to the loose areolar tissue of the rectovaginal septum before excising and/or vaporizing visible and palpable deep fibrotic endometriosis is used.[24]

Attention is first directed to complete dissection of the anterior rectum throughout its area of involvement until the loose areolar tissue of the rectovaginal space is reached. Using the rectal probe as a guide, the

rectal serosa is opened at its junction with the cul-de-sac lesion. Careful dissection ensues using aquadissection, suction-traction, laser, and scissors until the rectum is completely freed and identifiable below the lesion. Excision of the fibrotic endometriosis is done only after rectal dissection is completed.

Deep fibrotic, often nodular, endometriotic lesions are excised from the uterosacral ligaments, the upper posterior vagina, (the location of which is confirmed by the Valtchev retractor or a sponge in the posterior fornix), and the posterior cervix. The dissection on the outside of the vaginal wall proceeds using laser or scissors until soft pliable upper posterior vaginal wall is uncovered. It is frequently difficult to distinguish fibrotic endometriosis from cervix at the cervicovaginal junction and above. Frequent palpation using rectovaginal examinations helps identify occult lesions. When the lesion infiltrates through the vaginal wall, an "en bloc" laparoscopic resection from cul-de-sac to posterior vaginal wall is done, and the vagina is repaired laparoscopically with the pneumoperitoneum maintained with a 30-cc foley balloon in the vagina. Or, more recently, the vaginal lesion is mobilized vaginally, the vagina closed over the mobilized portion, and the en bloc lesion excision completed laparoscopically. Sometimes the fibrotic cul-de-sac lesion encompassing both uterosacral ligament insertions and the intervening posterior cervix-vagina and anterior rectal lesion can be excised as one en bloc specimen.

Endometriotic nodules infiltrating the anterior rectal muscularis are excised usually with the surgeon's or his assistant's finger in the rectum just beneath the lesion. In some cases, the anterior rectum is reperitonealized by plicating the uterosacral ligaments and lateral rectal peritoneum across the midline. Deep rectal muscularis defects are always closed with suture. Full thickness rectal lesion excisions are suture or staple repaired laparoscopically.

When a ureter is close to the lesion, its course in the deep pelvis is traced by opening its overlying peritoneum with scissors or laser. On the left, this often requires scissors reflection of the rectosigmoid, as previously described, starting at the pelvic brim. Bipolar forceps are used to control arterial and venous bleeding.

Adnexal Adhesiolysis[25]
SalpingoOvariolysis[26]

Ovarian adhesions to the pelvic sidewall can be filmy or fused. Initially, adhesions between the ovary and fallopian tubes and other peritoneal surfaces are identified. It is imperative that the surgeon knows the surrounding anatomy prior to cutting any tissue to avoid damage to vital structures. The plane of dissection is identified and followed to avoid damage to other structures. The uteroovarian ligament may be held with an atraumatic grasper to facilitate countertraction and expose the line of cleavage. During ovariolysis, it is important to preserve as much peritoneum as possible while freeing the ovary. Dissection starts either high in the pelvis just beneath the infundibulopelvic ligament or deep on the pelvic sidewall beneath the ureter in the pararectal space. In each case, scissors are used both bluntly and sharply to mobilize the ovary from the sidewall. Alternatively, aquadissection may be used to facilitate identification of adhesion layers and to provide a safe backstop for the CO2 laser. Once an adhesion layer is identified, the aquadissector can also be placed behind this ridge and used as a backstop during CO2 laser adhesiolysis. Adhesiolysis is performed sharply and bluntly in a methodical manner working caudad until the cul-de-sac is reached.

If fimbrioplasty is to be performed, then hydrodistention is achieved by transcervical injection of dilute indigo carmine through a uterine manipulator. This distends the distal portion of the tube which is stabilized, and the adhesive bands are freed using scissors, laser or micropoint electrosurgery. If necessary, the fimbriated end can be progressively dilated using 3 mm alligator-type forceps. The closed forceps are placed through the aperture, opened, and removed.

This is repeated one or more times. If the opening does not remain everted on its own, the intussusception salpingostomy method of McComb[27] is used to avoid thermal damage to the ciliated tubal epithelium from CO_2 laser or electrosurgery. The tip of the aquadissector is inserted approximately 2 cm into the newly opened tube, suction applied, and the tube fimbrial edges pulled around the instrument to turn the tube end inside-out. The borders of the incision act as a restrictive collar to maintain the mucosa in this newly everted configuration. In some cases, the ostial margin is sutured to the ampullary serosa with 6-0

Underwater surgery at the end of each procedure[28]

At the close of each operation, an underwater examination is used to document complete intraperitoneal hemostasis in stages; this detects bleeding from vessels and viscera tamponaded during the procedure by the increased intraperitoneal pressure of the CO_2 pneumoperitoneum. The integrity of the rectum and rectosigmoid is often checked at this time by instillation of dilute indigo carmine solution or air transanally through a 30 cc Foley catheter.

The CO_2 pneumoperitoneum is displaced with 2 to 5 L of Ringer's lactate solution, and the peritoneal cavity is vigorously irrigated and suctioned until the effluent is clear of blood products, usually after 10-20 L. Underwater inspection of the pelvis is performed to detect any further bleeding which is controlled using microbipolar irrigating forceps to coagulate through the electrolyte solution. First hemostasis is established with the patient in Trendelenburg position, then per underwater examination with the patient supine and in reverse Trendelenburg, and finally, with all instruments removed, including the uterine manipulator.

To visualize the pelvis with the patient supine, the 10-mm straight laparoscope and the actively irrigating aquadissector tip are manipulated together into the deep cul-de-sac beneath floating bowel and omentum. During this copious irrigation procedure, clear fluid is deposited into the pelvis and circulates into the upper abdomen, displacing upper abdominal bloody fluid which is suctioned after flowing back into the pelvis. An "underwater" examination is then performed to observe the completely separated tubes and ovaries and to confirm complete hemostasis.

A final copious lavage with Ringer's lactate solution is undertaken and all clots directly aspirated; at least 2 L of lactated Ringer's solution are left in the peritoneal cavity to displace CO_2 and to prevent fibrin adherences from forming by separating raw operated-upon surfaces during the initial stages of reperitonealization. Displacement of the CO_2 with Ringer's lactate diminishes the frequency and severity of shoulder pain from CO_2 insufflation. No other anti-adhesive agents are employed. No drains, antibiotic solutions, or heparin are used.

Handoscopy

Hand assisted laparoscopy or "handoscopy" has become popular over the last 5 years, mainly in the field of solid organ surgery and bowel surgery. The main advantage of handoscopy is that it allows the surgeon to regain the tactile feel of surrounding tissues previously lost to "laser" laparoscopists and permits a more purposeful manipulation of larger organs. Often, it is the use of handoscopy for tissue palpation, that enables a successful laparoscopic adhesiolysis. At times, during laparoscopic procedures, visualization can be poor due to dense adhesions and the inability to determine tissue planes. With the placement of the operator's hand inside the peritoneal cavity the surgeon is usually able to palpate surrounding organs and allow for a better tissue dissection plane that otherwise may not have been possible through direct visualization

only. Not only can the use of a hand port facilitate an otherwise tedious procedure, it effects a safer operation for the patient with less chance of bowel injury. If bowel resection should become necessary, the use of the hand port allows for exteriorization of the segment that requires resection once again making the procedure easier and less time consuming. A handoscopy incision is usually only 7-8 cm and is either placed in the left or right lower portion of the abdomen with insertion of the operator's non-dominant hand. The muscle splitting technique is used in a similar method as in performing an open appendectomy. The entire peritoneal cavity can be examined through either one of these incisions with the operator's hand and it can be used for organ extraction as well. Several different types of handoscopy ports are available and all provide equal access to the peritoneal cavity.

When placing a handoscopy port for adhesiolysis, the operator must first choose a location on the abdominal wall that will allow optimal access to the point where adhesions are greatest. After the hand port location is chosen, a marking pen should be used to outline the area of the abdominal wall where the hand port is to be placed. The area for the incision should be anesthetized with bupivicaine for post operative pain control and an incision should then be made into the skin. The size of the incision should be the same size as the operator's glove size. After this is completed, a muscle splitting technique should be used to enter the peritoneal cavity just as the operator would in performing an open appendectomy. Once the peritoneal cavity is entered, the hand port can then be placed. All of the hand port apparatus require that any adhesions on the peritoneal side of the incision be lysed prior to inserting the handoscopy device. Additionally, these devices should not be placed over any bony prominences, i.e., iliac crest, or encompassing any bowel in the peritoneal ring surface as to injure any bowel in the abdomen. If the handoscopy port is placed in the upper abdomen, the falciform ligament may require division prior to inserting the ring. Once the handoscopy device is in place the lysis of adhesions can precede in an orderly fashion by identifying the tissue planes by feel with the operator's fingers and additionally being able to provide appropriate traction and countertraction to allow for a safe adhesiolysis. Incidental enterotomies can be sutured with conventional suture and then tied using one hand knot tying technique with the intra abdominal hand. Should any bowel resections be required the hand port can be used as a mini laparotomy site for extraction of any specimens and for exteriorizing any bowel that may require resection and/or repair. Additionally all handoscopy devices that are placed through the abdominal wall act as a wound protector and may minimize post operative wound infections as well as protect from any potential tumor seeding if the operation is for malignancy. The opening of the Ethicon Lap-Disc^{TM} device is like a camera shutter that can be circumferentially reduced to seal the pneumoperitoneum around any size 5 mm trocar.

Once the procedure is completed the hand port device is removed, anterior and posterior rectus sheath muscle fascia are closed with either 0 or 2-0 absorbable suture and the skin is then closed in a subcuticular manner. Additionally, a variety of "pain buster" catheters are now available for insertion into the supra fascia layer of the wound which allows for excellent postoperative analgesia. These help to minimize postoperative narcotic requirements thereby facilitating an earlier return of bowel function and more expedient discharge from the hospital. It has been the author's personal experience that patients undergoing a handoscopy type of operation parallel their recovery in the same manner as a conventional laparoscopic case with a delay of only one day in recovery. If a bowel resection should be required the patient usually only requires to be NPO overnight and clear liquids may be started on the first postoperative day. The patient is

maintained on clear liquids until passing flatus and moving bowels. Most patients are discharged home on the second postoperative day if a bowel resection has been required.

In the event that a bowel resection is required, stapling instruments are used routinely for division of the bowel and anastomosis. The mesentery of the bowel can be divided with the use of surgical ties, Harmonic Scalpel, or vascular cartridge stapling devices. Bowel resection is preceded by first identifying the lines of resection, transection of the bowel, the use of stapling devices to transect the bowel proximally and distally, division of the mesentery, followed by re-anastomosis once again using stapling devices and closing the enterotomy required by the tines of the stapling device with an additional stapling device. Any mesentery defect caused by a small bowel resection are closed with a running 0 or 2-0 absorbable suture. Mesenteric defects need not be closed after large bowel resections.

Open Adhesiolysis

In certain situations an open adhesiolysis is best for the patients. It is usually performed after an attempted laparoscopic approach has been abandoned. If only a pelvic adhesiolysis is needed, a Pfannenstiel incision usually is adequate. However if the entire peritoneal cavity is encased in dense fibrotic adhesions a midline incision is usually required. Open adhesiolysis should be reserved for the worst possible cases where laparoscopic adhesiolysis has failed, where there has been several incidental enterotomies made, or adhesiolysis cannot be performed secondary to encasement of the bowel. Open adhesiolysis should also be considered in a patient unable to tolerate CO2 insufflation.

An open adhesiolysis is performed in the exact same way as a laparoscopic adhesiolysis. First, all adhesions are taken down from the abdominal wall usually with the Metzenbaum scissors. Second, all loops of bowel are extracted out of the pelvis. Finally, all interloop adhesions are lysed from the ligament of Treitz to the ileo-cecal valve. Any incidental enterotomies should be repaired at the time of discovery to avoid intra peritoneal contamination and development of an infection. Hemostasis must be meticulous during the entire dissection as in a laparoscopic procedure. An abundant use of warm irrigation fluid is used as well. It is extremely important to keep the tissues moist to prevent desiccation from atmospheric air as this can stimulate adhesion reformation. It has been a personal experience that the use of adhesion barriers has been ineffective in open procedures on the bowel and is not indicated.

ADHESION PREVENTION

Intraoperatively, the surgeon can minimize adhesion formation through careful tissue handling, complete hemostasis, abundant irrigation, limited thermal injury, infection prophylaxis, and minimizing foreign body reaction.[29,30] A recent Cochrane Database Systematic Review investigated whether pharmacological and liquid agents used as adjuvants during pelvic surgery in infertility patients lead to a reduction in the incidence or severity of postoperative adhesion (re-)formation, and/or an improvement in subsequent pregnancy rates. The results of this review are as follows: there is some evidence that intraperitoneal steroid administration decreases the

incidence and severity of postoperative adhesion formation; intraperitoneal administration of dextran did not decrease postoperative adhesion formation at second look laparoscopy; there is no evidence that intra-abdominal crystalloid instillation, calcium channel blocking agents, non-steroidal anti inflammatory drugs and proteolytics decrease postoperative adhesion formation.[31]

Barrier agents for prevention of adhesion formation are commercially available. The Cochrane Menstrual Disorders and Subfertility Group investigated the effects these agents have on postoperative adhesion formation. The 15 randomized controlled trials comprised laparoscopic and laparotomic surgical techniques. Results of the investigation were as follows: oxidized regenerated cellulose (Interceed: Johnson & Johnson Medical, Somerville, NJ) reduces the incidence of adhesion formation and re-formation at laparoscopy and laparotomy in the pelvis; polytetrafluoroethylene (GoreTex: W.L. Gore & Associates, Flagstaff, AZ) appears to be superior to Interceed in preventing adhesion formation in the pelvis but is limited by the need for suturing and later removal; Seprafilm (Genzyme, Cambridge, MA) does not appear to be effective in preventing adhesion formation.[32]

If Interceed is to be used for prevention of adhesion formation, the intrapelvic fluid should be completely aspirated. A piece of Interceed large enough to cover the at-risk area is placed and moistened with a small volume of irrigant. Complete hemostasis must be achieved prior to placing the material. If hemostasis has not been achieved, the Interceed will turn brown or black and must be replaced as this may actually increase adhesion formation.[33] Animal studies and clinical trials of a gel form of modified hyaluronic acid, a naturally occurring glycosaminoglycan, show evidence for reducing de novo adhesion formation.[34] Intergel (Gynecare, Johnson & Johnson Inc., Somerville, NJ) is commercially available for open surgery use.

The ideal barrier material should be easy to apply, both in open and laparoscopic surgeries. Additionally, it should be nonreactive, persist during the critical wound reepithelization period, stay in place on the target tissue for several days, and eventually be resorbed following peritoneal healing

A new product, currently undergoing clinical trials, SprayGel (Confluent Surgical, Waltham, MA), meets these criteria. SprayGel is composed of two liquids which are polyethylene glycol (PEG)-based. PEG is widely used in a variety of medical products. When these two liquids are applied while mixing them *in situ*, they polymerize within seconds to form a visible, adherent, and conforming hydrogel barrier on the target tissues. The gel remains intact for the next 5 to 7 days before breaking down by hydrolysis, and eventual clearance through the kidneys. Preclinical safety studies of SprayGel adhesion barrier demonstrate that it is a remarkably inert, biocompatible material, resulting in no signs of toxicity at multiple time points, even when tested at 25 times the anticipated normal dose. Clinical studies in Europe and the US further support the safety profile of this material as an implant. Preliminary prospective randomized clinical trials have evaluated SprayGel adhesion barrier in open and laparoscopic myomectomy surgery, as well as in laparoscopic ovarian surgery. In the European myomectomy study, a significant improvement was demonstrated in the tenacity of adhesions between the treated and control populations, when comparing the initial procedures and second-look laparoscopies, as evaluated by the surgeon. The product is currently under review in a multicenter pivotal clinical trial in the US.

CONCLUSION

Adhesion formation after gynecologic surgery is common. When compared to laparotomy, laparoscopy has been shown to result in less *de novo* adhesion formation, but adhesion reformation continues to be a problem.[35] Sequelae of intra-abdominal adhesion formation can be fatal, result in infertility, and be a source of chronic pelvic pain. Minimally invasive surgical management of adhesion formation affords the patient all of the known benefits of laparoscopic surgery including less postoperative analgesics, shorter hospital stays, and more rapid convalescence and return to normal activities. Unfortunately, recurrence rates after adhesiolysis for intestinal obstruction are reported to range from 8%[36] to 32%[37]. Thus, for some patients, adhesiolysis may become a repeat surgical procedure.

No longer can the surgeon ignore the benefits of minimally invasive surgery for adhesiolysis. While these techniques and procedures are not without risk, patients should not be denied their inherent advantages. Astute clinicians must work together to discern the most appropriate uses for this therapy

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