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Mechanisms of Hernia Recurrence After Preperitoneal Mesh Repair

Traditional and Laparoscopic

Anthony S. Lowham, M.D.,* Charles J. Filipi, M.D.,* Robert J. Fitzgibbons, Jr., M.D.,* Rene Stoppa, M.D.,† George E. Wantz, M.D.,‡ Edward L. Felix, M.D.,§ and W. Boyd Crafton, M.D.||

From the Department of Surgery, Creighton University School of Medicine, Omaha, Nebraska; the Department of Clinical Surgery,† Universitaire d' Amiens, Amiens, France; the Department of Surgery,‡ Cornell University Medical College, New York, New York; The Center for Hernia Repair,‡ Fresno, California; and Department of Surgery,|| Cincinnati University, Cincinnati, Ohio*

Objective
The authors provide an assessment of mechanisms leading to hernia recurrence after laparoscopic and traditional preperitoneal herniorrhaphy to allow surgeons using either technique to achieve better results.

Summary Background Data
The laparoscopic and traditional preperitoneal approaches to hernia repair are analogous in principle and outcome and have experienced a similar evolution over different time frames. The recurrence rate after preperitoneal herniorrhaphy should be low (<2%) to be considered a viable alternative to the most successful methods of conventional herniorrhaphy.

Methods
Experienced surgeons supply specifics regarding the mechanisms of recurrence and technical measures to avoid hernia recurrence when using the preperitoneal prosthetic repair. Videotapes of laparoscopic herniorrhaphy in 13 patients who subsequently experienced a recurrence also are used to determine technical causes of recurrence.

Results
Factors leading to recurrence include surgeon inexperience, inadequate dissection, insufficient prosthesis size, insufficient prosthesis overlap of hernia defects, improper fixation, prosthesis folding or twisting, missed hernias, or mesh lifting secondary to hematoma formation.

Conclusions
The predominant factor in successful preperitoneal hernia repair is adequate dissection with complete exposure and coverage of all potential groin hernia sites. Hematoma mesh lifting and inadequate lateral inferior and medial inferior mesh fixation represent the most common causes of recurrence for surgeons experienced in traditional or laparoscopic preperitoneal hernia repair.

The history of the most commonly performed surgical procedure, repair of the groin hernia, contains an evolution of arguments related to cause, anatomy, and technique. Dedicated surgeons have tested many surgical methods to best address the complexities of the groin hernia. Recently, the addition of laparoscopic herniorrhaphy to the surgical armamentarium has intensified the century-long debate. Of all factors used to compare the various methods of inguinal herniorrhaphy, the incidence of recurrence is most often held as the measure of success.

The principles of present day herniorrhaphy evolved from Bassini more than a century ago. Numerous modified techniques for the repair of groin hernias by the anterior inguinal approach have since been developed with improvement in morbidity, recurrence rates, and duration of hospitalization. Although a heterogenous group of techniques are available for surgeon selection, two methods of anterior herniorrhaphy, the Shouldice repair and the Lichtenstein repair, appear to show the best results. The Shouldice Clinic reports an overall recurrence rate of less than 1%. Inguinal hernias are repaired by experienced surgeons with a layered closure and supervised convalescence.[1] The Lichtenstein "tension-free" hernia repair uses an onlay prosthesis to reconstruct the inguinal floor and eliminate suture line tension, the disadvantage present in all modifications of the Bassini repair. General surgeons not specializing in the repair of inguinal hernias have reported recurrence rates of less than 1% when using the Lichtenstein repair.[2] Despite continued improvements and low reported recurrence rates, the overall recurrence rate for primary hernia repair is estimated at 10% and increases to 25% for repair of recurrent hernias.[3] Surgical repair of recurrent hernias leads to increased cost, is technically difficult, and carries a higher morbidity. It is thought that early recurrence after the anterior repair results from technical errors or tension on the suture line from the unnatural approximation of tissues. Late recurrence results from defects in collagen metabolism as a patient ages, with thinning of scar tissue and continued inherent weakness of the inguinal floor.[2,4] The Lichtenstein mesh repair was developed to address these mechanisms of recurrence.

An alternate strategy has developed that involves posterior assessment of the inguinal floor from a transabdominal or preperitoneal approach. This allows evaluation of the entire inguinal region and assessment of all potential hernia sites. The method has evolved from open preperitoneal techniques to present day laparoscopic preperitoneal herniorrhaphy. Both methods have undergone a similar evolution of technique but over different periods. The shared principle of the preperitoneal techniques of herniorrhaphy is the placement of a large inlay prosthesis to provide wide reinforcement of inadequate inguinal tissues. Although open preperitoneal herniorrhaphy with prosthetic placement has shown long-term success, laparoscopic herniorrhaphy in its current form has been in use less than half a decade, and long-term results are unknown. Generalized statements regarding recurrence (i.e., 40% to 50% of hernia recurrences appear 5 or more years after the original operation) as applied to classic anterior inguinal herniorrhaphy[2] are not applicable to preperitoneal herniorrhaphy. In addition, those factors leading to recurrence in the traditional repair (i.e., tension on the suture line, decreasing collagen content with age) do not lead to recurrence in the preperitoneal repair. To be considered as a viable alternative to the best methods of anterior repair, the hernia recurrence rate after laparoscopic herniorrhaphy should be low (<2%). To achieve this, an assessment of the mechanisms of recurrence in the analogous techniques of laparoscopic and open preperitoneal hernia repair is warranted.

Traditional Preperitoneal Hernia Repair

The transabdominal preperitoneal (TAPP) approach to expose the inguinal floor for hernia repair initially was described by Cheatle in 1920.[5] Nyhus et al.[6] were responsible for popularizing the technique of preperitoneal herniorrhaphy. They advocated a lower abdominal transverse incision to obtain exposure of the inguinal floor and described the suture approximation of transversalis fascia analogues (i.e., iliopubic tract, femoral sheath) to repair inguinal and femoral hernias. Nyhus[7] and Read[8] adopted this technique and reported long-term recurrence rates of 5.0% to 6.6%, but as this method of repair became popular during the next decade, other surgeons reported recurrence rates as high as 35%.[9] After the development of prosthetic materials for use in conventional hernia repair, preperitoneal prosthetic placement was initiated and increasing sizes were used to reinforce the floor of the groin. The prosthesis initially was used as an adjunct to the suture approximation of fascia and obviated the need for a relaxing incision.[10] Eventually, suture closure of defects was abandoned because it became evident that a large prosthesis itself formed an effective barrier to inguinal herniation. In 1975, Stoppa reported on the placement of an unsutured prosthesis in the preperitoneal space for treatment of groin hernias.[11] This eventually became known as Giant Prosthetic Reinforcement of the Visceral Sac (GPRVS), a technique to cover and overlap all potential groin hernia sites by placement of a large prosthetic mesh over Fruchauds myopectineal orifice. The myopectineal orifice contains the potential hernia sites of the groin

Address reprint requests to Charles J. Filipi, M.D., Creighton University, St. Joseph Hospital, Department of Surgery, Suite 3740, 601 N. 30th Street, Omaha, NE 68131-2197.

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and is a weak area in the inguinal floor bounded superiorly by the internal oblique and transversus abdominis muscles, laterally by the iliopsoas muscles, medially by the rectus muscle, and inferiorly by the pubic bone.[12] Reinforcement in this area allows intra-abdominal pressure to assist in securing the inlayed prosthesis to the pelvic floor rather than acting as a factor in recurrence. After mesh placement, the peritoneum becomes nondistendible; thus, there is no need for hernia defect closure. This technique has met particular success in the repair of bilateral hernias, large scrotal hernias, and recurrent or rerecurrent hernias in which conventional repair is difficult and carries a high morbidity and failure rate.[13] The GPRVS is not ideal for strangulated hernias because bowel resection may be required and mesh infection can result.

Mechanisms of Recurrence for Traditional Preperitoneal Herniorrhaphy

The evolution of the technique from suture closure to the use of a small prosthesis and finally placement of a large prosthesis to cover and sufficiently overlap all potential hernia sites (GPRVS) strongly has influenced the recurrence rate. Early techniques by Nyhus et al.[6] and Read,[8] which used suture approximation of fascia to close hernia defects, resulted in the same problem that had plagued surgeons performing conventional hernia repair: tension on the suture line. Prosthetic material then was introduced and initially used to repair isolated defects. With application of larger prostheses, results improved dramatically. Rignault[14] performed 1151 hernia repairs with a recurrence rate of 2.0% using a 12-cm x 10-cm mesh, and Stoppa[13] reported on the successful repair of 270 recurrent hernias using GPRVS with a recurrence rate of only 1.1%. A review of large series of traditional preperitoneal herniorrhaphy displays a disparity in the recurrence rate for those surgeons using simple suture closure or a small prosthesis and those using a large prosthesis. The decreasing rate of recurrence correlates well with the evolution of this method (Table 1).[6–10,12,14–18] The importance of adequate coverage is apparent in a study by Schaap,[17] who reported a high rerecurrence rate using the traditional preperitoneal approach in repair of 98 recurrent hernias. The techniques used were simple suture closure (rerecurrence, 35%) and application of mesh specified only as "small" (rerecurrence, 30%).

Most published series of traditional preperitoneal hernia repair supply limited descriptions relating to the exact mechanism of recurrence. Regarding preperitoneal suture approximation of isolated fascial defects (direct or indirect), the same factors predisposing to hernia recurrence in the conventional approach are present. Tissue is approximated under tension that may require a relaxing incision and lead to recurrence over time.[10] In addition, Peacock and Madden[4] thought that a fundamental defect in collagen metabolism in patients with acquired hernias resulted in pathologic abnormalities in the transversalis or endopelvic fascia. They noted structural fascial abnormalities on the clinically normal side in 11 of 20 patients undergoing surgery for unilateral hernia. Dyson et al.[9] noted a 35% recurrence rate for direct defects repaired by preperitoneal suture closure and reported a 10% rate of hernia formation in the contralateral groin during 3.5 years of follow-up. These results encouraged the application of prosthetic materials to address the weakened structures of the entire myopectineal orifice. Most recurrences after prosthetic repair occur during the first postoperative year and result from technical mistakes associated with selection of an insufficiently sized prosthesis, improper placement, or as a result of complications such as infection or a hematoma.[13] Wantz,[12] Stoppa,[13] and Rignault[14] all note that hernia recurrences in their respective series occur within the first postoperative year and often within 6 months. A large prosthesis placed to cover and sufficiently overlap all potential hernia sites of the myopectineal orifice is tension free and not affected by continued attenuation of groin tissues. Those activities that act to increase intra-abdominal pressure and favor hernia formation, including coughing and heavy lifting, will not affect the preperitoneal prosthetic repair. Although several variations regarding abdominal incision and prosthesis shape and size exist, all successful methods used presently are similar in that they use a large prosthesis that sufficiently covers and overlaps all hernia defects.

Stoppa[13] has achieved great success using the method of GPRVS. He fashions a large Dacron mesh in the shape of a chevron for use as a bilateral prosthesis. The transverse dimension is equal to the distance between both anterosuperior iliac spines minus 2 cm. The height is the distance between the umbilicus and the pubis with an average mesh size of 24 cm x 16 cm. He reports a long-term recurrence rate of 0.56% in 1922 primary repairs and 1.1% in recurrent hernias. It is thought that recurrence is related to technical error and, notably, all of his recurrences presented within the first postoperative year.[13,19] Stoppa advocates minimal suture placement, relying on intra-abdominal pressure to hold the prosthesis in place. Of 11 recurrences, 7 are described inferior to the mesh and were repaired by additional mesh placement or further fixation to Cooper's ligament. Three recurrences were noted lateral to the mesh.

Wantz[11] advocates use of a diamond-shaped Mersilene prosthesis (Ethicon, Inc., Somerville, NJ) measuring approximately 12 cm x 15 cm for unilateral GPRVS. He thinks the diamond shape conforms to the myopectineal orifice better than a rectangular mesh and ensures a circumferential and adequate overlap. The rectangular mesh was noted to become displaced medially, favoring the

Table 1. OPEN PREPERITONEAL HERNIORRHAPHY

Author (year)	Repair Type	Mesh? (size)	No. of Hernias	Recurrence (%)	Follow-up
Nyhus (1960–1978)	Suture closure	None	1200	5	1–10 yr
Dyson (1965)	Suture closure	None	159	14.4	2–42 mo
Margoles (1971)	Suture closure	None	150	25.2	5 yr
Read (1975)	Suture closure	None	1420	6.6	3 yr 5 mo (average)
Read (1976)	Mesh	7 × 4 cm	194	2.0	2 yr
Rignault (1986)	Mesh	12 × 10 cm	1151	2.2	1–13 yr
Rosenthal (1986)	Mesh	10 × 10 cm	50 (all recurrent)	0	1–30 mo
Wantz (1989)	Mesh	Chevron (bilateral)	152 (most recurrent)	5.9	DNS
		12 × 12 cm (unilateral)	85 (most recurrent)	0	DNS
Schaap (1992)	Suture closure	None	55 (all recurrent)	35	
	Mesh	"Small"	43 (all recurrent)	30	2–5 yr
Hoffman (1993)	Mesh	6 × 11 cm	204	0.5	3.5 yr (average)
Stoppa (1994)	Mesh	24 × 16 cm	1922	0.5 primary	
				1.1 recurrent	2–12 yr

DNS = data not specified.

formation of a recurrent indirect hernia. Since instituting the use of the diamond prosthesis with an extended inferior lateral margin, no recurrences have been noted. If the mesh is not to be fixed, Wantz[20] recommends Mersilene, because it is soft, conforms to the complex curves of the pelvis, and stays in place. Other meshes, all the polypropylene meshes and Gore-Tex (W. L. Gore and associates, Phoenix AZ), must be fixed along the periphery. The former because they are stiff, nonconforming, and will deform by investing scar tissue because intra-abdominal pressure is insufficient to hold them in place, and the latter because it is slow to become incorporated. It is emphasized that thorough dissection and identification of all fascial defects will prevent herniation external to the abdominal wall, the so-called "lipomatous hernia." Wantz[20] also recommends drainage in all patients with incomplete hemostasis or a large retained sac in which blood accumulates and may result in formation of a presumed recurrent hernia. In a recent report of 386 patients with predominantly recurrent hernias, he noted 16 recurrences of which 2 resulted from a hematoma dislodging the mesh and 3 were lipomatous hernias. Eight other recurrences were attributed to inadequately sized rectangular mesh, which resulted in deflection of the lateral mesh border and exposure of the myopectineal orifice at the inguinal ring.

Laparoscopic Preperitoneal Hernia Repair

The advent of laparoscopic hernia surgery evolved after the successful laparoscopic treatment of gynecologic and biliary disease. In 1982, under laparoscopic guidance, Ger et al.[21] used a Michel staple applied with a Kocher clamp to close the peritoneal opening of a hernia sac. They subsequently performed laparoscopic hernia repair on 12 dogs with congenital indirect inguinal hernias using a prototype stapler (the "herniostat"). They correctly predicted several advantages to laparoscopic herniorrhaphy, including minimal postoperative discomfort, fast postoperative recovery, the ability to perform diagnostic laparoscopy, and repair of concurrent bilateral hernias. Bogojavlensky[22] described laparoscopic filling of an indirect hernia defect with a plug of polypropylene mesh followed by suture closure of the internal ring. In 1990, the gynecologist Popp[23] published the first report of laparoscopic hernia repair. During a uterine myomectomy, he noted an internal ring defect, which he closed with extracorporeally tied sutures followed by placement of a 4-cm x 5-cm dura patch over the defect.[23] The first series of laparoscopic herniorrhaphy was conducted by Schultz,[24] who incised the peritoneum adjacent to an indirect defect, filled the inguinal canal with a mesh plug, and closed the sac opening with suture or staples. These authors provided information instrumental to the development of laparoscopic herniorrhaphy, but longer follow-up showed unacceptable recurrence rates (26%) with simple suture closure and plug-and-patch techniques.[25] This led to the development of methods that followed the principles of successful open preperitoneal repair, including thorough preperitoneal dissection to expose all potential hernia sites of the myopectineal orifice and increasing prosthesis size with better methods of fixation. In 1991, Arregui[26] described laparoscopic

Table 2. LAPAROSCOPIC PREPERITONEAL HERNIORRHAPHY

Author (year)	Repair Type	Mesh Size	Number of Hernias	Recurrence (%)	Follow-up (months)
Geis (1993)	TAPP	10 × 14 cm	450	0.7	6–30
Panton (1994)	TAPP	9 × 14 cm	106	0	1–12
Himpens (1993)	TAPP	10 × 15 cm	100	2.0	DNS
Felix (1995)	TAPP	6 × 10 cm with 15 × 15 cm buttress	733	0.3	24 (median)
Kavic (1995)	TAPP	7–10 × 12–15 cm	224	1.0	5–41
Fitzgibbons Multicenter Trial (1995)	IPOM		217	5.1	
	TAPP	9.2 × 6.0 cm (average)	562	5.0	15–34
	EXTRA		87	0	
Philips Multicenter Trial (1995)	IPOM		345	2.0	
	TAPP	DNS	1944	1.0	22 (average)
	EXTRA		578	0	

DNS = data not specified.

dissection of the preperitoneum, with full exposure of the inguinal floor and placement of a large preperitoneal prosthesis.

Three techniques for laparoscopic hernioplasty repair currently are used. The first, the intraperitoneal onlay mesh method, uses a pneumoperitoneum, polytetrafluorethylene, or polypropylene prosthesis placement and fixation directly on the peritoneal surface. Although resulting in decreased operative time, its main disadvantage is inadequate identification of anatomy, resulting in a higher incidence of neuralgia and recurrence.[27] A limited peritoneal dissection to define Cooper's ligament for improved inferomedial prosthesis fixation is recommended by some.[28] The second, the TAPP method, uses a pneumoperitoneum with creation of a peritoneal flap and exposure of the preperitoneal space. This allows complete dissection and anatomic assessment of the entire myopectineal orifice. After placement and fixation of the prosthesis, the peritoneal flap is closed with staples. Disadvantages of transabdominal methods (intraperitoneal onlay mesh and TAPP) include the required pneumoperitoneum, which necessitates general anesthesia, and the potential for visceral injury, ileus, and adhesion formation. The third, the totally extraperitoneal ([TEP] or EXTRA) method, uses an infraumbilical incision and blunt finger plus instrument or balloon dissection to develop the preperitoneal space. Insufflation with carbon dioxide then is used to maintain an operative space. Further dissection with prosthesis placement and staple fixation completes the procedure. This operation is most similar to the open preperitoneal method of hernia repair, and although not used widely because of perceived difficulty in dissection, this procedure shows excellent results with consistent low rates of recurrence in reported series by experienced surgeons.

Table 3. LAPAROSCOPIC EXTRAPERITONEAL HERNIORRHAPHY

Author (year)	Dissection Method	Mesh Size	No. of Hernias	Recurrence (%)	Follow-up (mo)
McKernan (1993)	CO_2/blunt	8 × 13 cm	51	0	DNS
Philips (1993)	CO_2/blunt	10 × 12 cm	68	0	12 (average)
Kieturakis (1994)	Balloon/CO_2	8 × 10 cm	150	2.0	6.3 (average)
Ferzli (1995)	Balloon/CO_2 CO_2/blunt	DNS	326	1.6	18 (average)
Voeller (1995)	Balloon/CO_2	10–12.5 × 15 cm	365	0	1–15
Felix (1995)	Balloon/CO_2	15 × 15 cm with 6 × 10 buttres	382	0.26	9 (median)

DNS = data not specified.
Total hernias, 1342; overall recurrence, 0.6%.

In addition to the avoidance of risks associated with a pneumoperitoneum and intra-abdominal entry, this procedure may be amenable to the use of regional anesthesia.[29,30]

Mechanisms of Recurrence for Laparoscopic Herniorrhaphy

The progression of the open and laparoscopic preperitoneal techniques followed similar paths of development. Advancement from simple suture or staple closure of isolated defects to the use of a prosthesis, first to cover a single defect and finally to cover and overlap all hernia sites, correlates well with the decreasing recurrence rate. This is shown by examining the experience of Shultz et al.[25] They reported a decrease in the rate of hernia recurrence from 26% to 0% when switching from the plug-and-patch repair to the preperitoneal placement of a large prosthesis secured with staple fixation. Similarly, a multicenter retrospective analysis by Tetik et al.[31] reported a recurrence rate of 22% in 82 plug-and-patch repairs and 0.7% in 553 TAPP repairs. The multicenter trial by Fitzgibbons et al.[27] with assessment of 869 hernia repairs showed an overall recurrence rate of 4.5% with a mean follow-up of 2 years. Mesh-plug repairs were not included in the study, and the highest recurrence rates were seen with the intraperitoneal onlay mesh (5.1%) and the TAPP (5.0%) repairs. Although this recurrence rate appears high, the initiation of this study in 1991 was at the same time that the principles and advantages of thorough preperitoneal dissection and large prosthetic reinforcement were just beginning to be implemented by the laparoscopic surgeon. This trial also showed an association between recurrence rate and surgeon experience. Despite only short-term experience using laparoscopic herniorrhaphy, its current success is evident. A review of large, single center laparoscopic hernia series shows a recurrence rate of 0% to 2% among authors using the TAPP[27,32–37] (Table 2) or TEP method of laparoscopic herniorrhaphy (Table 3).[29,30,35,38–40] Of special note is the low rate of recurrence consistently achieved by authors using the TEP repair. No recurrences were reported in 87 repairs during the multicenter trial by Fitzgibbons et al.[27] or 578 repairs reported in a collected series by Philips et al.,[37] and a recurrence rate of only 0.4% was seen in 457 repairs reported by Tetik et al.[31] A collection of authors with more than 50 TEP repairs shows a recurrence rate of only 0.6% in 1342 cases (Table 3). Although the follow-up period is short in these studies, laparoscopic preperitoneal herniorrhaphy should be expected to follow the recurrence pattern observed with open preperitoneal prosthetic herniorrhaphy with the majority of recurrences noted within the first postoperative year.

In an attempt to determine the mechanisms of recurrence, videotapes of 13 operations included in the laparoscopic multicenter trial by Fitzgibbons et al.[27] were examined. These included seven direct, five indirect, and one indirect plus femoral primary hernia repairs. The mean time to recurrence was 30 weeks. Several primary mechanisms for hernia recurrence were identified, and all were thought to be related to technical error. In addition, 11 of the 13 recurrences showed a secondary mechanism and 3 showed a possible tertiary mechanism (Table 4). The predominant primary factor resulting in hernia recurrence was found to be insufficient dissection. Inadequate prosthetic overlap and prosthetic size were related predominant primary and secondary factors. Specifics regarding prosthetic size, hernia type, and time to recurrence are detailed in Table 5.

In a review of 54 recurrences after 3229 laparoscopic hernia repairs by Philips et al.,[37] it was found that 60% resulted from inadequate prosthesis size. An additional major factor in recurrence included inadequate fixation due to the unavailability of staplers early in the development of laparoscopic herniorrhaphy or clips pulling through tissue.[41] Thus, a majority of recurrences after laparoscopic hernia repair could have been prevented with adequate dissection, full prosthetic coverage of all potential hernia sites, and adequate fixation.

DISCUSSION

A thorough understanding of the anatomy of the inguinal region as seen from the laparoscopic approach is foremost in importance. Full exposure of Cooper's ligament, removal of excess preperitoneal fat and cord lipomas, complete assessment of all potential hernia sites, full reduction of the direct sac, complete dissection of the proximal indirect sac from the cord (complete dissection of the distal sac can result in testicular atrophy), and identification of the vas deferens and gonadal vessels are required. The predominant mechanism of recurrence after laparoscopic hernia repair is *incomplete dissection.* Complete laparoscopic preperitoneal dissection is tedious, but inadequate dissection results in poor overall assessment of the groin floor, *missed hernias,* and insufficient delineation of fascial structures. A missed hernia is defined as repair of an isolated hernia defect but with incomplete evaluation and failure to repair a coexisting hernia in the ipsilateral groin. This was noted by Ryan[42] as a probable mechanism of recurrence in 11% of 284 recurrent hernias repaired at the Shouldice Clinic and in 14% of 73 patients with indirect or femoral recurrence after conventional hernia repair as reported by Postlethwait.[43] The importance of complete groin evaluation was further shown by Ekberg et al.,[44] who reported on the use of herniography to evaluate 1010 patients with groin pain and a negative physical examination result. Of 314 patients shown to have ingui-

Table 4. MECHANISMS OF RECURRENCE

Primary Mechanisms of Recurrence	No. of Hernias	Secondary Mechanisms of Recurrence	No. of Hernias
Incomplete dissection	6	Incomplete dissection	2
Inadequate mesh overlap	4	Inadequate mesh overlap	5
Size of mesh	2	Size of mesh	2
Mesh slitting	1	Mesh slitting	1
Fixation	0	Fixation	1
Total	13	Total	11

nal hernias, 71 (23%) had multiple hernias, including 53 (17%) with bilateral hernias and 18 (6%) with multiple ipsilateral hernias. Incomplete dissection leads to a number of secondary mechanisms of recurrence, including insufficient prosthetic size and overlap, incomplete fixation, and *lipomatous hernia "recurrence."* A lipomatous hernia results from the protrusion of preperitoneal fat (without a peritoneal sac) through a direct defect. It is apparent in the immediate postoperative period and results from incomplete dissection. In addition, if the preperitoneal space is not developed adequately and a prosthesis is inserted with insufficient room for placement, folding may result.

Spaw[45] and Rosser[46] described methods of systematic dissection and determination of anatomy with the peritoneum intact and dissected. In the TAPP repair, initial laparoscopic reference points with the peritoneum intact are identified. These include the median, medial, and lateral umbilical ligaments, as well as the vas deferens and spermatic vessels. After a peritoneal reflection is established, the TAPP and TEP procedures proceed in a similar manner with identification of Cooper's ligament, the transversus abdominous arch, and the iliopubic tract. Preperitoneal fat is removed, hernia defects are inspected, and hernia sacs are dissected before prosthesis placement and fixation. Adequate anatomic knowledge and complete dissection are the groundwork for a proper repair with a minimal chance of recurrence and the lowest possible morbidity.

Often cited as a mechanism for recurrence is the use of an *inadequately sized prosthesis* so that all defects are not covered and overlapped for a sufficient distance (2 cm). Both the open preperitoneal and laparoscopic approach experienced an evolutionary process of increasing mesh size and decreasing recurrence rate. A small prosthesis placed over an isolated defect may lead to recurrence because of subsequent enlargement of the defect or shrinkage of the prosthesis. Furthermore, a prosthesis placed over an isolated defect ignores the possible weakness of the entire inguinal region, and the result is a future recurrence at another site (i.e., direct repair with indirect recurrence). This can be labeled *inadequate coverage of potential hernia defects* because future development of a hernia at another site would have been prevented with a prosthesis covering the entire myopectineal orifice. In the multicenter trial by Fitzgibbons et al.[27], the average pros-

Table 5. VIDEOTAPE ANALYSIS OF 13 RECURRENCES

Patient No.	Hernia Type	Repair	Mesh Size (cm)	Time to Recurrence	Hernia Type
1	Direct	TAPP	6 × 11	7 mo	Indirect
2	Direct	TAPP	6 × 10	1 wk	Direct
3	Indirect/femoral	TAPP	7 × 10	1 yr	Femoral
4	Direct	TAPP	6 × 10	6 mo	Direct
5	Direct	TAPP	8 × 11	1 yr	Unknown
6	Indirect	TAPP	6 × 11	9 mo	Unknown
7	Indirect	TAPP	7 × 11	6 wk	Direct
8	Direct	TAPP	6 × 11	1 yr	Direct
9	Indirect	TAPP	9 × 11	3 wk	Indirect
10	Indirect	TAPP	6 × 11	2 yr	Indirect
11	Direct	IPOM	6 × 8	2 mo	Indirect
12	Indirect	TAPP	4 × 6	5 mo	Indirect
13	Direct	TAPP	8 × 10	2 wk	Direct

thetic size in patients with recurrence was 6.5 cm x 9.6 cm. The basic requirement is a sufficiently sized prosthesis to cover and adequately overlap all potential hernia sites (direct, indirect, and femoral) of the myopectineal orifice. Again, adequate dissection plays a pivotal role in selecting and placing the prosthesis. It appears a 10- to 15-cm x 10- to 15-cm prosthesis is necessary to form an adequate coverage of the inguinal floor. The size used by Wantz[11] in unilateral GPRVS and by Felix[35] in laparoscopic hernia repair is 15 cm x 15 cm.

Inadequate overlap as a mechanism in recurrence is related directly to inadequate dissection and an insufficiently sized prosthesis. Dissection must fully define the fascial edges of the hernia defects as well as the location of potential hernia sites to allow accurate prosthesis placement. It is thought that all defects should be overlapped by at least 2 cm if stapled and 3 cm if not stapled. Laparoscopic grasping forceps measure approximately 1.5 cm when opened and can be used as a measuring device before fixation.

Displacement of the prosthesis with uncovering of a hernia defect may lead to recurrence and most often results from improper *fixation.* Minimal migration or shrinkage of the prosthesis or both from fibroblast ingrowth may result in uncovering of the hernia defect if inadequate overlap is used. Stable fixation of an adequately sized prosthesis to Cooper's ligament and the transversus abdominis aponeurosis and arch is recommended. Fixation just above the iliopubic tract will provide additional adherence inferolaterally, but care must be taken to place staples superior to the iliopubic to avoid injury to the lateral femoral cutaneous nerve. Stoppa has shown success in open preperitoneal herniorrhaphy using a 24-cm x 16-cm prosthesis without staple or suture fixation.[13] This prosthesis allows wide overlap of all potential defects in both groins, and intra-abdominal pressure acts to secure the mesh until fibroblast ingrowth is complete. Fiennes and Taylor[47] think that desufflation after laparoscopic herniorrhaphy tends to elevate the lower edge of the prosthesis and predisposes to migration of the inferomedial aspect from the space of Retzius in the presence of a direct defect. They noted that four of five recurrences in their experience resulted from herniation inferomedially with the prosthesis and emphasized secure fixation to Cooper's ligament. Similarly, surgeons now using the intraperitoneal onlay mesh technique successfully realized that a small peritoneal incision and limited dissection at Cooper's ligament was necessary to ensure adequate fixation.[28]

The proper number of staples to place in the described landmarks is a question asked often. Dion et al.[48] studied the effects of staple placement in a dog model. Using a 5-cm x 7-cm polypropylene mesh fixed with either 16 or 4 staples to cover a 3.5-cm x 5.0-cm abdominal wall defect, they measured the bursting strength at 2 days, 2 weeks, and 2 months. The bursting strength was significantly higher in the 16-staple group at all periods, and the bursting strength increased in both groups as the study progressed. Microscopic examination results of the mesh showed cellular infiltration at 2 weeks and collagen deposition at 2 months, which resulted in the increased strength. Although tissue ingrowth is an important factor in mesh strength over time, staple fixation also remains an important factor. Proper staple fixation also acts to prevent early displacement, *folding* or *invagination* of the prosthesis into the defect in the early postoperative period, before cellular infiltration and collagen deposition.[48] A study by Powell et al.[49] also showed that a linear relation existed between the number of staples used (one to three) and the maximum load tolerated. Placement of at least three staples in the easily identified and firm Cooper's ligament and several staples horizontally oriented in the muscular aponeurosis and just anterior to the iliopubic tract is recommended for small prostheses (10 cm x 12 cm).

Some surgeons prefer to place a slit in the prosthesis to allow exit of cord structures. *Mesh slitting* has been noted to be a mechanism of recurrence in some studies. The prosthesis wraps around the vessels and is drawn into the inguinal canal leading to an indirect recurrence (Steffes BC, personal communication, 1994). If the slit edges are not reapproximated adequately, an opening is present for recurrence. Slitting also may be a disadvantage because it places the prosthesis in closer apposition to the iliac vessels, thus leading to difficult dissection if vascular or transplantation surgery is required at a later date.

Felix[35] reports on 733 hernias repaired via the TAPP procedure with a recurrence rate of 0.3% and a median follow-up of 24 months and 382 TEP hernia repairs with a recurrence rate of 0.26% and a median follow-up of 9 months. One recurrence was secondary to inadequate fixation of the lateral mesh because of a hematoma. *Hematoma mesh lifting* also has been noted by Wantz and Stoppa (personal communication, 1996) to produce hernia recurrence. Felix thinks a slit to accommodate the vas and spermatic vessels is needed because they tend to elevate the mesh off the inguinal floor. To prevent possible recurrence at the slit, he uses a double buttress technique and places a second 15-cm x 15-cm patch centered over the slit of the original 6-cm x 10-cm mesh.[35]

Crafton also emphasizes mesh size, placement, fixation, and proper slit placement as a means to prevent recurrence. Measuring from the pubic tubercle and medial border of the rectus muscle to the lateral-most aspect of the iliopubic tract gives the mesh width, and measuring from the inferior aspect of Cooper's ligament to 2 cm above the inferior edge of the transversus abdominis arch gives the mesh height with an average mesh size of 10 cm x

14 cm. After assured overlap of 2 to 3 cm of all defects, proper fixation is applied to Cooper's ligament, the transversus muscle, and iliopubic tract. Crafton favors an inferior mesh slit lying below the iliopubic tract with reapproximation by staples. Also emphasized is adequate dissection with removal of all preperitoneal fat.

Technical Guidelines

Technical guidelines are as follows:

1. Detailed knowledge of the inguinal anatomy is required.
2. Systematic complete dissection with identification of all potential hernia sites and landmarks of fixation is the mainstay of successful preperitoneal hernia repair.
3. The fascial edges of direct hernia defects must be defined fully.
4. The proximal hernia sac should be dissected free of the cord and reduced into the peritoneal cavity for indirect hernias.
5. The prosthesis must cover and overlap the entire myopectineal orifice without folding or twisting.
6. If a slit is placed for the vas deferens and gonadal vessels, it should be closed carefully with staples and a double buttress considered.
7. All smaller prostheses (<12 cm x 12 cm) require fixation to Cooper's ligament, the transversus abdominis aponeurosis, and anterior lateral abdominal wall with a stapling device developed for this purpose.
8. Care must be taken to place the inferior edge of the prosthesis flatly against the pelvic floor.

At first, laparoscopic surgeons tried to find simple solutions for the problem of inguinal hernia. Hernia recurrences were because of both inadequate dissection leading to missed hernias and mesh repairs much too small to withstand the abdominal forces exerted on the mesh. As proficiency has increased, it has become apparent that the most common causes of hernia recurrence for laparoscopic herniorrhaphy are no different from those of the traditional preperitoneal approach. Hematoma mesh lifting and lateral inferior and medial inferior mesh fixation still remain a cause of hernia recurrence but can be overcome by a large enough prosthesis carefully placed under the expanding peritoneum.

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