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Current strategies for the management of inguinal hernia: What are the available approaches and the key considerations?

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Introduction

Few surgical diagnoses have the degree of impact on the worldwide healthcare system as that of the inguinal hernia. It is estimated that approximately 20 million inguinal hernia repairs are performed each year throughout the world, with as many as 700,000 of these performed in the United States alone.[1,2] The lifetime risk of developing a groin hernia is estimated at 27%-43% in men and 3%-6% in women,[3] most of which will ultimately require repair.[4] Operation to repair inguinal hernias are often successful initially, but have historically been plagued by complications including (but not limited to) recurrence and chronic groin pain, with considerable variation as to the reported incidences of both.[5] Obviously, it is of great interest when possible for surgeons to define best practices that allow durable inguinal hernia repairs that are cost effective and are associated with minimal morbidity. This continues to be a challenge since the current treatment of inguinal hernia is not standardized, despite the publication of several well-researched guidelines manuscripts.[5]

To fully understand the scope of this monograph, some historical context is necessary. The first inguinal hernia repairs were performed in the 1500s. These were tissue-based repairs involving resection of the hernia sac and simple reapproximation of the muscular and fascial components surrounding the defect.[5] At the time, surgeons had little understanding of the complex anatomical relationships of the tissue planes they were working within, but this changed in the

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early 1800s with the work of Dr. Astley Cooper, whose elegant work on the subject of inguinal anatomy and inguinal hernia was instantly regarded as a seminal contribution to the medical literature.[6] Further work followed by giants such as Franz Hesselbach, Antonio Scarpa, and Jules Cloquet who collectively, along with Cooper, provided the surgical community with the understanding of inguinal anatomy and function that to this day provides the basis for modern inguinal hernia repair techniques. The significance of their work and its place in surgical history are further evidenced by the eponyms that bear their names within the inguinal anatomy, many of which are perhaps the most well-known eponyms in use in surgery worldwide.[6]

The better understanding of the inguinal anatomy provided by the anatomical studies by Cooper and colleagues paved the way for the subsequent tissue repair techniques that followed. The most common of these were the Bassini, Shouldice, and McVay repairs. A discussion of the nuances of the different tissue repairs is beyond the scope of this chapter, but for the reader's perspective we will offer a few generalizations. This typically involved reapproximation of the layers of the inguinal canal to the shelving edge of the inguinal ligament, either en masse (Bassini) or as individual layers (Shouldice). The McVay repair is similar to that of the Bsssini except that the first few sutures were placed between the conjoined tendon/transversus abdominis arch and the Cooper (pectineal) ligament, transitioning to the inguinal ligament at the point that the femoral vein was encountered.[7] Although the Shouldice repair is the most extensively studied and has yielded the best outcomes of the open repairs, the underlying theme of these repairs is that they involved reapproximating structures that were anatomically never together before so, by definition, they were all performed under tension. This led to unacceptably high recurrence rates with tissue repairs and to the widespread use of synthetic prosthetic mesh materials to avoid tension and support the repair.[5] Of note, a tension-free tissue repair – the Desarda repair – has been developed. In the Desarda repair, the external oblique is transposed under the spermatic cord to cover the inguinal floor and then incised and sutured to the conjoined tendon, thereby forming an autogenous bridging patch.[8] Although this repair is interesting and has yielded promising results in small studies, it lacks the long-term follow-up to endorse it as a viable alternative at this time. In fact, recent guidelines support only the Shouldice repair as the standard against which tissue-based repairs should be measured.[5]

Synthetic mesh was first developed in the 1950s, and was at that time suggested to be used only in patients with large or recurrent defects that were felt to carry a higher risk of recurrence and typically placed over a Bassini repair as a means of reinforcement. However, it was the routine use of polypropylene mesh placed in a tension-free manner that was perhaps the biggest innovation in hernia surgery since the famous anatomical treatises of Cooper. This technique, described in 1986, involved the placement of a sheet of polypropylene mesh over the inguinal floor with no attempt at reapproximation of the conjoined tendon to the inguinal ligament, followed by immediate ambulation and early return to normal activities as tolerated. Perhaps the most significant advantage of the Lichtenstein repair was the reproducibility of its excellent results by other surgeons – a phenomenon that had been unobtainable with the Shouldice repair.[9] Since then, a variety of open mesh-based tension-free repairs have emerged. These have included the "plug and patch" repair, bilayer polypropylene repair (Gilbert), and open preperitoneal approaches (transinguinal and transrectus). In recently released guidelines however, the Lichtenstein remains by consensus the "gold standard" open mesh repair, the most extensively studied, and the repair by which other open repairs are judged.[5]

Laparoendoscopic repair of inguinal hernia, in which the hernia sac is dissected free from the spermatic cord and the entire myopectineal orifice is covered with prosthetic mesh may be performed either laparoscopically (transabdominal preperitoneal (TAPP) or totally extraperitoneal preperitoneal (TEP), or robotically TAPP (rTAPP). The utilization of laparo-endoscopic techniques ranges from 55% in highly resourced countries to 0% in areas where resources are more sparser.[5] Although initial large scale randomized trials suggested that the laparo-endoscopic approach was inferior, subsequent analysis of these studies have suggested that success is more dependent on the skill of the operating surgeon – more specifically the number of cases he or she has performed to acquire the necessary proficiency to achieve excellent results with these techniques.[10] In any case, subsequent studies have indicated acceptable recurrence rates as well as perhaps

lower rates of acute and chronic pain with the laparo-endoscopic technique. In addition, the ability to exclude and treat a femoral defect without extending the scope of the operation is another theoretical advantage.[5] Whether or not technical advantages provided by robotic-wristed instruments and the lack of need for the use of expensive disposable dissecting balloons in performing a rTAPP provide any advantage to the robotic approach over conventional laparoscopy is another actively debated issue. All of these issues are explored more thoroughly in subsequent sections of the chapter.

As one can tell, the choices for the repair are many and varied, and this fact suggests that a "one size fits all best method" does not exist. Rather, one should view all of the different approaches as additional tools to add to one's armamentarium. So then, how does one choose which repair to employ and when? In the context of inguinal hernia repair we believe that there are several key considerations for the surgeon in choosing which approach to employ. However, before discussing these considerations one important point must be stressed. All of the recommendations made in the subsequent section must be considered within the context of the skill and experience of the individual surgeon and his or her level of experience with a given approach. Subsequently, the approach to each individual patient and their hernia must be tailored accordingly with safety and avoidance of operative and postoperative morbidity as a primary goal. Too often we have seen patients injured when a new technique is performed by a surgeon without adequate training or expertise in that particular procedure. Remember, primum non nocere. First, do no harm.

It is our goal to critically evaluate, compare and contrast the 3 major categories of inguinal hernia repair techniques: open, laparoscopic (both TAPP and TEP), and robotic (rTAPP). To do this effectively and objectively, we have identified 5 key areas for consideration by the surgeon in choosing his or her operative approach. Each has been given its own section later in the monograph. These include:

Consideration of recurrence rates

Recurrences after inguinal hernia are troublesome and costly. Traditionally, recurrence rates have been used as perhaps the most important benchmark when assessing the adequacy of an inguinal hernia repair. Presuming that the repairs are properly performed, are there substantial differences in recurrence rates between the open, laparoscopic, and robotic approaches? If so, which repairs are the most and least favorable, and how do we as surgeons integrate this information into an evidence-based choice?

Considerations regarding pain – Both acute and chronic

Both acute and chronic pain after inguinal hernia repair have emerged as major considerations for the practicing surgeon today. Reducing acute pain may facilitate an earlier return to normal activities, including work, and is associated with greater overall patient satisfaction. Chronic pain represents a significant challenge for the clinician. It is thought to occur in 1%-12% of patients, with an overall incidence of debilitating pain from 0.5% to 6%.[5] The treatment of chronic groin pain after hernia repair represents a significant challenge, so prevention of this condition is a topic of major interest. In this section differences in the magnitude and incidence of both acute and chronic pain with the different approaches are discussed. In addition, factors predisposing to chronic pain as well as strategies for the prevention and treatment of chronic pain are presented.

Cost considerations

Is one approach clearly advantageous over another in terms of cost to the healthcare system? Initial criticisms of laparo-endoscopic approaches focused heavily on this issue, touting

higher procedural costs associated with an endoscopic approach when compared with an open approach. This has been challenged in recent years, but it remains a significant point of debate when comparing the 2 approaches, and the addition of robotic inguinal hernia repair has only served to further fuel the debate.

Considerations relating to the learning curve of the various repairs

As mentioned previously, the learning curve has been linked to differences in outcomes in inguinal hernia repair, especially in laparoscopic repairs.[10] How much is this a factor today, especially as more and more surgeons are obtaining experience with laparoscopic and robotic technologies in their residencies and fellowships? How many cases are adequate to perform laparoscopic or robotic procedures proficiently, and how can proficiency be assessed objectively and consistently? Also, in a world where the paradigm for repair may be shifting more toward the laparoscopic approach, is it possible that the proficiency of surgeons in open repairs will suffer, much as the proficiency with tissue repairs has suffered as mesh-based repairs have become the standard in adult inguinal hernia repairs? All of these are reasonable and pertinent questions.

Consideration of special circumstances: Are there any specific clinical circumstances which clearly favor one approach over another?

Current expert opinion states that there is likely no single "best approach" to the treatment of inguinal hernia.[5] Rather, each approach should be viewed as a tool for the hernia surgeon's toolbox and should be used when clinical circumstances dictate. Simply put, are there cases – for example the acutely incarcerated hernia or the giant inguinoscrotal hernia, for example – that should be treated with one particular approach in most cases? In this section, specific clinical scenarios are discussed, with an emphasis on which procedural characteristics may provide an advantage leading to a superior result if used in a given particular clinical scenario.

Hernia surgery is currently undergoing a renaissance period in the United States and worldwide with the advent of better evidence-based clinical guidelines,[5] a greater understanding of the hernia patient and the specific challenges associated with this unique disease process, higher quality published outcomes data, and more elegant techniques for repair. Indeed, it is an exciting time to be a hernia surgeon. We hope that the following sections help to advance the reader's knowledge and understanding of this ever-evolving field of surgery.

Consideration of recurrence rates

With an estimated 20 million cases performed around the world annually, the inguinal hernia repair is a procedure known and often practiced by the general surgeon.[3] As with any operative procedure, the ultimate measure of success is often reflected in the outcomes. Here, we discuss one of the most important benchmarks of a successful hernia repair: a consideration of the recurrence rates of the various repair methods. In this section, we review the recurrence rates of the most common and accepted open methods (Shouldice and Lichtenstein), laparoscopic (TAPP and TEP), and robotically assisted TAPP (rTAPP) approaches to inguinal hernia repair.

Recurrence rates among the population of primary inguinal hernia repairs may reach as high as 15%, with large studies reporting rates ranging anywhere from 1.7% to 10%.[11] A recurrent inguinal hernia contributes to morbidity in several ways, including increased financial burden on the healthcare system and a negative impact on the patients' quality of life. When performed with experience, highly specialized centers have successfully demonstrated long-term recurrence rates as low as 1%.[12] Although considerations relating to the effect of the learning curve of the

laparoscopic approaches (TAPP, TEP, and rTAPP) on observed recurrence rates have been a point of discussion, the potential effects of this phenomenon will be explored in a subsequent section. This discussion presumes that the repairs studied were performed by a surgeon skilled in the described approach, and focuses on the recurrence rates that are inherent to the approach itself. Having said this, it is important to be aware of the patient factors that may contribute to recurrence independent of the chosen operative technique. These include the female sex[13] and surgeon volume (<5 cases annually).[14] Risk factors for recurrence that have moderate level supporting evidence include the presence of a sliding inguinal hernia, disorders of collagen formation, obesity, and cases in which repair was completed under local anesthesia.[5] The presence of postoperative hematoma[15] or the necessity of an emergent inguinal repair[16] have not definitively been shown to contribute to increased recurrence rates, although they may compromise other benchmarks of a successful repair.

Recurrence rates reported in the literature are often presented as retrospective case series from single institutions without the benefit of randomization or prospective study, and with follow-up periods of significantly varying length.[17] In addition, the reported recurrence rates are often determined by rates of reoperation, so it assumed that actual recurrence rates may be as much as twice the rate that is reported, since some patients with recurrence do not undergo reoperation – either at the same center or at all.[11] National registries have helped to clarify this issue, since they capture patients that are followed up within the entire country, providing a much broader follow-up than that of an institutional registry. The Danish Hernia Database and the Swedish Hernia Registry are 2 such examples. The Danish database captures 98% of inguinal hernia repairs in the country and the Swedish database captures approximately 80%.[18,19]

The recently developed Americas Hernia Society Quality Collaborative, in which members of the Americas Hernia Society report their results into a standardized database, may provide another mechanism by which this problem may be studied more effectively.

Now that we have acknowledged the risk factors contributing to increased recurrence and the limitations of the available literature in determining these rates, we may focus on the different operative techniques employed today.

The anterior approach remains the most common approach to the repair of inguinal hernia.[17] These include nonmesh tissue-based repairs and tension-free mesh repairs. Based on the 2009 European Guidelines, the grade A-level recommendation to approaching symptomatic inguinal hernia in male adults over the age of 30 years is a tension-free mesh repair.[7,20] Of the nonmesh tissue repairs, the Shouldice operation has been reviewed the most thoroughly.[5] A 2012 Cochrane review included all randomized controlled trials assessing the results of the Shouldice operation vs other mesh (Lichtenstein) and nonmesh techniques (Bassini, McVay).[21] The review included adults older than 18 years of either sex presenting with a primary inguinal hernia defined specifically as a groin protrusion. Recurrence was defined as a clinically appreciated bulge or protrusion worsened by a Valsalva maneuver in the previously operated groin. In all, 2566 Shouldice repairs were compared to 1122 Lichtenstein/plug and patch repairs, and 1608 by nonmesh Bassini or McVay techniques. The Shouldice operation was the superior nonmesh repair with an observed recurrence rate of 4.4%, compared to 6.9% with either the Bassini or McVay repair. However, the Shouldice repair was found to be inferior to the Lichtenstein repair, with reported rates of recurrence of 3.6% for the Shouldice repair compared to 0.8% with the Lichtenstein repair – findings consistent with and supportive of the 2009 European guidelines.[20,21] Although the benefits of mesh repair in emergent hernia cases (where incarceration occurs but bowel resection does not) outweigh the risks of introducing foreign material,[22] there is insufficient evidence to support mesh use in strangulated cases where bowel resection is needed.[23] This, along with considerations of the cost, unavailability, learning curve, and patient refusal of mesh demonstrates the need for the general surgeon to be familiar with and consider nonmesh repairs in select scenarios where the placement of mesh is ill-advised, while acknowledging the increased risks of recurrence with tissue-based repairs.

Dr. Irving L. Lichtenstein first described his now well-known and often practiced tension-free mesh repair in 1989 in *The Tension-Free Hernioplasty*.[24] There, he details the 2 predominant reasons for failure of an open nonmesh repair: (1) unnatural apposition of tendinous structures in

an attempt to reinforce the canal floor at the pubic tubercle and leading to suture line tension; and (2) an absence of bordering stitches at the medial and lateral ends of a nonmesh repair that fail to offer a method of force distribution, predisposing to tearing and, as Lichtenstein describes, an unzippering effect over time. With the introduction of mesh reinforcement of the canal floor without formal reconstruction and reapproximation, tension is avoided. Among 1000 operations, Lichtenstein did not report a single case of recurrence in the 6-year follow-up period.[24] Evidence 30 years later continues to support low recurrence rates with the Lichtenstein tension-free mesh repair in comparison to nonmesh tissue repair techniques. The Danish Hernia Database with more than 10,000 inguinal hernia repairs annually, describes a recurrence rate after 96 months at 8% for nonmesh repair vs 3% for the Lichtenstein technique.[18]

In the decades since the advent of the Lichtenstein technique, other tension-free mesh-based repairs have been explored, including use of preformed polypropylene plug systems, self-gripping mesh, and the more common plug-and-patch, explored first by Rutkow and Robbin in 1993.[25] The plug-and-patch method is a mesh-based technique meant to offer less anatomical dissection, reduced operative time, minimal postoperative discomfort, and reduced recurrence rates, even compared to the Lichtenstein technique.[25,26] Rutkow and Robbin reported recurrence rates of less than 0.2% after 2060 patch-and-plug repairs after follow-up of approximately 6 years.[25] Although an attractively low recurrence rate, these results have been difficult to reproduce. A meta-analysis of 7 randomized controlled trials comparing Lichtenstein to the plug-and-patch demonstrated no significant differences in recurrence rates along a range of long-term follow-up periods.[26] The plug-and-patch technique is an acceptable technique for treatment of primary inguinal hernias when considering recurrence rate as the primary outcome.[5] However, the generally shorter operative time[26] of the plug-and-match does not overcome the disadvantages of introducing increased foreign material (compared to a simple flat mesh in the Lichtenstein), additional costs, the violation of both the anterior and preperitoneal planes by plug placement, and concern of mesh migration and tissue erosion.[5] For these reasons, the Lichtenstein repair is still considered the recommended mesh-based open approach to the treatment of inguinal hernia, and the use of the hernia plug is specifically discouraged in recently published expert consensus.[5]

Within the last few decades, and with the advent of minimally invasive surgery and the emergence of laparoscopy, many procedures that were historically performed open are now often performed laparoscopically. The 2 prevailing laparoscopic repairs today are the TAPP repair and TEP repair.

In both laparoscopic repairs, mesh is placed in the preperitoneal plane but via different approaches. In TAPP, this is accomplished by an intraperitoneal approach in which the peritoneum is opened to expose the myopectineal orifice. In the TEP repair, the preperitoneal space is entered in an extraperitoneal fashion and expanded by the use of an inflatable dissection balloon.[5] A multicenter retrospective study involving 7 centers specialized in laparoscopic hernia repair reviewed 10,053 hernias repaired by either the TAPP or TEP approach.[27] In all, 89% of these patients were followed for at least 6 months, with a subsequent median follow-up duration of 3 years. The recurrence rate for these specialized centers ranged from 0.1% to 0.9%; the incidence of recurrence was 0.46% by the TAPP approach and 0.22% with TEP. Similarly, an analysis of various series comparing TAPP and TEP published from 1990 to 1998 demonstrated a recurrence rate of 1.33% for TAPP and 0.6% for TEP, compared to rates of 0.77% for TAPP and 0.54% for TEP the very following decade (1999-2008).[5] In light of these data, there is insufficient high-level evidence to recommend one technique definitively over the other. Current expert consensus states that when learning curve is accounted for, both TAPP and TEP laparoscopic techniques have similarly low recurrence rates and are both suitable choices for inguinal hernia repair.[5]

When comparing between the standard Lichtenstein repair and the laparoscopic TAPP or TEP techniques, there is currently insufficient evidence to suggest a clinically significant difference in recurrence rates.[5] A 2004 meta-analysis of 34 randomized controlled trials compared open mesh repairs with TAPP and TEP on multiple outcome measurements, including recurrence rates.[28] Of these, 23 trials focused specifically on the comparison between the Lichtenstein repair and the

laparoscopic approaches (4550 total patients). On initial evaluation, recurrence rates were found to be significantly higher for TAPP and TEP methods at 5.5% compared to Lichtenstein at 2.7%. However, after exclusion of the Veterans Affairs Multicenter Trial,[10] the recurrence difference was no longer statistically significant.[5] The exclusion of patients in the aforementioned VA trial is worthy of some explanation. First, the age of the patients enrolled in the VA Multicenter Trial was on average higher. In addition, this population had lower overall health-related quality of life scores than the general population. Second, the learning curve of the surgeons involved was an issue, with some having less experience than others in laparoscopic repair techniques. Finally, the mesh size utilized in the laparoscopic repairs in the VA Multicenter Trial was restricted (rather than being tailored to the size needed to effectively cover the myopectineal orifice), whereas the other studies in the meta-analysis were not.[5,10]

The 2014 European Hernia Society (EHS) guidelines reviewed pooled data from 7 studies evaluating recurrence rates after Lichtenstein repair vs laparoscopic repair, all with a minimum follow-up of 4 years.[29] As before, after exclusion of a single study[30] wherein a single operator contributed to 33% of TEP recurrences due to lack of surgical expertise (learning curve set at 25 laparoscopic repairs), the guidelines found no significant difference in recurrence rates between TAPP and TEP repairs vs Lichtenstein technique.[29] After careful review of available evidence, laparoscopic techniques – assuming sufficient operative experience – offer similar recurrence rates as the Lichtenstein repair.

An increasing number of procedures once performed laparoscopically are now being performed using a robotically assisted approach. Inguinal hernia repair via a robotically assisted TAPP (rTAPP) is one such procedure. Proponents of this approach have touted an enhanced visualization of the operative field and increased dexterity and degree of motion offered by the robotic platform over standard laparoscopic approaches.[31]

A 2017 single institution study reported the results of 159 inguinal hernia repairs performed on 82 consecutive patients by the robotically assisted TAPP approach.[31] This study assessed long-term quality of life outcomes, including a reported recurrence in only one single case (0.6%). The study was plagued by a low response rate to the follow-up survey (29 patients, response rate 35.4%). It has been suggested by some that this is reflective of high patient satisfaction by the failure of the patients to report complications or recurrences, although the validity of this conclusion is questionable.

A 2019 meta-analysis of 16 studies comparing tension-free mesh-based Lichtenstein, laparoscopic TAPP and TEP, and robotically assisted TAPP offered additional insight into reported recurrence rates.[32] Of the 51,037 patients available for study, 103 (0.2%) underwent rTAPP intervention. Follow-up ranging from 1 to 60 months revealed no statistically significant difference in recurrence rates between rTAPP and Lichtenstein (odds ratio (OR) 0.98; 95% confidence interval (CI) 0.45-2.10). Although no direct comparisons were made between rTAPP and TAPP or TEP, the meta-analysis suggests comparable recurrence rates among the 4 techniques.[32] Notable limitations include heterogenous postoperative follow-up lengths and limited numbers of rTAPP cases. Current evidence suggests similar recurrence rates in robotically assisted TAPP technique when compared to established Lichtenstein technique. This is logical, since the technique of the rTAPP is essentially identical to that of the laparoscopic TAPP with respect to technique of dissection and mesh placement. For these reasons, it is likely that rTAPP will compare favorably with the other 3 established techniques with respect to recurrence rates as more data becomes available.

Considerations regarding pain – Both acute and chronic

Pain after groin hernia repair remains a topic of great interest to surgeons and patients. The problem of chronic groin pain is a significant one and one that is likely underreported in the hernia literature. The incidence of chronic groin pain is estimated to be approximately 10%-12%, with the incidence of debilitating chronic symptoms present in 0.5%-6% of patients.[5] The specific definition of chronic groin pain is pain lasting longer than 3 months after hernia repair, and its

incidence has consistently been used as a benchmark to evaluate outcomes after inguinal hernia repair, with the goal obviously being to define practices that effectively reduce its incidence.[33] Consequently, knowledge of each approach's effect on the incidence of chronic groin pain is of great interest to hernia surgeons.

Before one can critically evaluate the procedural aspects related to groin pain that derive from the specific approach to repair, one must be aware of the patient factors that may predispose patients to the development of chronic pain postoperatively. These factors are elegantly described in the International Endohernia Society (IEHS) guidelines and include young age at time of repair, high pain intensity level prior to repair, lower preoperative optimism, impairment of daily activities, operation for recurrence, and genetic predisposition (via identification of the DQB1*03:3 human leucocyte antigen (HLA) haplotype) in the at-risk patient. If these clinical factors are present then it may be worthwhile to counsel these patients preoperatively regarding their postoperative pain expectations.[5,34] In addition, and not specifically related to the chosen operative approach, rates of chronic pain are higher after procedures performed by less experienced surgeons and in those performed outside of specialized high-volume hernia centers.[5,34,35]

Procedural factors not associated with the chosen operative procedure may also play a role and are worthy of mention. As mentioned above, the degree of pain experienced is substantially higher at all points of time when hernia repairs are performed by low volume surgeons – including rates of development of chronic pain.[5,35] The groin is richly innervated and several important nerves are at risk for injury or entrapment regardless of which technique is chosen for repair. During open hernia repair, identification of the highly variable distribution of the nerves is important,[35] but extensive dissection and/or neurolysis of the inguinal nerves (ilioinguinal, iliohypogastric, and genitofemoral) has been shown to correlate with higher rates of chronic groin pain and thus should be avoided.[5] It has been suggested that routine neurectomy might be beneficial in reducing observed rates of chronic groin pain, but the literature regarding this procedure has failed to show significant benefit, so expert consensus recommends against its routine practice.[5,36-38] That said, it is recommended that the "at risk" partially transected, entrapped or traumatized nerve be resected to avoid preventable painful sequelae. This practice is known as "pragmatic" nerve resection and has been endorsed in recent guidelines.[5,39] In laparoscopic and robotic procedures, dissection and fixation lateral to the internal ring should be specifically avoided to avoid nerve injury within the "triangle of pain."[5] It is further recommended that the patient who awakens with excruciating pain of a neuropathic nature undergo immediate re-exploration to identify a technical error and by doing so, free or transect what would be assumed to be an entrapped or injured nerve in hopes of preventing chronic pain.[5] In addition, the occurrence of perioperative complications such as hematoma, infection, or seroma also correlate with an increased incidence of chronic pain, further accentuating the importance of cautious, meticulous technique in hernia repair.[5,40] The nerves commonly encountered in open repairs are shown in Fig. 1, while the nerves encountered in the preperitoneal approach used for laparoscopic and robotic repairs are displayed in Fig. 2.

Mesh use in general, when compared to open tissue repairs, reduces the incidence of groin pain by facilitating a tension-free repair.[5] The type and weight of mesh used in both open and laparoscopic/robotic repairs has been a subject of considerable interest among surgeons in recent years. In general, flat meshes are preferable owing to an overall decreased volume of foreign material when compared to formed or shaped mesh devices and complications related to the use of mesh devices.[5,24] The mesh plug seems exceptionally problematic and has been associated with erosion and migration into adjacent tissue planes and organs. In addition, proper placement of the plug requires its insertion into the preperitoneal space, thereby violating both the anterior and posterior planes and therefore complicating repair of recurrences via both anterior and posterior approaches. For these reasons, it is recommended by expert consensus that mesh plug repairs be specifically avoided.[5]

Mesh fixation has also been shown to affect the incidence of chronic pain and relates to fixation technique regardless of procedural choice. Generally speaking, and as it relates to the development of chronic groin pain, the less fixation the better. In laparoscopic repairs, recent

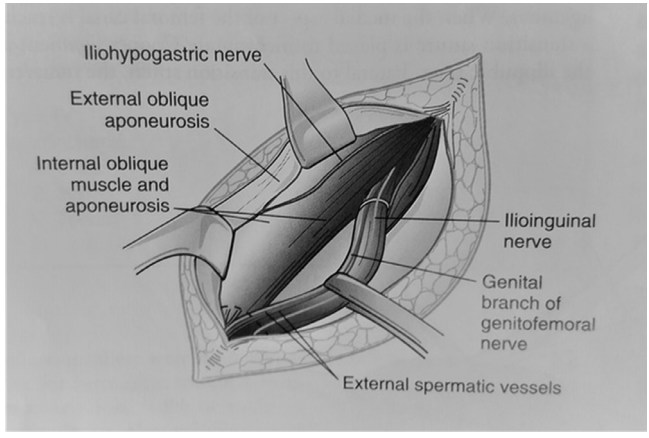

Fig. 1. Anatomy of nerves encountered in open inguinal hernia repair. (From Malangoni and colleagues.[17])

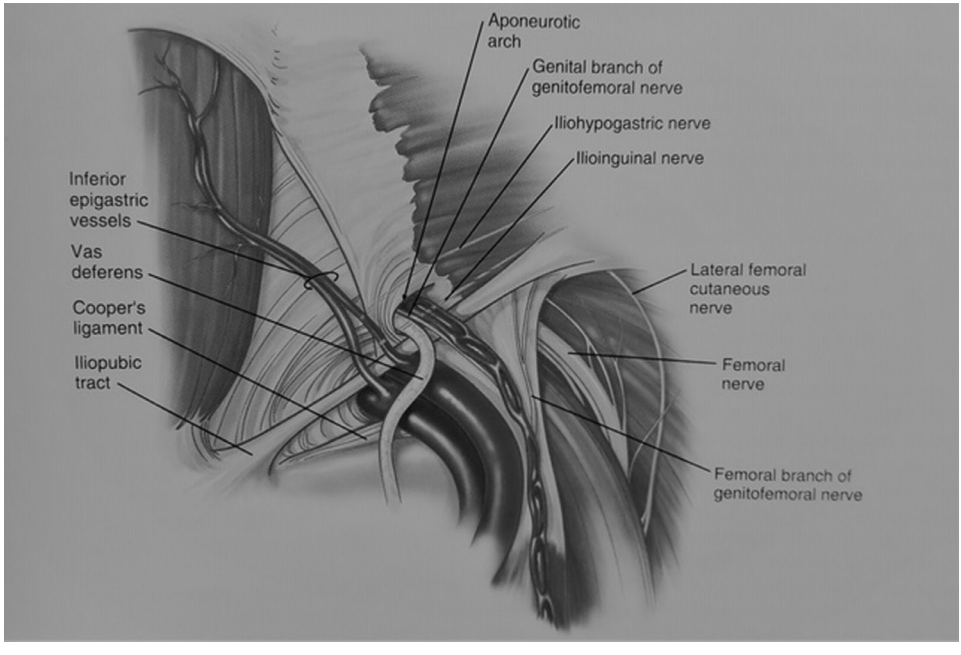

Fig. 2. Anatomy of nerves encountered in preperitoneal hernia repair. (From Ferzli GS, Edwards ED. Laparoscopic preperitoneal hernia repair. In: Frantzides CT, Carlson MA, eds. Atlas of Minimally Invasive Surgery. Philadelphia, PA: Elsevier Saunders; 2009:213.)

guidelines call for minimal or no fixation in both TAPP and TEP repairs, with the exception being large direct defects in which more points of fixation may be required to minimize recurrences.[5,34] The use of tacking devices or sutures (regardless of approach – open, laparoscopic, or robotic) are correlated with higher postoperative pain than in procedures where tissue glue is used, suggesting that this may be a preferable technique for fixation when required.[5] Interestingly, self-gripping meshes although typically implanted with minimal or no fixation, have

not been shown to reduce the amount of groin pain regardless of the operative approach.[41,42] If suture or tack fixation is used, care should be taken not to place the fixation directly into the periosteum, as this tissue plane is highly innervated and doing so may increase rates of chronic groin pain postoperatively.[5,43] As mentioned previously, lateral fixation should be strictly avoided in TAPP and TEP repairs, lest the surgeon violate the delicate innervation located within the "triangle of pain."

The issue of mesh weight has been another area of debate. It has been suggested that the use of lighter weight mesh (LWM) may be associated with a lower incidence of chronic postoperative groin pain than heavyweight mesh (HWM). Unfortunately, there is no universally accepted definition as to what constitutes a LWM vs a HWM.[5] This controversy has been examined in a variety of randomized controlled trials and then further analyzed via systematic review and meta-analysis. It appears that the use of LWM is not associated with higher rates of recurrence and may be associated with a lower sensation of foreign body, a faster recovery time, and less acute postoperative pain.[44,45] In addition, a meta-analysis published in 2012 by Sajid and colleagues did find a reduction of chronic pain in open repairs with the use of LWM over HWM,[46] but this finding has not been consistently demonstrated in other studies. Consequently, recent consensus statements do not endorse the use of LWM over HWM specifically.[5] Still, the authors feel that advocating the use of LWM over HWM is warranted based on the reduction in acute pain alone, once again with no increase in rates of recurrence. Additional randomized controlled trials may aid in further clarifying this issue.

Severe and poorly managed acute postoperative pain is recognized as a risk factor for the development of chronic pain[47]; therefore a comprehensive strategy for acute postoperative pain management should routinely be employed. The initial oral agents should be a combination of acetaminophen and nonsteroidal anti-inflammatory agents, with oral opioids added only if this combination is inadequate or if contraindications to elements of the nonopioid regimen are present.[5] The use of long acting local anesthetics (bupivacaine) is also of interest. The use of bupivacaine infiltration has been studied in open inguinal hernia repair and does appear to be superior to placebo for the management of acute postoperative pain. This has been indicated by the finding of lower postoperative pain scores, less supplementary analgesic use, and longer time to first analgesic request.[48] The benefit of local anesthetics appears to be greatest in infiltration or field blocks delivered via both subcutaneous and subfascial injection.[49] Whether or not there is additional benefit to be gained by injecting local anesthetics prior to incision (preemptive analgesia) is controversial and expert consensus takes no firm position on this.[5] Furthermore, the use of local anesthetics appears to be beneficial only in the management of acute pain. No benefit in the reduction of chronic groin pain with local anesthetic infiltration has been observed. The use of catheter/reservoir devices that slowly infuse local anesthetics into the wound have been studied on a small scale and appear to be superior to placebo in reducing pain as well, but further randomized controlled trials are necessary before these can be recommended over simple tissue infiltration.[50]

As one can appreciate, pain management after inguinal hernia repair is indeed a topic of significant complexity and consequently requires a comprehensive and multifaceted strategy to decrease the intensity of acute postoperative pain and avoid the problem of chronic groin pain as much as possible. The above strategies are applicable to inguinal hernia repair in general and are indeed valuable in that regard.

The question we now address is the one that most pertains to the debate that this chapter attempts to answer: Do any of the approaches in use today – open, laparoscopic (TAPP or TEP), or robotic (rTAPP) – convey any advantage in the reduction of acute or chronic pain, or both? This subject has been of interest for some time and has been included (along with recurrence rates, cost, and other variables) as an important metric in the evaluation of the various available inguinal hernia repair techniques. Consequently, the results of these studies have been recently analyzed in several meta-analyses and systematic reviews, allowing surgeons to benefit from data derived from tens of thousands of patient outcomes.

A study published in 2016 by Takata and colleagues examined 334 patients who had undergone 378 hernia repairs. These repairs performed were open onlay mesh repairs via the

Lichtenstein or bilayer prosthesis repair (Gilbert – Prolene hernia system (PHS)) and compared those outcomes against patients who had undergone repair via a preperitoneal technique, either open (Kugel) or laparoscopic. In their study, mesh fixation in the laparoscopic group was performed with 4-6 tacks and all operations included resident involvement but with the supervision of a specialist surgeon. The patients were followed from 2 to 3 weeks postoperatively at intervals up to 1 year. Pain was assessed via a patient-reported numerical score. These scores were lower for the patients who underwent laparoscopic repairs at the 2-3 week and 3-month time intervals. Similarly, the pain scores were also lower at the 6-month mark for the laparoscopic approach as well, supporting the conclusion that an endoscopic approach is associated with a lower incidence of pain – both acute and chronic.[51]

Similar results have been reported by various authors, lending this topic to meta-analysis. In 2017, Scheurmann and colleagues published a systematic review and meta-analysis of the Lichtenstein operation vs laparoscopic repair for the treatment of primary inguinal hernia. Eight randomized controlled trials were included in the analysis. Outcome measures included duration of operation, length of hospital stay, acute and chronic pain intensity, time to return to work, hematoma, wound infection, neuralgia, numbness, scrotal swelling, seroma, and recurrence. In this large series there were no significant differences in any of the outcome measures with the exception of chronic postoperative pain, which was significantly lower in the laparoscopic group (OR = 0.42; 95% confidence interval). This finding was observed despite the use of fixation techniques that are in excess of what is currently recommended today. The benefit of a laparoscopic approach was still realized in this series despite the fact that increased extent of tack fixation is correlated with a higher incidence of chronic pain.[52]

Lundstrom and colleagues recently published a cohort study of 22,917 patients studied through a combination of patient-reported outcomes and Swedish national registry data. The object of the study was to compare the results of various available hernia repairs including open anterior mesh repair via the Lichtenstein or bilayer technique to that of open or laparoscopic (TEP) preperitoneal approaches. The primary endpoints were that of chronic pain 1 year after the operation and the rates of recurrence. The overall rate of development of chronic pain in the series was substantially lower in the laparoscopic TEP repair group (OR 0.84; P= 0.013) when compared to other repair techniques.[53]

The results of these studies and others have led to recent consensus that laparoendoscopic approaches (TEP or TAPP) are associated with lower rates of the development of chronic pain than open repairs.[5,34] With the introduction of robotic technology, an increasing number of patients are undergoing hernia repair via a rTAPP approach. Proponents of this approach have touted increased technical ease of repair, shorter learning curve, and decreased cost related to the elimination of expensive disposable dissecting balloons and tracking devices, and early data suggest that it is technically feasible and safe. The issues relating to learning curve and cost are addressed in subsequent sections; however, the issue of postoperative pain will be addressed in this section.

Recently, robotic TAPP was compared to laparoscopic TAPP in a retrospective single-surgeon experience by Waite and colleagues. Outcome measures included cost, feasibility, operative time, and patient-reported pain scores among others. Of note, the average pain scores in this series were significantly less than those of the laparoscopic group (2.5 vs 3.8, P= 0.02). Of note, mesh use in both groups consisted of polypropylene mesh or self-fixing polyester mesh and fixation in both groups did not differ and consisted of 1-2 tacks in the polypropylene mesh group and no fixation in the self-fixing group. The authors hypothesized that suture fixation was less painful than tack fixation, but this remains theoretical in nature. Unfortunately no information was provided regarding the development of chronic pain in this study, so the impact of the use of the robotic approach on chronic pain cannot adequately be assessed.[54]

A subsequent study by Bittner and colleagues examined patient perceptions of acute pain and disruption following open, laparoscopic, and robotic approaches in 526 subjects. The results consisted of 526 subjects. Of these, 214 patients underwent open repair, 214 underwent laparoscopic repair, and 83 underwent robotic inguinal hernia repair. There were no differences in demographic or clinical characteristics. The robotic group reported significantly less acute

postoperative pain than the open group ($P< 0.01$), but similar to that of the laparoscopic group ($p = 0.37$). Once again, no assessment of the incidence of chronic groin pain was provided in this series.[55]

Based on the available data it is the position of the authors that, with respect to pain, laparoendoscopic approaches (laparoscopic or robotic) are associated with less acute postoperative pain than open approaches. In addition, laparoscopic repairs are associated with a lower incidence of chronic pain when compared with open repairs.[5] The similarities between the technical aspects of robotic TAPP and laparoscopic repairs lead the authors to suspect that the results of robotic TAPP will be comparable to that of laparoscopic TEP or TAPP with respect to the incidence of chronic pain, but this hypothesis will need to be confirmed in future studies, preferably via randomized controlled trials.

Cost considerations

Healthcare costs in the United States comprise 17.9% of gross domestic product in 2017, while overall health lags behind other developed nations. Contributors to these high costs include the cost of labor, goods, and administrative costs.[56] These healthcare costs continue to escalate, with healthcare spending projected to continue to outpace inflation.[57] In order to stem the tide of rising healthcare costs, providing cost-effective treatment is imperative.

Inguinal hernia repair is one of the most common surgical procedures performed in the United States. Although many techniques for inguinal hernia repair have been described, the most commonly performed repairs include the Lichtenstein repair, laparoscopic repairs (TAPP and TEP), and more recently the robotic TAPP (rTAPP) repair. Although each of these techniques has unique advantages from a clinical perspective, the costs associated with each procedure should be considered, especially with the excellent outcomes associated with all of the prevailing repair techniques. Furthermore, in the fee-for-service healthcare system of the United States, understanding the impact of any specific procedure upon provider costs, patient costs, employer costs, and insurer costs provides unique insight into the conflicting interests among interested parties and key stakeholders.

In assessing procedural costs there are several relevant considerations: patient out-of-pocket costs, insurance provider payments, hospital labor costs, costs associated with loss of work, cost of a recurrence, and impact upon long-term quality of life and patient function. The definition of cost is often dependent on the lens through which cost is being evaluated. From a societal perspective, the direct cost of the procedure, loss of labor, and insurance premiums would be major considerations. Because the United States is largely a fee-for-service healthcare system, patients face concerns with copayments, deductibles, and lost wages. Healthcare insurance companies aim to provide cost-effective long-term care for large populations, avoiding hospital readmissions, postoperative complications, and recurrent procedures while employers bear costs associated with healthcare insurance and loss of labor. All are drivers of costs for any given procedure.

The healthcare system is further complicated by the system of reimbursement for physicians, hospitals, and patient care facilities. Although the cost of care is an important metric, the net revenue associated with a procedure is an additional consideration. Facility payments vary based upon the type of procedure performed and as a result, the profitability of a procedure is based upon the difference between revenue and expenses. Accordingly, it is feasible for procedures to incur higher costs yet receive higher revenue resulting in greater profitability.

Furthermore, facilities will incur both direct and indirect costs. Direct costs are costs that can be attributed to a specific department.[58] These include operating room costs, disposable supply costs, and staff salary and expenses. Indirect costs are costs not directly attributable to any department such as housekeeping, laundry services, utilities, capital equipment, and service contracts.[58]

The Lichtenstein technique for inguinal hernia repair is generally considered to be the most cost-effective repair due to the minimal supplies required. The procedure is typically

performed in an outpatient setting with traditional surgical instrumentation, sutures, and low-cost polypropylene mesh. In contrast, laparoscopic repairs necessitate the use of cameras, insufflators, balloon dissectors, tracking devices, and trocars in addition to the costs incurred with an open repair. Because of this, laparoscopic inguinal hernia repairs have higher perioperative and short-term costs compared to open repairs.[59] A 2012 study comparing techniques demonstrated a significant difference in cost of supplies for Lichtenstein and laparoscopic repairs, respectively, of $343 and $1611.[60] A prospective multicenter randomized clinical trial by Eker and colleagues found TEP repairs to be associated with higher operative costs in the short term compared to the Lichtenstein repair, but total hospital costs were comparable.[61] This is further supported by a large prospective trial of more than 1000 patients demonstrating improved cost effectiveness of laparoscopic inguinal hernia repair for unilateral primary and recurrent inguinal hernia repairs 2 years following initial operation,[62] suggesting that downstream costs associated with factors such as higher rates of chronic pain with open repairs resulting in additional treatment costs may be relevant, as described below.

In a 5-year prospective trial comparing TEP repair to the Lichtenstein repair, the cost of the laparoscopic repair was more than 700 Euro greater per procedure. However, the cost of missed work in the open group offset the cost savings resulting in a cost benefit in the Lichtenstein group of only 292 Euro.[63] However, a prospective randomized trial by Ielpo and colleagues, comparing laparoscopic repair to the Lichtenstein approach for bilateral inguinal hernias favored a laparoscopic repair.[64] In this study, the incidence of postoperative complications (27.4% vs 8.6%, $P = 0.002$) and incidence of chronic pain (11.9% vs 2.5%, $P = 0.04$) contributed to the greater costs in the Lichtenstein group. Accordingly, despite the increased costs associated with both the operation and materials, the long-term results, in the opinion of the investigators, demonstrated an overall net cost benefit with the laparoscopic approach. These data remain controversial however, and in a similar study the cost benefit of laparoscopic bilateral inguinal hernia repair was not demonstrated. In a study by Hynes and colleagues, 2-year costs were less for open bilateral inguinal hernia repairs and there was no difference in quality adjusted life years between laparoscopic and open repairs.[62]

A 2014 analysis of 233,984 Medicare recipients evaluated the utilization and costs of care for common laparoscopic procedures. Laparoscopic inguinal hernia repair was found to be associated with 50% more frequent complications, 0.35 fewer hospital days, similar hospital readmission rates, $1614 in increased Medicare claim costs, and $156 in reduced Medicare reimbursement. Although this study does not evaluate hospital costs, it provides unique insight into the costs of inguinal hernia repair from the perspective of the insurer and clearly demonstrates higher costs for a laparoscopic inguinal hernia repair.[65]

Robotic inguinal hernia has emerged as an alternative to laparoscopic inguinal hernia and has been performed with increasing frequency although it still represents the minority of inguinal hernia repairs.[66] Enthusiasts have reported improved robotic outcomes relative to the open approach.[67,68] A 2018 study of 510 hernia repairs demonstrated significant difference in costs between robotic ($7162), laparoscopic ($4527), and open ($4264) inguinal hernia repair.[69] This study also evaluated hospital charges which were correspondingly increased for robotic ($27017), laparoscopic ($16016), and open ($14190) repairs. As this study did not report upon net revenue for each procedure, it is unclear as to whether the increased charge resulted in increased payments to offset the increased costs. Nevertheless, this study clearly demonstrates increased costs associated with robotic inguinal hernia repair as well as an increased operative time in the robotic group. Although speculative, the authors hypothesize the increased operative times as an explanation for the increased incidence of wound complications in the robotic group relative to the other technique,[69] which, if duplicated in subsequent studies, may further drive the cost of robotic repairs upward due to higher downstream costs related to complications. This hypothesis has not been well studied, however.

A multi-institutional study of 2405 cases of inguinal hernia which included 734 robotic and 1671 laparoscopic repairs demonstrated significantly greater total costs in the robotic group relative to laparoscopic repairs ($5517 vs $3269, $P < 0.001$). The increased costs for robotic procedures were attributed to the increased personnel costs, longer operative times, and increased

medical device costs. Despite the higher costs in the robotic group, there was no clear superiority in patient outcomes.[70]

A single institutional study comparing laparoscopic and robotic inguinal repair demonstrated the ability to perform robotic procedures at costs similar to laparoscopy ($3479 vs $3216, respectively). The authors were able to achieve these results despite increased operative times (77.5 vs 60.7 minutes, $P = 0.001$) in the robotic group.[54]

In general, short-term total costs associated with robotic inguinal hernia repair tend to be higher than laparoscopic or Lichtenstein repairs.[54,69-71] Fixed costs associated with robotic procedures far exceed fixed costs associated with laparoscopic surgery.[70] A 2018 report estimates average costs associated with robotic instruments and accessories at $1866 per case, with an additional $1701 per procedure for system maintenance, resulting in per case costs of $3568 inclusive of capital expense. Preprogrammed limits on the lifespan of the instruments are a significant contributor to this increased expense.[72]

In conclusion, inguinal hernia repair costs vary significantly based upon the surgical approach. The Lichtenstein repair is associated with the lowest initial costs, but the laparoscopic approaches may be equivalent when comparing total costs and long-term costs. Robotic inguinal hernia repair is associated with overall higher costs than both laparoscopic and open repairs with similar outcomes.

Considerations relating to the learning curve of the various repairs

Inguinal hernia repair remains one of the most common procedures performed by the general surgeon and accounts for nearly 75% of all hernias, with nearly 20 million repairs annually.[17] The most commonly utilized techniques for inguinal hernia repair in the United States include the Lichtenstein repair followed by laparoscopic repairs (TAPP and TEP) and, more recently, robotically assisted laparoendoscopic repairs (rTAPP). Laparoscopic repairs may be performed through a totally extraperitoneal approach (TEP) or by means of a TAPP approach while robotic-assisted laparoscopic repairs are performed utilizing a transabdominal preperitoneal approach (rTAPP). Each of these approaches require unique training and experience prior to obtaining competence. Throughout the learning curve, surgeons gain knowledge and experience which impacts patient outcomes prior to reaching a plateau in which patient outcomes are maximized and operative time is constant. Although each of these approaches is utilized in the same anatomical region, the learning curves for each of these procedures vary due to the unique skills required for each of the procedures. Furthermore, ascending the learning curve in a structured environment with safeguards to minimize patient complications is essential to patient safety.

The most common anterior approach for inguinal hernia repair is the open technique described by Lichtenstein.[9] Briefly, the Lichtenstein repair involves a transverse incision over the inguinal ligament extended through the soft tissues to the external oblique. The external oblique fascia is divided through the external ring with dissection of the cord from the inguinal canal. Dissection is performed to identify and dissect the hernia with careful attention to identify and protect the ilioinguinal, iliohypogastric, and genitofemoral nerves. Mesh is utilized to reconstruct the inguinal floor in a tension-free manner with careful attention to avoid entrapment of the sensory nerves. The external oblique is then closed over the spermatic cord followed by skin closure. This common approach for inguinal hernia repair has evolved as one of the most commonly performed procedures due to its infrequent complications, low recurrence rate, and short learning curve.

Laparoscopic approaches for inguinal hernia repair have been utilized for more than 2 decades although they are performed far less frequently than open repairs. Although both are unique, there are some similarities between the TEP and the TAPP repair which may impact the learning curve for surgeons with competency in one of these approaches.

The TAPP repair is often considered to be easier to learn than the TEPP repair although anatomically, the operations are similar except for the method utilized to access the preperitoneal space. The TAPP repair involves placement of intraperitoneal trocars to access the hernia.

The peritoneum is incised in the pelvis with dissection of a peritoneal flap to expose the hernia. Following complete dissection of the myopectineal orifice, a mesh is placed in the preperitoneal space to cover the direct, indirect, and femoral space followed by closure of the peritoneal flap. In distinction, the TEP approach is performed by accessing the extraperitoneal space at the umbilicus. Most commonly, the preperitoneal space is balloon dissected without violation of the peritoneum. Following dissection of the preperitoneal space, additional trocars are placed and utilized to identify and dissect hernias followed by mesh placement similar to mesh placement in the TAPP approach. Although the TEP approach creates unique challenges associated with working in a limited preperitoneal space, peritoneal closure after mesh placement is unnecessary because it was never violated.

Robotic approaches to inguinal hernia repair are generally performed by means of a TAPP approach (rTAPP), although some case reports of totally extraperitoneal robotic repairs have been reported. The operative steps for a rTAPP mimic that of a laparoscopic TAPP except for the additional training and skills required to utilize the robotic platform.[73]

Learning curve

The learning curve refers to the improvement in performance measures associated with increasing surgical experience. Each procedure will have its own unique curve based upon the complexity of the procedural elements. Furthermore, transference of skills between procedures may occur as a result of prior experiences in similar types of procedures or tasks.

The surgical learning curve has 4 phases. The first phase begins with the commencement of training and continues until acceptable standards of outcome measures are met. During this initial phase, performance improvements are generally rapid and significant. The second phase begins upon meeting acceptable standards and concludes at the time in which there is a plateau in performance. Improvements in phase 2 are more gradual and additional experience only incrementally enhances performance. During the plateau phase, there is minimal improvement with case volume. This represents the period in which the surgeon is capable of providing both quality and expedience. The fourth phase occurs during the latter aspect of a surgeon's career, where the outcomes may decrease due to deteriorating manual dexterity, eyesight, memory, and cognition.[74] For the purposes of this discussion, our focus will be on the first 3 phases, with the first 2 phases categorized as the learning phase.

Surgical measures of learning typically fall into 2 categories: measures of surgical process and measures of patient outcomes. Intraoperative measures such as operative time and blood loss are measures of the surgical process whereas length of stay, readmissions, surgical site infections, and recurrence rates are measures of patient outcomes.[74]

Open inguinal hernia repair is generally taught and learned more easily than laparoscopic or robotic repairs. The surgical approach is through an anterior incision located over the groin, so consequently the anatomical landmarks are more familiar to the surgeon and as a result, the Lichtenstein technique requires fewer cases for surgical trainees and nonexperts to match the patient outcomes of expert hernia surgeons.[75] In a study by Wagner and colleagues, an average of approximately 5 Lichtenstein repairs were required to achieve proficiency with the technique.[76] Because of the short learning curve and familiar anatomy as well as excellent long-term outcomes, the Lichtenstein approach has been widely adopted across the United States, and continues to have a major presence in modern hernia surgery.

In contrast, laparoscopic inguinal hernia repairs are generally more difficult to master. The laparoscopic repair is a posterior approach to the abdominal wall which requires an appreciation of the anatomical landmarks from the undersurface of the abdominal wall. Additionally, the skills required to perform a laparoscopic repair differ from open surgical techniques. As a result of the less familiar anatomy and challenges with appreciating 3-dimensional anatomy on a 2-dimensional monitor result in a learning curve reported to be as high as 100 cases in order to have comparable recurrence rates as experts, with the first half of the cases being the most critical, although some obtain competency sooner.[75]

Furthermore, the learning curves associated with laparoscopic TEP and TAPP repairs differ. Significant variability in reaching a plateau is reported in the TEP repair. In a study by Lau and colleagues of TEPP hernia repairs, operative duration of less than 1 hour is only achieved after a general surgeon performed 80 cases, while Choi and colleagues demonstrated a learning curve of 60 cases to reach a plateau of less than 30 minutes.[77,78] A single surgeon case series found operative times stabilized after 18 TEPP repairs for a newly licensed surgeon, with a mean operating time of 62 minutes.[79] Although there is no consensus on the exact number of procedures, TEP repairs are associated with a longer learning curve than the Lichtenstein repair. With respect to patient outcomes, there is a significantly higher rate of complications with laparoscopic repairs in the initial cases when compared to later cases. The complication rates for the initial cases range from 11% to 33%, whereas the complication rates in the later cases range from 3% to 15%.[80-83] Additionally, complication rates are significantly lower after the first 100 TEP repairs.[80] A similar trend is noted in recurrence rates, with the initial cases having a recurrence rate of 8%-30% and the later cases with a rate of 0.1%-5%.[10,80,83-86]

The learning curve for TAPP repairs appears to be shorter than for TEP repairs, possibly due to the familiar transabdominal anatomy of the TAPP relative to other laparoscopic operations and the wider operative field relative to the TEP repair.[87] In one study, operative times stabilized following 65 procedures.[88] Complication rates for the initial TAPP repairs range from 11% to 16% while cases later in the learning curve demonstrate complications ranging from 0% to 8%. Recurrence rates also demonstrate a similar trend, ranging from 5% to 12% initially, and infrequent or no recurrences later in the learning curve.[89,90] However, there are far fewer studies evaluating the learning curve associated with TAPP repairs, as compared to TEP repairs.

The use of robotic technology for inguinal hernia repair has recently evolved, although there is limited evidence as to the nature of the learning curve for the procedure. Robotic TAPP is identical to the laparoscopic TAPP procedure, although the learning curve also requires acquisition of robotic skills. It has been demonstrated, however, that with ascension of the learning curve, rTAPP repairs demonstrate a decrease in operative time eventually equaling laparoscopic TAPP repair times.[91] This is not surprising, since all repairs studied show a decrease in operative time as experience increases.[92] To date, there are no studies comparing the learning curve for rTAPP repairs with laparoscopic TAPP repairs. Some argue that the learning curve for rTAPP is likely to be shorter due to the advanced optics and wristed instruments associated with the robotic platform – both of which are purported to result in improved visualization and ease of dissection and suturing. In addition, because the anatomy of a TAPP repair is the same regardless of the approach, the robotic learning curve for those proficient in laparoscopic TAPP is likely to be accelerated when compared to surgeons without significant laparoscopic experience. Conversely, it is unknown whether proficiency with rTAPP confers any advantage to ascending the learning curve for traditional laparoscopic inguinal hernia repair. It is clear that further studies are required to evaluate the various learning curves associated with these procedures and the effects of the learning curve on patient outcomes.

In conclusion, the Lichtenstein repair has the shortest learning curve, whereas the TEP and TAPP require significantly more cases to achieve proficiency. There is insufficient evidence to determine where the rTAPP falls on the learning curve continuum. In addition to the advantages and disadvantages of each technique, the surgeon's specific expertise and position on the learning curve should be considered when determining the optimal approach for any inguinal hernia repair.

Consideration of special circumstances: Are there any specific clinical circumstances which favor one approach over another?

All hernia repairs should be performed in the safest and most effective way utilizing the technical skills and resources available to each individual surgeon. Each technique has a learning curve that must be worked through to allow equivalent outcomes. Once this is achieved the well-rounded hernia surgeon is then armed with all of the state-of-the-art approaches to the

task of inguinal hernia repair. In this situation, the choice of repair may still be affected by surgeon or patient preference, but there may also be clear circumstances in which one technique distinguishes itself as the procedure of choice. These unique circumstances are the focus of this section.

There are certain situations where both open anterior and laproendoscopic posterior approaches have shown superiority based on the clinical scenario. In this section, we discuss the recommendation from the guidelines published from the EHS, IEHS, European Association of Endoscopic Surgery (EAES), and the HerniaSurge Group.[5,20,34,93]

Primary elective unilateral inguinal hernias in males

The EHS guidelines and general consensus for repair of a primary inguinal hernia in men allows the surgeon to choose their most effective and safest approach. This includes open Lichtenstein, and laparoscopic TAPP or TEP repair.[29] In more recent years, synthetic plug and patch repairs have fallen out of favor due to plug-related complications as well as use of double-layered implants (such as the Gilbert prosthesis) that violate both the anterior and posterior tissue planes.[5,94] In younger active men between the ages of 18 and 30, the laparoscopic approach is favored as this population gains the most benefit from early mobility and return preoperative function with endoscopic approach.[93] The laparoscopic approach is associated with a lower rate of infection, hematoma formation, and earlier resumption of activities, with a lower risk of chronic nerve pain compared to open techniques in the general population ($P< 0.001$).[34,95]

Of note, large direct (M3) inguinal hernias that are approached via TEP or TAPP approach must include mesh fixation to prevent recurrence.[5] The risk of mesh migration and thereby recurrence was noted not only for these large direct defects, but also for combined hernias (OR 1.137) in analysis of the Herniamed registry study.[96]

Robotic-assisted transabdominal preperitoneal (rTAPP) inguinal hernia repairs have become more frequent in the United States. Gamagmi and colleagues published their experience compared to a matched cohort of open repairs. The patient population was predominately male, those with prior abdominal operations were more commonly performed open, and patients with a larger BMI were guided toward rTAPP. At 30 days postoperatively, fewer patients reported complications in the robotic group compared to the open group ($P= 0.047$). The reported complications within the open group were primarily groin and incisional pain and swelling. Operative times were 28 minutes longer for the rTAPP approach; however, this study did include surgeons in varying periods of their learning curve.[67]

Primary elective unilateral inguinal hernias in females

Primary unilateral inguinal hernias in women should be repaired according to the surgeon's expertise. A review of the Danish Hernia Registry noted an increased risk of recurrence after open primary repair in women compared to laparoscopic methods.[97] Of the nearly 6000 primary elective inguinal hernias performed and studied, there was a 5.2% overall recurrence reoperation rate; of these 38% were due to a recurrent femoral hernia. It is unclear if these femoral defects were either missed during the index open operation or true recurrences. Repair of a primary direct inguinal hernia was correlated with a higher reoperation rate of 11% compared to 3% after indirect hernias (OR = 2.4) for recurrent femoral hernias after direct hernia repair. All femoral hernias noted at reoperation occurred following an initial anterior Lichtenstein index repair. Laparoscopic approaches allow for visualization of the femoral space, in addition to routine mesh coverage of the entire myopectineal orifice. Consequently, this allows identification of these femoral hernias, if present, and permits repair at the index operation. Based on this registry, the multiple societies recommend a laparoscopic TAPP or TEP repair in women with inguinal hernia.[5,20,34]

If an open Lichtenstein approach is the only technique available to a particular surgeon, then the patient must be counseled regarding the risk for recurrence or missed femoral hernias due to this approach. The anterior approach in those with small indirect defects is appropriate since the volume of recurrence or missed femoral hernia was less in this patient population (3%).[97] Those with direct defects or femoral hernia complaints should be referred for laparoendoscopic repair, provided the necessary expertise is available.

Primary bilateral inguinal hernia, independent of sex

A laparoendoscopic approach is recommended for treatment of bilateral inguinal hernias identified preoperatively by physical examination or imaging (level 1B evidence).[5] Hernia guidelines cite the work of Feliu and colleagues in which patients undergoing bilateral Lichtenstein vs bilateral TEP repairs were compared. The authors reported shorter operative times, shorter hospital stays, and lower postoperative complication rates within the TEP group.[98] The advantages of faster recovery, lower risk of chronic pain, and cost-effectiveness are also supported as reasons for a laparoendoscopic approach.[5,20] There is no clearly demonstrated advantage of the TEP vs TAPP approach for bilateral repairs that is currently supported in the literature.[93] There is a clear advantage, however, for the TAPP approach in identifying an occult contralateral hernia, as this is clearly evident from within the peritoneal space, and allows a diagnostic evaluation of the contralateral side without disrupting the preperitoneal space. The incidence of occult hernias varies widely in the literature from 13% to 58% and the natural history of these hernias is poorly understood.[5] Concomitant repair of an asymptomatic contralateral occult hernia is still widely debated without clear recommendations to date. Additional studies are needed before clear recommendations can be made regarding this clinical circumstance.

Primary inguinoscrotal hernia

Primary scrotal inguinal hernias are a complex condition whereby failure to dissect out the large hernia sac from the cord structures and scrotum can result in persistent seroma. The EHS recommends an open approach for repair of scrotal hernias.[20,29] Limited series have been described by expert robotic surgeons who report that, in expert hands, the robotic TAPP (rTAPP) approach is preferred over standard laparoscopic approaches, owing to greater ease in dissection, dexterity of sac manipulation, and reduction in the risk of skin complications associated with an open approach. An rTAPP approach in expert hands also allows for larger preperitoneal mesh overlap. Inverting the lax fascia transversalis or attempts at closing the defect is currently widely debated with concerns to variability in the nerve anatomy leading to entrapment as the main concern. An increase in seroma formation is noted with posterior approaches, but most resolve in 6-8 weeks.[99] Please note that if significant skin resections are required due to a giant scrotal hernia or ulcerations, then an open approach unequivocally becomes the procedure of choice.

Previous lower midline incision

Many patients present with unilateral or bilateral symptomatic inguinal hernias after prior midline incisions for abdominal exploration or cesarean section. The inguinal hernia approach should be once again chosen based on individual upon surgeon expertise. For unilateral hernias, an open approach is appropriate; however, if endoscopic expertise is available, then the TAPP technique is preferred over TEP due to balloon dissection limitations with prior midline scarring. Expert TEP surgeons have published successful repairs on patients after prior lower midline incisions with a modified unilateral port placement, however the skill required for this

dissection limits its universal acceptance.[100] If bilateral hernias are present without significant known intra-abdominal adhesions, then an endoscopic TAPP approach is favored after prior lower midline, either laparoscopic or robotic.

Previous pelvic or lower abdominal surgery

Patients with inguinal hernia development after prior pelvic operations including prostatectomy, cystectomy, or vascular interventions such as aortic-bifemoral graft or femoral-femoral grafts, should be offered an open mesh technique as a preferred technique.[29] Complex endoscopic preperitoneal repair can be technically possible in select patient situations, but should only be performed by expert laparoscopic surgeons per the IEHS and EAES since these reoperative endoscopic cases have a steep learning curve, longer operative times, and required multiple techniques available to manage intraoperative complications and variations in scarring/available tissue layers.[34,93]

Elderly patient population

A patient's fitness for surgery is not determined by age. After a through history and preoperative evaluation, individuals identified with cardiac and pulmonary risk factors deemed unfit for general anesthesia with a symptomatic inguinal hernia should undergo an open technique with local or regional anesthesia.[101] Please note that the Swedish Hernia Registry did show increased risk of recurrence after primary hernia repair under local anesthesia; however, the risk was lowest with a Lichtenstein mesh repair.[16] Some reports in the literature describe safe yet variable experiences with TEP repairs performed under spinal or epidural anesthesia.[102,103] Of note, the TEP procedure does require more minute ventilation when compared to a TAPP repair. Consequently patients with chronic obstructive lung disease may be at greater risk of CO_2 retention with the TEP approach.[104]

A small cohort study in 2013 followed octogenarians, predominately male, undergoing endoscopic vs open hernia repairs for 31 months. Those with bilateral hernias were predominately performed endoscopically under general anesthesia while two-thirds of open cases were performed under local anesthesia with sedation. There were no differences in American Society of Anesthesiologists (ASA) class (average ASA 3), morbidity ($P = 1.0$), or overall study duration mortality ($P = 0.5$) with death occurring on average 18 months postoperatively from comorbidities.[105] More recently, individuals older than 70 were compared to a cohort younger than 70 undergoing TEP repairs with no difference reported in overall complications ($P = 0.117$), anesthesia-related complications ($P = 0.617$), or operative times.[106] Despite these results, consensus guidelines support same day surgery with an open Lichtenstein operation under local anesthetic for any ASA class III and IV individuals.[5,29,101]

Recurrence

The approach for repair of a recurrent inguinal hernia is based on surgeon expertise and determining which anatomical layer is available and appropriate for reoperation. All recurrent inguinal operations should include exploration for femoral hernias which have an incidence of 9%-35%.[107,108]

For those with the prior open anterior repair, the endoscopic approach during recurrent reoperation is performed in the preperitoneal layer which has not been previously dissected.[29,109] It is important to review the patient's operative reports, if available, to determine the exact nature of the previous repair. Lichtenstein repairs do not violate the preperiteonal space. However, if a plug or Gilbert hernia prosthesis (PHS) was placed at the index operation then the endoscopic

surgeon must anticipate greater adhesions and mesh products in the preperitoneal space. CT imaging for recurrent hernias without prior operative reports aids in operative planning. In these cases, the anatomy of the myopectineal orifice will be altered and an understanding of the preperitoneal space is paramount to reoperation. If PHS was placed, a TAPP approach, robotically if available, allows for improved ease of dissection. Plugs can be dissected and manipulated from an endoscopic TEP or TAPP approach, however the improved dexterity provided by the robotic platform does aid in plug manipulation and resection if it is adherent to the cord structures or vasculature. A systematic review published in 2019, noted a significantly shorter operative time in cases for hernia recurrence for a TAPP repair compared to aTEP repair.[110] In a Swedish Hernia Registry study, posterior recurrent inguinal hernia repair reported a lower rate of second recurrence compared to a repeat open approach (5.6% vs 11%).[111] Per the EHS 2014 analysis, there is a decreased incidence of chronic pain following recurrent inguinal hernia repair utilizing endoscopic approach (OR = 0.31).[29]

If the primary repair was a tissue repair, then either the anterior or posterior endoscopic or open approach can be used for the recurrent repair.[5] For nonendoscopic surgeons the recurrent open anterior repair should be via Lichtenstein repair with mesh implantation including femoral space exploration.[20]

For recurrences after prior endoscopic posterior repairs, the standard recommendation by the EHS and HerniaSurge is that an anterior open Lichtenstein operation be performed.[5,20] Experienced minimally invasive surgeons may approach this from an endoscopic TAPP approach, after careful planning with CT imaging to determine if the prior preperitoneal mesh has folded and/or was undersized.[112] Review of prior operative reports are important, as some surgeons have previously placed biologic or biosynthetic products in the posterior space. In these cases, patients can undergo a recurrent endoscopic repair with fewer adhesions when compared with synthetic implants. Repeat endoscopic repair requires the previous mesh to remain adherent to the peritoneum during initial dissection to allow for identification of normal anatomical landmarks down to the level of the cord structures and external iliac vessels which may shift with mesh adhesions. It is important to dissect "outside in," meaning lateral and midline attachments prior to recurrent hernia sac or cord structures. Only after these structures are identified should the surgeon move onto old mesh removal or partial removal from the peritoneum. Robotic approaches compared to laparoscopic mesh removal have been shown to have a significantly lower incidence of both vascular injury (0 vs 5, $P< 0.05$) and nerve injury (1 vs 4).[113]

Patients with multiply recurrent hernias or failures of anterior and posterior repairs should be evaluated by a hernia specialist due to the risk of testicular atrophy, chronic pain, and higher risk of subsequent recurrence. Options available to these experienced specialists include repeat laparoscopy with either TAPP or modified intraperitoneal onlay mesh or repair by giant prosthetic reinforcement of the visceral sac to be completed via an open midline preperitoneal Stoppa repair.[112]

Emergency intervention for symptomatic incarcerated or strangulated inguinal hernias

The risk of a direct or indirect inguinal hernia becoming incarnated is less than 3% per year.[20] Femoral hernias occur more frequently in women and on the right, with a higher risk of incarceration and strangulation due to the narrow nature of the femoral canal.[114] Strangulation with necrotic bowel requiring resection occurs in 7% of patients with delayed presentation of 24 hours, increasing to 33% for those admitted 48 hours after initial complaints. Acutely symptomatic incarcerated or strangulated inguinal hernias constitute a surgical emergency. Bowel viability should be determined first by diagnostic laparoscopy with reduction of incarcerated or strangulated contents under direct visualization from an intra-abdominal position.[93] For contents that do not reduce with insufflation or external manual pressure with intra-abdominal lateralizing pressure, incising the cranial hernia ring may be necessary. Proper extension of the hernia ring varies depending on the hernia location: direct – ventromedial, indirect – ventrolateral, or femoral by incising the lacunar ligament. Most frequently, demonstration of bowel or

omental viability after reduction allows for progression of hernia repair simultaneously via the surgeon's preferred technique open anterior, or laparoscopic TEP or TAPP repair with mesh.[101] If the bowel is viable but transmural peritonitis is present, then the hernia sac can be ligated with a suture and an open anterior mesh repair performed after desufflation, leaving the peritoneum intact.[101] Independent risk factors in the literature for bowel resection include lack of health insurance, obvious peritonitis, or femoral hernia.[115] Lower wound morbidity and shorter hospital stay have been published for laparoscopic emergency repairs compared to open exploration without increases in operative time or recurrence.[116] Emergent femoral hernias, similar to elective cases, should be repaired with endoscopic techniques when expertise is available.[114]

The guidelines for simultaneous mesh implantation at the time of bowel necrosis requiring resection have varied over the years. The principles for mesh implantion should follow safe surgical practices including physician judgement regarding the level of contamination. EHS, EAES, and HerniaSurge consensus statement include that the use of mesh after bowel resection is weakly supported, with a need for definitive research on this complex topic. Due to the infrequency of bowel resection required at the time of emergency inguinal surgery, randomized controlled trials are not available in the literature. Prospectively collected experiences have reported "feasible" TAPP repairs for incarceration, but only 11% of emergency cases required bowel resection at the time of mesh implantation without an increase in morbidity.[117] Published reviews report "safe" implantation of nonabsorbable mesh with acceptable, albeit higher wound infection, and recurrence rates when bowel resection was required for clean contaminated Lichtenstein repairs.[118,119]

Currently there is only level 2a evidence supporting the use of nonabsorbable mesh in clean-contaminated cases where a bowel resection was completed extracorporeally with gauze or a wound protector used with saline lavage following resection. Necrotic omental resection or intracorporeal appendectomy were not considered complications for mesh implantation.[5,93] In the setting of an infected abdominal wall or contaminated or dirty cases then the sac should be ligated or closed from a laparoscopic position without mesh implantation or via open tissue repair depending on surgeon judgment and expertise.[34]

Conclusions

In the last few years inguinal hernia repair has experienced a renaissance period, with the result being an expanded range of available options for repair under various clinical circumstances. The data reviewed in this monograph demonstrate that there is no "one size fits all" approach, and that what may be the right repair for one patient may not be the best choice for another patient. All of the considerations-recurrence rates, costs both initial and downstream, experience and learning curve, acute and chronic pain, and the individual clinical circumstances of each case – should be considered in choosing the best repair for each patient. It behooves the well-rounded hernia surgeon to be knowledgeable and experienced in all of the discussed repairs, so the patient may be afforded the benefit of the correct choice for his or her circumstances. Well-researched guidelines are available for reference and should be regularly reviewed and updated to maintain a uniform standard of practice among hernia surgeons. Finally, this discussion should be further explored via well-designed randomized controlled trials with a focus on all of the pertinent outcome measures.

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