Causes of recurrence in laparoscopic inguinal hernia repair

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Abstract

Purpose Recurrence after laparoscopic inguinal herniorrhaphy is poorly understood. Reports suggest that up to 13% of all inguinal herniorrhaphies worldwide, irrespective of the approach, are repaired for recurrence. We aim to review the risk factors responsible for these recurrences in laparoscopic mesh techniques.

Methods A search of the Medline, Embase, Science Citation Index, Current Contents and PubMed databases identified English language, peer reviewed articles on the causes of recurrence following laparoscopic mesh inguinal herniorrhaphy published between 1990 and 2018. The search terms included ‘Laparoscopic methods’, ‘Inguinal hernia; Mesh repair’, ‘Recurrence’, ‘Causes’, ‘Humans’.

Results The literature revealed several contributing risk factors that were responsible for recurrence following laparoscopic mesh inguinal herniorrhaphy. These included modifiable and non-modifiable risk factors related to patient and surgical techniques.

Conclusions Recurrence can occur at any stage following inguinal hernia surgery. Patients’ risk factors such as higher BMI, smoking, diabetes and postoperative surgical site infections increase the risk of recurrence and can be modified. Amongst the surgical factors, surgeon’s experience, larger mesh with better tissue overlap and careful surgical techniques to reduce the incidence of seroma or hematoma help reduce the recurrence rate. Other factors including type of mesh and fixation of mesh have not shown any difference in the incidence of recurrence. It is hoped that future randomized controlled trials will address some of these issues and initiate preoperative management strategies to modify some of these risk factors to lower the risk of recurrence following laparoscopic inguinal herniorrhaphy.

Keywords Laparoscopic methods · Inguinal hernia · Mesh repair · Recurrence · Causes · Humans

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Introduction

Inguinal hernia repair is one of the most commonly performed general surgical operations with reported rates ranging from 10 per 100,000 of the population in the United Kingdom to 28 per 100,000 in the United States [1]. Worldwide, more than 20 million patients undergo groin hernia repair annually. Reports suggest that up to 13% of all inguinal hernias performed worldwide, irrespective of the approach, are recurrent inguinal hernias [2]. Two common laparoscopic approaches (i.e. transabdominal preperitoneal-TAPP and totally extraperitoneal-TEP) have been increasingly utilized in recent days and claimed to be associated with lower rates of recurrence compared to its open counterpart [3–5]. Recurrence following laparoscopic inguinal herniorrhaphy can occur at any stage after the operation but tend to be more common if the patients are younger and in the first 3 years following the surgery [6–8]. Use of mesh in inguinal hernia surgery, irrespective of the approach, reduces recurrence rate by 50–75% compared to suture repair of hernias [9, 10]. The recurrence rate following laparoscopic mesh herniorrhaphy has been reported to be between 1 and 7.9%, the highest rate being reported from Australia and has remained unchanged for the last 2 decades [11–13].

The reason as to why inguinal hernias recur is most likely multifactorial. This includes both technical and non-technical patient-related risk factors and it is possible that the different groin hernia subtypes have different pathophysiology [14]. The non-technical patient-related risk factors in all probability have the greatest impact on the risk of recurrence. Optimizing some of the patient factors perioperatively and improved intraoperative surgical techniques aid in decreasing the recurrence rate of hernia. As much as the surgical factors could be modified and improved, patient factors are largely non-modifiable, especially when a patient presents as an emergency case. Some of the patient risk factors could be optimized when the operation is performed in an elective setting, and includes body mass index (BMI), smoking, diabetes and iatrogenic induced immunosuppressive states such as steroid intake. The following discussion aims to address various modifiable and non-modifiable risk factors in an evidence-based manner impacting the recurrence following inguinal herniorrhaphy and is based on published literature.

Patient factors

Gender

Female gender has been reported in some studies as a risk factor for recurrence [14, 15]. This assumption has been based primarily on observational and review studies in open inguinal hernia repairs. Burcharth et al. [14] have suggested that the increased rate of recurrence in female patients after open inguinal hernia repair is due to missed femoral hernias, which the surgeons failed to look for routinely during an open inguinal herniorrhaphy. These femoral hernias may become apparent and symptomatic at a later date. The authors formed their opinion based on one of the largest epidemiological studies spanning over 14 years with a total of 108,775 patients. 5893 of these patients were females who were followed up for up to 6 years and found to have a higher recurrence rate after indirect inguinal herniorrhaphies. But this finding has not been observed when evaluating recurrence after laparoscopic inguinal herniorrhaphy [16]. This may be because during the laparoscopic inguinal hernia repair, the presence of femoral hernia (or for that matter any other groin hernia) is far easily detectable during a methodical dissection and exploration of the preperitoneal or extraperitoneal space with high resolution and magnified imaging technology routinely deployed for laparoscopic procedures.

Age

Regarding patients' age, a very large Danish Study by Burcharth [17] has provided the most convincing proof that age has no relevance in laparoscopic inguinal herniorrhaphy recurrence. This study was a systematic review and meta-analysis of non-technical patient-related risk factors for recurrence. From a total of 5,061 potentially relevant records they included 40 studies in the review covering 719,901 procedures in 714,167 patients. Of those, 14 studies covering 378,824 procedures in 375,620 patients were included into meta-analysis of eight risk factors (gender, age, hernia type, hernia size, re-recurrence, bilaterality, mode of admission and smoking). The author failed to show the impact of postoperative convalescence and age as a risk factor for recurrence.

BMI

Higher BMI is associated with poor wound healing and increased incidence of complications. Both of these factors in turn increase the risk of recurrence. Schjøth-Iversen et al. [11] found that a BMI of ≥ 30 has a threefold higher

risk of recurrence rate compared to those with a BMI of < 30. The study analyzed > 1000 patients with a 2 year follow-up and found that high BMI was an independent risk factor for recurrence after laparoscopic TEP approach on both univariate and multivariate analysis. Apart from poor wound healing and surgical site infection associated with high BMIs, other immunosuppressive factors (such as diabetes, smoking and steroid intake) lead to poor inflammatory response, which may contribute to increased recurrence from poor tissue integration of the mesh [18].

Cord lipomas

The incidence of cord lipomas is higher in patients with increasing BMIs [19]. Furthermore, some surgeons choose not to excise these lipomas especially in male patients, fearing that this may compromise the blood supply to the testicle. These two factors may contribute to *pseudo-recurrence*, which may lead to patients seeking a second opinion and undergoing further unnecessary surgery [20]. It is, therefore, recommended that these lipomas should be excised in the safest possible manner to prevent confusion in future exploration for a true recurrence of inguinal hernia.

Location of the hernia

Location of the defect could influence the rate of recurrence. The hernia may be an indirect (lateral) or a direct (medial), and it may be either localized to an inguinal region or involving the scrotum i.e. inguinoscrotal. Schjøth-Iversen et al. [11], in their prospective cohort study with a 2 year follow-up, found that patients with medial hernias had more recurrences than those with lateral hernias. The rate of recurrences was 8.1 vs 3.6% with a hazard ratio of 2.37. Similarly, Burcharth et al. [17] in their very large epidemiological study found a direct inguinal hernia at primary operation was a substantial risk factor for recurrence with a Hazard ratio of 3.1 compared with an indirect inguinal hernia at primary operation. It is unclear whether this increased recurrence with direct hernias was because of insufficient mesh coverage beyond the pubic tubercle medially or it is purely an anatomical factor, such as much larger defects encountered in direct hernias compared to the indirect ones irrespective of the size of the hernia sac itself. The authors noted that fixation vs no fixation of the mesh did not make any difference when the hernias were more medially placed. One could, therefore, conclude that larger medial hernias would benefit from the use of larger mesh coverage especially the medial aspect.

Postoperative complications

Various postoperative complications have been claimed to be the causative factors for recurrence following laparoscopic herniorrhaphy, however, very few have been studied. Postoperative infection is a feared complication following an inguinal hernia repair. El-Dhuwai et al. [8] demonstrated an association between postoperative wound infection and recurrence. Their longitudinal cohort study analyzed 120,342 patients who had undergone inguinal hernia repair between 2002 and 2004 and were followed up until April 2009 across multiple centers in the United Kingdom. They found that laparoscopic compared to open mesh repair was associated with lower incidence of wound infection, yet the recurrence rate was higher for the laparoscopic group 4 vs. 2.1% in the first year. Similar findings were noted in various systematic reviews comparing open and laparoscopic inguinal hernia repairs suggesting that infection, although may have an association, is not solely responsible for significant recurrences [21–23].

Other risk factors that have been attributed to recurrence include seroma and hematoma formation between the mesh and anterior abdominal wall. This may lead to mesh lifting off the rectus muscle/sheath impairing tissue integration and consequently hernia recurrence. Olmi et al. [3] in their RCT, reported a seroma and recurrence rate of 6.3–7.5 and 1.5% for hernias where tacking devices were used to fix the mesh compared to 2.2% and 0 when Tissucol biocompatible fibrin sealant was used. According to these authors, Tissucol provides prosthesis stability leading to a significant reduced incidence of seroma formation and prevention of hematomas at the prosthetic site influencing lower recurrence rate. However, this has been contradicted by a recent study from Kockerling et al. [24] who analysed 20,004 male patients with TAPP repair of primary unilateral inguinal hernia. Univariable analysis revealed the highly significant impact of the fixation technique on the seroma rate (non-fixation 0.7% vs. tacks 2.1% vs. glue 3.9%; $p < 0.001$). Multivariable analysis, however, showed that glue compared to tacks and non-fixation led to a significantly increased seroma rate. Furthermore, a large hernia defect (III and II vs I) presented a significantly higher risk of seroma formation. Likewise, medial compared to lateral inguinal hernias had a significantly higher seroma rate. The authors concluded that mesh fixation with tacks or glue, a larger hernia defect, and medial defect localization present a higher risk for seroma development in TAPP inguinal hernia repair. These contradictory results have muddled the water further and, therefore, any firm recommendation whether to undertake mesh fixation or not is difficult to formulate.

Surgical factors

Types of repair and approach

Laparoscopic inguinal hernia repair has evolved since its introduction in the early 1990s. Different approaches have been utilized ranging from TAPP [7] to TEP repair [4] and from multiple incisions (MILS) [25] to single incision approaches (SILS) [26]. Whichever method or approach is used, the plane of dissection and the placement of mesh remains the same, i.e. preperitoneal. As surgeons are becoming more comfortable with laparoscopic inguinal herniorrhaphy, it is now routinely used for the inguinoscrotal hernias where TEP method could act as an adjunct to open and TAPP may act as a fall back method for TEP [27–29]. These two techniques are particularly helpful when treating a recurrence from an open-approach as the plane of dissection and placement of mesh would not have been violated previously. The TEP approach was introduced well after the TAPP and does take longer to master, and so has been claimed in the past to be a cause of recurrence earlier in the learning curve more than the TAPP approach [30, 31].

A number of comparative studies including RCTs have been conducted comparing TEP and TAPP technique. Most of them have been small volume underpowered studies (around 50 patients) [32–34] with short follow up ranging from a few weeks to a few months. The follow-up, nonetheless, varied widely where Schrenk et al. [32] followed their patients only for 3 months, Dedemadi et al. [33] for 3 years and Butler et al. [34] for 2 years. A RCT from Bansal et al. [35] where each group had nearly 160 patients reported a recurrence rate of 0.3% in the TAPP and none in the TEP group at a median follow-up of 36 months. The study included both bilateral and unilateral hernias. A similar RCT from Wang et al. [36] followed 252 patients for up to 32 months and found no recurrence in either of these groups. The largest prospective comparative study of nearly 18,000 patients comparing TEP and TAPP for recurrent unilateral inguinal herniorrhaphy shows no difference in recurrence rates at 1 year with 0.82% for TEP and 0.9% for TAPP patients [37]. More recently Sharma et al. [38] evaluated the effect of these two techniques on bilateral inguinal hernias only in their RCT. They found no early recurrence in their cohort of 60 patients within 30 days.

One of the first systematic reviews to compare the two techniques was by McCormack et al. [39]. They reported on nearly 16,000 patients that included only one RCT and eight non-randomized studies and concluded that there was no difference in recurrence between the two techniques. They noted only one recurrence in the TAPP group and

none in the TEP group in a single RCT that was part of this analysis. Since then there have been a few meta-analyses and systematic reviews. Antoniou et al. [40] analyzed 516 patients from 7 RCTs and found no difference in recurrence rates between TAPP (3.1%) and TEP (2.4%). Wei et al. [41] included 10 RCTs encompassing just over 1000 patients which showed no difference in the recurrence rate between the two methods, suggesting equal efficacy of both these techniques. The latest systematic review and meta-analysis by Chen et al. [42] analyzing 8 of the 16 RCTs comparing TEP vs TAPP reporting on recurrences totaling 778 patients showed no significant differences in the recurrence rate between the primary as well as primary plus recurrent hernias. The recurrence rate may not be the true recurrence rate as the follow-up duration, which is an important indicator of recurrence, was less than 5 years for several studies.

One of the very infrequently used techniques is that of intraperitoneal on lay mesh (IPOM) repair. Chan et al. [43] reported an unacceptable recurrence rate of 5% at 3 months in a cohort of 39 patients undergoing repair with IPOM technique. Hatzitheofilou et al. [3, 44] analysed 52 inguinal hernias in 50 patients using IPOM technique. They reported a recurrence rate of 4% between 7 and 31 months of follow up. However, the authors were concerned regarding the safety of this method because one of their patients had not only recurrence, but bowel strangulation also. Olmi et al. [45] at 23 months reported no recurrence of inguinal hernia in a cohort of 60 IPOM patients using Parietex composite mesh and a fibrin glue for its fixation. However, they cautioned the readers regarding these short-term results. The technique of IPOM for inguinal hernia, in spite of efforts from a few surgeons, has failed to gain popularity due to non-anatomical repair and some earlier studies showing high recurrence and complication rate.

Finally, there seems to be an ongoing debate regarding SILS vs MISL techniques for inguinal hernia repair. A recent systematic review analyzed the recurrence rate between SILS and MILS techniques [25] involving 16 studies, including 4 RCTs and nearly 1600 patients. They found no difference in the recurrence rate between the two groups. One of the reasons behind poor uptake of SILS is the issue of ergonomics and higher risk of port site hernias compared to conventional laparoscopic surgery [46].

One can, therefore, conclude that except for IPOM which has fallen into disrepute and no longer routinely used for inguinal hernia repair, both TEP and TAPP have shown equivalent results in terms of recurrence rate. Furthermore, both SILS and MILS can be utilized by surgeons depending on their preferences without exposing patients to unnecessarily higher rate of recurrence. However, SILS is associated with a significantly higher risk of port site hernias. The

choice of technique should be tailored to surgeon's expertise to provide the best possible outcome for the patient.

Surgeon's learning curve, case load, experience and frustrations

Surgeons' experience plays a vital role in the outcome of any surgery and inguinal hernia is no exception. The experience of a surgeon varies at different stages of their training and learning curve with regards to a particular procedure. Having said that, a resident or a fellow who has negotiated the learning curve, may perform and achieve better results than senior colleagues.

A "learning curve" is typically defined as the number of cases needed to perform a particular surgical procedure to achieve acceptable operative times, good clinical outcomes, and for the surgeon to reach a "comfort zone". It is generally believed that the learning curve for performing laparoscopic inguinal hernia repair is longer than for conventional open Lichtenstein repair, due to the limited working space and different appreciation of the anatomical landmarks. Several authorities and authors have proposed between 13 and 250 cases to reach the mastery in endoscopic hernia surgery and low recurrence rates [30, 47, 48]. The 2009 EHS guidelines [49] suggest that it ranges between 50 and 100 procedures, with the first 30–50 being critical. El-Dhuwai et al. [8] found that surgeons' reoperation rate for recurrence could decrease and plateau with as few as 20 cases. Their study of the UK NHS database found, that as the surgeons gained more experience with the increase in national uptake of laparoscopic inguinal hernia repair, their recurrence rates decreased from 4 to 2%, which reduced further to 1% beyond 60 cases. In another study by Bansal et al. [50] the authors have concluded that the learning curve for TEP repair can be achieved by performing as little as 13 hernias and for TAPP, 14 hernias. Therefore, during the learning curve there is a higher recurrence rates for surgeons until they reach mastery [8, 51, 52]. Bracale et al. [53] published a study comparing 100 TAPP procedures by two different trainees and a senior surgeon. Two tests were used to evaluate completion of the learning curve: The Cumulative Sum (CUSUM) and KPSS tests. The authors' evaluation showed that both trainees fully completed their learning curves for the TAPP after 65 procedures, providing the authors of this paper a parameter, which can be taken into consideration when establishing the minimum volume necessary to guarantee correct training in laparoscopic inguinal hernia repair by a TAPP technique. A large RCT [48] comparing laparoscopic with open inguinal herniorrhaphy found a 10.1% recurrence rate following laparoscopic repair. In this study, 69 surgeons performed 989 repairs. Prior to the study's commencement, only 20 of the 69 surgeons reported an experience of more than 250 repairs. For this highly experienced group, the recurrence

rate for laparoscopic repair of primary hernia dropped to 5.1% and was comparable to a recurrence rate after open repair at 4.1%. The authors concluded that an experience of 250 inguinal herniorrhaphy was necessary to achieve a significant reduction in recurrence rates. In yet another study from the Netherlands [54] analyzing TEP herniorrhaphy, the authors demonstrated a decline in the conversion rate, incidence of short-term postoperative complications, and the operative time even after more than 400 individually performed TEP procedures; indicating a rather long learning curve. However, when it comes to intraoperative complications and recurrence the learning curve period of TEP hernia repair seems relatively short and is expected to be overcome in the first 50–100 TEP repairs.

Once the learning curve is achieved then there may not be much of a difference in the recurrence rate for inguinal hernia repair between fellows and consultants. This was demonstrated by Schjøth-Iversen et al. [11], who showed the recurrence rate between fellows and consultants was similar, i.e. 5.2% and 5.4%, respectively. It is, however, important to note that both groups performed well over 300 hernias. Out of the 345 procedures performed by residents and fellows, 146 were performed without the supervision of an attending surgeon and 199 were performed supervised by an attending; the recurrence rates were not statistically different 6.8% and 4%. Therefore, one can assume that a team-based approach was utilized and a second opinion was sought more often than not in difficult cases to provide the best possible outcome for the patient. As the TEP method proved challenging for novices, attention to detail and a second opinion rather than just the number of cases helped surgeons achieve mastery earlier on in their learning curve and minimized recurrence rate [55]. However, the recent International guidelines [56] for groin hernia management have specifically implicated annual inguinal herniorrhaphy volume of < 5 cases and limited surgical experience as one of the key factors in hernia recurrence which could be modified by surgical coaching and increasing caseload as discussed above.

Finally, a study by Kaafarani et al. [57] evaluated the relationship between the attending surgeons' frustration and satisfaction and recurrence and complications of open and laparoscopic inguinal hernia repair at 14 Veterans Affairs hospitals. After completion of the procedure, surgeons were asked to assess their level of frustration during the operation and their overall satisfaction with the operative result. Reasons for surgeon frustration were evaluated. Patients were followed for 2 years for recurrence and complications. 1622 (808 open, 813 laparoscopic) patients were analysed. Surgeons reported less frustration and more satisfaction with open than with laparoscopic repair. Frustration was associated with a higher rate of hernia recurrence at 2 years in open repair, and a higher overall rate of postoperative complications in both open and laparoscopic hernia repair.

The authors concluded that the level of a surgeon's frustration during performance of an inguinal herniorrhaphy was a better predictor of outcomes of the operation than was satisfaction with the procedure. According to these authors sources of intraoperative frustration should be controlled to improve outcomes.

Type of mesh

Use of mesh for the repair of hernia has been proven and established since the early twentieth century [58, 59]. The mechanism by which the mesh provides for a stronger support compared to suture only repair was demonstrated in 1990s [60]. The foreign body reaction that the mesh creates allows for inflammation to set in and the mesh get incorporated into the surrounding tissue, thereby resulting in fibrosis or scarring. Ideally one would wish for a scar net, which is more flexible than a scar plate, which is relatively rigid. This flexibility is vital in the inguinal region, which is an area of constant movement either with mid body or lower limb motion.

Polypropylene (Prolene) has been used traditionally in both open and laparoscopic inguinal herniorrhaphy. The initial prolene meshes were heavy weight ($> 80 \text{ g/m}^2$) and micro porous ($< 1 \text{ mm}$) meshes, although lighter-weight polypropylene is available now days. The foreign body reaction resulting in intense fibrosis has been thought to potentially result in chronic pain syndrome after inguinal hernia repairs. This led to various modifications of mesh, in weight (light, medium and heavy), porosity ($> 1\text{--}2.5 \text{ mm}$) and composition (monofilament, polyfilament, single material, composite, synthetic, biological, absorbable and non-absorbable). Changing the mesh properties also affects various other outcomes including recurrence and patients' perception of whether or not they can feel the mesh. There is strong evidence that mesh selection can change clinical outcomes (e.g. foreign-body sensation, chronic pain, sperm motility, seroma formation and recurrence). A single perfect mesh does not exist and, therefore, the choice of mesh remains an individual preference and its availability. However, the surgeon should be aware of the specific mesh characteristics that may lead to potential complications. The HerniaSurg group [56] has suggested large pores ($1\text{--}1.5 \text{ mm}$) monofilament synthetic flat meshes with a bursting strength of 16 N/cm^2 and consisting of minimal tensile strength in all directions including subsequent tearing force of 16 N/cm^2 .

A recent study by Trandafir et al. [61] analyzing four RCTs, eight reviews, eight prospective, seven retrospective and three experimental studies concluded that there was no difference in recurrence rate between heavy and light weight meshes. They also found no difference in acute or chronic pain, rate of seroma formation and quality of life. They noticed that the most commonly used mesh in various

trials was polypropylene light-weight mesh, monofilament, with large pore size, a minimum tensile strength $> 16 \text{ N/cm}^2$, and minimal dimensions of $10 \times 15 \text{ cm}$. In one of the first RCTs comparing two different types of mesh (prolene and Vipro II) in TEP repair of recurrent unilateral hernia, Heikkinen et al. [62] showed no difference in recurrence rates and quality of life after a short follow-up of 8 weeks. Since then several different types of meshes have been compared in both the TEP and TAPP methods [63–65]. The commonest types of meshes that have been studied include polypropylene [63], VYPRO—combination of polypropylene–polyglactin [62] and ultrapro [64]. Currie et al. [66] in a meta-analysis of 6 RCTs comparing heavy and light weight meshes, encompassing nearly 1500 patients reported no difference in recurrence rates (1%) between the two groups. Furthermore, they found no difference in recurrence rate when subgroup analysis of TEP and TAPP was undertaken. In contradiction to all the above studies, a long-term follow-up study of > 15 years by the Swedish national registry totaling 17,348 patients, reported a significantly higher recurrence rate with lower weight mesh in comparison to standard heavy weight polypropylene [67].

The latest introduction is that of a self-gripping mesh made of polyester with multiple small barbs made from polylactic acid, which fixes the mesh to the tissue and secures it in the desirable position. It is a medium weight, macroporous mesh satisfying many properties of an ideal mesh. Although the mesh has been in use since 2008 and has been used in open inguinal hernia repairs, the first study to report its outcome in a laparoscopic herniorrhaphy was by Kirk et al. [68]. They reported a recurrence rate of 1.4% in their cohort of 220 patients who were analyzed retrospectively over a period of 23 months. This is in agreement with another prospective study by Ozmen et al. [69] who performed 235 TAPP inguinal herniorrhaphies with a self gripping mesh and found no recurrence at a mean follow-up of 15 months. Fumagalli et al. [70] were the first to compare polypropylene and self-gripping polyester mesh involving 96 patients in a prospective non-randomized study. At 6 months follow-up they found only one recurrence in the polypropylene group. Recently, Ferrarese et al. [71] in their RCT analyzing 60 patients, showed a recurrence rate of 13.3% in the polypropylene group and 16.6% in the self gripping polyester group, which was not statistically significant at a mean follow-up period of 11 months. These studies [68–71] demonstrate that the self gripping meshes are comparable to the well-established polypropylene mesh in their outcomes with an added advantage of not having to use any fixation techniques during the laparoscopic herniorrhaphy. Whether the avoidance of fixation technique will have any impact on the recurrence rate and chronic pain syndrome in the future remains to be seen and the long-term data is awaited.

Mesh size

Adequate coverage of the hernia defect is imperative when performing a hernia operation with mesh. There is no consensus or guideline with regards to the mesh coverage of the inguinal hernia defect compared to ventral hernia defects. Surprisingly enough, even the recent International Groin Hernia Management Guidelines [56] have ignored this topic. The importance of using a large enough mesh was stressed as early as 1973 by Stoppa [72] in open inguinal hernia and the same holds true for the laparoscopic inguinal hernia repair. It has even been proposed that most of the recurrences after laparoscopic hernia repairs are due to inappropriate mesh size [73]. Fitzgibbons et al. [73] reported 5% recurrence in the TAPP inguinal hernia repair when they used a mesh measuring 9.2×6 cm which is most often the size used in open inguinal hernia repair. This begs the question whether we have always been using a smaller mesh in open inguinal hernia or the preperitoneal dissection is much more extensive compared to its open counterpart and requires a large mesh to cover all the potential groin hernia sites? In addition, shrinkage of the mesh needs to be considered as it has been demonstrated that meshes, especially the heavy weight ones can shrink up to 20–25% [70] and, therefore, may contribute to recurrence. Studies since have demonstrated that using a larger mesh results in lower recurrence rates, from 5 to 0.16% [74]. This is probably not just because it covers a wider area well beyond the effaced edges of the hernia orifice but also covers all of the different potential hernia sites in the inguinal region such as direct, Indirect and femoral hernia areas. Kapisiris et al. [74] have dropped their recurrence rate from 5 to 0.16% using a larger mesh measuring 10×15 cm. Similarly, Leibl et al. [75] looked at two important issues when analyzing their recurrence rate following TAPP repairs. The first was that of the size of the mesh and the second, slitting of the mesh. They decreased their recurrence rate from 2.8% (phase I) to 0.36% (phase II) after using a large mesh (10×15 cm) without a slit. If the slit edges are not reapproximated adequately, an opening is present for recurrence. Some surgeons even use 16×15 cm non-split mesh routinely. However, placing such a large mesh in the TEP repair can prove quite a daunting task although extended-TEP (e-TEP) seems to have solved this problem. So adequate and methodical dissection to expose all the potential hernias sites, along with the use of large enough mesh without any slit to adequately overlap the myopectineal orifice, tailored to individual patient size (but not less than 10×15 cm), one would hope will continue to reduce the recurrence rate in laparoscopic herniorrhaphy [75–78].

Mesh fixation vs non-fixation

Fixation of the mesh is an element that has been fiercely argued for a long time. Most surgeons prefer to fix the mesh in one-way or another. There are various techniques used to place and secure a mesh in the preperitoneal space which includes using absorbable and non-absorbable tacks, fibrin glue, Tisseel spray and sutures to name but a few [79]. When using the traumatic methods such as tacks or sutures, the aim is to avoid blood vessels in the triangle of doom and nerves in the triangle of pain. The sole purpose of fixation is to prevent mesh migration or displacement, which may contribute to hernia recurrence although its mechanics are neither investigated in detail nor well understood [80, 81]. Irrespective of the method used to place and secure the mesh in place it is suggested that desufflation should be carried out under vision while watching for any obvious shift in the placement of the mesh [82]. Curling of mesh at the inferior aspect could potentially lift the whole mesh if it is not placed properly e.g. placed too low down or the pre- or extraperitoneal space is inadequately dissected to properly accommodate the entire mesh, or the mesh is too large, or if the mesh is not secured properly. Increasingly more and more surgeons aim to fix the mesh in a non-traumatic manner with the use of various materials such as fibrin glue or Tissell [83, 84]. The advantages include securing the mesh inferiorly (including inferomedial and inferolateral corners) without fear of injury to the iliac vessels and bladder where tacks cannot be used. This method prevents mesh lifting or folding inferiorly thereby preventing recurrence, supposedly preventing or reducing chronic pain syndrome and hematoma/seromas formation [3, 79].

However, there is an ongoing debate regarding which fixation technique is better than the other in terms of recurrence and QoL such as acute or chronic pain [3, 83]. Liew et al. [79] in their RCT of 66 TAPP patients found no difference in pain outcome or recurrence rate (0%) at short term follow-up of 6 months between the tacks (non-absorbable metal) and glue (cyanoacrylate) groups. Prior to this RCT, a few other authors in their observational studies had noted a similar outcome. Schwab et al. [4] compared 186 patients with a mean follow up period of 23.7 months and found a recurrence rate of 5% in the tack group (non-absorbable) and 2% in the glue group (fibrin), which was not statistically significant. Yet another TEP study by Topart et al. [85] compared 66 patients with fixed mesh using either tacks (non-absorbable) or Tisseel glue and found no difference in recurrence rates between 12 and 39 months of follow-up with only one recurrence in the glue group. Kaul et al. [83], in their meta-analysis combining two observational and one RCT comparing the tacks and glue fixation method showed no difference in recurrence rates between the two groups. Contrary to the above studies, Olmi et al. [3] in their RCT

of 300 patients showed an increased incidence of recurrence in the tack group (1.5%) compared to the glue group (0%). The possible mechanism could be an increased incidence of hematoma and seroma with tacks, 6.3 vs 2.2%, which may have led to displacement of the mesh.

Non-fixation of mesh using TAPP [74, 86] and TEP [87, 88] techniques has been proven to be safe. This is because some surgeons feel that the preperitoneal space is an enclosed space, which may not allow for significant migration of the mesh. Schjøth-Iversen et al. [11] reported no difference in the rate of recurrence between patients with fixed and unfixed mesh. The recurrence rate was 5.2 and 5.1%, respectively. This is the largest single center study to date analyzing 1194 patients over 2 years. The findings are in agreement with the two RCTs [76, 82]. Garg et al. [76] reported no recurrence at 25 months follow-up between the two methods. They suggested that wide dissection and application of larger mesh contributes to lower recurrence. These studies suggest that fixation of the mesh may not be that vital and attention to detail along with proper surgical technique is a crucial factor in preventing recurrence. Claus et al. [82], compared tacks (absorbable) and non-fixation in a cohort of 60 patients undergoing TEP repair. They found that the mesh did not migrate irrespective of whether it was tacked or not based on the radiological examination that was guided by marking clips placed at the time of mesh placement. Teng et al. [89] in their meta-analysis, which included 6 RCTs and 772 patients, found no difference in recurrence rates between those who had their mesh fixed or not using TEP technique. Additionally, they found no difference in seroma formation and postoperative pain between the two groups. Similarly another meta-analysis [90] comprising of eight RCTs totaling approximately 1400 cases found no difference between the mesh fixation group and non-fixation group.

The matter of mesh fixation has further been studied in a clinical situation while the patient is on the operating table. Choy et al. [91] confirmed that the movement of well-placed mesh in the preperitoneal space is minimal or nil. They showed that there was no movement of unfixed mesh on relaparoscopy of the extraperitoneal plane following hip flexion and extension immediately postoperatively on the operating table. These movements were carried out with the preperitoneal space deflated. Irving et al. [92] as early as 1995 demonstrated that an unfixed mesh moves minimally following herniorrhaphy utilizing the TAPP technique. They marked the edges of the mesh with radio-opaque material, which were X-rayed postoperatively to assess for any migration. Furthermore, Dion et al. [93] in their in vitro studies using dogs, have proved that mesh integration following hernia repair is complete by 2 months as the cellular ingrowth and collagen deposition occurs within the mesh. This proves that proper placement of mesh in between two lamellar structures such as peritoneum and anterior abdominal wall or between the two layers of the

rectus sheath provides early fixation, tissue incorporation and long-term stability and, therefore, the use of tacks may be superfluous and may even increase the risk of complications. One can, therefore, conclude that in laparoscopic inguinal herniorrhaphy, the current evidence suggests that fixation of a mesh has no impact on the recurrence rate and if possible should be avoided.

Conclusions

Recurrences can occur at any stage after laparoscopic inguinal herniorrhaphy and carries substantial morbidity. The reason as to why hernias recur is most likely multifactorial and includes both technical and non-technical patient-related risk factors and it is possible that the different groin hernia subtypes have different pathophysiology. There are a number of patient related and surgical risk factors that are responsible for these recurrences after the laparoscopic inguinal herniorrhaphy. Identification of these risk factors certainly will help prevent recurrences. Patients need to be counselled on some of the non-technical or modifiable risk factors such as higher BMI, smoking, diabetes, and use of steroids to minimize the risk of recurrence. Certain surgical factors such as surgeon's experience, proper surgical technique, use of appropriate size mesh with better tissue overlap beyond the edge of the hernia orifice, prevention of postoperative infection, seroma and hematoma will further decrease the incidence of recurrence rate and for that surgeons need to be educated. Certain other factors such as the type of repair (TEP vs TAPP), type of mesh and the use or avoidance of mesh fixation does not seem to contribute towards hernia recurrence. It is imperative that both surgeons and patients are educated to achieve the best possible outcome following the laparoscopic inguinal herniorrhaphy. The guidelines from various hernia societies and the patient consent form should provide a realistic account of these risk factors leading to hernia recurrence following the laparoscopic repair. Finally, future randomized controlled trials should incorporate all these perioperative modifiable and non-modifiable risks factors to provide better understanding of their role in the long-term longitudinal studies. It is important to remember as Tran et al. [56] have eloquently stated that "This situation (i.e. recurrence rate following inguinal herniorrhaphy) needs improvement. Reorienting our thinking, such that recurrence is routinely considered a complication rather than an expectation is a necessary first step". We agree with this sentiment.

Compliance with ethical standards

Conflict of interest MSS declares no conflict of interest. DA declares no conflict of interest. MAM declares no conflict of interest. BM declares no conflict of interest.

Ethical approval No ethical approval is required as this is a literature review.

Human and animal rights This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent For this type of study, formal consent is not required.

References

- Jenkins JT, O'Dwyer PJ (2008) Inguinal hernias. *Br Med J* 336(7638):269–272. <https://doi.org/10.1136/bmj.39450.42827.5.AD>
- Kehlet H, Bay-Nielsen M, Danish Hernia Database C (2008) Nationwide quality improvement of groin hernia repair from the danish hernia database of 87,840 patients from 1998 to 2005. *Hernia* 12:1–7. <https://doi.org/10.1007/s10029-007-0285-5>
- Olmi S, Scaini A, Erba L, Guaglio M, Croce E (2007) Quantification of pain in laparoscopic transabdominal preperitoneal (TAPP) inguinal hernioplasty identifies marked differences between prosthesis fixation systems. *Surgery* 142:40–46
- Schwab R, Willms A, Kroger A, Becker HP (2006) Less chronic pain following mesh fixation using a fibrin sealant in TEP inguinal hernia repair. *Hernia* 10:272–277
- Lovisetto F, Zonta S, Rota E, Bottero L, Faillace G, Turra G, Fantini A, Longoni M (2007) Laparoscopic transabdominal preperitoneal (TAPP) hernia repair: surgical phases and complications. *Surg Endosc* 21:646–652. <https://doi.org/10.1007/s00464-006-9031-9>
- Junge K, Rosch R, Klinge U, Schwab R, Peiper C, Binnebosel M, Schenten F, Schumpelick V (2006) Risk factors related to recurrence in inguinal hernia repair: a retrospective analysis. *Hernia* 10:309–315
- Memon MA, Feliu X, Sallent EF, Camps J, Fitzgibbons RJ Jr (1999) Laparoscopic repair of recurrent hernias. *Surg Endosc* 13:807–810
- El-Dhuwaib Y, Corless D, Emmett C, Deakin M, Slavin J (2013) Laparoscopic versus open repair of inguinal hernia: a longitudinal cohort study. *Surg Endosc* 27:936–945. <https://doi.org/10.1007/s00464-012-2538-3>
- Scott NW, McCormack K, Graham P, Go PM, Ross SJ, Grant AM (2002) Open mesh versus non-mesh for repair of femoral and inguinal hernia. *Cochrane Database Syst Rev* 4:CD002197. <https://doi.org/10.1002/14651858.CD002197>
- Amato B, Moja L, Panico S, Persico G, Rispoli C, Rocco N, Moschetti I (2012) Shouldice technique versus other open techniques for inguinal hernia repair. *Cochrane Database Syst Rev* 4:CD001543
- Schjøth-Iversen L, Refsum A, Brudvik KW (2017) Factors associated with hernia recurrence after laparoscopic total extraperitoneal repair for inguinal hernia: a 2-year prospective cohort study. *Hernia* 21:729–735. <https://doi.org/10.1007/s10029-017-1634-7>
- van der Pool AE, Harlaar JJ, den Hoed PT, Weidema WF, van Veen RN (2010) Long-term follow-up evaluation of chronic pain after endoscopic total extraperitoneal repair of primary and recurrent inguinal hernia. *Surg Endosc* 24:1707–1711. <https://doi.org/10.1007/s00464-009-0833-4>
- Tran H, Tran K, Turingan I, Zajkowska M, Lam V, Hawthorne W (2015) Single-incision laparoscopic inguinal herniorrhaphy with telescopic extraperitoneal dissection: technical aspects and potential benefits. *Hernia* 19:407–416. <https://doi.org/10.1007/s10029-015-1349-6>
- Burcharth J, Andresen K, Pommergaard HC, Bisgaard T, Rosenberg J (2014) Direct inguinal hernias and anterior surgical approach are risk factors for female inguinal hernia recurrences. *Langenbecks Arch Surg* 399:71–76. <https://doi.org/10.1007/s00423-013-1124-z>
- Burcharth J, Pommergaard HC, Bisgaard T, Rosenberg J (2015) Patient-related risk factors for recurrence after inguinal hernia repair: a systematic review and meta-analysis of observational studies. *Surg Innov* 22:303–317. <https://doi.org/10.1177/1553350614552731>
- Burcharth J, Andresen K, Pommergaard H-C, Rosenberg J (2015) Groin hernia subtypes are associated in patients with bilateral hernias: a 14-year nationwide epidemiologic study. *Surg Endosc* 29:2019–2026. <https://doi.org/10.1007/s00464-014-3905-z>
- Burcharth J (2014) The epidemiology and risk factors for recurrence after inguinal hernia surgery. *Da Med J* 61:B4846
- Furukawa S, Fujita T, Shimabukuro M, Iwaki M, Yamada Y, Nakajima Y, Nakayama O, Makishima M, Matsuda M, Shimomura I (2004) Increased oxidative stress in obesity and its impact on metabolic syndrome. *J Clin Invest* 114:1752–1761. <https://doi.org/10.1172/JCI21625>
- Carilli SAA, Emre A (2004) Inguinal cord lipomas. *Hernia* 8:252–254
- Niebuhr HKF (2017) Surgical risk factors for recurrence in inguinal hernia repair—a review of the literature. *Innov Surg Sci* 2:53–59
- de Lange DH, Aufenacker TJ, Roest M, Simmermacher RKJ, Gouma DJ, Simons MP (2005) Inguinal hernia surgery in The Netherlands: a baseline study before the introduction of the Dutch Guidelines. *Hernia* 9:172–177
- McCormack K, Scott NW, Go PM, Ross S, Grant AM, Collaboration EUHT (2003) Laparoscopic techniques versus open techniques for inguinal hernia repair. *Cochrane Database Syst Rev* 1:CD001785
- Karthikesalingam A, Markar SR, Holt PJE, Praseedom RK (2010) Meta-analysis of randomized controlled trials comparing laparoscopic with open mesh repair of recurrent inguinal hernia. *Br J Surg* 97:4–11
- Kockerling F, Bittner R, Adolf D, Fortelny R, Niebuhr H, Mayer F, Schug-Pass C (2018) Seroma following transabdominal preperitoneal patch plasty (TAPP): incidence, risk factors, and preventive measures. *Surg Endosc* 32:2222–2231. <https://doi.org/10.1007/s00464-017-5912-3>
- Sajid MS, Khawaja AH, Sayegh M, Baig MK (2016) A systematic review comparing single-incision versus multi-incision laparoscopic surgery for inguinal hernia repair with mesh. *Int J Surg* 29:25–35. <https://doi.org/10.1016/j.ijsu.2016.02.088>
- Wakasugi M, Tei M, Akamatsu H (2016) Single-incision totally extraperitoneal inguinal hernia repair after previous inguinal hernia repair. *Surg Laparosc Endosc Percutan Tech* 26:e149–e152. <https://doi.org/10.1097/sle.0000000000000346>
- Bittner R, Montgomery MA, Arregui E, Bansal V, Bingener J, Bisgaard T, Buhck H, Dudai M, Ferzli GS, Fitzgibbons RJ, Fortelny RH, Grimes KL, Klinge U, Kockerling F, Koeckerling F, Kumar S, Kukleta J, Lomanto D, Misra MC, Morales-Conde S, Reinhold W, Rosenberg J, Singh K, Timoney M, Weyhe D, Chowbey P, International Endohernia S (2015) Update of guidelines on laparoscopic (TAPP) and endoscopic (TEP) treatment of inguinal hernia (International Endohernia Society). *Surg Endosc* 29:289–321
- Ferzli GS, Rim S, Edwards ED (2013) Combined laparoscopic and open extraperitoneal approach to scrotal hernias. *Hernia* 17:223–228
- Siow SL, Mahendran HA, Hardin M, Chea CH, Nik Azim NA (2013) Laparoscopic transabdominal approach and its modified technique for incarcerated scrotal hernias. *Asian J Surg* 36:64–68

30. Lal P, Kajla RK, Chander J, Ramteke VK (2004) Laparoscopic total extraperitoneal (TEP) inguinal hernia repair: overcoming the learning curve. *Surg Endosc* 18:642–645
31. Morales-Conde S, Socas M, Fingerhut A (2012) Endoscopic surgeons' preferences for inguinal hernia repair: TEP, TAPP, or OPEN. *Surg Endosc* 26:2639–2643
32. Schrenk P, Woisetschlager R, Rieger R, Wayand W (1996) Prospective randomized trial comparing postoperative pain and return to physical activity after transabdominal preperitoneal, total preperitoneal or Shouldice technique for inguinal hernia repair. *Br J Surg* 83:1563–1566
33. Dedemadi G, Sgourakis G, Karaliotis C, Christofides T, Kouraklis G, Karaliotis C (2006) Comparison of laparoscopic and open tension-free repair of recurrent inguinal hernias: a prospective randomized study. *Surg Endosc* 20:1099–1104
34. Butler RE, Burke R, Schneider JJ, Brar H, Lucha PA Jr (2007) The economic impact of laparoscopic inguinal hernia repair: results of a double-blinded, prospective, randomized trial. *Surg Endosc* 21:387–390
35. Bansal VK, Misra MC, Babu D, Victor J, Kumar S, Sagar R, Rajeshwari S, Krishna A, Rewari V (2013) A prospective, randomized comparison of long-term outcomes: chronic groin pain and quality of life following totally extraperitoneal (TEP) and transabdominal preperitoneal (TAPP) laparoscopic inguinal hernia repair. *Surg Endosc* 27:2373–2382
36. Wang W-J, Chen J-Z, Fang Q, Li J-F, Jin P-F, Li Z-T (2013) Comparison of the effects of laparoscopic hernia repair and Lichtenstein tension-free hernia repair. *J Laparoendosc Adv Surg Tech A* 23(4):301–305
37. Kockerling F, Bittner R, Jacob DA, Seidelmann L, Keller T, Adolf D, Kraft B, Kuthe A (2015) TEP versus TAPP: comparison of the perioperative outcome in 17,587 patients with a primary unilateral inguinal hernia. *Surg Endosc* 29:3750–3760. <https://doi.org/10.1007/s00464-015-4150-9>
38. Sharma D, Yadav K, Hazrah P, Borgharia S, Lal R, Thomas S (2015) Prospective randomized trial comparing laparoscopic transabdominal preperitoneal (TAPP) and laparoscopic totally extra peritoneal (TEP) approach for bilateral inguinal hernias. *Int J Surg* 22:110–117. <https://doi.org/10.1016/j.ijsu.2015.07.713>
39. McCormack K, Wake BL, Fraser C, Vale L, Perez J, Grant A (2005) Transabdominal pre-peritoneal (TAPP) versus totally extraperitoneal (TEP) laparoscopic techniques for inguinal hernia repair: a systematic review. *Hernia* 9:109–114. <https://doi.org/10.1007/s10029-004-0309-3>
40. Antoniou SA, Antoniou GA, Bartsch DK, Fendrich V, Koch OO, Pointner R, Granderath FA (2013) Transabdominal preperitoneal versus totally extraperitoneal repair of inguinal hernia: a meta-analysis of randomized studies. *Am J Surg* 206:245–252.e241
41. Wei FX, Zhang YC, Han W, Zhang YL, Shao Y, Ni R (2015) Transabdominal preperitoneal (TAPP) versus totally extraperitoneal (TEP) for laparoscopic hernia repair: a meta-analysis. *Surg Laparosc Endosc Percutan Tech* 25:375–383
42. Chen LS, Chen WC, Kang YN, Wu CC, Tsai LW, Liu MZ (2018) Effects of transabdominal preperitoneal and totally extraperitoneal inguinal hernia repair: an update systematic review and meta-analysis of randomized controlled trials. *Surg Endosc*. <https://doi.org/10.1007/s00464-018-6314-x> (Epub ahead of print)
43. Chan AC, Lee TW, Ng KW, Chung SC, Li AK (1994) Early results of laparoscopic intraperitoneal onlay mesh repair for inguinal hernia. *Br J Surg* 81:1761–1762
44. Hatzitheofilou C, Lakhoo M, Sofianos C, Levy RD, Velmahos G, Saadia R (1997) Laparoscopic inguinal hernia repair by an intraperitoneal onlay mesh technique using expanded PTFE: a prospective study. *Surg Laparosc Endosc* 7:451–455
45. Olmi S, Scaini A, Erba L, Bertolini A, Croce E (2007) Laparoscopic repair of inguinal hernias using an intraperitoneal onlay mesh technique and a Parietex composite mesh fixed with fibrin glue (Tissucol). Personal technique and preliminary results. *Surg Endosc* 21:1961–1964. <https://doi.org/10.1007/s00464-007-9355-0>
46. Antoniou SA, Garcia-Alamino JM, Hajibandeh S, Hajibandeh S, Weitzendorfer M, Muysoms FE, Granderath FA, Chalkiadakis GE, Emmanuel K, Antoniou GA, Gioumidou M, Iliopoulou-Kosmadaki S, Mathioudaki M, Souliotis K (2018) Single-incision surgery trocar-site hernia: an updated systematic review meta-analysis with trial sequential analysis by the minimally invasive surgery synthesis of interventions outcomes network (MISSION). *Surg Endosc* 32:14–23. <https://doi.org/10.1007/s00464-017-5717-4>
47. Voitek AJ (1998) The learning curve in laparoscopic inguinal hernia repair for the community general surgeon. *Can J Surg* 41:446–450
48. Edwards CC 2nd, Bailey RW (2000) Laparoscopic hernia repair: the learning curve. *Surg Laparosc Endosc Percutan Tech* 10:149–153
49. Simons MP, Aufenacker T, Bay-Nielsen M, Bouillot JL, Campanelli G, Conze J, de Lange D, Fortelny R, Heikkinen T, Kingsnorth A, Kukleta J, Morales-Conde S, Nordin P, Schumpelick V, Smedberg S, Smietanski M, Weber G, Miserez M (2009) European Hernia Society guidelines on the treatment of inguinal hernia in adult patients. *Hernia* 13:343–403. <https://doi.org/10.1007/s10029-009-0529-7>
50. Bansal VK, Krishna A, Misra MC, Kumar S (2016) Learning curve in laparoscopic inguinal hernia repair: experience at a tertiary care centre. *Ind J Surg* 78:197–202. <https://doi.org/10.1007/s12262-015-1341-5>
51. Bittner R, Arregui ME, Bisgaard T, Dudai M, Ferzli GS, Fitzgibbons RJ, Fortelny RH, Klinge U, Kockerling F, Kuhry E, Kukleta J, Lomanto D, Misra MC, Montgomery A, Morales-Conde S, Reinhold W, Rosenberg J, Sauerland S, Schug-Pass C, Singh K, Timoney M, Weyhe D, Chowbey P (2011) Guidelines for laparoscopic (TAPP) and endoscopic (TEP) treatment of inguinal hernia [International Endohernia Society (IEHS)]. *Surg Endosc* 25:2773–2843
52. Bokeler U, Schwarz J, Bittner R, Zacheja S, Smaxwil C (2013) Teaching and training in laparoscopic inguinal hernia repair (TAPP): impact of the learning curve on patient outcome. *Surg Endosc* 27:2886–2893. <https://doi.org/10.1007/s00464-013-2849-z>
53. Bracale U, Merola G, Sciuto A, Cavallaro G, Andreuccetti J, Pignata G (2018) Achieving the learning curve in laparoscopic inguinal hernia repair by Tapp: a quality improvement study. *J Invest Surg* June 14:1–8. <https://doi.org/10.1080/08941939.2018.1468944>
54. Schouten N, Simmermacher RK, van Dalen T, Smakman N, Clevvers GJ, Davids PH, Verleisdonk EJ, Burgmans JP (2013) Is there an end of the “learning curve” of endoscopic totally extraperitoneal (TEP) hernia repair? *Surg Endosc* 27:789–794. <https://doi.org/10.1007/s00464-012-2512-0>
55. Lamb AD, Robson AJ, Nixon SJ (2006) Recurrence after totally extraperitoneal laparoscopic repair: implications for operative technique and surgical training. *Surgeon* 4:299–307
56. HerniaSurg Group (2018) International guidelines for groin hernia management. *Hernia* 22:1–165. <https://doi.org/10.1007/s10029-017-1668-x>
57. Kaafarani HM, Itani KM, Giobbie-Hurder A, Gleysteen JJ, McCarthy M Jr, Gibbs J, Neumayer L (2005) Does surgeon frustration and satisfaction with the operation predict outcomes of open or laparoscopic inguinal hernia repair? *J Am Coll Surg* 200:677–683. <https://doi.org/10.1016/j.jamcollsurg.2004.11.018>
58. Cheatele GL (1921) An Operation for Inguinal Hernia. *Br Med J* 2:1025–1026

59. Henry A (1936) Operation for femoral hernia by a midline extra-peritoneal approach; with a preliminary note on the use of this route for reducible inguinal hernia. *Lancet* 1:531–533
60. Klinge U, Klosterhalfen B, Muller M, Schumpelick V (1999) Foreign body reaction to meshes used for the repair of abdominal wall hernias. *Eur J Surg* 165:665–673
61. Trandafir AF, Popa DE, Vasile D (2017) Prostheses used in laparoscopic inguinal hernia repair: biocompatibility, postoperative complications and quality of life—review of the literature. *Maedica (Buchar)* 12:202–207
62. Heikkinen T, Wollert S, Österberg J, Smedberg S, Bringman S (2006) Early results of a randomised trial comparing Prolene and VyproII-mesh in endoscopic extraperitoneal inguinal hernia repair (TEP) of recurrent unilateral hernias. *Hernia* 10:34–40. <https://doi.org/10.1007/s10029-005-0026-6>
63. Bittner R, Leibl BJ, Kraft B, Schwarz J (2011) One-year results of a prospective, randomised clinical trial comparing four meshes in laparoscopic inguinal hernia repair (TAPP). *Hernia* 15:503–510
64. Chowbey PK, Garg N, Sharma A, Khullar R, Soni V, Bajjal M, Mittal T (2010) Prospective randomized clinical trial comparing lightweight mesh and heavyweight polypropylene mesh in endoscopic totally extraperitoneal groin hernia repair. *Surg Endosc* 24:3073–3079
65. Langenbach MR, Schmidt J, Ubrig B, Zirngibl H (2008) Sixty-month follow-up after endoscopic inguinal hernia repair with three types of mesh: a prospective randomized trial. *Surg Endosc* 22:1790–1797. <https://doi.org/10.1007/s00464-008-9863-6>
66. Currie A, Andrew H, Tonsi A, Hurley PR, Taribagil S (2012) Lightweight versus heavyweight mesh in laparoscopic inguinal hernia repair: a meta-analysis. *Surg Endosc* 26:2126–2133. <https://doi.org/10.1007/s00464-012-2179-6>
67. Melkemichel M, Bringman S, Widhe B (2017) Lower recurrence rate with heavyweight mesh compared to lightweight mesh in laparoscopic total extra-peritoneal (TEP) inguinal hernia repair. A nationwide population-based register study. *Hernia* 21:S162. <https://doi.org/10.1007/s10029-017-1595-x>
68. Birk D, Hess S, Garcia-Pardo C (2013) Low recurrence rate and low chronic pain associated with inguinal hernia repair by laparoscopic placement of Parietex ProGrip mesh: clinical outcomes of 220 hernias with mean follow-up at 23 months. *Hernia* 17:313–320. <https://doi.org/10.1007/s10029-013-1053-3>
69. Ozmen J, Choi V, Hepburn K, Hawkins W, Loi K (2015) Laparoscopic totally extraperitoneal groin hernia repair using a self-gripping mesh: clinical results of 235 primary and recurrent groin hernias. *J Laparoendosc Adv Surg Tech A* 25:915–919
70. Fumagalli Romario U, Puccetti F, Elmore U, Massaron S, Rosati R (2013) Self-gripping mesh versus staple fixation in laparoscopic inguinal hernia repair: a prospective comparison. *Surg Endosc* 27:1798–1802
71. Ferrarese A, Bindi M, Rivelli M, Solej M, Enrico S, Martino V (2016) Self-gripping mesh versus fibrin glue fixation in laparoscopic inguinal hernia repair: a randomized prospective clinical trial in young and elderly patients. *Open Med (Wars)* 11:497–508
72. Stoppa R, Petit J, Abourachid H, Henry X, Duclaye C, Monchaux G, Hillebrant JP (1973) Original procedure of groin hernia repair: interposition without fixation of Dacron tulle prosthesis by sub-peritoneal median approach. *Chir* 99:119–123
73. Phillips EH, Rosenthal R, Fallas M, Carroll B, Arregui M, Corbitt J, Fitzgibbons R, Seid A, Schultz L, Toy F et al (1995) Reasons for early recurrence following laparoscopic hernioplasty. *Surg Endosc* 9:140–144
74. Kapisir SA, Brough WA, Royston CM, O'Boyle C, Sedman PC (2001) Laparoscopic transabdominal preperitoneal (TAPP) hernia repair. A 7-year two-center experience in 3017 patients. *Surg Endosc* 15:972–975
75. Leibl BJ, Schmedt CG, Kraft K, Ulrich M, Bittner R (2000) Recurrence after endoscopic transperitoneal hernia repair (TAPP): causes, reparative techniques, and results of the reoperation. *J Am Coll Surg* 190:651–655
76. Garg P, Nair S, Shereef M, Thakur JD, Nain N, Menon GR, Ismail M (2011) Mesh fixation compared to nonfixation in total extraperitoneal inguinal hernia repair: a randomized controlled trial in a rural center in India. *Surg Endosc* 25:3300–3306. <https://doi.org/10.1007/s00464-011-1708-z>
77. Messaris E, Nicastrì G, Dudrick SJ (2010) Total extraperitoneal laparoscopic inguinal hernia repair without mesh fixation: prospective study with 1-year follow-up results. *Arch Surg* 145:334–338
78. Morrison JE Jr, Jacobs VR (2008) Laparoscopic preperitoneal inguinal hernia repair using preformed polyester mesh without fixation: prospective study with 1-year follow-up results in a rural setting. *Surg Laparosc Endosc Percutan Tech* 18:33–39. <https://doi.org/10.1097/SLE.0b013e318157b155>
79. Liew W, Wai YY, Kosai NR, Gendeh HS (2017) Tackers versus glue mesh fixation: an objective assessment of postoperative acute and chronic pain using inflammatory markers. *Hernia* 21:549–554
80. Liem MS, van Duyn EB, van der Graaf Y, van Vroonhoven TJ (2003) Recurrences after conventional anterior and laparoscopic inguinal hernia repair: a randomized comparison. *Ann Surg* 237:136–141. <https://doi.org/10.1097/01.sla.0000041049.69383.0e>
81. Arvidsson D, Smedberg S (2000) Laparoscopic compared with open hernia surgery: complications, recurrences and current trends. *Eur J Surg* 166(Suppl 585):40–47
82. Claus CMRG, Campos AC, Bonin EA, Dimbarre D, Loureiro MP, Coelho JC (2016) Prospective, randomized and controlled study of mesh displacement after laparoscopic inguinal repair: fixation versus no fixation of mesh. *Surg Endosc* 30:1134–1140
83. Kaul A, Hutfless S, Le H, Hamed SA, Tymitz K, Nguyen H, Marohn MR (2012) Staple versus fibrin glue fixation in laparoscopic total extraperitoneal repair of inguinal hernia: a systematic review and meta-analysis. *Surg Endosc* 26:1269–1278. <https://doi.org/10.1007/s00464-011-2025-2>
84. Lau H (2005) Fibrin sealant versus mechanical stapling for mesh fixation during endoscopic extraperitoneal inguinal hernioplasty: a randomized prospective trial. *Ann Surg* 242:670–675
85. Topart P, Vandenbroucke F, Lozac'h P (2005) Tisseel versus tack staples as mesh fixation in totally extraperitoneal laparoscopic repair of groin hernias: a retrospective analysis. *Surg Endosc* 19:724–727
86. Smith AI, Royston CM, Sedman PC (1999) Stapled and nonstapled laparoscopic transabdominal preperitoneal (TAPP) inguinal hernia repair. A prospective randomized trial. *Surg Endosc* 13:804–806
87. Ferzli GS, Frezza EE, Pecoraro AM Jr, Ahern KD (1999) Prospective randomized study of stapled versus unstapled mesh in a laparoscopic preperitoneal inguinal hernia repair. *J Am Coll Surg* 188:461–465
88. Garg P, Rajagopal M, Varghese V, Ismail M (2009) Laparoscopic total extraperitoneal inguinal hernia repair with nonfixation of the mesh for 1,692 hernias. *Surg Endosc* 23:1241–1245
89. Teng YJ, Pan SM, Liu YL, Yang KH, Zhang YC, Tian JH, Han JX (2011) A meta-analysis of randomized controlled trials of fixation versus nonfixation of mesh in laparoscopic total extraperitoneal inguinal hernia repair. *Surg Endosc* 25:2849–2858. <https://doi.org/10.1007/s00464-011-1668-3>
90. Sajid MS, Ladwa N, Kalra L, Hutson K, Sains P, Baig MK (2012) A meta-analysis examining the use of tackler fixation versus nonfixation of mesh in laparoscopic inguinal hernia repair. *Int J Surg* 10:224–231

91. Choy C, Shapiro K, Patel S, Graham A, Ferzli G (2004) Investigating a possible cause of mesh migration during totally extraperitoneal (TEP) repair. *Surg Endosc* 18:523–525
92. Irving SODG, Sedman PC, Royston CM, Brough WA (1995) Does the mesh move after TAPP hernia repair? An X-ray study. *Minim Invasive ther* 4:54
93. Dion YM, Laplante R, Charara J, Marois M (1994) The influence of the number of endoclips and of mesh incorporation on the strength of an experimental hernia patch repair. *Surg Endosc* 8:1324–1328