Incisional and Parastomal Hernia Prevention

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Introduction

Incisional hernias (IH) are arguably the most common complication of abdominal surgery with many presentations and timelines. The incidence of IH repair likely represents only a fraction of the number of patients who have developed IH, as many are occult [1] or asymptomatic. Most commonly, patients will develop a noticeable protuberance within an abdominal incision with or without associated symptoms. Patients requiring operative repair of their IH occur costs that significantly increase overall healthcare costs relative to those who do not develop hernias [2]. Fortunately, only a small minority of patients will present with urgent or life-threatening problems necessitating more urgent hernia repair with or without bowel resection related to incarcerated or strangulated viscera. Historically, the presence of an IH was deemed an indication for repair due to concerns for incarceration and strangulation when nonoperative strategies are employed [3]. However, IHs present emergently in fewer than 5% of all cases [4].

Accordingly, strategies to identify patients at greatest risk for the development of IH have evolved to reduce the incidence of this common condition.

Recent decades have been marked with innovations in surgery resulting in more precise procedures through smaller incisions with reduced morbidity [5]. Technologic advancements have enabled surgeons to broaden the net of pathology that can be safely and effectively managed, resulting in enhanced overall procedural outcomes and quality of life [2, 6, 7]. More specifically, laparoscopic surgery has dramatically impacted the overall number of open abdominal operations performed in the United States with significant adoption for many common conditions. However, the use of open surgical techniques for abdominal surgery remains a reality today for many procedures due to challenges related to training, equipment, and patient complexity. Accordingly, open abdominal operations will likely remain within the scope of surgery for the foreseeable future. Having said that, abdominal incisions are associated with not infrequent complications, and the optimal means of abdominal closure has yet to be elucidated. Despite technical improvement and adherence to principles [8], the overall incidence of IH following laparotomy is reported to be as high as 20% [9] with significantly higher rates after postoperative wound infection and other wound complications [10]. It is also expectedly higher in patients with genetic predispositions or comorbidities favoring abnormal tissue healing. In a 10-year prospective study by Mudge and Hughes [10], fewer than 50% of IHs occur in the first year after surgery. Suffice it to say, patient follow-up in excess of 1 year is needed to adequately assess the true incidence of hernia. Gallup et al. [11] concluded that a 10-year follow-up of such patients is probably needed to determine the actual incidence of IH. The associated costs attributed to the long-term incidence of IH formation result in significant economic [12] and health management burdens [13–15] which are likely further compounded considering the not insignificant rate of recurrence following IH repair (despite the widespread use of mesh as reinforcement) [16]. Significant medical comorbidities, advanced preoperative wound class, and postoperative complications further increase costs of ventral hernia repair [17].

Patient risk factors and the mechanism behind IH are well studied [16, 18, 19]. Although not inclusive, obesity [20], connective tissue disorders, chronic obstructive pulmonary disease, tobacco use, malnourishment, corticosteroid dependency, and prostatism are among the most notable [21]. In light of the risks associated with IH repair [22] and the impact upon quality of life, the prevention of IH should be the primary goal at every instance an abdominal incision is created.

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More than 2 million open abdominal operations are performed annually in the United States with approximately 100,000 patients undergoing IH repair annually [23]. The technique of abdominal wall closure is one of the most important factors in the prevention of IHs [24]. It is arguably the only risk factor that is entirely within the control of the surgeon. Aponeurotic tissue needs a considerably longer time to heal than, for example, skin and mucosa. A normally healed wound will obtain 50% of its original strength after approximately 6 weeks [25], and the aponeurosis may never completely regain its original strength (only 60–90% after 1 year) [26]. During the period of wound healing, the technique for closure and suture material will greatly impact overall the strength of incision. Numerous studies have been conducted in an attempt to identify the optimal fascial closure, evaluating suture materials [27] and suturing technique [28]. The short stitch technique for wound closure utilizing a 2-0 slowly resorbing suture has emerged as a technique with a lower incidence of IH rates compared to a traditional running closure utilizing a looped suture in prospective studies [29]. While dramatic and significant reductions in IH rates (38%) have been demonstrated by altering the technique for suture placement, rates of IH remain in excess of 10% in this study. As a result, the development of additional strategies to further reduce the incidence of IH formation continues to evolve.

In an effort to decrease occurrence of IHs, investigators have pioneered techniques for mesh reinforcement of abdominal wall closure following elective laparotomy for patients deemed to be at increased risk for hernia formation. These "high-risk" patients often demonstrate comorbidities including obesity, smoking, immunosuppression, steroid use, and abdominal aortic aneurysm. Numerous mesh materials and techniques for mesh placement have been evaluated. By choosing to use mesh as an adjunct to the abdominal wall closure, surgeons must consider not only the incidence of IH formation but also cost-effectiveness, risk for mesh complications, impact upon future operations, and quality of life.

Mesh Prophylaxis Use at the Time of Midline Laparotomy Closure

The earliest descriptions of the use of prophylactic mesh as an adjunct to laparotomy closure were in the 1990s at the time of open weight loss surgery [30]. The authors studied the IH outcome on 288 morbidly obese patients randomly assigned to polyglactin mesh (21.5 × 26.5 cm) reinforcement (144 patients) compared to sutured midline laparotomy wound closure (144 patients). They excluded patients with any history of prior midline incisions from their series. Interestingly, the intraperitoneal mesh was not secured, but care was taken to spread it as far as possible into the flanks. With a follow-up averaging 30 months, 83% of the patients were evaluated through physical examinations, while the remaining were assessed through phone and mail communication. Eighty-seven percent of the hernias were observed during the first 18 postoperative months, and the incidence of IH was similar between mesh (23%) and non-mesh group (28%). The authors concluded that intraperitoneal absorbable prosthetic mesh was not successful in reducing IH rates in the morbidly obese population, although the study demonstrated risk factors for hernia formation including advanced age, male gender, and high BMI. Although not successful in reducing IH rates, from this study was born the concept of mesh prophylaxis for IH prevention.

The use of a permanent synthetic mesh offers some potential advantages over a rapidly absorbed mesh in the prevention of hernia by buttressing the abdominal wall in the event of early fascial dehiscence. In the event of small fascial separations, the permanent prosthetic remains in position, stabilizes the fascia, and prevents herniation. As many IHs begin as an occult fascial dehiscence, reinforcement of the incision with a permanent mesh serves to protect the incision from the postoperative problems (suture failure, knot failure, fascial tears, etc.) that may result in fascial separation. While the use of reinforcing synthetic mesh has appeal, safety concerns related to potential for mesh complications require address. Furthermore, an appreciation of the cost-effectiveness of mesh prophylaxis is required in order to appreciate not only the savings associated with a reduction in IH rates but also to appreciate any increased costs associated with the management of complications related to the use of mesh as prophylaxis. In light of the potential for morbidity associated with implanting a permanent synthetic mesh prophylactically, most studies to date have evaluated the use of prophylactic mesh in patients at greatest risk for incisional hernia formation.

Synthetic polypropylene mesh has been studied in the prophylaxis of IH repair following gastric bypass [31, 32]. In a prospective randomized trial, 36 gastric bypass patients undergoing abdominal closure with a retrorectus polypropylene mesh (8 cm width with extension 2 cm beyond incision cranially and caudally) were compared to 38 patients who underwent mass closure of the abdominal wall with 2-0 polypropylene suture. With follow-up ranging from 6 to 38 months, there was no difference in adverse events or major complications related to either the mesh placement or the gastric bypass between groups. The incidence of seromas and minor wound complications was similar in both groups. The incidence of hernia formation was 21% in the suture group and 3% in the mesh group. Although this study was not blinded, these results reinforce the results of a prior non-randomized study by the same author [32] in which hernia rates were dramatically reduced with mesh prophylaxis. In

these studies, the polypropylene mesh was placed in an onlay location (reportedly to minimize the risk of bowel fistula of intraperitoneal mesh location) and used on morbidly obese patients who were considered at the greatest risk of postoperative hernia or evisceration (BMI of 45 kg/m^2 or higher, history of abdominal hernias, and liver function tests suggesting profound liver damage or cirrhosis).

Abo-Ryia et al. [33] replicated similar outcomes in a randomized controlled trial of morbidly obese patients undergoing prophylactic preperitoneal mesh placement following weight loss surgery. The polypropylene mesh was approximately 4–5 cm longer than the wound length and 10–12 cm wider. Postoperative wound-related complications (seroma, infection, and partial dehiscence) were similar between groups and were all managed conservatively. Over a mean follow-up of 4 years, the incidence of IH in the prophylactic mesh group (3.1%) compared favorably to the non-mesh group (28.1%) $p < 0.01$. Among advantages of mesh placement in the retrorectus space, the authors felt it would not hinder any aesthetic abdominal surgery planned following maximum weight reduction.

In contrast, others have reported favorable outcomes with placement of a prophylactic mesh in the intraperitoneal position [34]. In this study, 40 high-risk patients at risk for the development of IH were randomized into matched groups of 20 patients, with patients undergoing closure with either polypropylene suture or an intraperitoneal polypropylene with 2 cm overlap secured with only 4 corner sutures. The incidence of seroma, surgical site infection, and partial wound disruption was similarly low in both groups. With a follow-up averaging 3 years, only one patient (5%) in the mesh group and three patients (15%) in the non-mesh group developed IHs. However, chronic wound pain was only seen in the mesh group (three patients) but was not statistically significant. While not significant, the potential for mesh-related complications associated with prophylactic mesh placement requires further consideration. This study sheds some insight into the potential for chronic pain associated with prophylactic mesh. Larger studies with attention to quality of life metrics, including pain, are needed to appreciate all potential impacts, both intended and unintended of the use of prophylactic mesh to prevent IH.

A larger prospective randomized study of 100 high-risk patients compared standard fascial closure with and without the onlay placement of a heavyweight (82 g/m^2) knitted polypropylene mesh with 3 cm overlap [34, 35]. With 3-year follow-up in 88 of the patients (44 in each group), the mesh group experienced no IHs, whereas 5 hernias (11.3%) occurred in the non-mesh group. Postoperative pain was noticed in the mesh group and persisted beyond 3 months in 2 patients. A decade later, Caro-Tarrago et al. [36] studied onlay mesh use with 3 cm overlap to reinforce abdominal wall closures at the time of elective supra- and infraumbilical laparotomies. This study utilized a macroporous lightweight (40 g/m^2) polypropylene mesh and included high- and low-risk patients and patients with all degrees of wound contamination; exclusion criteria included patients with ASA score greater than 3, patients with prior herniorrhaphy or ostomy, and patients on steroid therapy. Eighty patients in each arm underwent oncologic or gastrointestinal operations with 1-year follow-up. A significantly higher rate of seroma was encountered in the mesh group (28.8%) compared to the standard abdominal wall closure (11.3%). Although most (73.8%) of the mesh group cases were contaminated, there was no impact on the rate of either superficial (6.3%) or deep (3.8%) wound infection rates. No mesh explants were reported. This study suggests safety in using prosthetic mesh in contaminated wounds as have other series [37]. The lightweight mesh dramatically decreased the rate of IH (1.5%) in comparison to the non-mesh group (35.9%), and no patient experienced chronic pain. The differences in lightweight and heavyweight polypropylene mesh are often debated. Lightweight mesh was popularized as a material with reduced mass of polypropylene often with greater porosity allowing for rapid integration into the abdominal wall. In a meta-analysis comparing lightweight mesh to standard polypropylene in hernia repair, the former has been associated with less chronic pain [38, 39]. Others have reported the use of lightweight polypropylene mesh in contaminated hernia repair with incidences of mesh removal less than 5%. However, the incidence of hernia recurrence is higher with lightweight polypropylene relative to other non-lightweight materials. It is not clear as of now whether the use of lightweight mesh for IH prophylaxis will result in improved outcomes relative to heavyweight polypropylene. Although speculative, there may be patient populations that are best served with different mesh types when performing IH prophylaxis.

The ideal technique for mesh fixation in IH requires investigation. Mesh placement strategies include absorbable and permanent suture, tacking devices (i.e., tackers, staplers), glues, self-adhering mesh, or fixation-free placement. Timmermans et al. [39] published short-term outcomes of an ongoing randomized controlled trial (RCT) comparing standard suture with glued onlay mesh and glued sublay mesh augmentation. The onlay mesh group experienced a greater incidence of wound seroma (18.1%) than the sublay group (7%) with an odds ratio of 2.9, while the non-mesh group showed the lowest rate of wound seroma (4.7%). Increased seroma rates with the onlay approach may be explained by the dead space following the creation of the suprafascial flaps and the inherent characteristics of the mesh use. However, a large proportion of postoperative seromas are clinically innocuous and resolve without intervention. Nevertheless, an appreciation of the implications of each mesh position is important in determining the ideal strategy for mesh placement in prophylaxis.

Abdominal Aortic Aneurysm Incisional Hernia Prophylaxis

Aneurysmal disease of the aorta has been associated with a fivefold [40] increased risk of IH development compared with those patients undergoing surgery for aortic occlusive disease with rates as high as 38% [41]. Bevis et al. [42] reported an excellent outcome of their RCT with the use of preperitoneal polypropylene mesh as a reinforcement of the laparotomy closure at the time of open elective abdominal aortic aneurysm (AAA) repair. In this study, there were no exclusion criteria, and patients were not stratified. Among 85 randomized patients, 40 patients had a 15 × 15 cm polypropylene mesh placed preperitoneally before fascial closure, and 45 patients underwent standard fascial closure. With a follow-up ranging from 35 to 1510 days, the incidence of IH was significantly lower in the mesh group (13.5%) than in the non-mesh group (37.2%). Two infectious events in each group were recorded without any mesh infection. Two cases of seroma were recorded in the mesh group that did not have any significant consequences. A 2016 study of 120 AAA patients prospectively undergoing IH prophylaxis with a large-pore lightweight polypropylene mesh in the preperitoneal space performed at 8 centers demonstrated a reduction of IH rates from 28% to 0% with no mesh infections or increase in wound complications, although operative time was increased by 16 min [29].

In 2013, a task force group was created with the goal to investigate and elaborate guidelines for "the prevention of IH" [43]. The group reviewed the previously detailed six randomized controlled trials covering the 2003–2014 period, all of which studied different variants of polypropylene mesh in different anatomical locations. Despite the favorable and consistent data for prophylactic mesh augmentation, the Guidelines Development Group decided that larger trials are needed to make a strong recommendation to perform prophylactic mesh augmentation for all patients within certain risk groups.

At this time, there appears to be a benefit to IH prophylaxis with synthetic mesh in the studied patient populations. However, many unanswered questions remain regarding mesh type, mesh location, and mesh fixation. While all techniques appear safe and beneficial relative to sutured closure alone, it is unclear which strategy is most efficacious with the lowest incidence of adverse events.

Biologic Mesh IH Prophylaxis

Biologic meshes represent a heterogeneous group of materials derived from different biologic sources and have in common the valuable inherent property of being resistant to infection [44]. Despite their expense, their efficacy in complex and contaminated surgical environments is well established. Synthetic meshes have demonstrated efficacy in hernia repair, but their use is more frequently associated with wound infection compared to suture repair [45]. This fact has prompted some authors to investigate the use of the alternative biologic mesh as a reinforcement material to the laparotomy closure at the time of contaminated surgical operations (i.e., open bariatric surgery, etc.) or to prevent future prosthetic graft infection (i.e., open AAA repair, etc.). Sarr et al. [46] conducted a RCT targeting the outcome of porcine small intestinal submucosa mesh in the reinforcement of the midline incision after primary and revision Roux-en-Y gastric bypass surgery. A total of 380 morbidly obese patients with BMI averaging 48 kg/m^2 (range: 35–79) were selected excluding patients with pre-existing IH, known connective tissue disorder (i.e., Ehlers-Danlos syndrome), diastasis recti, umbilical hernia >2.5 cm in diameter, or active infection at the time of operation. The technique involved placement of the mesh with 4 cm lateral and 2 cm cranial/caudal overlap in a preperitoneal location with peripheral transfascial stitches and no associated drains. Two-year prospective follow-up was achieved in 75% of the 139 patients randomized to mesh reinforcement and in 72% of the 141 patients with standard fascial closure. There was no difference in IH rates between groups (17.3% mesh vs. 19.5% suture) in this study.

A study of gastric bypass patients undergoing hernia prophylaxis with a human acellular dermal matrix demonstrated a benefit compared to sutured closure alone [47]. This study utilized an intraperitoneal mesh placement using a 16 × 6 cm mesh. Significantly, more seromas (13.6%) were seen in association with mesh use compared to 1.6% in the non-mesh group. The incidence of IH at mean follow-up of 17 months was 2% in the mesh group compared with 18% in concomitant nonrandomized controls, suggesting a benefit to IH prophylaxis with a human acellular dermal matrix.

A study of 40 patients using bovine pericardium mesh [48] as a reinforcement of the midline laparotomy closure at the time of AAA repair utilized an onlay mesh with 4 cm overlap secured with a running nonabsorbable suture compared to sutured closure. Patients underwent annual physical examination and CT scan. With a 3-year follow-up of 95%, there were two seromas in the mesh group and one in the sutured closure. No other wound complications were recorded in either of the groups. The non-mesh group IH incidence was 31.6%, whereas no patients in the mesh group developed hernias.

The mixed results seen with IH prophylaxis utilizing biologic meshes are unable to clearly demonstrate a benefit. The overall small study sizes and heterogeneity in patient population and technique limit applicability. Appealing to the use of biologic mesh in IH prophylaxis is the inherent properties of biologic mesh resulting in infection resistance. The infection

resistance of biologic mesh may be advantageous when performing IH prophylaxis in clean-contaminated and contaminated surgical wounds. However, the relative cost of biologic mesh relative to synthetic mesh may represent a further constraint. As of the present time, we feel that the current evidence is not capable of supporting the use of biologic mesh for IH prophylaxis, but future investigations are warranted.

Parastomal Hernia Prophylaxis

Parastomal hernia (PSH) or enterostomy-associated hernia is by definition an IH created by a weakened abdominal wall traversed by an ostomy [49]. According to Israelsson [50], PSH is any palpable defect or bulge adjacent to the stoma detected when the patient is supine with legs elevated or while coughing or straining when the patient is erect and/or CT scan showing the protrusion of any intra-abdominal content along the ostomy. Enterostomies exist in different configurations and shapes that include temporary and permanent, end and loop, as well as ileostomy and colostomy. Ostomy types, variability in clinical and radiographic detection methods, heterogeneous patient groups, and heterogeneous follow-up periods are all contributing factors in the uncertainty of the true incidence of PSH. Nonetheless, it is widely accepted that the overall incidence approaches 50% [51].

It is important to distinguish PSH from similar yet different phenomena. In a Cochrane report on loop stomas, PSH was defined as the formation of a hernia beside the stoma; stoma prolapse was defined as eversion of the stoma [52]. Such differentiation is of great importance considering that the mechanism and the management of each are different. Mesh prophylaxis offers no benefit in the prophylaxis of stoma prolapse.

Any stoma through the abdominal wall results in a risk for subsequent parastomal herniation, which in turn may negatively affect quality of life and increase healthcare expenditures. Such hernias are common to the point where some degree of parastomal herniation has even been considered to be an almost inevitable complication of colostomy formation [50]. Carne et al. [51] wrote in 2003 a review discussing the available standardized means of decreasing the rate of PH. Although authors did not touch on the use of mesh as a means of lowering the rate of such hernias, they acknowledged the limitations of the armamentarium of tools available to surgeons in constructing enterostomies.

Considering the lowest recurrence rates for parastomal hernia repair are demonstrated with the use of mesh, some authors have investigated the use of prophylactic mesh at the time of stoma creation as a mean to decrease the incidence of parastomal herniation. This concept is in congruence with the repair of an IH with a mesh. Constructing a stoma essentially creates an IH, since it is characterized by abdominal contents protruding through a defect in the abdominal wall [53].

Parastomal Hernia Prophylaxis with Synthetic Mesh

Numerous case series, prospective trials, and systematic reviews have emerged since the first reported experience with the use of prosthetic mesh as a mean of reinforcing enterostomy sites at the time of stoma creation. In one of the largest RCTs to date by Jänes et al. [54, 55], reinforcement of permanent end colostomies with a 10 × 10 cm lightweight polypropylene and partially absorbable mesh was studied. The RCT included a total of 54 patients, half of which received prophylactic mesh. The investigators standardized their technique with the passage of the colostomy limb through an opening in the rectus muscle and the placement of the mesh in the retrorectus space. A cross cut of 2.5 × 2.5 cm in the center of mesh allowed the colostomy limb to traverse. The mesh was anchored to the posterior rectus sheath with absorbable stitches placed in its lateral corners. The authors included few emergency laparotomies (4 in the control group and 1 in the mesh group) and mostly elective colectomies with malignant pathology representing more than 80% the indications for surgery in both groups. With a follow-up averaging 24 months (12–38 months), only 1 IH was diagnosed in the mesh group in comparison to 13 in the control group. No wound complications or chronic pain were reported. With overwhelmingly favorable results, the trial was halted due to ethical concerns related to not routinely offering mesh prophylaxis. In a follow-up report, the authors published outcomes up to 5 years following initial operation [56]. The control group was reduced to 21 surviving patients with 17 cases of PSHs compared to 2 PSHs among the remaining 15 alive patients with prophylactic mesh. The control group witnessed a rate of PSH of 50% at 12 months and 81% at 5 years. Of the 2 patients from the mesh group found to have PSH, 1 was diagnosed after 12 months and another after 5-year follow-up. The wound complication rates remained unchanged for the entire duration of the follow-up and no mesh explantation was recorded. The authors concluded on the safety and efficacy of the prophylactic mesh use and they attributed such favorable results to two main factors: the lightweight nature of the partially absorbable mesh and its location in the retrorectus space away from the bowel. Although the quality of the study was good, the authors did not record the extra time required to place the mesh, and no final conclusions were drawn as the study was not blinded.

In the interim of this trial's long-term follow-up, other authors followed the lead and investigated the application of

different types of prosthetic meshes at the time of enterostomy creation. Berger [57] prospectively evaluated the outcome of 25 enterostomies subjected to the placement of an intraperitoneal mesh utilizing the modified Sugarbaker technique. In this study, a mesh made of a polyvinylidene fluoride (PVDF) with a small amount of polypropylene on the parietal side was utilized. The patient sample was a mix of laparoscopic and open cases and included 24 colostomies and 1 ileostomy. With a median of 11-month follow-up, the author reported no PSHs or wound complications on physical examination or CT scan obtained 6 months post-surgery on 12 patients.

Gogenur et al. [58] described an onlay approach with a laser cut polypropylene mesh with six arms to reinforce permanent end colostomies at the time of elective colorectal resection. A total of 25 patients were selected and prospectively followed for 1 year with clinical examination and abdominal wall ultrasounds at 6 and 12 months. Only two PSHs were documented on ultrasounds, and no wound/mesh complications were reported. A keyhole approach was studied by Marimuthu et al. [59] utilizing a polypropylene mesh placed preperitoneally at the time of 18 elective end colostomy creations. With a follow-up reaching up to 28 months, they reported no PSHs or any other direct complications.

As proven by experience, there is frequently discrepancy between the rate of hernias diagnosed with abdominal wall imaging (i.e., ultrasounds, CT scan, etc.) and those reported clinically. This is to say that some subclinical PSHs may have been missed in the few reported studies. Despite this weakness in the current literature, we do not feel this should significantly affect the overall perception of the benefits of prophylactic mesh use.

Shabbir et al. [60] reported the first systematic review investigating the outcomes with the use of prosthetic mesh at the time of primary stoma creation. The study evaluated publications between 1980 and 2010 including English and foreign language written series but did not differentiate between synthetic and biologic meshes. The meta-analysis selected 3 RCTs with a total of 128 patients of which 50% had mesh placed at the time of the index surgery.

Although methodological flaws exist within the three RCTs and the overall patient population was small, this systematic review demonstrated that the use of a prophylactic mesh at the primary operation reduces the incidence of PSH with a hernia incidence of 12.5% in the mesh group compared to 53% in the control group (risk ratio, 95%, CI, 0.25 (0.13, 0.48), $p < 0.0001$) with a follow-up period of 7–83 months. This study did not identify the optimal mesh type or anatomic location but further reinforced the benefits of prophylaxis while acknowledging the need for a large randomized, double-blind clinical trial with long-term follow-up before advocating mesh use as a standardized approach.

Among the RCTs identified in the meta-analysis was a trial evaluating the use of prophylactic mesh reinforcement at the time of temporary ileostomy creation. This prospective randomized trial evaluated 20 patients utilizing a cross-linked porcine dermal matrix for parastomal prevention [61]. After an average follow-up of approximately 6 months, fewer hernias were seen in the mesh group than in controls (0% vs. 30%). Despite the results of this small study, we question the value of mesh prophylaxis at the time of temporary fecal diversion. The added cost, potential for mesh complications, and potential for increased difficulty of a subsequent operation related to adhesions are not clear. And accordingly we would not recommend prophylaxis in this situation.

Lopez-Cano et al. reported two successive RCTs in the years of 2012 [62] and 2016 [63]. A large-pore lightweight composite mesh was used in both trials (12 × 12 cm polypropylene/oxidized regenerated cellulose and 15 × 15 cm polypropylene/poliglecaprone 25 mesh, respectively). A sublay keyhole technique was adopted in the first study and the Sugarbaker technique in the later trial. In both RCTs, the studied groups were homogeneous, without statistically significant differences in all epidemiological characteristics and risk factors. The first trial included 36 patients with lower rectal cancer of which 19 were randomized to the mesh group and 17 to the control group, excluding patients with prior hernia repair with mesh or life expectancy less than 1 year. At 12 months, a CT scan was obtained demonstrating 9 (50%) PSHs among 18 patients in the mesh group and in 15 of 16 (93.8%) patients in the control group ($p = 0.008$). Further hernia repair was required on three patients from the control group and on one in the mesh group. The latter RCT recruited 52 patients comprised of a group of 28 mesh prophylaxis colostomy patients and 24 controls. Follow-up CT scans were again obtained at 12 months. In this study, 6 of 24 patients (25%) were observed in the mesh group compared with 18 of 28 (64.3%) in the non-mesh group (odds ratio 0.39, 95% confidence interval 0.18–0.82; $p = 0.04$). The authors did not experience any mesh-related complications in either of the RCTs. The rate of PSH was reduced by 50% between trials and between the mesh groups. Plausible explanations for outcome differences between these two studies include difference in the surgical technique in placing the mesh within the peritoneal cavity or the inherent characteristics of the mesh. The finding of noticeable difference between the rates of PSH between the non-mesh groups is of unknown significance considering that the technique of ostomy construction was similar.

A systematic review of RCTs between 1980 and March of 2016 evaluated eight RCTs comparing mesh prophylaxis and non-reinforced stomas (522 patients) [64]. The mesh group was found to have significantly lower risk ratio, 0.2 (95% confidence interval 0.13–0.38; $p < 0.00001$). This systematic

review has also proven the safety of mesh use as the rate of the wound complications was found similar between the study and the control groups. The authors concluded that mesh reinforcement of primary colostomy formation is a promising method for the prevention of parastomal herniation.

A 2017 meta-analysis evaluated 10 randomized trials with a total of 649 patients of which 324 patients underwent mesh prophylaxis at the time of their index surgery. Parastomal herniation was found in 53 of 324 (16.4%) in the mesh group and 119 of 325 (36.6%) in the non-mesh group ($p < 0.001$). The type of mesh used and/or its anatomical location did not have any significant bearing on those favorable results. Furthermore, no differences in the wound and/or ostomy complication were reported between groups. A contemporaneous 2017 meta-analysis of 7 randomized PSH mesh prophylaxis trials (encompassing 432 patients) excluded studies with less than 12-month follow-up [65]. This study evaluated mesh type (synthetic and biologic) and technique of placement (onlay, inlay, and sublay) as well as the surgical approach (open and laparoscopic). Similar to other studies, mesh use was concluded to be safe and effective with 10.8% of PSH formation in the mesh group and 32.4% in the non-mesh group ($p = 0.001$). The rate of hernia formation was greater in both arms when radiological evaluations for hernia diagnosis were utilized, but the difference in outcomes remained significant (34.6% in mesh vs. 55.3% in the non-mesh group).

In the largest meta-analysis of this topic, Pianka et al. [61] evaluated manuscripts written in any language including 11 randomized and 3 nonrandomized controlled trials comprising a total of 755 patients. Like others, the RCTs demonstrated a significant decrease of PSH incidence in the mesh group (OR 0.24; 95% CI 0.10–0.58, $p = 0.034$). However, non-RCTs showed no benefit of mesh usage.

Although individual studies are limited in patient numbers, the collective body of evidence is supportive of the use of prophylactic mesh during stoma creation. Mesh complications are infrequent, and hernia rates are dramatically reduced. Although long-term follow-up is lacking in many studies, the benefits to the use of mesh are compelling. Identification of the ideal prosthetic, anatomic location, and technique for placement remain areas requiring further investigation.

PSH Prophylaxis with Biologic Mesh

Biologic mesh may be considered an alternative to a synthetic mesh in the prevention of PSH and may be favored by some in an attempt to avoid long-term complications associated with synthetic mesh. Although mesh erosion and infection are possible, the incidence of these events is low. Nevertheless, interest in biologic materials has resulted in several small series of parastomal prophylaxis. While these studies would not be considered landmark publications, they provide some insight into the anticipated outcomes associated with their use in PSH prophylaxis.

To date, there are limited publications evaluating the role of biologic mesh in the prevention of PSH. These studies include the previously mentioned randomized trial by Hammond et al. [66] evaluating PSH prophylaxis of loop ileostomy as well as a double-blinded multicenter RCT by Fleshman et al. [67] evaluating a non-cross-linked porcine acellular dermal matrix in patients undergoing elective permanent end stoma creations (71 colostomies, 42 ileostomies). In the latter study, the surgical technique was not standardized as the measured ostomy circumference in the mesh prophylaxis group was significantly larger (6.4 ± 3.9 vs. 4.8 ± 2.9 cm; $p = 0.002$) than the control group. Stoma size has been demonstrated to be directly related to the incidence of parastomal herniation with higher rates of hernia seen when the aperture is greater than 35 mm [68]. The larger stoma apertures in the mesh group may have impacted outcomes in this study. Nevertheless, the surgical technique was standardized to a mesh (average size 4.8 × 4.8 cm) with a 2 cm cruciate opening in the center of the mesh positioned in the retrorectus space without fixation. Following 24 months of follow-up, there was no difference in the incidence of parastomal herniation between groups (12.2% mesh vs. 13.2% control) with similar quality of life indicators. Accordingly, no benefit could be ascribed to the use of biologic mesh in the prevention of PSH in this study.

In light of the paucity of compelling data evaluating the role of biologic mesh for PSH prophylaxis, it is difficult to recommend this practice. Further well-designed studies comparing biologic mesh PSH prophylaxis to both synthetic mesh prophylaxis and controls are needed to fully understand both the advantages and drawbacks.

Conclusion

IHs are the most common complication of a laparotomy. Efforts to reduce the incidence of IH are needed due to the cost and morbidity of IH repair. Identification of patients at greatest risk for the development of IH may provide opportunities for demonstrating the greatest patient benefit when utilizing techniques to prevent IH. Numerous studies have demonstrated a benefit to the placement of mesh at the time of laparotomy closure in high-risk groups with morbidity comparable to sutured laparotomy closure. In light of the current evidence, consideration for placement of prophylactic mesh at the time of laparotomy closure in studied patient populations should be considered. It is not clear whether routine prophylaxis of all abdominal incisions will translate into improved outcomes and at this time cannot be recommended as a routine practice.

Complications following the placement of prophylactic mesh during laparotomy closure are infrequently reported and similar to the incidence of wound complications following laparotomy closure with sutures. Considering the incidence of IH today, further evaluation and assessment of current laparotomy closure techniques is warranted.

PSH rates are exceedingly common following the creation of stomas. Careful surgical technique with small stomal apertures and the use of prophylactic mesh may minimize hernia rates. Synthetic polypropylene mesh has demonstrated efficacy and safety when utilized adjacent to a stoma in the prevention of PSH. Despite the potential for inoculation of mesh with bacteria during stoma creation, synthetic mesh placed at the site of colostomy infrequently results in complications. Future studies will be required to understand the best techniques, mesh choice, and fixation methods when performing PSH prophylaxis.

Abdominal operations are performed commonly with significant rates of postoperative hernia formation. Efforts to reduce the incidence of this common complication should translate into improved patient outcomes and reduced healthcare costs. The use of mesh as a prophylactic measure is a burgeoning approach to enhancing patient care outcomes following abdominal surgery.

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