Incisional Reinforcement in High-Risk Patients

Timothy F. Feldmann, MD¹ Monica T. Young, MD¹ Alessio Pigazzi, MD, PhD¹

¹ Department of Surgery, University of California Irvine, Orange County, California

Address for correspondence: Alessio Pigazzi, MD, PhD, Department of Surgery, University of California, Irvine School of Medicine, 333 City Blvd. West Suite 1600, Orange County, CA 92868 (e-mail: apigazzi@uci.edu).

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Abstract

Hernia formation after surgical procedures continues to be an important cause of surgical morbidity. Incisional reinforcement at the time of the initial operation has been used in some patient populations to reduce the risk of subsequent hernia formation. In this article, reinforcement techniques in different surgical wounds are examined to identify situations in which hernia formation may be prevented. Mesh use for midline closure, pelvic floor reconstruction, and stoma site reinforcement is discussed. Additionally, the use of retention sutures, closure of the open abdomen, and reinforcement after component separation are examined using current literature. Although existing studies do not support the routine use of mesh reinforcement for all surgical incisions, certain patient populations appear to benefit from reinforcement with lower rates of subsequent hernia formation. The identification and characterization of these groups will guide the future use of mesh reinforcement in surgical incisions.

Keywords

- incisional reinforcement
- mesh reinforcement
- wound closure
- incisional hernia

CME Objectives:

- Review current literature on incisional reinforcement
- Examine the use of biologic materials in wound closure
- Review closure options for open abdomens and complex hernias

The prevention of wound dehiscence and incisional hernia formation has long been an area of challenge to general surgeons and surgical specialists. Using a mesh prosthesis to strengthen a surgical repair was first attempted at the end of the 19th century.¹ Surgeon Oscar Witzel used handmade silver wires interwoven in a filigree pattern and implanted them as a prosthetic mesh.² Although initial results seemed promising, the silver mesh fell out of favor in the late 1950s due to patient discomfort, seroma formation, sinus tract formation, and the development of new synthetic materials.³ Polypropylene was introduced in 1954 by Nobel Prize winner Giulio Natta and Karl Ziegler, and became widely adopted as the material of choice for hernia repair.

Rising costs of health care worldwide have resulted in a great impetus to find ways of preventing postoperative hernia formation. Although advanced materials such as biologics are expensive, the potential savings gathered by a decreased rate of hernia recurrence are significant. Furthermore, being able

to prevent the morbidity and mortality associated with wound dehiscence and hernia formation offers unmistakable rewards. The objective of this article is to review current indications, evidence, and outcomes of incisional reinforcement in high-risk patients with midline laparotomy, perineal incisions, an open abdomen, component separation, and ostomy takedown procedures.

Midline Laparotomy Reinforcement and Modern Alternatives to “Retention Sutures”

Entrance into the peritoneal cavity may be achieved through a multitude of surgical incisions. A vertical midline incision through the linea alba is commonly used to provide exposure and allow visualization of all portions of the abdominal cavity. However, one of the limitations of this incision is that it carries a higher risk of hernia formation. Incisional hernias are estimated to occur in 5 to 15% of patients at 1 year.^{4–6} In a long-term study by Mudge and Hughes,⁷ 11% of patients had developed a hernia 10 years after their initial operation. This number can be significantly larger in high-risk patients such as the morbidly obese, rising to an incisional hernia rate of between 26 and 39% at 1 year.⁸ Overall risk of hernia formation should be evaluated on a case-to-case basis, as each

patient can have different factors predisposing them to this condition. Risk factors such as age, nutrition, body mass index, comorbidities, the presence of infection, and tobacco use should all be taken into account during surgical planning for a patient's method of abdominal closure.

Currently, the most widely used technique for closure of the midline laparotomy incision is a continuous looped absorbable suture.^{9,10} Even with precise surgical technique and the optimal suture length to incision length ratio, the overall incidence of incisional hernia following laparotomy is reported to be between 11 and 23%.¹¹ Due to the high rate of hernia formation, prophylactic use of mesh has been considered to reinforce these defects. Both biologic and synthetic mesh have been used and shown to lower incidence of hernia formation in high-risk patients.^{11–15} However, there are limited data supporting the use of reinforcement in routine midline laparotomies.¹⁶ The randomized controlled trials that have been published to date are small with relatively short follow-up periods.^{13–15} In 2011, Llaguna et al¹¹ analyzed 134 patients who underwent open Roux-en-Y gastric bypass to evaluate if prophylactic use of a biologic mesh protects against the development of incisional hernia for high-risk patients. In this randomized controlled trial, the overall incidence of incisional hernia was 11.3%, with significantly lower incidence in the mesh group compared with the nonmesh group (2.3 vs. 17.7%). A few older randomized controlled studies by Strzelczyk et al¹⁷ and Gutiérrez de la Peña et al¹² similarly found prophylactic polypropylene mesh placement to be protective against incisional hernia development. While long-term outcomes of prophylactic mesh use are still unclear, mesh repair of incisional hernias after laparotomy has been found to be safe and effective, particularly when used as an underlay reinforcement.^{18,19}

In 2010, the Ventral Hernia Working Group (VHWG) proposed a grading system to better assess each patient's risk for surgical-site occurrence or hernia occurrence. With regard to the choice of repair material, the authors of this article emphasized the selection of biologic reinforcement for increasing amounts of contamination in ventral hernias.²⁰ This recommendation has been adopted and promoted by many surgeons; however, there are no randomized prospective studies comparing the clinical outcomes of biologic versus nonbiologic grafts in hernia repair. A recent systematic review and meta-analysis by Darehzereshki and colleagues²¹ concluded that the use of biologic mesh for ventral hernia repair results in less surgical site infections but similar recurrence rates compared with nonbiologic mesh. Another recent study by Souza and Dumanian²² challenged the recommendation by the VHWG, stating that the use of uncoated polypropylene mesh to reinforce midline ventral hernia repairs was not associated with increased rates of infection, fistula formation, or clinically significant adhesions. It is important to note that the cost of biologic mesh is significantly higher than that of synthetic materials. In 2012, Reynolds and colleagues published an analysis of the financial implications of ventral hernia repair.²³ In their review of cost data on 415 consecutive patients undergoing open ventral hernia repair, the median direct cost for cases performed without mesh was \$5,432, median

direct cost for repairs using synthetic mesh was \$7,590, and median direct cost for repair with biologic mesh was \$16,970. Further studies are necessary to determine if routine use of these materials for reinforcement will prove to be cost-effective through improvements in long-term outcomes.

Despite many advances in surgical technology, fascial dehiscence still ranges from 0.2 to 6% with mortality ranging from 9 to 44%.^{24,25} Wound infection plays one of the largest roles in the breakdown of a fascial closure.²⁶ There is little evidence supporting the routine use of retention sutures in the general patient population; however, they may be of use in high-risk groups.²⁷ A recent study by Khorgami et al examined 300 high-risk patients undergoing midline laparotomy. Closure was randomized to continuous running looped suture versus continuous running looped suture with added retention sutures. They found a higher rate of dehiscence (13.5 vs. 4.1%) and reoperation for dehiscence (13.5 vs. 3.4%) in the group without retention sutures.²⁷ Each patient had at least two of the following risk factors: poor nutritional status, emergent surgery, intra-abdominal infection, advanced malignancy, use of steroids within the last 12 months, uremia, hemodynamic instability, anemia, abdominal distension such as due to ascites, chronic pulmonary disease, age greater than 60 years, diabetes, or jaundice.²⁷ Retention sutures are still useful in certain circumstances and their use should be assessed on an individual patient basis. Disadvantages to the use of retention sutures are unsightly scarring that may result from their use, as well as added postoperative pain. Perhaps this could be avoided by replacing retention sutures with prophylactic mesh reinforcement, although no studies have been performed analyzing outcomes of this technique in conjunction with mesh placement or compared with mesh placement for laparotomy closure or hernia repair.

Reinforcement of a midline incision may be advantageous in some high-risk patients, but this specific population has yet to be described. Studies have described methods that are useful in predicting those that will develop an incisional hernia, but none have been effective in predicting hernia based on information known at the time of incisional closure.²⁸ This limits our ability to employ the most cost-effective use of mesh prophylaxis. Routine mesh reinforcement does not appear to have a defined role at this time, but appears to have the potential to decrease recurrence rates. The choice of mesh must take into account the contamination of the surgical field and the patient's risk factors that would predispose to poor wound healing.

Abdominoperineal Resection Incision and Pelvic Floor Reinforcement

Abdominoperineal resection (APR) allows for treatment of cancers of the anus and low rectum. A permanent end colostomy is created after resection of the anal complex and closure of the perineum. The perineal wound has been a source of frequent complication since the operation was first performed in 1908.²⁹ Multiple techniques have been applied with varying success. Perineal wound complications are estimated to occur in up to 66% of cases.^{30,31}

Myocutaneous flaps have been used as an alternative to primary closure of the perineal wound after APR. This technique transfers healthy tissue from the abdominal wall into the pelvic cavity. In 1984, Shukla and Hughes described using a vertical rectus abdominis myocutaneous flap for perineal closure in three patients.³² Several decades later in 2010, Shukla and Tewari reviewed 22 studies describing the use of a rectus flap for perineal cancer resection and showed improved morbidity.³⁰ The gracilis flap was also used as an alternative to primary closure.^{33,34} Although it appears to have lower morbidity, one drawback of the gracilis flap is the limited amount of tissue which can be provided for large defects in the perineum. Tan et al³⁵ have also proposed a lower gluteal muscle flap to overcome this disadvantage; initial results have been favorable in small series.

The rate of wound complications can double when primary closure is performed in patients undergoing neoadjuvant radiation therapy.³⁶ Myocutaneous flap coverage has been shown to significantly decrease wound complications in these patients.^{31,37–39} However, these improved outcomes come at a cost. The majority of myocutaneous flap procedures are performed by plastic surgeons leading to increased expense and a longer operative time due to a larger dissection.⁴⁰ Christensen et al⁴¹ also noted a longer mean hospital stay after flap procedures compared with a perineal mesh repair (14 vs. 9 days).

APR has historically been associated with poor oncological outcomes, specifically high local recurrence rates of up to 30%, despite aggressive adjuvant therapy.⁴² These outcomes may be due to the technical challenges of the operation or aggressive tumor characteristics that require APR. Regardless, some surgeons have adopted a more cylindrical dissection or extra levator abdominoperineal excision (ELAPE) as a means of ensuring negative circumferential margins. While this appears to have improved oncologic outcomes, these surgical techniques also result in the creation of a larger pelvic defect. Reconstruction of the pelvic floor with a biologic or synthetic mesh can be accomplished by attaching the mesh to the origin of the levator muscles, which are removed during an ELAPE.⁴³ This allows for reinforcement of the pelvis underneath the ischiorectal fat and perineal skin (►Fig. 1). Due to the contamination inherently present in the surgical field, use

of synthetic mesh has rarely been described.⁴⁴ However, multiple biologic meshes have been studied and appear to have similar outcomes to flap reconstruction.^{40,41,45} A systematic review performed in 2011 by Foster et al⁴⁵ examined 11 cohorts with a pooled analysis of 255 patients undergoing flap repair and 85 patients undergoing biologic mesh repair. There was no significant difference in perineal complications between the two groups. Marshall et al⁴³ similarly reviewed nine articles examining the use of biologic mesh after ELAPE and concluded that outcomes of reconstruction with biologics is comparable to that of myocutaneous flaps. There are no current studies analyzing outcomes between different types of biologic mesh.

Perineal wound closure after APR continues to be an evolving field. Primary closure in a nonradiated patient is reasonable; however, advanced closure techniques may allow for improved outcomes overall. Myocutaneous flaps are a surgical option but can lead to longer operative times, increased cost, and a longer hospital stay.⁴¹ Recent literature has shown biologic mesh reinforcement to be a viable closure method.⁴⁵ Additional research is necessary to evaluate short- and long-term outcomes of these approaches.

Dealing with the Open Abdomen

An open abdomen presents a complex surgical wound that must be managed until the patient's status improves. The open abdomen can result from a variety of intra-abdominal catastrophes in which a patient's physiological status or underlying disease process does not allow for a complete fascial closure at the time of initial operation. Many techniques have been applied throughout surgical history to treat this condition including vacuum-assisted devices, mesh implantation, Bogota bags, Wittmann patch, abdominal packing, and dynamic retention sutures.⁴⁶ Rates of mortality and morbidity following this condition are often high due to the patient's underlying status as well as the typically long length of hospital stay. Complication rates can range from 10 to 52% depending on the method used and the etiology of the illness.⁴⁷ Morbidities such as enteroatmospheric fistula (1–41%), abscess (2–21%), or ventral hernia development (32–100%) can be seen.⁴⁷

Mesh closure of an open abdomen is usually accomplished by bridging a biologic or synthetic mesh across the fascial defect. This prosthetic may provide the only barrier protecting the viscera from the external environment. Mesh cinching or further coverage with a split-thickness skin graft can be considered depending on the individual circumstances in an attempt to maximize coverage of the defect.⁴⁸ Some studies have shown higher fistula formation with synthetic meshes.^{49,50} For example, Fansler et al⁵⁰ showed fistula rates of 40 to 50% after synthetic mesh use in midline wounds that were allowed to close by secondary intention or split-thickness skin grafting. For this reason, biologic meshes have become more widely used for closure of midline defects after laparotomy.⁴⁶

Although placement of a bridging mesh may allow for temporary abdominal closure, many of these patients (21–37%) will

Fig. 1 Reinforcement of the pelvic floor with mesh after abdominal perineal resection.

still require definitive closure in the future.⁴⁸ Quyn et al⁴⁶ reported a closure rate of only 35% in a meta-analysis of 106 articles describing management of the open abdomen. The highest closure rates described in the literature have been reported with the Wittmann patch, dynamic retention sutures, and vacuum therapy.⁴⁶ As expected, methods that result in higher rates of fascial closure were associated with lower rates of postoperative morbidity and mortality.^{47,51} It is important to note that no single closure method has been shown to be ideal and further research is necessary to determine the long-term role of prosthetic compared with biologic mesh use. Therefore, individual surgeon experience should guide decision making and influence the chosen technique that is safe and feasible in these complex patients.

Component Separation Reinforcement

Mesh has been used in the reinforcement of ventral hernias since the early 1990s.⁵² The concept of prosthetic reinforcement developed because of unacceptable high recurrence rates following traditional methods of hernia repair.^{53,54} Studies with long-term follow-up reported recurrence rates greater than 50% following primary open suture repair with fascial reapproximation.^{55–57} After development of synthetic mesh, techniques of tension-free mesh reinforcement rapidly gained widespread acceptance for hernia repair. However, the ideal method of mesh implantation is still under debate and long-term recurrence rates have been reported to be as high as 32%.^{18,58,59} In 1990, Ramirez et al⁶⁰ described the technique of medial fascial advancement to assist with midline closure. In this article, the posterior rectus sheath was first released and then, if necessary, the external oblique was secondarily released. Recurrence rates after a component separation have been reported to range between 10 and 22%.^{61–64} Obesity, age, male gender, postoperative seroma, and preoperative infection have all been identified as risk factors for hernia recurrences.⁶⁵

Several studies have examined the use of biologic and synthetic mesh during component separation with varying results.^{62,63,65,66} Lowe et al examined 30 patients undergoing component separation for closure of complex abdominal wall defects; however, 23% of patients did not have complete fascial reapproximation.⁶⁴ In these circumstances, mesh can be used to bridge the remaining defect present after release of the components. However, studies have shown that reapproximation of the linea alba leads to lower rates of recurrence.^{60,64,67} Care must be taken if biologic mesh is used for this purpose, as breakdown over time may result in high hernia recurrence rates, reportedly up to 80%.⁶⁷

A variety of techniques have been described for medial fascial advancement. These can broadly be divided into anterior and posterior approaches to component separation. A review of the literature and surgical techniques recently published by Pauli and Rosen described multiple options for component separation with mesh reinforcement.⁶⁸ The mesh can be placed as an underlay within the peritoneal cavity, sublay within the retrorectus space (► Fig. 2), or an onlay over the closed midline repair. Regardless of the implant location or

Fig. 2 Mesh reinforcement after posterior component separation. The mesh is placed as a sublay in the retrorectal space.

type, the authors recommend securing the mesh with slowly absorbing monofilament suture and placing it under physiologic tension. Drains are also generally placed above the mesh regardless of implant location. Recurrence rates after anterior component separation were reported to range between 3 and 32% and recurrence rates after posterior component separation ranged between 1.1 and 7.3%.⁶⁸ Another recent article by Alicuben and Demeester⁶⁹ described their experience and outcomes of biologic onlay mesh reinforcement for ventral hernia repair. The majority (73%) of patients also underwent a bilateral external oblique component separation. Median hospital length of stay was 7 days and intervention for seroma formation occurred in 27% of patients. Although the series is small with a total of 22 patients, there was only one hernia recurrence at median follow-up of 7 months. The recurrence occurred in a patient who was bridged with mesh as a staged procedure for loss of domain.

As with all prosthetic devices, the risk of infectious complications and erosion must always be considered. No definitive evidence has shown a specific mesh product to be superior and factors such as cost, recurrence, and the presence of infection can help guide the choice of mesh used. Familiarity with multiple reinforcement techniques allows for adaptability during complex abdominal wall reconstruction.

Ostomy Takedown Site Reinforcement

Ostomy reversal can provide patients with improved quality of life but carries considerable potential for postoperative complications. Hernia formation at a previous ostomy site occurs in up to 30% of patients and half of these patients will require surgical intervention.⁷⁰ Subsequent operations for repair of a ventral hernia carry further potential for morbidity. The current standard for stoma reversal is to primarily close the fascial defect present at an ostomy site. If a hernia occurs, it is electively repaired in a standard fashion using laparoscopic or open techniques.

Slater et al⁷¹ performed a systematic review of ventral hernia repairs with biologic mesh placement in 2013 and

reported postoperative infection and overall rate of surgical morbidity as key factors in hernia recurrence. A significant difference in recurrence was seen between clean and clean-contaminated cases (2.9%) versus contaminated and dirty cases (23.1%). These infectious complications must be taken into consideration when placing mesh at an ostomy site. A large prospective study performed by Helgstrand et al⁷² in 2013 examined a Danish database of elective incisional hernia repairs. Rates of 30-day readmission and 30-day reoperation were found to be 13.3 and 2.2%, respectively. New techniques to decrease the rate of stoma site hernia formation would help prevent additional perioperative morbidity associated with reoperation and readmission.

Prophylactic mesh placement at the time of stoma closure has been described as a potential method of decreasing hernia formation. However, ostomy site closure is slightly complicated by the presence of contamination from intestinal flora at the surgical site. No large scale studies have been performed examining outcomes of mesh placement at the time of stoma closure. Synthetic and biologic meshes have been examined for other indications, such as parastomal hernia repair, with favorable results.^{73,74} Liu et al described the use of a synthetic onlay mesh placed during stoma closure. No difference in overall complication rates was seen when compared with conventional ostomy closure and no mesh infections were reported.⁷⁵ Hernias were seen in 36.1% of the stomas closed without mesh and only 6.4% of the stomas closed with mesh. A slightly modified approach was taken by van Barneveld et al who reported a decrease in hernia formation after intraperitoneal mesh placement at the time of stoma creation.⁷⁶ This mesh was then reapproximated during ostomy reversal. No hernias were seen postoperatively at a median follow-up of 26 months.

Ostomy site closure carries a significant risk of hernia formation leading to long-term morbidity. In some limited studies, mesh reinforcement has been shown to decrease hernia recurrence at these sites without an increase in infectious complications. However, mesh choice has not been standardized and further investigation is needed to determine optimal technique and prosthetic material. Additional research is also necessary to determine perioperative and long-term outcomes of routine stoma site reinforcement during ostomy takedown.

Conclusion

A multitude of different techniques have been described to close and reinforce surgical incisions. Primary suture closure of a wound is no longer the only option. New materials and methods have altered the standard approach to treatment of abdominal incisions or complex ventral hernias, and this continues to evolve with scientific advancements. Although mesh reinforcement is not the standard of care for the majority of surgical incisions, emerging data show that it may have long-term benefits in hernia formation and recurrence. As new materials emerge and production cost is reduced, the role of mesh in incisional reinforcement will likely continue to expand.

References

- Basile F, Biondi A, Donati M. Surgical approach to abdominal wall defects: history and new trends. *Int J Surg* 2013;11(Suppl 1): S20–S23
- Jacob BP, Ramshaw B. Society of American Gastrointestinal Endoscopic Surgeons. The SAGES manual of hernia repair. Springer; 2013
- Poole GV Jr. Mechanical factors in abdominal wound closure: the prevention of fascial dehiscence. *Surgery* 1985;97(6): 631–640
- O'Dwyer PJ, Courtney CA. Factors involved in abdominal wall closure and subsequent incisional hernia. *Surgeon* 2003;1(1): 17–22
- Naraynsingh V, Maharaj R, Dan D, Hariharan S. Strong linea alba: myth or reality? *Med Hypotheses* 2012;78(2):291–292
- Burger JW, Lange JF, Halm JA, Kleinrensink GJ, Jeekel H. Incisional hernia: early complication of abdominal surgery. *World J Surg* 2005;29(12):1608–1613
- Mudge M, Hughes LE. Incisional hernia: a 10. year prospective study of incidence and attitudes. *Br J Surg* 1985;72(1):70–71
- Caro-Tarrago A, Olona Casas C, Jimenez Salido A, Duque Guilera E, Moreno Fernandez F, Vicente Guillen V. Prevention of incisional hernia in midline laparotomy with an onlay mesh: a randomized clinical trial. *World J Surg* 2014;38(9):2223–2230
- Weiland DE, Bay RC, Del Sordi S. Choosing the best abdominal closure by meta-analysis. *Am J Surg* 1998;176(6):666–670
- Diener MK, Voss S, Jensen K, Büchler MW, Seiler CM. Elective midline laparotomy closure: the INLINE systematic review and meta-analysis. *Ann Surg* 2010;251(5):843–856
- Llaguna OH, Avgerinos DV, Nagda P, Elfant D, Leitman IM, Goodman E. Does prophylactic biologic mesh placement protect against the development of incisional hernia in high-risk patients? *World J Surg* 2011;35(7):1651–1655
- Gutiérrez de la Peña C, Medina Achirica C, Domínguez-Adame E, Medina Díez J. Primary closure of laparotomies with high risk of incisional hernia using prosthetic material: analysis of usefulness. *Hernia* 2003;7(3):134–136
- Strzelczyk JM, Szymański D, Nowicki ME, Wilczyński W, Gaszynski T, Czupryniak L. Randomized clinical trial of postoperative hernia prophylaxis in open bariatric surgery. *Br J Surg* 2006;93(11): 1347–1350
- El-Khadrawy OH, Moussa G, Mansour O, Hashish MS. Prophylactic prosthetic reinforcement of midline abdominal incisions in high-risk patients. *Hernia* 2009;13(3):267–274
- Bevis PM, Windhaber RA, Lear PA, Poskitt KR, Earnshaw JJ, Mitchell DC. Randomized clinical trial of mesh versus sutured wound closure after open abdominal aortic aneurysm surgery. *Br J Surg* 2010;97(10):1497–1502
- Bhangu A, Fitzgerald JE, Singh P, Battersby N, Marriott P, Pinkney T. Systematic review and meta-analysis of prophylactic mesh placement for prevention of incisional hernia following midline laparotomy. *Hernia* 2013;17(4):445–455
- Strzelczyk J, Czupryniak L, Loba J, Wasiak J. The use of polypropylene mesh in midline incision closure following gastric by-pass surgery reduces the risk of postoperative hernia. *Langenbecks Arch Surg* 2002;387(7-8):294–297
- Luijendijk RW, Hop WC, van den Tol MP, et al. A comparison of suture repair with mesh repair for incisional hernia. *N Engl J Med* 2000;343(6):392–398
- Burger JW, Luijendijk RW, Hop WC, Halm JA, Verdaasdonk EG, Jeekel J. Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. *Ann Surg* 2004; 240(4):578–583, discussion 583–585
- Breuing K, Butler CE, Ferzoco S, et al; Ventral Hernia Working Group. Incisional ventral hernias: review of the literature and recommendations regarding the grading and technique of repair. *Surgery* 2010;148(3):544–558

- 21 Darehzereshki A, Goldfarb M, Zehetner J, et al. Biologic versus nonbiologic mesh in ventral hernia repair: a systematic review and meta-analysis. *World J Surg* 2014;38(1):40–50
- 22 Souza JM, Dumanian GA. Routine use of bioprosthetic mesh is not necessary: a retrospective review of 100 consecutive cases of intra-abdominal midweight polypropylene mesh for ventral hernia repair. *Surgery* 2013;153(3):393–399
- 23 Reynolds D, Davenport DL, Korosec RL, Roth JS. Financial implications of ventral hernia repair: a hospital cost analysis. *J Gastrointest Surg* 2013;17(1):159–166, discussion 166–167
- 24 Riou JP, Cohen JR, Johnson H Jr. Factors influencing wound dehiscence. *Am J Surg* 1992;163(3):324–330
- 25 Ramneesh G, Sheerin S, Surinder S, Bir S. A prospective study of predictors for post laparotomy abdominal wound dehiscence. *J Clin Diagn Res* 2014;8(1):80–83
- 26 Gislason H, Grønbech JE, Søreide O. Burst abdomen and incisional hernia after major gastrointestinal operations—comparison of three closure techniques. *Eur J Surg* 1995;161(5):349–354
- 27 Khorgami Z, Shoar S, Laghaie B, Aminian A, Hosseini Araghi N, Soroush A. Prophylactic retention sutures in midline laparotomy in high-risk patients for wound dehiscence: a randomized controlled trial. *J Surg Res* 2013;180(2):238–243
- 28 Veljkovic R, Protic M, Gluhovic A, Potic Z, Milosevic Z, Stojadinovic A. Prospective clinical trial of factors predicting the early development of incisional hernia after midline laparotomy. *J Am Coll Surg* 2010;210(2):210–219
- 29 Perry WB, Connaughton JC. Abdominoperineal resection: how is it done and what are the results? *Clin Colon Rectal Surg* 2007;20(3):213–220
- 30 Shukla HS, Tewari M. An evolution of clinical application of inferior pedicle based rectus abdominis myocutaneous flap for repair of perineal defects after radical surgery for cancer. *J Surg Oncol* 2010;102(3):287–294
- 31 Chessin DB, Hartley J, Cohen AM, et al. Rectus flap reconstruction decreases perineal wound complications after pelvic chemoradiation and surgery: a cohort study. *Ann Surg Oncol* 2005;12(2):104–110
- 32 Shukla HS, Hughes LE. The rectus abdominis flap for perineal wounds. *Ann R Coll Surg Engl* 1984;66(5):337–339
- 33 Shibata D, Hyland W, Busse P, et al. Immediate reconstruction of the perineal wound with gracilis muscle flaps following abdominoperineal resection and intraoperative radiation therapy for recurrent carcinoma of the rectum. *Ann Surg Oncol* 1999;6(1):33–37
- 34 Persichetti P, Cogliandro A, Marangi GF, et al. Pelvic and perineal reconstruction following abdominoperineal resection: the role of gracilis flap. *Ann Plast Surg* 2007;59(2):168–172
- 35 Tan BK, Terence G, Wong CH, Sim R. Lower gluteal muscle flap and buttock fascio-cutaneous rotation flap for reconstruction of perineal defects after abdomino-perineal resections. *J Plast Reconstr Aesthet Surg* 2012;65(12):1678–1683
- 36 Bullard KM, Trudel JL, Baxter NN, Rothenberger DA. Primary perineal wound closure after preoperative radiotherapy and abdominoperineal resection has a high incidence of wound failure. *Dis Colon Rectum* 2005;48(3):438–443
- 37 Chadwick MA, Vieten D, Pettitt E, Dixon AR, Roe AM. Short course preoperative radiotherapy is the single most important risk factor for perineal wound complications after abdominoperineal excision of the rectum. *Colorectal Dis* 2006;8(9):756–761
- 38 Khoo AK, Skibber JM, Nabawi AS, et al. Indications for immediate tissue transfer for soft tissue reconstruction in visceral pelvic surgery. *Surgery* 2001;130(3):463–469
- 39 Howell AM, Jarraal OA, Faiz O, Ziprin P, Darzi A, Zacharakis E. How should perineal wounds be closed following abdominoperineal resection in patients post radiotherapy—primary closure or flap repair? Best evidence topic (BET). *Int J Surg* 2013;11(7):514–517
- 40 Peacock O, Simpson JA, Tou SI, et al. Outcomes after biological mesh reconstruction of the pelvic floor following extra-levator abdominoperineal excision of rectum (APER). *Tech Coloproctol* 2014;18(6):571–577
- 41 Christensen HK, Nerstrøm P, Tei T, Laurberg S. Perineal repair after extralevator abdominoperineal excision for low rectal cancer. *Dis Colon Rectum* 2011;54(6):711–717
- 42 Mauvais F, Sabbagh C, Brehant O, et al. The current abdominoperineal resection: oncological problems and surgical modifications for low rectal cancer. *J Vis Surg* 2011;148(2):e85–e93
- 43 Marshall MJ, Smart NJ, Daniels IR. Biologic meshes in perineal reconstruction following extra-levator abdominoperineal excision (eAPE). *Colorectal Dis* 2012;14(Suppl 3):12–18
- 44 Cui J, Ma JP, Xiang J, et al. Prospective study of reconstructing pelvic floor with GORE-TEX Dual Mesh in abdominoperineal resection. *Chin Med J (Engl)* 2009;122(18):2138–2141
- 45 Foster JD, Pathak S, Smart NJ, et al. Reconstruction of the perineum following extralevator abdominoperineal excision for carcinoma of the lower rectum: a systematic review. *Colorectal Dis* 2012;14(9):1052–1059
- 46 Quyn AJ, Johnston C, Hall D, et al. The open abdomen and temporary abdominal closure systems—historical evolution and systematic review. *Colorectal Dis* 2012;14(8):e429–e438
- 47 Jannasch O, Tautenhahn J, Lippert H, Meyer F. [Temporary abdominal closure and early and late pathophysiological consequences of treating an open abdomen]. *Zentralbl Chir* 2011;136(6):575–584
- 48 Bee TK, Croce MA, Magnotti LJ, et al. Temporary abdominal closure techniques: a prospective randomized trial comparing polyglactin 910 mesh and vacuum-assisted closure. *J Trauma* 2008;65(2):337–342, discussion 342–344
- 49 Nagy KK, Fildes JJ, Mahr C, et al. Experience with three prosthetic materials in temporary abdominal wall closure. *Am Surg* 1996;62(5):331–335
- 50 Fansler RF, Taheri P, Cullinane C, Sabates B, Flint LM. Polypropylene mesh closure of the complicated abdominal wound. *Am J Surg* 1995;170(1):15–18
- 51 Boele van Hensbroek P, Wind J, Dijkgraaf MG, Busch OR, Goslings JC. Temporary closure of the open abdomen: a systematic review on delayed primary fascial closure in patients with an open abdomen. *World J Surg* 2009;33(2):199–207
- 52 Shankaran V, Weber DJ, Reed RL II, Luchette FA. A review of available prosthetics for ventral hernia repair. *Ann Surg* 2011;253(1):16–26
- 53 Cobb WS, Kercher KW, Heniford BT. Laparoscopic repair of incisional hernias. *Surg Clin North Am* 2005;85(1):91–103, ix
- 54 Jin J, Rosen MJ. Laparoscopic versus open ventral hernia repair. *Surg Clin North Am* 2008;88(5):1083–1100, viii
- 55 Cassar K, Munro A. Surgical treatment of incisional hernia. *Br J Surg* 2002;89(5):534–545
- 56 Paul A, Korenkov M, Peters S, Köhler L, Fischer S, Troidl H. Unacceptable results of the Mayo procedure for repair of abdominal incisional hernias. *Eur J Surg* 1998;164(5):361–367
- 57 Flum DR, Horvath K, Koepsell T. Have outcomes of incisional hernia repair improved with time? A population-based analysis. *Ann Surg* 2003;237(1):129–135
- 58 Koller R, Miholic J, Jakl RJ. Repair of incisional hernias with expanded polytetrafluoroethylene. *Eur J Surg* 1997;163(4):261–266
- 59 de Vries Reilingh TS, van Goor H, Charbon JA, et al. Repair of giant midline abdominal wall hernias: “components separation technique” versus prosthetic repair: interim analysis of a randomized controlled trial. *World J Surg* 2007;31(4):756–763
- 60 Ramirez OM, Ruas E, Dellon AL. “Components separation” method for closure of abdominal-wall defects: an anatomic and clinical study. *Plast Reconstr Surg* 1990;86(3):519–526
- 61 Hultman CS, Tong WM, Kittinger BJ, Cairns B, Overby DW, Rich PB. Management of recurrent hernia after components separation: 10-year experience with abdominal wall reconstruction at an academic medical center. *Ann Plast Surg* 2011;66(5):504–507

- 62 Ko JH, Wang EC, Salvay DM, Paul BC, Dumanian GA. Abdominal wall reconstruction: lessons learned from 200 "components separation" procedures. *Arch Surg* 2009;144(11):1047–1055
- 63 Patel KM, Nahabedian MY, Gatti M, Bhanot P. Indications and outcomes following complex abdominal reconstruction with component separation combined with porcine acellular dermal matrix reinforcement. *Ann Plast Surg* 2012;69(4):394–398
- 64 Lowe JB III, Lowe JB, Baty JD, Garza JR. Risks associated with "components separation" for closure of complex abdominal wall defects. *Plast Reconstr Surg* 2003;111(3):1276–1283, quiz 1284–1285, discussion 1286–1288
- 65 Sailes FC, Walls J, Guelig D, et al. Synthetic and biological mesh in component separation: a 10-year single institution review. *Ann Plast Surg* 2010;64(5):696–698
- 66 Hood K, Millikan K, Pittman T, et al. Abdominal wall reconstruction: a case series of ventral hernia repair using the component separation technique with biologic mesh. *Am J Surg* 2013;205(3):322–327, discussion 327–328
- 67 Koltz PF, Frey JD, Bell DE, Girotto JA, Christiano JG, Langstein HN. Evolution of abdominal wall reconstruction: development of a unified algorithm with improved outcomes. *Ann Plast Surg* 2013;71(5):554–560
- 68 Pauli EM, Rosen MJ. Open ventral hernia repair with component separation. *Surg Clin North Am* 2013;93(5):1111–1133
- 69 Alicuben ET, Demeester SR. Onlay ventral hernia repairs using porcine non-cross-linked dermal biologic mesh. *Hernia* 2014;18(5):705–712
- 70 Bhangu A, Nepogodiev D, Futaba K. West Midlands Research Collaborative. Systematic review and meta-analysis of the incidence of incisional hernia at the site of stoma closure. *World J Surg* 2012;36(5):973–983
- 71 Slater NJ, van der Kolk M, Hendriks T, van Goor H, Bleichrodt RP. Biologic grafts for ventral hernia repair: a systematic review. *Am J Surg* 2013;205(2):220–230
- 72 Helgstrand F, Rosenberg J, Kehlet H, Jorgensen LN, Bisgaard T. Nationwide prospective study of outcomes after elective incisional hernia repair. *J Am Coll Surg* 2013;216(2):217–228
- 73 Helgstrand F, Gögenur I, Rosenberg J. Prevention of parastomal hernia by the placement of a mesh at the primary operation. *Hernia* 2008;12(6):577–582
- 74 Jänes A, Cengiz Y, Israelsson LA. Randomized clinical trial of the use of a prosthetic mesh to prevent parastomal hernia. *Br J Surg* 2004;91(3):280–282
- 75 Liu DS, Banham E, Yellapu S. Prophylactic mesh reinforcement reduces stomal site incisional hernia after ileostomy closure. *World J Surg* 2013;37(9):2039–2045
- 76 van Barneveld KW, Vogels RR, Beets GL, et al. Prophylactic intra-peritoneal mesh placement to prevent incisional hernia after stoma reversal: a feasibility study. *Surg Endosc* 2014;28(5):1522–1527