Chapter 23
Prevention and Treatment of Major Complications After Closure of Abdominal Wall and Repair of Abdominal Wall Hernias

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Closure of Abdominal Wall

Early Postoperative Complications After Closure of Abdominal Wall

Wound complications that occur after closure of laparotomy remain challenging. Early wound complications included subcutaneous wound infection, deep wound infection, dehiscence, fistula, and suture sinus. Surgical site infections and wound and tissue dehiscence are the most frequent postoperative complications in gastrointestinal surgery that surgeons have to deal with, and usually both of them are related one to another. In fact, concurrent infection is a risk factor for abdominal wound dehiscence, and the prevention of wound infection would reduce substantially the incidence of dehiscence and herniation in abdominal wounds. Presence of bacteria in the healing tissue affects all processes of healing and promotes impairment of collagen synthesis and release of proteolytic enzymes, which promotes dehiscence by decreasing the suture-holding capacity of the tissue [1]. When present, infection and disruption of wounds and tissues are associated with a

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higher risk of reoperation and a prolonged postoperative admission [2]. On the other hand, disruption of the local vascular supply, thrombosis of the vessels, and tissue hypoxia [3] bacterial contamination in the wound will affect the process involved in healing increasing the risk of wound infection, delayed healing, and dehiscence.

As it has been mentioned, traditionally, local factors such as the degree of contamination and the surgical technique have been regarded as strong predictors for surgical site infection, wound dehiscence, and hernias [4]. Literature supports, however, the concept that patient's factors are a major determinant of wound outcome following surgery, and systemic factors such as high age, gender, lifestyle, and coexisting morbidity play a significant role in the pathogenesis of these complications [5, 6]. In fact, lifestyle such as smoking and comorbidity such as diabetes, cardiovascular disease, and lung disease have been associated in different studies with surgical site infections and dehiscence of tissue and wounds [7, 8], which are being involved with several pathogenetic mechanisms. Smoking, microvascular disease, and severe lung disease are known to cause peripheral tissue hypoxia [9], which increases the risk of wound infection and dehiscence [10]. In addition, some studies suggest that hypoxia, smoking, and diabetes reduce collagen synthesis and oxidative killing mechanisms of neutrophils [11, 12]. On the other hand, following elective operations, perioperative blood loss was a predictor of postoperative tissue and wound complications in a dose-dependent manner when adjusting for other risk factors and confounders. This finding confirms previous reports [13] and suggests that hypovolemia and reduction of tissue oxygenation by loss of red blood cells are detrimental to healing and increase the risk of infection and tissue dehiscence [14, 15].

Different studies demonstrate also a significantly higher incidence of postoperative tissue and wound complications in emergency than elective surgery [16]. In emergency surgery, peritonitis in terms of localized pus or diffuse peritonitis was a strong predictor of wound and tissue complications. As shown by others, wound infection is likely to occur when peritonitis with a large intra-abdominal bacterial load and bacteremia is present, despite intravenous antibiotics administered perioperatively [17, 18].

It has been also described how optimal wound healing requires adequate nutrition. Nutrition deficiencies impede the normal processes that allow progression through stages of wound healing. Malnutrition has also been related to decrease wound tensile strength and increase infection rates. Malnourished patients can develop infections and delayed wound healing that result in chronic nonhealing wounds. Chronic wounds are a significant cause of morbidity and mortality for many patients and therefore constitute a serious clinical concern [19].

How to Prevent Early Wound Complications

There have been major advances in the management of patients undergoing surgery in order to prevent wound complications including aseptic techniques, prophylactic antibiotics, and advances in surgical approaches such us minimally invasive

surgery. Prevention of wound infection requires standard principles of infection control after laparotomy, being essential sterile technique and conscientious efforts to avoid wound contamination. Perioperative systemic antibiotics, depending on the type of surgery, may reduce wound infection rates in the wounds that are closed primarily.

But, as it has been mentioned, wounds are exquisitely sensitive to hypoxia, which is common and preventable. Perioperative management can be adapted to promote postoperative wound healing and resistance to infection. Along with aseptic technique and prophylactic antibiotics, maintenance of perfusion and oxygenation of the wound is paramount. There is strong clinical evidence that once perfusion is assured, the addition of increased inspired oxygen substantially reduces site infection in at-risk patients.

There is enough data to establish that intraoperative care of patients has repercussions far into the postoperative period. The impact of anesthetic technique on wound healing and resistance to infection is becoming an important factor in order to avoid early wound complications. The most important factors include temperature management, increased arterial oxygen tension (PaO_2), pain control, fluid management, and, as it has been long recognized, appropriate sterile technique and administration of prophylactic antibiotics. All but the last relate particularly to maintaining perfusion and oxygenation of the wound.

All anesthetics tend to cause hypothermia by causing vasodilatation, which redistributes heat from core to periphery in previously vasoconstricted patients and increase heat loss, and by decreasing heat production. Vasoconstriction is uncommon intraoperatively, but it is often severe in the immediate postoperative period when thermoregulatory threshold returns to normal. The onset of pain with emergence from anesthesia adds to this vasoconstriction. Pain control should be addressed intraoperatively so that patients do not have severe pain upon emergence from anesthesia. Maintenance of normothermia intraoperatively has been shown to decrease the wound infection rate by two-thirds in patients undergoing colon surgery [20]. Rapid rewarming of hypothermic patients in the postanesthesia care unit also appears to be effective.

Surgical stress results in increased intravenous fluid requirements. Inflammatory mediators cause both vasodilatation and an increase in vascular permeability [21]. Optimizing the perioperative fluid administration remains a controversial challenge. Current best recommendations include replacing fluid losses based on standard recommendations for the type of surgery, replacing blood loss, and replacing other ongoing fluid loss.

All vasoconstrictive stimuli must be corrected simultaneously to allow optimal healing. Volume is the last to be corrected because vasoconstriction for other reasons induces diuresis and renders patients hypovolemic. Assessing perfusion is critical. Unfortunately, urine output is a poor and often misleading guide to peripheral perfusion. Markedly low output may indicate decreased renal perfusion, but normal or even high urine output has little correlation to wound and tissue PO_2. Physical examination of the patient is a better guide to dehydration and vasoconstriction.

Fig. 23.1 Wound abscess

Regarding local management of the wounds, topical antibiotics and antiseptics are not of proven value and may interfere with wound healing or cause tissue injury. In grossly contaminated wounds, leaving the skin/subcutaneous tissue open is advisable. Systemic antibiotics do not reduce wound infection rates in wound that are managed by open methods. Necrotizing fasciitis is purportedly less frequent when contaminated wounds are left open.

Prevention of dehiscence/evisceration entails avoidance of infection, technical errors in closure, minimization of tension on the wound closure, and avoidance of wound ischemia. Edematous, distended intestine in the multiply operated abdomen results in the tense fascia closure which has a high rate of dehiscence. Severe edema and distention may preclude fascia closure even after attempts at intestinal decompression. Alternative strategies avoid dehiscence, damage to the fascial edges, bowel injury from evisceration, and abdominal compartment syndrome [22]. When an abdominal wall stoma is required, an important strategy is to place it remote from the reoperative open wound if possible to avoid secondary contamination. But when a fistula appears in an open abdomen, the situation becomes a problem difficult to deal with.

Early Diagnosis of Early Wound Complications

The diagnosis of wound infection is made from the identification of pus which is discharged from the closed wound, but classic signs of inflammation, such as induration or erythema, suggest infection (Fig. 23.1). Fever in the operated patient is a nonspecific finding of little value in the diagnosis. In the open wound, advancing cellulitis and progressive wound necrosis of the soft tissue margins confirm the diagnosis. Cultures are useful from the wound in the multiply operated patient and

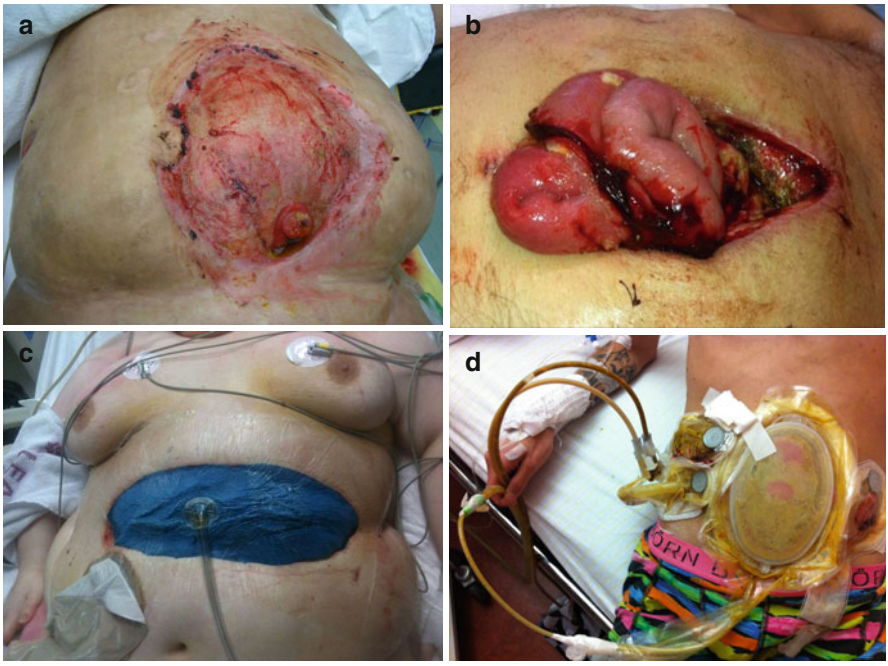

Fig. 23.2 (**a**) open abdomen with intestinal fistula; (**b**) Dehiscence of the wound; (**c**) VAC therapy; (**d**) Care of open abdomen with intestinal fistulas

will reflect the source of contamination responsible for the infection. Open surgical wounds that are culture positive or have superficial exudate but are without either necrosis or cellulitis should not be considered infected.

Necrotizing fasciitis is a clinical diagnosis from the identification of necrosis and suppuration of the wound fascia. The infection will be noted to invade laterally from the midline wound. Necrotic fat is commonly present from the subcutaneous space but skin or muscle may show minimal changes. Cultures are of value for the selection of antibiotics. Late necrotizing infection from multiply operated open wounds may reflect resistant nosocomial pathogens from the intensive care unit environment, and require cultures.

The diagnosis of dehiscence/evisceration is purely a clinical observation. Fascial separation is usually heralded by discharge of serous, bloody, or suppurative fluid from a closed wound. Opening the wound confirms the fascial separation (Fig. 23.2b). Fascial separation in the already open wound is readily seen.

How to Treat Early Wound Complications

Even with appropriate perioperative management, some wounds become infected or fail to heal. Management of wound infection from the closed abdominal wound is removal of skin sutures, opening and drainage of pus, and mechanical

debridement of fibrin. Systemic antibiotics are not necessary unless necrotic soft tissue or a perimeter of cellulitis is present. If it is a simple case of infection, the wound will generally heal rapidly by secondary intention with just attention to basic care. If other complicating factors are involved, it may take more effort to achieve healing. In either case, basic proper wound care is crucial to ensure success. Basic care to avoid infection include:

- The first step to ensure a proper care of a wound includes reducing the bacterial load, especially by washing the wound gently. All open wounds are contaminated with bacteria and most of them are normally resident on the skin.
- Saline kept refrigerated or at room temperature should be avoided in order to avoid local vasoconstriction.
- Antibacterial agents, including antibacterial soaps, betadine, bleach, hydrogen peroxide, and alcohol, are effective at reducing bacterial load, but they do so at the cost of inactivating white cells and harming granulating tissue.
- It is also important to maintain moist wound environment, since moist wounds heal about 50 % faster than dry ones. The open wound is managed with moist gauze dressings without topical antiseptics or antibiotics.
- Invasive infection in open wounds requires debridement of necrosis. Localized debridement may spare elements of muscle or posterior fascia. Small areas of debridement may create fascial defects, and if no bowel is exposed, these small defects may be subsequently managed by secondary intention or small split-thickness skin grafts when culture is negative. In advanced stage, when necrotizing fasciitis exists, the dead tissues need to be debrided until only viable bleeding tissue remains.
- The vacuum-assisted closure (VAC) therapy has been also demonstrated to accelerate the healing process in open wounds (Fig. 23.2c).
- Regarding systemic antibiotics, we should take under consideration the fact that gram stain of exudate may guide antibiotic choice. Antibiotic choices are selected based on in-hospital protocols.
- While taking care of local wound it is important to pay attention to systemic factors. Nutrition and perfusion are essential to improve wound healing.

Open abdomen is another condition to deal with. There are some conditions in which closure of the fascial layer and skin may not be favorable in some surgical conditions, such us peritonitis, trauma, or mesenteric ischemia. The definitive closure of the abdominal wall is not possible, and a laparotomy is created to facilitate reexploration or to prevent abdominal compartment syndrome (Figs. 23.2a, d). Regarding the technique and material used for the temporary closure, no prospective randomized data exists, but mesh materials are commonly used. They provide drainage of infectious material, permit visual control of the underlying viscera, facilitate access to the abdominal wall, preserve the fascial margin, enable healing by secondary intention, and allow mobilization of the patient. In the case of decreasing intra-abdominal pressure, meshes can be trimmed to centralize the rectus muscle and to facilitate definitive closure. Nonabsorbable meshes have been frequently reported to cause enteric fistulae and persistent infection necessitating mesh

explantation; for that reason the use of absorbable mesh material is common in these patients, but it should be determined in the near future the role of biological meshes in these types of wounds. While these infectious complications appear to occur less frequently with the use of absorbable materials, these meshes will finally lead to an incisional hernia, requiring repair with nonabsorbable mesh after a period of 6–12 months [23].

But new systems such as the vacuum-assisted fascial closure (VAFC) therapy can be used in open abdomen under a carefully applied protocol. The use of VAFC may result in significantly higher fascial closure rates, obviating the need for subsequent hernia repair in most patients [24]. The utility of this technique is not limited to the early postoperative period, but it can be successful as much as 3–4 weeks after initial operation. VAFC differs from these and other techniques in that it prevents both fascial retraction and visceral adherence, allowing for continuing attempts at abdominal closure several weeks after laparotomy. This is an extension of the standard vacuum pack technique and has two important components allowing for later closure. The first is the perforated polyethylene sheet placed over the bowel. This must be tucked under the fascial edges to prevent adherence. The second is the thick polyurethane sponge as opposed to the surgical towel used in the original technique. This provides suction to the cross section of the abdominal wall, preventing fascial retraction by creating constant medial tension on the fascia without injuring it as some similar techniques using suture might.

Late Postoperative Complications After Closure of Abdominal Wall

Incisional hernia is a late complication following abdominal surgery, occurring as a result of breakdown or loss of fascial closure and, as such, an iatrogenic disease. The incidence after laparotomy has been reported as ranging between 4 and 12 % in large series [25], but the true incidence is probably underestimated [26]. Many incisional hernias are asymptomatic, but if symptoms are present, an incisional hernia may be associated with major morbidity, loss of time from productive employment, and diminished quality of life. Given the financial cost of incisional hernia repair and the disappointing recurrence rates, incisional hernia remains a significant challenge for most surgeons.

A number of factors associated with incisional hernia have been identified, some of which are local, such as wound infection, surgical technique [27], and surgeon's experience, and some systemic, such as older age, male sex, and altered collagen metabolism [28]. In addition, a lifestyle factor such as obesity or smoking has been found to be associated with incisional hernias [29, 30].

Postoperative wound infection is a well-documented risk factor for early dehiscence of incisional wounds and fascia and for later development of incisional hernia [25]. The pathogenesis is related to proliferation of bacteria in a wound, which affects each process involved in healing leading to decreased collagen

synthesis, decreased bursting strength of the abdominal wall, and an increased risk of dehiscence.

Re-laparotomy is the strongest predictor for incisional hernia. Reoperations have previously been found to increase the rate of abdominal wound dehiscence and may also be responsible for the development of incisional hernia [31], especially due to the need of re-suturing a relatively nonvascular scar tissue of the fascia. In addition, patients undergoing re-laparotomy are likely to have bacterial contamination of the wound and may in addition have peritonitis, which increase the risk of wound infection and delayed healing.

Regarding the systemic factors that may influence on the presence of incisional hernias, we observe how high age is associated with atrophy of the abdominal wall and changes in connective tissue. Inherent connective tissue disorders may result in a deterioration of abdominal wall connective tissue and the tensile strength of scar tissue may be decreased. Diabetics are prone to wound infection, which impairs wound healing. Moreover, atherosclerosis in diabetics may impair wound healing, as may obesity, which is often the cause of diabetes development. Corticosteroids have a deleterious effect on wound healing and are used by large groups of patients, especially those with pulmonary disease. In addition, malnutrition, radiotherapy, smoking, and cancer are known to cause impaired wound healing.

Smoking is another factor to be considered since several pathogenic mechanisms seem to be involved. Peripheral tissue hypoxia, which may be caused by smoking, increases the risk of wound infection and dehiscence, presumably through reduction of the oxidative killing mechanism of neutrophils, which constitute a critical defense against surgical pathogens. In addition, decreased collagen deposition in surgical test wounds has been found in smokers, a mechanism that may further attenuate the fascia in addition to the reduced collagen I–collagen III ratio present in incisional hernia. Degradation of connective tissue caused by an imbalance between proteases and their inhibitors may also be responsible. The latter mechanism, which is enhanced by smoking, is believed to cause tissue-destructive disorders like abdominal aorta aneurysm and pulmonary emphysema. Both diseases are associated with abdominal wall herniation. In fact, the incisional hernia rate has been reported as high as 31 % following midline laparotomy for abdominal aorta aneurysm repair.

Increased intra-abdominal pressure has been identified as another important factor that influences the development of incisional hernias after a laparotomy. Several conditions cause increased intra-abdominal pressure, such as chronic pulmonary disease with cough, obesity, ascites, prostatism, constipation, pregnancy, and ileus. During raised intra-abdominal pressure the strain put on the abdominal wall scar is increased, which could lead to wound failure and subsequent hernia development.

How to Prevent Late Postoperative Complications

The control of any of the aspects, previously mentioned, that influence hernia development will help to prevent incisional hernias, but surgical factors also play an important role. Some types of incisions, such as the lateral paramedian and

transverse incisions have proven to cause less incisional hernias than, for example, the midline incisions. This is caused by several factors, including the anatomical structures that are cut by the incision, since richly vascularized structures heal better than avascular structures, while division of major arteries may result in impaired wound healing. Another important factor is the pulling force of the abdominal muscles, which is mainly transverse. This means that the wound edges in vertical incisions are likely to be separated by this force, while transverse wound edges are approximated.

Suture technique is also an important factor involved in incisional hernia development. The length of the suture used to close the abdomen should exceed the length of the wound by at least four times (suture length to wound length ratio 4:1) [32, 33]. The length of the stitch, or tissue bite, should at least be one centimeter, but not bigger than 5 cm. The suture should include aponeurotic tissues, may include muscle, but not peritoneum or subcutaneous tissue, and may be either interrupted or continuous. It is important to realize that the tensile strength of the wound increases to approximately 50 % at 4 weeks after operation. After 6–12 months, the wound reaches 80 % of its original strength. Suture materials should remain their tensile strength for at least 6 weeks to allow the wound to regain sufficient tensile strength. Rapidly absorbable suture materials, such as polyglyconate (Vicryl), should not be used, while slowly absorbable materials such as polydioxanone (PDS) perform equally well as nonabsorbable materials, such as nylon and polypropylene [34, 35]. Multifilament sutures result in an increased incidence of wound infection and should therefore not be used. In addition to type of incision and suture technique, prevention of wound infection by aseptic techniques will prevent wound infection, together with prophylactic antibiotics, atraumatic surgical technique, meticulous hemostasis, and removal of necrotic and breakdown tissues [36].

Early Diagnosis of Late Postoperative Complications

As we have seen, it has been suggested that early development of incisional hernias is caused by perioperative factors, such as surgical technique and wound infection, together with systemic factors, such as connective tissue disorders. Burger et al. [36] conducted a study in order to determine whether incisional hernias develop early after abdominal surgery might be predictive. Patients who underwent a midline laparotomy were submitted to a CT scan during the first postoperative month. The distance between the two rectus abdominis muscles was measured on these CT scans, after which several parameters were calculated to predict incisional hernia development, being hernia development established clinically. The average and maximum distances between the left and right rectus abdominis muscles were significantly larger in patients with subsequent incisional hernia development than in those without an incisional hernia. Altogether, 92 % of incisional hernia patients had a maximum distance of more than 25 mm compared to only 18 % of patients without an incisional hernia. This study concluded that incisional hernia occurrence can thus be predicted by measuring the distance between the rectus abdominis

muscles on a postoperative CT scan, although its clinical manifestation may take years. On the other hand, this study shows the importance of perioperative factors in incisional hernia development and how prevention should focus on controlling this type of factors.

The diagnosis of incisional hernia is normally made based on clinical examination. However, small hernias, hernias in obese patients or patients with abdominal pain, distension, or various other factors can be difficult to diagnose. In cases in which there is clinical uncertainty of the diagnosis of an incisional hernia, ultrasound or CT scan, and even magnetic nuclear resonance, can be used to detect these clinically unsuspected incisional hernias. CT scan can show the exact size, location, and content of each incisional hernia. The evaluation of postsurgical abdomen by CT scan should include a careful assessment of previous laparotomy sites in search of occult incisional hernias that may be the source of the patient's abdominal symptoms.

How to Treat Late Postoperative Complications

The treatment of late postoperative complications, such as incisional hernias, must follow the basic principles of ventral hernia repair.

Abdominal Wall Hernia Repair

Open or laparoscopic mesh implantation for hernia repair of abdominal wall defects has been the gold standard treatment since it appears to reduce the rate of recurrence by an average of 30–50 % in comparison with nonmesh herniorrhaphy. However, the use of prosthetic materials is not without potential clinical problems and might lead to various complications such as seromas, adhesions, acute and chronic pain, migration of the mesh, rejection, and mesh-related infections [37, 38].

Mesh-related infection, along with seroma formation, is the most common complication following ventral hernia repair. Risk factors for surgical site infection after mesh implantation include gender, age over 70, comorbidities (diabetes, obesity), operating time, and the prophylactic use of drainages. Mesh-related infection rates are also associated [37] to the type of mesh, type of surgical technique used to place the mesh (laparoscopic or open), relationship of the mesh to the subcutaneous tissue, perioperative use of prophylactic antibiotics, sterile technique to apply the mesh, mesh placement in contaminated wounds, and systemic factors such as smoking and immunosuppression.

Elective primary mesh hernia repair is considered a clean surgery, with infection rates of up to 8 % being reported [37], being in most of the cases a problem related to open repair. On the other hand, one of the main advantages of laparoscopic ventral hernia repair is the lower mesh infection rate, especially when compared to open repair. But the main problems associated to the laparoscopic approach are adhesion and seroma formations.

The influence of the type of mesh on overall mesh-related complications is very important. The choice of the proper mesh to repair a ventral hernia, either by laparoscopic or open approach, may influence on the results and not only on the recurrence rate. Type of biomaterial, pore size, and weight are important factors that lead surgeons to select one or other mesh depending on the approach, the surgical field, the risk factors associated to the patient, and the risk of recurrence based on the size of the defect.

The development of polypropylene prosthetics revolutionized surgery for the repair of abdominal wall hernias. A tension-free mesh technique has drastically reduced recurrence rates for all hernias compared to tissue repairs and has made possible to reconstruct large ventral defects that were previously irreparable. The repair of abdominal wall defects is one of the most commonly performed general surgical procedures, and more research is needed to investigate the interaction of abdominal wall forces on a ventral hernia repair or the required amount or strength of the foreign-body material necessary for an adequate hernia repair.

The long-term consequences of implantable prosthesis are not without concern. The body generates an intense inflammatory response to the prosthetic that results in scar plate formation, increased stiffness of the abdominal wall, and shrinkage of the biomaterial. Reducing the density of the prosthetic material and creating a "lightweight" mesh theoretically induces less foreign-body response, results in improved abdominal wall compliance, causes less contraction or shrinkage of the mesh, and allows for better tissue incorporation, but the potential increase of recurrence should be still investigated. Different studies of the laboratory data and short-term clinical follow-up have been reviewed to provide a strong basis or argument for the use of "lightweight" prosthetics in hernia surgery.

Infection

How to Prevent Infection

New improved techniques and stricter aseptic protocols in the operating room have contributed to a decrease in wound infection rates after hernia repair. Principles to avoid wound infection must be followed after any laparotomy. Due to the special features of implant devices, the best way to treat an implant-related infection without destroying the implant is to take the appropriate measures to avoid initial exposure to infection agents.

Preoperative administration of antimicrobial agents in clean surgical procedures such as primary hernioplasty has been a matter of considerable debate for years, but a recent meta-analysis published by Sanabria et al. [39] of the accumulated evidence suggests that infection rates were decreased by almost 50 % in patients who received antimicrobial prophylaxis.

Considerable efforts are being made to develop techniques that will restrain the fundamental mechanism for implant-related infections, which are bacterial

adhesion and colonization of artificial surfaces and biofilm formation. Various strategies such as the previously mentioned antimicrobial prophylaxis and mesh coatings of antimicrobial biomaterials are being developed, but so far there is a lack of data regarding the influence of this coated material in infection rate. Apart from antibiotic coating, silver, gold, titanium, carbonitride, polyglactin, gelatine, and other biomaterials have been used as coatings, with different mechanism of action.

Laparoscopic ventral hernia repair compared with open mesh techniques has been proven to induce a lower incidence of surgical wound infections, probably due to the lack or relatively limited physical contact of the mesh with the surgical wound during surgery.

The type of mesh is also of vital importance regarding the development or not of an infection. Monofilament polypropylene is the most frequently used biomaterial for open repair of an abdominal wall defect due to the low infection rates compared with other nonabsorbable types of meshes. The biocompatibility and the large pore size of this PP textile permit the relatively uncompromised inflammatory response of the immune system on the surface of this material. Surgical infection promoted by implantation of biomaterials is caused by infection and proliferation of bacteria into and within the pores and interstices of these synthetic materials. When pores are less than 10 μm, bacteria averaging 1 μm cannot be eliminated by macrophages and neutrophilic granulocytes, which are too large to enter a 10-μm three-dimensional pore. Totally macroporous prostheses, containing pores larger than 75 μm, deter housing and growth of bacteria by allowing macrophages, rapid fibroplasias, and angiogenesis, which also prevent infiltration and growth of bacteria. On the other hand, totally microporous prostheses (pores less than 10 μm) and macroporous prostheses with multifilamentous and microporous components are similar to braided suture materials, and by harboring bacteria, they can promote their growth, likewise resulting in biomaterial-related infection. Based on these principles, some authors have concluded that in cases of infection, the totally macroporous prostheses do not have to be removed, which leads us to select the proper mesh based on the risk factors of a wound to develop an infection.

Hernia repair is considered a clean operation, nevertheless, when bowel opening or abdominal wound infection has previously occurred, this procedure becomes contaminated; thus, the use of a prosthetic material was thought for years to be contraindicated. However, recent studies suggest that minor morbidity, minimal risk of infection, and minor wound-related mortality are observed after mesh placement in contaminated tissues.

Early Diagnosed Infection

Surgical wound infections are the most commonly encountered type of infection, presenting at an early postoperative stage, usually days or a few weeks after the mesh placement. The symptoms and signs are typical of local acute inflammation: pain, erythema, swelling with locally increased temperature, and confined tenderness.

Inappropriate treatment of surgical wound infections may be complicated by the formation of discharging fistula, intra-abdominal abscess, or, rarely, osteomyelitis. The emergence of systemic symptoms such as fever, chills, or rigor and malaise should urge prompt investigations and initiation of therapeutic actions before sepsis occurs.

Deep-seated mesh infections generally manifest in the early postoperative period, but infrequently they can also be observed as a late-onset phenomenon that is delayed for month or years (up to 4–5 years after the operation) [40]. Deep-seated infections may result from persistent fluid collection (seromas) leading to chronic sepsis. Symptoms can be chronic, recurrent, or totally absent until the progression to sepsis.

The combination of clinical presentation, physical examination, laboratory values, and previous medical history is usually adequate to establish a diagnosis. However, when there are doubts regarding differential diagnosis, two noninvasive imaging techniques could provide the diagnosis. Abdominal ultrasound and CT scan may reveal the inflammatory process in the adipose tissue around the implant as well as complications related to mesh infection such as the presence of a fistula or an intra-abdominal abscess. Diagnostic puncture of a mesh-related seroma when there is no sign of inflammation should be carefully considered and not performed routinely, since there is a high risk of transforming a potentially aseptic reaction to an infectious process through the introduction of bacteria into the previously aseptic seromas.

Treat Infection

The therapeutic options available following the development of mesh-related infection can be separated according to the type and severity of infection and the type of implanted mesh.

- Superficial wound infections after prosthetic material implantation may have better prognosis and may be treated conservatively using proper intravenous antimicrobial coverage and drainage when signs of accumulated exudates exist. However, the use of drainage is still controversial due to insufficient evidence.
- Deep-seated infections of the mesh required prolonged antibiotic treatment in combination with percutaneous or open drainage, since it has been demonstrated to be effective to restrain the infectious process. However, when extensive infections is present, due to biofilm formation and limited penetration of the drug in the area, mesh removal and surgical cleaning of the wound pose the best possible treatment to eradicate the infection. Hernia recurrence could be a postoperative complication if adequate fibrous tissue has not developed earlier.

The choice between conservative and surgical treatment could also be influenced by the type of implanted mesh. Structural (monofilament or multifilament) and biochemical (hydrophobic or hydrophilic) properties influence the potential response of the infection to the administered antibiotics. Clinical findings in combination with recent in vitro experiments suggest that infected hydrophobic meshes, such as PTFE and ePTFE, are most likely to be removed in order to achieve complete cure.

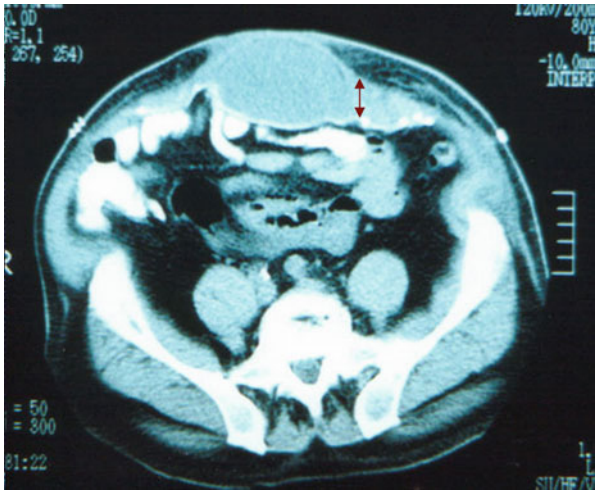

Fig. 23.3 Seroma could be related to recurrence, since it could disattach the tacks due to its weight (disattachment of the tackers of the inner crown is indicated by the *arrow*)

Seroma After Laparoscopic Ventral Hernia Repair

The potential complications related to seroma formation include pain, discomfort to the patient, and cellulitis, being the most important complication of them the possibility of getting infected. The infection of a seroma is considered one of the most challenging complications since it might lead to mesh removal and recurrence.

The rate of cellulitis and infection after laparoscopic ventral hernia repair varies from one series to another. Seroma-related cellulitis is considered by some authors to be a common problem that it is present in most of the patients in whom a seroma is detected [41]. This cellulitis can lead to mesh infection, postoperative morbidity, and further need for operative care. Some authors have proposed the administration of 7 days of postoperative prophylactic antibiotics to decrease the rate of patients with seroma developing cellulitis [41].

Seroma after laparoscopic ventral hernia repair could also be related to recurrence, since the weight of this serous fluid between the mesh and the anterior abdominal wall could increase the tensile strength on the fixation of the mesh and therefore disattach tackers (Fig. 23.3) from its original fixation to the anterior wall and be responsible of an improper anchoring of the mesh right after surgery, which may influence in the presence of recurrence in the future. In fact, some authors have observed at reoperation, due to recurrences, how they appeared to be due to mesh detachment, and this fact might be related to the presence of a seroma.

How to Prevent Seroma

The real importance of seroma formation and the influence of them in the quality of life in the postoperative period of the patient are also still to be determined. But it

can be concluded that seroma is not really a key factor in the postoperative period after this surgery and its simple presence cannot be considered a complication. But it would be better to avoid it since, in some cases, it could be responsible for some sort of discomfort to the patient and because it could confuse both patients and surgeons about a possible recurrence.

Different methods are being proposed lately in order to decrease seroma formation, but since the method of describing the presence of seroma is not described in the same way by different authors, it is difficult to determine the effectiveness of one method compared to the other. Some authors have proposed that defect closure confers a strong advantage in laparoscopic ventral hernia repair, since there is a shift of the paradigm towards more physiologic abdominal wall reconstruction, and especially because defect closure essentially eliminated postoperative seroma. These authors advocate routine use of the closure of the defect technique during laparoscopic ventral hernia repair [42], but for other authors, such as Palanivelu et al. [43], this maneuver of closing the defect has no influence in the rate of seroma formation.

Other methods have been described to decrease the rate of this serous fluid between the mesh and the sac, such us cauterization of the hernia sac [44] and use of argon bean to treat the hernia sac or to excise it, and to decrease the seroma-related complications, such us the use of postoperative antibiotics to decrease the incidence of seroma-related cellulitis and decrease the possibility of mesh removal due to this cellulitis [41].

The studies conducted to reduce the presence of seromas, like the one described by Fernandez-Lobato et al. [45] and JP Chevrel, by using fibrin glue after conventional open ventral hernia repair, together with other publications of the reduction of seroma with the same substance in other pathologies like breast surgery or plastic and reconstructive surgery, made us develop a protocol looking for a solution to also decrease the presence of seroma. We have conducted a clinical study in which we have observed that the use of fibrin glue in the sac after laparoscopic ventral hernia repair seems to have an important value in the laparoscopic treatment of abdominal wall hernias in reducing seromas, while favoring, on the other hand, the ingrowth of meshes.

Early Diagnosed Seroma

Seroma, defined as serous fluid retention between the mesh and the anterior abdominal wall, is present in most of the cases after laparoscopic ventral hernia repair, as different series that analyzed its presence by radiological exams show. Its presence cannot be considered a complication since patients do not even detect them in most of the cases. For these reasons, it is important to define that seroma must be considered an incident after this surgery which may lead to complications.

The real incidence of seroma after this procedure is difficult to be determined and not being properly documented and analyzed since its presence varies from one series to another. Different studies have shown how seroma formation is very

Table 23.1 Clinical incidence of seroma after laparoscopic ventral hernia repair

Author	Clinical seroma (%)
3rd Parker et al. [77]	0.5
Morales-Conde et al. [78]	2.1
Heniford et al. [55]	2.6
Ferrari et al. [79]	2.6
Carbonell et al. [80]	2.7
Heniford et al. [55]	3
Bedi et al. [47] (systematic review)	5.4
Kaafarani et al. [57]	6.8
Uranues et al. [81]	7
Varnell et al. [58]	8.5
Tessier et al. [56]	9
Perrone et al. [50]	10.7
Farrakha et al. [82]	10.9
Sodergren et al. [83]	14.5
Sharma et al. [51]	25
Chowbey et al. [84]	32
Edwards et al. [41]	32.3
Edwards et al. [41]	33
Susmallian et al. [49]	35
Birch et al. [85]	78

Table 23.2 Radiological incidence of seroma after laparoscopic ventral hernia repair

Author	Radiological seroma (%)
Morales-Conde et al. [78]	95.2
Susmallian et al. [49]	100

variable, ranging the different series from 0.5 to 78 % [46] (Table 23.1), being the rate of the systematic review published by Bedi et al. of 5.4 % [47]. But this data is related to the presence of clinical seroma following different criteria, since one of our studies [48] and the study conducted by Susmallian et al. [49] show that seroma is present in radiological exams in almost all cases (Table 23.2).

One of the main problems related to the variety of these results is that seromas have been considered following different criteria by different authors. For some authors it is considered just a complication [43], for others it is considered one of the main complications of this technique [50] or even as the most common sequel of this surgery [51], but others just think it is a minor complication [52] or an incident [6].

On the other hand, an additional problem related to the description of seromas is observed in most of the series: authors have been using different parameters, difficult to be measured, to quantify the rate of seroma formation. Some authors have included the definition of "significant seroma" [42] or "prolonged seroma"; others described seroma as a fluid retention that requires surgical intervention [53] or the need to be punctured [54]; or based on the time lasting after surgery, lasting more than 4 weeks [55], more than 6 weeks [56], or even more than 8 weeks [57]; or they

Table 23.3 Clinical classification of seroma

Type 0	*No clinical seroma*		No clinical seroma
	0a	Neither clinical nor radiological seroma	
	0b	No clinical seroma, but it can be detected by radiological exams	
Type I	*Clinical seroma lasting less than* 1 *month*		Incident
Type II	*Clinical seroma lasting more than* 1 *month*		
	IIa	Between 1 and 3 months	
	IIb	Between 3 and 6 months	
Type III	*Minor seroma-related complications*		Complication
	IIIa	Clinical seroma lasting more than 6 months	
	IIIb	Important discomfort which does not allow normal activity	
	IIIc	Pain	
	IIId	Cellulitis	
Type IV	*Major seroma-related complications*		
	IVa	Need to puncture the seroma to decrease symptoms	
	IVb	Infection	
	IVc	Recurrence related to seroma	
	IVd	Mesh rejection related to seroma	

are just defined as "a symptomatic seroma" [58] or by the presence of a complication such as seroma-related cellulitis.

Based on these facts, in order to early diagnose a seroma, we have to determine first what we want to diagnose, since seroma is going to be present in almost all the case if its presence is determine by ultrasound or CT scan.

For that reason we propose a clinical classification of seroma after laparoscopic ventral hernia repair in order to unify different criteria so we can establish in the near future in the surgical literature the proper incidence of seroma and its clinical importance (Table 23.3).

Treat Postoperative Seroma

It is difficult to know, based on the literature, the best method to manage patients presenting seromas and theirs complications in the postoperative period. Different treatment options for postoperative seromas have been described including observation for spontaneous resolution, percutaneous aspiration [41], closed suction drainage, abdominal blinders, and sclerosant [59]. While some groups recommend puncturing the seroma just in case of pain or discomfort, other groups recommend not doing it in order to avoid contamination. Most of the authors considered that spontaneous resolution of seroma occurs in the vast majority of the cases, being not necessary to puncture any of them or the number of seromas that need to be aspirated is very low. But, it can also be observed in the literature review that the reasons that lead different authors to puncture seromas and the complications of this invasive approach are also not well defined. Based on this data, we have observed that the rate of seromas being punctured varies from one author to another, from 0 to 33.3 %.

Adhesions After Laparoscopic Ventral Hernia Repair

The formation of adhesions is an extremely complex process, which has not been well-determined so far. As a result, many of the studies on this phenomenon are still empirical, but the results published are so far promising and it is possible that we can control this process in the near future, whether stimulating or inhibiting it, depending on the circumstances. The consequence of these studies could lead in the future to use prosthetic materials for intra-abdominal placement in laparoscopic surgery of the abdominal wall, with no risk of creating adhesions and the subsequent consequences, such as fistulas or bowel occlusion.

In the meantime, while we try to determine the different factors involved in adhesion formation, the ideal material and substance to prevent them are still far from being found. Different studies performed so far have proved that it is possible to reduce the quantity and the quality of these adhesions, but not to prevent them completely. Full tissue integration without adhesion formation is still a challenge for intra-abdominal mesh materials.

Different factors have been related to the process of adhesion formation, but the need of the bowel and the intraperitoneal organs to isolate foreign agents, such us prosthetic materials, sutures, and bacteria, seems to have an important role in this issue. However, during laparoscopic repair of ventral hernia, the presence of intraperitoneal adhesions is not a result of only the material itself, since other experimental studies have related them to other factors: spiral tacks, improper placement and fixing of the mesh, or leaving the parietal side of these materials exposed to the intra-abdominal viscera [60] (Fig. 23.4).

On the other hand we also have a lack of information about the healing process involved on adhesion formation. It would be interesting for the future to determine

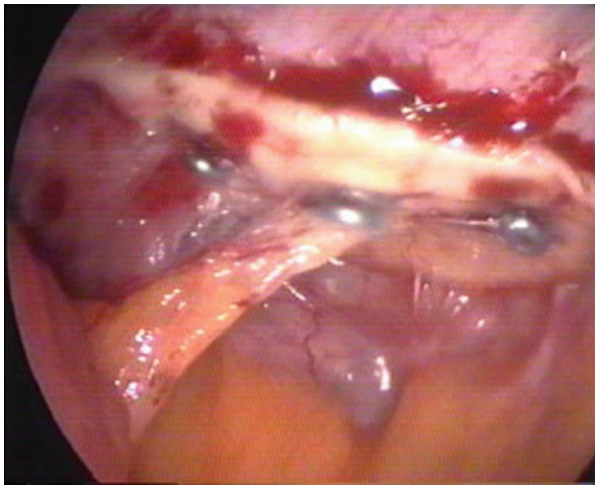

Fig. 23.4 Adhesions to the edge of the mesh after laparoscopic ventral hernia repair

the critical moment in which adhesions to the prosthetic materials are formed. For that reason some authors have designed different studies by using sequential laparoscopy to monitor the real-time adhesion formation process and the critical period when most adhesions form [61].

If we analyze the factors involved on adhesion formation when a mesh is placed intraperitoneally, we can determine the following:

- Material: Different studies published [62] have shown how porosity of the material is considered as one of the most important factors related to adhesion formation and ingrowth. Large porosity has been related to an increase amount of adhesions. Polypropylene meshes are considered a high porosity prosthetic material which creates an important scar tissue involved in adhesion formation. On the other hand, a low porosity material, such as ePTFE (expanded polytetrafluoroethylene) [62, 63], produces a capsule of tissue that covers the mesh, forming few or no adhesions. So, we can conclude that pore size of mesh is critical in the development and maintenance of abdominal adhesions and tissue ingrowth, but it has been demonstrated, however, that a reduction in the amount of material and an increase in pore size results in better mesh biocompatibility with a potential reduction of adhesion formations [64, 65], as it has been trying to demonstrate with the new "low weight" polypropylene. These large-pore polypropylene meshes in the intra-abdominal position showed a reduced inflammatory tissue reaction, so they could be considered an alternative for the future development of intraperitoneal onlay meshes [66]. In fact, new studies with reduced weight polypropylene mesh have demonstrated a smallest change in the adjacent tissue pliability/compliance and smallest amount of adhesion than conventional polypropylene [67]. On the other hand, these factors should be also analyzed in the future regarding the pore size of other materials such as PTFE. The large pore size, thinner meshes such as condensed PTFE (c-PTFE), led to better tissue integration compared to the other meshes with PTFE based or polypropylene. Through hydrophobic chemistry, low profile, and increased pore size, c-PTFE balances the rapid resolution of the inflammatory and wound healing response that resists adhesion formation, with efficient integration within the surrounding abdominal tissue [68].
- Surgical technique to place the mesh: An experimental study conducted by our group [60] has demonstrated the influence of the surgical technique during mesh placement during laparoscopic ventral hernia repair. In this study, most of the adhesions to the ePTFE meshes were observed at the edges compared to the central part of this prosthetic material. The potential reasons of these adhesions were analyzed, and it could be seen how adhesions were formed to the undesired exposition of the parietal face of the prosthesis or to tackers improperly introduced into the mesh. These issues demonstrate the need of a meticulous technique to avoid complications related to adhesions, such us bowel occlusion and/or perforation. The mesh must be properly extended so the parietal face do not end expose to the bowel and tackers should be introduced all the way into the mesh to avoid them hanging from the anterior abdominal wall.

- Role of fixation on adhesion formation: As it has been said previously adhesions to spiral tacks may occur and we have observed them in experimental study. Resent clinical papers have even reported cases of obstruction and/or perforation of the small bowel resulting from a band adhesion caused by a displaced spiral tacker [69, 70].
- Surgical trauma: Surgical trauma to the bowel or to the peritoneal surface of the anterior abdominal wall, during the process of adhesiolysis, has some influence in adhesion formation, even if the ideal mesh to be placed intra-abdominally is used. Adhesions result from the normal peritoneal wound healing response and develop in the first 5–7 days after injury. Adhesion formation and adhesion-free re-epithelialization are alternative pathways, both of which begin with coagulation which initiates a cascade of events resulting in the buildup of fibrin gel matrix. If not removed, the fibrin gel matrix serves as the progenitor to adhesions by forming a band or bridge when two peritoneal surfaces coated with it are apposed [71]. The band or bridge becomes the basis for the organization of an adhesion, especially if a foreign-body reaction is added to the process when a mesh is placed intra-abdominally, becoming of great importance the surgical trauma on the surface of the bowel [72].

How to Prevent Adhesions

Little clinical information based on preoperative findings is available about adhesions to biomaterials placed intra-abdominally. RH Koehler at al. [73] published a multi-institutional study of adhesions to implanted expanded polytetrafluoroethylene (ePTFE) mesh at reoperation in patients who had previously undergone laparoscopic incisional hernia repair done with the same mesh implantation technique. In this large series of reoperations after laparoscopic incisional hernia repair, no or minimal formation of adhesions to implanted ePTFE mesh was observed in 91 % of cases, and no severe cohesive adhesions were found. This study shows how the selection of the proper mesh may reduce the incidence of adhesion formation.

On the other hand, as it has been already mentioned, a meticulous technique is one of the most important factors involved in reducing adhesion formation: avoid unnecessary surgical trauma on the surface of the peritoneum and on the serosa of the bowel, avoid the parietal face of the mesh to be exposed to the abdominal cavity, and avoid the spiral tacks to be hanging from the mesh due to an improper introduction through the prosthetic material.

But, since these circumstances are not usually possible to avoid due to the process of adhesiolysis needed or to the location of the defect that makes difficult to place properly the mesh or the tackers, alternative method to avoid adhesion is under investigation. Moreover, efforts to prevent or reduce adhesions have been unsuccessful, hindered by their empirical basis, the lack of good predictive animal models, and the biochemical complexities of adhesiogenesis. The two major strategies for adhesion prevention or reduction are adjusting surgical technique, as it has been already proposed, and applying adjuvants.

Different studies have been published using a variety of substances to prevent adhesion formation to the prosthetic materials with different results: hyaluronic acid/carboxymethyl cellulose (HA/CMC) membrane has been used as an effective measure to prevent polypropylene-induced adhesions; taurolidine 2 % solution has been proposed as a cost-effective alternative to HA/CMC membranes when a polypropylene mesh is used in direct contact with the abdominal viscera; hyaluronate sodium in the form of a bioresorbant membrane has also been demonstrated to significantly reduce the development of intra-abdominal adhesions found after implantation of a polypropylene mesh in the context of surgical hernia repair; and a collagen foil (CF) has also been used to reduce adhesion formation.

Looking for a cost-effective alternative to reduce adhesion formation during laparoscopic ventral hernia repair to the mesh placed intra-abdominally, we have conducted different studies with two substances that can guarantee a good coverage of the complete surface of the mesh, even if we use a large prosthetic material [74, 75]. The two substances used are fibrin glue (Tissucol ®, Baxter Biosurgery, Vienna, Austria) and hyaluronidase cream. Both substances have been able to decrease, in an animal model, the number and the quantity of the adhesions to both polypropylene and ePTFE meshes. The reduction of adhesions with hyaluronidase cream is a consequence of an acceleration in the normal process of healing needed to create adhesions. This factor may also influence in the reduction of adhesion with fibrin glue, but may also be related to other facts: the mechanical barrier that the fibrin glue produces 3–5 min after its application, and the capsule of new tissue created by the fibrin glue with a different process of healing compared to the inflammatory process necessary to create an adhesion.

Early Diagnosed Adhesions

Laparoscopic ventral incisional hernia repair involves intra-abdominal placement of a synthetic mesh, and the possibility of formation of severe visceral adhesions to the prosthesis is a principal concern. Adhesions cause increased morbidity and mortality, with subsequent socioeconomic consequences. Zinther et al. [76] have recently published a structured literature search of medical databases based on English literature published until September 2009 in order to assess the presence of adhesions to implanted synthetic mesh after laparoscopic ventral hernia repair. The search identified transabdominal ultrasonography (TAU) and cine magnetic resonance imaging (cine MRI) as relevant tools matching the search criteria. In all, 12 publications concerning TAU and four publications concerning cine MRI were identified. Both TAU and cine MRI seem able to identify intra-abdominal adhesions using visceral slide with accuracy of 76–92 %. Unfortunately, the studies are biased by being nonblinded, which influenced the final sensitivity, specificity, and accuracy. Accordingly, a need exists for a systematic well-conducted double-blinded comparative study to validate these radiologic techniques.

Treat Postoperative Adhesions

Adhesions do not need to be treated unless complications, such as chronic pain, bowel occlusion, or fistulas, appear.

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