

Chapter 19

Abdominal Wall Reconstruction and Biological Prosthesis

**Roberto Manfredi, Federico Coccolini, Stefano Magnone,
Paolo Bertoli, Dario Piazzalunga, and Luca Ansaloni**

19.1 Introduction

The significant advancement in the management of the acute surgical and critically injured patients has led to improve survival during the last decades [1–3]. However, a significant number of patients that are victims of catastrophic abdominal injuries will develop large abdominal wall defects that require complex abdominal wall reconstruction. The damage control surgical approach often results in open abdomen. This last condition often exits in giant abdominal wall defect. The subsequent reconstruction may represent a challenge for both the patient and the surgeon. Frequent complications are associated to these procedures (i.e., wound infections, seromas, fistula formation, recurrence of the defect, and mortality) [1, 3]. Abdominal wall reconstruction following an open abdomen is

R. Manfredi • F. Coccolini • S. Magnone • P. Bertoli • D. Piazzalunga
L. Ansaloni, MD (✉)
Department of General and Emergency Surgery,
Papa Giovanni XXIII Hospital, Bergamo, Italy
e-mail: lansaloni@ospedaliriuniti.bergamo.it

often associated with decreased physical functions and high prevalence of psychiatric complications, such as post-traumatic stress disorders or depression [4]. As a counterpart of the different techniques for abdominal wall reconstruction [1, 3, 4], only few 5-year or longer follow-up clinical studies have been reported. Recurrence rates following abdominal wall reconstruction have been reported to reach 54 % [5]. These rates vary depending on multiple factors: the technique employed, the approach (open vs. laparoscopic), the type of repair (suture vs. mesh), the type of prosthesis, surgical site infection, and comorbidities [5–8]. Different surgical techniques with many modifications have been reported with promising results [5].

Dealing with open abdomens, the aim is to achieve primary fascial closure as soon as possible. The decision to leave the fascia open can be unavoidable or deliberate [1]. It most commonly results from staged repair due to trauma, peritonitis, pancreatitis, abdominal vascular emergencies, or abdominal compartment syndrome. In patients who survive to damage control approach, the hernia is a favorable outcome with the aim of repairing it at a later safe stage. Depending on the type of skin coverage over the viscera, the abdominal wall defects can be categorized as a type I or II defect. Type I defect comprehends cases with intact or stable skin coverage, whereas type II defects have absent or unstable skin coverage. In type I defects with at least stable skin coverage, bridging the fascial gap with prosthetic material or autologous tissue is the most frequently applied method. In type II defects, fascial repair alone is not sufficient, and it needs a skin coverage, requiring complex reconstruction techniques.

Specific criteria used to identify patients who may require special closure techniques for an abdominal wall defect include one or more of the following: (1) large size (40 cm²), (2) absence of stable skin coverage, (3) recurrence of defect after prior closure attempts, (4) infected or exposed mesh, (5) patient who is systemically compromised (e.g., intercurrent malignancy),

(6) compromised local abdominal tissues (e.g., irradiation, corticosteroid dependence), and (7) concomitant visceral complications (e.g., enterocutaneous fistula) [5].

The aims of abdominal wall reconstruction are mainly to restore structural support, to provide stable soft-tissue coverage, and to optimize aesthetic appearance. Reconstruction of small midline defects (less than 5 cm in width) is most often accomplished with medial advancement of adjacent abdominal wall structures, provided that these tissues are available, well vascularized, and mobile, i.e., not fixed by cicatrix or scar. When full-thickness abdominal wall defects become larger than 5 cm in diameter, closure has most often required the application of synthetic mesh [1, 2]. Moreover, it is necessary to consider the eventual contamination or infection of the surgical field. In presence of such a complicating factor, the use of a biological prosthesis is to be considered. Reconstructions with autogenous tissue utilize the transposition of local or regional musculocutaneous or musculofascial flaps [3] and, occasionally, the provision of a free flap transfer.

19.2 Abdominal Wall Reconstruction Techniques

19.2.1 Component Separation

The essential surgical technique in the components separation procedure is the lateral mobilization of rectus abdominis musculofascial component to reach the midline. Different methods were described to anatomically reconstruct the abdominal wall (i.e., Guillouid in 1892, Chrobak in 1892, Gersuny in 1893, and Noble in 1895). In 1951, Alfonso Albanese described the possibility to vertically split the external oblique muscle to enable

closure at midline. This technique, however, was not widely known before Ramirez's paper in 1990 [2]. With the use of fresh cadavers, they demonstrate that the flap of the rectus muscle could be advanced of 10 cm. The division of the external oblique muscle can also be performed through small separate incisions using open or laparoscopy-assisted techniques. A retrospective comparison of endoscopic and open component separation techniques in 44 patients showed that the two techniques had similar rates of recurrence (about 30 %) and that the endoscopy group had fewer major wound complications and shorter lengths of stay. It is important to stress the attention on the use of mesh reinforcement in almost all cases (95 % in open surgery group and 100 % in endoscopy group). The field was described as contaminated in 91 % of cases of the open group and in 73 % of the endoscopy one. Biological mesh was used in the 86 % and 82 % of cases, respectively, permanent synthetic mesh in 0 % and 18 %, and absorbable synthetic mesh in 9 % and 0 %, respectively.

A randomized, controlled trial comparing the efficacy of component separation with mesh repair in a small group of giant midline abdominal wall hernias reported higher recurrence rates in the component separation group and increasing in wound complications in the mesh repair one.

19.2.2 Modified Component Separation Technique

A modification of the standard components separation was developed at the Presley Memorial Trauma Center in Memphis, Tennessee. This technique allows to obtain more tissue (up to 20 cm in the umbilical region) and consequentially to close the abdomen with native tissue alone. A recent study showed how this technique, with or without the use of prosthetics, leads to

good long-term outcomes with low recurrence rates. With a follow-up of more than 5 years, the recurrence rate was 5 % in patients treated with this technique without mesh, compared with 44 % in those treated with the standard components separation with mesh.

19.2.3 Microvascular Flaps

Vascularized flaps provide healthy autologous tissue coverage without implantation of foreign material at the closure site. The so-called pedicled flaps can be used in small and mid-sized defects in the arch of the rotation of the flap around the pedicle which is represented by a vessel. Microvascular flaps are required if the defect is large or located in the upper abdomen or if pedicled options have already been used. It offers an efficient autologous, single-stage reconstructive solution. The tensor fasciae lata myocutaneous free flap has been described for the first time in 1978, and since then, about 100 cases have been reported [9–11]. To re-create the linea alba and to achieve mid-line closure are the most important aspect of reconstructing a functional abdominal wall [12]. Differently from inert material, the abdominal musculature provides dynamic support of innervated tissue to redistribute the mechanical stress applied from intra-abdominal pressures. Complex reconstruction techniques are required mainly in extensive defects without intact skin or when previous repair has failed, such as in infected and/or exposed mesh. The most complex cases would be probably best treated in specialized centers [13]. Even when performed in specialized centers, these procedures involve high site morbidity with significant scarring and contour deformity. Moreover, sometimes due to the denervation of the muscles, they do not provide adequate structural support; this results in additional mesh necessity.

19.2.4 Mesh Repair

Abdominal wall reconstruction with synthetic mesh is widely used with the possibility to choose among many different resorbable and non-resorbable materials. The main aspects to keep into consideration in extensive abdominal wall reconstruction with synthetic mesh are the following: availability of sufficient normal skin to cover the mesh, possibility to pose the mesh directly over the bowel without causing bowel erosion with fistula formation or excessive adhesion formation, and lastly the risk of infection when used in contaminated fields.

19.2.5 Suture Versus Mesh

The significant increase in the use of synthetic mesh during the past decades suggested to evaluate the differences between the direct suture techniques and the use of prosthesis. Luijendijk et al. demonstrated that mesh repair is superior to suture repair with regard to hernia recurrence rate (23 vs. 46 %) in a randomized controlled trial. This superiority resulted independent from the hernia size.

19.2.6 Open Versus Laparoscopy

A quite null application field has been found for the laparoscopy in trauma. However, in reconstructive surgical techniques, the laparoscopic approach could found a few applications. There is only one long-term follow-up study comparing minimal invasive surgery versus open in hernia repair. It demonstrated similar recurrence rates at 5 years: 29 % in laparoscopic group versus 28 % in open hernia repair with mesh. The laparoscopic converted to open approach had a 60 % recurrence rate at 5

years. The high rates of recurrence were related to patient's selection criteria. A significant number of patients in this group in fact were immunosuppressed, had ascites, and had a significantly larger size defect. The study highlighted the importance of preoperatively identification of patient and consideration of an alternative repair if the complication or recurrence rate could be suspected as high. This could be utilized as an indication to cautiously evaluate the application of laparoscopy in abdominal reconstruction after trauma.

19.2.7 Vacuum-Assisted Closure Technique

This technique is widely employed as a bridge for a delayed or stage closure. It is being used in contaminated field and in the intensive care unit to enhance the rate of wound closure. This technique may be used with or without mesh. The mesh could be either synthetic or biologic.

The vacuum-assisted technique has been progressively more utilized with the increasing of the capacities to treat patients with a temporary laparotomy. Open abdominal management with temporary abdominal closure is used for patients with critically ill trauma and for general and vascular surgery very compromised patients who have been operated in emergency setting [14].

The main indications for leaving the abdomen open include damage control laparotomy for trauma or infection, intra-abdominal hypertension with abdominal compartment syndrome, and planned relaparotomy. A number of temporary abdominal closure techniques have been used for patient in the aforementioned conditions. These techniques include the following: Bogota' bag, Wittmann patch (Starsurgical Inc., Burlington, WI), Barker's vacuum pack, and commercial negative-pressure wound therapy (NPWT) systems [14, 15].

NPWT systems find a fundamental field of application in the downgrading of the infection. The use of these systems allows

to reduce the bacterial load and to reduce the infection of the field by removing eventual enteric or purulent fluids in order to facilitate the secondary abdominal wall closure.

Moreover, NPWT may facilitate fascial closure rates by preventing visceral adherence to the abdominal wall while maintaining a mild medial fascial traction. The other advantage of this technique is that it facilitates the removing of proinflammatory cytokine-rich peritoneal fluid. This helps to reduce the systemic inflammatory response to injury and/or sepsis and associated organ dysfunction. NPWT also stretches and deforms the abdominal wound, which increases its surface area and induces cell proliferation and angiogenesis through several mechanisms [16]. The use of this technique is believed to be linked with a higher rate of adverse events as intestinal fistulae.

A systematic review published by Roberts et al. analyzed the use of NPWT versus alternative temporary abdominal closure techniques in critically ill adult patients [17].

This review evaluated the effect of NPWT and other alternative temporary abdominal closure methods on the following: in-hospital mortality, fascial closure rate, and hospital and ICU length of stay. Although current evidences remain insufficient, data from a limited number of prospective comparative studies suggest that NPWT may be associated with improved outcomes. Moreover, no evidence exists to support the supposed greater risk to develop intestinal fistula. However, the author concluded saying “because the studies supporting these improved outcomes are clinically heterogeneous and linked with at least a moderate risk of bias, our findings are preliminary, and no definitive conclusions regarding the preferential use of NPWT over alternative temporary abdominal closure techniques can be afforded. Adequately powered and internally valid RCTs comparing the ABThera or KCI VAC with other methods, particularly Barker’s vacuum pack technique and the Wittmann patch, are required before NPWT can be advocated as a superior surgical intervention.”

19.2.8 Biological Prosthesis

One of the main criticalities in the management of the open abdomen is that bacterial contamination is seen in any open wound. All bacteria, whether in an acute or chronic wound or in a contaminated versus a colonized wound, will produce virulence factors (e.g., exotoxins, endotoxins), all of which have deleterious effects to wound healing [18, 19]. Moreover, these bacteria could compromise the use of synthetic materials in restoring the abdominal wall continuity. As mentioned earlier, abdominal wall reconstruction frequently requires placement of prosthesis to replace the missing fascial tissue and strengthen the repair. The main used nonabsorbable synthetic materials (i.e., polypropylene mesh) reinforce the fascial repair by a combination of mechanical tension and intense inflammatory reaction, resulting in the entrapment of the mesh into scar tissue. The persistent inflammatory response may induce local side effects such as adhesions, erosions, and fistula formation, particularly when mesh is directly in contact with viscera [20]. Moreover, in irradiated fields or in patients on steroids or immunosuppressive medications or in the presence of bacterial contamination, their use could result in a larger number of complications [21]. Because of the limitations of the nonabsorbable synthetic meshes, reconstructive surgeons have started to explore the use of biological scaffolds in abdominal wall reconstruction. Biological prostheses (BP) are collagen mesh derived from allogenic or xenogenic sources. They could be cross-linked or not, and for this reason, they respectively result to be completely remodeling or partially remodeling. The differences in remodeling times should be kept in mind when considering these materials. Each prosthesis permits and encourages host tissue ingrowth. The partially remodeling prostheses are also optimal for resisting mechanical stress [22]. They are physically modified with cross-linkages between the collagen fibers to strengthen the prosthesis. This process stabilizes the implant by preventing its degradation

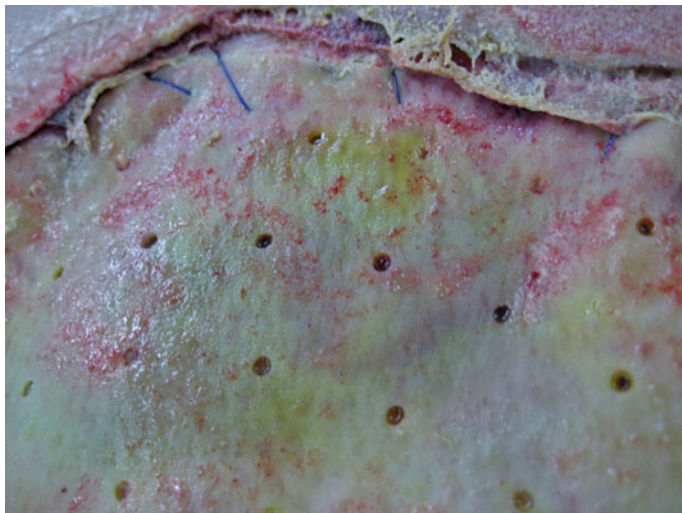


Fig. 19.1 Granulating tissue demonstrating the healing process

by human or bacterial collagenase [23]. Cross-linked collagen implants have been associated with limited tissue integration and persistent inflammation [24] (Fig. 19.1).

The implementation in the use of BP has greatly facilitated the complex hernia treatment. This kind of ventral hernia repair represents a significant challenge for surgeons. The complexity of hernias could derive from trauma, contamination/infection, tissue loss, dimensions, anatomic position, and clinical or pharmacological data (Figs. 19.2 and 19.3). BP have completely changed the way to face the hernia surgery. They introduced the tissue engineering in surgical practice. The implantation of a biologic material triggers a cascade of events leading to new healthy tissue deposition and prosthesis remodeling. It also allows blood, growth and pro-/anti-inflammatory factors, and drugs to reach the surgical field during the first phases of healing process. This for sure enhances the effect against potential or



Fig. 19.2 Biological prosthesis applied in the closure of a laparotomy for trauma-related injuries; it could be utilized with vacuum-assisted closure techniques as in this case (the vacuum dispositive has been removed). To be noted is the presence of the stoma

certain contamination/infection [25]. It has been demonstrated in animal models as the tensile strength is different between cross-linked and non-cross-linked meshes during the first months after the implant. However, it reaches similar values after 12 months with the two kinds of meshes. Moreover, the strength of the repair sites doesn't change over time. This might indicate that new tissue is deposited in the repair site as the scaffold is degraded, preventing the site from weakening over time. Another factor that should be kept into account in choosing which kind of BP to use is the demonstration that non-cross-linked material exhibits more favorable remodeling characteristics. This has a

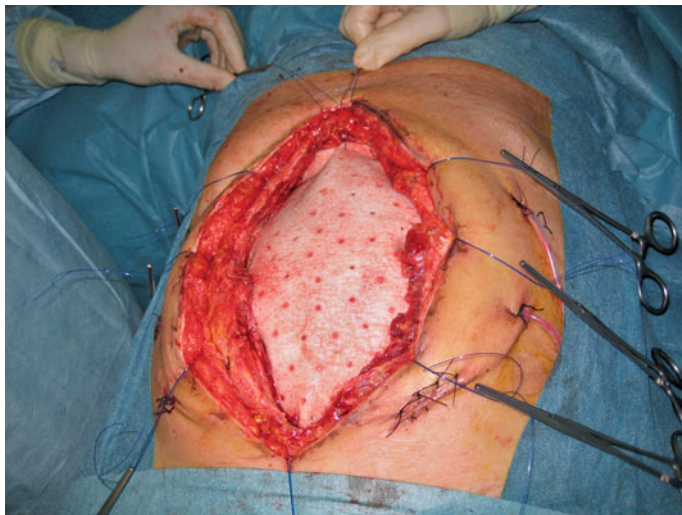


Fig. 19.3 A biological prosthesis utilized as a bridge between fascial margins to close a laparotomy for trauma-related injuries

great importance when BP are used as bridge to cover tissue loss. In fact, discordant data have been published about the use of BP to bridge wide defect. Few different nonrandomized studies have been published reporting recurrence rate ranging between 100 % and 0 % if the prosthesis are placed, respectively, either as a bridge or not. Even if high-quality comparative data about BP exists in animal models, only clinical reports of a restricted number of cases are reported for humans. No definitive evidence-based conclusions could be obtained from the literature. The majority of surgeons stated they use BP in “difficult” situations, especially those with contaminated or infected field [11].

The Italian Biological Prosthesis Work Group (IBPWG) proposed a decisional model in the use of BP to facilitate the choice between the different types of BP [25].

The aforementioned decisional model suggests that the decision about which prosthesis to utilize should always be a

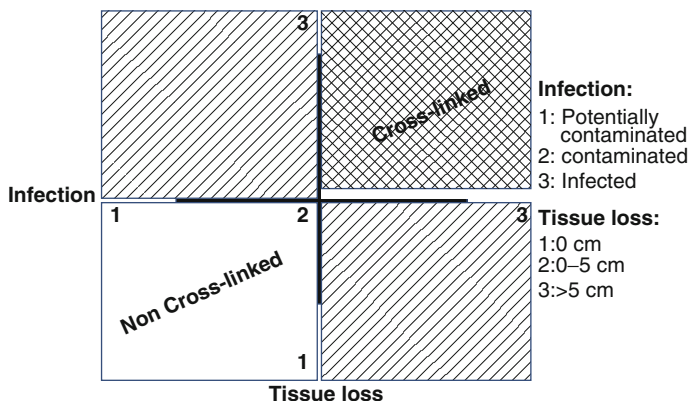


Fig. 19.4 Decisional model diagram: the product of the infection and the loss of tissue scores give as a result the value which indicates the kind of biological prosthesis to use

dynamic process mediated by the surgeon decisional capability. The principal variables to keep in mind in deciding the kind of BP to use are infection grade and loss of tissue size.

Infection has been divided into three possible grades:

- 1: potentially contaminated
- 2: contaminated
- 3: infected

The same three-step division has been adopted for the tissue loss:

- 1: no tissue loss
- 2: 0–5 cm defect
- 3: >5 cm defect

By combining together these variables (multiplication), a score could be obtained which suggests the necessity to use either a cross-linked or a non-cross-linked BP (Figs. 19.4 and 19.5).

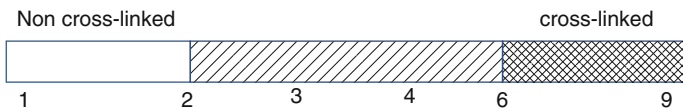


Fig. 19.5 Decision line: the different results indicate the kind of biological prosthesis to use

19.2.9 Quality of Life After Abdominal Wall Reconstruction

Many studies well documented the immediate impact of injury on overall quality of life (QoL). Immediately after the injury, there is a decrease in QoL with a recovery to near baseline over a period lasting at least 1 year [26]. However, most of these studies focused more on trauma patients in general than on patients managed with open abdomens. The reconstruction of the abdominal wall after an open abdomen usually takes place during the first year after injury. At this time point, QoL and functional ability have not returned to near baseline yet. This leads to a “second hit” to QoL and functional ability. Cheatham et al. reported the long-term outcomes of open abdomen management in two papers [27]. On one hand, the authors demonstrated a decrease in QoL in both studies immediately after the first intervention, and on the other hand, they showed that patients recovered to near-normal QoL after abdominal wall reconstructive procedure. The main criticisms of the aforementioned studies are the shortness of the follow-up and the absence of measurement of depression and/or post-traumatic stress disorder. The real effect of the “second hit” on recovery might be investigated with multicenter prospective study in those centers that habitually treat these kinds of disease.

19.3 Conclusions

The best evidence available suggests that the great majority of large abdominal wall defect repair should be performed with the use of prosthetic materials as reinforcement. Due to its complexity, the abdominal wall reconstruction needs to be performed in specialized centers with a multidisciplinary approach. In contaminated or infected field, biological prosthesis should be considered as a fundamental part of the armamentarium of our surgical practice.

References

1. Usher FC, Fries JG, Ochsner JL et al (1959) Marlex mesh, a new plastic mesh for replacing tissue defects: II. Clinical studies. *Arch Surg* 78:138
2. Larson GM, Harrower AW (1978) Plastic mesh repair of incisional hernias. *Am J Surg* 135:559
3. Williams JK, Carlson GW, DeChalain T et al (1998) Role of tensor fasciae latae in abdominal wall reconstruction. *Plast Reconstr Surg* 101(3):713–8
4. Voyles CR, Richardson JD, Bland KI et al (1981) Emergency abdominal wall reconstruction with polypropylene mesh: short-term benefits versus long-term complications. *Ann Surg* 194:219
5. Mathes SJ, Steinwald PM, Foster RD, Hoffman WY, Anthony JP (2000) Complex abdominal wall reconstruction: a comparison of flap and mesh closure. *Ann Surg* 232(4):586–596
6. de Moya MA, Dunham M, Inaba K et al (2008) Long-term outcome of acellular dermal matrix when used for large traumatic open abdomen. *J Trauma* 65:349–353
7. Pomahac B, Aflaki P (2010) Use of a non-cross-linked porcine dermal scaffold in abdominal wall reconstruction. *Am J Surg* 199:22–27
8. Patton HJ Jr, Berry S, Kralovich KA (2006) Use of human acellular dermal matrix in complex and contaminated abdominal wall reconstructions. *Am J Surg* 193:360–363
9. Hill HL, Nahai F, Vasconez LO (1978) The tensor fasciae latae myocutaneous free flap. *Plast Reconstr Surg* 61:517–522

10. Heitmann C, Pelzer M, Menke H et al (2000) The free musculocutaneous tensor fascia lata flap as a backup procedure in tumor surgery. *Ann Plast Surg* 45:399–404
11. Tukiainen E, Leppäniemi A (2011) Reconstruction of extensive abdominal wall defects with microvascular tensor fascia late flap. *Br J Surg* 98:880–884
12. Harth KC, Rosen MJ (2010) Endoscopic versus open component separation in complex abdominal wall reconstruction. *Am J Surg* 199:342–347
13. Connolly PT, Teubner E, Lees NP et al (2008) Outcome of reconstructive surgery for intestinal fistula in the open abdomen. *Ann Surg* 247:440–444
14. Diaz JJ Jr, Cullinane DC, Dutton WD, Jerome R, Bagdonas R, Bilaniuk JW, Collier BR, Como JJ, Cumming J, Griffen M et al (2010) The management of the open abdomen in trauma and emergency general surgery: part 1-damage control. *J Trauma* 68:1425–1438
15. Barker DE, Kaufman HJ, Smith LA, Ciraulo DL, Richart CL, Burns RP (2000) Vacuum pack technique of temporary abdominal closure: a 7-year experience with 112 patients. *J Trauma* 48:201–206
16. Benninger E, Labler L, Seifert B, Trentz O, Menger MD, Meier C (2008) In vitro comparison of intra-abdominal hypertension development after different temporary abdominal closure techniques. *J Surg Res* 144:102–106
17. Roberts DJ, Zygun DA, Grendar J, Ball CG, Robertson HL, Ouellet JF, Cheatham ML, Kirkpatrick AW (2012) Negative-pressure wound therapy for critically ill adults with open abdominal wounds: a systematic review. *J Trauma Acute Care Surg* 73(3):629–639
18. Stannard JP, Robinson JT, Anderson ER, McGwin G Jr, Volgas DA, Alonso JE (2006) Negative pressure wound therapy to treat hematomas and surgical incisions following high-energy trauma. *J Trauma* 60(6):1301–1306
19. Armstrong DG, Attinger CE, Boulton AJ et al (2004) Guidelines regarding negative pressure wound therapy (NPWT) in the diabetic foot: results of the Tucson expert consensus Conference (TECC) on V.A.C. Therapy. *Ostomy Wound Manage* 50(4 Suppl):3S–27S
20. Dinsmore RC, Calton WC Jr, Harvey SB et al (2000) Prevention of adhesions to polypropylene mesh in a traumatized bowel model. *J Am Coll Surg* 191:131–136
21. Disa JJ, Klein MH, Goldberg NH (1996) Advantages of autologous fascia versus synthetic patch abdominal reconstruction in experimental animal defects. *Plast Reconstr Surg* 97:801–806

22. Coccolini F, Catena F, Ansaloni L, Neri F, Gazzotti F, Lazzareschi D, Pinna AD (2011) An innovative abdominal wall repair technique for infected prosthesis: the Eskimo technique. *Ulus Travma Acil Cerrahi Derg* 17(4):354–358
23. Badylak SF (2002) The extracellular matrix as a scaffold for tissue reconstruction. *Semin Cell Dev Biol* 13:377–383
24. Petter-Puchner AH, Fortelny RH, Walder N et al (2008) Adverse effects associated with the use of porcine cross-linked collagen implants in an experimental model of incisional hernia repair. *J Surg Res* 145:105–110
25. Coccolini F, Agresta F, Bassi A, Catena F, Crovella F et al (2012) Italian Biological Prosthesis Work-Group (IBPWG): proposal for a decisional model in using biological prosthesis. *World J Emerg Surg* 7(1):34
26. Michaels AJ, Michaels CE, Smith JS, Moon CH, Peterson C, Long WB (2000) Outcome from injury: general health, work status, and satisfaction 12 months after trauma. *J Trauma* 48(74):841–848, PubMed: 10823527
27. Cheatham ML, Safcsak K, Llerena LE, Morrow CE, Block EFJ (2004) Long-term physical, mental, and functional consequences of abdominal decompression. *J Trauma* 56:237–242, PubMed: 14960962