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Review Article

Complex Incisional Hernias

Review

Incisional hernias are the most frequent "late complications" after laparotomy. They develop in more than 10% of patients and their incidence is related to numerous risk factors (Table 1).

The most important risk factors are obesity, impaired wound healing of the laparotomy wound, malnutrition and tobacco smoking. Regarding the multifactorial pathogenesis of the disease local tissue ischemia is one of the most important risk factors. This causes weakness of the fascia and finally incisional hernia [4,5]. In addition, there are more rare causes, such as immunosuppression, diseases of the collagen metabolism and connective tissue diseases (e.g. patients with aneurysms, Ehlers-Danlos-syndrome). Any factors which are characterized by a persistent or frequent high intra-abdominal pressure (e.g. chronic cough) contribute to the development of an incisional hernia. An important risk factor is the surgeon her/himself, i.e. the quality of the abdominal closure and this is not sufficiently considered in the scientific literature. The pathogenesis of an incisional hernia is in general multifactorial.

In Germany, approximately 50 000 patients with incisional hernias are undergoing corrective surgery per year; in the USA, this number is approximately 350 000 [6-8]. The economic impact of the condition is enormous. The costs for 350 000 patients undergoing surgery per year (USA) have been calculated to be 3.2 billion US Dollars [7,8].

Recurrences after incisional hernia surgery are an unsolved problem to date. The reports in the literature range from 1% to 50% [2,9]. The recurrence rate is correlated to the follow-up time and there are only few high-quality studies with a long-term follow-up. It is generally accepted that the recurrence rate can be reduced by half at least with the use of synthetic meshes.

Over the past 20 to 30 years, the surgical techniques have been further developed with special consideration to the individual risks and anatomic conditions: today, we speak of a tailored approach which means that the hernia morphology and the risk factors as well as the surgeon's level of expertise and experience are taken into account. In Germany, approximately 30% of incisional hernias are being treated by laparoscopic IPOM, 30% by sublay, 13% by open IPOM, 5% by onlay and 12% by sutures only. Component separation is being implemented in 1.6% of patients (Herniamed quality assurance data, Professor F. Köckerling, Berlin).

High-quality prospective randomized trials on the broad subject of incisional hernias are rare in the scientific literature. Thus, there are no generally applicable recommendations, a fact that is emphasized by the mentioned Herniamed data. With respect to the issue of *complex incisional hernias* there are even less reliable data which might yield

Table 1: Risk factors for Incisional Hernias [1-5].

Patient related risk factors / comorbidity	
Major risk factors	**Minor risk factors**
COPD Obesity Steroids Diabetes Malnutrition Hypoalbuminaemia Jaundice Radiotherapye Chemotherapy Oral anticoagulation Smoking	Male gender Postoperative ventilation Renal failure Connective tissue disease Malignancy Blood transfusion Anaemia
Wound related risk factors	**Laparotomy closure related**
Disturbances of the collagen metabolism Reduced ratio of collagen type I/III Reduced expression of MMP-1 and MMP-13 Enhanced expression of active MMP-2 Closure of the peritoneum Midline laparotomy Wound infection	Suture length/wound length ratio < 4/1 Small bite technique (?) Enhanced abdominal wall tension Re-laparotomy within 1 month > 2 laparotomies/year
Situation related	**Postoperative / mechanical stress**
Emergency Bleeding Trauma Abdominal Sepsis	Coughing Abdominal distension Heavy physical exercise Straining during defacation Vomiting
Laparoscopy related	
Diameter of the portsite ≥ 10 mm Multiple insertions Long duration of surgery Large quantities of fluid left in the peritoneal cavity Inadequate evacuation of pneumoperitoneum Unrelaxed abdominal wall at the end of the procedure Increased abdominal pressure at the end of surgery	**other** Postoperative complications Antibiotic prophylaxis Surgeon Length of follow-up Use of electric cautery (?)

generally applicable evidence based recommendations. This reveals the need to intensify multi-center and possibly multi-disciplinary co-operation and, thus, to establish generally accepted classifications.

There are no established general procedures for the treatment of complex incisional hernias: the more extended and demanding the hernia treatment, the less general rules are available [10].

This paper focuses on the particularities of complex hernias with respect to hernia classifications, diagnosis, treatment modalities and desirable inter-disciplinary co-operation. Thus, I will try to suggest practical solutions for a still challenging problem in abdominal surgery.

Incisional hernia classifications in general

There is an agreement among experts that an incisional hernia classification is urgently required in order to compare treatment results of different hernioplasty methods and also for patient's stratification. On the other hand, there is yet no generally accepted incisional hernia classification even though numerous attempts including activities of the respective professional associations on this issue have been documented. The parameters which have been included in existing classifications are summarized in Table 2.

The following requirements have been suggested in different hernia classifications [2,3,11-16,18-25]:

- They should be simple, convenient and internationally accepted
- They should facilitate the comparison of results
- They should facilitate the planning of clinical trials
- They should facilitate peri-operative planning and standardized diagnosis
- They should help estimate the costs
- They should facilitate treatment planning / selecting the most suitable treatment method
- They should facilitate the estimation of the expected complexity of minimally invasive treatment methods

Table 2: Incisional Hernia Classification Criteria.

Criterion / parameter	References
Size	[2,3,11-16]
Localization / Morphology	[2,3,11-17]
Recurrent Hernia	[2,3,11-16]
Grade of Reducibility	[11,13,16]
Symptomatology	[13,16]
Specific localization (e. g. lumbar hernia, Pfannenstiel incision, subcostal incision, extended sternotomy incision)	[16]
Eventration in upright and supine position	[11]
Stability of the adjacent abdominal wall	[11]
Patient's Body Type (subcostal angle, attenuated muscles, voluminous abdomen)	[2,3]
Palpability of the gap edges	[16]
Hernia content	[16]
More planning regarding port placement, mesh fixation and/or colon mobilisation is required	[16]
Multiple scarred abdomen	[16]
Multiple previous incisions	[16]
Presenting as acute obstruction	[16]
Ratio Abdominal wall surface/wall defect surface	[15]
Risk factors for recurrence	[2,3]
Number of hernia gaps	[11]
Differentiation primary ventral hernia/incisional hernia	[14]

It is obvious that any incisional hernia classification can only include a very limited number of relevant factors and that they should be restricted to those factors which have the strongest predictive value [12].

At a consensus meeting in 2009, an incisional hernia classification has been proposed for further scientific evaluation and definition of subgroups [14]. The established minimal requirements for a hernia classification [11] have been fulfilled and "location", "size" and "recurrence" have been included as parameters [14]. Similar to the classification of inguinal hernias, classifications for all types of abdominal wall hernias shall be developed by the EHS. For example, an EHS expert meeting proposed a parastomal hernia classification [22]. In general, the consideration of all relevant risk factors would be desirable [2,3,18,22]. In reality, this may be difficult to implement completely in one classification system because of the above mentioned complex multifactorial scenario.

Characteristics and classifications of complex incisional hernias

Even though the term "complex incisional hernia" is used increasingly, so far there is no generally accepted definition available. Complex incisional hernias are characterized in particular by the presence of certain general risk factors, anatomic peculiarities and/or a risk with respect to infection. Usually, there are several concomitant risk factors. Frequently, these are recurrent hernias and the patients have a history of complications. Also, there is a risk of complications from the treatment of the hernias. Post-operatively impaired wound healing and recurrences are frequently observed.

The treatment of complex hernias is an outstanding example for the so called tailored approach in hernia surgery. Complex hernias are surgical challenges and their treatment requires the entire spectrum of techniques and equipment (including interdisciplinary co-operation, e.g. with the plastic surgeon). So far, there are two (completely different) suggestions for the classification of complex incisional hernias. On the basis of 22 patient-related and hernia-related variables, the suggestion of Slater et al. has four categories which are divided in three groups of severity. These are supposed to allow an estimation of the perioperative planning, the risk of complications and the expected expenditure of resources [24]. The classification suggested by Hadeed et al. is very simple but with respect to the required detailed treatment planning and the aim of further standardized treatment algorithms it may not be sufficient in clinical practice [25].

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Slater's classification has the advantage of listing almost all factors that are relevant for a complex hernia. It appears, however, to be a problem, that even *one* risk factor for impaired wound healing (obesity, diabetes, steroid use, tobacco smoking, old age or poor nutritional status/albumin < 30 g/dl) is sufficient to define a "minor" class complex hernia. Accordingly, two of these factors are sufficient to classify a "moderate" class complex hernia. This classification of complex hernias appears to be unrealistic in everyday clinical practice as many patients present with one or more of these factors while one cannot speak of a complex hernia unless at the same time there are other aggravating factors (anatomical or infectious) simultaneously present.

Synthetic hernia meshes

In the international literature, more than 90% of patients with inguinal hernias are being treated with synthetic mesh implantation. Similar numbers may be expected for common incisional hernia surgery. According to the Herniamed register, only 10% of incisional hernia patients do not have a mesh implanted. For complex hernias, it may be assumed that none of the affected patients can be treated without any augmentation material at all.

Synthetic meshes can often be applied in the surgery of complex hernias under the condition that there is no infection and no increased risk for a potential infection. The most common materials are currently polypropylene, (expanded) polytretrafluorethylene, polyester and PVDF [26,27]. In addition to the respective polymer, processing-dependent factors, such as mesh thickness, amount of material, filament structure and weaving specifications, surface and pore size play a role. Low-weight macro-porous meshes, in particular polypropylene, have an acceptable biocompatibility and an appropriate price.

Biological implants

Hiles et al. have been among the first who have in 2009 published a comprehensive review on the effectiveness of biological meshes for hernia repairs [28]. They found an overall success rate of more than 90%, however there was a limited evidence level (level III) for the analyzed materials (small intestinal submucosa [SIS], acellular human dermis [AHD] and porcine dermis [PD]). With cross-linked meshes, however, there was a rather high number of adverse effects so that from the beginning there were also voices of concern [29,30]. Currently, more than one dozen biological meshes are commercially available [27,31,32]. They are manufactured on the basis of human, porcine or bovine dermis, bovine pericardium or porcine small intestinal submucosa. Their role cannot be determined conclusively to date for reasons of limited data. Generally, they may be considered as a significant improvement for the repair of complex hernias. This is mainly due to the potential use in the contaminated field: the main advantages are neovascularization which enables the material to withstand infection or treatment of a pre-existing infection with open wound treatment or vacuum therapy without the need to remove the material from the hernioplasty. Also, there is a comparably minor foreign body reaction which causes fewer adhesions and enables the use as IPOM. Furthermore, the biological meshes provide stability with host tissue in-growth which provides the adequate tissue strength [33]. What happens with this tissue in-growth is a cycle of remodeling consisting of degradation of the mesh and regeneration of the collagen scaffold. The remodeling is mediated mainly by growth factors, endothelial cell attraction and fibroblast in-growth and is strongly supported by the three-dimensional nature and the porosity of the mesh. The commercially available biological meshes are treated with the chemical process of cross-linking. This is well known from the leather industry and leads to the establishment of disulfide bridges between the collagen fibrils (cross-links). It is supposed to restrict collagen degradation and, thus, enhance the mechanical stability of the biological "mesh". The extent of the cross-linking influences the neovascularization, the substance of the extracellular matrix, the cellular infiltration and ultimately the dynamics of the "degradation" of the collagen scaffold. In simple terms, one may say that increased cross-linking results in an increased resistance against enzymatic degradation and that the rate of cellular in-growth is reduced, favoring fibroblast-mediated encapsulation [34-36]. From a scientific point of view, there are currently substantial deficits in research into biological meshes. First of all, the processing of the material is largely intransparent as the manufacturers avoid disclosure of their specialist knowledge (such as type and extent of decellularization, sterilization process etc.) for reasons of competitive markets. Also, there are only few (large) animal models which compare different bio-prostheses. Furthermore, the evidence level of clinical research is still low as hardly any high-quality, prospective, randomized comparative studies have been published.

The currently available systematic reviews on the subject show an inconclusive picture. Beale et al. suggest that biological mesh does play a beneficial role in abdominal wall reconstruction but allograft dermal matrix is of concern regarding a higher recurrence rate compared with xenograft products [37]. Poussier et al., see the role in complex situations where the parietal reinforcement has to be made in potentially contaminated or infected fields [38]. Darehzereshki et al., conclude that the use of biological mesh for ventral hernia repair results in less infectious wound complications but similar recurrence rate compared to non-biological mesh. This supports the application of biological mesh for ventral hernia repair in high-risk patients or patients with a previous history of wound infection only when the significant additional cost of these materials can be justified and synthetic mesh is considered inappropriate [39]. Slater et al., point out that biological grafts are associated with a high salvage rate when faced with infection [40]. They and Bellows et al. [41], emphasize at the same time that there is an insufficient level of high-quality evidence in the literature and that randomized controlled trials that use standardized reporting are needed.

The initial indication for the use of a biological mesh was only in contaminated/infected or potentially infected scenarios. The indication has been extended to practically all hernia situations, in particular in the USA and in particular over the last decade. Thus, it should not be forgotten that this phenomenon is driving a multi-million dollar market. Several authors caution against overuse and call for a more critical evaluation [42-45]. Biological meshes have been available for 15 years. The focus of approval by the health authorities, e.g. the FDA, is on the safety of the material. The approval criteria do not provide any information about the efficacy of the material. There

is on-going criticism that in spite of long-term clinical use the efficacy (wound complications, long-term performance and incidence of hernia recurrence) has been insufficiently investigated. Because of the high costs (10-20fold more expensive) and missing level I evidence, there is a warning against uncritical use [42-45].

Surgical techniques

Generally, all common surgical methods may be implemented for the repair of complex hernias, in particular sublay, onlay, laparoscopic and open IPOM. Even though there is no clear evidence against the onlay procedure to date, this has to be regarded as the second-best choice because of the large-area subcutaneous dissection and the mechanical aspects in complex hernias. A sublay procedure is possible in principle but because of the specific morphological aspects of complex hernias there are frequently constellations which speak against a sublay. These are in particular wide eccentric defects, large hernia defects, a close-to-bone-situation, much scarring and pre-existing infections. Thus, a bridging procedure will be much more frequent than a pure sublay. Under the proper conditions, laparoscopic IPOM is a suitable technique also for the repair of complex hernias and it is also advantageous in obese patients [46]. Elective laparoscopic repair with cross-linked biological meshes can be considered a reasonable surgical option and should not be performed with the use of a non-cross-linked biological mesh with a bridging technique. Laparoscopic repair of incisional and ventral hernias with non-cross-linked biological meshes in an infected or potentially contaminated surgical field may be a viable option if the hernia defect is closed primarily [47]. Complex hernias, however, present frequently with eccentric defects, large hernia defects (> 10 cm), a close-to-bone-situation, a loss-of-domain-situation, full-thickness defect with the respective tissue loss for the soft-tissue coverage or concurrent scarring and infections which require debridement. A combination of these factors is more common than not. The above mentioned factors necessitate open IPOM as one of the most frequently performed techniques for complex hernias. Furthermore, combinations of the individual techniques are used.

Components separation

The key surgical invention in the components separation (CS) is the creation of a musculofascial rectus abdominis component that can be mobilized laterally and brought to the midline [48]. Towards the end of the 19. Century, Guillouid, Chrobak, Gersuny and Noble described various methods to close midline defects with sutures and fascial flaps [48]. However, it was Alfonso Roque Albanese from Argentina who in 1951 described the method of dividing the external oblique muscle vertically to enable the closure at the midline by suturing together the rectus abdominis muscles [48-51]. The method was rediscovered and refined by Ramirez and co-workers in their elegant study from 1990 [48,52]. These days, "components separation" is used for several different techniques which use only or in combination the separation of the fascias of the anterior and posterior rectus sheath, the M. obliquus abdominis internus, the M. obliquus abdominis externus or the M. transversus abdominis [10,53-56]. The techniques of CS can be performed with and without (synthetic/biological) mesh reinforcement. The mesh reinforcement is controversially discussed for reasons of costs. The recurrence rate is (in the available non-controlled studies) reported comparably high (10-35%) and it is higher without mesh reinforcement [57-65]. The method can be performed in principal laparoscopically, too [66-68] and with advantages in obese patients [69]. Components separation surgical outcomes were similar whether or not the rectus complex was violated [70]. Analytic morphomics can be used to compare pre- and post-operative changes in patients undergoing CS. Components separation affects the dimension of the entire abdomen but leaves the fascia area and circumference relatively unchanged. Altogether it is a functional operation that restores fascial area but better defining the effects can help to understand the effects of its clinical significance [71].

The CS is a sensible addition of the methods spectrum in complex hernias, too. The technique can also be used in a violated rectus complex [70]. In very complex hernias, however, with increasing destruction of the original fascial situation (re-recurrence, much scarring, florid infection etc.), the CS can be sensibly used only partially or not at all. Also, a CS with the conventional technique enlarges the wound area significantly and is, thus, in complex hernias not without problems. In these cases, it is sensible to evaluate alternatives, such as CS via lateral ancillary incisions or via a minimally invasive access [48,66,72-75). Furthermore, the use of CS follows obviously national preferences. The literature suggests that the technique is widely used in the USA while it is used in less than 2% of patients in Germany (Herniamed Qualitätssicherungsdaten, Professor F. Köckerling, Berlin).

Loss of domain

A loss-of-domain-situation (LODS) is a classical factor that makes an incisional hernia a complex hernia. To date, there is no consensus on the definition of LODS. On physical examination, the inability to reduce the herniated contents below the fascia level when the patient is lying supine should raise suspicion of a LODS [76]. On the basis of CT studies, an extra peritoneal volume from 20-25% warrants the term LODS [77,78]. However, there are much higher volumes in the literature (e.g. 50% according to [76]). There is consent that the best method for the determination of LODS is CT. More accurately LODS is defined when the ratio of the volume of the hernia sac to the volume of the abdominal cavity is ≥ 0.5 [76]. The volume is measured via the sagittal and axial reconstruction of the CT scan. Using the formula to measure the volume of an ellipsoid ($V = ¾ \times \pi \times r1 \times r2 \times r3$; in a simplification: $V = 0.52 \times L \times H \times W$) the hernia sac and abdominal cavity volumes can be measured and compared [76]. To re-accommodate such a large volume of hernia content, the surgeon must employ a modality which increases the volume of the abdominal cavity by lengthening the abdominal wall musculature via mechanical expansion, anatomic alteration, synthetic/biological replacement or combination of these techniques [76]. In general, tissue expanders or – more elegantly – the progressive pre-operative pneumoperitoneum (PPP) may be used for mechanical expansion [76,79-81]. For this, an increasing pneumoperitoneum is being maintained for seven days or longer via a suitable catheter that can be blocked and locked (e.g. peritoneal dialysis catheter). In this way, an increasing chronic abdominal compartment syndrome is being created. The patient is forced to overcome the adverse respiratory and cardiovascular effects of the progressive pneumoperitoneum and is, thus, not confronted

with the development of an acute abdominal compartment syndrome after the operation. The PPP may be combined with botulinum toxin injection as required [82].

Because of the large hernia defect, the mismatch between the intra-abdominal volume and the extra-peritoneal hernia volume and a frequently concurrent soft tissue defect, the vast majority of cases require a bridging procedure in the sense of IPOM for abdominal wall replacement, when indicated in combination with CS. Depending on the size, a plastic reconstruction may be considered (see below). In rare cases, a resection of parts of the small and/or large bowel may be necessary.

Carbonell et al. [76], recommend for massive ventral hernia with LODS a staged procedure:

Stage I:

- percutaneous vena cava filter and anti-thrombotic medication because of high risk for thromboembolic events
- explorative laparoscopy and placement of the insufflation catheter
- thereafter monitoring of pulse oximetry and vital signs
- full liquid diet with protein supplementation
- the patient is instructed to utilize incentive spirometry and ambulate daily

Stage II:

- beginning of PPP on POD 1 (from air hose at patient's bedside)
- if patient will begin to complain of abdominal tightness and mild flank discomfort, insufflation is stopped once the patient begins to experience some shortness of breath or mild anxiety (there is no specific volume of air that should be insufflated nor the intra-abdominal pressure measured, endpoint of insufflation will always be the patient's level of discomfort; if at any point the patient becomes hemodynamically unstable or the urine output decreases, the pneumoperitoneum can be evacuated).
- daily moisturizing of the skin because of dryness and cracking
- after 7 days of PPP, CT scan is repeated to determine the suitability of the abdominal wall repair (if the bowel has not fallen back and the volume of the abdomen does not look to have increased significantly, the PPP should continue for more 4 to 5 days and CT scan is repeated).

Stage III

- Rives-Stoppa retromuscular hernia repair technique with or without the addition of a posterior CS or
- IPOM

Risk factors for respiratory complications and general peri-operative optimization

Fischer et al. reviewed the 2005 to 2010 American College of Surgeons National Surgical Quality Improvement Program databases, identifying encounters for Current Procedural Terminology codes for both hernia repair and CS. 6% (102/1706) of the patients with complex abdominal reconstructions experienced respiratory failure. Multivariate logistic regression revealed COPD, dyspnea at rest, dependent functional status, malnutrition, recurrent incarcerated hernia, concurrent intra-abdominal procedure, SAA Score > 3 and prolonged operative time as variables significantly associated with higher rates of postoperative respiratory failure [83]. The study of Blatnik et al., revealed that patients with an increase in their plateau pressure (respiratory ventilator) of greater than 6 cm H2O are at an increased risk of severe post-operative respiratory complications [84]. Patients with complex hernia repairs experiencing post-operative failure have a higher mortality rate (14.7 vs. 0.1%, [83]). The pre-operative optimization and the risk assessment as such are of paramount importance.

A number of peri-operative relevant factors should be optimized as best as possible prior to complex abdominal wall reconstruction: optimal drug treatment of COPD. Patients should diligently practice respiratory exercises preoperatively (Triflow, physiotherapy). Smokers should abstain from nicotine as early as possible. A comprehensive pre-operative cardiac diagnostic routine is required and any respective treatment should be optimized. A pre-existing diabetes mellitus should be treated optimally (HbA1c < 7%). Obese patients should aim for a weight reduction pre-operatively. This is, however, realistic in very few patients for reasons of the vicious circle (e.g. sedentary lifestyle because of the hernia symptoms; embarrassment in front of the public because of cosmetic disfigurement etc.). Bariatric procedures (gastric balloon/endobarrier or even surgery) may be recommended to morbidly obese patients to support weight loss. A catabolic nutritional state should also be avoided and relevant malnutrition should be corrected preoperatively. If ulcers or impetigo are present, these have to be treated pre-operatively. In cases of fistulas or mesh infections, antibiotics must be administered targeting the causative agent(s). In patients with immunosuppression, it needs to be decided whether these can be terminated or switched to medication with less impact on the wound healing. As the wound areas are often rather large, any medication with anticoagulant properties should be reduced to the necessary minimum in order to avoid postoperative hematomas or hemorrhage. On the other side, consequent drug and mechanical prophylaxis against thrombosis is necessary because of the increased risk from increased intra-abdominal pressure/decreased venous return.

Simultaneous complex abdominal wall reconstruction and enterocutaneous fistula takedown

The surgical management of enterocutaneous fistulas and/or stoma closure in the setting of large abdominal wall defects can be very challenging for multiple reasons:

- Incomplete sterility
- Impaired nutritional status of patients, frequently taking total parenteral nutrition
- Difficult anatomy
- Difficult underlying disease (e.g. IBD, complicated course e.g. following sepsis und/or peritonitis)

- Frequently large skin and soft tissue defects
- Psychological situation (feeling of stigma from stoma/fistula, patients have undergone a procedure with complications and are facing another procedure with potential complications)

It is not possible within the scope of this paper to discuss all implications of these factors. Thus, in the following only the most important are being mentioned and we refer to the quoted literature [85,86].

Incomplete sterility with potential contamination from enteric organisms implicates the more prominent role of biological hernia implants and autologous reconstructive methods, such as CS. Furthermore, sequential procedures are more frequently performed. The large soft tissue defects frequently necessitate reconstructions with pedicled and free flaps or a combination of the two. Many patients with enterocutaneous fistulas are nutritionally depleted, and nutritional support in these patients is required for restoration of lean body mass and to optimize recovery from surgical treatment [85]. Patients with acute intestinal failure which usually corresponds to a high-output fistula, generally require parenteral nutrition. In patients with mucocutaneous continuity, however, the ability to cannulate the gut distal to the fistula enables nutritional support by feeding directly downstream of the fistula (fistuloclycis, [85,87,88]). Thorough diagnostic procedures are necessary to evaluate the anatomical situation. In individual cases, multiple resections and anastomoses are necessary and these should be based on minute planning. In patients with IBD, the drug treatment has to be optimized. The highly complex treatment of these patients should, thus, primarily be managed by an interdisciplinary team with gastroenterologists, nutritional specialists, abdominal surgeons, plastic surgeons, pain specialists and clinical psychologists.

Plastic surgery procedures

A defect through all layers of the abdominal wall poses a very complex scenario for the abdominal wall reconstruction and requires close co-operation between the hernia surgeon and the plastic surgeon. In the literature, numerous reconstructive techniques and flap types are reported, mainly on the basis of case series (most of them $n < 10$). The decision for the choice of the reconstructive technique is mainly based on the underlying disease (most frequent situation: trauma, mutilating infection, abdominal wall resection for tumors, enterocutaneous fistulas, radiogenic alterations and laparostoma) and the anatomic location of the defect. The subxiphoid region requires – according to the size of the defect – almost always a free microvascular-connected flap transfer. All other regions allow under favorable conditions (size and location of the defect) a pedicled flap from the trunk, back or thigh. Large abdominal defects can in general not be covered by a flap from the abdominal region. Furthermore, very large defects necessitate the combination of different (free and/or pedicled) flaps. Free flaps may in principle be connected to the inguinal (epigastric and femoral vessels), axillary (thoracodorsal pedicle, axillary vessels) or chest wall (internal mammary) vessels. For additional pedicle length, vein grafts like the great saphenous vein may be required for both the arterial and venous elongation. Factors like the vascular pedicle length, the donor site morbidity and the skin paddle size play also a major role in the flap selection. Strategic considerations are also important (e.g. necessary re-intervention for closure of a stoma, potential re-intervention for Crohn's disease) as subsequent surgery should ideally be performed beside the flap. Even though numerous myocutaneous flaps may also be performed with nerve reconstruction (e.g. innervated free latissimus dorsi flap) and functional deficits of the myocutaneous flap can thus be ameliorated as the muscle-fascia-complex does not or to a lesser extent become atrophic, the majority of abdominal wall reconstructions require an additional mesh inset, sublay or IPOM (biologic/synthetic).

As regional lower extremity-based flaps the following are reported:

Tensor fascia latae flap

Rectus femoris flap

Vastus lateralis flap

Sartorius flap

Anterolateral thigh flap and

Subtotal thigh flap [53, 89-94].

The serratus anterior myofascial flap is an option used for smaller defects of the abdominal wall in the lateral and superior portion of the abdomen [90].

Perforator flaps have proven to be another reasonable option with which to restore any skin deficiencies whether as pedicled or free flaps [95]. By definition no muscle is ever included. Maximum function preservation of the abdominal wall is achieved because denervation of functioning muscle is avoided. The most suitable (local) perforator flaps are the deep inferior epigastric artery perforator flap (DIEAP), the anterolateral thigh flap (ALT) and the deep superior epigastric artery perforator flap (DSEAP). Primary choice is the DIEAP and ALT for the infraumbilical zone, the ALT for the lateral abdominal zone, the DSEAP for the epigastric zone and the DIEAP for the periumbilical zone. Alternatives/secondary choices depending on the abdominal zone are the tensor fasciae latae/lateral circumflex femoral artery flap (TFL), the medial circumflex femoral artery perforator flap (MCFAP), the lumbar artery perforator flap (LAP), the superficial circumflex iliac artery perforator flap (SCIAP), the superficial inferior epigastric artery perforator flap (SIEAP), the superficial pudendal artery perforator flap (SPAP), the lateral branch of posterior intercostal artery perforator flap (LPIAP), the internal mammary artery perforator flap (IMAP) and the anterior intercostal artery perforator flap (AICAP, [95]).

Several other free flap methods have been reported, in particular the latissimus dorsi muscle flap, the tensor fasciae latae flap and the anterolateral thigh flap [48,53,90,94,96-103]. Here, possible disadvantages are flap loss from vascular problems and morbidity and loss of function from the flap harvesting. However, the loss of function is surprisingly little e.g. with the latissimus dorsi muscle flap and it improves over time [104]. The main advantage is that even large defects in almost every location can be covered sufficiently. Depending on the location of the defect, an extension of the vascular axis with a venous graft may be necessary (48,90,101].

Summary and critical evaluation of the surgical methods

To date, there are no guidelines based on a high level of evidence on the treatment of incisional hernias. Furthermore, different approaches are favored in different countries. Both of these statements pertain in particular to complex incisional hernias. There is no single method recommended for the treatment of complex incisional hernias. With increasing extent and complexity of the hernias, there are less general rules for the treatment [10]. Complex incisional hernias require the full range of surgical techniques and equipment. They also require experience and possibly close inter-disciplinary co-operation (plastic surgery, critical care, meticulous anesthetic planning and care). It is, thus, sensible to manage patients with complex hernias at surgical units with special experience in this area of work. Furthermore, the clinical research on a multi-center basis should be strengthened in order to standardize the surgical technique on the basis of higher evidence levels. In spite of technical and pre-operative optimization efforts, the recurrence rate will be high, in particular with respect to impaired wound healing. This implies a rather high number of re-interventions. This has to be considered with respect to the medical professional, the reimbursement and especially for the communication with patients and their expectations.

In spite of the statement that there is no general rule, a number of general hints and recommendations with respect to the surgical technique and the materials can be offered.

The (pure) sublay technique is the method of choice even in complex hernias (best mesh incorporation; least subcutaneous dissection area; avoidance of intraperitoneal mesh position; frequently, the use of a synthetic mesh is possible). However, the pure sublay technique is possible only in few cases. The next step up would be the so called bridging procedure with its different modifications. As bridging is often necessary for complex hernias, IPOM as the maximum type of a bridging is frequently performed. The main advantage of IPOM is the significant reduction of the wound area as the need to dissect subcutaneously and within the muscle-fascia-compartment is significantly reduced: the frequently encountered mismatch between the hernia size (defect size and the necessary overlap) and the necessary dissection area is optimized. The main disadvantages of IPOM are the long-term intra-peritoneal implant, the primary intra-peritoneal approach and the need of a frequently very extended adhesiolysis. CS (in its different varieties) is a good complement for both techniques, especially when it does indeed facilitate a fascia closure in the median line or in the middle of the hernia defect, respectively. If at all possible, the minimally invasive approach should be chosen for CS. The close-to-bone-situation often requires extra-peritoneal preparation (Spatium Retzii, subcostal, lumbal). In rare cases, when other fixations of the mesh are impossible or the respective mesh overlap (e.g. with additional glue) is impossible, bone anchors or even drillings for transosseous fixation (os ileum) may be used. In all cases with primary (pre-existing large defect, e.g. following extended resection) or secondary (e.g. when a large resection is required in an infectious situation) insufficient soft tissue covering, the use of a free or pedicled flap should be considered in co-operation with the plastic surgeon. In a loss-of-domain-situation it is necessary to obtain a valid estimation of the volume deficit as well as the cardio-pulmonary reserve pre-operatively. In preparation, tissue expanders and PPP, possibly with the addition of botulinum toxin injection into the abdominal wall [82], may be used. The interdisciplinary co-operation during the post-operative recovery (intensive physiotherapy/respiratory therapy, ICU, possibly post-operative mechanical ventilation) is important. The last resort in a loss-of-domain-situation is bowel resection. In patients who may be at risk for post-operative impaired wound healing (this is the case in very many complex hernias), in those with pre-existing bowel fistulas, simultaneously planned closure of stomas or those with bowel resections in hernias in an acute infection (e.g. mesh infection), the use of a biological mesh should be considered. Even though the role of biologicals has not yet been fully evaluated, they are very useful in the above mentioned problem constellations. In case of severely impaired wound healing, synthetic meshes often need to be (at least partially) removed and, thus, a recurrence becomes a very real possibility. With the use of biologicals, even severely impaired wound healing can be treated with specific wound therapy and vacuum dressings where appropriate. In very complex cases or presentations, sequential treatment should be considered. The method of choice depends on the individual presentation (e.g. soft tissue-/flap coverage during the interval, hernia repair in the interval after resection or treatment of an acute infection).

Conclusion

Complex incisional hernias are essentially characterized by the following: large hernia defect, large abdominal wall/soft tissue defect and/or enterocutaneous fistula, several hernias in anatomically distant locations, re-recurrence, loss-of-domain, close-to-bone or local infection. The repair of complex hernias is challenging. It requires a broad range of methods and often interdisciplinary co-operation. The rate of recurrence and wound complications is high. The patients' expectations and all aspects of hernia-related quality of life need to be included in the treatment plan. Even though the role of biological meshes has not yet been fully evaluated, they are very useful in contaminated and infected locations. Good preoperative planning is crucial and includes the reduction of risk factors that can be targeted. Complex hernias are a classical field for the so called tailored approach. The more extensive and challenging the hernia repair, the less general rules are available. There are only few high-quality clinical studies in this field. The complex morphology and the scarcity of cases suggest research into this clinical problem on a multi-center and registry basis with relevant risk stratification and pooling of results. As a rule of thumb, one should aim for the method that is technically the simplest to achieve the desired outcome. The costs for the treatment of complex hernias are high and are properly reimbursed in the minority of cases. This calls for a close co-operation of the medical professional with the health insurance authority and a proper reimbursement scheme (at least with respect to the German health care system). The treatment of complex hernias requires much experience. These hernia patients should be treated at specialized centers with experience in hernia surgery.

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