SHORT THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PHD)

Significance of Autologous Tissues in The Treatment of Complicated and Eventrated Abdominal Wall Hernias

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1. Introduction and literature overview

Repair of complicated, large, or eventrated abdominal wall hernias poses a considerable challenge for surgeons. Conditions characterized by the presence of an eventrated scar hernia and an extensive abdominal wall defect developed from an – initially – small ventral abdominal wall hernia are not infrequent in the surgical practice. Progression of incisional hernias in laparotomy scars may lead to a similar condition.

Reconstruction of abdominal wall hernias accounts for 3 to 11% of all surgeries performed in general surgical wards, depending on the type and profile of the institute. Incisional hernias have a special significance in the surgical practice for two reasons: first, they develop as a consequence of an earlier intervention and have to be corrected, preferably in a definitive way, also satisfactory to the patient; second, abdominal wall hernias cannot always be resolved definitively despite all efforts. Scar hernias may recur for various reasons.

They may be the consequence of inadequate surgical technique; in many cases, however, they are due to lack of compliance and discipline (strain exerted too early and not in a gradual fashion) on the patient's part. The question whether scar hernias are complications or natural corollaries of surgical interventions has been asked by several authors. Whatever the reason, flat abdominal muscles lose their adherence partly or completely along the linea alba in the midline of the abdominal wall, and a progressive, well-

defined and well-known vicious circle is started. Since the reconstructed abdominal wall must resist, as much as possible, the intra-abdominal pressure – which often rises abruptly - as well as tension due to physical strain, reinforcement of the abdominal wall is a key factor in the surgery of abdominal wall hernias.

Four kinds of techniques, each fundamentally different from the other, have evolved for the repair of abdominal wall hernias.

- The *first* is direct abdominal wall suture, with a synthetic mesh implanted in one of the following positions: epifascial (onlay), interfascial (inlay) or subfascial (sublay).
- The *second* is the so-called components separation technique, in which closure of the defect is achieved by specific release of individual muscular components in the abdominal wall.
- The *third* is laparoscopic abdominal wall reconstruction, in which a synthetic mesh is used to reinforce the abdominal wall.
- The *fourth* technique involves bridging or replacement of the abdominal wall defect using synthetic or biological substances. The common objectives of all these techniques are reducing the incidence of surgical complications, lowering recurrence rate, and improving the patients' quality of life.

Infected/compromised and eventrated abdominal wall hernias account for 1 to 8% of all (ventral and incisional) abdominal wall hernias in various institutes. Treatment of complicated, large or infected incisional hernias

places a considerable burden on the patient, the hospital staff, the GP, as well as the social insurance.

The common objectives of all procedures performed in such cases are: 1) *elimination of contamination* in the abdominal wall environment; 2) *closure* of the abdominal wall *defect* with as little tension as possible; 3) maintenance of near-*normal intra-abdominal pressure*; 4) *reduction* of postoperative surgical *complications*; 5) *reduction* of hernia *recurrence*; and last but not least 6) *improvement of the quality of life*.

1.1.Definition, terminology

The use of a unified and unequivocal terminology is essential in the surgery of abdominal wall hernias. The nomenclature follows the recommendations of the European Hernia Society (EHS).

Ventral abdominal wall hernias aredefined as abdominal wall defects of non-surgical origin, through which intra-abdominal tissues and organs leave the abdominal cavity and enter among subcutaneous tissues. Ventral hernias are located in an area bordered by the bilateral anterior axillary line, the costal arches and the pubic bone.

Incisional abdominal wall hernias are defined as abdominal wall defects developing in the scars of an earlier surgical intervention allowing tissues and organs to leave the abdominal cavity and enter among subcutaneous tissues.

Medial abdominal wall hernias are defined as hernias between the medial margins of the bilateral rectus abdominis sheaths; they can be M1: xyphoidal,

M2: epigastric, M3: umbilical, M4: infraumbilical, and M5: suprapubic hernias.

Lateral abdominal wall hernias are defined as abdominal wall defects located lateral of the outer margin of the rectus abdominis sheath, with L1being: subcostal, L2: iliac, L3: lumbar, L4: inguinal.

Small abdominal wall hernia: the longest diameter of the abdominal wall defect is less than 2 cm.

Medium-sized abdominal wall hernia: the longest diameter of the abdominal wall defect is between 4 and 10 cm.

Large abdominal wall hernia: the shortest diameter of the abdominal wall defect is at least 10 cm.

Midline scar hernias are defined as incisional hernias developed in the scars of median laparotomies.

Lateral scar hernias are defined as incisional abdominal wall hernias located lateral of the rectus abdominis sheath.

Recurrent abdominal wall hernias are defined as scar hernias which have been repaired at least once in an earlier surgery. They consist of two basic components: the abdominal wall defect and the hernia sac with the hernia contents. It should be borne in mind that an abdominal wall protuberance is not an abdominal wall hernia by definition.

A *seroma* is a circumscribed, encapsulated pocket of interstitial non-infected fluid developing between the abdominal wall fascia and the subcutis in the operative area. A diffuse, unencapsulated collection of fluid is not to be interpreted as a seroma.

An *enterocutaneous fistula* is an abnormal passage allowing chronic communication between two epithelial surfaces (e.g. the small or large intestine and the skin).

A *subcutaneous fistula* is a chronic abnormal communication system connecting the abdominal wall superficial fascia and the implanted synthetic/biological material.

Graft: fixed synthetic or biological material without blood supply of its own implanted over, under, or among the abdominal wall fascia.

Flap: a tissue with its own blood supply transferred from another area of the body to cover or replacethe abdominal wall defect.

Synthetic grafts are man-made substances (polyethylene, polypropylene, teflon) used to reinforce the abdominal wall.

Xeno- and allografts: specially prepared biological substances of animal (porcine, bovine) or human origin used for reinforcement and/or replacementof the abdominal wall in special cases.

Autografts: tissues collected from the patient's own body, suitable for replacement and/or reinforcement of abdominal wall defects.

A *superficial wound infection* is an inflammatory process at the site of the operation affecting exclusively the skin and the subcutaneous fatty tissue.

A *deep wound infection* is an inflammatory process at the site of the operation affecting the skin, the subcutaneous fatty tissue, the abdominal wall fascia, the muscles, as well as the implanted mesh. The abdominal cavity is not affected by this process.

Wound dehiscence: partial, clean or clean-contaminated rupture of continuity affecting the skin and the subcutaneous tissue.

Centers for Disease Control and Prevention (CDC) wound environment: classification of wounds by cleanliness into 4 categories. CDC 1: clean, sterile; CDC 2: clean but contaminated; CDC 3: infected; CDC 4: severely contaminated, necrotic.

An *infected abdominal wall hernia* is defined as confirmed bacterial infection of the implanted synthetic graft or biological substance with simultaneous recurrence of the hernia. Earlier reconstructive surgery and recurring hernia are both assumed.

Compromised graft: current or earlier bacterial infection of a synthetic graft. At best, it means a potentially contaminated environment (CDC 2).

The term *complicated* is used for incisional abdominal wall hernias which have recurred once or several times, featuring a compromised, or infected, synthetic graft and/orenterocutaneous fistula, with its hernia gate at least 10 cm in diameter.

Abdominal wall incisional hernias with hernia sacs corresponding to at least 50% of the volume of the abdominal cavity, or chronically containing more than 50% of intra-abdominal organs as defined by some authors, are called *eventrated*. The terms ‘loss of domain’ and ‘loss of abdominal wall domain’ are commonly used in the literature.

2. Aims of the thesis

1. Presentation of the technical details of reconstructive surgery using autologous double-layer dermal grafts in large recurrent infected abdominal wall hernias.
2. Presentation of short- and long-term outcomes and the results of quality of life studies following surgery with double layer dermal grafts.
3. Presentation of a novel instrument making for applying special sutures in to the far part of the abdominal wall during the reconstruction by double layer dermal grafts.
4. Presentation of computed tomographic (CT) examination of the musculo-aponeurotic elements of the abdominal wall and discussion of its importance in the design of full midline giant abdominal wall hernia operations.
5. Presentation of the technical details of bilateral release and turnover of the rectus abdominis muscle and subsequent midline recreation, a surgical technique developed for the resolution of eventrated midline abdominal wall hernias.
6. Discussion of the short- and long-term outcomes of rectus turn-over and changes in the quality of life following surgery.

2.1. Assumptions prior the studies considering their applicability

1. I assumed prior the study, among biological grafts, the most suitable for implantation, reinforcement and completing of the abdominal wall could be the autologous dermal grafts, since we apply only the own tissues of the body.
2. I assumed that we can apply the procedure only if we can harvest suitable amount of dermal autografts.
3. I assumed that we can harvest sufficient amount of dermal graft from obese patients.
4. I assumed that a dermal graft applied by double layer fashion is able to give better abdominal wall reinforcement.
5. I assumed that a considerable midline gap can be reconstructed by autologous tissues.
6. I assumed that the rectus abdominis muscles are kept viable if them mobilised from their original places and turned-over to the midline direction.

3. Patients and methods

3.1. Use of autologous double-layer dermal grafts in infected/recurrent large abdominal wall incisional hernias

The surgical procedure developed by themselves in an interventional and observational, prospective, consecutive cohort study carried out at the Department of Surgery of the University of Debrecen, Health and Science Center. The study was conducted between 1 January 2011 and 31 December 2020 consisted of two main parts: (1) the accurate description of the surgical procedure and technique, and (2) closely monitored, 1-year follow-up of each patient. Each surgery was performed by two surgeons experienced in the field of abdominal wall hernia surgery. Follow-up examinations and data collection were performed by the same surgeon in all cases, at the outpatient department of the institute. Inclusion criteria were as follows: male or femalepatients older than 18 years (pregnancy was an exclusion criterion) with an incisional abdominal wall hernia proved clinically and by abdominal ultrasonography as well, which has recurred at least once. Patients with a BMI exceeding 25 kg/m^2 were eligible. The presence of a contaminated abdominal wall environment and/or abdominal fistula was not considered as ground for exclusion but only if the contaminated environment had been present for at least 3 months. A signed informed consent form obtained prior to the surgery was an inclusion criterion. Any condition possibly resulting in an immunocompromised state was deemed as grounds for exclusion. Exclusion criteriawere as follows: (1)

the patient was not eligible for an at least 1-year long follow-up period, (2) refractory therapy resistant ascites, (3) class IV as per the American Society of Anesthesiologists (ASA) classification, (4) heart failure class IV as per the New York Heart Association (NYHA) functional classification, (5) any disease or condition which is associated with a life expectancy of less than 2 years, (6) the presence of a progressive stage IV malignant disease, (7) newly diagnosed or untreated type II diabetes mellitus, (8) type IV wounds as per the classification of the Centers for Disease Control and Prevention (CDC) if one of the following apply: presence of diffuse purulent peritonitis and/or extensive tissue necrosis (however, neither infection of the synthetic mesh and/or soft tissue nor the presence of subcutaneous or enterocutaneous fistulas were listed among the exclusion criteria). The number of previous incisional hernia surgeries was recorded, body mass index (BMI), and, in case of diabetes mellitus, the type and duration were registered. Infections associated with the previously implanted mesh and the presence of fistulas (enterocutaneous or subcutaneous) were recorded. The weight of the tissues removed by dermolipectomy was measured during the surgeries. The circumference of abdominal wall hernias was measured, which was then used for the calculation of the abdominal wall defect area. In case of multiple abdominal wall defects, the sizes of the respective areas were added. The duration of the surgeryfrom the incision until the completion of dermal sutur es was recorded. Blood loss was estimated during each operation. Blood loss was estimated based on the haematocrit (htc) values measured 1 day before and 1 day after the surgery, and the estimated

adult blood volume (EBV = 70 ml/kg) (EBL = EBVxln (Hi/Hf; EBV: estimated blood loss, ml; EBV: estimated blood volume, ml; Hif: haematocrit initial, and final). A piece of the prepared dermal flap measuring 1 cm2 was sent for histological assessment and was tested for the presence or absence of epidermal tissue segments using haematoxylin–eosin staining. Each incisional hernia was categorized according to the recommendations of the European Hernia Society (EHS) (midline—M1–5, and lateral—L1–4). The course of the surgery and significant steps were documentedin photographs. In the early post-operative period, on days 1, 3 and 5, intra-abdominal pressure was measured in supine position, using an intra-abdominal pressure monitoring set (IAPMS). In the early (days 1–7) and late (days 8–28) postoperative period, the development of superficial and deepwound infections, along with the formation of any wound dehiscence, seroma or haematoma, was registered. In case of wound infections or wound dehiscence, open wound care was conducted until healing. In case of a seroma formation, the fluid was removed by percutaneous tappingat the outpatient clinic. In case of haematoma formation, wound exploration and haematoma evacuation were carried out, eliminating the source of bleeding along with wound closure at the same time. The mobilization of patients started on the second post-operative day by a physiotherapist. Minor analgesics (non-steroidal anti-inflammatory drugs, NSAIDs) were used to relieve postsurgical pain, only on demand. The post-operative

pain was rated by the patients on a five-point scale (1: no pain 2: mild, 3: moderate, 4: significant and 5: very strong) on the first, third and fifth post-operative days, and also during the follow-up examinations. Antibiotics were administered intravenously to all patients for 3 days in the form of daily 1 x 2 g cephalosporin or daily 3 x 1.2 g amoxicillin/clavulanic acid (or daily 3 x 600 mg clindamycin iv. in cases of penicillin allergy). In case of fever or surgical site infection, amoxicillin–clavulanic acid was continued and combined empirically with intravenous 15 mg/kg/day metronidazole. From the first post-operative day, patients were given enoxaparin daily 1 x 0.6 or 1 x 0.8 ml sc. as deep vein thrombosis prophylaxis for 21 days. The patients wore adjustable elastic abdominal binders with Velcro™ ongoing from the time of the surgery end. The binders were worn for almost 24 h in the first 2 months and then during the day for at least 2 additional months. Suction drains were not removed at the same time. The drains were removed when the amount of fluid discharged reduced below 15 ml/day. The sutures were not removed at once. Every second suture was removed on post-operative day 14, and the other half of the sutures was subsequently removed after 10 additional days. No intracutaneous absorbable suture was used for skin closure. The average hospital inpatient time was determined in days. The first life questionnaire was completed by the patients completed on the day of leaving the hospital ward. Each patient participating in the study was followed up for 1 year. No data collected

after 1 year were included in the study. After the 1-year follow-up examination, the patients were out from the study. Follow-up examinations were performed 1, 3, 6, 9 and 12 months after the surgery. During each follow-up visit, physical examination of the abdomen was carried out in standing and supine positions. The surgical wound status, any seroma formation, the presence of fistulas, any abdominal bulking or laxity of the autograft, the development of recurrent hernia were registered, and the quality of life questionnaire was updated. In months 1, 3, 9 and 12, abdominal ultrasonography was done. The time needed to return to previous activities was registered in days. Six months after surgery, a CT examination was performed.

3.1.1. Surgical technique

The intervention is performed under general intratracheal anaesthesia in a state of complete muscle relaxation. A wide laurel-leave-shaped skin incision is made crosswise between both spinae iliaca anterior superior. The cutaneous-subcutaneous panniculus is removed (dermolipectomy), with the greater omentum carefully spared. The synthetic mesh implanted earlier is completely removed. The abdominal wall edges left behind should be strictly intact. The hernia sac should be spared if possible. In the case of multiple hernia gates, individual intact abdominal wall bridges are not opened into each other.

3.1.2. Preparation of the dermal grafts

The retained panniculus is stretched in all directions and the epidermis is completely removed. The next step is removal of the subcutaneous adipose tissue. The prepared dermal graft is stored in a 2:1 solution of H2O2-povidone iodine until being used. An adequately prepared dermal graft contains the reticular and vascular layers, as well as a small amount of adipose tissue, without epidermal elements, hair follicles, sebaceous or sweat glands on its surface. The dermal graft is then cut to size in a way that its margins extend beyond the margins of the abdominal wall defect by at least 5 cm. On the basis of our own measurements, a dermal graft can be expanded to 130-135% of its original size when stretched.

3.1.3 Crucial steps of the procedure

The graft is placed in the abdominal cavity with its original surface facing outwards. Two procedures may be used here, depending on the status of the greater omentum (intact or not). In case there is no greater omentum, the spared hernia sac and the peritoneum are circularly separated from the inner surface of the abdominal wall, corresponding to the size of the implanted graft. The hernia sac and the peritoneum are closed with 3/0 absorbable thread, then the graft is placed over the closed peritoneum. The first graft complements the abdominal wall defect. The edges of the abdominal wall are fixed to the graft circularly using 3/0 non-penetrating, knotty, non-absorbable stitches.

In the next step, the second graft is cut to size with its margins extending beyond the margins of the abdominal wall by approximately 2 cm. The graft

is placed with its original surface facing inwards. This way, the original epidermal surfaces face each other. Like the first one, the second graftis fixed to the abdominal wall fascia with non-absorbable knotty stitches, in a non-fully stretched state.

The outer dermal graft can also be applied perforated. The surgical area is rinsed with a 2:1 solution of H2O2-povidone iodine, with two or three suction drains left behind. The subcutis is 'anchored' to the abdominal wall fascia with 8-10 absorbable stitches. The wound must be closed tension-free, using double-layer non-absorbable subcutaneous and knotty or intracutaneous skin sutures.

3.1.4. Complications, recurrence and quality of life following abdominal wall reconstructions with autologous double-layer dermal grafts

Reconstructions with autologous double-layer dermal grafts are not free from complications. Hematomas (2.5%), superficial wound infections (3%) and deep wound infections (2.5%) are the most frequent complications in the early postoperative stage. In the late postoperative period, diffuse fluid build-up is the most common complication (17%). These fluid collections, however, are not circumscribed real seromas and can be successfully treated by percutaneous or ultrasound guided puncture. Genuine subcutaneous seromas are very rare and require surgical exploration. Deep infection in the surgical area may lead to the formation of subcutaneous fistulas (2.5%), which must be removed surgically as they are not likely to resolve spontaneously.

Inadequate preparation of the dermal grafts (epidermal elements, such as sebaceous glands or hair follicles, left on the surface) may also lead to complications.

An adequately prepared dermal graft should contain nothing but the stratum reticularis and the stratum vascularis of the dermis, with a minimum amount of subcutaneous fatty tissue islands, but without *any* epidermal structures. Dermal grafts have no blood supply of their own. The grafts serve as a kind of connective tissue 'scaffolding' for integration and remodelling. Neovascularisation starts partly from the subcutaneousadipose tissue and partly from the greater omentum. The process takes 4 to 5 weeks.

Adipose derived stem cells (ADSCs), present in large quantities in the fatty tissue, play an important role in angiogenesis and connective tissue remodelling. Without remodelling and integration, the hernia will recur. Recurrence is invariably preceded by the dermal graft becoming lax, followed by recurrence of the hernia. Abdominal wall laxity occurs in 10 to 15% of the cases after such operations. Laxity develops in the first 12 months and recurrences occur in the first 2 years.

Predisposing factors include smoking, diabetes mellitus (DM), chronic obstructive pulmonary disease (COPD), negligence of the use of elastic trusses, and physical activity too intensive or started too early following surgery. The rate of recurrence can be reduced provided the patients wear the hook-and-loop elastic truss for long enough and in the right way, properly fitted. Medium or heavy physical load should be avoided during this period.

Patients are recommended to follow a regimen of light meals several times a day, avoid foods that cause bloating, and lose weight.

If the hernia recurs, further dermal graft reconstruction is usually no longer feasible, as grafts of the required quality and quantity are no longer available after the previous operation. In such cases, components separation, rectus muscle turnover, reinforcement with a synthetic or biological graftor reconstruction using pedicled or free musculo-aponeurotic flaps may be considered.

In case the surgical intervention is performed in a complicated CDC 2-3 (infected synthetic mesh, enterocutaneous or subcutaneous fistulas) or CDC 4 (peritonitis, necrotic abdominal wall) environment, the patient should receive antibiotics. The recommended regimen is i.v.amoxicillin-clavulanate 1.2 g three times a day for 5 days (or i.v.cephalosporin 2 g once a day or i.v.clindamycin 600 mg three times a dayin case of hypersensitivity to penicillin) and i.v. metronidazole 15 mg/kg/day. No antibiotic is required for surgeries in CDC 1 environment, unless the operation lasts longer than 180 minutes. To prevent deep venous thrombosis and pulmonary embolism, subcutaneous enoxaparine 0.6-0.8 ml once a day should be administered prophylactically for 3 weeks from the 2nd postoperative day.

Mobilisation should start on day 2 following the operation, assisted by a physiotherapist, with loading applied in a stepwise fashion. First the patient is allowed to sit up from a supine position, and then stand upwith help in the beginning. Gradual mobilization without the risk of overexertion is one of the most important postoperative rules to be observed in these cases.

Postoperative pain gradually subsides (measured on a 10-point numerical rating scale, RNS). On day 1 following surgery the mean score of pain intensity was 5.9±1.7, which decreased to3.4±0.76 by day 5. Ninety % of the patients reported that the intensity of pain was significantly lower following surgery with dermal grafts compared to earlier abdominal wall reconstruction(s) and 100% would prefer reconstruction with dermal grafts if allowed to choose.

With regard to the quality of life, 30 months after the operation 84% of the patients are satisfied with the result of the intervention and their load capacity. They have had no significant difficulty sitting or standing up from a supine position since the third postoperative month and more than 82% of the patients would opt for dermal graft surgery as opposed to earlier interventions. Recurrences generally occurat months 12 to 24. Return to pre-surgery activities should be gradual. In the first 4 weeks, the patients are allowed nothing but light strolls while wearing their elastic trusses; they must avoid carrying any load. In the second 4-week period, light physical load is permitted: the patients may lift loads of 2 to 7 kg, walk or stroll, or go for a light swim. At weeks 9 to 12, they may return to their earlier activities but should wear the elastic truss during the day. Cycling is allowed. To protect the reconstructed abdominal wall and prevent it from becoming lax again, the patients should continue wearing the truss in case of major physical strain. Subcutaneous or enterocutaneousfistulas are invariably eliminated by adequately performed surgery, a fact appreciated by patients much more than the repair of the recurrent hernia itself.

The use of double-layer dermal grafts improves the quality of life in both the early and the late postoperative periods. Since the intra-abdominal pressure is low following the interventions (12.1±2.3, 11.3±3.1, 9.5±1.3 8.7±2.2 and 7.2±1.9 mmHg on days 1 to 5 after surgery), pain is less intense, making mobilization significantly easier and more successful.

Patients should be checked every 6, then every 12 months in the first 2 years; follow-up visits should include physical examination in supine and standing position, as well as abdominal ultrasonography.

3.2. Bilateral rectus abdominis muscle release, turning-over and recreation of the midline gap in the cases of eventrated loss of abdominal wall domain hernias

Complete lack of the midline, with the bilateral rectus abdominis muscles moved further away from each other, leading to medial abdominal wall hernia and eventration, is a well-known phenomenon following serial intra-abdominal surgeries. Following open abdomen treatment or intra-abdominal serial surgeries, the medial section of the abdominal wall usually heals *per secundam intentionem* between the medial margins of the dynamically lateralizing rectus abdominis muscles. This state makes the patients disabled not only in an aesthetic sense but also functionally. The procedure consists in a tension-free *recreation* of the *midline* and the linea alba, lateral release of both *rectus abdominis muscles* from the posterior fascia of the rectus sheath, their *turning-over* at a degree of 180^{o} towards the midline, with blood supply

to the muscles retained. Only the spared hernia sac and the intact bilateral rectus abdominis muscles are used for the reconstruction.

3.2.1. Significance of preoperative computed tomography to perform the rectus muscle turning-over procedure

The evolution of abdominal wall hernias (including dynamics, time course, and changes in the size of the bilateral rectus muscle) after intra-abdominal serial surgeries and/or open abdomen treatment follows a typical course. The combined width of the bilateral rectus muscles is sufficient to cover the midline abdominal wall defect in a tension-free way, but performance of the intervention has an 'optimal' time interval. Detailed and precise evaluation of the musculo-aponeurotic elements of the abdominal wall is essential before reconstructive surgery with the rectus muscles. Feasibility of the intervention must be assessed by CT/MR imaging prior to surgery. The bilateral rectus muscles will be able to cover the complete midline abdominal wall defect free of tension if their *combined* width is nearly the same.

3.2.2. Surgical technique

The operation is performed under general anaesthesia in a state of complete muscular relaxation. Pre-operative antibiotic prophylaxis is not

necessary. Following a full median or transverse skin incision, the intact hernia sac is not removed, only in case it is severely damaged. The choice of a median or transverse incision depends on the quality of the midline skin. The aim is to spare as much as possible of the hernia sac, which will be the inner layer of the recreated abdominal wall.

The next step is identification of the lateral margin of the bilateral rectus abdominis muscle. After this, the anterior rectus muscle fascia is incised from the origin to the adhesion of the muscle, to reveal the rectus abdominis muscle. Starting fromitslateral margin, the full length of the muscle, except its 2-cm medial margin, isprepared off the posterior wall fascia.

During mobilization, at least 3 minor perforant segmental arteries and veins are revealed; each of them is dissected and tied up. The origin of the muscle is separated from the 7th and 8th rib cartilage. The medial half of the muscular origin (processusxyphoideus, 5th and 6th rib cartilage) is left intact. The arteria epigastrica superior and inferior vessels are carefully spared. Release of the lateral half of the muscular adhesion from the symphysis is also performed. The arteria and vena epigastrica inferior vessels are spared. The released muscle is turned over in the direction of the midline at a degree of 180^{o}.

The abdominal wall defect is reconstructed in the following way: the spared hernia sac is precisely cut to size and closed in the midline with 3/0 absorbable monofilament running stitchesThereleased rectus muscle is turned over medially at a degree of 180^{o}. The fascia (originally anterior, becoming

posteriorwhen the muscle is turned over) is closed with 3/0 absorbable, monofilament running stitches at a distance of 1 cm from each other.

The rectus muscles laid next to each other are closed in the midline with 3/0 absorbable, monofilament knotty stitches placed at a distance of 2 cm from each other. Laterally, the fascia of the obliquus externus and internus muscles is sewn to the posterior wall fascia with running 3/0 absorbable monofilament stitches.

Before skin closure, the subcutis is fixed to the fascia with 8-10 absorbable, knotty 3/0 subcutaneous anchor stitches. The midline is closed with 3/0interrupted subcutaneous stitches and 2/0 interrupted non-absorbable monofilament skin stitches.

After the operation, *before extubation*, an adjustable elastic abdominal wall bandage must be placed on the abdominal wall.

4.Results

The rate of surgical complications in the early postoperative stage following rectus muscle turnover is less than 2%. Superficial wound infections and wound dehiscence requiring local treatment are the most frequent complications. Normally, there is no need for antibiotic administration.

Deep wound infection occurs in less than 1% of the patients. In such cases, empiric antibiotic therapy (i.v. amoxicillin-clavulanic acid 1.2 g three times daily or, in the case of hypersensitivity to penicillin, i.v. clindamycin 300 mg three times daily for 5 days) or antibiogram-based targeted antibiotic administration is required, in addition to open wound treatment. Subcutaneous fluid build-up, which can be successfully controlled by percutaneous puncture, develops in less than 10% of the cases.

Genuine seromas are very rare. In the early postoperative stage, necrosis of the turned-over rectus muscle may theoretically occur. It happens when blood supply to the muscle stops during turning-over. Prevention is paramount: the arteria epigastrica superior and inferior vessels must be spared applying extreme caution. Should the vessels be damaged, reconstruction should preferably be performed by a vascular surgeon. A circumscribed dark purple discoloration may develop on the surface of the turned-over muscle during surgery; it does not require any intervention and causes no complications. The operation does not require antibiotic administration, except when reconstruction of the eventratedabdominal wall hernia is performed as an emergency for mechanical ileus or peritonitis.

To prevent deep venous thrombosis or pulmonary embolism, the patients are given s.c. enoxaparine prophylactically in a dose of 0.4 – 0.8 ml once daily, depending on body weight, for 3 weeks. On the first 5 days following the operation, the mean scores of pain intensity on the NRS scale were 6.9±2.4, 6.1±1.64, 6.2±0.99, 5.5±1.1 and 4.7±0.67. Intra-abdominal pressure gradually falls during the first 5 postoperative days (13.5±2.5, 12.9±1.7, 10,.2±2.6, 10.1±0.3 and 8.2±2.4 mmHg).

Abdominal wall laxity following reconstructions with the rectus muscle develops in 2% of the cases; recurrence of the abdominal wall hernia, however, was not observed during a mean follow-up of 24-months. Elimination of eventrated hernias leads to a marked improvement in the quality of life.

There is a significant difference in the quality of life when the periods before and after the surgery are compared. By the evidence of a quality of life test performed after the first 30 days, the patients were completely satisfied with the outcome of the surgery (satisfactory score: 6.0±0,0). In our study, the mean QoLscore (measured by the Ferrans-Power quality of life test adapted to the study) was 23.3±13.59 before the reconstructive surgery, increased to 46.7±6.38 by day 30 following the intervention. The difference was statistically significant, p=0.0013, Student's unpairedt-test. The mean QoL scores at months 6, 12, 18, 24, and 30 were: 47.1±4.2, 45.2±5.3, 48.0±2.9, 47.4±4.5, 46.4±4.8; the differences were not significant (p: ns, Student's unpaired t-test).

5. Discussion

The presence of large, infected, or eventrated abdominal wall hernias is an intolerable condition for patients. Complicated, recurrent and/or infected incisional hernias and eventrated giant abdominal wall hernias are considered to be the consequence of earlier surgical interventions.

We fully agree with Kohler et al., who claim (when discussing the question whether complicated incisional hernias are a natural corollary or a surgical complication) that surgical technique and accuracy of abdominal wall closure are key factors in the development of these conditions.

There are two other factors playing a role: these are the presence of *predisposing* factors, a phenomenon extensively researched, and the patients themselves, to the extent they comply with the instructions they are given following surgery. The reason why ventral and incisional hernias are increasingly researched is their increasing incidence and the growing costs involved. In the USA, approximately 3.5 billion dollars are spent on the treatment of abdominal wall hernias each year.

Although prevention of recurrences and complications should be a major consideration at the very first intervention when doing reconstructive surgery in patients with abdominal wall hernia, the fact is that 20 to 37% of ventral hernias and 40 to 64% of incisional hernias recur and the number of complications increases with each intervention. Infection of the synthetic material implanted during an earlier surgery (or surgeries) is the most

significant complication. The cost of hospitalization is doubled and, furthermore, there is a 6-time increase in the cost of dressing changes when the operative area and/or the mesh become infected.

We can agree with Sanchez, who claims that the treatment of infected/compromised grafts varies from case to case, with the mesh either spared or not in the end. Predisposing factors for mesh infection include a high BMI ($\geq$25kg/m^2), DM, COPD, infection of the site of an earlier operation, prolonged duration of surgery, opening of an intestine, and presence of enterocutaneous fistulas. The implanted mesh is removed in $\approx$5% of the cases, infection being the most common reason (69%). When repairing a recurrent and/or compromised incisional hernia, the surgeon usually faces two major problems:**1**) the surgical environment is infected (CDC 3-4) or contaminated (CDC 2); **2**) the abdominal wall defect is too extensive and cannot be closed free of tension. In such cases, most surgeons are understandably reluctant to implant another synthetic graft.

In cases requiring extensive abdominal wall replacement, the use of biological allo- and xenografts and various autologous tissues is the preferred choice in reconstructive surgeries. Of biological grafts, human, porcine and bovine ADMs have been used. In the vast majority of the cases, there is no question about the resolution of small or medium-size abdominal wall hernias.

However, when faced with a *large*, *eventrated*, *complicated*, or *incarcerated* hernia and an *infected* (CDC 3-4*) environment*, the surgeon must adopt a fundamentally different strategy.

To choose the most appropriate surgical technique, the surgeon must have precise information on the condition of the musculo-aponeurotic elements in the abdominal wall. The best way to obtain such information is abdominal CT/MR imaging, allowing assessment of the position of individual abdominal wall components, size of the hernia gate(s) and the volume of the hernia contents. In the case of eventrated hernias, determination of the size of the hernia sac is essential.

Another important factor is knowledge of the various surgical techniques, necessary for the selection of the procedure which imposes the least possible stress in a *specific case*. Evaluation of literary data shows that the use of autologous tissues is indispensable in the repair of complicated, eventrated, or giant abdominal wall hernias. There are procedures which can be applied in certain cases only and their use would be a mistake in any other case.

Direct abdominal wall sutures should never be used in *elective* or *acute* surgery of large, eventrated, or complicated hernias. Implantation of synthetic materials for abdominal wall reinforcement (but not replacement) is an option for elective surgeries in a CDC 1-2 environment. Implantation of a synthetic substance in a CDC 3-4 environment is associated with a high incidence of surgical complications in the operative area (25-65%), as well as a high recurrence rate (30-70%); for this reason, use of synthetic materials is not recommended in such cases.

The use of ADMs may be an alternative; however, the high cost of the procedure, coupled with a high recurrence rate, is a limitation to its use. Generally, there are several options in each case; it is important, however, that

the one involving the least possible stress should be selected and applied. Of autologous tissues, the use of dermal grafts is associated with the least strain during and after surgery; this is followed by rectus muscle turnover and the various component separation techniques, and finally by reconstructions with free or pedicled flaps.

For choosing the most applicable technique, it is important to know the possible solutions for reconstruction. The recurrency ratio itself is far from enough to be determined the absolute value of a certain procedure.

The practical importance of the table is that we can determine the most suitable procedure giving the best result prior the surgery on the basis of comparing the advantages and disadvantages of each technique to the actual abdominal wall status.

Different reconstruction opportunities with autologous tissues					
	Technique	**Advantage**	**Disadvantage**	**Recurrency**	**Reference**
1	Anterior component separation (ACS)	Complete medline reconstruction approx. 7-10 cms	Unsuitable for complicated hernias	17-30%	Pauli [62,63,64]
2	Posterior component separation (PCS)	Good for cases of recurrency after ACS	It requieres synthetic graft as a rule	13-21%	Petro [43,65,66]
3	Transverse muscle release (TAR)	Eventrated hernias	Megbontja a laterális hasfali egységet	10-17%	Novitsky [67,68,69,70,71]
4	Component separation (CS)	Short operating time	High complication and recurrency ratio	25-32%	Ramirez [72,73,74]
5	Rectus sheath plastic (RSP)	Suitable for eventrated hernias, could be combinated	Frequent bulking formation	24-32%	da Silva [75,76]
6	Fascia lata graft (FLG)	Easy to apply	Suitabe only for small hernias	11-18%	Hill [77,78]
7	Tensor fascia lata flap (TFLF)	For large and eventrated hernias	Unsuitable for M1-M3 hernias	5-15%	Williams [79,80,81]
8	M. rectus femoris flap (RFF)	Suitable for recurrent hernias	Frequent flap necrosis	25-31%	Miyamoto [82,83,84,85]
9	M. latissimus dorsi graft (LDFF)	For eventrated hernias and for CDC 4 environment	Not recommended for M4-M5 hernias	0-27%	Bodin [86,87]
10	M.latissimus dorsi flap (LDPF)	Recurrent eventrated hernias	Not good for covering midline hernias	5-11%	Rouchfuss [88,89]
11	Myocutan flap (MCF)	For great lack of abdominal wall in cases of malignat infiltration of abdominal wall	Flap necrosis could be as high as 30 %	11-22%	Lambe [90,91,92,93,94, 95,96]
12	Onlay autodermal graft (ODG)	Small and medium hernias	In cases of low BMI not recommended	5-12%	Özkaya [97,98]
13	Double layer dermal graft (DLDG)	Suitable for bridging large and eventrated hernias	Not applicable in cases of low BMI	11%	Martis [14,42]
14	Perforated double layer dermal graft (PDLDG)	Applicable in cases of CDC 4 environment as well. Faster graft integration	Not applicable in cases of low BMI	n.a.	Martis [99]
15	M. rectus abdominis fascia reconstruction (OBFR)	easy to apply	Only for complete midline reconstruction	13-15%	Ennis [100,101]
16	Bilateral rectus abdominis muscle turning-over (BRTO)	Complete and wide (14-17cm) midline covering	Only in cases of untidy bilateral rectus muscles	0%	Martis [102]

The most important consideration when using autologous dermal grafts is the availability of tissues of adequate size and quality for reconstruction. To cover a defect of 10 cm in diameter (an area of 78.5cm^2), the area of the dermal graft should be at least 220 cm^2. The 30-35% expansion capacity of a properly prepared graft should also be taken into account. All this means that grafts of adequate size and quality can only be obtained from obese patients. Prepared dermal grafts should not contain any epidermal elements or scar tissue.

Double-layer dermal grafts are preferred in cases of large medial or lateral incisional hernias having recurred at least once, in which a synthetic mesh was implanted during an earlier reconstructive surgery and CDC 2-3 environment, compromised graft, deep wound infection, or subcutaneous and/or enterocutaneous fistulas developed in the postoperative period. In a CDC 1 environment, this is the preferred choice if the hernia is large and a direct abdominal wall suture would lead to a significant increase in intra-abdominal pressure. The procedure has obvious advantages in obese patients, where grafts are usually available in sufficient quantities, making synthetic grafts unnecessary. In patients with BMIs higher than 25 kg/m^2, the quantity and quality of dermal grafts are sufficient for the reconstruction of large hernias. In patients with DM or COPD, conditions associated with a higher risk for recurrence and infection of the operative area, the use of autologous grafts is preferred to direct sutures or synthetic grafts.

Perforated double-layer dermal grafts can successfully be used in CDC 4 environments. Their advantages include faster integration and a significantly lower risk of infection at the site of operation. However, this procedure cannot

be used in patients in whom dermal grafts of appropriate quantity and quality are not available. There are data, although limited, on the use of double-layer dermal grafts in CDC 4 environments and in the case of extensive abdominal wall necrosis. Large abdominal wall defects can be repaired relatively quickly and cost-effectively without implanting synthetic or allo- or xenografts and without significant early postoperative tension even in CDC 4 environments.

A precondition of bilateral rectus muscle turnover is the intact state of the bilateral rectus muscle confirmed by CT. A CT examination prior to surgery allows assessment of the size of the abdominal wall defect and the state of the bilateral rectus muscle, and serves as basis for the indication or contraindication of the intervention. In patients with COPD or having a high BMI, the procedure is clearly preferred, as there is no risk of increased intra-abdominal pressure following surgery. Maintaining blood supply to the rectus muscle from the epigastric vessels is essential. In case of injury, the artery must be reconstructed. Maintaining blood supply to the rectus muscle is the most critical element of the intervention. Although release of the muscle from the medial direction leads to partial muscle denervation, the outcome of abdominal wall reconstruction is not affected and the turned-over muscle retains its function. To prevent the development of abdominal wall bulking, patients should wear an adjustable elastic abdominal wall binding with Velcro for at least three months following surgery and also later when exposed to physical load.

The procedure of bilateral rectus muscle release and turnover is used to reconstruct eventrations and midline abdominal wall defects developed after

open abdomen treatments, retroperitoneal and/or intra-abdominal serial operations. The technique is also suitable for resolution of midline, recurrent or neglected, primary medial giant abdominal wall hernias. The intervention can successfully be performed in patients with incarcerated eventrated hernias or in CDC 3-4 environments. It is crucial that in case the rectus muscle was damaged or intersected during an earlier surgery, or the patient underwent transverse laparotomy (involving transverse intersection of the rectus muscle) earlier, the intervention cannot be performed. The width of the midline abdominal wall defect and the combined width of the bilateral rectus muscles along their full length must be carefully assessed. If the values ‘correspond’ to each other, the intervention can be indicated from a morphological-anatomical point of view.

6. Summary. Novel statements

Solution of large, complicated, eventrated and/or incarcerated incisional hernias is a real challenge for surgeons until now. Two novel surgical procedures, both of them applied by me, have been presented in this thesis. Both methods can be applied under well determined and certain circumstances in the surgical practice. Follow-up examinations of the procedures have been carried out, pre- and postoperative quality of life tests were compared and statistical analyses were performed.

The novel statements related to the surgical procedures are summarized as follows:

1. I successfully applied the homogenous double-layer autologous dermal grafts in cases of large and/or recurrent incisional abdominal wall hernias under circumstances of CDC 2-3 surgical site environment.

2. The abdominal wall gap was bridged and completed with the dermal grafts. No direct abdominal wall sutures were used.

- There have not been detected of significant and long lasting intra-abdominal pressure elevation.

- Patients' quality of life values significantly improved in the postoperative period.

- All sub- and enterocutaneous fistulas could be definitely eliminated and the surgical site occurrence was acceptably low in the early and late postoperative period.

- The recurrence rate was 11%.

- Disadvantage of the procedure is that sufficient quantity and quality of dermal graft can only be harvested from overweight (BMI≥25kg/m^2) patients.

3. Double-layer dermal grafts could also be used in *CDC 4* surgical environments. In this case, the outer graft is implanted in perforated fashion with the aim of shorter granulation and integration of the implanted grafts.

4. A new surgical device has been developed and the prototype of the device was successfully applied when remote sutures had to put into the abdominal wall in order to fix the inner overlapped dermal grafts. Using the device, the eventual collateral bowel damages can be avoided and fastening of the inner graft has been considerably simplified.

5. I successfully applied the bilateral rectus muscle turning-over technique for eventrated and complicated midline loss of abdominal wall domain.

- Statistical analysis of the quality of life tests proved a significant improvement.

- I did not register significant postoperative intraabdominal pressure elevation after this procedure.

- I have not registered yet recurrency regarding this operating method in the follow-up period.

Additional new statements can be specialized as follows:

1. *In recurrent infected abdominal* wall hernias, *the infected synthetic mesh* should be *removed* completely. Partial removal fails to provide a permanent solution in most cases. In case the hernia has not recurred but the graft is infected, a VAC treatment may be attempted. VAC is not recommended when recurrence and mesh infection occur simultaneously.
2. Patient's follow-up examinations is recommended four-, two- and one-times in the first second and third postoperative year, respectively.
3. The method is not recommended in cases of extended, large abdominal wall gaps and/or eventrated hernias.
4. The procedure is recommended for reconstruction of repeatedly recurring midline (M_1-M_5) giant eventrated abdominal wall hernias developing chiefly after *open abdomen treatments* or retroperitoneal *serial surgeries*. In these cases, applying this method is superior to implantation of xeno- or allografts considering surgical site occurrences and recurrencies.

5. The procedure is also suitable for *emergency* operations (incarcerated hernia or CDC 3-4). Before using the technique in emergency cases however, surgeons should gain experience in elective interventions.
6. Abdominal CT allowing assessment of the volume of the hernia, the size of the midline abdominal wall defect and morphometry of the bilateral rectus *muscle* should be performed prior to the operation. An intact bilateral rectus muscle is a precondition of the procedure.
7. Evolution of the midline loss of abdominal wall domain and the changes of the abdominal wall musculo-aponeurotic elements have a characteristic dynamism. On the basis of the study, the bilateral, realesed rectus muscles together must cover whole width of the midline gap. Thus, there is optimal timeframe of the procedure. It is recommended to follow the midline gap evolution to be chosen the optimal time of the reconstruction.
8. The preoperative CT imaging and evaluation of the abdominal wall structures is decisive.
9. *Primary prevention* (increasing the proportion of minimally invasive intra-abdominal surgeries) and *secondary prevention* (*lege artis* closure of laparotomies, use of a truss and avoidance of overexertion following surgery) of abdominal wall incisional hernias may significantly reduce the incidence of large and complicated hernias.

10. The use of autologous tissues is *unavoidable* in the reconstruction of large, eventrated, or complicated abdominal wall incisional hernias in elective as well as acute interventions. Their application must be carefully weighed in these cases.
11. Reconstruction of complicated abdominal wall hernias must be preceded by careful evaluation of the available techniques and selection of the one which is the most effective and the least stressful for the patient.

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List of publications related to the dissertation

1. **Martis, G.**, Laczik, R., Németh, N., Martis, G., Damjanovich, L.: Bilateral rectus muscle turning-over for complicated and eventrated abdominal wall hernias: results of a novel method.
   Acta Cir. Bras. 39, 1-15, 2024.
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2. **Martis, G.**, Damjanovich, L.: Use of double-layer autologous dermal flap in the treatment of recurrent and/or infected incisional hernias: presentation of the surgical technique and the results of 1-year follow-up-a prospective, consecutive cohort study.
   Hernia. 20 (3), 461-470, 2015.
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List of other publications

3. **Martis, G.**, Laczik, R., Damjanovich, L.: A komputertomográfia jelentősége az eventerált, óriás hasfali sérvek műtéteinek tervezésében.
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4. **Martis, G.**, Damjanovich, L.: Significance of Autologous Tissues in the Treatment of Complicated, Large, and Eventrated Abdominal Wall Hernias.
   In: Hernia. Ed.: Fethi Derbel, INTECH, Croatia, 117-149, 2017.
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6. **Martis, G.**, Laczik, R.: The role of radical surgery in the management of CEAP C5/6 and lipodermatosclerosis.
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