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ORIGINAL ARTICLE

Autologous dermal grafts for rectus sheath reconstruction and application in closure of ventral myofascial defects

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Abstract Ventral abdominal hernias pose a reconstructive challenge, with recurrence rates after primary closure exceeding 50 % and synthetic options at high risk for infection. We describe our experience with using autologous dermis, sourced from the redundant overlying abdominal skin, for reconstruction of ventral abdominal wall defects. We describe the surgical technique, applied anatomy and an analysis of short- and long-term outcomes. Twelve consecutive patients undergoing repair of medium–large size, reducible abdominal wall defects were recruited. The dermal graft technique was used in each case, utilizing an autologous running strip of abdominal skin for reconstruction. Both short- and long-term outcomes were assessed prospectively. Scores were given on a scale of 1–10, with 1 = least/worst and 10 = most/best. The described technique was successfully undertaken in all patients. Long-term follow-up demonstrated a 100 % resumption of normal activities, with an improvement in quality of life and physical activity scores postoperatively, and no recurrences. Short-term complications were notable, with five patients requiring postoperative intensive care unit admission, and seven patients requiring respiratory support. In conclusion, the use of autologous rectus sheath reinforcement may achieve good surgical outcomes and high patient satisfaction. While early respiratory complications should be noted, the potential utility of this technique is worthy of future investigation.

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Introduction

The abdominal wall is essential for stabilization and movement of the axial skeleton, respiration, micturition, defecation and protection of viscera [35]. These important tasks require reliability in techniques used for reconstruction. When reconstruction of defects of the abdominal is required, restoration of structural anatomy is thus sought.

Despite the intricate nature of the layers of the abdominal wall, its structure can be compromised, often by iatrogenic disruption such as midline laparotomy. Midline abdominal wall hernias are not infrequent complications following major abdominal surgery, with reported incidence rates of ventral hernias often exceeding 10 % [17, 23, 33, 34]. Protrusion of gastrointestinal contents with distention of the abdomen can result in a functional and cosmetic hindrance for patients.

There have been many approaches that have attempted to achieve quality reconstruction in this setting. Primary approximation of the rectus muscles results in inacceptable recurrence rates of 46–49 % [28, 35, 43], and thus many surgeons have resorted to the use of prosthetic meshes to cover abdominal wall hernias [3, 4]. The use of mesh in abdominal hernia repair has been shown to reduce recurrence rates, particularly in hernias measuring 6 cm or less; however, a large variability in recurrence rate (0–34 %) has still been reported [25, 26, 31, 36].

While mesh has proven effective in repairing abdominal wall herniation, the use of mesh has been associated with an increased risk of infection, enterocutaneous fistula formation and extrusion in the abdomen when used in contaminated wounds and recurrent hernias [22, 25, 27, 45]. Particularly, large hernias often cannot be primarily closed due to unacceptable tension on wound closure, or can be at high risk for abdominal compartment syndrome or respiratory compromise, but some medium–large hernias can be directly closed despite still requiring tension in order to approximate the hernia margins, and this may contribute to recurrence rates.

There are autologous reconstructive options available, with the limitation of many of these techniques being disruption of the innate abdominal wall anatomy. The technique of component separation divides the attachments of the anterolateral musculature, and thus distorts normal anatomical planes. The importation of additional tissue in the form of local or free tissue flaps necessarily alters normal tissue composition and boundaries. An alternative technique is to reconstruct the midline defect to match the original anatomy that has been disturbed, and to reinforce the rectus sheath with autologous tissues to strengthen it and potentially return it to its innate structure. We explore the use of autologous dermal grafting for abdominal wall reconstruction, sourced from the redundant overlying abdominal skin, for reconstruction of ventral abdominal wall defects.

Methods

A series of 12 reconstructive procedures using the technique described herein were undertaken on 12 patients, all of whom required repair of ventral abdominal wall defects. Patients were selected for inclusion initially based on the size of the hernia defect, with a reducible ventral abdominal hernia and dimensions in both length and width of between 5 and 15 cm being inclusion criteria. Larger hernias were felt not well-suited and at too high risk for complications. While the presence of sufficient excess overlying skin and adequate premorbid respiratory status were also inclusion criteria, there were no exclusions based upon these. As such, the surgical decision to proceed with this technique is based on the presence of intact rectus abdominis and sheath, and a defect amenable to direct midline approximation.

All patients underwent preoperative respiratory function testing. While some patients had mild impairment on respiratory function testing, some were asthmatics and some were smokers, all were judged to have adequate respiratory reserve for direct hernia closure. All patients were consented appropriately for inclusion in the study.

Prospectively collected outcome data were combined with retrospectively analyzed operative and demographic data. All patients were operated on in the same hospital and by the same senior surgeon (RA). Retrospective collected data comprised patient demographic data including comorbidities and etiology of the abdominal wall defect, perioperative data including total operating time and blood loss, and postoperative data including administered pain medication, the need for intensive care or respiratory support and the total time of hospital stay.

Early assessment was performed during initial hospital inpatient stay through a combination of objective and subjective assessment and chart analysis, and longer term follow-up was performed at two-staged intervals. Short-term assessment was performed at a mean period of 4 months postoperatively, with surgical and medical complications all recorded by the investigator. Long-term outcomes were assessed at a mean of 40 months postoperatively, with differences in quality of life before and after hernia repair, differences in physical activity levels before and after repair, and both objective and subjective experience of postoperative complications all evaluated. The tools for assessment comprised both analysis of quantitative data where appropriate and subjective analysis by means of a visual analogue scale (VAS) for other assessments: each of these scores were assessed on a scale of 1 to 10, with 1 being least/worst and 10 being most/best. VASs have been validated in many studies, many of which were analyzed in a critical review of VAS by McCormack et al. [32]. VASs are simple and rapid tests and took not more than 20 s per participant to complete. Participants were asked to place a mark at the point on a 10-cm horizontal line, which represented a scale from 1 to 10 as above. All data were compared qualitatively.

Surgical technique

Following suitable patient selection as described, with hernia size of 5–15 cm width and appropriate premorbid patient status, the patient proceeds to surgery (see Figs. 1, 2). The described technique utilizes autologous dermal grafts for abdominal wall reconstruction, sourced from the redundant overlying abdominal skin. The overlying skin is redundant secondary to long-standing tissue expansion by the ventral hernia, and similarly, the rectus sheath requires reinforcement secondary to thinning of the rectus sheath by the hernia. The dermal graft is taken from the excess skin tissue which is excised from above the abdominal wall hernia. A continuous strip of skin, 2 cm in width is excised from the sides of the excision line on the abdominal wall. A length of 60–90 cm, in single or multiple strips, is required depending on the size of the abdomen and the extent of hernia protrusion. It is preferable to use well-perfused skin tissue and to avoid scars. The skin is incised through its full thickness and deep subcutaneous tissue (fat) is removed, while the epidermis is de-epithelialized through sharp excision with scalpel or

Fig. 1 Preoperative photograph of a sizeable ventral abdominal hernia, with pre-expanded overlying skin

Fig. 2 Intraoperative photograph of the same ventral hernia as in Fig. 1, prior to repair

scissors. The strip is tested for strength and soaked in an antiseptic solution for 15 min.

The strip of dermis is firmly sutured to the rectus abdominis muscle, beginning at the caudal border of the diastasis, using a combination of permanent and long-lasting absorbable sutures. Subsequently, the strip is passed upwards through the opposing edges of the rectus sheath at regular intervals of 3–4 cm, creating a zigzag pattern (see Fig. 3). Perforations are thus made through either the linea alba alone or in combination with additional anterior and/or posterior rectus sheath, with the rectus muscle spared from any insult. These perforations are approximately 1 cm in length, and only made large enough to allow passing of the dermal strip. Upon perforation of the anterior rectus sheath, it is essential to exert caution not to penetrate the rectus muscle (and the inferior epigastric arteries within the sheath) or the abdominal cavity. Every junction/corner is reinforced with permanent sutures. Re-approximation of the rectus abdominis edges is performed using towel clips attached to the rectus sheath, facilitating some intraoperative tissue expansion of the sheath as a means to aid closure. Traction is applied to the dermal strips until the fascial edges approach each other without tension. In cases where there was felt to be greater tension, the use of synthetic mesh reinforcement was used. The decision to use mesh was based on subjective assessment of tension by the operative surgeon, if there was felt to be insufficient dermis to adequately reinforce the approximation of rectus edges. Suturing to the midline can then be performed without tension (see Fig. 4). Primary closure of the overlying skin is then performed over suction drainage (see Fig. 5).

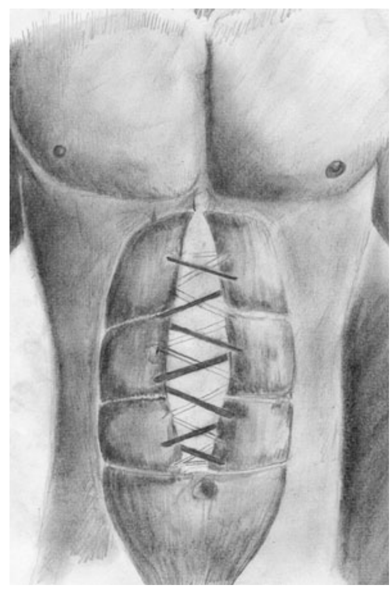

Fig. 3 Schematic representation of the technique of utilizing continuous running strips of autologous dermis sourced from redundant, pre-expanded overlying abdominal-wall skin to facilitate primary repair of ventral abdominal hernias

Results

Twelve consecutive patients were included in the study, comprising 6 women and 6 men, with a mean age of 56 years (range 17–74) (see Table 1). Median body mass index (BMI) was 25 (range 19–33). Mean time for short-term follow-up was 4 months and for long-term follow-up was 40 months. The contributory factors for abdominal wall herniation comprised previous abdominal surgery in

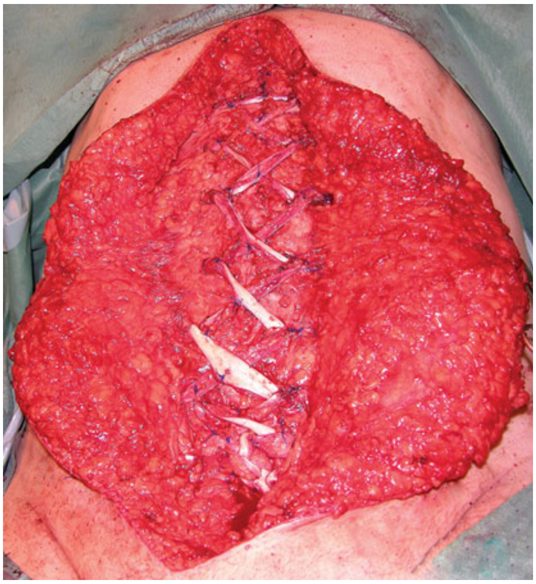

Fig. 4 Intraoperative photograph following definitive hernia repair, with continuous running strips of autologous dermis sourced from the redundant, pre-expanded overlying abdominal-wall skin to facilitate primary repair of the ventral hernia

Fig. 5 Postoperative photograph after ventral hernia repair

ten patients and trauma in two patients. There were comorbidities in most patients in this series, with two patients having comorbid malignancies, one having cardiac failure, one patient hypertensive, one patient having type 2 diabetes mellitus, and two patients with asthma. One patient had undergone previous abdominal wall radiotherapy.

All patients underwent the technique as described for closure of a ventral abdominal wall hernia (see Table 2). In

Table 1 Patient demographics

Age (mean)	56 (range 17–74)
Body mass index (median)	25 (range 19–33)
Cause of abdominal wall defect (*n*)	
Previous abdominal surgery	10
Trauma	2
Comorbidities (*n*)	
Cancer	2
Cardiac failure	2
Hypertension	2
Diabetes	1
Asthma	2
Previous abdominal wall radiotherapy	1

Table 2 Intraoperative and postoperative details

Intraoperative details	
Length of operation (median)	305 min (range 160–610)
Blood loss (median)	525 mL (range 15–3,900)
Use of mesh	5 patients
Postoperative details	
Intensive care unit (ICU) admission	5 patients
Length of ICU stay (median)	8 days
Respiratory support postoperatively	7 patients
CPAP	3 patients
Intubation	4 patients

all cases, the abdominal wall contents and hernial sac were reduced, with dimensions in both length and width of between 5 and 15 cm, and hernia edges opposed easily. In five patients, direct hernia closure was reinforced with the use of onlay mesh (polypropylene in two cases and Gortex in three cases), in cases where there was felt to be insufficient dermis to adequately reinforce the approximation of rectus edges. As mentioned above, while felt not to be absolutely required, these five cases were selected based on subjective assessment of tension by the operative surgeon. There was no association between any patient demographic (including BMI, comorbidities or sex) and the use of mesh reinforcement. In all cases the skin was also primarily closed. Median operative time was 305 min (range 160–610 min) and median perioperative blood loss was 525 mL (range 15–3,900 mL).

Postoperatively, five patients required intensive care unit (ICU) admission, with a median stay of 8 days. Seven patients required respiratory support, three with continuous positive airways pressure (CPAP) and four with intubation. Median time for CPAP use was 4 days and intubation 5 days. For postoperative analgesia, six patients received epidural anesthesia (median duration 4.5 days), five patients used intravenous patient-controlled analgesia (PCA) (median

Table 3 Complications

Complication	Number
Infection	1
Seroma	1
Enterocutaneous fistula	1
Myocardial infarction	1
Cardiac arrythmia	1
Chronic respiratory decline	1
Chronic abdominal pain	5
Hypertrophic scar	1
Ileus	2

duration 5 days), and four patients used intermittent pain medication using simple analgesia or opioids as required.

There were several complications in the series (see Table 3). One patient developed a postoperative wound infection while on corticosteroids and which resolved with conservative management. One patient developed an enterocutaneous fistula, and another patient developed a seroma. There were two cardiovascular complications, with one patient having a myocardial infarction postoperatively and one patient having a short run of cardiac arrhythmia, with both patients surviving. One patient had postoperative respiratory decline. Three patients reported postoperative lower back pain. Median length of hospital stay was 10 days (range 5–48).

Of the 12 patients, only 10 patients were available for late follow-up, as one patient died of an unrelated illness and one patient was unavailable for follow-up. Of the two patients included for long-term follow-up, three patients had resumed full-time work, while seven patients were retired, and all had resumed normal activities. None of the patients had a recurrence or suspicion of recurrence, and there were no late postoperative ileus or obstructive symptoms in any patients.

Of the five patients that had mesh reinforcement of the sheath, three had respiratory complications and no other complications. While not statistically significant, the preselection of these patients with increased tension in closure highlights the higher risk of respiratory complications in this cohort. Mesh was not obviously associated with any other complications.

Assessment of quality of life, achieved quantitatively with VAS, revealed a higher postoperative quality of life score with a median score of 4.5 compared to preoperative median score of 2.5. No patients had lower postoperative scores, with only two patients showing no differences between pre- and postoperative scores. The median difference pre- and postoperatively was 2.5.

Level of physical activity assessment with VAS revealed four patients reporting an improvement in physical activity postoperatively, five reporting no difference and one patient reporting a negative difference. The median preoperative value for activity score was 3 and postoperatively was 4.

Scores of patients for specific activities were also questioned, particularly activities of daily living assessment with VAS: in terms of getting dressed, three patients reported an improvement, one patient a worsening and six patients reported no difference; in terms of sporting activities, four reported an improvement, one patient a worsening and five patients no difference. Two patients volunteered the information of an increase in self-esteem. On specific questioning, nine out of ten patients were highly satisfied with the outcome of surgery, felt they had made the right decision to proceed with surgery, and would recommend this operation to friends or family members with abdominal hernias.

Discussion

Clinical anatomy

The anterior abdominal wall is a multi-layered structure comprising skin, subcutaneous fat, superficial fascia with the rich vasculature system traversing its layers (Camper's and Scarpa's fasciae), the tougher deep fascia, paired abdominal muscles (the horizontal external oblique, internal oblique and transversus abdominis laterally and vertical rectus abdominis and pyramidalis medially), their aponeuroses forming the rectus sheath, the extraperitoneal fascia and fat, and parietal peritoneum [35]. Structurally, the musculofascial layers are the major source of strength to the abdominal wall and the integrity of this wall plays an important role in its function [20].

The vascular anatomy of the anterior abdominal wall is derived from direct cutaneous and musculocutaneous perforators of the deep and superficial epigastric arterial system (inferior and superior), and from intercoastal and circumflex iliac vessels laterally, and it has been shown that the main supply is by the musculocutaneous perforators [16]. The sensory innervation is from T6 to L1, while motor function is derived from intercostal nerves, the subcostal nerve, and the iliohypogastric and ilioinguinal nerves.

Embryologically, the abdominal wall is formed from the parietal layer of the lateral plate of the intraembryonic mesoderm at approximately day 22, as the embryo folds in both ventrally and in cranial–caudal directions bringing in the surface ectoderm. These layers have fused by week 4. It has been proposed that this fusion process involves apoptosis, cell-to-cell contact and cell migration [2, 12, 13, 37]. The bone, muscle and skin components of the abdominal wall are derived from the ventral hypomere and are composed of the sclerotome, myotome and dermatome regions of the paraxial mesoderm. Some of these sclerotome and myotome regions migrate in the lateral plate of mesoderm and form the external and internal oblique and transversus abdominis while the ventral longitudinal column forms the rectus abdominis muscle. The application of this developmental anatomy to the reconstruction is discussed below.

Reconstruction of ventral hernias

Incisional hernias are a serious and disabling complication occurring in over 10 % of general abdominal surgeries [17, 23, 33, 34]. Complications associated with ventral abdominal incisional hernias are potential risk of incarceration, bowel obstruction, and potential ischemia/necrosis of bowel and omentum. With larger hernias, respiration can be compromised, back pain is common and reduced mobility and quality of life have been widely described. With reconstruction thus essential to optimal functioning, DiBello and Moore [14] described the criteria for ideal abdominal wall reconstruction: prevent protrusion of the viscera through the abdominal wall, integrate repair into the abdominal wall, give dynamic support to the abdominal wall, and be stress tolerant [14, 18].

Multiple techniques have been employed for the repair of abdominal incisional hernias with varying rates of success. Synthetic mesh repair has formed the mainstay of treatment, with polypropylene (prolene) and polytetrafluoroethylene (PTFE) used extensively in the repair of ventral defects [15, 41, 42, 45]. Each of these techniques predisposes to infection and is associated with adhesion formation [1, 6, 9, 10, 21, 24]. As such, contaminated or large hernias represent major surgical dilemmas, with autologous options often preferred.

This can include the use of pedicled muscle or musculocutaneous flaps such as tensor fasciae lata, rectus femoris and sartorius flaps, with all these described in the repair of defects involving the lower abdominal wall, while latissimus dorsi muscle flaps have been used for upper abdominal wall defects [7, 38–40, 46]. The use of flap coverage does have advantages, with rich blood supply providing strength to tissues and resistance to infection [8, 29, 44]. However, these advantages come at the cost of donor site morbidity, difficult and lengthy surgery, and flap-related complications that have the potential for significant morbidity. An additional autologous technique for the repair of such hernias is the technique of component separation. This technique enables the bridging of the fascial gap without the use of prosthetic material, relying on the separation of the muscle components of the abdominal wall in order to facilitate greater mobilization of the rectus muscle to the midline [11, 14, 19].

As discussed, reconstituted structural anatomy is pivotal in optimal reconstruction [20]. Though the use of a pedicled muscle or musculocutaneous flap can fill the dead-space, add bulk to the defect, close the cutaneous deficit and add muscular strength (particularly if innervated), it cannot achieve a return to original anatomy. So too, harvest of a donor muscle necessarily causes a donor deficit in muscular function, and transfer cannot achieve return of abdominal wall sensation, motor function, and excursion of muscle contraction.

The use of autologous skin to reinforce a hernia repair allows the benefits of mesh repair, and while synthetic material can be used as a reinforcement, it is not absolutely required. In addition, while not necessarily stronger than mesh, autologous dermis alone can avoid synthetic material and the inherent associated risk of infection. The use of a technique using autologous dermis in such a role for abdominal hernia repair was first introduced by Gosset [19]. Subsequent studies reinforced the technique, showing that the excess skin overlying sizeable abdominal hernias can provide material of suitable mechanical properties for hernia repair [5, 30]. Marchac et al. [30] showed that upon re-exploration of the abdominal wall after closure with skin strips, a clinically normal aponeurosis had replaced the skin strips. Histopathological examination showed that all epidermal and dermal structures had been replaced by aponeurotic tissue, providing a collagen dense reinforcement to the hernia repair, and qualities to the reconstruction that match the fibrous qualities of aponeurosis rather than the elastic qualities of skin. The use of permanent sutures reinforces this repair, providing further strength. There is therefore a true reconstruction of the ultra-structural anatomy of the anterior rectus sheath.

The ventral folds have been hypothesized to develop into the abdominal wall in a similar way as neural fold where proliferation of overlying ectoderm leads to cell proliferation and matrix production [2]. When we consider that the dermis of the abdominal wall is derived from a fusion of ectoderm and dermatomal cells of the paraxial mesoderm in the form of the hypomere and the rectus abdominis from the myotomes from the mesoderm, a similar embryological and developmental origin exists for each tissue type. This could explain the clinically and histologically normal aponeurosis that forms after repair with dermal grafting as described. This embryologic hypothesis is theoretical, and further investigation is clearly required in this field.

In evaluating surgical outcomes in the current series, it was evident that the more significant complications that arose were usually seen within the first days after surgery, at which time there is maximal effect from the newly increased intra-abdominal pressure of returned abdominal contents. Of the two more serious complications in this regard, there were no cases of abdominal compartment syndrome; however, respiratory compromise was encountered more frequently than predicted preoperatively. This was most evident in patients with premorbid respiratory disease, smoking history and obesity. Five such patients required ICU admission, with three patients requiring intubation and three patients requiring postoperative CPAP. However, in all of these patients there were ultimately good outcomes, and all patients were highly satisfied with the outcomes. Despite, consideration of approaches to further improve respiratory outcomes should be considered, including a higher threshold for premorbid respiratory function, cessation of smoking, weight loss or other therapies for improving respiratory function.

Overall patient satisfaction was established both in the short and the long term, and notably, nine out of ten patients contacted were highly satisfied with the outcome of the surgery. Despite the low but real incidence of complications in this cohort, patients reported improved mobility, activities of daily living and levels of physical activity reflecting a clinical as well as anatomical restoration of function. This translated to higher levels of satisfaction and self-esteem. As such, careful assessment of premorbid respiratory status, interventions to improve respiratory status, assessment of hernia dimensions and assessment of other comorbidities are all suggested approaches to achieving optimal outcomes with this surgical technique.

Conclusion

The use of autologous dermal grafts to reinforce primary closure of the rectus sheaths for ventral hernia repair may be able to restore the structural anatomy of the anterior abdominal wall to approach its premorbid structure. By restoring native anatomy, useful principles in abdominal wall reconstruction can be achieved. Using continuous running strips of autologous dermis sourced from the redundant, pre-expanded abdominal wall skin overlying the ventral abdominal hernia, we highlight the potential utility of the technique in selected patients with medium size reducible hernias and good premorbid respiratory function. Good surgical outcomes and high levels of patient satisfaction were reported overall, and the potential utility of this technique and appropriate patient selection are worthy of future investigation.

Conflict of interest The authors declare that there is no source of financial or other support, or any financial or professional relationships which may pose a competing interest.

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