# Techniques for abdominal wall reconstruction in intestinal transplantation

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**Purpose of review**
One of the most important challenges in the intestinal (ITx) and multivisceral transplant (MVTx) is to achieve a successful abdominal wall closure.

**Recent findings**
A tension-free primary closure should be our aim. In most of the cases, we need to perform a component separation technique, alone or combined, to the use of a synthetic mesh. If those options are not feasible, the abdominal wall composite vascularized allograft transplant (AW-CVA) utilizing direct orthotopic vascularization can be considered. The nonvascularized abdominal rectus fascia has also become an alternative method used worldwide, proving to be simple and well tolerated procedure. Furthermore, the use of the AW has been recently proposed as a new tool for a sentinel monitoring of the intestinal or pancreas allograft.

**Summary**
There are different validated options for abdominal wall closure following intestinal transplantation. The long-term benefits of transplanting the abdominal wall, full or partial thickness and vascularized or nonvascularised, were shown. New developments might help to expand their applications in different areas such as reconstructive surgery and immunology.

**Keywords**
abdominal wall closure, abdominal wall transplantation, intestinal transplantation, vascularized composite allograft

## INTRODUCTION

One of the most important challenges in managing intestinal (ITx) and multivisceral transplant (MVTx) candidates is the loss of the recipients' abdominal domain. Therefore, abdominal wall closure becomes not only the last but also one of the most important parts of the procedure, requiring a thoughtful process to obtain an appropriate outcome.

The simple tension-free and primary abdominal wall closure unfortunately is not always possible, as many patients have the concomitant existence of a frozen abdomen secondary to multiple abdominal procedures, the loss of bowel length from prior bowel resection, the presence of multiple fistulas or ostomies, or extensive skin lesions secondary to the scarring process of a healed fistula, or a removed ostomy. These findings are most commonly a consequence of processes that lead to short gut syndrome, the primary cause of chronic intestinal failure.

To overcome the need for an adequate closure at the end of the transplant, two main strategies have been proposed: either to use a smaller donor or to reduce the length/size of the transplanted graft; or to enlarge the abdominal domain. The later has become the preferred approach.

The need to find a standard and reproducible solution brought multiple alternatives to the field, from the use of the component separation technique, to the use of synthetic or biological mashes, to the extreme need of performing an abdominal wall transplant. The later was originally described by Levy *et al.* [1], and it has been recognized as a cornerstone manuscript in the surgical field. The

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## KEY POINTS

- Abdominal wall closure after intestinal transplantation should start with an appropriate evaluation, followed by an accurate strategy design, to achieve a primary closure.
- Today, the use of an absorbable mesh or the nonvascularized fascia of the rectus muscle from the same donor has proved to be a valuable option, when separation component technique is insufficient.
- Although vascularized abdominal wall transplant has been used in a limited number of centers, over time it has impacted transplant surgery and may now be adapted for use in other fields.

innovation proposed, together with the future development of the hand and face transplant, were responsible to create a significant change in the transplant field when the US Secretary of Health formally grouped these together as vascularized composite allografts (VCAs) under the domain of the United Network for Organ Sharing; the governing institution that regulates solid organ procurement and allocation in the United States. This new nomenclature was accepted and reaffirmed by the American Society of Reconstructive Surgery [2▪▪]. Since then, regulations for evaluation, listing, procurement, and transplantation were developed in the United States and elsewhere.

In this article, we aim to review the evolution and the current state of the different surgical armamentarium available to achieve a successful abdominal wall closure after intestinal transplant. We would also like to present innovations that would not only move this field forward but also broad the use and indications beyond the transplant field.

## UNDERSTANDING THE PROBLEM

Eighty percent of the intestinal transplant candidates presented to evaluation with a primary diagnosis of short gut syndrome; most have one or more of the conditions mentioned in the introduction, which will lead to lose the abdominal domain.

Although it has been reported that less than 30% of intestinal transplant candidates required some surgical technique other than a simple primary closure, there is no comprehensive comparison of the alternative procedures for abdominal wall closure. Since the first intestinal transplant, plastic and reconstructive surgeons along with transplant surgeons have developed various techniques to improve the rate of primary closures following intestinal transplantation [3].

Mangus *et al.* [4] reported that 37 of 146 (25%) of the recipients required the use of a foreign material for fascial closure, and 12 patients (8%) more required a ventral hernia repair in the long term. However, it was not mentioned how the rest of the patients were closed. At the Charité Hospital in Berlin, a primary fascial closure was possible in 18 patients of 30 recipients (60%), and in 12 patients a staged abdominal closure was required. Other centers, like Pittsburgh, performed direct skin closure, living the fascia underneath open to achieve primary closure. But the magnitude of the problem remains unclear.

In our unpublished experience, of 43 intestinal transplants performed, 39% [5] required the use of the abdominal rectus fascia (ARF) for primary closure; 20% [6] were closed with a prosthetic mesh and 2% [1] required a component separation technique; therefore, 63% of the transplants required an additional procedure to be able to achieve a primary abdominal wall closure. As we mentioned in a recent editorial letter [7], there are enough possibilities to offer today in order to perform a primary closure in most of our patients. An appropriate strategy should be established during the evaluation phase, eliminating the need to improvise at the end of a transplant.

## PRIMUN NON-NOCERE: THE PRE-EMPTIVE APPROACH

One of most common patterns found has been the use of the Crux incision. The current worldwide availability of new abdominal retractors, like the Thompson retractor or similar ones, allows us to perform any Itx or MVTx using just a xypho-pubic midline incision (Fig. 1).

The present approach avoids further surgical injury on an already damaged wall, proving that there is no further need to transversally transect and devascularize the rectus muscles and the scarred skin to obtain sufficient exposure. This approach will further increase the options for a better ostomy placement, away from any abdominal incision. The use of smaller donors or the reduction of the graft size becomes a second component of this approach, promising to reduce or avoid the risk of requiring a delayed closure, but this practice can prolong the waiting time, thus increasing the risk of mortality on the waiting list.

## AIMING FOR A PRIMARY CLOSURE

At the end of the transplant, a tension-free primary closure should always be our aim. In most of our cases, there is a need to perform a component

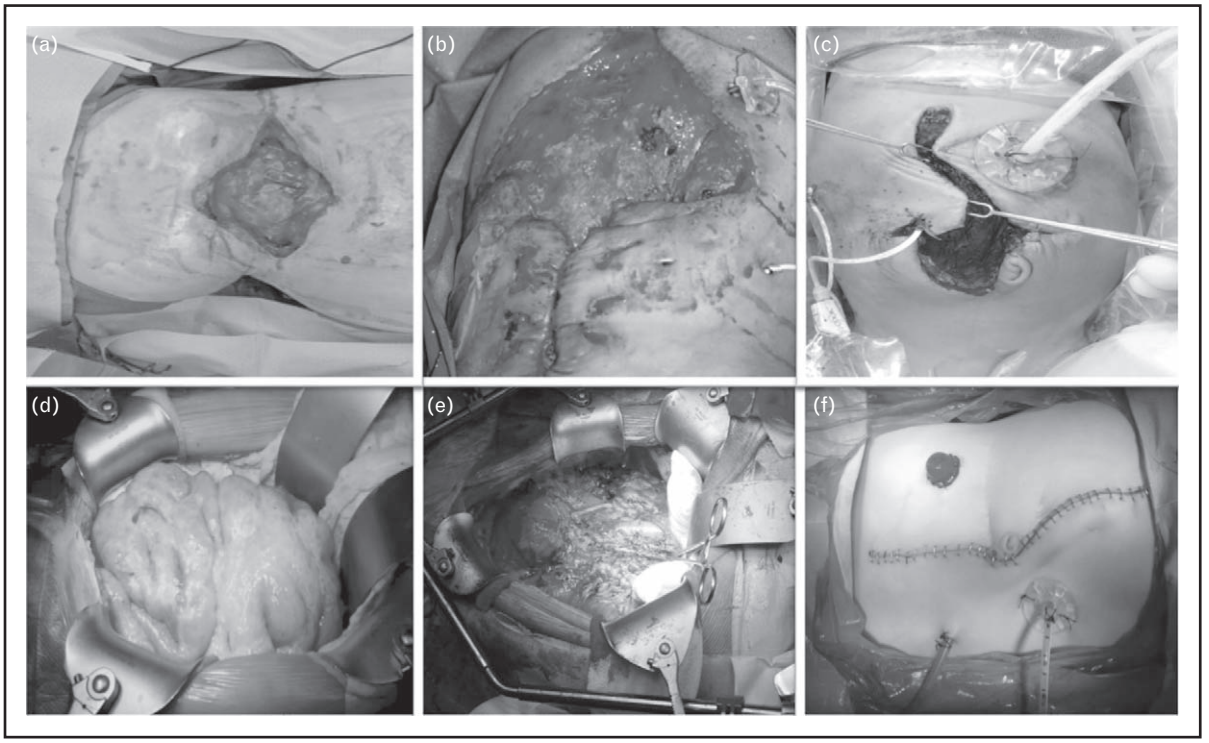


**FIGURE 1.** (a–c) Challenging cases previously published. (d–f) Examples of intestinal transplant performed using midline incision with adequate abdominal wall retraction.

separation technique (partial or complete). The existence of previous scars mandates the need to separate the skin from the fascia in both sides of the incision to allow the skin, to reach the midline, even if the fascias do not. If the separation component technique allows primary fascia closure, it is the recommended approach, if it does not and there is no other alternative material available, a simple skin closure can be performed [8]; otherwise, synthetic meshes can be considered.

We recommend the use of the absorbable meshes like Vicry (polyglactin 910, Ethicon) or Bio-A (polyglycolic acid andtrimethylene carbonate, Gore), because, in spite of the fact that they will lead to a chronic ventral hernia, the management in the setting of an infected wound is favorable. We avoid the use of nonabsorbable meshes like prolene, or silastic containing meshes, because of the increased risk for fistula formation and the difficulties observed for managing in the setting of a local infection [9]. Biological meshes such as AlloDerm (LifeCell), an acellular human tissue matrix [4]; or Permacol (Covidien), a porcine acellular dermal collagen matrix, alone or in combination with a Vicryl mesh and vacuum-assisted wound closure device have been successfully reported. There are some considerations related to the size of the patch, usually the defects are large and if a biological mesh is used in general, more than one might be required [10]. In such a case, the cost of those prosthesis, together with the lack of worldwide availability, have become a limitation for its use. Those were some of the main arguments for us, to think about a novel and affordable worldwide alternative, leading to conceive the use the fascia of the rectus abdominal muscle.

## TECHNICAL ADVANCES AND CURRENT CLASSIFICATIONS FOR ABDOMINAL WALL TRANSPLANT (ABDOMINAL WALL–COMPOSITE VASCULARIZED ALLOGRAFTS)

At the beginning, the abdominal wall transplant was conceived to perform a full-thickness vascularized transplant of abdominal rectus muscles, complete fascia, skin in the outer aspect of the graft, and peritoneal coverage on the inner side. The procedure was initially described utilizing direct orthothopic vascularization using iliac grafts to the aorta and cava, then microsurgical reconstruction over the epigastric vascular pedicles was proposed [6]. A remote revascularization of abdominal wall transplants using the forearm was recently proposed and satisfactorily performed in six recipients of an isolated small bowel transplant. The abdominal wall is

implanted to the recipient radial or ulnar artery, simultaneously with two teams operating synchronously on the abdomen and forearm. Revascularization on the forearm does increase the complexity of the procedure overall, but there was no evidence of abdominal wall ischemia, and no evidence of necrosis of the transplanted rectus muscle. None of the patients experienced any signs of ischemia in the hand [11]. The lack of nerve anastomosis led patients to develop atrophy of the muscular layer of the graft; however, no significant ventral defect has been reported.

The AWT is monitored by observation of the skin perfusion by color, temperature, and capillary return, particularly in the first few days. Healing in all AWT has been as rapid as native adjacent wound healing [12▪]. Overall results of the abdominal wall transplant have been recently published and have been updated for this manuscript (Table 1).

In order to follow the recent change in nomenclature, the abdominal wall transplant will be called AW-CVA from now on in our manuscript. The AW-CVA is supposed to be procured from the same cadaveric donor [1], although procurements from a different donor have been reported.

The novelty triggers further interest from other disciplines such as regenerative medicine and plastic surgery, leading to the development of a new research model in rats [13] and the proposal of retaining functional movement and sensation through repairing sensory and motor nerves during the procedure [14]. With the microsurgical skills developed by reconstructive surgeons, and their knowledge in vascularized tissue transfer they will be able to help restoring abdominal wall integrity in patients with critical composite deficiencies of the abdominal domain, not being only part of the transplant team, but also working together with general, pediatric and transplant surgeons.

Datta *et al.* [2▪▪] also opened a new area for improvement in his recent publication; the need to established a new algorithm for combined multiorgan and composite tissues procurement for transplantation. The new algorithm will affect procurement strategies and time courses, including the need to obtain vertebral bone morrow [2▪▪], and the recent proposal of starting the procedure with the face procurement followed by the sternotomy and the celiotomy [15]. The addition of bilateral upper extremities and or face retrieval presents new challenges for the close future: teams should start together, under donor instability, VCA are procured after thoracic and solid organs, at the end of the procurement, customized prosthesis are placed on the donor, and a prefabricated face mask is then applied to the donor defect site, before returning the donor to the family. The need for donor customized prosthesis opens a new era to be developed within the procurement organizations worldwide.

## NONVASCULARIZED ABDOMINAL WALL TRANSPLANT (ABDOMINAL WALL NONVASCULARIZED, NONCOMPOSITE ALLOGRAFT)

The need for a more affordable and reproducible alternative, together with the ethical and body

**Table 1.** Abdominal wall composite vascularized allografts (AW-CVA) and abdominal wall, vascularized non-composite allograft (AW-V non-CA) by center

| Center | Publications year | Patient | Abdominal wall graft implanted | Children | Adult | Abdominal graft | Anastomoses type | Transplant type | Mayor complication |
|---|---|---|---|---|---|---|---|---|---|
| UM | 2009 | 14 | 15 | 4 | 10 | AW-VCA | 12 Conventional<br>3 Micro | 9 IITx<br>4 MVTx<br>2MMVTx | 4 Rejection<br>2 Thrombosis (1 re-transplant) |
| UB | 2007 | 3 | 3 | | 3 | AW-VCA | 3 Micro | 3 IITx | 1 Rejection<br>1 Rejection + PTLD |
| DU | 2012 | 2 | 2 | 2 | | VPRMF | | 2 MVTx | 1 Rejection |
| OTC | 2016 | 13 | 14 | | 13 | AW-VCA | 9 Micro<br>5 Micro (remote via forearm)[a] | 12 IITx<br>2 MMVTx | 6 Rejection<br>2 GVHD |
| Summary | 10 years | 32 | 34 | 6 | 26 | 32 AW-VCA<br>2 VPRMF | 12 Conventional/<br>20 micro | 24 IITx | _ |

[a]In a previous publication (2014), the Oxford Group reported six cases of remote revascularization of abdominal wall transplants using the forearm. AW-VCA, abdominal wall composite vascularized allografts transplant; DU, Duke University; GVHD, graft versus host disease; IITx, small bowel transplant; MMVTx, modified multivisceral transplantation; MVTx, multivisceral transplant; OTC, Oxford Transplant Center; PTLD, posttransplant lymphoproliferative disease; UB, University of Bologna; UM, University of Miami; VPRMF, vascularized posterior rectus muscle fascia.

**Table 2.** AW-non-V non-CA: non-vascularized abdominal rectus fascia, by center

| Center | Patient | Children | Adult | Transplant type | Wound infections | Incisional ventral hernial |
|---|---|---|---|---|---|---|
| FF | 17 | 9 | 8 | 11 IITx<br>4 MVTx<br>2 CLITx | 2 | 0 |
| UM | 9 | 4 | 5 | 4 MVTx<br>2 IITx<br>2 MMVTx<br>1 CLITx | 4 | 0 |
| MSSN | 1 | | 1 | 1 IItx | 0 | 0 |
| CUB | 5 | | 5 | 5 MVTx | 0 | 0 |
| Summary | 32 | 13 | 19 | 14 IITx, 13 MVTx,<br>4 MMVTx, 3 CLITx | 6 | 0 |

CLITx, combined liver and intestinal transplant; CUB, Charite' Universitatsmedizin Berlin; FF, Fundación Favaloro; IITx, isolated intestinal transplant; MMVTx, modified multivisceral transplantation; MSSN, Mount Sinai School of Medicine; MVTx, multivisceral transplant; UM, University of Miami.

image aspects seen in the AW-VCA, brought us to revise the originally described procedure with the use of abdominal rectus fascia in 2009 [16]; presently, it might be named as abdominal wall non-vascularized composite allografts (AW-non-V non-CA).

The original report includes the description of two techniques: the use of the anterior fascia or the combined use of the anterior and posterior fascias. The fascia has the additional advantage of being preserved at 4°C, to be used in the immediate post-operative period; therefore, the abdominal closure surgery can be planned if needed and differed to a different day, using a preserved fresh fascia or a new fascia from a different donor [16]. Several wound infections were described, which were often because of incomplete skin coverage over the fascia, and the group from Germany recommended the use of a negative pressure dressing over the fascia when skin closure is not possible [8].

The global reported experience using AW-non VCA-non is shown in Table 2. Presently, up to 32 patients have received an AW-non-V non-CA. In another unpublished experience, of 19 cases, 15 were not previously reported and two were in liver transplant recipients. Eleven were isolated intestinal transplant recipients, two were combined liver and intestine, four were multiorgan transplant (one was a re-transplant with kidneys en-block), and two patients were recipients of a liver re-transplant. Nine were pediatric and 10 were adult recipients; 12 of 19 recipients of ARF (63.15%) required 21 reoperations. Of those, 16 re-operations were done during the first month, and five were performed after the first month. In two cases, the fascia was replaced for a Vycril mesh in the early period. At a mean follow-up of 52.17 months (±43.6), none of the patients who remained with the fascia as part of their abdominal wall ($N = 17$) developed ventral hernias and none presented with adhesions to the transplanted abdominal wall, even when the reason for admission was small bowel obstruction (Fig. 2).

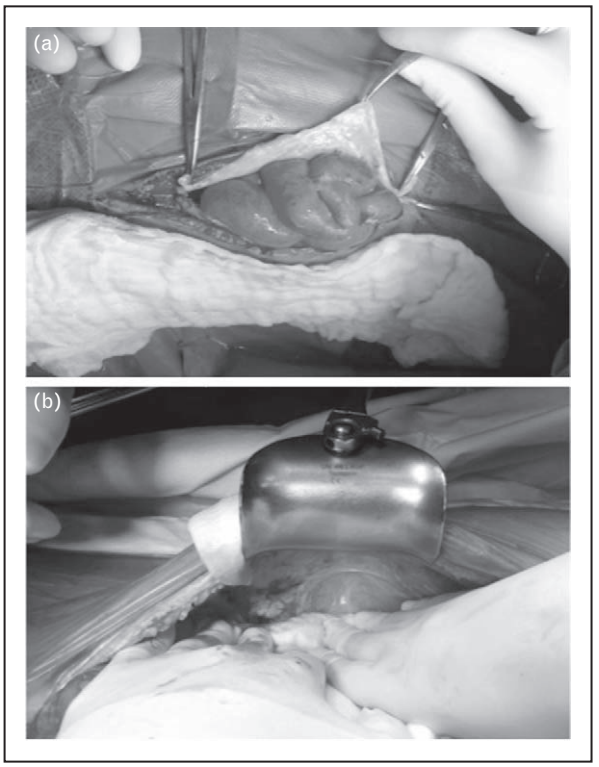


**FIGURE 2.** Early (a) and late (b) intraoperative findings, where there is no adhesion between the intra-abdominal organs and the abdominal rectus fascia.

## VASCULARIZED POSTERIOR RECTUS MUSCLE FASCIA, A NEW ADDITION TO THE RECENTLY STABILIZED CLASSIFICATION: THE ABDOMINAL WALL–VASCULARIZED NONCOMPOSITE ALLOGRAFT

In 2010, The University of Chicago published the case of a 3-year-old patient who underwent a combined liver and bilateral kidney transplant. The abdominal closure was achieved with the help of the vascularized donor rectus sheath, which had been procured attached to the liver by the falciform ligament [17]. Later, Ravindra *et al.* [8] described the use of this technique in two pediatric multivisceral transplant recipients. The simplicity of the procedure is a major advantage over full-thickness abdominal wall transplantation and the presence of vascularity appears likely to diminish the risk for local infection.

His technique has been proposed to be useful in the following scenarios: in multiorgan transplantation when there is a donor-to-recipient size mismatch; after liver or intestinal containing transplant when there are associated congenital abdominal wall defects and for re-transplant cases [18].

## NEW APPLICATIONS FOR AN ALREADY NOVEL SURGICAL TECHNIQUE

The potential use of the AW-CVA has been extended far beyond the initial thought; to find a simple and reproducible solution to solve a significant abdominal wall defect. The skin of the CVA was found to be useful as 'sentinel' for immunological activity of the host; therefore, it could potentially be used as an immunological tool for assessing graft rejection, avoiding the need of scheduled endoscopic biopsies.

This year the groups from Berlin and Oxford [19▪▪] reported their experience and long-term follow-up after AW-CVA. In their experience, transplanted patients with infectious diarrhea did not have any clinical sign in the abdominal wall; but five patients presented with rush, and proven skin graft rejection in the biopsy; from them only one presented simultaneous intestinal graft rejection, favoring the fact that the skin rejection appears before the intestinal graft was compromised in most cases. In three other cases, patients presented with native skin graft rush, and normal skin on the transplanted abdominal wall, the presence of this clinical sign, helped to accelerate the diagnosis and treatment for graft-versus-host disease. This observations triggered the idea of using a remote CVA as an 'immunological barometer' [20] and they started to place it in the forearm of intestinal or pancreas recipients. Furthermore, it has been recently proposed the use of a simpler procedure that is a vascularized sentinel skin flap, looking for the potential reduction of endoscopies and biopsies to improve graft survival and to reduce the long-term morbidity associated to immunosuppressive drugs.

## CONCLUSION

Transplant literature has shown the long-term benefits of transplanting the abdominal wall, not only in intestine or multiviscerals, but also in the treatment of other organs like the liver. The use of the AW-non-C non-VA proved to require less surgical resources, lower operative time, and has acceptable long-term morbidity and mortality. With the advancements made in immunosuppressive therapy and tolerance, this technique might evolve beyond the solid organ or multivisceral patient to include those patients with composite losses of the abdominal wall that are not amenable to reconstruction with conventional measures.

Finally, the translation from the AW-CVA to the AW-non-C non-VA to the simple use of skin flaps from the same donor will provide a new tool for 'immune monitoring' of the transplanted graft.

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### Conflicts of interest

*The authors have no conflicts of interest.*

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- ▪▪ of outstanding interest

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