



Modified Chevrel technique for abdominal closure in critically ill patients with abdominal hypertension and limited options for closure

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Abstract

Abdominal compartment syndrome is a potentially life-threatening condition seen in critically ill patients, and most often caused by acute pancreatitis, postoperative abdominal vascular thrombosis or mesenteric ischemia. A decompressive laparotomy is sometimes required, often resulting in hernias, and subsequent definitive wall closure is challenging.

Aim This study aims to describe short term results after a modified Chevrel technique for midline laparotomies in patients with abdominal hypertension.

Materials and methods We performed a modified Chevrel as an abdominal closure technique in 9 patients between January 2016 and January 2022. All patients presented varying degrees of abdominal hypertension.

Results Nine patients were treated with new technique (6 male and 3 female), all of whom had conditions that precluded unfolding the contralateral side as a means for closure. The reasons for this were diverse, including presence of ileostomies, intraabdominal drainages, Kher tubes or an inverted T scar from previous transplant. The use of mesh was initially dismissed in 8 of the patients (88.9%) because they required subsequent abdominal surgeries or active infection. None of the patients developed a hernia, although two died 6 months after the procedure. Only one patient developed bulging. A decrease in intrabdominal pressure was achieved in all patients.

Conclusion The modified Chevrel technique can be used as a closure option for midline laparotomies in cases where the entire abdominal wall cannot be used.

Keywords Abdominal wall closure · Abdominal hypertension · Pancreatitis · Modified Chevrel technique

Introduction

The integrity of the abdominal wall is not only fundamental for the protection of vital internal organs but is also necessary for maintaining several bodily functions that rely on the ability to effectively perform the Valsalva maneuver, such as urination, coughing, and defecation [1]. Notably, the cases we describe herein are case series solving abdominal

hypertension in highly selected, critically ill patients which are contextual considerations that should be taken into account.

There are several causes for compartmental syndromes of the abdomen, the most common of which is acute pancreatitis, followed by abdominal vascular thromboses and mesenteric ischemia, which are treated surgically [2]. To avoid closing a laparotomy under tension or to decrease the intraabdominal pressure, it is sometimes necessary to leave the abdomen open, use a device such as the Bogotá bag, or use a "sandwich technique" [3, 4]. Decompressive laparotomy has also been proven effective in reducing mortality after compartment syndrome in trauma victims or major burn victims with abdominal compromise [5, 6]. In any of the above-mentioned cases, subsequent closure of the laparotomy must follow two basic premises to avoid worsening of the compartment syndrome: the cavity must be watertight, and the closure must be free of tension. Likewise, the closure must prevent subsequent hernias, respect

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tissue vascularization, and avoid tension in the tissues during closure while at the same time maintaining sufficient tension to adequately support ventilatory function [7].

Incisional hernias continue to be the most frequent long-term complication of abdominal surgery, with recurrence rates close to 10% when mesh repairs are performed [8] and up to 31–40% in mesh-free repairs [9, 10]. The technique described by Chevrel for reconstruction of the alba line with pre-muscular mesh placement (onlay) [11] has the advantage of avoiding contact between the mesh and the abdominal contents and reducing tension in midline closures. However, it requires significant dissection of the subcutaneous planes, which can be associated with higher rates of seroma and wound infection [12], even in its modified version [13]. The position in which the mesh is placed is fundamental because it determines the impact of the mesh on tissues, integration, and the tensile strength generated in the abdominal wall, all of which are factors that influence hernia recurrence [8]. On the other hand, the tension generated by the repair has direct repercussions on the abdominal contents, including an inverse effect on the blood supply to the abdominal viscera when extreme pressures are reached [14, 15] and a direct effect on respiratory resistance [7]. In this technique, splitting the anterior rectus sheath increases the abdominal capacity, and if this gain is insufficient, there is an increase in intraabdominal pressure when introducing the herniated content, which increases respiratory resistance [7]. Several other techniques have been developed in an attempt to further expand the abdominal capacity in these cases, including the technique of anterior component separation first described by Albanese [16], which involves releasing the insertion of the external oblique muscle. Despite these existing techniques, there is still, unfortunately, a small group of patients in which up to half of the abdominal wall is not functional or available to be used in repair techniques due to multiple previous surgeries or failed closure attempts but who nonetheless require definitive closure of the abdominal wall or hernia repair. These complex cases require innovative solutions, such as the one presented herein.

Materials and methods

We performed our new technique on 9 patients between January 2016 and January 2022. We initially treated only critically ill patients and then expanded our indication to include less acute patients after our positive initial experience. Nonetheless, overall, there are very few patients who will benefit from this technique.

Patients who had suffered gastrointestinal diseases or postoperative complications and were left with varying degrees of abdominal hypertension were included. We considered this surgical approach in patients with

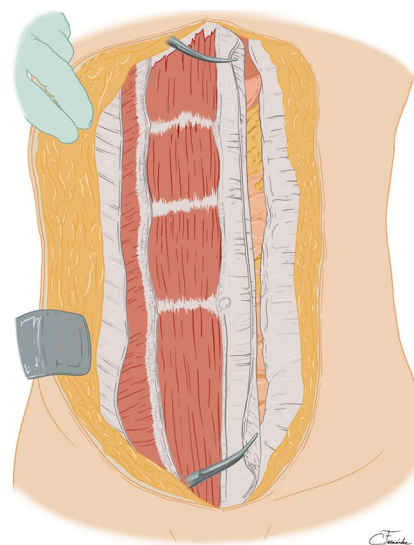
intraabdominal pressures exceeding 20 mmHg and clinical symptoms compatible with abdominal hypertension who were deemed stable enough to undergo surgery but in whom only one half of the abdominal wall could be used for reconstruction. Surgical options were considered after medical interventions had failed to resolve the high abdominal tension. These interventions included image-guided drainage of any existing collections, volume restriction, changes in patient positioning, removal of any abdominal dressings or bandages, optimization of ventilatory parameters, placement of nasogastric tubes for suction, and use of rectal enemas and renal replacement therapy when necessary. All of the surgeries were performed by two surgeons experienced in the surgical management of the abdominal wall.

Description of the technique

Most of the patients in our series had a previously undergone a midline laparotomy to decrease intraabdominal pressure or for exploration of the abdominal cavity due to acute pancreatitis.

The midline laparotomy was reopened, and we confirmed the integrity of at least one of the two halves of the abdominal wall, ensuring that the ipsilateral rectus sheath was complete. After this, we attempted an initial aponeurotic closure and measured the tension and intraabdominal pressure as estimated by the bladder pressure. The closure was completed when the intraabdominal pressure was below 20 cmH₂O, but we attempted additional techniques in the patients whose pressure exceeded this value to decrease the pressure at closure. The first step of the technique consisted of unilateral anterior component separation. To do this, a significant subcutaneous flap was raised from the anterior abdominal wall fascia on the side that could be used for closure. Once the anterior fascia was fully exposed, we released the anterior aponeurosis of the oblique muscle. We then repeated an estimation of the intraabdominal pressure after closure, and if it was still above 20 cmH₂O, we unfolded the anterior sheath of the previously released rectus, creating a fascial advancement flap that increased the abdominal capacity. We performed a final measurement to confirm an adequate decrease in the intraabdominal pressure. Once the pressure fell, ideally below 20 cmH₂O, closure was performed with a 2/0 or 0 thickness nonabsorbable monofilament (polypropylene) as an interrupted suture (Figs. 1 and 2). We reinforced the closure with a polypropylene mesh on one occasion. The decision to use a mesh depended primarily on the local conditions, as the site was most often contaminated during these procedures, precluding the use of a mesh.

Fig. 1 Closure with an interrupted suture using a nonabsorbable monofilament in a patient with a Kehr T-tube and an ileostomy on the right side



Results

Almost half of our patients suffered from abdominal hypertension secondary to acute pancreatitis. All patients had hypertension, as estimated by bladder measurement, when attempting to close the midline during surgery. The vast majority (66.6%) of patients were in the intensive care unit at the time of the procedure. All patients presented with some degree of abdominal hypertension during the attempt to close, and in all patients, only one of the abdominal wall halves could be used for reconstruction (Table 1). The body mass index of the patients ranged from morbidly obese to severely underweight. A third of the patients passed away during the postoperative phase.

Several reasons precluded the use of the contralateral side for closure, including ileostomies, intraabdominal drains,

Kehr tubes, and inverted T-scars from prior transplants (Fig. 3).

We decided against using a mesh in eight patients (88.9%); in three of them, the decision was due to planned subsequent surgeries (restoration of bowel continuity in two cases and esophagectomy in the third). We entered the abdomen in all of our patients via the previously used midline incision, and closure was performed with a continuous monofilament suture, given the good appearance and strong consistency of the tissues in the abdominal wall. In the remaining cases, the use of a mesh was contraindicated because of a concomitant superinfection with necro-hemorrhagic pancreatitis. None of the patients developed a hernia, although two of them died within 6 months, limiting long-term assessment. Only one patient developed bulging; this patient had undergone transplantation and developed portal thrombosis. In this case, early extubation was prioritized to avoid superinfection, and a watchful waiting strategy was

Fig. 2 Rectus abdominis sheath use conditioned by the presence of a jejunostomy and an ileostomy on the patient's left side

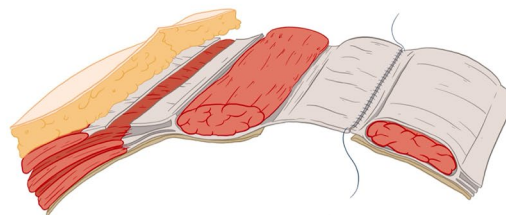
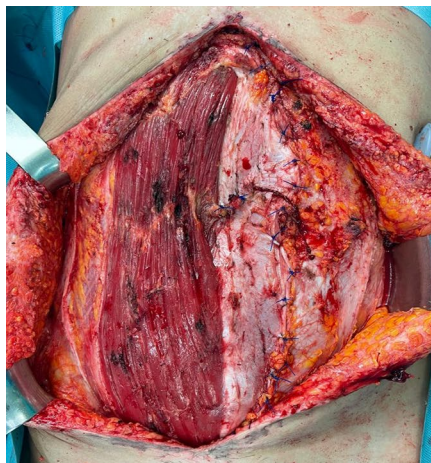


Table 1 Characteristics of patients treated with the new technique

Case	Origin	Age	Prev. Surg	Pre IAP	Post IAP	Sex	Technical cause	Mesh (yes/no)	Defect size (cm)	BMI	Wound type	Alive/dead (80 months)	Hernia complication	Ventral hernia staging system	Ventral hernia working group	EHS classification	Patient in ICU (yes/no)
1	Complicated acute pancreatitis	54	2	27	18	Male	Right drains due to late fistula	No	15×20	41	Contaminated	Alive (80 months)	No	III	Grade 4	M1-M4	Yes
2	Complicated cephalic duodenopancreatotomy	59	6	25	17	Male	Right-sided ileostomy and Kehr tube	No	15×10	21	Clean-contaminated	Alive (53 months)	No	II	Grade 3	M1-M5	Yes
3	Acute necrohemorrhagic pancreatitis	58	3	29	20	Male	Right ileostomy	No	15×20	29	Clean-contaminated	Dead (stroke) (23 months)	No	III	Grade 3	M1-M3	Yes
4	Post-liver transplantation portal thrombosis	63	3	24	19	Male	Right drains and T-incision	No	20×10	31	Clean-contaminated	Alive (41 months)	Bulging haematoma	III	Grade 2	M1-M3	Yes
5	Caustic oesophagitis with secondary intestinal volvulus and Bogotá bag	27	2	28	19	Female	Feeding left jejunostomy	No	15×14	19	Clean-contaminated	Alive (21 months)	No	II	Grade 2	M1-M5	No
6	Massive bowel resection	65	4			Male	Multiple enterocutaneous fistulas	No	15×20	21	Contaminated	Alive (16 months)	No	III	Grade 4	M1-M5	No
7	Acute necrohemorrhagic pancreatitis	71	2	28	20	Female	Right drains, late fistula	No	15×10	39	Clean-contaminated	Dead (pancreatitis) 6 months cx	Seroma	III	Grade 3	M1—M3	Yes
8	Right post-colectomy pancreatitis	76	4	26	17	Female	Right ileostomy	No	15×10	28	Contaminated	Dead (pancreatitis) 1 month after surgery	No	III	Grade 4	M1-M4	Yes

Table 1 (continued)

Case Origin	Age	Prev. Surg.	Pre IAP	Post IAP	Sex	Technical cause	Mesh (yes/no)	Defect size (cm)	BMI	Wound type	Alive/dead	Hernia complication	Ventral hernia staging system	Ventral hernia working group	EHS classification	Patient in ICU (yes/no)
9 Incarcerated eventration	70	3	21	16	Male	Right ileostomy	Yes	10×10	30	Clean-contaminated	Alive (12 months)	No	II	Grade 3	MI-M3	No

IAP intraabdominal pressure

established to allow time for the abdominal distension secondary to portal thrombosis to decrease.

At the time of completion of the final surgery, all patients had a decreased intraabdominal pressure relative to their baseline, but the magnitude of this decrease ranged from 5 to 9 cmH₂O.

None of our patients developed hernia recurrence, although there was one case each of bulging, hematoma and seroma. Our results are limited by the 33% mortality rate observed within the first two years.

Discussion

Abdominal wall closure in patients with abdominal hypertension must both decrease intraabdominal pressure, by either increasing the available space or in many cases decreasing the abdominal contents, and ensure sufficient tension for adequate respiratory progression.

Our study describes a surgical method for use under exceptional surgical circumstances of abdominal hypertension in critical ill patients requiring mechanical ventilation. It is well known that abdominal hypertension exerts deleterious effects on the abdominal viscera, diminishing venous return through the vena cava, decreasing the preload and hence the arterial flow to abdominal organs [17, 18], and causing difficulties for both mechanical and spontaneous ventilation [7, 19].

In our study, 4 patients (44.4%) had been left with an open abdomen due to hypertension after necro-hemorrhagic pancreatitis. Acute pancreatitis has an unpredictable course, but up to 25% of patients develop multi-organ failure [20], and up to 17% present abdominal hypertension at some point, with a mortality rate of 37% [3]. In our series, 4/9 patients had acute pancreatitis. In these patients, decreasing the intra-abdominal pressure is usually a prerequisite for successful weaning from the ventilator [21], and survival outcomes are inversely proportional to ventilator-dependent time. In fact, intra-abdominal pressure is likely a prognostic factor in acute pancreatitis [3].

It is important to remember that the rectus abdominis sheath can only be completely unfolded when at least one of the muscles is intact. In patients with a history of previous surgeries, the rectus sheath can be used when there is fibrosis in the junction, but we do not recommend unfolding the sheath in these cases to avoid creating areas of weakness that need to be sutured upon closure. In patients without a history of previous surgeries, and depending on the patient's size, this technique can be used to cover sizeable defects, as the aponeurosis size depends on the patient's size and physique.

In general, the larger the patient's rectus muscle sheath, the larger the size of the defect that can be covered, since



Fig. 3 Patient with multiple right-sided entero-cutaneous fistulas, which required major resection of the right muscular wall and subsequent reconstruction. Six months after the intervention, he showed no hernial defects or bulging

the size of the rectus is proportional to the patient's size. Performing component separation before unfolding the rectus muscle increases the volume of the abdominal cavity by combining both techniques but also increases the possible complications associated with them. In fact, the subcutaneous dissection for this technique is very extensive, even when only one muscle is unfolded, and seroma has been described as a complication of component separation in as many as 30% of patients [22]. Another option in these complex cases is reducing the abdominal content via either omentectomy, retroperitoneal fat resection, or even intestinal resection [23, 24], which are not advisable in the context of abdominal hypertension. The above techniques can be used in patients who do not have hyper-acute syndromes of abdominal hypertension, particularly patients who are relatively stable and progressing towards extubation [25].

The most important complication associated with the technique we describe in this paper was bulging in a patient with post-transplantation portal thrombosis. The speed at which the abdominal hypertension was produced in this setting could explain the excess abdominal capacity left after the intervention. In fact, transitory closing techniques, such as those involving a Bogota bag or the sandwich technique, could be attempted before considering this technique; alternatively, even short cycles of treatments with compounds such as neostigmine appear to be effective in patients with pancreatitis [2].

In conventional hernia repair techniques, the correction of defects larger than 7.5 cm requires the use of a mesh to ensure biomechanical stability [26, 27]. However, the use of conventional meshes in these types of patients, most of whom have contaminated wounds, could yield hernia recurrence rates as high as 23.8–30% and infectious complication rates up to 13–20.8% [28, 29]. The use of meshes was not an option in our series because of concomitant infection of the surgical field or the need for additional surgery in the near future.

Another alternative in these patients is the use of biological meshes [30]. Biological meshes have the advantage of not weakening the abdominal wall or requiring subcutaneous dissection; however, they predispose patients to more frequent bulging, are more expensive, and are a foreign body associated with a higher frequency of seromas.

Some authors defend staged closure [31] or closure using progressive tension suture fixation [32], with or without the use of a biological mesh. These techniques require multiple interventions and have a significant rate of complications, including seroma, hematoma, and hernia recurrence.

The technique we describe maintains the structure of the wall in a more physiological way than transposition of the posterior rectus [33], hinge flaps [34], or bilateral anterior turnover [35] and is more feasible in patients with a history of previous surgeries than component separation [36, 37]. We also believe that it leads to less debilitation of the abdominal wall than bilateral anterior and posterior component separation [38] (Table 2). Recent studies agree that the Chevrel technique is relatively superior to hernia repairs using onlay meshes, in regards to recurrence [39], with excellent results in some series [25]. The main disadvantage of our technique is the significant dissection of the subcutaneous plane, which facilitates hematoma and seroma development. However, it is an additional technical resource in cases of abdominal hypertension when none of the abdominal wall can be used for closure and there is a need to expand the abdominal capacity. In such situations, pre-habilitation with weight loss, cessation of smoking, or physiotherapy is not possible. For this same reason, botulinum toxin therapy is not possible, as it would require approximately 4 weeks to be effective [40]. The use of meshes in these types of patients is controversial since they do reinforce the wall closure but could also increase the likelihood of infectious complications. The decision to use meshes depends on the local conditions and the likelihood of requiring reinterventions [41]. Vacuum-assisted therapy plays a role in the closure of an open abdomen in that it may assist in keeping the wound

Table 2 Different options for abdominal closure in critically ill patients with abdominal hypertension

Techniques		Pros	Cons	Comparative advantages of our technique
Staged closure [31]		Less hernia recurrence	Multiple interventions Seroma Haematoma	Allows for closure in a single procedure
Progressive tension suture [32]		Generally, leads to firmer closure with less hernia recurrence	Multiple interventions Seroma Haematoma	Allows for closure in a single procedure
Flap techniques	Transposition of posterior rectus sheath [33]/hinge flaps [34]	Excellent tension even without mesh	Need for rectus sheath integrity Complex surgery in an infected area (not ideal for infectious causes)	Allows for treatment of larger defects and does not require entering the abdominal cavity in order to release the flap
	Anterior bilateral turnover [35]	Excellent tension even without mesh	Need for rectus sheath integrity Poor option in the context of sepsis	Generates less bulging
Component separation	Anterior [36, 37]	Can cover a wide range of defects	Needs extensive subcutaneous flaps Requires integrity of the entire abdominal wall (i.e., cannot be used in cases of pre-existing stomas, Kehr tubes, etc.)	Allows for treatment of larger defects
	Bilateral anterior and posterior [38]	Can cover larger defects	Requires the use of a mesh (not ideal for infected areas) Causes a more significant loss of structure in the abdominal wall	Abdominal wall is not weakened bilaterally
Biological meshes		Integrate well even in infected sites	More expensive Higher rates of postoperative bulging	Allows for reinterventions with lower adhesion rates

clean and facilitate closure of the posterior fascia [41]; however, some studies have reported mortality rates as high as 45.2% [42]. In our experience, all these different techniques can play a role, depending on the intraoperative findings and anatomy of each patient. The advantage of our technique is that it allows for the closure of very large defects in a single procedure by modifying only one side of the abdominal wall.

In conclusion, our modified Chevrel technique can be used as an optional tool in the surgical armamentarium for the closure of midline defects in cases where critically ill patients require urgent or emergent solutions for abdominal hypertension problems, but none of the abdominal wall can be used.

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Author contributions All authors approved the submitted manuscript and have made important contributions to this research. Iago Justo, Carlos Jiménez-Romero, and Cristina Rivas: writing the article; Iago Justo, Carlos Jiménez-Romero, Cristina Rivas, Oscar Caso, Alberto Marcacuzco: study design, interpretation, drafting, and critical review of the article; Iago Justo, Carlos Jiménez-Romero, Viviana Vega,

Alberto Marcacuzco, Alejandro Manrique, Clara Fernández, Jorge Calvo Pulido, and Alvaro García-Sesma: data collection, and data analysis.

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Data availability statement The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors declare no conflict of interest.

Ethical approval The Ethics Committee of the “Doce de Octubre” University Hospital waived approval due to the retrospective nature of the study.

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