Abdominal Wall Reconstruction Utilizing the Combination of Absorbable and Permanent Mesh in a Retromuscular Position: A Multicenter Prospective Study

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Abstract

Background

Optimal mesh reinforcement for abdominal wall reconstruction (AWR) in complex hernias remains questionable. Use of biologic, absorbable and synthetic meshes has been described. The idea of using an absorbable mesh (AM) under a permanent mesh (PM) in a retromuscular position may help in these challenging situations.

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Methods

Between 2011 and 2016, consecutive patients undergoing open AWR utilizing an AM as posterior layer reinforcement and configuration of a large PM were identified in a multicenter ~~that~~ prospectively maintained database in four hospitals. Main outcomes included demographics, ventral hernia classifications, perioperative data, complications and recurrences.

Results

A total of 169 complex incisional hernias were analyzed. Mean age was 60.9, with mean body mass index 30.7 (range: 20–46). Location of incisional hernias (IH) was: 80 midline, 59 lateral and 30 midline and lateral. 78% were grade I and II in Ventral Hernia Working Group classification. 52% of patients were discharged with no complication. There were 19% seromas, 13% hematomas, 12% surgical-site infection and 10% skin dehiscence. Only partial mesh removal was necessary in one patient. After a mean follow-up of 26 months (range 15–59), there were five (3.2%) recurrences. Reoperations on patients showed a band of fibrosis separating the peritoneum from the PM.

Conclusion

The combination of AM with very large PM in the same retromuscular position in AWR seems to be safe. The efficacy with recurrence rates below 4% in complex midline and lateral IH may be explained by the use of larger PMs that are extended and configured with the support of AMs. Reoperations on patients have confirmed the previous experimental reports on the use of the AM.

Electronic supplementary material

The online version of this article (https://doi.org/10.1007/s00268-018-4765-9) contains supplementary material, which is available to authorized users.

Introduction

Incisional hernia (IH) repair is one of the most frequent operations performed in the world [1]. Some of these IH are considered to be complex, due to technical factors or the patient's characteristics [2]. In the last decade, there has been an important contribution for improvement in the surgical treatment of complex IH: the development of new retromuscular surgical techniques in AWR and the appearance of new meshes that reinforce the hernia repair in complex scenarios.

Although the established retromuscular preperitoneal dissection according to Rives-Stoppa may solve a number of these complex IHs [3, 4], the introduction of posterior components separation has facilitated the closure of both posterior and anterior layers in wide defects and the location of large meshes in a completely retromuscular preperitoneal space [5, 6, 7, 8]. Transversus abdominis release (TAR) is the posterior components separation technique that has gained more popularity, and there are many publications regarding the successful treatment in a wide variety of complex repairs: multirecurrences, loss of domain, open abdomen and iliac hernias [9, 10, 11, 12].

To date, the meshes used after a TAR to reinforce the posterior layer have been synthetic, biologic and absorbable [9, 13, 14]. In the TAR technique, the openings on the peritoneum during the dissection are very common, and in very large defects or multirecurrent IHs, complete closure of posterior layer may be impossible. Under these surgical situations, the possibility of using a combination of an absorbable mesh (AM) with a permanent synthetic mesh (PM) as a barrier to separate the PM from viscera has been proposed [15]. Some of the potential benefits of the AM would be the complete closure of the posterior layer and the prevention of future adhesions of the bowel to the PM [16]. In 2011, our group started using AM to close the posterior layer in those cases of IH after urologic procedures in which the absence of peritoneum in Retzius space was a frequent finding. We realized that this AM not only avoided the contact of PM with the viscera but also provided a mechanical support to the extension and three-dimensional (3D) configuration of the PM, and started using both meshes in AWR. This idea was adopted by other European hospitals dedicated to complex IHs. The aim of this study is to present the results of the first multicenter experience using the combination of AM and PM in AWR.

Methods

From December 2011 to December 2016, patients with complex IH undergoing retromuscular repair with the combination of an absorbable and permanent meshes with a minimum follow-up of 15 months in four European institutions were identified in a prospectively maintained database. The hospitals involved in the study are recognized referral centers for complex abdominal wall repair. All the patients met the inclusion criteria to consider the IH to be complex [2]. We have included incisional hernias in midline (M1–M5 EHS classification) and lateral abdominal wall (L1–L4 EHS classification).

Patient demographics included age, sex, body mass index (BMI), comorbidities, the number of previous hernia operations and cause of first operation. Hernia characteristics included location, Carolina's risk index [17], length and width of defect and mesh area. Intraoperative wound assessments were recorded using Center for Disease Control (CDC) guidelines, and hernia grades were determined according to several classifications [18, 19, 20]. All patients had a preoperative computed tomography (CT) scan to evaluate the surgical strategy.

Postoperative data included both local and systemic complications, time in intensive care unit and length of hospitalization. Surgical-site events (SSE) include surgical-site infections (SSI) [21] and any wound dehiscence, seroma, skin necrosis or hematoma [19].

Standard follow-up protocol consisted of physical examination during a visit to the outpatient clinic at 6 weeks, 3 months, 6 months and every year. CT scans were routinely obtained in case of any abdominal discomfort or any doubt of potential recurrence on clinical exploration. Recurrence was defined as a recurrent hernia seen on CT scan or noted on physical examination by the primary surgeon. Bulging was defined as an area of weakness or asymmetry in the inspection or exploration of abdominal wall, but in the CT, there is no defect on the abdominal wall. Preoperative pneumoperitoneum was performed in 26 cases of loss of domain as it has been described [22].

Surgical technique

For midline incisional hernia (M1–M5 EHS classification), the repair was made through previous incisional scars. Previous implanted meshes were only removed in case of infection, fistula, lack of integration or intense adhesions. The sac was preserved until the moment when the closure of layers started. Typically, the sac is cut longitudinally to obtain two halves. One half of the sac was left attached to the posterior rectus sheath to facilitate posterior layer closure, and the contralateral flap of sac was used to cover the mesh in case of impossibility to approximate the midline. Adhesions of abdominal viscera to the abdominal wall were released. Then, a retrorectus dissection was performed in all cases according to Rives-Stoppa technique, preserving the neurovascular bundles that come to innervate the rectus muscle [23, 24]. When the midline could not be completely approximated despite the retrorectus dissection, a TAR was added. Briefly, the TAR was made down-to-up, starting with the lateral incision on the posterior rectus sheath from arcuate line, 1-cm medial to linea semilunaris. Then, the preperitoneal plane was dissected from lateral to medial ascending the lateral incision on the posterior rectus sheath parallel to linea semilunaris to reach the fibers of transversus abdominis in epigastric area [25]. After cutting the fibers of the muscle as originally described [8], the preperitoneal plane was changed to the pre-transversalis plane. Then, the retromuscular plane behind the visceral sac is widely dissected as far as the central tendon of the diaphragm (cranially), Cooper's ligament (caudally) and psoas muscle (laterally to the ~~level of~~ posterior axillary line). In one case, a Carbonell technique was performed [5]. Then, in most cases, the posterior layer composed of the medialized posterior rectus sheaths and peritoneal sac could be closed with running absorbable monofilament sutures. The unavoidable tears greater than 1 cm on the peritoneum were also closed.

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Next, an absorbable 20 × 30 cm mesh (GORE® BIO-A® Tissue Reinforcement, W. L. Gore & Associates, Inc. Flagstaff, AZ, USA), usually trimmed to adapt to the shape of the space dissected, was placed without any fixation to reinforce the posterior layer (Video 1 of Electronic Supplementary Material). At the myopectineal area, the mesh is usually cut to adjust to the shape of the ileopubic tracts. This mesh will help to make the "taco" or 3D configuration of the PM that will be shaped as Stoppa described [23] (Figs. 1 and 2) (Video 2 of Electronic Supplementary Material). A large uncoated macroporous PM was also placed in the same retromuscular position over the AM. The size of PMs used was 26 × 36 cm polypropylene (Optilene mesh, B. Braun, Melsungen, Hessen, Germany) for Rives procedures, and 50 × 50 cm polypropylene (Bulevb®, Dipro Medical Devices SRL, Torino, Italy) or 60 × 45 cm polyvinylidene fluoride (PVDF) (Cicat®, Dynamesh, FEG Textiltechnik mbH Aachen, Germany) for TAR surgeries. These meshes were also cut to adjust to the size of the plane dissected (Figs. 1 and 2). These PMs were only secured cranially and caudally in the midline with slowly absorbable sutures: Cranially, retroxyphoid to the posterior rectus sheaths insertions on cartilages or to the central tendon of diaphragm. Caudally was only fixed with ~~one~~ 1 stitch to both Cooper's ligaments. No lateral or transparietal fixation was made. Drains were normally placed between the polypropylene mesh and the muscles. The linea alba was restored with slowly absorbable sutures. When the linea alba (the medial borders of the anterior rectus sheaths) could not be completely closed, the borders of the anterior rectus sheaths were fixed to both meshes, leaving a bridge that is usually covered with remnant of sacs or fibrous tissues. The maximum width of the bridge was registered. We have also considered bridging those cases when the anterior layer was completely closed with rest of fibrosis, previous meshes or peritoneal sac but not with anterior rectus sheaths. The redundant sacs, soft tissues and skins were then removed.

Fig. 1

a Shape of the PM in the Rives-Stoppa repair in midline IH. The arrow shows bending of the mesh at the retroinguinal area. **b** Shape of the AM to support the 3D configuration of PM in the Rives-Stoppa repair in midline IH. **c** PM placed over the AM to wrap inferiorly the visceral sac in the Rives-Stoppa repair in midline IH

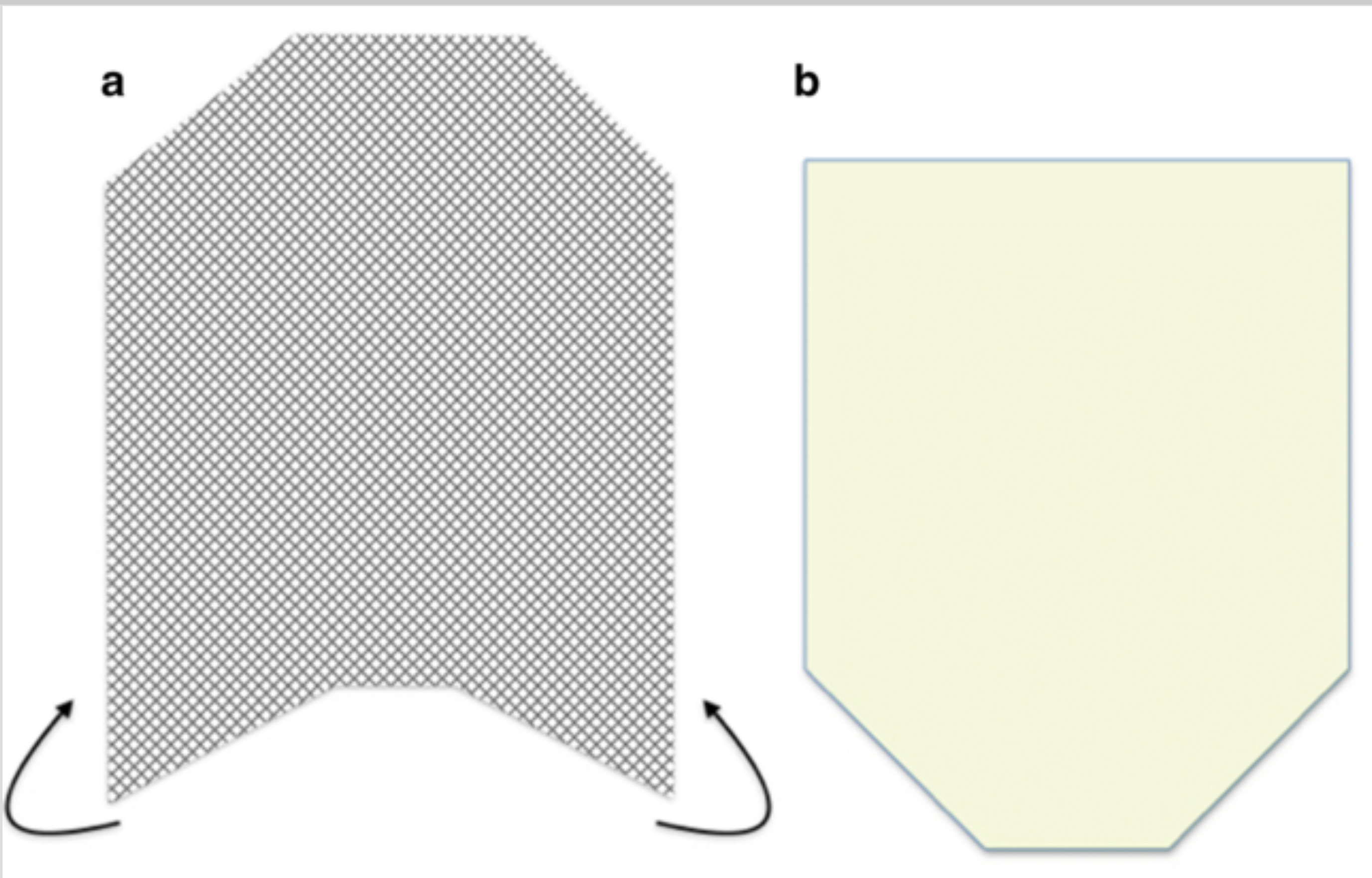
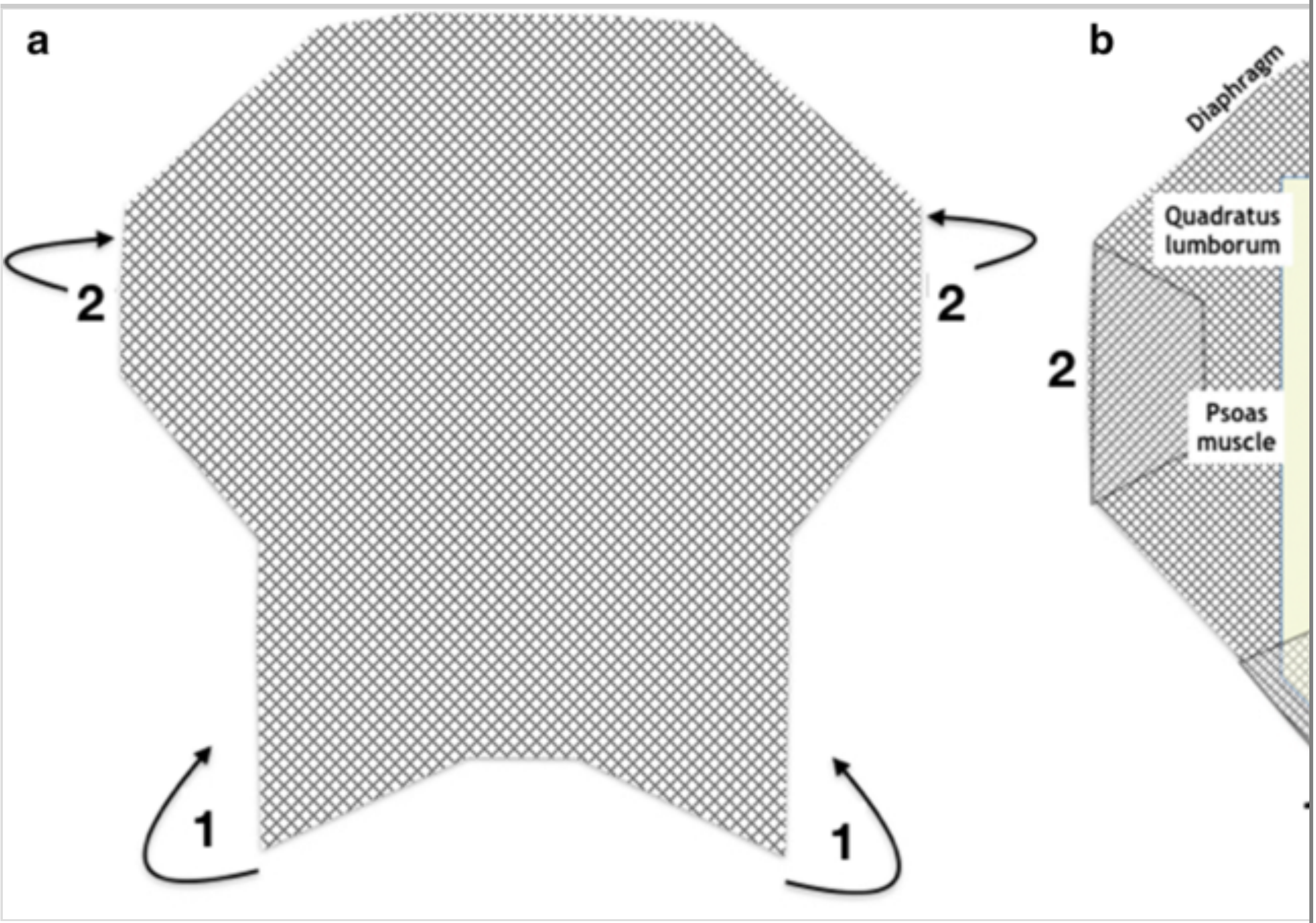


Fig. 2

a. Shape of the PM in the TAR repair in midline IH. Arrows 1 shows bending of the mesh at the retroinguinal area and arrows 2 shows bending of the mesh laterally toward the back over the psoas muscle, quadratus lumborum and diaphragm. **b** Shape of the absorbable mesh to support the 3D configuration of permanent mesh in TAR repair in midline IH



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In lateral incisional hernias (L1–L4 EHS classification), a retromuscular preperitoneal dissection was made to achieve, at least, 10 cm dissection in all directions from the limits of the defect. When this dissection could not be enough to obtain adequate overlap of 10 cm, then a TAR from lateral to medial was performed to obtain a wide preperitoneal retromuscular space. A reinforcement of AM and PM was also used in a similar way to midline IH. The AM was placed again without fixation, and the PM was secured cranially with one or two transparietal stitches in the intercostal spaces and inferiorly to iliac crest and/or Cooper’s ligaments. In most cases, the layers of lateral muscles could be closed with 2–3 rows of running sutures. A drain was also regularly placed.

Postoperative care

Patients were extubated within the next 24 h. Intradural catheters were used to control immediate postoperative pain but without following a strict protocol. Patients were discharged from the intensive care unit to the ward in 24–48 h, beginning oral intake if no clinical signs of ileus were present. Ambulation was also encouraged as soon as the patient arrived at the ward. Drains were removed when output was less than 50 mL.

Statistics

To report the results of this cohort study, we have followed current recommendations [26, 27]. Quantitative variables were expressed as mean and standard deviation, and categorical variables, as absolute numbers and percentages. The comparative analysis was performed with the Student's t test or the χ^2 test. In the logistic regression analysis, we included those factors with $p < 0.05$ in the univariate analysis. Overall recurrence as a function of time has been estimated using the Kaplan–Meier method. All statistical analysis was performed using SPSS v.18.0 (IBM Corp., Armonk, NY, USA).

Results

Our review of our prospective European database found 169 patients who met the inclusion criteria. We have operated more males than females (99/70), and mean age was 60.9. In Table 1, the demographics, comorbidities and characteristics of IH have been collected. Only three cases were operated in emergency situation. The different IH classifications that have been used are shown in Table 2. Regarding the location of IH, 80 (47.3%) were middle IH, 59 (34.9%) were lateral IH and 30 (17.8%) were midline IH associated to a lateral IH. In eight patients (4.7%), an inguinal hernia was discovered during preperitoneal dissection. In another two patients, a small lateral IH was also found, that was not previously diagnosed, probably due to drains implanted in the previous procedures.

Table 1

Patient demographics and comorbidities

Variable	Total patients ($n = 169$)
Sex	

Male	99 (58.6%)
Female	70 (41.4%)
Age, mean (range)	60.9 (32–86)
BMI, mean (range)	30.7 (20.3–46.9)
Obesity (BMI > 30)	108 (63.9%)
Comorbidities	
Smoking	61 (36.1%)
Anticoagulation	42 (24.9%)
Diabetes	52 (30.8%)
Immunosuppression	19 (11.2%)
COPD	27 (16.0%)
Hypertension	92 (54.4%)
Neoplasia	65 (38.5%)
CEDAR mean (range)	29.2 (7–90)
<30%	96 (56.8%)
30–60%	61 (36.0%)
>60%	12 (7.1%)
ASA, median	2
I	22 (13.0%)
II	94 (55.6%)
III	49 (29.0%)
IV	4 (2.4%)
Prior history of hernias	63 (37.3%)
Number of previous hernia repairs, mean (range)	2.2 (1–18)
Time of previous surgery (years), mean (range)	4.0 (0.5–25)
Cause of first surgery	
Digestive	64 (37.9%)
Urologic	33 (19.5%)

Liver-pancreatic	24 (14.2%)
Abdominal wall	21 (12.4%)
Gynecologic	12 (7.1%)
Post-traumatic	9 (5.3%)
Cardiac	3 (1.8%)
Others	3 (1.8%)

ASA, American Society of Anesthesiologists physical status classification; BMI, body mass index in kg/m^2

Table 2

Characteristics of IH

Variables	**Total patients (*n* = 169)**
EHS classification	
Medial	104 (47.3%)
M1–M3	9 (5.3%)
M1–M5	83 (49.1%)
M3–M5	12 (7.1%)
Lateral	65 (34.9%)
L1	18 (10.7%)
L3	32 (18.9%)
L4	15 (8.9%)
Slater’s classification [2]	
Grade 1	9 (5.3%)
Grade 2	52 (30.7%)
Grade 3	108 (63.9%)
VHWG classification [19]	
Grade 1	48 (28.4%)
Grade 2	85 (50.3%)

Grade 3	29 (17.2%)
Grade 4	7 (4.1%)
Wound classification	
Clean	143 (84.6%)
Clean-contaminated	11 (6.5%)
Contaminated	11 (6.5%)
Dirty	4 (2.4%)
VHSS [20]	
Grade 1	66 (39.1%)
Grade 2	77 (45.6%)
Grade 3	26 (5.4%)

VHWG, ventral hernia working group hernia classification; VHSS, ventral hernia staging system classification

Operative variables are shown in Table 3. Fourteen patients with midline IH could be solved with a Rives-Stoppa. The rest needed a posterior components separation technique. In eight patients (4.7%), the posterior layer was reconstructed with the AM, suturing the mesh as a bridge to the peritoneum. A right-extended colectomy was used only in two cases when size of the visceral content made it impossible to close the posterior layer. In 39%, the anterior layer was not completely closed with anterior rectus sheath, leaving an average bridge of 5 cm (range: 2–20) (Fig. 3). Mean time until ~~for~~ drain removal wa 10.3s ~~10,3~~ (range: 2–50).

Table 3

Operative data

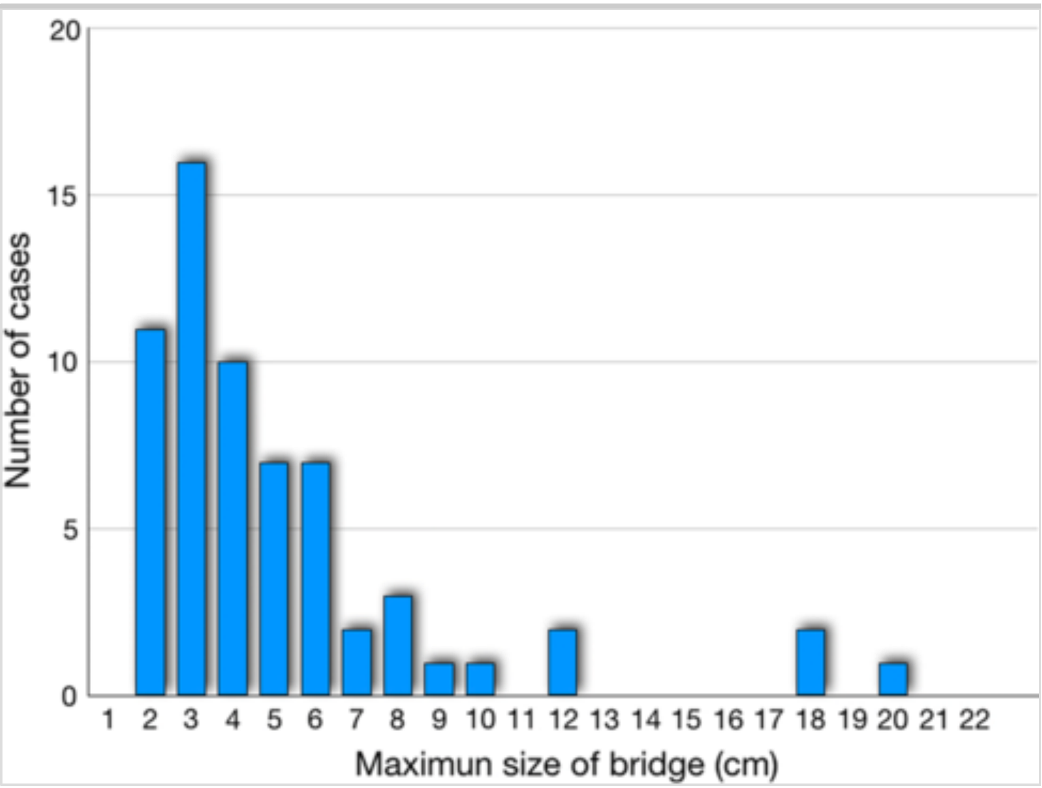
Variables	**Total patients (n = 169)**
Type of surgery	
Elective	166 (98.2%)
Emergency	3 (1.8%)
Size of defect in anterior layer	

Width, cm, mean (range)	12.7 (4–40)
Area, cm^2, mean (range)	447.3 (240–1380)
Surgical technique	
Midline	
Rives-Stoppa [23]	14 (8.3%)
Carbonell [5]	1 (0.6%)
TAR [6]	89 (52.6%)
Lateral	
Retromuscular preperitoneal [36]	16 (9.4%)
Carbonell [5]	2 (1.2%)
Reverse TAR [33]	47 (27.8%)
Bridging of posterior layer after TAR*	8 (4.7%)
Midline	5
Lateral	3
Bridging of anterior layer after TAR**	66 (39.0%)
Midline	47
Lateral	19
Diameter of bridging after TAR, median (range)	4 (2–20) cm
0–5 cm	41 (62.1%)
5–10 cm	20 (30.3%)
10 cm	5 (7.6%)
Associated surgery to the IH repair	
Resection of omentum	2 (1.2%)
Closure of bowel opening	7 (4.1%)
Intestinal resection	9 (5.3%)
Another abdominal surgery	9 (5.3%)
Panniculectomy	22 (13.0%)

Size of mesh used, cm^2	
Absorbable	555 (300–1200)
Permanent	2100 (750–3000)
Type of permanent mesh used	
Polypropylene	143 (84.6%)
PVDF	26 (15.4%)
Operative time, mean (range)	219 (65–490) min
TAR, transversus abdominis release; PVDF, polyvinylidene fluoride	
*Impossibility to completely close peritoneum and/or posterior rectus sheaths	
**Impossibility to completely close linea alba (borders of anterior rectus sheaths)	

Fig. 3

Histogram of the size of the bridge of patients in whom it was not possible to completely close the anterior rectus sheaths in the midline



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The complications observed are shown in Table 4 and classified according to Clavien–Dindo classification [28]. 60.4% of patients were discharged without any surgical-site event. 12.4% developed a SSI. There was no SSI in lateral incisional hernias. Table 5 shows the perioperative factors statistically significant in the univariate analysis. In the multivariate analysis, wound classification was an independent factor for SSI, ileus and respiratory insufficiency ($p = 0.007$, 0.016 and 0.009). VHSS classification was also an independent risk factor for seroma ($p = 0.013$) and panniculectomy for skin dehiscence (0.02).

Table 4

Postoperative complications

	***N* (%)**	**Clavien–Dindo >1**
Any complication	81 (47.9%)	
Surgical-site events		
Any surgical-site event	67 (39.6%)	
Surgical-site infection	21 (12.4%)	
Superficial	15 (8.9%)	1 IIIb
Deep	4 (2.4%)	1 IIIa
Organ/space	2 (1.2%)	2 IIIb
Hematoma	23 (13.6%)	1 IIIa, 2 IIIb
Seroma	33 (19.5%)	
Skin/wound dehiscence	17 (10.1%)	
Abdominal complications		
Paralytic ileus	13 (7.7%)	9 II
Intestinal fistula	4 (2.4%)	3 IIIa, 1 V
Intra-abdominal hypertension	2 (1.2%)	2 IVa
Systemic complications		
Urinary infection	4 (2.4%)	
Venous line infection	4 (2.4%)	

Respiratory insufficiency	8 (4.7%)	6 II, 2 IVa
Renal insufficiency	3 (1.7%)	3 II
Pneumonia	2 (1.2%)	2 II
Cardiac complications	4 (2.4%)	3 III, 1 V
DVT/PE	1 (0.5%)	1 II
Clostridium difficile sepsis	1 (0.5%)	1 V
Pain > 48 h requiring opioids	28 (16.6%)	
ICU stay	79 (46.7%)	
Mean (range)	2.4 (1–14)	
Length of hospitalization, mean (range)	8.7 (3–98)	
Mortality	3 (1.7%)	
Readmission	15 (8.9%)	

DVT/PE, deep venous thrombosis/pulmonary thromboembolism; ICU, intensive care unit

Table 5

Statistically significant perioperative variables for postoperative complications

Complication	***p***	**OR (CI)***
SSI		
Wound classification	0.001	
VHWG	0.009	
VHSS	0.018	
Seroma		
Obesity (BMI > 30)	0.004	0.45 (0.20–0.97)
VHSS	0.007	
Hematoma		
Hypertension	0.014	
Skin/wound dehiscence		

Hypertension	0.015	3.5 (1.23–1.93)
Immunosuppression	0.001	11.3 (3.67–35.37)
ASA	0.003	
Panniculectomy	0.034	3.3 (1.03–10.54)
Respiratory insufficiency		
ASA	0.003	
COPD	0.003	10.5 (2.34–47.21)
Wound classification	0.002	
CEDAR	0.01	
VHWG	0.037	
VHSS	0.001	
Neumonia		
Wound classification	0.004	
VHSS	0.004	
Postoperative ileus		
Hypertension	0.004	11.4 (1.44–89.80)
Immunosuppression	0.043	4.17 (1.14–15.21)
ASA	0.018	
Wound classification	0.001	
VHWG	0.002	
VHSS	0.007	
Cardiac complications		
ASA	0.018	

OR(CI)*, odds ratio. Confidence interval, when applicable; VHWG, ventral hernia working group classification; VHSS, ventral hernia staging system classification; ASA, American Society of Anesthesiologists; COPD, chronic obstructive pulmonary disease

Three patients died in the immediate postoperative period: 1 from sepsis due to anastomotic fistula, one from cardiac failure after emergency surgery and one from Clostridium difficile sepsis on postoperative day 3. None of the patients have developed an intraparietal hernia into the retrorectus space or preperitoneal space. Follow-up could be accomplished in the outpatient clinic in 91.7% of patients ($n = 155$). One patient was readmitted 7 weeks after surgery due to fever and abdominal pain. The CT scan revealed a localized inflammatory reaction on the right rectus muscle without collections to be drained, and the patient was discharged after 7 days of broad-spectrum antibiotic therapy.

Three patients died during surveillance from reasons not related to IH: a recurrent tumor disease, a stroke and a cardiac disease. With a mean follow-up of 26.4 months (range: 15–59), we have had identified five recurrences (3.2%): one epigastric recurrence after a Rives-Stoppa; one central recurrence in a patient that had a postoperative fistula after a TAR that drained through the wound and the mesh was partially removed in the midline to control local sepsis; two patients with a symptomatic bulging in the midline after a bridged TAR; and one patient with a symptomatic bulging after a retromuscular repair in a lumbar hernia. The timing of recurrence was between 10 and 21 months (Fig. 4). The last four patients with recurrence have already been reoperated with a new retromuscular preperitoneal approach. In these reoperations, it was not difficult to enter the space between the fibrosis over the peritoneum caused by the AM and the fibrosis infiltrating the PM (Fig. 5). The pathologic specimens taken at reoperations showed a thick band of fibrosis replacing the AM and separating it from the fibrosis of the PM (Figs. 6 and 7). After 2 years, another patient underwent an emergency surgery due to intestinal obstruction by an adhesion of small bowel to pelvis. In this reoperation, we could also check the replacement by fibrous tissue of AM and a lack of adhesions to abdominal wall.

Fig. 4

Estimated freedom of incisional hernia curve (Kaplan–Meier)

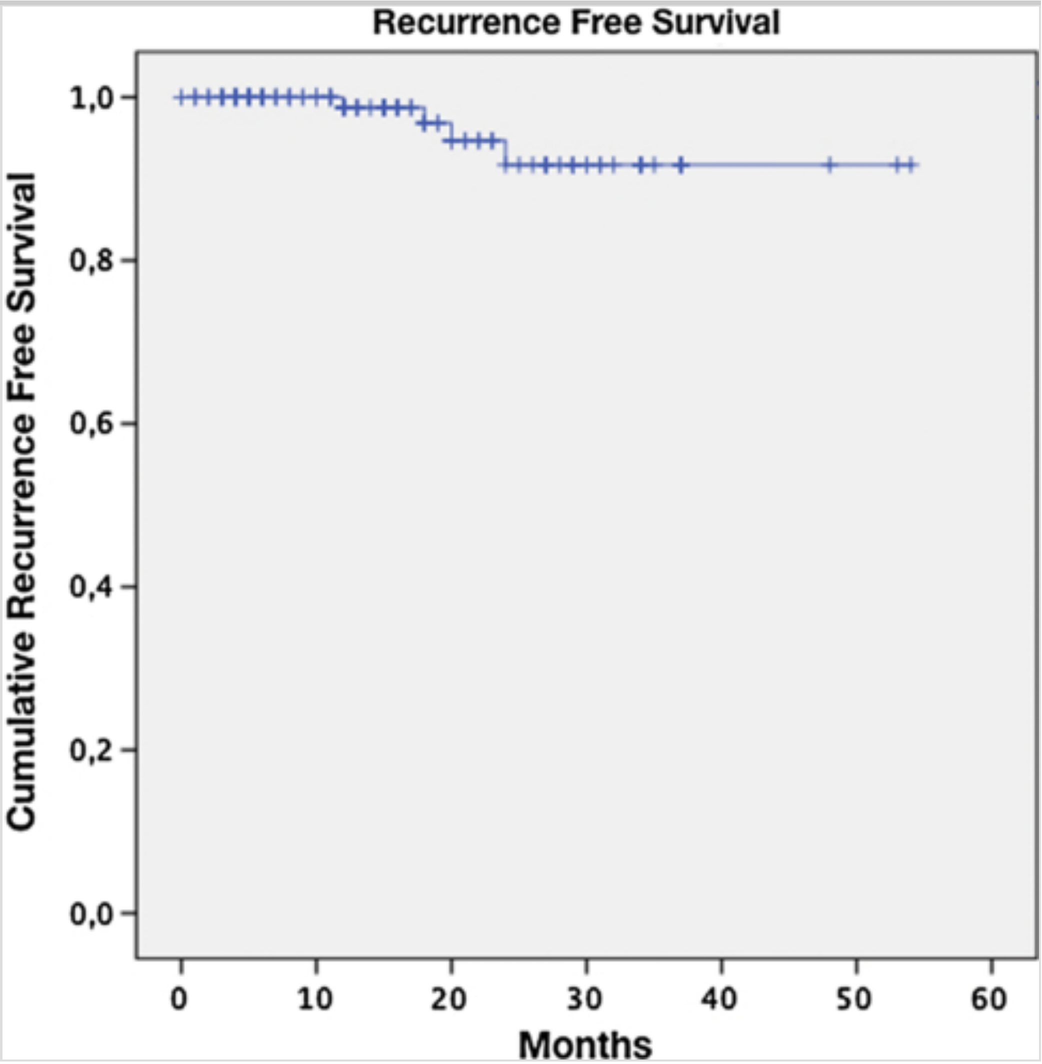


Fig. 5

Picture of the reoperation on one of the recurrent lumbar IH after the combination of absorbable and permanent mesh repair. The fibrosis infiltrating the permanent mesh (**a**) could be easily detached from the fibrosis over the peritoneum that have replaced the absorbable mesh (**b**)

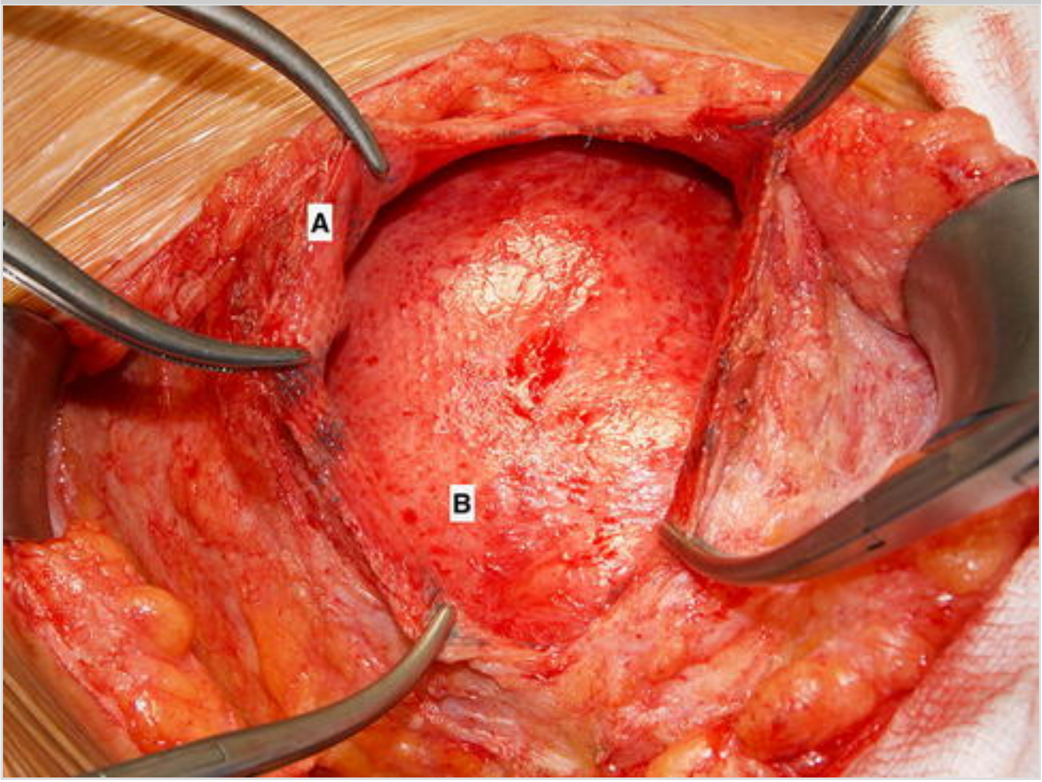


Fig. 6

Low-magnification image of representative pathologic examination of biopsy taken at reoperation of patient of Fig. 5. Layer A denotes areas where rare device remnants reside. Layer B is region of highly oriented and densely packed collagen. Layer C on the periphery is composed of loosely arranged collagen fibers. H&E stain

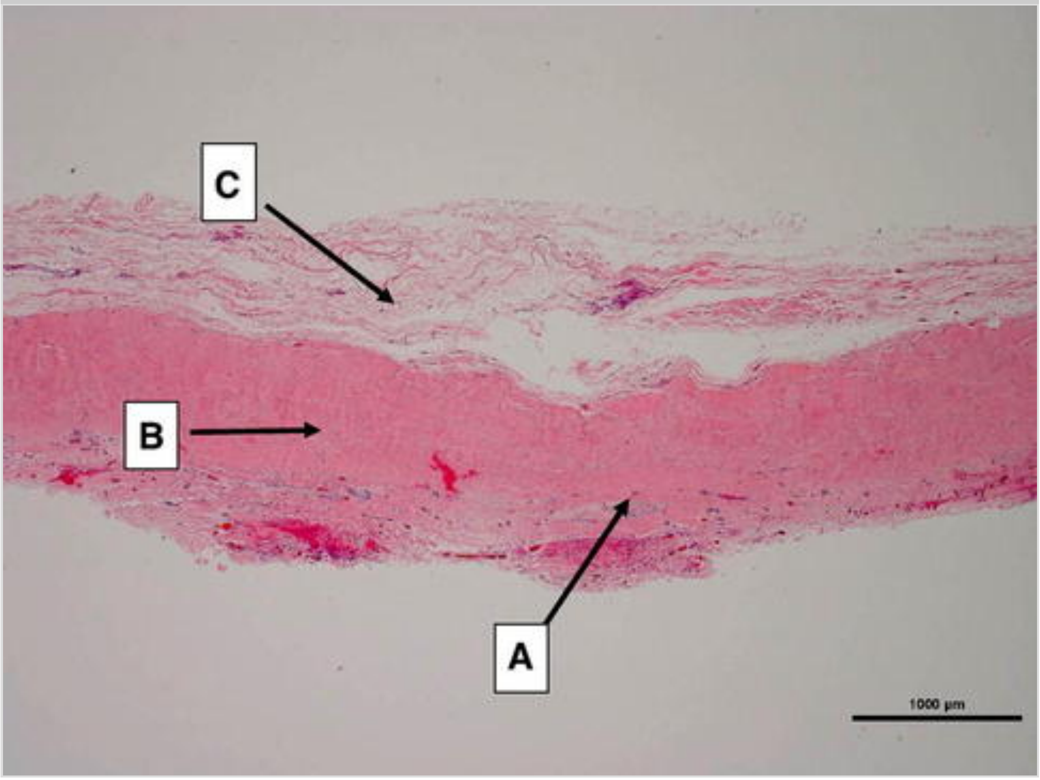
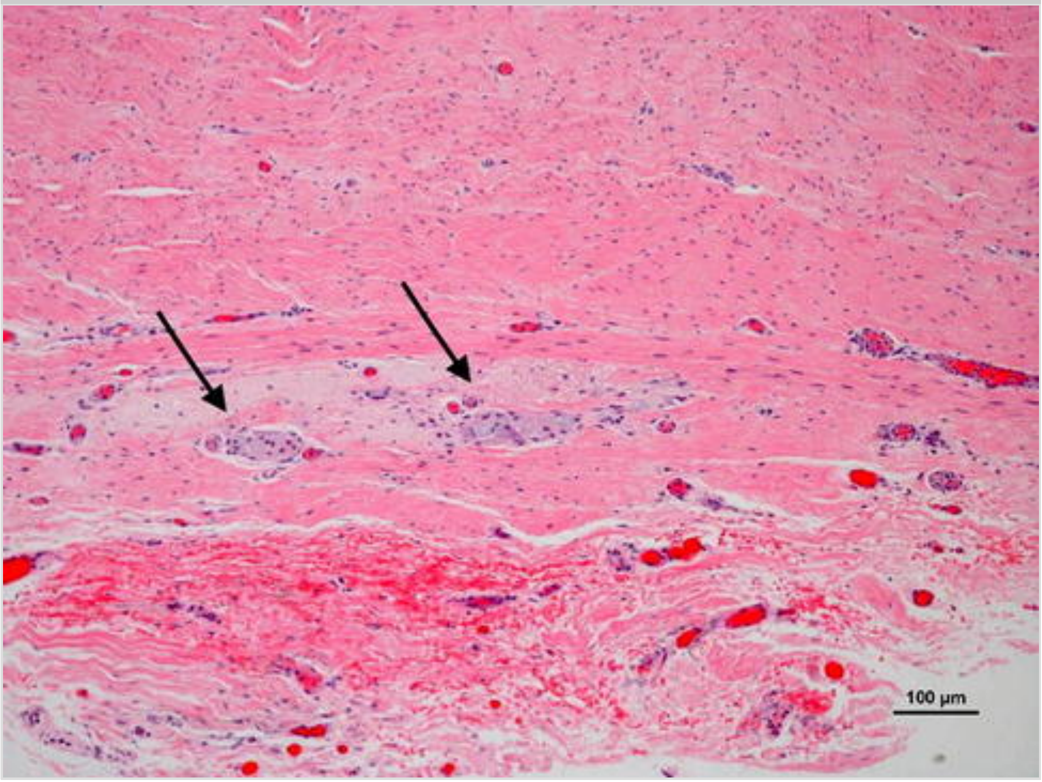


Fig. 7

High-magnification image of Fig. 6. Small number of macrophages with intracellular material (arrows) are present along the base of thick band of collagenous tissue. H&E stain



Regarding the other reported long-term complications, there are three patients with chronic pain, and four with chronic superficial seroma—two of them with reoperations after failure of conservative treatment. We have not observed any complication related to fistulae or chronic mesh infection. The only mesh that has been partially removed was that due to the postoperative fistula of anastomosis that had to be reoperated of recurrence.

Discussion

There have been several studies demonstrating that sublay mesh reinforcement after posterior components separation technique is safe and effective, with recurrence rates below 10% [9, 10, 11]. In fact, in the largest cohort study published with 428 patients, the recurrence rate was 3.7% with a mean follow-up of more than 30 months [13]. Although our follow-up is not as long, we have observed even fewer recurrences ($n = 5$) during our clinical follow-up of more than 90% of patients included. This low rate is arguably the result of the retromuscular approach with posterior components technique and the combination of meshes used as sublay reinforcement. There are two significant aspects that suggest that the combination of meshes is advantageous for AWR. First, we have not observed in our series the central mesh recurrence due to breakdown of the mesh that has been observed in other studies using low-density meshes [29]. The only central recurrence was in a patient in whom the mesh was partially removed to control local sepsis. The second aspect is that the AWR can be bridged without producing high number of recurrences; 39% of patients have been bridged in our series (Table 3), and we have only seen five recurrences up to date. The elevated rate of incomplete closure of anterior layer may be related to the detail that we strictly define as incomplete, those patients with any final gap between the true medial borders of anterior rectus sheaths or anterior aponeurosis. Those patients in which the midline is finally closed with remnant of healing tissues, previous meshes, fibrosis or sacs are also considered as bridging. In the previous studies using biologic meshes, there were more recurrences and complications in those patients who underwent a bridged repair [30, 31, 32]. We have not observed these differences, possibly due to the fact that the combination of meshes implanted achieves a durable repair that was checked in the reoperated patients (Fig. 5). However, we strongly agree with the accepted recommendation to avoid bridging whenever possible as 2 out of 5 of our recurrences were in bridged repairs.

The posterior components separation technique allows the perfect application of the principles of “giant reinforcement of the visceral sac” proposed by Stoppa [23]. As it was initially described [6], and later thoroughly explained [8], the space obtained is extended from the diaphragm to Cooper’s ligaments (craniocaudally) and from the quadratus lumborum and psoas muscles (transversely). In our experience, these principles are not only useful for midline but also for lateral defects that can be very difficult to repair due to the proximity of bones structures and the lack of aponeurosis outside the limit of the linea semilunaris. The extension of the retromuscular space between the parietal peritoneum and the muscles allows achieving a great overlap for subcostal, lumbar and iliac defects. This space can also be continued to the midline making a reverse TAR, from lateral to medial [33].

52% of patients were discharged without any complication, both wound and systemic, despite the characteristics of the patients included. Very few patients had to be reoperated under general anesthesia due to specific wound complications: two hematomas and three SSI. Interestingly, hypertension was a risk factor for hematomas in the univariate analysis. The few but severe systemic complications observed reveal the complexity of these patients that had a mean CEDAR of 29%. Although in our series CEDAR was not statistically significant associated to any specific complication, this mobile application has helped us in explaining to the patient the importance of controlling risk factors to reduce morbidity [17]. The comparative analysis demonstrated that the different classifications of complexity that have been used are valuable. In our series, the most recent VHSS predicted more postoperative complications. We agree that its simplicity may help in the stratification of morbidity [20]. Panniculectomy was associated with more skin dehiscence, confirming that adding this procedure increases the number of complications after IH open repair [34].

The use of an AM in combination with a PM was advocated in an experimental study [15]. Recently, a series of 36 patients from two different hospitals have been reported using an AM as a bridge on the posterior layer [16]. The AM used in these studies was made of short-term absorbable polyglactin. In the experimental study focused on the mesh-viscera interphase, the AM did not prevent adhesions formation but formed a thick fibrous capsule that seemed to protect the PM from the viscera. This experimental observation has been confirmed clinically in our reoperated patients, using a mid-term AM, made up of polyglycolic acid and trimethylene carbonate. We have also observed this band of fibrosis covering the peritoneum that has replaced the AM (Figs. 6 and 7). This finding also confirmed the experimental studies made on the host tissue response to this AM in which the mesh was gradually absorbed, served as tissue-building scaffold and replaced by a high-quality connective tissue [35]. No intense adhesions to the repaired abdominal wall were seen in any of the reoperated patients. This can be explained due to the placement of the AM in the retromuscular sublay position under the PM. Only in eight patients, the AM was used as a bridge to close the posterior layer, facing the viscera. In these clinical scenarios where the defect on posterior layer cannot be closed, we also agree that the combination of AM may protect the viscera from the synthetic uncoated mesh, and they are preferable to composite meshes that may produce seromas or infections [15]. Interestingly, the PM infiltrated by fibrosis could be easily peeled off from the fibrous tissue on the peritoneum, and the retromuscular space could be dissected again in these second-look operations (Fig. 5). In two cases, the peritoneum was not even opened during this repeated retromuscular dissection. We really think this is an additional advantage to use a combination of meshes in these complex situations.

Although the initial rigidity on manipulation of the AM may be awkward, we have found it very useful in locating the mesh in the sublay retromuscular preperitoneal position without any means of fixation (Video 1 and 2). It also covers the small holes in the peritoneum that are easily made during the TAR. Inferiorly, the mesh is trimmed to adapt to shape of both ileopubic tracts, allowing the 3D-configuration of the PM that was cut following the shape that Stoppa recommended [23] (Figs. 1 and 2). The rigidity of the AM acts like a cardboard and helps in extending the PM over it because, otherwise, it wrinkles and easily folds in such large dissected spaces of more than 1500 cm^2. It is also helpful in lumbar and large subcostal incisional hernias because the convexity and extension of the PM are given by the rigidity of the AM. Furthermore, ~~the~~ its 1.7~~1,7~~ mm thickness ~~of the mesh~~ allows suturing the borders of the fascial and muscular defects in case of bridging with no danger of injury to the viscera that would be only protected with a thin layer of peritoneum without this absorbable mesh [25].

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Nevertheless, our series presents important limitations. Although it is a prospective multicenter study, there is no group for comparison. So, we cannot conclude that the combination of AM with PM is better than utilizing the PM alone, although the operative findings in reoperated cases were very persuasive. While most recurrences appear before 24 months in most studies, longer follow-up is going to be necessary to confirm that any other long-term complication will not occur, like more recurrences, adhesions, fistulas or chronic infection. Finally, we have not included a quality-of-life study on our patients that would undoubtedly give more valuable results.

This multicenter series shows that the combination of AM with large PM in the same retromuscular position in AWR is safe up to a mean 2-year follow-up. The efficacy with recurrence rates below 4% in complex midline and lateral IH may be explained by the use of larger PMs placed in a retromuscular position that are shaped and extended with the support of absorbable meshes. These results are good despite the incomplete closure of the anterior layer and lack of lateral fixations of the meshes. The reoperations on patients have confirmed clinically that the AM used in this study is replaced by fibrous tissue that protects the viscera from the PM as observed in the previous experimental reports.

Compliance with ethical standards

Conflict of interest García-Urena has received speaker fees for symposium organized by Dynamesh, Braun, and Gore. Lopez-Monclús has received speaker fees for symposium organized by Gore.

Electronic supplementary material

Below is the link to the electronic supplementary material.

VIDEO 1

3D-configuration of a large PM with the support of AM after a left TAR and right Rives in a large iliac incisional hernia (MP4 55,539 kb)

VIDEO 2

Stoppa configuration and extension of a large PM after a bilateral TAR in a complex midline incisional hernia (MP4 28,417 kb)

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