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ORIGINAL ARTICLE

The results of expanded-polytetrafluoroethylene mesh repair in difficult abdominal wall defects

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KEYWORDS
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Abdominal wall defects;
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Summary *Background:* The repair of difficult abdominal wall defects (AWDs) continues to be a crucial and demanding issue for surgeons. This study aimed to present the risk factors and the long-term results of usage of an expanded-polytetrafluoroethylene (e-PTFE) synthetic mesh for the AWR of difficult abdominal wall defects.
Methods: This study included 156 adult patients who underwent difficult AWR with e-PTFE mesh for incisional hernia, ventral hernia, and created AWDs of various etiopathologies. The association between the risk factors and the postoperative complications of AWR was analyzed, and overall long-term outcomes of e-PTFE repair were assessed.
Results: The median follow-up duration was 119.1 (ranging from 2 to 206) months. In 70 (44.8%) patients, there were major co-morbidities. A surgical site infection developed in 17 (10.9%) patients. Of these, only 2 (1.3%) patients had e-PTFE mesh infection. Seven (4.4%) patients experienced recurrence. Recalcitrant seroma formation occurred in 8 (36.3%) patients.
Conclusion: E-PTFE synthetic mesh usage for difficult abdominal wall hernias can help the hernia surgeon obtain safe and durable long-term results of sound repair.

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1. Introduction

Abdominal wall hernia is a major complication with a rate of 2%–20% after abdominopelvic surgery.[1] The reconstruction of difficult abdominal wall defects (AWDs) continues to be a crucial and demanding issue for surgeons. Failure to perform a sound, durable, and dynamic abdominal wall reconstruction (AWR) in various types of musculofascial defects leads to unexpectedly high recurrence of AWDs with a lower overall success rate and increased rate of morbidity and mortality. Growing evidence has suggested that staged abdominal wall defect reconstruction, with synthetic or biologic mesh for replacement or reinforcement, is the technique of choice in both difficult primary AWDs and (multi-)recurrent, catastrophic cases complicated by severe soft-tissue loss, infected mesh protrusion, and/or entero-cutaneous (-atmospheric) fistula.[2,3] In a multicenter study, the 10-year cumulative recurrence rate was found to be 60% for sutured repairs and 32% for synthetic mesh repairs.[4] Despite the current use of different types of biomaterials and a wide array of surgical techniques for reconstruction of AWD, there is no consensus about which biomaterial is ideal in terms of versatility, compliance, and inertness and the surgical approach for complication, recurrence, and pain-free repair.[5–7] Although synthetic biomaterials used intensely for stable AWR had significantly reduced recurrence rates, they are not immune to unexpected complications such as infection, seroma formation, chronic pain, intestinal wall erosion, entero-cutaneous fistula, and intestinal obstruction.[3,8] Choosing among the currently available materials must be a decision based on individual patient needs, surgeon preference, and hospital materials contracts.

Expanded-polytetrafluoroethylene (e-PTFE) dual mesh is an inert fluorocarbon polymer. Its macroporous ventral surface contains indentations and protrusions that allow adjacent tissues to grow in and provide a higher tensile resistance. The microporous visceral surface, on the other hand, is soft, non-erosive, and resistant to infections, and it provides a safe contact with bowel segments with its adhesion-preventing property.[9–12] Many studies have reported that the usage of e-PTFE graft in AWR offer a safe, effective repair with less adhesion, entero-cutaneous fistula formation, and possibility of severe late complications.[13–17]

This study aimed to present the long-term results and the risk factors of usage of an e-PTFE synthetic mesh for the AWR of difficult abdominal wall defects.

2. Patients and methods

2.1. Patients

This study included 156 adult patients who underwent difficult AWR with e-PTFE mesh for incisional hernia, ventral hernia, and created AWDs of various etiopathologies (substantial loss of abdominal wall due to severe abdominal sepsis, carcinomatous/sarcomatous involvement, or high-velocity torso trauma) at Dokuz Eylül University Medical Faculty Hospital between October 1997 and June 2011 (Fig. 1). The study data was collected prospectively and analyzed retrospectively. Patient age, sex, body height and weight, body mass index (BMI), duration of hernia formation, co-existing disease(s) [(chronic obstructive pulmonary disease (COPD), diabetes mellitus, carcinoma, bleeding diathesis, and benign prostatic hypertrophy (BPH)], steroid use, alcohol intake, smoking, the number of previous abdominal operations and the occurrence of wound infection after these operations, history of abdominal wall blunt trauma, AWD type and diameter, and the length of preoperative hospital stay were evaluated as the patient-related factors. Choice of antibiotic prophylaxis, surgical expertise (performance of the operation by a surgeon specialized in herniology), the incisional length, the presence of incarceration and/or strangulation, biomaterial surface area, type of mesh stabilization, plane of mesh placement, operative time, and drain usage were all evaluated as the surgical procedural factors. The length of postoperative hospital stay and follow-up time were recorded as the associated risk factors affecting the final outcome for the patient. The relationship between all these factors and the postoperative complications of AWR, including pain, abdominal discomfort, seroma, surgical site infection, recurrence rate, hematoma, and mesh rejection, was analyzed and the risk factors related to these complications were assessed.

Using the Wuerzburg classification described by Dietz et al, we made a risk factor scoring scale of the patients. The association between these defined risk factors and the occurrence of the complications was estimated (Table 1).[18]

Postoperative wound infection was defined as reddening of and purulent discharge from the wound site.[8,19] Superficial wound infections were confined to skin and subcutaneous tissue, whereas deep wound infections affected fascia and generally required biomaterial removal.

Seroma was defined as fluid accumulation severe enough at the operation site to require percutaneous drainage or aspiration after drain removal.[8]

Chronic pain was defined as a discomfort that limits a patient's daily activities.[8] Pain was evaluated according to the Visual Analog Pain Score.

2.2. Surgical technique

All patients underwent an open repair under intratracheal general anesthesia. As an antibiotic prophylaxis, 118 (75.6%) patients received a single dose of IV cefazolin sodium (Cefamezin® 1 g vial, Eczacıbaşı Drug Industries, Istanbul, Turkey) at a dose of 1 g, and 34 (21.8%) took a single dose of IV sultamicillin (Duocid® 500 mg vial, Pfizer Drug Ltd Co., Istanbul, Turkey) at a dose of 1 g during anesthesia induction. Both antibiotics were re-administered at the same doses when the operation time exceeded 4 h. Four (2.5%) patients with penicillin allergy received IV vancomycin (Vancocin CP® 500 mg vial, Lilly Drug Trade Ltd Co., Istanbul, Turkey). Fifteen (9.6%) patients diagnosed with an incarcerated bowel segment during the operation and 5 (3.2%) patients with bowel strangulation were also administered IV metronidazole (Flagyl® 500 mg/100 mL suspension, Eczacıbaşı Drug Industries, Istanbul, Turkey) infusion. For the prophylaxis of deep vein thrombosis, the patients had compression

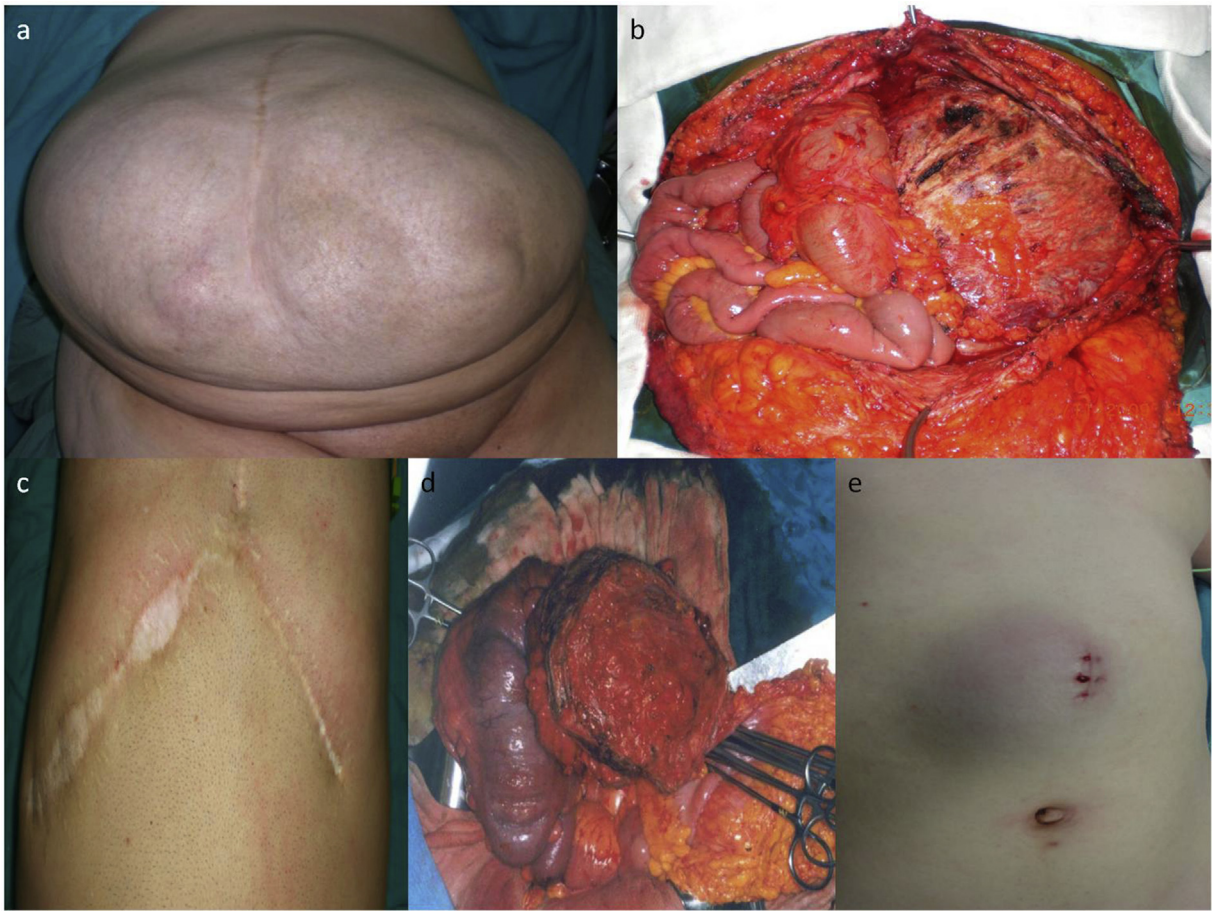

Figure 1 a. Primary giant difficult incisional abdominal wall hernia. b. Recurrent complex abdominal wall hernia. c. Complex abdominal wall hernia after liver transplantation. d. Locally advanced primary right colonic carcinoma infiltrated to the abdominal wall. e. Biopsy-proved primary abdominal wall rhabdomyosarcoma.

stockings applied at the preoperative period and given low molecular—weight heparin (Enoxparin sodyum, Clexane® injectable vials, Aventis Pharma, Istanbul, Turkey) after the postoperative 8th hour.

Table 1 Wuerzburg classification risk factors[18].

Risk factors
Age > 45 years
Male gender
Underlying disease[a]
BMI > 25 kg/m^2
Postoperative complications
>2 Laparotomies last year
Nicotine abuse
2nd Laparotomy/month
Wound contamination
Anaemia

[a] Tumors, chronic obstructive pulmonary disease, diabetes mellitus, coronary heart disease, aortic anoyrism, collagen metabolism disorders (Marfan's syndrome, Ehlers-Danlos' syndrome, osteogenesis imperfecta, etc.

After skin antisepsis with 10% povidone iodine (Poviseptin® solution, Mertsel Drug Industries, Izmir, Turkey), skin incision was done. In cases with incisional hernia, the previous skin incision scar was removed. In ventral and incisional hernias, the hernia sac was dissected with blunt and sharp dissections, and the musculofascial defect was exposed. The hernia sac was opened to enter the peritoneal cavity. Adhesiolysis by sharp dissection was carried out as indicated. Bowel resection and anastomosis (±partial omentectomy) was performed in cases with clear-cut strangulation. Patients with bowel incarceration having tissue viability did not require bowel resection. Then, the size of the abdominal wall defect was measured and an appropriately sized e-PTFE (Gore-Tex Dual Mesh®, W. L. Gore and Associates, Inc., Flagstaff, Arizona, USA) mesh was placed beneath the fascia in 147 (94.2%) patients and over the fascia in 9 (5.8%) patients with a technique of application 6 cm distant from each fascial border in a tension-free fashion with an e-PTFE suture material (Gore-Tex THX CV0® suture, W. L. Gore and Associates, Inc., Flagstaff, Arizona, USA) placed in a continuous or an interrupted suture pattern depending on surgeon's discretion. Occasionally, if it is possible, the remnant part of the hernial sac that was intuitively preserved during surgical

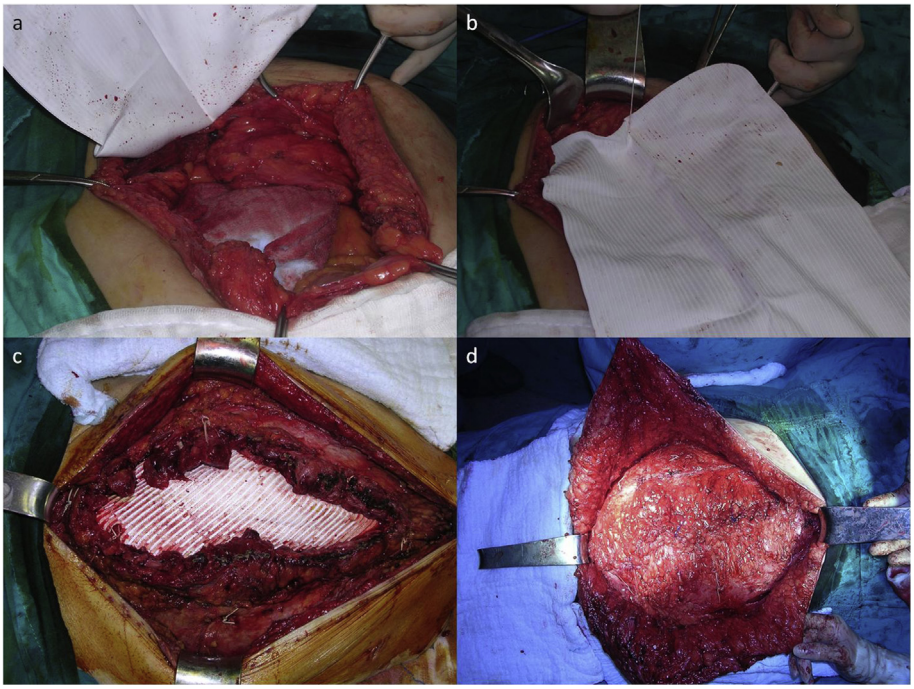

Figure 2 a. Implantation and fixation of e-PTFE mesh under the fascia. b. Securing the mesh with CV-0 e-PTFE sutures through the whole fascial borders. c. Application of e-PTFE to the abdominal wall defect for a sound and durable repair. d. Primary anatomic fascial closure by using partial component separation technique.

dissection as a native covering flap was folded onto the mesh. The modified component separation technique was used to reduce the size of the hernia defect in 6 (3.8%) patients (Figs. 2 and 3). After placing suction drains [Smooth Silicone Flat Drain® (Jackson—Pratt drain), 4a Medical Product Industries, Ankara, Turkey] under the subcutaneous tissue over the e-PTFE mesh, the subcutaneous tissue and skin were closed. The e-PTFE grafts were similarly used for bridging abdominal wall defects during the multivisceral extended oncoplastic radical resections performed for treatment of complex intra-abdominal malignant tumors invading the abdominal wall and with failed primary abdominal wall repairs due to a plethora of pathologies. In other groups of cases with a significant abdominal wall loss and/or increased intra-abdominal pressure rendering the primary closure impossible, it was mandatory to bridge the difficult defect with an e-PTFE biomaterial (semi-open abdomen technique). Rarely, the skin was closed at a later stage in such conditions.[20]

Thromboemboli prophylaxis was continued with low molecular—weight heparin therapy (Enoxaparine sodium, Clexane injectable vial®, Aventis Pharma Industry and Trade Ltd. Co, Mecidiyekoy, Istanbul, Turkey) at the post-operative period until the time of discharge.

The patients' recovery was monitored by physical examination at the clinic ward during the first month after the surgery. Patients were evaluated in terms of surgical outcomes, particularly for recurrences and complications, every third month for the subsequent first year, and every six months for the next years. No patients were lost to the follow-up except those who died.

2.3. Statistical analysis

Statistical analyses were performed using SPSS software version 15.0 for Windows (SPSS, Chicago, Illinois. United States). Data are expressed as the mean $\pm$ SD; median and range values are provided when appropriate. Quantitative variables were compared using the student *t*-test and Mann—Whitney *U* test. Comparison between groups with regard to qualitative variables was performed using the chi-square test and Fisher's exact test. The hernia recurrence rate was calculated using Kaplan—Meier estimates, with comparisons made using the log rank test. $P < 0.05$ was considered statistically significant.

3. Results

One hundred and eight (69.2%) of the patients were women, and 48 (30.8%) were men. The median age was 59.5 (ranging from 19 to 83) years. Abdominal wall reconstructions were performed for primary or recurrent incisional hernia in 129 (82.7%) patients, for abdominal wall loss due to different clinical situations in 16 (10.3%) patients, and ventral hernia in 11 (7%) patients. Nine (56.3%) of the abdominal wall loss repairs were performed in patients with foreseen intra-abdominal acute/subacute compartmental syndrome such as blunt abdominal trauma, acute mesenteric ischemia, and severe necrotizing pancreatitis, and 7 (43.7%) of them were abdominal wall reconstructions in patients requiring extended *en block* abdominal wall resection for treatment of the primary, locally advanced intraabdominal/retroperitoneal malignancies.

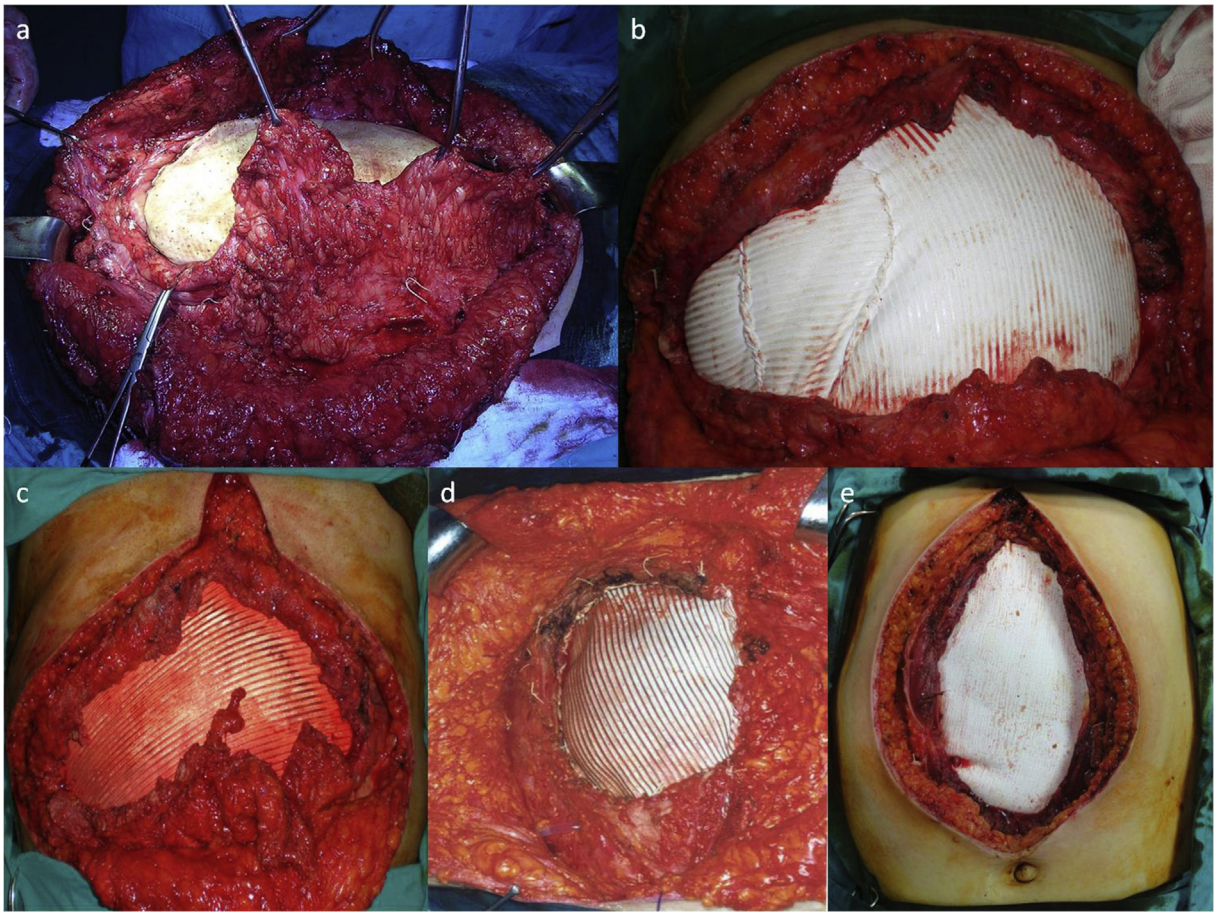

Figure 3 a—e:E-PTFE synthetic mesh repair depictions of various types of difficult abdominal wall defects.

The median follow-up duration was 119.1 (ranging from 2 to 206) months. It was 117.9 (ranging from 2.2 to 206.1) months for incisional hernias, 122.3 (ranging from 2.1 to 188.1) months for created abdominal wall losses, and 119.4 (ranging from 52.7 to 184.6) months for umbilical hernias.

The clinicopathologic features of the patients are presented in Table 2.

The univariate and multivariate analyses of the clinicopathologic characteristics and the complications were presented in Table 3 and Table 4, respectively.

3.1. Recurrence

Seven (4.4%) patients experienced recurrence (Fig. 4a). For the overall study population, the recurrence risk at 1, 3, 5, and 10 years were 0.7%, 2%, 3.4%, and 3.4%, respectively (Fig. 5). There were no significant differences among incisional hernias, abdominal wall defects, and umbilical hernias with respect to recurrence rates (Log-rank, $p = 0.480$) (Fig. 6). In univariate analysis, an incisional length greater than 19.49 cm ($p = 0.010$), a defect diameter greater than 14.54 cm ($p = 0.026$), an operation time greater than 160 min ($p = 0.004$), and a duration of hospital stay greater than 13.7 days ($p = 0.037$) were associated with recurrence. A multivariate analysis revealed that only an operation time greater than 160 min significantly predicted recurrence (OR 1.012, 95% CI 1.004—1.019; $p = 0.001$).

3.2. Infection

A surgical site infection developed in 17 (10.9%) patients (Fig. 4b and c). Of these, 10 (7.75%) had incisional hernia, four (25.0%) had created AWD, and three (27.7%) had umbilical hernia. Three (17.7%) patients had open abdomens. Six (35.2%) patients had a BMI greater than 30; six (35.2%) patients had a history of malignancy; one (5.9%) patient had AWD due to acute abdominal compartment syndrome following intraabdominal massive bleeding after liver transplantation. Two (11.8%) patients had simultaneous subcutaneous hematoma, five (29.4%) had resistant seroma, two (11.8%) had small-bowel incarceration, and two (11.8%) had small-bowel strangulation. Fifteen (88.3%) patients developed superficial surgical site infection within 5 days of surgery. Of these, eight (47.0%) improved only with antibiotics, others required intense wound care and dressings in addition to antibiotherapy. Fourteen (82.3%) patients had a single-species proliferation in bacterial culture [*Escherichia coli*: 10 (58.8%) patients, *Staphylococcus aureus*: 2 (11.8%) patients, *Staphylococcus epidermidis*: 2 (11.8%) patients], and 2 (11.8%) had dual-species proliferation (*Escherichia coli* and *Acinetobacter* spp.). Of those who had more than single proliferation in bacterial culture, one was for open abdomen in liver transplantation and the other was for trauma. These patients died of uncontrolled sepsis in the postoperative third and second months, respectively. One (5.9%) patient had no culture positivity.

Table 2 According to the hernia type, preoperative, operative and postoperative data.

	Incisional hernia (n = 129)	Abdominal wall defect (n = 16)	Ventral hernia (n = 11)
Gender			
M/F[a] n (%)	38/91 (29.5/70.5)	7/9 (43.8/56,1)	3/8 (27.3/72.7)
Age (Mean ± SD[b])	58.14 ± 12.78	56.19 ± 15.98	61.27 ± 10.27
BMI (kg/m^2) Mean ± SD	28.46 ± 5.27	27.13 ± 4.92	31.77 ± 8.24
BMI ≥ 30 kg/m^2 n (%)	49 (38)	4 (25)	6 (54.5)
Co-morbid conditions n (%)			
COPD[c]	18 (14)	–	3 (27.3)
Diabetes mellitus	19 (14.7)	2 (12.5)	2 (18.2)
Connective tissue disease	5 (3.9)	–	1 (9.1)
Cancer	25 (19.4)	8 (50)	1 (9.1)
Benign prostatic hypertrophy	6 (11.5)	1 (12.5)	–
Hemorrhagic diathesis	10 (7.8)	2 (12.5)	–
Chronic systemic steroid use	8 (6.2)	2 (12.5)	–
Liver transplantation n (%)	7 (0.5)	1 (6.25)	–
Smoking n (%)	22 (17.1)	3 (18.8)	2 (18.2)
Alcohol use n (%)	11 (8.5)	3 (18.8)	2 (18.2)
Previous SSI[d] n (%)	25 (19.4)	–	–
Wuerzburg score			
0–2 n (%)	60 (46.5)	3 (18.8)	4 (36.4)
≥3 n (%)	69 (53.5)	13 (81.3)	7 (63.6)
Mean ± SD	2.73 ± 1.10	3.06 ± 0.93	3.00 ± 1.34
Presentation time of IH[e] after first operation Mean ± SD (months)	16.63 ± 22.50	–	–
Number of previous IH repair n (%)			
0	42 (32.6)	–	–
1	46 (35.7)		
2	23 (17.8)		
3	9 (7)		
4	5 (3.9)		
5	3 (2.3)		
7	1 (0.8)		
Preoperative hospital stay, Mean ± SD (day)	2.72 ± 3.67	11.75 ± 27.41	1.36 ± 1.91
Emergency operation n (%)	14 (10.9)	7 (43.8)	1 (9.1)
Length of incision Mean ± SD (cm)	20.22 ± 7.67	22.94 ± 7.08	6.00 ± 7.25
Defect diameter Mean ± SD (cm)	15.11 ± 6.99	14.44 ± 6.34	8.09 ± 4.36
Expertise of the surgeon n (%)			
General surgeon	27 (20.9)	4 (25.0)	2 (18.2)
Consultant	102 (79.1)	12 (75.0)	9 (81.8)
Mesh size Mean ± SD (cm^2)	391.50 ± 238.22	299.50 ± 159.09	143.91 ± 108.38
Mesh plane n (%)			
Inlay	122 (94.6)	16 (100)	9 (81.8)
Onlay	7 (5.4)	–	2 (18.2)
Mesh fixation technique			
Continue n (%)	87 (67.4)	10 (62.5)	6 (54.5)
Interrupted n (%)	42 (32.6)	6 (37.5)	5(45.5))
Incarceration n (%)	11 (8.5)	1 (6.3)	3 (27.3)
Strangulation n (%)	4 (3.1)	–	1 (9.1)
Postoperative hospital stay, Mean ± SD (day)	11.82 ± 15.05	32.50 ± 43.39	7.91 ± 4.80
Follow-up time, Mean ± SD (month)	117.97 ± 51.96	112.53 ± 62.98	122.63 ± 55.25

[a] M/F: Male/Female.
[b] SD: Standard deviation, BMI: Body mass index.
[c] COPD: Chronic obstructive pulmonary disease.
[d] SSI: Surgical site infection.
[e] IH: Incisional hernia.

Table 3 Univariate analysis of preoperative, operative and postoperative data, according to the postoperative complications.

	Infection		Hematoma		Seroma		Pain		Rejection		Recurrence	
	n (%)	*p*	n (%)	*p*	n (%)	*p*	n (%)	*p*	n (%)	*p*	n (%)	*p*
Gender												
Male n (%)	8 (16.7)	0.123	2 (4.2)	0.587	8 (16.7)	0.540	13 (27.1)	0.065	1 (2.1)	–	2 (4.2)	–
Female n (%)	9 (8.3)		2 (1.9)		14 (13)		46 (42.6)		2 (1.9)		5 (4.6)	
Age (Mean ± SD[a])		0.950		0.114		0.094		0.814		0.519		0.877
Weight (kg)		0.647		0.185		0.367		0.970		0469		0.348
Length (cm)		0.089		0.609		**0.008**		0.862		0.851		0.455
BMI[b] ≥30 kg/m^2	6 (10.2)	0.820	–	0.298	8 (13.6)	0.879	20 (33.9)	0.431	1 (1.7)	–	5 (8.5)	0.105
Co-morbid conditions												
COPD[c]	3 (14.3)	0.704	–	–	3 (14.3)	–	7 (33.3)	0.649	1 (4.8)	0.354	1 (4.8)	–
Diabetes mellitus	6 (26.1)	0.022	–	–	2 (8.7)	0.534	11 (47.8)	0.284	–	–	–	0.595
Connective tissue disease	–	–	–	–	–	0596	–	0.084	–	–	1 (16.7)	0.244
Cancer	6 (17.6)	0.209	–	0.577	6 (17.6)	0.578	12 (35.3)	0.731	2 (5.9)	0.120	2 (5.9)	0.647
BPH[d]	1 (14.3)	0.8856	–	–	1 (14.3)	–	2 (26.8)	0.998	1 (14.3)	–	1 (14.3)	–
Hemorrhagic diathesis	2 (16.7)	0.622	2 (16.7)	0.030	1 (8.3)	–	3 (25)	0.537	1 (8.3)	0.215	1 (8.3)	0.436
Chronic steroid use	1 (10)	–	2 (20)	0.021	1 (10)	–	1 (10)	0.091	–	–	2 (20)	0.066
Smoking	4 (14.8)	0.498	–	–	6 (22.2)	0.222	8 (29.6)	0.334	2 (7.4)	0.078	2 (7.4)	0.349
Alcohol use	4 (25)	0.077	–	–	2 (12.5)	–	3 (18.8)	0.097	1 (6.3)	0.279	2 (12.5)	0.153
Previous abdominal trauma	1 (25)	0.373	–	–	2 (50)	0.096	1 (25)	–	–	–	–	–
Previous surgical site infection	6 (20.7)	0.092	1 (3.4)	0.565	6 (20.7)	0.250	15 (51.7)	0.087	2 (6.9)	0.089	2 (6.9)	0.615
Wuerzburg score												
0–2 n (%)	1 (1.5)	0.001	1 (1.5)	0.635	6 (9)	0.109	29 (43.3)	0.222	–	0.260	2 (3)	0.699
≥3 n (%)	16 (18)		1 (3.4)		16 (18)		30 (33.7)		3 (3.4)		5 (5.6)	
Wuerzburg score		0.000		0.861		0.030		0.360		0.058		0.277
Presentation time of incisional hernia after first operation		0.770		0.672		0.546		0.342		0.232		0.025
Number of the incisional hernia repair		0.632		0.583		0.316		0.079		0.620		0.978
Preoperative hospital stay, Mean ± SD (day)		0.196		0.506		0.591		0.275		0.231		0.044
Emergency operation	4 (18.2)	0.265	2 (9.1)	0.096	3 (13.6)	–	8 (36.4)	0.879	–	–	1 (4.5)	–
Defect type												
Incisional hernia	10 (7.8)	–	2 (1.6)	–	18 (14)	–	54 (41.9)	0.056	3 (2.3)	–	7 (5.4)	–
Abdominal wall defect	4 (25)		2 (12.5)		1 (9.1)		2 (12.5)		–		–	
Umbilical hernia	3 (27.3)		–		3(18.8		3 (27.3)		–		–	
Length of incision Mean ± SD (cm)		0.041		0.392		0.849		0.625		0.248		0.010
Defect diameter Mean ± SD (cm)		0.057		0.059		0.737		0.319		0.341		0.026

(*continued on next page*)

Table 3 (*continued*)

	Infection		Hematoma		Seroma		Pain		Rejection		Recurrence	
	n (%)	*p*	n (%)	*p*	n (%)	*p*	n (%)	*p*	n (%)	*p*	n (%)	*p*
Expertisel of the surgeon												
General surgeon (n = 33)	0	0.024	0	0.579	3 (9.1)	0.573	7 (21.2)	0.027	0	1.000	1 (3)	1.000
Consultant (n = 123)	17 (13.8)		4 (3.3)		19 (15.4)		52 (42.3)		3 (2.4)		6 (4.9)	
Mesh size Mean ± SD (cm^2)		0.091		0.339		0.439		0,784		0.316		0.034
Mesh plane												
Inlay	16 (10.9)	1.000	4 (2.7)	1.000	21 (14.3)	1.000	56 (38.1)	1.000	3 (2)	1.000	7 (4.8)	1.000
Onlay	1 (11.1)		0		1 (11.1)		3 (33.3)		0		0	
Mesh fixation technique												
Continue	13 (12.6)	0.335	3 (2.9)	1.000	18 (17.5)	0.092	37 (35.9)	0.496	3 (2.9)	0.551	6 (5.8)	0.424
Interrupted	4 (7.5)		1 (1.9)		4 (7.5)		22 (41.5)		0		1 (1.9)	
Incarceration (+)	2 (13.3)	0.669	–	–	0	0.131	7 (46.7)	0.457	–	–	–	–
Strangulation (+)	2 (40)	0.092	–	–	–	–	2 (40)	1.000	–	–	–	–
Drain use		0.611		1.000		0.365		0.536		–		0.078
Drain (−)	0		–		0		3 (27.3)		–		2 (18.2)	
Drain (+)	17 (11.7)		4 (2.8)		22 (15.2)		56 (38.6)		3 (2.1)		5 (3.4)	
Open abdomen (n = 9)	4 (44.4)	0.009	1 (11.1)	0.213	4 (44.4)[e]	0.024	2 (22.2)	0.484	–	–	1 (11.1)	0.346
Operation time (min)		0.185		0.656		0.850		0.276		0.354		0.004
Postoperative hospital stay, Mean ± SD (day)		0.000		0.465		0.004		0.829		0.103		0.037

[a] SD: Standard deviation.
[b] BMI: Body mass index.
[c] COPD: Chronic obstructive pulmonary disease.
[d] BPH: Benign prostatic hypertrophy.
[e] After closure of the open abdomen.

Table 4 Multivariate analysis of preoperative, operative and postoperative data, according to the postoperative complications.

Variables	OR	95% CI	*p*
Infection			
Wuerzburg score ≥ 3	3.832	1.771–8.296	0.001
Recurrence			
Operation time > 160 min	1.012	1.004–1.019	0.001

Two (11.8%) of the patients who developed wound infection required biomaterial removal on the second and fifth months, owing to untreatable infection. The infectious agent was *Escherichia coli* in both patients. They were treated with dedicated open-wound dressings and care after biomaterial removal, and the defect was primarily closed after sufficient granulation tissue developed. One of these patients developed perforated small-bowel strangulation in the recurrent hernia defect 13 years after the primary operation, and she was operated on for small-bowel resection and open-abdomen approach. However, she died of sepsis 2 months after the reoperation. The other patient died due to subarachnoid hemorrhage 2 years after the initial operation.

In univariate analysis, diabetes mellitus ($p = 0.02$), the modified Wuerzburg score of 3 or greater ($p = 0.001$), an incisional length greater than 19.5 cm ($p = 0.04$), a defect diameter greater than 14.5 cm ($p = 0.05$), the level of the expertise of the surgical team ($p = 0.02$), and the presence of open abdomen ($p = 0.01$) were significant factors of infection. The duration of hospital stay was significantly longer for patients who developed infection than for patients who did not (48 vs. 9 days) ($p = 0.001$).

The multivariate analysis showed that only the modified Wuerzburg score of 3 or greater was a robust predictive factor for infection development (OR 3.832, 95% CI 1.771–8.296; $p = 0.001$) (Table 4).

3.3. Hematoma

Four (2.7%) patients developed wound hematoma. Of these, two had a hemorrhagic diathesis due to warfarin use. The other patients had a history of chronic steroid use and had previously undergone liver transplantation. A superficial surgical site infection developed in one patient, seroma in one, and both seroma and superficial field infection in one. None of them required an additional intervention. Antibiotic therapy was applied to the patient who had infection. The univariate analysis revealed that hemorrhagic diathesis ($p = 0.030$) and chronic steroid use ($p = 0.021$) were significant predictors of subcutaneous hematoma development. A multivariate analysis failed to detect any significant factor for this complication.

3.4. Seroma

Twenty-two (14.1%) patients developed seroma (Fig. 4d). Fourteen (63.6%) of them required no intervention. In eight (36.3%) patients, seroma was percutaneously drained under ultrasonic guidance. Of these eight patients, six underwent repeated (2–3 times) drainage procedures. Four of six patients undergoing repetitive drainage procedures developed surgical site infection, but just one of the patients undergoing a single drainage procedure developed the same complication. The

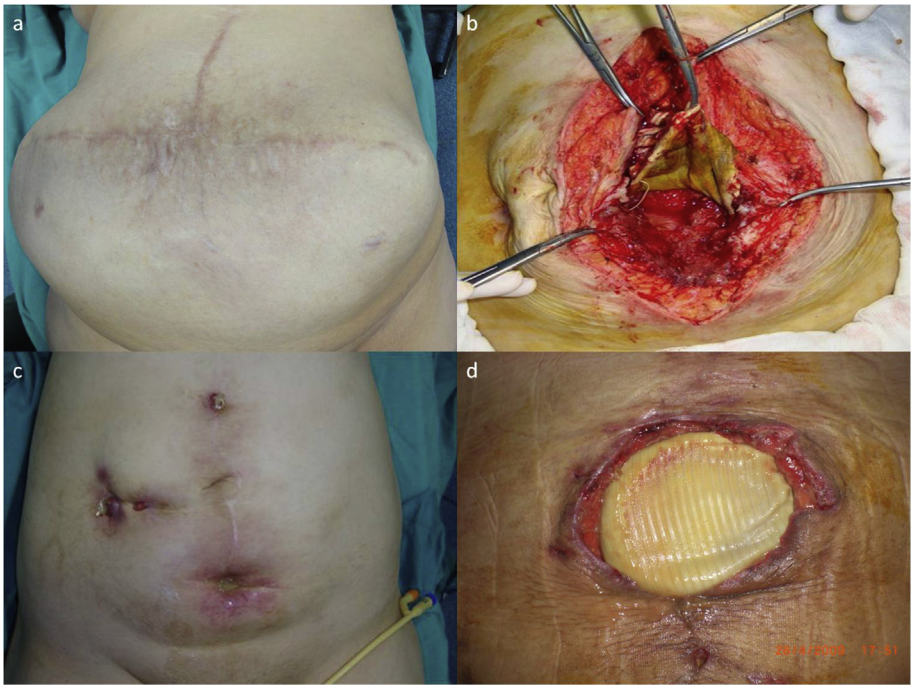

Figure 4 a. Hernia recurrence after e-PTFE repair. b. Infected e-PTFE synthetic mesh. c. Fistula formation after usage of e-PTFE in the repair. d. Exposure of e-PTFE due to recalcitrant seroma formation.

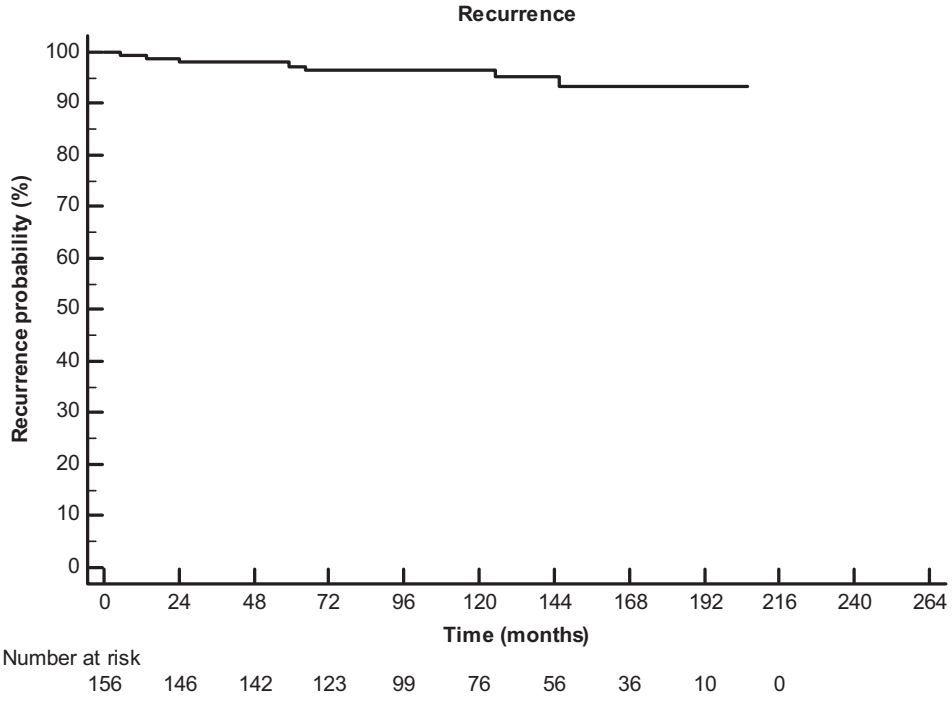

Figure 5 Recurrence rate for all of the study population.

synthetic mesh had to be removed in only one of these patients who developed infection. A univariate analysis revealed that patients' length of incision greater than 163 cm ($p = 0.008$), a Wuerzburg score greater than 2.78 ($p = 0.030$), and mesh coverage or containment for open abdomen (after skin closure) ($p = 0.024$) were significant predictors for seroma complication. A multivariate analysis revealed no significant variables to predict seroma development. The length of hospital stay was significantly greater for the patients who developed seroma than for those who did not ($p = 0.004$).

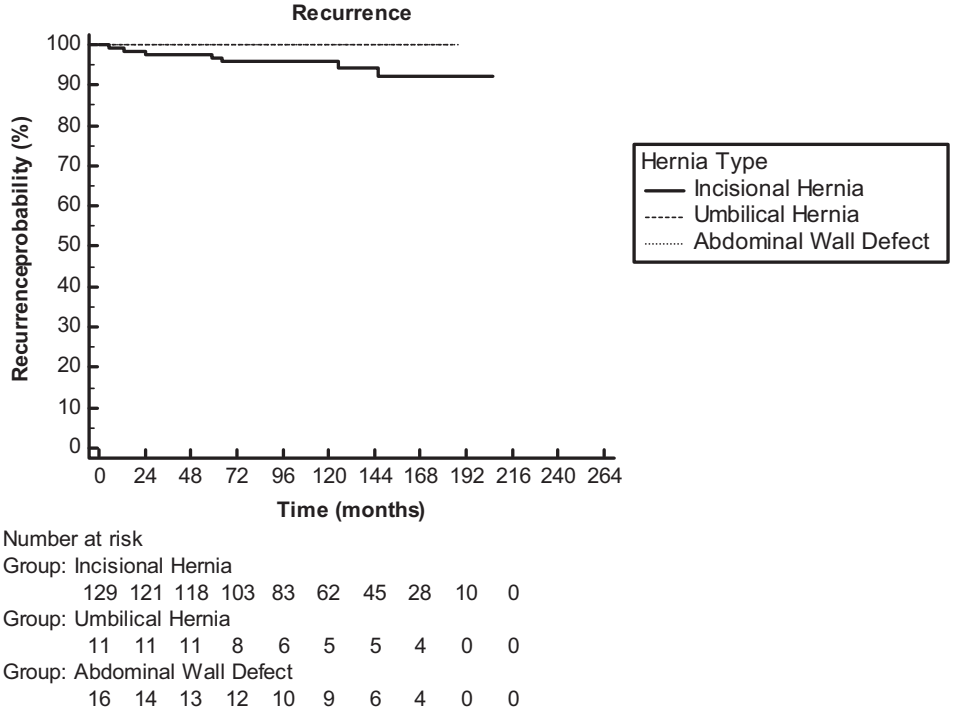

Figure 6 Recurrence rate according to hernia type.

3.5. Pain

During follow-up, 59 (37.8%) patients had chronic pain in varying levels that did not affect daily activities and/or quality of life. A univariate analysis showed that more patients had pain when the operations were carried out by surgeons experienced for hernia repair ($p = 0.027$). On multivariate analysis, no variable was estimated to be a significant predictor of pain.

3.6. Mesh rejection

Three (1.9%) patients had mesh rejection. One of them had both seroma and superficial surgical site infection (SSI), and the other had only superficial SSI.

3.7. Strangulated cases

Intestinal strangulation was detected in 5 (3.2%) patients. Four (80%) patients had incisional and 1 (20%) patient had umbilical hernia. All of these patients were female and mean age was 62.6 (range, 53—73) years. Of these, two patients had both COPD and diabetes mellitus, 1 patient had COPD only. Body mass index was over 30 in 3 patients. Average Wuerzburg score was 3.6. Mean fascial defect diameter was 20.8 (range, 8—35) cm. Bowel resection and anastomosis (±partial omentectomy) was performed in cases with clear-cut strangulation. Mean operation time was 208 (range, 125—340) minutes. Superficial surgical site infection developed in 2 cases. The infected patients required oral systemic antibiotherapy only. None of these patients had hernia recurrence. Mean follow-up time of these patients was 72.2 (range, 22—110.8) months.

4. Discussion

Challenging abdominal wall defects are a multifactorial and heterogeneous surgical problem that may vary in extent and complexity. This seminal concept raised novel surgical techniques and specific biomaterials. These reconstructive procedures are generally rendered more demanding by patient co-morbidities and previous incompetent operative attempts that increased the risk of sound and successful repair. The authors' approach to AWR was intimately individualized to each patient's specific clinical scenario and special anatomic considerations. Their goal was to expand the spectrum of available operative techniques and biomaterials. Nevertheless, the debate surrounding the technique of mesh implantation (mesh position, mode of mesh stabilization, etc.) and the biomaterial type continues.[21] Many new achievements have been introduced that expand our knowledge base and provide us with a spectrum of innovative reconstructive options.

A short time after the initial usage of e-PTFE grafts for abdominal wall repair in newborns, the clinical application of this synthetic mesh became widespread.[22,23] In many studies using open or laparoscopic hernia repair, intraperitoneal placement of e-PTFE patches have yielded quite favorable outcomes.[3] Although it was initially thought that the use of prosthetic materials appears to be extra-aggressive for repair of umbilical, epigastric, and small ventral hernias, many authors now have been reporting significantly lower rates of recurrence and higher rates of compliance with the use of prosthetic materials compared to the conventional reconstructive techniques.[24—26]

The success after hernia repair is generally evaluated by the rate of recurrence.[27] Various factors such as improper technique, insufficient inflammatory response, and the rate of biomaterial contraction might contribute to failure rates after hernia repair. In this study, with the mean defect diameters of 15.11 ± 6.99 cm for incisional hernias, 14.44 ± 6.34 cm for abdominal wall defects, and 8.09 ± 4.36 cm for umbilical hernias, the recurrence rate after repair were 5.4% for large incisional hernias and none for AWDs. The recurrence rate was higher in patients who had a defect size greater than 14.54 cm ($p = 0.000$) and an operation time greater than 160 min. This longer operative time may be explained as a consequence of the increased complexity of some cases. A study reported by Liem et al comparing conventional inguinal hernia repairs and laparoscopic hernia repairs similarly revealed operation time as a risk factor for recurrence.[28]

Seroma development is one of the most frequent complications of prosthetic mesh usage for AWD repair.[29] Seroma may lead to septated cyst formation or cellulitis and can result in the most morbid complication of frank biomaterial infection. Carter et al demonstrated that seroma formation of laparoscopic ventral hernia repair with e-PTFE graft was seen in 8.6% of patients.[27] They noted that the median transverse implanted mesh size was 18 cm, with a range of 10—34 cm. In our study, seroma formation occurred in 14.1% of patients, and the implanted mesh sizes were 15.11 ± 6.99 cm in incisional hernias, 14.44 ± 6.34 cm in AWDs, and 8.09 ± 4.36 in ventral hernias.

The exact incidence of mesh infections is difficult to obtain due to the variable presentation period after surgery.[30] The incidence of mesh-site infection has been reported from 0.001% to 8%.[31—37] The rate of mesh infection is strikingly influenced by underlying co-morbidity, immunosuppression, incision length, morbid obesity, history of previous hernia repair, wound infection, and tobacco use.[29,31—37] In our series, the surgical site infection rate was 10.9%. Only two (1.28%) of all patients developed mesh-related infection.

Postoperative pain after AWR is another important problem. We detected 37.3% of early postoperative pain after AWR in the study group. The transfascial suture technique used in all patients could be responsible for this finding. However, Bansal et al prospectively randomized patients either to transfascial suture fixation alone or to metal tacks. Their study showed that significantly higher pain scores were obtained at each 3-month follow-up postoperatively in the metal tack group in comparison to the transfascial suture group.[38]

The precise risk of bowel erosion due to the synthetic mesh in hernia repair has been difficult to quantify. In contrast, the use of the e-PTFE patch is usually associated with a decreased risk of bowel-erosive complications.[39—41] This feature of the e-PTFE patch provides a significant advantage when compared with the other patches. In animal models, the e-PTFE patch was shown to develop fewer adhesions to the bowel than macroporous prosthetics;

however, the trade-off was that the incorporation of the e-PTFE patch was significantly less.[12,42–44] In review of 252 adverse events related to mesh herniorrhaphy that were reported to the Food and Drug Administration from 1996 to 2004, 13 intestinal complications involved e-PTFE.[45] In this cohort of 156 patients, enterocutaneous fistula formation was not detected in any patient. E-PTFE patches are safe and reliable for the definitive repair of selected complex AWDs, including incisional hernia, ventral hernia, and other AWDs without facing enterocutaneous (-atmospheric) fistula complication.

In certain circumstances, to decide to close the abdominal wall primarily in patients with severe peritonitis, serious abdominal trauma, or severe acute pancreatitis with or without abdominal compartment syndrome can be perplexing.[20] In such troublesome conditions, e-PTFE patch usage may be a reliable method for salvage-closure of the abdominal wall until the patient's physiological difficulties can improve. The growing population of morbidly obese patients, in addition to those with multiple co-morbidities, relaparotomies, advanced malignancy treated with multimodal aggressive strategies, previous failed reconstructions, and loss of domain of the abdominal wall that influence the native strength and perfusion of tissues, compound demands on the surgeon's stamina.

This study has common drawbacks due to retro-prospective design and the low number of patients. Despite these limitations, the given data of long-term follow-up of a complex group of patients is the specific feature of this study (The duration of median follow-up was 119.1, ranging from 2 to 206 months).

The authors believe that the abdominal wall defect repair culture—that is, the accumulated surgical skill and experience of the surgeons and the center—is crucial to achieve success in AWR, particularly at the time of the first operation, for the patients' best chance of cure. Because of the various complex differences among patients and their pathologies, there will likely never be one ideal biomaterial to use for all patients and all clinical presentations.

5. Conclusion

E-PTFE synthetic patch usage for difficult abdominal wall hernias can help the hernia surgeon obtain safe and durable long-term results of sound repair.

Conflict of interest

No financial and nonfinancial conflicts of interest.

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