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Open Abdomen Therapy with Vacuum and Mesh Mediated Fascial Traction After Aortic Repair: an International Multicentre Study

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WHAT THIS PAPER ADDS

In this multicentre cohort study including 191 patients needing long-term open abdomen after aortic repair, the primary delayed fascial closure rate was 91.8%. The 103 who had an open abdomen at primary operation had significantly less severe initial open abdomen status, less intestinal ischaemia, shorter duration of open abdomen, and less renal replacement therapy, compared with the 88 who had an open abdomen at secondary operation. On table intra-abdominal pressure measurement at the end of the primary operation and strict post-operative intra-abdominal pressure monitoring for identification and prevention of abdominal compartment syndrome may improve outcome after aortic repair.

Objectives: Open abdomen therapy may be necessary to prevent or treat abdominal compartment syndrome (ACS). The aim of the study was to analyse the primary delayed fascial closure (PDFC) rate and complications after open abdomen therapy with vacuum and mesh mediated fascial traction (VACM) after aortic repair and to compare outcomes between those treated with open abdomen after primary versus secondary operation.
Methods: This was a retrospective cohort, multicentre study in Sweden, Finland, and Norway, including consecutive patients treated with open abdomen and VACM after aortic repair at six vascular centres in 2006–2015. The primary endpoint was PDFC rate.
Results: Among 191 patients, 155 were men. The median age was 71 years (IQR 66–76). Ruptured abdominal aortic aneurysm (RAAA) occurred in 69.1%. Endovascular/hybrid and open repairs were performed in 49 and 142 patients, respectively. The indications for open abdomen were inability to close the abdomen (62%) at primary operation and ACS (80%) at secondary operation. Duration of open abdomen was 11 days (IQR 7–16) in 157 patients alive at open abdomen termination. The PDFC rate was 91.8%. Open abdomen initiated at primary (N=103), compared with secondary operation (N=88), was associated with less severe initial open abdomen status (p=.006), less intestinal ischaemia (p=.002), shorter duration of open abdomen (p=.007), and less renal replacement therapy (RRT, $p<.001$). In hospital mortality was 39.3%, and after entero-atmospheric fistula (N=9) was 88.9%. Seven developed graft infection within 6 months, 1 year mortality was 28.6%. Intestinal ischaemia (OR 3.71, 95% CI 1.55–8.91), RRT (OR 3.62, 95% CI 1.72–7.65), and age (OR 1.12, 95% CI 1.06–1.12), were independent factors associated with in hospital mortality, but not open abdomen initiated at primary versus secondary operation.
Conclusions: VACM was associated with a high PDFC rate after prolonged open abdomen therapy following aortic repair. Patient outcomes seemed better when open abdomen was initiated at primary, compared with secondary operation but a selection effect is possible.

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INTRODUCTION

Open abdomen therapy may be life saving after repair of ruptured abdominal aortic aneurysm (RAAA), or elective repair of complex abdominal aortic aneurysm (AAA) to prevent or treat an abdominal compartment syndrome (ACS). The proportion of patients who develop ACS after open compared with endovascular aneurysm repair (EVAR) of RAAA seems to be similar, 20-30%.[1,2] In a population based study reporting from a cohort of 6612 aortic repairs, the proportion who developed ACS after RAAA was 6.9% after EVAR and 6.8% after open repair, but in the latter group another 10.7% had the abdomen left open at the end of the primary operation.[3] These elderly patients with AAA, often have co-existent comorbidities and compromised cardiopulmonary and renal function, precluding them from effective reduction of fluid overload and early abdominal closure.[4] Hence, it is very important to have a durable and easy to learn temporary abdominal closure system that prevents further complications and facilitates abdominal closure. The vacuum assisted and mesh mediated (VACM) fascial traction technique was first described in 2007,[5] and results have since then been reported from various centres and countries.[6–11] Fascial closure rates of 80–100% in mixed surgical patients have been reported.[12] Patient reported outcome measures such as quality of life were also reported, with similar results in those with and without an incisional hernia at 5 years of follow-up.[13] However, open abdomen therapy might be considered hazardous after implantation of an aortic prosthesis because of the risk of developing a graft infection, a condition associated with mortality rates of 25–88%.[14,15] There are only smaller previously published series[7,16] of open abdomen after AAA surgery.

The primary aims of the present international multicentre study were to report primary delayed fascial closure (PDFC), entero-atmospheric fistula (EAF), and graft infection rates, and factors associated with outcomes in a large series of patients with open abdomen after repair for aortic disease treated with VACM. A secondary aim was to compare outcomes between those treated with open abdomen after primary and secondary operation.

Patients and Methods

This study was approved by the regional ethical review board in Lund, Sweden (Dnr 2016/327) and in Mid-Norway (Dnr 2014/957), and by the institutional review board of University of Helsinki, Finland.

All consecutive patients treated with open abdomen with VACM after surgery for aortic disease at four study centres in Sweden (Falun, Gävle, Malmö, and Uppsala), at Helsinki University Hospital, Finland, and at Trondheim University Hospital, Norway, between 2006 and 2015 were included in the study. The majority of recruited patients were treated at four tertiary vascular centres in Scandinavia. Falun and Gävle are included in the tertiary catchment population of Uppsala. Uppsala, Malmö, Trondheim, and Helsinki have tertiary catchment populations of approximately 2.0, 1.5, 0.7, and 1.4 million inhabitants, respectively. A predefined protocol with defined variables was used for patient data entry. Patients were registered prospectively in clinical databases, and case-records were reviewed retrospectively. Twenty-nine patients exclusively treated by an open abdomen technique other than VACM at the six study centres were excluded; 23 because of a short period of vacuum assisted wound closure treatment without mesh, of whom seven survived and 16 died, and six with Bogotá bag exclusively, of whom two survived and four died. Thirty patients undergoing AAA repair and open abdomen treatment with VACM in the abovementioned Swedish centres between 2006 and 2009 have been reported previously, with 1 year follow-up results.[16] End of follow-up of this study was March 2016, and median follow-up time was 15 months (IQR 1–61). Median follow-up among survivors who were transferred home was 52 months (IQR 24–75). Completeness of follow-up data on mortality was assured by automatic linkage within 2 weeks from the respective national population registries, based on the patient's personal identity number, to the respective national vascular registries and the inpatient databases, where survival status was retrieved. Thus, survival was not surgeon reported.

Outcome variables

The main endpoint, PDFC, is achieved when the whole length of fascia is closed by suturing after open abdomen treatment. Abdominal closure refers to PDFC or abdominal wall reconstruction with mesh or component separation technique. Entero-atmospheric fistula was present when there was a communication between the gastrointestinal tract and the atmosphere in an open abdomen. A diagnosis of graft infection was based on a combination of clinical, laboratory test, bacteriological cultures, and/or radiological findings with computed tomography or positron emission tomography/computed tomography.

Definitions

Intra-abdominal pressure was measured intermittently as urinary bladder pressure through an indwelling catheter by means of the Foley manometer technique (Holtech Medical, Charlottenlund, Denmark), before and repeatedly after initiation of open abdomen treatment. Intra-abdominal hypertension and ACS were defined according to the World Society of the Abdominal Compartment Syndrome consensus definitions.[17] Intra-abdominal hypertension was defined as intra-abdominal pressure $\geq$12 mm Hg and ACS as an intra-abdominal pressure $>$20 mmHg with newly developed organ dysfunction.

The term "secondary operation" was used instead of relaparotomy, to also include patients who were primarily treated by EVAR. Graft infection was defined according to Szilagyi group III, where the arterial prosthesis is involved in the infection.[18] Intra-abdominal pressure was evaluated immediately before and the morning after initiation of open abdomen treatment. Classification of open abdomen status[19] (Table S1) was performed at the initiation of open

abdomen treatment, and at re-dressings. The worst open abdomen classification was defined as the most serious form during the entire treatment. Duration of open abdomen treatment lasted from initiation of open abdomen until abdominal closure.

Vacuum assisted wound closure and mesh mediated fascial traction

Patients were usually treated by vacuum assisted closure alone at the operation for leaving the patient with an open abdomen, to avoid prolonging the laparotomy as part of a damage control strategy. A polypropylene mesh was applied at the first redressing after 2 to 3 days. A 30 × 30 cm mesh (Prolene; Ethicon, Johnson & Johnson, Somerville, NJ, USA) was divided in two halves and sutured to the fascial edges on each side with a running 0 polypropylene suture (Prolene). A vacuum assisted closure system (V.A.C Abdominal Dressing System; KCI, San Antonio, TX, USA) was applied; the perforated polyethylene sheet with a central thin polyurethane sponge was placed intra-abdominally, covering the viscera and tucked under the abdominal wall far out laterally on both sides (Fig. 1). The two mesh halves were then sutured in the midline with a running 0 polypropylene suture, ventral to the polyethylene sheet (Fig. 2). The thick polyurethane sponge was placed on top of the polypropylene mesh, and the wound was covered with occlusive self adhesive thin polyethylene sheets. A continuous negative pressure of 75—150 mmHg was then applied according to the surgeon's preference (Fig. 3). The VACM system was changed by releasing the suture in the midline of the mesh, changing the innermost polyethylene sheet covering the viscera and tightening the mesh, if possible, under general anaesthesia every 2 to 3 days. Finally, the mesh was removed after removing the running polypropylene suture in the fascial edges on each side. The fascia was then closed with a running 0 polydioxanone suture (PDS II, Ethicon), by means of a standardised suturing technique aiming at a suture length to wound length ratio of at least 4:1. Successful delayed primary fascial closure was defined as complete closure of the whole length of the incised fascia.

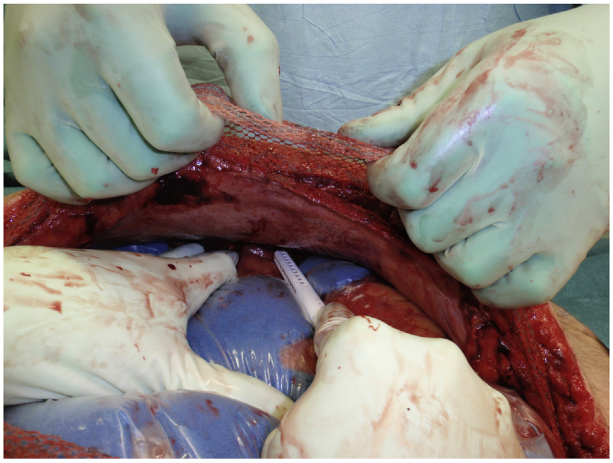

Figure 1. Each mesh half was first sutured to the fascial edges, which can now easily be retracted laterally and upwards to open up the midline wound. The innermost plastic sheet (ABThera; KCI, San Antonio, TX, USA) is carefully placed far out laterally to prevent formation of adhesions between the bowel and abdominal wall, which otherwise may compromise proper sliding of the abdominal wall and the possibility of achieving complete primary fascial closure.

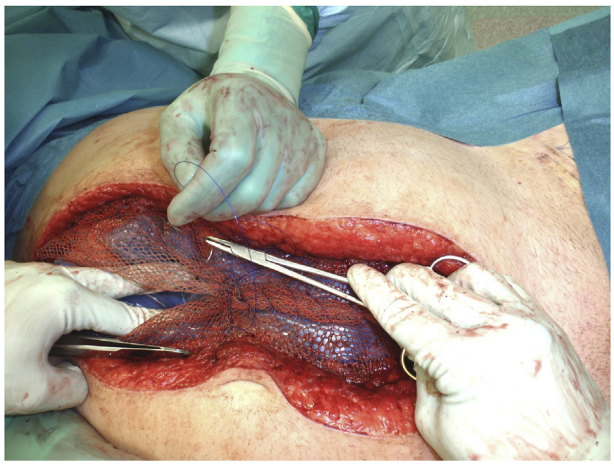

Figure 2. The mesh halves are sutured together with a running 0 polypropylene suture.

Figure 3. The thick blue foam is applied above the mesh and covered with plastic film. A hole is cut in the film above the blue foam and the suction device is attached and connected to the vacuum machine.

Statistical analysis

Continuous variables were expressed as median (interquartile range [IQR]), and group differences were analysed by means of the Mann-Whitney *U* or Wilcoxon signed rank test. Discrete variables were analysed with Pearson's chi square test, Fisher's exact test or Kendall's τ-b test, as appropriate. Variables associated with in hospital mortality ($p < .1$) were entered into a multivariate binary logistic regression analysis, and associations were expressed in terms of OR with 95% CI. Cumulative primary delayed fascial closure per protocol was assessed in patients treated with primary and secondary open abdomen with the Kaplan-Meier method with life tables and group difference analysed with the log rank test. A *p* value of $< .05$ was considered to be statistically significant. Statistical analysis was performed using SPSS version 22.0 (SPSS, Chicago, IL, USA).

RESULTS

Patient characteristics

One hundred and ninety one patients were included, 155 (81.2%) men and 36 (18.8%) women. Median age was 71 years (IQR 66–76). The aetiologies were RAAA ($n=132$; 69.1%), intact AAA ($n=52$; 27.2%), and acute type B dissection ($n=7$; 3.7%). The aneurysms were anatomically classified as infrarenal ($n=135$), pararenal ($n=31$), and thoraco-abdominal ($n=18$), and the rupture rates were 79.3% ($n=107$), 77.4% ($n=24$), and 5.6% ($n=1$), respectively. Open, endovascular, and hybrid repair of aortic disease were performed in 142 (74.3%), 33 (17.3%), and 16 (8.4%), respectively.

Open abdomen management

The open abdomen was initiated at the primary operation in 103 (53.9%) patients and at secondary operation in 88 patients (46.1%). Among 142 open repairs, it was difficult or not possible to close the abdomen in 64 (45.1%) patients at the primary operation. Among 49 patients undergoing endovascular or hybrid repair, 25 (51.0%) had a laparotomy during the primary operation. The median intra-abdominal pressure in patients undergoing decompressive laparotomy at a second operation was 22 mmHg (IQR 20–26) ($n=70$) prior to laparotomy and 12 mmHg (IQR 10–15) ($n=71$) after laparotomy ($p<.001$). The indications for decompressive laparotomy at secondary operation were ACS ($n=56$) and intra-abdominal hypertension ($n=14$). The indication for open abdomen could not be determined in 18 patients because of missing intra-abdominal pressure data, and the frequency of ACS prior to the secondary operation was 80% (56/70). Among 157 patients who were alive when the open abdomen therapy was terminated, the median open abdomen therapy time was 11 days (IQR 7–16) with VACM for 9 days (IQR 6–15), and the median number of dressing changes with mesh tightening procedures was 4 (IQR 2–6). The overall primary delayed fascial closure rate and abdominal closure rate including mesh ($n=10$) and component separation (n=1) was 91.8% (145/157) and 99.4% (156/157), respectively. One patient was left with a giant ventral hernia. Patients with an open abdomen worst grade >1A ($n=70$) had a lower primary fascial closure rate, 83.0%, than those with grade 1A throughout the treatment ($n=118$), 97.1%, $p=.002$.

Open abdomen initiated at primary versus secondary operation

Patients treated with open abdomen at primary operation included a higher proportion of RAAA ($p<.001$) and were administered a larger volume of blood peri-operatively ($p=.018$), than those treated with open abdomen at secondary operation (Table 1). The open abdomen status (Table S1) at initiation of open abdomen at second operation was more severe ($p=.006$), and the frequency of intestinal ischaemia ($p=.002$), bowel resection ($p<.001$), and creation of stoma ($p<.001$) was higher compared with those with open abdomen initiated at primary operation. In patients with open abdomen initiated at second operation, the duration of open abdomen treatment was longer ($p=.006$) and primary fascial closure rate per protocol (excluding patients who died with an open abdomen) was lower ($p=.003$), compared with those with open abdomen initiated at primary operation (Table 2, Fig. 4). The frequency of renal replacement therapy (RRT) was higher ($p<.001$) and intensive care unit stay was longer ($p=.005$) in patients with open abdomens initiated at secondary versus primary operation (Table 3).

Entero-atmospheric fistula (EAF)

There were nine (4.7%) patients who developed EAF: six had undergone endovascular or hybrid repair (6/49, 12.2%), and three open repair (3/142, 2.1%), $p=.010$. Among 36 patients with intestinal ischaemia, five (13.9%) later developed EAF, compared with 4/155 (2.6%) without intestinal

Table 1. Characteristics in patients with initiation of open abdomen at primary versus secondary operation.

	Open abdomen at primary operation	Open abdomen at secondary operation	*p*
Patients	103	88	
Median (IQR) age	71 (65–77)	71 (68–76)	.54
Men (%)	80 (77.7)	75 (85.2)	.18
RAAA (%)	83 (80.6)	49 (55.7)	<.001
Endovascular/hybrid repair (%)	25 (24.3)	24 (27.3)	.64
Median (IQR) blood transfusion, peri-operatively (L)	4.9 (3.0–7.5)	4.0 (2.0–5.8)	.018

RAAA = ruptured abdominal aortic aneurysm.

Table 2. Characteristics in open abdomen initiated at primary versus secondary operation.

	Open abdomen at primary operation	Open abdomen at secondary operation	*p*
Patients	103	88	
Open abdomen grade at initiation			
1A	98	73	
1B	4	8	
1C	1	2	
2A	0	2	
2B	0	3	
2C	0	0	
3A	0	0	
3B	0	0	
4	0	0	.006
Open abdomen, worst grade			
1A	68	50	
1B	15	15	
1C	3	2	
2A	7	6	
2B	3	6	
2C	3	4	
3A	0	2	
3B	1	0	
4	0	3	.064
Median (IQR) duration of open abdomen (days)	9 (6–14)	13 (8-20)	.006
Intestinal ischaemia (%)	11 (10.7)	25 (28.4)	.002
Bowel resection (%)	15 (14.6)	37 (42.0)	<.001
Any stoma (%)	8 (7.8)	28 (31.8)	<.001
Primary fascial closure per protocol, (%)	89/91 (97.8)	56/66 (84.8)	.003
Abdominal closure, any technique per protocol (%)	91/91 (100)	65/66 (98.5)	.42

ischaemia, $p=.013$. Six patients of 52 developed EAF (11.5%) after bowel resection, compared with 3/139 (2.2%) without bowel resection, $p=.013$.

Graft infection

There were seven (7/191, 3.7%) graft infections, three stent graft infections after endovascular or hybrid repair, and four graft infections after open repair. These were diagnosed at median time of 1 month (range 1–6) post-operatively. Four (11.1%) patients of 36 with intestinal ischaemia had graft infection, compared with 3/155 (1.9%) without intestinal ischaemia ($p=.025$). Four (7.7%) patients with graft infection were among those 52 patients that had undergone bowel resection, compared with three (2.2%) of 139 without bowel resection ($p=.089$). All seven graft infections were managed conservatively with antibiotics and without graft explantation. Two stent graft infections were also treated by percutaneous insertion of two large calibre drains through the back into the aneurysm sac for drainage and intermittent sac irrigation with saline for weeks.

Risk factors associated with failure of primary delayed fascial closure

Open abdomen initiated at secondary versus primary ($p=0.003$), duration of open abdomen ($p<.001$), and bowel resection ($p=.008$) were associated with failure of PDFC. After entering these three variables into a multivariate logistic regression model, duration of open abdomen (OR 1.18 [95% CI 1.08–1.28]) remained as an independent risk factor associated with failure of PDFC.

Risk factors associated with mortality

Death before abdominal closure occurred in 17.8% (34/191). In hospital and 1 year mortalities were 39.3% (75/191) and 41.9% (80/191), respectively. In hospital mortality was increased, compared with the control group not developing the complication, in patients developing intestinal ischaemia (69.4%; 25/36, $p<.001$), EAF (88.9%; 8/9, $p=.003$) and requiring RRT (53.6%; 45/84, $p<.001$). The in hospital mortality in patients with initiation of open abdomen at primary operation was lower compared with initiation at secondary operation, 31.1% (32/103) versus 48.9% (43/88), respectively ($p=.012$) (Table 3). The in hospital mortality after endovascular or hybrid repair compared with open repair was 51.0% (25/49) versus 35.2% (50/142), respectively ($p=.051$). Factors such as gender ($p=.74$), RAAA ($p=.56$), and anatomical classification of AAA ($p=.51$) were not associated with in hospital mortality. Higher age was associated with increased mortality ($p<.001$), whereas volume of peri-operative blood transfusion ($p=.47$) and duration of open abdomen ($p=.71$) were not. In hospital and 1 year mortality in patients with graft infection was the

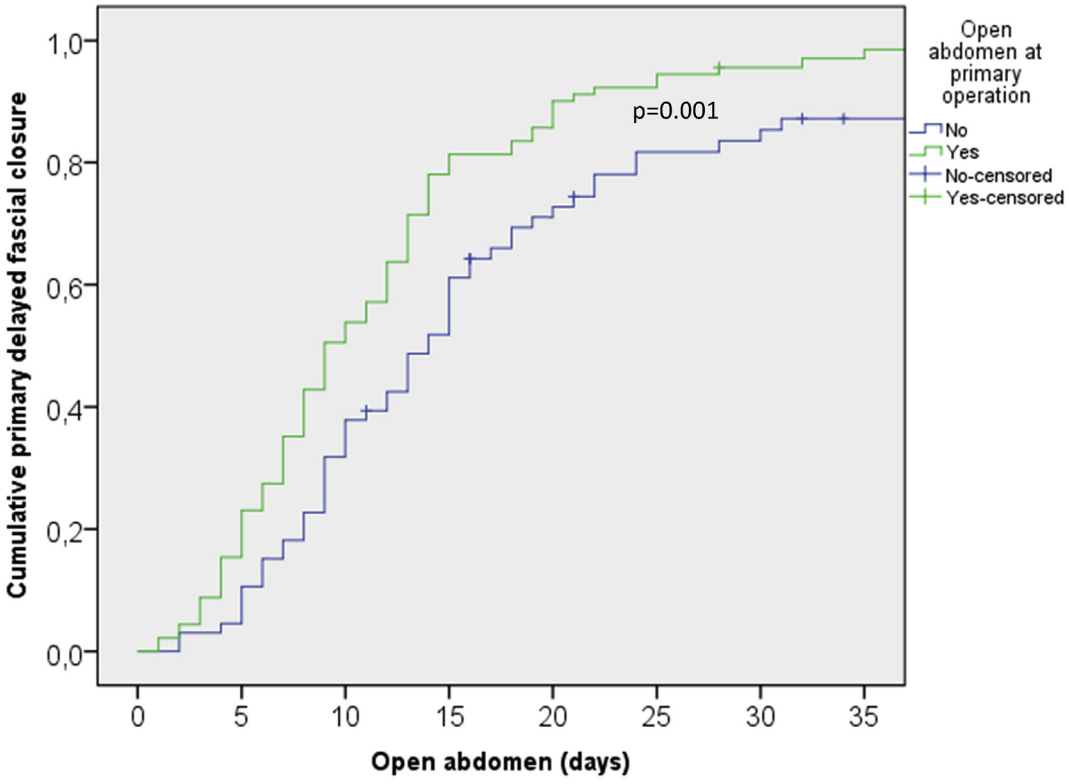

Figure 4. Higher cumulative primary delayed fascial closure rate in patients with open abdomen initiated at primary compared with secondary operation (p=.001).

same (28.6%; 2/7), and did not differ compared with those without graft infection (p=.71 and p=.70, respectively).

After entering the variables age, open abdomen initiated at primary versus secondary operation, endovascular/hybrid versus open repair, intestinal ischaemia or not, and RRT or not, into a multivariate binary logistic regression model, intestinal ischaemia (OR 3.71, 95% CI 1.55—8.91]), RRT (OR 3.62 [95% CI 1.72—7.65]), and age (OR 1.12 [95% CI 1.06—1.12]) remained as independent risk factors associated with in hospital mortality (Table 4).

DISCUSSION

The results of the present study show that the VACM technique works well as a temporary abdominal closure system, with a primary delayed fascial closure rate exceeding 90% in a large series of patients operated on for aortic disease, treated with long-term open abdomen. The primary delayed fascial closure rate in the more complicated open abdomen with a higher open abdomen grading was significantly lower, but still exceeded 80% in the per protocol analysis. The inclusion of centres from different

Table 3. Complications and mortality in patients with initiation of open abdomen at primary versus secondary operation.

	Open abdomen at primary operation	Open abdomen at secondary operation	p
Patients	103	88	
EAF (%)	4 (3.9)	5 (5.7)	.74
RRT (%)	29 (28.2)	55 (62.5)	<.001
Median (IQR) ICU stay (days)	12 (7—20)	17 (10—27)	.005
Median (IQR) in hospital stay (days)	28 (17—44)	35 (17—59)	.17
Graft infection (%)	3 (2.9)	4 (4.5)	.70
Mortality			
In hospital (%)	32 (31.1)	43 (48.9)	.012
1 year (%)	36 (35.0)	44 (50.0)	.036

EAF = entero-atmospheric fistula; RRT = renal replacement therapy; ICU = intensive care unit.

Table 4. Multivariate analysis of risk factors associated with in hospital mortality in patients with open abdomen after aortic surgery.

	In hospital mortality risk estimates OR (95% CI)	*p* value
Age	1.12 (1.06–1.18)	<.001
Open abdomen initiated at primary versus secondary operation	0.79 (0.39–1.57)	.50
Endovascular/hybrid vs. open repair	1.63 (0.74–3.59)	.23
Intestinal ischaemia	3.71 (1.55–8.91)	.003
Renal replacement therapy	3.62 (1.72–7.65)	.001

countries in the present study makes these results generalisable to other settings. Similar primary fascial closure rates with the same technique exceeding 80% were reported in a review with mixed surgical patients and a high rate of abdominal sepsis.[12] Applying mechanical fascial traction counteracts lateral retraction effectively, and in combination with vacuum therapy, results in higher fascial closure rates than vacuum therapy alone.[20–22] Vacuum and controlled fascial traction with other techniques, such as traction with # 1-polydioxanone sutures,[23] vessel loops as dynamic sutures,[24–26] or a dynamic closure system called abdominal re-approximation anchor system,[27] have been described and reported to achieve a high fascial closure rates. None of these techniques, however, have been reported from a large number of independent researchers, nor were they evaluated regarding long-term outcome in terms of abdominal wall discomfort and quality of life, as the VACM technique.[13]

An interesting result from this investigation was that patients with open abdomen initiated at the second operation, compared with those left open at the primary operation, had more severe open abdomen status, higher frequency of intestinal ischaemia, longer open abdomen time, lower primary fascial closure rate, higher frequency of RRT, longer intensive care unit stay, and higher in hospital mortality. This could be explained by differences in casemix, but the group left open at a secondary operation less often had a RAAA and had a lower volume of peri-operative blood transfusion administered, indicating that they probably had a lower risk of developing ACS. Hence, patients undergoing decompressive laparotomy at secondary operation may have benefitted from prophylactic use of open abdomen at primary operation, even if this management has not been recommended in the updated consensus definitions and clinical practice guidelines from the World Society of the Abdominal Compartment Syndrome.[17] These results must be interpreted with great caution, however, as most analyses did not adjust for confounders.

The authors are aware of one retrospective study advocating a more liberal approach to open abdomen at primary EVAR operation for RAAA with overall 30 day mortality of only 13%, 8% in those without versus 30% in those with ACS.[28]

Timing of open abdomen was not an independent risk factor associated with in hospital mortality in the multivariate analysis, which may be a result of residual confounding. The fact that the abdomen was impossible to close in many patients at primary operation after open repair may actually have saved lives. A prospective population based cohort study from the Swedish vascular registry, SWEDVASC, reported increased mortality among patients with ACS compared with those treated with open abdomen without ACS, supporting the finding of this study.[3] A randomised controlled trial comparing these two approaches, primary open abdomen versus decompressive laparotomy on demand, would be ideal, however it would be difficult to perform. To randomise patients who are difficult to close at the end of open repair would not be ethical, and they are the patients most likely to benefit from open abdomen treatment. Unresolved issues include what monitoring of intra-abdominal pressure is ideal after AAA repair, how ACS should be prevented, and identification of the exact indications for secondary open abdomen treatment.

Patients with intestinal ischaemia undergoing bowel resection after aortic repair and open abdomen therapy are predisposed to EAF and graft infections, which was reported in a previous cohort study with mixed surgical patients treated with VACM.[6] The EAF rate was low, 4.7%, compared with other reports,[29–31] but mortality among those who developed the complication was very high, 89%. This is in strong contrast to a previous report by Seternes, in which all nine patients with EAF survived.[30] In that report,[30] however, EAF occurred after gastrointestinal surgery in relatively young patients with a median age of 52 years, who are clearly more likely to survive this serious complication than patients with aortic disease.

The graft infection rate was low, 3.7%, in the present study. This finding should be interpreted with caution because of the high overall in hospital mortality. Follow-up among survivors who left the hospital was longer, however, with a median of 52 months. Furthermore, all graft infections occurred early in the post-operative course, a finding that contrasts with reports that state that the majority of aortic graft infections occur late, 1 to 3 years after endovascular aortic aneurysm repair.[32,33] The three patients with stent graft infection were likely to have been infected as a result of haematogenous dissemination rather than directly through the open abdomen, the closed retroperitoneum, and aortic wall, whereas those patients with graft infection after open repair might be infected by both direct and haematogenous contamination. It may be that elderly patients with a complicated open abdomen after aortic surgery are more prone to develop an early graft infection because of higher bacterial loads in very ill patients with compromised immunological defence systems. Nevertheless, and somewhat unexpectedly, in hospital mortality was comparably low in this group of patients at 1 year.

The proportion of patients undergoing EVAR for RAAA is increasing at the expense of a decreasing proportion of open repairs,[34] a result strengthened by the UK IMPROVE Trial that showed better outcomes after EVAR, although

there was no difference in 30 day survival.[35] Patients undergoing EVAR for RAAA in the real world setting are generally older[3,34,36] and often have a higher burden of comorbidities,[35] sometimes making surgeons reluctant to perform laparotomy for a tense abdomen after EVAR. This is a serious mistake. The risks of developing ACS after EVAR and after open repair of RAAA are similar.[26] There was a trend that the endovascular group had higher in hospital mortality than the open group in the present study, which is in line with another report.[1] Time delay in performing decompressive laparotomy in the endovascular group in the present study might have been longer compared with the open group, and perhaps laparotomy should have been performed more often after endovascular exclusion of the aneurysm during the primary operation.

This study has limitations. The retrospective study design and post-hoc analysis means that there was no algorithm protocol for management of ACS and intra-abdominal hypertension, and no time lag in hours was available for evaluation of the adverse effects of the delayed decompressive laparotomy. The clinical follow-up data were insufficient to report incisional hernia rate, which would have required a prospective study design. A previous publication on patients treated with VACM after different pathologies (gastrointestinal emergencies, trauma and aortic repair) showed a rather high risk of incisional hernia at 5 year follow-up, although most of those hernias were asymptomatic.[13] One selection bias identified from the excluded patient series were the 20 patients that died shortly after the index operation, of whom most probably would have been eligible for the VACM technique if they had survived longer. Although the open abdomen with VACM was quite standardised, the study cohort was heterogenous and the decision making regarding how to monitor the patients, and when to perform decompressive laparotomy, was performed by a large cohort of vascular surgeons and intensivists 24/7, at the six hospitals. After adjusting for some confounders, however, no difference in hospital mortality and failure of PDFC was found between the two open abdomen groups. In a recent multicentre study on 33 patients who underwent laparotomy for ACS, it was shown that urinary output and oxygenation improved rapidly, suggesting that decompression should not be delayed.[37] Thus, it is not certain that it was the decision to close the abdomen, or not to open it after EVAR, that explains the inferior results in the group of patients who underwent a secondary decompression, it may just as easily be a result of delaying decompression for too long.

On-table intra-abdominal pressure measurement at the end of the primary operation and strict post-operative intra-abdominal pressure monitoring, and laparotomy before ACS develops, seem to be justified especially in patients with RAAA and may improve outcome after aortic repair.

CONCLUSION

Vacuum and mesh mediated fascial traction was associated with a high primary delayed fascial closure rate after long-term open abdomen therapy following aortic surgery in this international multicentre study. Patients had better outcomes when open abdomen was initiated at the primary operation than at a second operation in this post-hoc analysis. This result cannot be interpreted as an argument for prophylactic open abdomen treatment however, as the two patient groups were very different in many aspects. An attempt to perform a prospective randomised trial is warranted.

CONFLICT OF INTEREST

None.

FUNDING

None.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ejvs.2017.09.002.

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