'Superior primary fascial closure rate and lower mortality after open abdomen using negative pressure wound therapy with continuous fascial traction'

Rasilainen, S, Mentula, P, Salminen, P, Koivukangas, V, Hyöty, M, Mäntymäki, L-M, Pinta, T, Haikonen, J, Rintala, J, Rantanen, T, Strander, T & Leppäniemi, A

**Abstract**

Background: Open abdomen (OA) is a useful option for treatment strategy in many acute abdominal catastrophes. A number of temporary abdominal closure (TAC) methods are used with limited number of comparative studies. The present study was done to examine risk factors for failed delayed primary fascial closure (DPFC) and risk factors for mortality in patients treated with OA.

Methods: This study was a multicenter retrospective analysis of the hospital records of all consecutive patients treated with OA during the years 2009–2016 at 5 tertiary referral hospitals and 3 secondary referral centers in Finland.

Results: 676 patients treated with OA were included in the study. Vacuum-assisted closure with continuous mesh-mediated fascial traction (VACM) was the most popular TAC method used (N=398, 59%) followed by VAC (N=128, 19%), Bogota bag (N=128, 19%) and self-designed methods (N=22, 3%). In multivariate analysis enteroathmospheric fistula and the number of needed TAC changes increased the risk for failed DPFC (OR=8.9, 95%C.I. 6.2–12.8, $P$<.001 and OR=1.1, 95% CI, 1.0–1.3, $P$<.001, respectively). Instead VACM and ruptured abdominal aortic aneurysm as cause for OA both decreased the risk for failed DPFC (OR=0.1, 95%C.I. 0.0–0.3, $P$<.001 and OR=0.2, 95%C.I. 0.1–0.7, $P$ = .012). The overall mortality rate was 30%. In multivariate analysis for mortality, multi organ dysfunction (OR=2.4, 95%C.I. 1.6–3.6, $P$<.001) and increasing age (OR=4.5, 95%C.I. 2.0–9.7, $P$<,001) predicted increased mortality. Institutional large annual patient volume (OR=0.4 95%C.I. 0.3–0.6, $P$<.001) and ileus and postoperative peritonitis in comparison to SAP associated with decreased mortality (OR=0.2 95%C.I. 0.1-0.4, $P$<.001; OR=0.5 95%C.I. 0.3-0.8, $P$=.009). Kaplan-Meier analysis showed increased survival in patients treated with VACM in comparison with other TAC methods (LogRank $P$=.019).

Conclusions: We report superior role for VACM methodology in terms of successful primary fascial closure and increased survival in patients with OA.

Manuscript

**Background**

Open abdomen (OA) is today a widely used treatment strategy, used for several critical and/or life-threatening conditions. Its indications have expanded in number since the original trauma setting, and thus, many severely ill patients are taken care of by the means of laparostomy.[1–4] These protocols have been suited to manage both acute abdominal catastrophes (as damage control) and more stable but challenging situations in which the expert judgement prefers leaving the abdomen open. Guidelines for these strategies are regularly updated by international expert organizations, which support their safe and reasonable use at various levels of health care units.[5]

Despite its life-saving nature, the imminent comorbidities and complications linked with OA are not to be underestimated.[6–8] Hence, the decision-making on whether to proceed to OA or not needs to be based on specialist opinion. Equally important is the assessment of the level of expertise present at the center and referring the patient to a unit with adequate facilities without delay when required.

The primary aims of this national multicenter study were to report the number and characteristics of patients treated with OA in Finland, to clarify the treatment strategies for OA on a national level, and to report the outcomes. The primary outcome was to assess the risk factors for failed delayed primary fascial closure (DPFC) and the secondary outcome was to assess the risk factors for mortality. Based on these findings, a treatment recommendation or algorithm for OA will be designed for Finnish surgical units that are active in managing critical surgical patients.

Based on previous knowledge our hypothesis was that temporary closure of OA with a negative pressure system combined to continuous fascial traction is superior in comparison with other methods in relation to primary fascial closure and survival.

## Methods

This study was a multicenter retrospective analysis of the hospital records of all the consecutive patients treated with OA during the years 2009–2016 at all 5 tertiary referral hospitals in Finland (aka *tertiary referral centers*; the university hospitals of Helsinki, Turku, Tampere, Oulu, and Kuopio) and 3 secondary referral centers (the central hospitals in Seinäjoki, Rovaniemi, and Pori). Patients treated with OA were harvested and identified from hospital databases according to procedure codes for laparostomy and temporary abdominal closure (TAC) change (JAH30 and JAH33). The inclusion criteria were 1) OA treatment during the chosen time period and 2) age 18 to 99 years. The only exclusion criterion was incomplete hospital records. The study protocol was approved by each separate institutional review board at each contributing center.

## Definitions

### Indications for laparostomy

The indications for laparostomy were retrospectively divided into 4 main causes according to patient records: (1) abdominal compartment syndrome (ACS), (2) intra-abdominal hypertension (IAH), (3) the inability to close the abdomen, and (4) prophylactic OA. The last of these was used for the indications described in our previous study [9] (i.e., OA was used in anticipation of the high risk of the development of IAH or ACS related to the fascial closure of an initial laparotomy or planned relaparotomy).

**TAC methods**

The methods used for TAC were categorized into 4 alternatives: (1) using a plastic silo (a Bogota bag), (2) commercial vacuum-assisted closure without fascial traction (VAC), (3) commercial vacuum-assisted closure with continuous mesh-mediated fascial traction (VACM), and (4) other, self-made, systems with or without topical negative pressure treatment.

A plastic silo (a Bogota bag) is used as a single layer to protect the viscera and is attached by continuous sutures to the skin margins. VAC is a commercial system (V.A.C.® Abdominal Dressing System, KCI, San Antonio, Texas, USA; VISTA wound vacuum system, Smith+Nephew Inc.; RENASYS, Abdominal Dressing Kit with Soft Port, Smith+Nephew), used as instructed and creating a topical negative pressure environment.

The VACM methodology has been described before.[10] Briefly, the components of the commercial VAC system are used. First, a permeable sheet is laid to cover the viscera. Then, an oval-shaped polypropylene mesh is attached by sutures to the fascial edges and covered by a polyurethane sponge. Last, an occlusive film is set on top, perforated in the middle and attached to a suction device to create a topical negative pressure environment.

Other TAC systems used include pierced films covered with saline dressings, either combined with silicon tube drainage or not.

TAC changes were performed every 2 to 3 days, mostly in the operating room but sometimes bedside in the intensive care unit (ICU). Regarding VACM, at the first TAC change, the mesh was cut in midline, the innermost permeable sheet changed, and the mesh sutured and tightened with running monofilament thread. Finally, at the last TAC change, the mesh was removed, and the fascia closed in midline in the established manner of individual institutions (running or interrupted sutures).

### Statistical methods

IBM SPSS Statistics, version 22.0 for Windows (IBM, Armonk, New York, USA), was used for statistical analysis. A $P$ value of $< .05$ was considered statistically significant. Categorical variables were analyzed by using Pearson's chi-square test and Fisher's exact test. Continuous variables with normal distribution are expressed as means with standard deviation and were compared using one-way Anova. Continuous variables with non-normal distribution are expressed in medians with inter-quartile range and compared with non-parametric tests. For multivariate analysis, generalized linear mixed models were used. This methodology was chosen to avoid the clustering effects by facility in a multicenter trial. For survival analysis a Kaplan-Meier method was used. Due to a discovered selection bias, patients who died within the first 3 days after laparostomy ($N$ = 50) were excluded from mortality analyses.

## Results

### Patient characteristics

Data on 688 (*N* = 688) patients were gathered in total. Five (5) patients were only treated with superficial negative pressure treatment with a closed fascial layer and thus there was no OA, and they were excluded. Four (4) patients were less than 18 years old and considered pediatric and excluded. Three (3) patients had incomplete hospital records, leaving critical data on fascial closure and survival uncertain, and were thus excluded. The remaining 676 patients were included in the study and analyzed. Detailed patient characteristics are summarized in Table 1.

In this group including all patients, the median length of stay (LOS) from laparostomy to discharge was 25 days (IQR 13–43; range 1–391).

Five hundred and seventy-six (576; 85%) patients were admitted to the ICU at some point during their hospital care. The median time of the ICU visit was 7 days (IQR 2–18, range 1–143). Out of these 576 patients, 97 (17%) were re-admitted to the ICU at a later time point and the median duration of the re-admissions was 5 days (IQR 3–13, range 1–48).

Organ failure was diagnosed in 79% (*N* = 531) of the patients: in detail, there was cardiac insufficiency in 67% of the patients (*N* = 452), renal insufficiency in 44% of the patients (*N* = 294), and respiratory insufficiency in 67% of the patients (*N* = 454). Seventy-two (72) of the 676 (11%) patients developed an enteroathmospheric fistula (EAF) and, of these, 18 (25%) died with OA.

**OA treatment and TAC**

Of all the 676 patients, 143 died with OA (see Figure 1). For these patients, the TAC methods used were as follows: VACM was used for 55 patients, VAC was used for 20 patients, a Bogota bag was used for 58 patients, and self-made methods were used for 10 patients.

In the remaining 533 patients, the median duration of OA treatment was 10 days (IQR 5–21, range 0–186). The indications for laparostomy are detailed in Table 1. Of these 533 patients, those with prophylactic indication had the shortest OA duration (median 6, IQR 3–16, range 0–76) and those with ACS had the longest OA duration (median 12, IQR 6–25, range 1–161). Comparing patients with preoperative ACS with those without it, the median OA duration (12 d, IQR 6–25, range 1–161 vs. 10 d, IQR 5–20, range 0–186, *P* = .052) was longer, although not significantly. The median LOS from laparostomy to discharge was significantly longer in patients with preoperative ACS compared to those without ACS (38d, IQR 23-66, range 4-187 vs. 29 d, IQR 18-44, range 1–391, *P* = .001) . The patients with severe acute pancreatitis (SAP) had significantly longer OA duration (median 16.5 d, IQR 7–44, range 3–159) in comparison with patients with all other diagnoses (median 9.5 d, IQR 5–19, range 0–186) (*P* = .001).

Within the 533 patients, the main TAC method used was VACM (*N* = 343, 64%) followed by VAC (*N* = 108, 20%), a Bogota bag (*N* = 70, 13%), and other self-designed methods (*N* = 12, 2%). A median of 3 (IQR 2–5, range 0–29) TAC changes were performed for every patient. A median of 1 (IQR 1, range 0–8) other surgical procedure was performed for every patient during the OA treatment.

## Delayed primary fascial closure and planned hernias

Of the 533 patients who did not die with OA, 435 (82%) reached delayed primary fascial closure **(**DPFC). The rest (*N* = 98) were treated with a planned hernia approach (see Figure 1).

With VACM as the TAC, 317/343 (92%) patients reached DPFC in comparison to 72/108 (67%) with commercial VAC, 41/70 (59%) with a Bogota bag, and 5/12 (42%) with self-made systems (*P* < .001). This result was corroborated in univariate analysis as VACM had a negative predictive value for failed DPFC (OR = 0.1, 95% CI, 0.1–0.2, *P* < .001). Furthermore, univariate analysis showed that an increasing number of TAC changes significantly predicted failed DPFC (OR = 1.2, 95% CI, 1.1–

1.2, *P* < .001; see Table 2). Twenty-four (24, 6%) of the 435 patients with DPFC developed fascial dehiscence, 16 of which were repaired and 8 were not. Components separation procedure was performed for 42 (10%) of the 435 patients during the OA treatment and, of these, 41 fasciae endured and 1 ruptured.

An EAF was detected in 27 (6%) of the 435 patients with DPFC and in 27 (28%) of the 98 patients treated with the planned hernia approach.

Of the 435 patients with DPFC, 59 (14%) died during the index hospitalization period. Of those with the planned hernia approach, only 3/98 (3%) patients died. According to the records, 33 of these 95 survivors have so far been though hernia reconstruction.

In univariate analyses for factors predicting failed DPFC, an EAF was shown to significantly increase this risk. Of the diagnoses leading to OA an abdominal aortic aneurysm (AAA) or AAA with rupture (RAAA), trauma and hemorrhage were associated with decreased risk for failed DPFC in comparison to SAP (see Table 2).

A multivariate (generalized linear mixed models) analysis of the risk factors for failed DPFC was performed that included all the factors that were proven significant in univariate analysis. An EAF (OR = 8.9, 95% CI, 6.2–12.8, *P* < .001) and an increased number of TAC changes (OR = 1.1, 95% CI, 1.0–1.3, *P* < .001) increased the risk of failed DPFC.VACM as the TAC (OR = 0.1, 95% CI, 0.0–0.3, *P* < .001) decreased the risk of failed DPFC as did AAA/RAAA (OR = 0.2, 95% CI, 0.1–0.7, *P* = .012) as reason for OA in comparison to SAP..

**Mortality**

The overall in-hospital mortality was 30% (205/676), and 143 (21%) patients died with OA. A Kaplan-Meier analysis, including all 676 patients, showed that patients treated with non-negative pressure systems showed disproportionate mortality within the first 3 days after laparostomy (see Fig. 2a). This was interpreted to be due to selection bias, manifesting in, for example, situations where a Bogota bag was selected as the first TAC method but was planned to be changed to a VAC or VACM system during the first TAC change, which never happened due to death. Thus, all patients who died within the first 3 days after laparostomy despite the TAC method ($N = 50$) were excluded from the further analyses for mortality.

In the remaining 626 patients, the groups of diagnoses leading to OA were tested in terms of mortality in a univariate analysis compared to SAP. Bowel ischemia associated with significantly poorer survival while ileus, fascial dehiscence, and trauma showed a significantly better outcome in comparison with SAP. Dysfunction in all 3 organ systems (the cardiac, respiratory, and renal systems) was shown to associate with increased mortality. Furthermore, increasing age also associated with mortality. VACM predicted decreased mortality in univariate analysis compared to a Bogota bag (see Table 3).

In low-volume centers (≤10 patients with OA/year) the mortality was 35% (46/133 patients) in comparison with large volume centers (>10 patients with OA/year) where there was a 22% (109/493 patients) mortality rate ($P = .003$). In univariate analysis, large annual patient volume associated with significantly decreased mortality (see Table 3).

A multivariate analysis on potential factors affecting mortality was performed, including all factors proven significant in univariate analyses. The analysis revealed 5 independent and significant predicting factors. 2 of these:  dysfunction in all 3 organ systems, and increasing age predicted increased mortality. On the other hand large annual patient volume and ileus or postoperative peritonitis as primary diagnoses leading to OA in comparison to SAP, significantly predicted reduced mortality (see Table 4). VACM showed a trend towards decreased mortality but did not quite reach significance.

A Kaplan-Meier analysis showed significantly better survival in patients treated with VACM in comparison with VAC or non-negative pressure methods (see Figure 2).

## Discussion

In this study we report an important role for negative pressure wound therapy with continuous fascial traction in terms of both primary fascial closure rate and survival after OA. The evidence for a VACM-associated improvement in the DPFC rate has been there since Petersson et al. described it in 2007.[9] On the contrary, the data on the potential role for VACM in mortality have so far been scarce. For VAC (without a mesh) the literature shows an association with lower mortality in comparison to TAC methods without topical negative pressure on the level of a meta-analysis.[11] That result was corroborated once again in this study.

Despite the development of treatment strategies, OA still remains a challenge. The intricate process begins with the critical decision-making about whether the patient would profit from laparostomy, which often associates with potentially crippling complications.[12–13] This nationwide study included both minor-volume and major-volume centers and revealed that in centers with over 10 OA patients per year, the mortality was significantly reduced. This implies that these complex patients mostly requiring ICU monitoring and the feasibility of reacting operatively 24/7 should be centralized in tertiary referral hospitals. Furthermore, after acute care and OA therapy, patients often require daily support in order to manage. In our study population only half of the surviving patients were discharged home, the other half were referred to a local communal health care unit for rehabilitation.

The 3 general reasons for leaving the abdomen open[14] were well represented in the current study, with 44% of the reasons being anatomical (loss of domain or intraoperative swelling), 31% being physiological (IAH/ACS), and 25% being logistical (planned relaparotomy or the second look procedure). If characterized accordingly, the fascial closure rate was poorest with anatomical indications (57%) and highest with logistical indications (75%), as presumed. These data are in line with those reported by Rezende-Neto, who furthermore showed a trend towards increased mortality and multiorgan failure in patients with physiological indications, although this was insignificant.[14] In our patient population, both the median duration of OA and median LOS were longer in patients with preoperative ACS. As previously known, the longer the OA management, the greater the risk for complications. This was also shown in this study as an association of a higher amount of medical complications and longer OA duration (20 d vs. 12 d, $P < .001$). Together these reports highlight the dangers of IAH/ACS.

The most common diagnosis leading to OA was AAA (17%) followed by SAP, fascial dehiscence, and peritonitis (each 12–15%). Only 6% of OA patients represented trauma. This is reflected in the results since overall survival has previously been shown to be significantly better and the complication rate lower in patients with trauma compared with non-trauma.[15–16] For patients with peritonitis, inconclusive results have been reported considering the benefits of OA.[17–19] In this study, patients with peritonitis did quite well, with a survival rate of 74% in comparison with patients with SAP (with a 65% rate) and RAAA (with a 61% rate). However, RAAA diagnosis was shown to have negative predictive value for failed DPFC, which assumedly represents the cleaner and less challenging status of the OA. Mortality was greatest among patients with bowel ischemia, of which only 42% survived.. This is in line with the poor outcome for these patients in an acute setting even without OA treatment.[20]

As previously presented, topical negative pressure combined with continuous fascial traction serves best as a temporary covering of the abdomen.[9, 21–22] This was again shown here with an over 30% difference in the fascial closure rate and a trend towards a shorter LOS for the benefit of VACM in comparison with other TAC methods. Patients treated with VACM as the TAC also presented fewer EAFs, which is in line with the observed predictive role of an EAF in failed DPFC. The power of VACM continues as it first leads to an improved DPFC rate and, further on, increases survival in comparison to other TAC methods. These data are in concordance with the 2018 World Society of Emergency Surgery (WSES) consensus statement that recommends negative pressure wound therapy with continuous fascial traction as the primary technique for TAC.[5]

This study has several limitations. First, its design is retrospective and observational. Also, the selection of a specific TAC method was made by the operating surgeon on the basis of the prevailing intra-operative circumstances and was uncontrolled. Additionally, the study period covers 7 years, during which time the management and treatment options of critically ill patients have evolved. This might have had an impact on the outcome.

In summary, this is the first multi-center study on OA management in Finland. Eight-year data (2009–2016) from all the university hospitals (tertiary referral centers) and 3 secondary referral centers were collected, leaving some secondary centers out of the sampling. According to these data, most OA patients are primarily treated in tertiary referral centers. They mostly represent critical illnesses with trauma only accounting for a minority of patients. The majority of these patients present with organ dysfunction and need ICU care during their index hospitalization. The most common TAC method used was VACM and the median OA duration matched the average reported in the literature, as did the overall rates of diagnosed complications and mortality.

We report a superior role for VACM methodology in terms of successful primary fascial closure and increased survival after OA. An EAF and multiple TAC changes were associated with failed DPFC. Dysfunction in all 3 vital organ systems and increasing age predicted decreased survival.

The authors declare no conflicts of interest.

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**Author Contribution**

Rasilainen, Suvi: literature search, study design, data collection, data analysis, data interpretation

Mentula, Panu: study design, data analysis, data interpretation, critical revision

Salminen, Paulina: data collection, critical revision

Koivukangas, Vesa: data collection, critical revision

Hyöty, Marja: critical revision

Mäntymäki, Leena-Maija: data collection, critical revision

Pinta, Tarja: data collection, critical revision

Haikonen, Jyrki: data collection, critical revision

Rintala, Jukka: data collection, critical revision

Rantanen, Tuomo: data collection, critical revision

Strander, Tapani: data collection

Leppäniemi, Ari: study design, data analysis, data interpretation, critical revision

**References**


1. Ivatury RR, Nallathambi M, Rao PM, Rohman M, Stahl WM. Open management of the septic abdomen: therapeutic and prognostic considerations based on APACHE II. *Crit Care Med*. 1989 Jun;17(6):511-7

2. Adkins AL, Robbins J, Villalba M, Bendick P, Shanley CJ. Open abdomen management of intra-abdominal sepsis. *Am Surg*. 2004 Feb;70(2):137-40

3. Regner JL, Kobayashi L, Coimbra R. Surgical strategies for management of the open abdomen. *World J Surg*. 2012 Mar;36(3):497-510

4. Björck M, Petersson U, Bjarnason T, Cheatham ML. Intra-abdominal hypertension and abdominal compartment syndrome in nontrauma surgical patients. *Am Surg*. 2011 Jul;77(Suppl 1):S62-6

5. Coccolini F, Roberts D, Ansaloni L, Ivatury R, Gamberini E, Kluger Y, Moore EE, Coimbra R, Kirkpatrick AW, Pereira BM et al. The open abdomen in trauma and non-trauma patients: WSES guidelines. *World J Emerg Surg*. 2018 Feb 2;13:7

6. Di Saverio S, Tarasconi A, Walczak DA, Cirocchi R, Mandrioli M, Birindelli A, Tugnoli G. Classification, prevention and management of entero-atmospheric fistula: a state-of-the-art review. *Langenbecks Arch Surg*. 2016 Feb;401(1):1-13

7. Goverman J, Yelon JA, Platz JJ, Singson RC, Turcinovic M. The "Fistula VAC," a technique for management of enterocutaneous fistulae arising within the open abdomen: report of 5 cases. *J Trauma*. 2006 Feb;60(2):428-31

8. Björck M, Kirkpatrick AW, Cheatham M, Kaplan M, Leppäniemi A, De Waele JJ. Amended Classification of the Open Abdomen. *Scand J Surg.* 2016 Mar;105(1):5-10

9. Rasilainen SK, Mentula PJ, Leppäniemi AK. Vacuum and mesh-mediated fascial traction for primary closure of the open abdomen in critically ill surgical patients. *Br J Surg.* 2012;99:1725-32

10. Petersson U, Acosta S, Björck M. Vacuum-assisted wound closure and mesh-mediated fascial traction – a novel technique for late closure of the open abdomen. *World J Surg*. 2007;31:2133-7

11. Ribeiro Junior MA, Barros EA, de Carvalho SM, Nascimento VP, Cruvinel Neto J, Fonseca AZ. Open abdomen in gastrointestinal surgery: Which technique is the best for temporary closure during damage control? *World J Gastroenterol Surg*. 2016 Aug; 27;8(8):590-7

12. Cristaudo AT1, Jennings SB, Hitos K, Gunnarsson R, DeCosta A. Treatments and other prognostic factors in the management of the open abdomen: A systematic review. *J Trauma Acute Care Surg*. 2017 Feb;82(2):407-18

13. Strang SG, Van Lieshout EM, Verhoeven RA, Van Waes OJ, Verhofstad MH, IAH-ACS Study Group. Recognition and management of intra-abdominal hypertension and abdominal compartment syndrome; a survey among Dutch surgeons. *Eur J Trauma Emerg Surg*. 2017 Feb;43(1):85-98.

14. Rezende-Neto J, Rice T, Abreu ES, Rotstein O, Rizoli S. Anatomical, physiological, and logistical indications for the open abdomen: a proposal for a new classification system. *World J Emerg Surg*. 2016 Jun;14;11:28.

15. Coccolini F, Biffl W, Catena F, Ceresoli M, Chiara O, Cimbanassi S, Fattori L, Leppaniemi A, Manfredi R, Montori G, et al. The open abdomen, indications, management and definitive closure. *World J Emerg Surg*. 2015 Jul;25;10:32

16. Sartelli M, Catena F, Di Saverio S, Ansaloni L, Malangoni M, Moore EE, Moore FA, Ivatury R, Coimbra R, Leppaniemi A, et al. Current concept of abdominal sepsis: WSES position paper. *World J Emerg Surg*. 2014 Mar 27;9(1):22.

17. Robledo FA, Luque-de-León E, Suárez R, Sánchez P, de-la-Fuente M, Vargas A, Mier J. Open versus closed management of the abdomen in the surgical treatment of severe secondary peritonitis: a randomized clinical trial. *Surg Infect*. 2007 Feb;8(1):63-72

18. Bleszynski MS, Chan T, Buczkowski AK. Open abdomen with negative pressure device vs primary abdominal closure for the management of surgical abdominal sepsis: a retrospective review. *Am J Surg*. 2016 May;211(5):926-32

19. Tolonen M, Mentula P, Sallinen V, Rasilainen S, Bäcklund M, Leppäniemi A. Open abdomen with vacuum-assisted wound closure and mesh-mediated fascial traction in patients with complicated diffuse secondary peritonitis: A single-center 8-year experience. *J Trauma Acute Care Surg*. 2017 Jun;82(6):1100-5

20. Lemma AN, Tolonen M, Vikatmaa P, Mentula P, Vikatmaa L, Kantonen I, Leppäniemi A, Sallinen V. Choice of first emergency room affects the fate of patients with acute mesenteric ischaemia: The importance of referral patterns and triage. *Eur J Vasc Endovasc Surg*. 2019 Jun;57(6):842-9

21. Seternes A, Fasting S, Klepstad P, Mo S, Dahl T, Björck M, Wibe A. Bedside dressing changes for open abdomen in the intensive care unit is safe and time and staff efficient. *Crit Care*. 2016 May;28;20(1):164.

22. Acosta S, Bjarnason T, Petersson U, Pålsson B, Wanhainen A, Svensson M, Djavani K, Björck M. Multicentre prospective study of fascial closure rate after open abdomen with vacuum and mesh-mediated fascial traction. *Br J Surg.* 2011;98:735-43

Figure Legends:

Figure 1

Abbreviations:

OA = open abdomen

Figure 2a

Abbreviations:

TAC = temporary abdominal closure

VAC= vacuum assisted closure

VACM = vacuum assisted closure with mesh-mediated fascial traction

Figure 2b

Abbreviations:

TAC = temporary abdominal closure

VAC= vacuum assisted closure

VACM = vacuum assisted closure with mesh-mediated fascial traction

Table 1. Patient characteristics, all patients ($N$ = 676)

| | | | |
|---|---|---|---|
| Age in years (mean, range) | 61 (18–93) | | |
| Sex (male, %) | 466 (69) | | |
| BMI (mean, range) | 28 (13–60) | | |
| | | *N* | % |
| Diagnosis | RAAA/AAA | 114 | 16.9 |
| | SAP | 102 | 15.1 |
| | Postoperative peritonitis | 95 | 14.1 |
| | Fascial dehiscense | 83 | 12.3 |
| | Peritonitis | 81 | 12 |
| | Visceral ischemia | 53 | 7.8 |
| | Trauma | 39 | 5.8 |
| | Ileus | 28 | 4.1 |
| | Hemorragia | 27 | 4 |
| | Other | 47 | 7 |
| | | | |
| | | *N* | % |
| Indication for OA | ACS | 164 | 24.3 |
| | IAH | 42 | 6.2 |
| | Inability to close the abdomen | 298 | 44.1 |
| | Prophylaxis | 169 | 25 |
| | | | |
| | | *N* | % |
| First abdominal closure method | A Bogota bag | 321 | 47.5 |
| | Commercial VAC | 133 | 19.7 |
| | VACM | 197 | 29.1 |
| | Other | 25 | 3.7 |
| | | | |
| | | *N* | % |
| Principal abdominal closure method | A Bogota bag | 128 | 18.9 |
| | Commercial VAC | 128 | 18.9 |
| | VACM | 398 | 58.9 |
| | Other | 22 | 3.3 |
| | | | |
| | | *N* | % |
| Organ dysfunction during hospital stay | Respiratory | 454 | 67.2 |
| | Cardiac | 452 | 66.9 |
| | Renal | 294 | 43.5 |

Abbreviations Table 1:

BMI = body mass index. RAAA/AAA = ruptured abdominal aortic aneurysm / abdominal aortic aneurysm, SAP = severe acute pancreatitis, OA = open abdomen, ACS = abdominal compartment syndrome, IAH = intra-abdominal hypertension, VAC = vacuum assisted closure, VACM = vacuum assisted closure with mesh-mediated fascial traction

Table 2. Univariate analysis of the risk factors for failed DPFC in patients who did not die with OA (*N* = 533)

| | | | 95% CI for the OR | |
|---|---|---|---|---|
| | Sig. (*P*) | OR | Lower | Upper |
| **EAF** | .001 | 5.746 | 3.186 | 10.366 |
| **Preop ACS** | .056 | 0.576 | 0.327 | 1.014 |
| **TAC** | | | | |
| Bogota bag | .001 | Reference | | |
| VAC | .274 | 0.707 | 0.380 | 1.316 |
| VACM | .001 | 0.116 | 0.062 | 0.216 |
| Other | .281 | 1.979 | 0.571 | 6.855 |
| ***N* of TAC changes** | .001 | 1.155 | 1.092 | 1.223 |
| **Diagnosis** | | | | |
| SAP | .01 | Reference | | |
| Peritonitis | .529 | 0.78 | 0.361 | 1.689 |
| Fascial dehiscence | .211 | 0.651 | 0.228 | 1.314 |
| AAA/RAAA | .000 | 0.121 | 0.039 | 0.376 |
| Peritonitis (secondary or postoperative) | .447 | 0.755 | 0.361 | 1.559 |
| Trauma | .041 | 0.296 | 0.092 | 0.953 |
| Ileus | .452 | 0.667 | 0.232 | 1.917 |
| Bowel ischemia | .998 | 0.000 | 0.000 | |
| Hemorrhage | .033 | 0.205 | 0.013 | 0.838 |
| Other | .030 | 0.276 | 0.086 | 0.883 |

Abbreviations Table 2:

DPFC = delayed primary fascial closure, EAF = enteroatmospheric fistula, BMI = body mass index, ACS = abdominal compartment syndrome, TAC = temporary abdominal closure, VAC = vacuum assisted closure, VACM = vacuum assisted closure with mesh-mediated fascial traction, N = number, SAP = severe acute pancreatitis, AAA/RAAA = abdominal aortic aneurysm / ruptured abdominal aortic aneurysm

Table 3. Univariate analysis of the risk factors for mortality in patients who did not die during the first 3 days after laparostomy (*N* = 626)

| | Sig.(*P*) | OR | 95% CI for the OR | |
|---|---|---|---|---|
| | | | Lower | Upper |
| **TAC** | | | | |
| Other (non-negative pressure system) | .002 | Ref. | | |
| VAC | .235 | 0.718 | 0.415 | 1.240 |
| VACM | .001 | 0.461 | 0.293 | 0.727 |
| **Diagnosis** | | | | |
| SAP | .000 | Ref. | | |
| Peritonitis | .296 | 0.695 | 0.351 | 1.376 |
| Postoperative peritonitis | .075 | 0.542 | 0.277 | 1.063 |
| AAA/RAAA | .905 | 1.037 | 0.570 | 1.886 |
| Fascial dehiscence | .013 | 0.388 | 0.183 | 0.822 |
| Trauma | .016 | 0.213 | 0.060 | 0.751 |
| Ileus | .047 | 0.275 | 0.077 | 0.985 |
| Bowel ischemia | .017 | 2.400 | 1.166 | 4.939 |
| Hemorrhage | .420 | 0.660 | 0.241 | 1.811 |
| Other | .164 | 0.533 | 0.220 | 1.292 |
| **Failure of ≥3 organs** | .000 | 2.364 | 1.603 | 3.484 |
| **Patient volume >10/year** | .001 | 0.523 | 0.358 | 0.763 |
| **EAF** | .075 | 1.615 | 0.952 | 2.737 |
| **Age** | | | | |
| Age 18–65 years | .000 | Ref. | | |
| Age 60–69 years | .001 | 2.336 | 1.429 | 3.819 |
| Age >70 years | .000 | 3.194 | 2.005 | 5.087 |

Abbreviations Table 3:

TAC = temporary abdominal closure, VAC = vacuum assisted closure, VACM = vacuum assisted closure with mesh-mediated fascial traction, SAP = severe acute pancreatitis, AAA/RAAA = abdominal aortic aneurysm / ruptured abdominal aortic aneurysm, EAF = enteroatmospheric fistula

Table 4. Multivariate analysis of the risk factors for mortality (using generalized linear mixed models) in patients who did not die during the first 3 days after laparostomy ($N$ = 626)

| | Sig. ($P$) | OR | 95% CI for OR | |
|---|---|---|---|---|
| | | | Lower | Upper |
| Intercept (hospital) | .001 | 0.417 | 0.319 | 0.544 |
| **Failure of ≥3 organs** | .001 | 2.414 | 1.616 | 3.605 |
| **Age** | | | | |
| Age >70 years | .001 | 4.463 | 2.049 | 9.717 |
| Age 60–69 years | .007 | 2.914 | 1.350 | 6.292 |
| Age 18–65 years | Reference | | | |
| **Diagnosis** | | | | |
| Other | .102 | 0.558 | 0.277 | 1.123 |
| Hemorrrhage | .239 | 0.558 | 0.211 | 1.475 |
| Bowel ischemia | .26 | 1.275 | 0.836 | 1.944 |
| Ileus | .001 | 0.192 | 0.089 | 0.41 |
| Trauma | .078 | 0.236 | 0.047 | 1.178 |
| Fascial dehiscence | .206 | 0.353 | 0.07 | 1.776 |
| AAA/RAAA | .082 | 0.61 | 0.35 | 1.065 |
| Postoperative peritonitis | .009 | 0.49 | 0.287 | 0.837 |
| Peritonitis | .055 | 0.524 | 0.271 | 1.013 |
| SAP | Reference | | | |
| **Patient volume >10/year** | .001 | 0.408 | 0.277 | 0.601 |
| **VACM** | .061 | 0.579 | 0.327 | 1.025 |

Abbreviations Table 4:

SAP = severe acute pancreatitis, VACM = vacuum assisted closure with mesh-mediated fascial traction, AAA/RAAA = abdominal aortic aneurysm / ruptured abdominal aortic aneurysm