

Temporary Closure of the Open Abdomen: A Systematic Review on Delayed Primary Fascial Closure in Patients with an Open Abdomen

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Abstract

Background This study was designed to systematically review the literature to assess which temporary abdominal closure (TAC) technique is associated with the highest delayed primary fascial closure (FC) rate. In some cases of abdominal trauma or infection, edema or packing precludes fascial closure after laparotomy. This “open abdomen” must then be temporarily closed. However, the FC rate varies between techniques.

Methods The Cochrane Register of Controlled Trials, MEDLINE, and EMBASE databases were searched until December 2007. References were checked for additional studies. Search criteria included (synonyms of) “open abdomen,” “fascial closure,” “vacuum,” “reapproximation,” and “ventral hernia.” Open abdomen was defined as “the inability to close the abdominal fascia after laparotomy.” Two reviewers independently extracted data from original articles by using a predefined checklist.

Results The search identified 154 abstracts of which 96 were considered relevant. No comparative studies were identified. After reading them, 51 articles, including 57 case series were included. The techniques described were vacuum-assisted closure (VAC; 8 series), vacuum pack (15 series), artificial burr (4 series), Mesh/sheet (16 series), zipper (7 series), silo (3 series), skin closure (2 series), dynamic retention sutures (DRS), and loose packing (1 series each). The highest FC rates were seen in the artificial burr (90%), DRS (85%), and VAC (60%). The lowest mortality rates were seen in the artificial burr (17%), VAC (18%), and DRS (23%).

Conclusions These results suggest that the artificial burr and the VAC are associated with the highest FC rates and the lowest mortality rates.

Introduction

At the end of most laparotomies, the abdominal fascia can be closed primarily. However, sometimes full fascial closure is not possible and the operating surgeon is forced to leave the abdomen open. The open abdomen is associated with mortality rates of >30% [1–4].

In general, three scenarios commonly result in the commencement of an open abdomen. In patients with peritonitis, the infection causes bowel edema. During laparotomy, the expansion of the bowel may force the surgeon to leave the abdomen open. The increased intra-abdominal pressure in patients with abdominal compartment syndrome (ACS) often requires a “decompressive laparotomy.” In severe cases, the intra-abdominal pressure persists after the laparotomy and the surgeon must leave the abdomen open. Many trauma patients with intra-abdominal bleeding require damage control

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surgery. This consists of rapid assessment of the injuries and control of bleeding by direct suture/ligation or gauze packing. As part of the damage control surgery, the abdomen may be left open or the bowel edema and/or the gauze packing may simply preclude full fascial closure in these patients.

The open abdomen requires temporary closure. Several techniques are available for this temporary abdominal closure (TAC) (Table 1) [5–12]. After temporary abdominal closure, the abdominal fascia must be closed primarily. The first goal is delayed primary fascial closure; however, many surgeons do not attempt primary fascial closure at all. Often, they use mesh and/or granulation tissue with split-thickness skin grafting to close the abdominal wound. In case of persistent visceral edema, loss of domain, or lateral retraction, the only option is to close the wound with mesh or granulation tissue with split-thickness skin grafting. In doing so, they create a “planned ventral hernia,” which can be corrected at a later stage.

All patients who do not receive delayed primary fascial closure are at risk of developing a ventral hernia. These ventral hernias (whether planned or unplanned) may cause a considerable burden. Although surgical correction of a ventral hernia is possible, recovery frequently takes several

months. Furthermore, reconstructive surgery, like all abdominal surgery, has a risk of mortality. The surgeon must take these burdens and risks into account when he chooses the strategy for TAC or permanent abdominal closure. However, there have been no (randomized) comparative trials on the effect of the TAC strategy on the delayed primary fascial closure rate. Furthermore, it is unknown what factors influence the delayed primary fascial closure rate.

This study was designed to systematically review the literature on temporary closure of the open abdomen to assess which TAC technique is associated with the highest delayed primary fascial closure rates.

Materials and methods

The authors searched the Cochrane Database of systematic reviews, the Cochrane central register of controlled trials, and MEDLINE databases using keywords related to open abdominal treatment (Table 2). In addition, they hand-searched electronic links to related articles and references of selected articles. The search period started in 1966 and extended until December 2007. They did not search

Table 1 Overview and characteristics of the temporary abdominal closure (TAC) techniques

Technique	Description	Mechanism
Vacuum-assisted closure (VAC™)	A perforated plastic sheet covers the viscera and a sponge is placed between the fascial edges. The wound is covered by an airtight seal, which is pierced by a suction drain that is connected to a suction pump and fluid collection system.	The (active and adjustable) negative pressure supplied by the pump keeps constant tension on the fascial edges while it collects excess abdominal fluid and helps to resolve edema.
Vacuum pack	A perforated plastic sheet covers the viscera, damp surgical towels are placed in the wound, and a surgical drain is placed on the towels. An airtight seal covers the wound and negative pressure is applied through the drain.	The negative pressure keeps constant tension on the fascial edges and excess fluid is collected.
Artificial burr (Wittmann patch)	Two opposite Velcro sheets (hooks and loops, one on each side) are sutured to the fascial edges. The Velcro sheets connect in the middle.	This technique allows for easy access and stepwise reapproximation of the fascial edges.
Dynamic retention sutures	The viscera are covered with a sheet (e.g., ISODrape™). Horizontal sutures are placed through a large-diameter catheter and through entire abdominal wall on both sides.	The sutures keep tension on the fascia and may be tightened to allow staged reapproximation of the fascial edges. May be combined with a vacuum system.
Plastic silo (Bogotá bag)	A sterile X-ray film cassette bag or sterile 3-L urology irrigation bag is sutured between the fascial edges or the skin and opened in the middle.	An easy technique that allows for easy access. The bag may be reduced in size to approximate the fascial edges.
Mesh/sheet	An absorbable or nonabsorbable mesh or sheet is sutured between the fascial edges. Examples are Dexon™ mesh, Marlex™ mesh, and Vicryl™ mesh. Examples of sheets are Silastic™ or silicone sheets.	The mesh or sheet may be reduced in size to allow for reapproximation. Nonresorbable meshes may be removed or left in place at the end of the open abdominal period.
Loose packing	The fascial defect is covered by standard wound dressing only.	This technique is simple but does not prevent fascial retraction.
Skin approximation	The skin is closed over the fascial defect with towel clips or a running suture.	Skin provides a “natural cover” for the viscera, but the towel clips obstruct radiological imaging and do not prevent fascial retraction.
Zipper	A mesh or sheet with a sterilized zipper is sutured between the fascial edges.	This technique is comparable to the mesh/sheet and allows for easy access.

Table 2 Search terms, as used in the systematic review

Search terms	
MeSH	Not used
Free text words	(Open abdomen OR laparostomy OR open peritoneal cavity OR celiotomy OR open management abdomen OR abdominal wall defect OR open abdominal wound) AND (VAC OR V.A.C. OR vacuum OR closure OR reapproximation OR re-approximation OR fascial closure OR ventral hernia OR temporary abdominal closure OR bogota bag OR fascial dehiscence)
Field	All fields
Limits	None

MeSH medical subject headings

journals and conference proceedings by hand. The search was not restricted to any language; however, in the systematic review only studies published in English, German, or Dutch were reviewed.

Study selection and data extraction

The authors included all original articles on open abdominal treatment that mentioned a delayed primary fascial closure rate. The definition of open abdominal treatment included “the inability to close the abdominal fascia after laparotomy.” Exclusion criteria were: reviews, series of less than five patients, nonconsecutive inclusion period, series with subcostal incisions, and multiple TAC techniques in the same study population. Two investigators (PBvH, JW) independently extracted data from the original studies using a preformatted sheet. These data included the inclusion period, number of patients, underlying condition, age, sex, Injury Severity Score (ISS) [13], and APACHE (Acute Physical and Chronic Health Evaluation) II [14]. Other collected data included TAC technique, mortality, complications (i.e., abscesses, fistulae), and number of surgical interventions until final closure, duration of TAC, intensive care unit stay, length of hospital stay, percentage of delayed primary fascial closure, permanent abdominal closure, planned ventral hernias, and length of follow-up.

The two investigators critically appraised each selected study by using a modified form as proposed by the Dutch Cochrane Collaboration [15]. In case of retrospective analysis of data collected prospectively, a study was defined as prospective. Final inclusion was done after consensus was reached. The investigators resolved the discrepancies in judgment by discussion. In case an article described separate series with specific patient groups (underlying conditions or TAC techniques), each series was assessed separately. The authors contacted the corresponding authors of articles in case some of the reported data were unclear. They did not contact all corresponding authors to retrieve all missing data.

Analysis and presentation of data

The authors analyzed the data per technique. They calculated the delayed primary fascial closure rate by dividing the number of patients with delayed fascial closure by the total number of included patients. They pooled the percentages of delayed primary fascial closure, male patients, fistulae and abscesses, and the median age per TAC technique. The concerning percentages were weighted for study size (1/variance). For calculating the mortality rate, only the in-hospital mortality was considered.

Results

Included studies

The searches identified 1,493 articles. Based on the title, 154 articles remained. After reading the abstracts, the authors excluded 58 articles because they did not meet the inclusion criteria. Five of these abstracts were excluded because the articles were written in Chinese, Norwegian, French (all once), or Russian (2 articles). The authors considered 96 abstracts relevant and obtained the complete articles. Of these, another 45 articles did not meet the inclusion criteria. The remaining 51 articles were included in this review [1–9, 11, 12, 16–55]. These articles were published between 1981 and 2007. There were no randomized, controlled trials or other comparative studies. The 51 included articles described 57 case series with 3,169 patients. The inclusion periods ranged from 6 to 168 (median, 48) months.

Patients

Nineteen series described trauma patients only [5, 8, 9, 17, 18, 21–23, 29, 32, 36–40, 47, 51, 55], and an additional 16 series described trauma, vascular surgery, and general surgical patients [2, 11, 24–28, 33, 34, 43, 44, 48–50]. Eight series described peritonitis patients only [6, 7, 12, 19, 20, 35, 45, 54], and three described vascular patients only [16, 18, 42]. The remaining 11 series described general surgical, peritonitis, pancreatitis, and vascular patients [1, 3, 4, 18, 21, 30, 31, 41, 46, 52, 53].

Forty series (70%) described the sex distribution. The percentage of male patients ranged from 62–94%. Forty-four series (77%) reported the age. The median age for these series was 40.1 (range, 29.5–75) years. The ISS was reported in 23 series (39%). Nineteen series reported the mean ISS (instead of the median ISS) despite the small numbers of patients and the fact that the ISS is not a continuous variable. The reported mean ISS ranged from 20.3 to 30.5. Only two series reported the median ISS (41 and 30.5). The APACHE-II score was reported in 13 series

only (22%). Eight of these series reported the mean APACHE II despite the small numbers of patients and the fact that the APACHE II is not a continuous variable. The reported mean APACHE II ranged from 17.8 to 24.7. Five series reported the median APACHE II. The reported median APACHE II in these series ranged from 19 to 29.5.

Temporary closure techniques described

The VAC technique was applied in eight series (Table 3) [3, 24, 25, 34, 37, 41, 47, 48]. The vacuum pack has been described in 15 series (Table 3) [5, 18, 20–22, 28, 38, 40, 44, 46, 51, 53]. Four series described the artificial burr (Table 3) [1, 12, 17, 29]. Sixteen series described meshes or sheets (Table 4) [8, 9, 11, 16, 23, 27, 32, 35, 36, 39, 42, 43, 49, 50, 54, 55]. Zippers were used in seven series

(Table 4) [4, 6, 19, 30, 31, 45, 52]. The silo was used in three series [2, 7, 11], and skin only in two series [9, 11]. Loose packing and dynamic retention sutures were each used in one series (Table 4) [26, 33].

Fascial closure

The artificial burr (90%), the dynamic retention sutures (85%), and the VAC (60%) showed the highest weighted pooled fascial closure rates (Table 3). The weighted closure rates in the other techniques ranged from 11% in the one series with skin-only closure to 52% in the vacuum-pack series. When calculated per etiology, the closure rate was 65% in the 19 trauma-only series, 50% in the 7 peritonitis-only series, 1% in the ACS-only series, and 43% in the vascular-only series.

Table 3 VAC, vacuum pack, and artificial burr series

Technique	Author	Year	Inclusion	Group	No. of patients	Mortality (%)	Closure (%)
VAC	Stonerock	2003	Retrospective	Tr; Gs	15	7	67
	Miller	2004	Prospective	Tr	53	15	72
	Stone	2004	–	Tr	48	33	54
	Labler	2005	–	Tr; ACS; Pt	18	28	67
	DeFranzo	2006	Retrospective	Tr; Pt; CS; Gs; Om	30	10	33
	Cothren	2006	Retrospective	Tr; ACS	14	7	100
	Oetting	2006	–	Pt; ACS; NF	36	22	72
	Perez	2007	Prospective	Pt; ACS	37	38	35
Vacuum pack	Brock	1995	Retrospective	Mi; RAAA; Pc	11	36	18
	Brock	1995	Retrospective	Tr	17	35	71
	Smith	1997	Retrospective	Pc; Mi, CD	38	42	55
	Sherck	1998	Retrospective	Tr; Pt; Mi; Pc; Bl	50	36	68
	Barker	2000	Retrospective	Tr	112	26	55
	Bosscha	2000	Retrospective	Pt	67	42	28
	Foy	2003	Retrospective	Tr; Pt; AAA	134	38	47
	Navsaria	2003	Retrospective	Tr	55	45	29
	Chavarria-Aguilar	2004	Retrospective	Tr	29	10	76
	Miller	2005	Retrospective	Tr	344	20	52
	Barker	2007	Retrospective	GS	120	23	61
	Barker	2007	Retrospective	Va	22	41	64
	Barker	2007	Retrospective	Tr	116	26	58
	van As	2007	–	Tr	60	42	27
	Wilde	2007	Prospective	Pt; Mi; Bl	11	0	91
Artificial burr	Aprahamian	1990	Prospective	Tr	20	20	75
	Wittmann	2000	–	Pt	128	19	93
	Hadeed	2007	Retrospective	Tr	26	8	77
	Keramati	2007	–	ACS	6	67	33

(R) AAA (ruptured) abdominal aortic aneurysm, ACS abdominal compartment syndrome, Bl bleeding, CD Crohn's disease, GS general surgery, Gs gastroschisis, Mi mesenteric ischemia, Om omphalocele, NF necrotizing fasciitis, Pc pancreatitis, Pt peritonitis, Tr = trauma, Va vascular – missing

Table 4 Mesh/sheet, zipper, silo, skin only, loose packing, and dynamic retention sutures series

Technique	Author	Year	Inclusion	Group	No. of patients	Mortality (%)	Closure (%)
Mesh/sheet	Wouters	1983		Pt	20	20	75
	Akers	1991	–	Va	6	50	67
	Smith	1992	–	Tr	5	20	20
	Cohn	1995	Retrospective	Tr	14	29	64
	Fansler	1995	Retrospective	Tr; GS; Pc	26	12	15
	Nagy	1996	Retrospective	Tr	25	30	40
	Yeh	1996	Retrospective	Tr	36	28	22
	Losanoff	1997	–	Pt	19	21	79
	Sugrue	1998	Prospective	Tr; Pt; GS; Va	49	43	33
	Töns	2000	–	Tr; Pt; IL; Mi	377	21	18
	Tremblay	2001	Retrospective	Tr; Bl; Pc; Mi	12	33	8
	Rasmussen	2002	Retrospective	AAA	45	56	31
	Schachtrupp	2002	–	Tr; Pt; Mi; ACS	40	20	58
	Jernigan	2003	–	Tr	274	43	14
	Howdieshell	2004	–	Tr	88	19	27
	Mayberry	2004	Retrospective	Tr	140	17	31
Zipper	Cuesta	1991	Retrospective	Pt	7	29	0
	Bose	1991	Retrospective	Pt	5	60	20
	Hannon	1992	–	Pt; Mi	8	0	100
	Singh	1993	–	Pt	8	25	38
	Hubens	1994	–	Pt; NEC; Pc	23	39	35
	Goor, van	1997	Retrospective	Pt; Mi	24	29	54
	Zingales	2001	Retrospective	Pt; Pc; IC; Pi	60	38	20
	Doyon	2001	Retrospective	Pt	17	18	82
Silo	Tremblay	2001	Retrospective	Tr; Bl; Pc; Mi	75	53	17
	Kushimoto	2007	Retrospective	Tr; NT	17	31	29
Skin only	Smith	1992	–	Tr	8	25	75
	Tremblay	2001	Retrospective	Tr; Bl; Pc; Mi	93	40	40
Loose packing	Duff	1981	Retrospective	Tr; Pt	18	39	11
Dynamic retention sutures	Koniaris	2001	Retrospective	Tr; Pt; IL; AAA; ACS; Pc	13	23	85

AAA (ruptured) abdominal aortic aneurysm, ACS abdominal compartment syndrome, GS general surgery, Mi mesenterial ischemia, Pc pancreatitis, Pt peritonitis, Tr trauma, Va vascular

– missing

Fistulae and abscesses

Forty-four series (77%) reported the occurrence of fistulae as a complication of TAC. Twenty-nine series (51%) reported the number of abscesses. Table 5 lists the weighted rates of fistulae and abscesses for the different techniques.

Mortality

The weighted mortality rate for all techniques was 26% (95% confidence interval (CI), 24–27). The silo (41%), skin only (39%), and loose packing (39%) showed the

highest weighted mortality rates. The artificial burr series (17%) and the VAC (18%) showed the lowest overall mortality rates (Table 4).

Discussion

Scientific question

In this systematic review on the treatment of the open abdomen, the highest weighted delayed primary fascial closure rates were seen in the series with the artificial burr or VAC. Dynamic retention sutures, although described in

Table 5 Weighted percentages of male patients, abscesses, fistulae, mortality, and primary delayed fascial closure as well as median age per temporary abdominal closure technique

Case series	n	Patients		Male patients		Age (yr)		Fistulae		Abscesses		Mortality		Closure		
		n	%	(95% CI)	Median	(Range)	%	(95% CI)	%	(95% CI)	n	%	(95% CI)	n	%	(95% CI)
VAC	8	251	68	(60–77)	41	(35–65)	2.9	(0.7–5.1)	2.6	(0.2–5)	56	18	(13–22)	149	60	(54–66)
Vacuum pack	15	1186	70	(67–72)	42.5	(32–62)	5.7	(4.3–7)	4.1	(2.9–5.3)	340	27	(24–29)	611	52	(49–54)
Artificial burr	4	180	94	(87–100)	34	(30–43)	2	(–0.1 to 4.1)	3.0	(–1.9 to 7.9)	34	17	(12–23)	156	90	(86–95)
DRS	1	13	62		50		NR		NR		3	23		11	85	
Silo	3	109	74	(65–83)	43.9	(40–48)	0		6		48	41	(32–51)	32	29	(20–37)
Mesh/sheet	16	1176	80	(78–83)	37	(31–75)	5.5	(3.6–6.7)	2.1	(0.7–3.6)	334	26	(23–28)	293	23	(20–25)
Loose packing	1	18	NR		NR		28		NR		7	39		2	11	
Skin only	2	101	90	(84–96)	36.1	(32–40)	NR		NR		39	39	(29–48)	43	43	(34–53)
Zipper	7	135	72	(64–80)	46	(32–64)	13.8	(7.6–20)	5.8	(–2.7 to 14.3)	46	33	(25–41)	45	39	(31–47)

CI confidence interval, NR not reported

The series reported only the mean age, therefore, this table lists the median values over the reported mean age in the series; all percentages are weighted for study size

only one series, also showed a high rate of delayed primary fascial closure.

Included series

The included studies were generally retrospective chart reviews and not comparative trials. Furthermore, most articles revealed little information about their methodology. Many studies suffered from considerable bias in both patient and treatment selection. Instead of using predefined criteria, patient and treatment selection were usually left to the discretion of the operating surgeon. Furthermore, the authors did not explain the rationale behind it. The articles infrequently reported on scoring systems that reflect the severity of the underlying condition (e.g., APACHE II and ISS). Therefore, the authors of this review were unable to assess the influence of the severity of the underlying condition.

Some techniques were used in only one series (dynamic retention sutures and loose packing) with less than 20 patients per series. Because this was not one of the predefined exclusion criteria, the authors choose not to exclude them. Furthermore, the authors considered it important to describe all TAC techniques. However, the results of these single and small series should be put into perspective.

Patient characteristics

Overall, the majority of patients were men. This could partly be explained by the high percentage of male patients in the series with trauma patients [5, 18, 38]. However, even the series without trauma patients showed high percentages of male patients [4, 18, 52]. The authors did not find a reason for this difference in the current literature on peritonitis or pancreatitis.

Temporary abdominal closure

Although the authors categorized the techniques in this review, the techniques were not standardized. Therefore, an unknown amount of practice variation for each technique remains. Subdivision of the series per patient group and technique resulted in small numbers of patients and heterogeneous results and was omitted.

The availability and preference for techniques seems to have evolved during the past 30 years. At present, vacuum-based techniques seem to be popular because 85% of the studies published since 1998 describe a vacuum technique.

Fascial closure

For the purpose of this study, the authors pooled the results per technique. The artificial burr, VAC, and dynamic

retention sutures seemed to produce the highest rates of delayed primary fascial closure. These techniques might simply have been superior to the other techniques. However, little information was available on the severity of the underlying condition. Therefore, the higher closure rates might have been due to less severe disease (inclusion bias). An indication for this could be the low mortality rates in these series; however, this remains speculation.

As mentioned in *Materials and methods*, the authors calculated the delayed primary fascial closure rate for all included patients. This was done because the moment of death (before or after closure) often was not recorded. However, it is likely that many patients died before closure [32]. Therefore, the delayed fascial closure rate of the survivors might have been higher than the rates reported above. This applies to all TAC techniques.

Some techniques were used in hundreds of patients, whereas others were used in less than 20 patients. Although the authors considered this by weighing the rates of delayed fascial closure rate and mortality, the reliability of the weighted estimate of fascial closure per series differs.

Fistulae and abscesses

Fistulae and abscesses were the most consistently reported complications. However, the reported rates may be underestimated because, in retrospective chart reviews, complications may be difficult to identify.

Like the fascial closure, the fistulae and abscesses could have been the result of initial peritoneal contamination rather than a function of the TAC technique. Furthermore, a higher likelihood of fistulae or abscesses might have influenced the choice of technique (inclusion bias). Again, this remains speculation.

Mortality

All series reported a mortality rate. Despite the high overall mortality, two series reported no mortality. This is most likely the result of inclusion bias and the small number of patients in these series (8 and 11 patients). The four techniques with the highest delayed fascial closure rates also showed the lowest mortality rates.

Limitations

This systematic review suffers from an unknown but presumably large amount of inclusion bias and lack of standardization of techniques. Therefore, it cannot be determined whether the fascial closure rate and mortality shown in this review are the result of the TAC technique, the severity of the underlying condition, or other factors not included in the retrospective studies. These issues stress

that, although this is the strongest evidence in this field of surgery, the conclusions that can be drawn from this systematic review are limited.

Conclusions

The results of this review may suggest that the artificial burr and the VAC are associated with the highest closure rates as well as the lowest mortality rates (level IV evidence) [56].

The lack of high-quality comparative data underlines the need for randomized, clinical trials in this field. The authors realize that a randomized, clinical trial in this rare condition may be difficult to conduct.

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