



Blurring the boundary between open abdomen treatment and ventral hernia repair

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Received: 26 March 2018 / Accepted: 23 January 2019 / Published online: 7 February 2019
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Abstract

Purpose Therapeutic approaches for septic open abdomen treatment remain a major challenge with many uncertainties. The most convincing method is vacuum-assisted wound closure with mesh-mediated fascia traction with a protective plastic sheet placed on the viscera. As this plastic sheet and the mesh must be removed before final fascial closure, such a technique only allows temporary abdominal closure. This retrospective study analyzes the results of a modification of this technique allowing final abdominal closure using an anti-adhesive permeable polyvinylidene fluoride (PVDF) mesh.

Methods The outcome of all consecutive patients with septic open abdomen treatment at one academic surgical department from January 2013 to June 2015 was retrospectively analyzed.

Results Retrospectively, 57 severely ill consecutive patients with septic open abdomen treatment with a 30-day mortality of 26% and a 2-year mortality of 51% were included in the study. In 26 patients, no mesh was implanted; in 31 patients, mesh implantation was done at median third-look laparotomy, median 5 days postoperative. Re-laparotomies after mesh implantation (median $n = 2$) revealed anastomotic leakage in 16% but no new bowel fistula. In 40% of those patients who had mesh implantation, fascia closure was not achieved and the mesh was left in place in a bridging position avoiding planned ventral hernia.

Conclusion The application of an anti-adhesive PVDF mesh for fascia traction in vacuum-assisted wound closure of septic open abdomen is novel, versatile, and seems to be safe. It offers the highly relevant possibility for provisional and final abdominal closure.

Keywords Abdominal sepsis · Open abdomen treatment · Vacuum-assisted wound closure · Mesh-mediated fascia traction · Bridging mesh

Introduction

Abdominal sepsis represents the second most common form of sepsis [1] with a persisting high mortality rate of about 33% [2]. Most patients with abdominal sepsis can be managed with early antibiotic therapy, one single laparotomy with efficient source control, modern intensive care and on-demand second laparotomy [2–4]. However, open abdomen treatment remains an important bailout procedure in those patients with severe abdominal sepsis associated with organ dysfunction with

generalized peritonitis, with consecutive severe intestinal edema or abdominal compartment syndrome [5, 6]. In general, the abdomen is closed as soon as the source of the abdominal sepsis is under control and the peritonitis has resolved.

Great improvements have been made in provisional closure of open abdomen. Traditionally, the open abdomen was closed by loose packing with surgery towels [7–9]. Retention sutures of the fascia or polypropylene meshes sutured to the fascia were then used to avoid the common problem of fascia retraction [9, 10]. Zippers or Velcro sheets were added to this technique to facilitate further laparotomies [11]. Then the vacuum-dressing system combined with a protective plastic sheet was adopted for provisional closure of open abdomen and for optimal drainage of abdominal fluid [12–15] and became the standard surgical technique for open abdomen treatment [16]. To minimize fascia retraction, the vacuum dressings often were combined with mesh [17] or dynamic suture-

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mediated traction [17–20]. In vacuum-assisted wound closure with mesh-mediated fascia traction, a protective plastic sheet is placed below a polypropylene mesh to avoid bowel injury or fistula induced by vacuum dressing, and to avoid adhesions between the bowel and the abdominal wall or mesh [17, 20, 21]. As this plastic sheet must be removed before final fascial closure, this technique only allows temporary abdominal closure. Indeed, in a randomized study including patients with abdominal sepsis, a polypropylene mesh used in a bridging position between the fascia edges without such a plastic sheet was conducted and had to be stopped after the first interim analysis due to a high mortality rate of 55% compared with 30% in the group with primary closure without a mesh [22].

Contrary to traumatic open abdomen treatment, the fascia closure rates in septic open abdomen treatment remain disappointing, in particular in patients with protracted critical illness and retracted fascia edges [13, 15, 19, 23–25]. Although component separation or anterior rectus sheath turnover techniques show promising results in this setting [24, 26], planned ventral hernia remains the only bailout in a considerable amount of patients (12–62%) [13, 15, 19, 23–25].

We present a modified vacuum-assisted wound closure with mesh-mediated fascia traction technique offering the highly relevant possibility for provisional and final abdominal closure by replacing the polypropylene mesh with an anti-adhesive polyvinylidene fluoride (PVDF) mesh.

Methods

Retrospectively, the outcome of all patients with septic open abdomen treatment at one academic surgical department from January 2013 to June 2015 was analyzed. Temporary abdominal closure in open abdomen treatment for severe abdominal sepsis was done with an abdominal vacuum dressing and a protective plastic sheet. Based on extent and type of peritonitis, intestinal edema, and fascia tension, the surgeon-in-charge decided at every further re-look laparotomy if primary closure of the fascia was feasible or not. If no primary closure of the fascia was foreseeable within a useful period, mesh implantation was done.

Primary fascia closure was done with at least two late-absorbable monofilament polydioxanone loop threads (PDS II size 1; Ethicon™ by Johnson & Johnson™, New Brunswick, NJ, USA). The stitching technique consisted of a single-layer continuous suture technique by picking up the peritoneum, the posterior rectus sheath, the rectus muscle, and the anterior rectus sheath.

Mesh implantation was done by suturing an anti-adhesive PVDF mesh to the fascia edges typically with four threads (Prolene, size 1, Ethicon™ by Johnson & Johnson™, New Brunswick, NJ, USA) to provide continuous fascial traction. A polyurethane sponge was placed on the mesh and covered

by occlusive sheets allowing for the application of continuous negative pressure by a suction device. At the following laparotomies, the PVDF mesh was cut in the midline and contracted with a suture (typically Prolene, size 1). If fascia closure was done as described above, the mesh was explanted prior to fascia closure and the fascia was closed as described above with two late-absorbable monofilament polydioxanone loop threads with mesh reinforcement in a sublay position or without mesh reinforcement [27]. If no final fascia closure could be achieved, the PVDF mesh was left in situ without a protective plastic sheet in a bridging position avoiding planned ventral hernia repair. The technique is depicted in Fig. 1.

Results

Fifty-seven patients with septic open abdomen treatment from January 2013 to June 2015 were identified. Most patients were in a severe health condition with a median ASA (American Society of Anesthesiologists) score of 4. Four patients died within 72 h. The patient characteristics are shown in Table 1. More than two thirds of the patients suffered from bowel perforation or anastomotic leakage as the underlying septic focus and various surgical procedures were performed, according to the underlying diseases. The index operations and the detailed underlying septic diseases are shown in Table 2. In 26 patients, no mesh was used. In 31 patients, an anti-adhesive PVDF mesh was implanted at median postoperative day 5 (range 0–25) and at the median third look laparotomy (range 1–13). The median number of further abdominal explorations after mesh implantation was 2 (range 0–9).

Complete fascial closure was achieved in 66% (35/57) of all patients included in the study. Complete fascial closure was

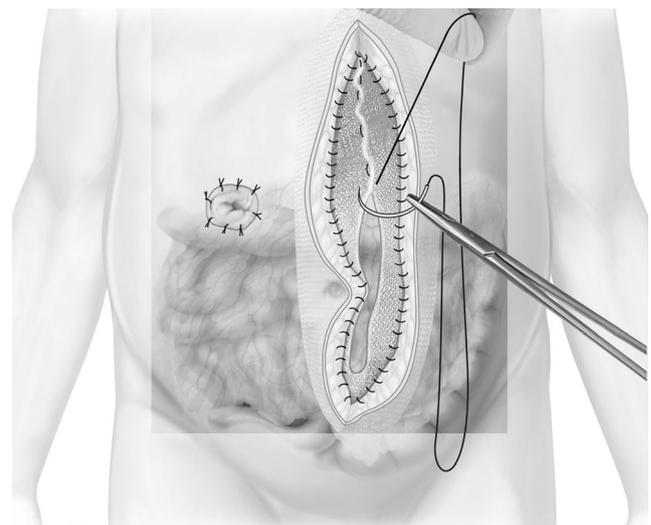


Fig. 1 Operative situs during contraction of a polyvinylidene fluoride mesh in open abdomen treatment prior to vacuum dressing

Table 1 Patient characteristics

Total number of patients with septic open abdomen treatment	Overall <i>n</i> = 57	Bridging mesh <i>n</i> = 31	No mesh <i>n</i> = 26
Male gender	63% (<i>n</i> = 36)	65% (<i>n</i> = 20)	62% (<i>n</i> = 16)
Median age in years (range)	63 (20–87)	58 (20–87)	65 (39–86)
Median ASA ⁺ score (range)	4 (2–5)	4 (2–5)	4 (2–5)
Death within 72 h	7% (<i>n</i> = 4)	3% (<i>n</i> = 1)	12% (<i>n</i> = 3)

⁺ American Society of Anesthesiologists

achieved in 65% (17/26) of the patients without a mesh and in 58% (18/31) of the patients with a mesh. In the remaining 42% (13/31) of patients with a mesh, the anti-adhesive mesh was left in place in a bridging position as final abdominal closure avoiding planned ventral hernia. An overview of the study is depicted in Fig. 2.

Anastomotic leakage after mesh implantation occurred in 5 patients (16%) but no new bowel fistula occurred. Overall, thirty-day mortality rate was 26% (15/57). At 2 years postoperative, 4 patients were lost to follow-up. The follow-up rate was 93%. The 1-year mortality rate was 51% (27/53), and the 2-year mortality rate was 58% (31/53). According to the medical records, the overall hernia incidence rate in living patients was 27% (6/22) at 2 years follow-up.

Discussion

Most patients with abdominal sepsis can be successfully managed with one single laparotomy and modern perioperative treatment [2–4]. To optimize the treatment of those patients with severe abdominal sepsis, several goals must be reached. First, the underlying disease needs optimal control with as few re-laparotomies as possible [3, 28]. Second, the right time to start open abdomen treatment should not be missed [3, 5].

Third, the optimal abdominal closure technique with the least side effects and highest fascial closure rate must be applied.

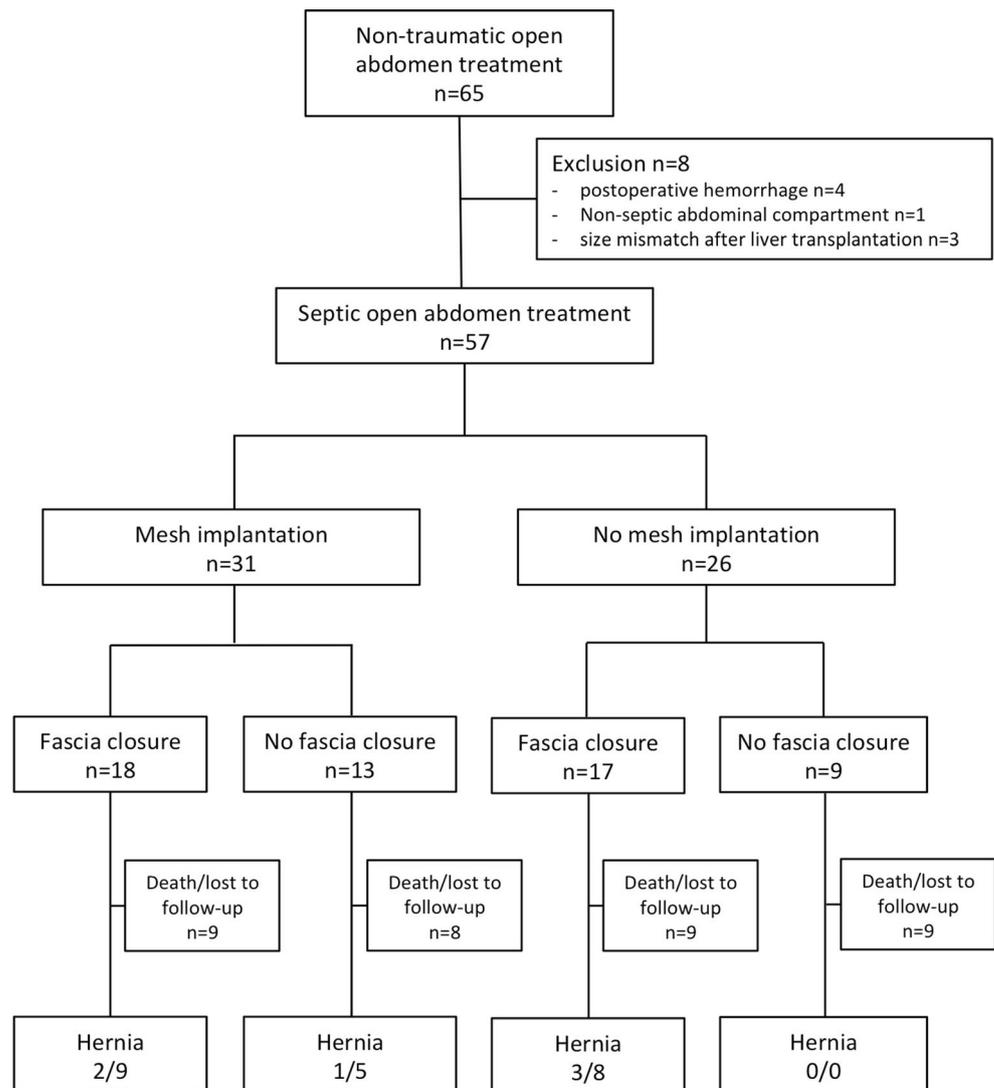
Great improvements have been made in the techniques of temporary abdominal closure in open abdomen treatment in the past few years resulting in vacuum-assisted wound closure with mesh-mediated fascia traction with a protective plastic sheet as the most promising technique today [17, 21]. However, the reported rates of patients without possible fascia closure remain unacceptably high, especially in patients with abdominal sepsis (12–62%) [13, 15, 19, 21, 24, 25, 29], resulting in high rates of patients with planned ventral hernia. These rates might even be higher in patients outside study conditions.

To improve fascia closure rates different techniques have been developed. One promising method is to open the rectal sheath at the second look and to place the mesh during open abdomen treatment in a retromuscular position leaving a stripe at the end to enforce the midline suture [23]. Another possibility is to perform complex abdominal wall reconstruction for abdominal wall closure. This can include components separation techniques [24]. A further technique to reduce tension and to allow fascia closure is to perform bilateral anterior rectus abdominis sheath turnover flaps [24, 26]. This technique can also be combined with mesh enforcement [30]. However, it has to

Table 2 Index surgery combined with open abdomen treatment and underlying main focus for peritonitis

	Bridging mesh (<i>n</i> = 31)	No mesh (<i>n</i> = 26)
Partial gastrectomy or suture for gastric perforation/ischemia	3	1
Suture for duodenal perforation	1	5
Hepatobiliary redo-surgery for postoperative bile leak	4	0
Pancreatic surgery for pancreatic fistula/necrotizing pancreatitis	3	5
Surgery for small bowel perforation/ischemia/anastomotic leakage	7	5
Appendectomy for perforated appendicitis	0	1
Discontinuity right-sided/transverse large bowel resection for colon perforation/ischemia	6	5
Discontinuity left-sided large bowel resection for colon perforation/-ischemia	3	4
Discontinuity left-sided large bowel resection for anastomotic leakage	2	0
Laparotomy for peritonitis after urinary leakage	1	0
Laparotomy for peritonitis in septic gonarthrosis	1	0

Fig. 2 Overview of the study methodology



be kept in mind, that abdominal wall reconstruction can be avoided in the majority of patients [31]. If performed too early, the results seem to be poorer than if performed at the time point of delayed fascia closure [24].

We tackled the problem differently, by extending the standard technique of temporary abdominal closure in open abdomen treatment. By using an anti-adhesive mesh instead of the polypropylene mesh/protective plastic sheet, the mesh could be left in place (in a bridging position) in those patients without possible fascia closure. Hereby, planned ventral hernia was avoided in a remarkable number of patients.

In our experience, this technique has no disadvantage if delayed fascial closure is possible without mesh enforcement. However, if fascia closure is not possible, it offers a tailored and versatile treatment and it avoids operative burden for the severely ill patient. Furthermore, the surgical planes used for abdominal wall reconstruction remain untouched. An

important advantage, if ventral hernia repair is required in the later course.

We performed an institutional review to look at the outcome of all consecutive patients treated from January 2013 to June 2015 with this novel technique at our institution. Various underlying sources of abdominal sepsis were identified (see Table 2). The anastomotic leakage/fistulation rate after mesh implantation was 16%. Reported fistulation rates from other retrospective series in literature are 1.2%–20% [24, 31, 32]. The fascia closure rate was 61% in the present cohort of patients. Other groups report fascia closure rates in patients with open abdomen treatment for abdominal sepsis of 38% to 88% [13, 15, 19, 21, 24, 25, 29]. The high mortality rate at 72 h of 7% and the thirty-day mortality rate of 28% underline that survival is limited by the underlying disease and its management [29]. The type of fascia closure seems to influence long-term morbidity rather than short-term complications.

Limitations

Due to the retrospective nature of this study on a cohort of consecutive patient without a control group and without a clear structured protocol or treatment algorithm, the results of this study can be biased and need to be interpreted with caution. However, as the outcome of all consecutive patients with open abdomen treatment and abdominal sepsis treated at one institution were analyzed, biasing towards better outcomes for patients in “inside study conditions” could be avoided.

Abdominal sepsis needing open abdomen treatment is afflicted with high mortality. Mainly related to death a high rate of patients could not be followed up and the sample size at the 1-year control turned out to be small.

The presented technique with an anti-adhesive PVDF mesh for fascia traction in vacuum-assisted septic open abdomen treatment is promising. To compare it to the standard technique with a polypropylene mesh/plastic sheet a multicenter randomized control trial is warranted.

Conclusion

The application of an anti-adhesive PVDF mesh for fascia traction in VAC of septic open abdomen is novel, versatile, and seems to be safe. It offers the highly relevant possibility for provisional and final abdominal closure.

Compliance with ethical standards

Conflict of interest This study has not been funded. All authors have declared that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

With permission of the University of Zurich Ethics Commission (BASEC No 2016-00164), this retrospective study on all consecutive patients with open abdomen treatment at one institution from January 2013 to June 2015 was performed. Mainly due to high mortality, informed consent could not be obtained from all individuals included in this retrospective study.

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References

- Roberts DJ, Ball CG, Kirkpatrick AW (2016) Increased pressure within the abdominal compartment: intra-abdominal hypertension and the abdominal compartment syndrome. *Curr Opin Crit Care* 22(2):174–185. <https://doi.org/10.1097/MCC.0000000000000289>
- van Ruler O, Mahler CW, Boer KR, Reuland EA, Gooszen HG, Opmeer BC, de Graaf PW, Lamme B, Gerhards MF, Steller EP, van Till JW, de Borgie CJ, Gouma DJ, Reitsma JB, Boermeester MA, Dutch Peritonitis Study G (2007) Comparison of on-demand vs planned relaparotomy strategy in patients with severe peritonitis: a randomized trial. *JAMA: the Journal of the American Medical Association* 298(8):865–872. <https://doi.org/10.1001/jama.298.8.865>
- Strobel O, Werner J, Buchler MW (2011) Surgical therapy of peritonitis. *Der Chirurg; Zeitschrift für alle Gebiete der operativen Medizin* 82(3):242–248. <https://doi.org/10.1007/s00104-010-2015-2>
- Ferrer R, Martin-Loeches I, Phillips G, Osborn TM, Townsend S, Dellinger RP, Artigas A, Schorr C, Levy MM (2014) Empiric antibiotic treatment reduces mortality in severe sepsis and septic shock from the first hour: results from a guideline-based performance improvement program. *Crit Care Med* 42(8):1749–1755. <https://doi.org/10.1097/CCM.0000000000000330>
- Sartelli M, Abu-Zidan FM, Ansaloni L, Bala M, Beltran MA, Biffl WL, Catena F, Chiara O, Coccolini F, Coimbra R, Demetrasvili Z, Demetriades D, Diaz JJ, Di Saverio S, Fraga GP, Ghnnam W, Griffiths EA, Gupta S, Hecker A, Karamarkovic A, Kong VY, Kafka-Ritsch R, Kluger Y, Latifi R, Leppaniemi A, Lee JG, McFarlane M, Marwah S, Moore FA, Ordonez CA, Pereira GA, Plaudis H, Shelat VG, Ulrych J, Zachariah SK, Zielinski MD, Garcia MP, Moore EE (2015) The role of the open abdomen procedure in managing severe abdominal sepsis: WSES position paper. *World Journal of Emergency Surgery: WJES* 10:35. <https://doi.org/10.1186/s13017-015-0032-7>
- Sartelli M, Abu-Zidan FM, Catena F, Griffiths EA, Di Saverio S, Coimbra R, Ordonez CA, Leppaniemi A, Fraga GP, Coccolini F, Agresta F, Abbas A, Abdel Kader S, Agboola J, Amhed A, Ajibade A, Akkucuk S, Alharthi B, Anyfantakis D, Augustin G, Baiocchi G, Bala M, Baraket O, Bayrak S, Bellanova G, Beltran MA, Bini R, Boal M, Borodach AV, Bouliaris K, Branger F, Brunelli D, Catani M, Che Jusoh A, Chichom-Mefire A, Cocorullo G, Colak E, Costa D, Costa S, Cui Y, Curca GL, Curry T, Das K, Delibegovic S, Demetrasvili Z, Di Carlo I, Drozdova N, El Zalabany T, Enani MA, Faro M, Gachabayov M, Gimenez Maurel T, Gkiokas G, Gomes CA, Gonsaga RA, Guercioni G, Guner A, Gupta S, Gutierrez S, Hutan M, Ioannidis O, Isik A, Izawa Y, Jain SA, Jokubauskas M, Karamarkovic A, Kauhanen S, Kaushik R, Kenig J, Khokha V, Kim JI, Kong V, Koshy R, Krasniqi A, Kshirsagar A, Kuliesius Z, Lasithiotakis K, Leao P, Lee JG, Leon M, Lizarazu Perez A, Lohsiriwat V, Lopez-Tomassetti Fernandez E, Litoridis E, Mn R, Major P, Marinis A, Marrelli D, Martinez-Perez A, Marwah S, McFarlane M, Melo RB, Mesina C, Michalopoulos N, Moldovanu R, Mouaqt O, Munyika A, Negroi I, Nikolopoulos I, Nita GE, Olaoye I, Omari A, Ossa PR, Ozkan Z, Padmakumar R, Pata F, Pereira Junior GA, Pereira J, Pintar T, Pougouras K, Prabhu V, Rauser S, Rems M, Rios-Cruz D, Sakakushev B, Sanchez de Molina ML, Seretis C, Shelat V, Simoes RL, Sinibaldi G, Skrovina M, Smirnov D, Spyropoulos C, Tepp J, Tezcaner T, Tolonen M, Torba M, Ulrych J, Uzunoglu MY, van Dellen D, van Ramshorst GH, Vasquez G, Venara A, Vereczkei A, Vettoretto N, Vlad N, Yadav SK, Yilmaz TU, Yuan KC, Zachariah SK, Zida M, Zilinskas J, Ansaloni L (2015) Global validation of the WSES sepsis severity score for patients with complicated intra-abdominal infections: a prospective multicentre study (WISS Study). *World Journal of Emergency Surgery: WJES* 10:61. <https://doi.org/10.1186/s13017-015-0055-0>
- Champault G, Magnier M, Psalmon F, Patel JC (1979) Controlled evisceration in the treatment of severe peritonitis. *Chirurgie; memoires de l'Academie de chirurgie* 105(9):866–869
- Steinberg D (1979) On leaving the peritoneal cavity open in acute generalized suppurative peritonitis. *Am J Surg* 137(2):216–220
- Quyn AJ, Johnston C, Hall D, Chambers A, Arapova N, Ogston S, Amin AI (2012) The open abdomen and temporary abdominal closure systems—historical evolution and systematic review. *Color Dis*

- 14(8):e429–e438. <https://doi.org/10.1111/j.1463-1318.2012.03045.x>
10. Koniaris LG, Hendrickson RJ, Drugas G, Abt P, Schoeniger LO (2001) Dynamic retention: a technique for closure of the complex abdomen in critically ill patients. *Arch Surg* 136(12):1359–1362 discussion 1363
 11. Wittmann DH, Aprahamian C, Bergstein JM (1990) Etappenlavage: advanced diffuse peritonitis managed by planned multiple laparotomies utilizing zippers, slide fastener, and Velcro analogue for temporary abdominal closure. *World J Surg* 14(2): 218–226
 12. Brock WB, Barker DE, Burns RP (1995) Temporary closure of open abdominal wounds: the vacuum pack. *Am Surg* 61(1):30–35
 13. Miller PR, Thompson JT, Faler BJ, Meredith JW, Chang MC (2002) Late fascial closure in lieu of ventral hernia: the next step in open abdomen management. *J Trauma* 53(5):843–849. <https://doi.org/10.1097/01.TA.0000027879.14969.C9>
 14. Miller PR, Meredith JW, Johnson JC, Chang MC (2004) Prospective evaluation of vacuum-assisted fascial closure after open abdomen: planned ventral hernia rate is substantially reduced. *Ann Surg* 239(5):608–614 discussion 614–606
 15. Perez D, Wildi S, Demartines N, Bramkamp M, Koehler C, Clavien PA (2007) Prospective evaluation of vacuum-assisted closure in abdominal compartment syndrome and severe abdominal sepsis. *J Am Coll Surg* 205(4):586–592. <https://doi.org/10.1016/j.jamcollsurg.2007.05.015>
 16. Herrle F, Hasenberg T, Fini B, Jonescheit J, Shang E, Kienle P, Post S, Niedergethmann M (2011) Open abdomen 2009. A national survey of open abdomen treatment in Germany. *Der Chirurg; Zeitschrift für alle Gebiete der operativen Medizin* 82(8):684–690. <https://doi.org/10.1007/s00104-010-2042-z>
 17. Petersson U, Acosta S, Bjorck M (2007) Vacuum-assisted wound closure and mesh-mediated fascial traction—a novel technique for late closure of the open abdomen. *World J Surg* 31(11):2133–2137. <https://doi.org/10.1007/s00268-007-9222-0>
 18. Salman AE, Yetisir F, Aksoy M, Tokac M, Yildirim MB, Kilic M (2014) Use of dynamic wound closure system in conjunction with vacuum-assisted closure therapy in delayed closure of open abdomen. *Hernia: the Journal of Hernias and Abdominal Wall Surgery* 18(1):99–104. <https://doi.org/10.1007/s10029-012-1008-0>
 19. Verdam FJ, Dolmans DE, Loos MJ, Raber MH, de Wit RJ, Charbon JA, Vroemen JP (2011) Delayed primary closure of the septic open abdomen with a dynamic closure system. *World J Surg* 35(10): 2348–2355. <https://doi.org/10.1007/s00268-011-1210-8>
 20. Rasilainen SK, Mentula PJ, Leppaniemi AK (2012) Vacuum and mesh-mediated fascial traction for primary closure of the open abdomen in critically ill surgical patients. *Br J Surg* 99(12):1725–1732. <https://doi.org/10.1002/bjs.8914>
 21. Atema JJ, Gans SL, Boermeester MA (2015) Systematic review and meta-analysis of the open abdomen and temporary abdominal closure techniques in non-trauma patients. *World J Surg* 39(4):912–925. <https://doi.org/10.1007/s00268-014-2883-6>
 22. Robledo FA, Luque-de-Leon E, Suarez R, Sanchez P, de-la-Fuente M, Vargas A, Mier J (2007) Open versus closed management of the abdomen in the surgical treatment of severe secondary peritonitis: a randomized clinical trial. *Surg Infect* 8(1):63–72. <https://doi.org/10.1089/sur.2006.8.016>
 23. Salamone G, Licari L, Guercio G, Comelli A, Mangiapane M, Falco N, Tutino R, Bagarella N, Campanella S, Porrello C, Gullo R, Cocorullo G, Gulotta G (2018) Vacuum-assisted wound closure with mesh-mediated fascial traction achieves better outcomes than vacuum-assisted wound closure alone: a comparative study. *World J Surg* 42(6):1679–1686. <https://doi.org/10.1007/s00268-017-4354-3>
 24. Rasilainen SK, Mentula PJ, Leppaniemi AK (2016) Components separation technique is feasible for assisting delayed primary fascial closure of open abdomen. *Scandinavian Journal of Surgery: Official Organ for the Finnish Surgical Society and the Scandinavian Surgical Society* 105(1):17–21. <https://doi.org/10.1177/1457496915586651>
 25. Rausei S, Dionigi G, Boni L, Rovera F, Minoja G, Cuffari S, Dionigi R (2014) Open abdomen management of intra-abdominal infections: analysis of a twenty-year experience. *Surg Infect* 15(3): 200–206. <https://doi.org/10.1089/sur.2012.180>
 26. Kushimoto S, Yamamoto Y, Aiboshi J, Ogawa F, Koido Y, Yoshida R, Kawai M (2007) Usefulness of the bilateral anterior rectus abdominis sheath turnover flap method for early fascial closure in patients requiring open abdominal management. *World J Surg* 31(1):2–8; discussion 9–10. <https://doi.org/10.1007/s00268-006-0282-3>
 27. Berrevoet F (2018) Prevention of incisional hernias after open abdomen treatment. *Frontiers in surgery* 5:11. <https://doi.org/10.3389/fsurg.2018.00011>
 28. Lamme B, Boermeester MA, Belt EJ, van Till JW, Gouma DJ, Obertop H (2004) Mortality and morbidity of planned relaparotomy versus relaparotomy on demand for secondary peritonitis. *Br J Surg* 91(8):1046–1054. <https://doi.org/10.1002/bjs.4517>
 29. Tsuei BJ, Skinner JC, Bernard AC, Kearney PA, Boulanger BR (2004) The open peritoneal cavity: etiology correlates with the likelihood of fascial closure. *Am Surg* 70(7):652–656
 30. Arai M, Kushimoto S, Kim S, Masuno T, Hagiwara J, Ishii H, Yokota H (2015) A novel technique for managing open abdomen with the combined use of mesh-mediated traction and the bilateral anterior rectus abdominis sheath turnover flap method: how to do it. *Surg Today* 45(10):1335–1339. <https://doi.org/10.1007/s00595-015-1133-3>
 31. Willms A, Schaaf S, Schwab R, Richardsen I, Bieler D, Wagner B, Gusgen C (2016) Abdominal wall integrity after open abdomen: long-term results of vacuum-assisted wound closure and mesh-mediated fascial traction (VAWCM). *Hernia: the Journal of Hernias and Abdominal Wall Surgery* 20(6):849–858. <https://doi.org/10.1007/s10029-016-1534-2>
 32. Rao M, Burke D, Finan PJ, Sagar PM (2007) The use of vacuum-assisted closure of abdominal wounds: a word of caution. *Color Dis* 9(3):266–268. <https://doi.org/10.1111/j.1463-1318.2006.01154.x>