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ORIGINAL ARTICLE

Management of abdominal wound dehiscence: update of the literature and meta-analysis

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Abstract

Purpose Abdominal wound dehiscence (AWD) is associated with significant morbidity and mortality. We aimed to provide a contemporary overview of management strategies for AWD.

Methods PubMed, EMBASE, the Cochrane library and a clinical trials registry were searched from 2009 onwards using the key words "abdominal wound dehiscence", "fascial dehiscence" and "burst abdomen". Study outcomes included surgical site infection (SSI), recurrence, incisional hernia and 30-day mortality. Studies reported by the EHS clinical guidelines on AWD were included and compared with. OpenMetaAnalyst was used for meta-analysis to calculate statistical significance and odds ratios (OR).

Results Nineteen studies were included reporting on a total of 632 patients: 16 retrospective studies, one early terminated randomized controlled trial, one review and the European Hernia Society guidelines. Nine studies reported use of synthetic mesh ($n=241$), two of which used vacuum-assisted mesh-mediated fascial traction (VAWCM) ($n=19$), six without VAWCM ($n=198$) and one used synthetic mesh with both VAWCM ($n=6$) and without VAWCM ($n=18$); two used biological mesh ($n=19$). Seven studies reported primary suture closure ($n=299$). Three studies reported on an alternative method ($n=91$). Follow-up ranged between 1 and 96 months. Meta-analysis was performed to compare the primary suture group with the synthetic mesh group. Heterogeneity was low to moderate depending on outcome. The overall SSI rate in the primary suture group was 27.6% versus 27.9% in the synthetic mesh group, resulting in mesh explantation in five patients; OR 0.65 (95% CI 0.23–1.81). Incisional hernia rates were 11.1% in the synthetic mesh group (19/171) and 30.7% in the primary suture group (67/218); OR 4.01 (95% CI 1.70–9.46). Recurrence rate did not show a statistically significant difference at 2.7% in the synthetic mesh group (3/112), compared to 10.2% in the primary suture group (21/206); OR 1.81 (95% CI 0.18–17.80). Mortality rates varied between 11.2% and 16.7% for primary suture group versus synthetic mesh; OR 1.85 (95% CI 0.91–3.76).

Conclusion Included studies were of low to very low quality. The use of synthetic mesh results in a significantly lower rate of incisional hernia, whereas SSI rate was comparable to primary suture repair.

Introduction

Abdominal wound dehiscence (AWD) is a serious postoperative complication associated with significant morbidity and mortality. The incidence of AWD ranges between 2% and 5.5% [1–6]. Mortality has been reported as high as 20.9% [7–18].

AWD usually occurs between the 6th and 12th postoperative day [12, 18–20]. It is associated with high costs prolonged hospital stay, repeat surgery and a frequent need for ambulatory wound care and follow-up visits [21].

Frequently reported surgery-related risk factors include the type of incision and type of closure technique. Data on the management of AWD are scarce, with low grades of evidence for the most effective management [22].

The European Hernia Society (EHS) formulated clinical guidelines for the treatment of burst abdomen [22]. It is suggested to treat patients with mesh reinforcement whenever fascial closure is possible, while the type and location of mesh should be evaluated by the treating surgeon [22].

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Primary suture is a possible classical alternative, using continuous monofilament sutures, 5–8 mm from the wound edge, using a suture length to wound length ratio (SL:WL) of at least 4:1 [22–25]. The use of mesh was associated with an increased incidence of surgical site occurrence (SSO), as SSO for patients treated with mesh was 48.8% compared to 23.5% for primary suture closure [22].

This study represents an overview of recently published articles on the management of AWD, with an aim to investigate the impact of mesh and other techniques on the core clinical outcomes of surgical site infection (SSI), recurrence and hernia formation [22].

Methods

As a follow-up on a previously published review paper in 2010 [19], PubMed, EMBASE, the Cochrane Library and a trial registry (www.clinicaltrials.gov) were searched in duplicate from January 2009 onwards up to December 2019 using the keywords "abdominal wound dehiscence", "fascial dehiscence" and "burst abdomen". Studies reporting on a non-abdominal wound dehiscence, animals, children and studies with no original data were excluded. Non-English language articles were excluded. Only studies reporting on adults with AWD after midline incision and one or more of the outcomes surgical site infection (SSI), recurrence, incisional hernia or 30-day mortality were included.

Recurrence was defined as the result of a technical failure after surgical repair, presenting as fascial reburst of the abdominal wall. SSI was defined using Centers for Disease Control and Prevention criteria [26]. Incisional hernia was defined by the EHS as "any abdominal wall gap with or without a bulge in the area of a postoperative scar perceptible or palpable by clinical examination or imaging" [27, 28]. References of included studies were evaluated for potentially relevant articles. Included studies were grouped by management method and data extraction was performed by AD and checked by GvR. The characteristics of included studies are described in Table 1.

Relevant data of studies included in the earlier meta-analysis for the EHS guidelines were also considered in our study [29], following the same methodology and analysis strategy with OpenMetaAnalyst [22, 29]. Collected data were presented as the risk ratio with 95% confidence interval (CI). Heterogeneity was assessed using I^2 statistics, considering I^2 below 50 as low heterogeneity, 50–70 as moderate heterogeneity and over 70 as high heterogeneity. Results were calculated with Binary Random-Effects Model.

Results

The search resulted in 4395 hits. After removal of duplicates, 4312 articles remained. After screening based on title and abstract, 4275 articles were excluded. Thirty-seven full-text articles were assessed for eligibility. Twenty-four articles were excluded based on no midline incision ($n=1$), no clear difference in patient population ($n=1$), not abdominal ($n=2$), no abdominal wound dehiscence ($n=2$), reporting on animals ($n=1$), reporting on children ($n=1$), no original data ($n=3$) and no full text available for two articles. After cross-referencing, five articles were added, see Fig. 1; one study was identified in the trial registry. A total number of 19 studies were included: 16 retrospective studies, one early terminated randomized controlled trial, one review and the EHS guidelines. No prospective non-randomised studies were found. Follow-up ranged between 1–96 months.

Patient characteristics of the 19 included studies are described in Table 2; many did not report on possible confounding variables. Scholtes et al. reported 23 patients with wound class 3 (contaminated) (51.1%) and 22 patients with wound class 4 (dirty) (48.9%) treated with primary suture. In the synthetic mesh group 22 patients were reported with wound class 3 (66.7%) and 11 with wound class 4 (dirty; 33.3%) [8]. Dumanian et al. reported 20 patients with wound class 2 (clean-contaminated) (41.7%), 16 with wound class 3 (33.3%) and 12 with wound class 4 (25%) [13]. Other included studies did not report on wound class.

Patients were treated with synthetic mesh, with or without vacuum-assisted wound closure with mesh-mediated fascial traction (VAWCM), biological mesh, primary suture closure or an alternative management method. Alternative management methods include 'retention-type' use of nasogastric tubes (NGT), intrawound continuous negative pressure and irrigation therapy (IW-CONPIT) and synthetic mesh strips.

Mesh

Nine studies reported the use of synthetic mesh, with a total of 241 patients [8, 10–12, 14, 17, 30]. The synthetic mesh was made of polypropylene in five studies, with a total of 142 patients [8–12]. Lord et al. reported one patient treated with a Prolene® mesh [31]. Jakob et al. treated 54 patients with a polypropylene mesh and 16 patients with a polyester mesh [14]. McNeeley compared the use of Marlex® mesh, Prolene® mesh and Vicryl® mesh on, respectively, seven, four and seven patients [17]. Three studies with a total of 25 patients reported the

Table 1 included studies

Author	Year	Type of Study	No. patients	Technique (Number of Patients and Specific Aspects)	Recurrence Rate	Mortality Rate	SSI	Incisional Hernia Rate	Follow-Up (Range)	Group
McNeeley [17]	1998	Retrospective	18	7 synthetic mesh consisting of Marlex® 4 synthetic mesh consisting of Prolene® 7 synthetic mesh consisting of Vicryl®	NR	11.1% (2/18)	NR	NR	6 m	Synthetic mesh
Gislason [18]	1999	Retrospective	78	29 interrupted + retention sutures 8 continuous + retention sutures 9 interrupted sutures 2 continuous sutures 5 retention sutures alone 17 died during the first year 8 were lost to follow-up	1.3% (1/78)	14.1% (11/78)	43.6 (34/78)	43.4% (23/53)	NR	Primary suture closure
Abbott [30]	2007	Retrospective	37	27 primary suture closure 10 single layer polyglactin mesh	32.4% (12/37)	NR	54.1% (20/37)	NR	3 m–8 y	Primary suture closure Synthetic mesh
Kelley [7]	2010	Retrospective	1	1 onlay Strattice® mesh	0.0% (0/1)	0.0% (0/1)	0.0% (0/1)	0.0% (0/1)	6 wk	Biological mesh
Scholtes [8]	2012	Retrospective	78	45 sutured using PDS® loop 1 sutures or additional Vicryl® strings 33 with polypropylene mesh implantation	NR	10.3% (8/78)	NR	14.1% (11/78)	8–14 m	Primary suture closure Synthetic mesh
Bjørsum-Meyer [9]	2013	Retrospective	18	18 temporary polypropylene mesh with VAWCM Delayed primary sutured closure	20.0% (3/15)	16.7% (3/18)	NR	21.4% (3/14)	1–36 m	VAWCM

Table 1 (continued)

Author	Year	Type of Study	No. patients	Technique (Number of Patients and Specific Aspects)	Recurrence Rate	Mortality Rate	SSI	Incisional Hernia Rate	Follow-Up (Range)	Group
López-Cano [20]	2013	Review	NR	Continuous suture (4:1 SL:WL) Delayed closure method Compression garment	NR	NR	NR	NR	NR	–
NCT01083472 [32]	2013	Randomised controlled trial (terminated)	37	18 intraperitoneal or retrorectus Strattice® mesh 19 primary suture or inlay polyglactin mesh	16.7% (3/18)	NR	22.2% (4/18)	0.0%	NR	Biological mesh
Petersson [10]	2014	Retrospective	46	22 Suture (polydioxanone or polypropylene) 6 VAWCM, temporary polypropylene mesh. Delayed closure by suturing or retromuscular mesh 18 retromuscular mesh repair (polypropylene or polyvinylidene fluoride mesh)	11.6% (5/46)	12.5% (6/48)	30.8% (12/39)	25.7% (9/35)	205–1.042 d	Primary suture closure VAWCM Synthetic mesh
Lord [31]	2015	Retrospective	1	1 VAWCM, Prolene® mesh	NR	NR	NR	NR	115 d	VAWCM
López-Cano [11]	2015	Retrospective	91	35 running polydioxanone suture 56 running polypropylene suture + onlay polypropylene mesh	0.0% (0/91)	20.9% (19/91)	25.6% (23/91)	25.0% (14/56)	0- (more then) 12 m	Primary suture closure Synthetic mesh
Abo-Ryia [12]	2017	Retrospective	11	11 polypropylene mesh + larger polypropylene mesh, skin closed with interrupted Prolene® stitches	0.0% (0/11)	0.0% (0/11)	45.5% (5/11)	0.0% (0/11)	6–26 m	Synthetic mesh

Table 1 (continued)

Author	Year	Type of Study	No. patients	Technique (Number of Patients and Specific Aspects)	Recurrence Rate	Mortality Rate	SSI	Incisional Hernia Rate	Follow-Up (Range)	Group
Deleyto [36]	2017	Retrospective	45	35 conventional dressings (saline-soaked dressings, antiseptic solutions and open lavage) 11 NPWTi (hypertonic saline as irrigation solution)	NR	NR	NR	NR	NR	CWT NPWTi
Dumanian [13]	2018	Retrospective	48	48 polypropylene mesh strips (2 cm) placed in interrupted fashion and spaced 1 cm from each other. Sutured with polypropylene suture	6.4% (3/47)	2.1% (1/48)	19.1% (9/47)	6.4% (3/47)	11.8 m	Synthetic mesh strips
Vahedian [33]	2018	Retrospective	25	25 ultraviolet sterilized black NGT (10FG), interrupting suture technique	0.0% (0/25)	0.0% (0/25)	0.0% (0/25)	0.0% (0/25)	1 m	NGT
Jakob [14]	2018	Retrospective	119	49 single running suture 54 polypropylene mesh intraperitoneally 16 polyester mesh intraperitoneally	NR	16.8% (20/119)	22.2% (22/99)	23.2% (23/99)	281–335 d	Primary suture closure Synthetic mesh
Tilt [15]	2018	Retrospective	43	43 vertical mattress sutures using Prolene®, with minimal deep suture placement	7.0% (3/43)	9.3% (4/43)	9.3% (4/43)	7.0% (3/43)	NR	Primary suture closure

Table 1 (continued)

Author	Year	Type of Study	No. patients	Technique (Number of Patients and Specific Aspects)	Recurrence Rate	Mortality Rate	SSI	Incisional Hernia Rate	Follow-Up (Range)	Group
López-Cano [22]	2018	Guidelines	NR	Continuous monofilament sutures Mesh reinforcement NPWT MMFT + NPWT Abdominal girdle	NR	NR	NR	NR	NR	
Morinaga [16]	2019	Retrospective	18	18 artificial dermis + IW-CONPIT	NR	0.0% (0/18)	NR	NR	NR	IW-CONPIT

NR not reported, *m* month(s), *wk* week(s), *d* day(s)

VACWM Vacuum-assisted mesh-mediated fascial traction, *NPWT* negative pressure wound therapy, *NGT* nasogastric tube, *MMFT* mesh-mediated fascial traction, *TT* Transversus abdominus muscle with internal oblique muscle, *TIE* Transversus abdominus muscle with internal oblique muscle and external oblique muscle, *TIES* Transversus abdominus muscle with internal oblique muscle, external oblique muscle and Scarpa's fascia

use of synthetic mesh in combination with VAWCM [9, 10, 31]. In seven studies 216 patients were treated with synthetic mesh only, without VAWCM [8, 10–12, 14]. Bjørnsum–Meyer et al. used a temporary polypropylene mesh for VAWCM and performed the final closure using a delayed primary suture closure [9]. Petersson et al. also used a temporary polypropylene mesh, but performed a delayed closure by delayed primary suture or using a retromuscular polypropylene or polyvinylidene mesh [10]. Lord et al. used a Prolene® mesh sutured to the sheath, and the sheath was eventually closed with interrupted nylon sutures after mesh removal [31]. Abbott et al. used a polyglactin mesh to treat ten patients [30].

Kelley et al. performed a retrospective case study on one patient with a 200-cm^2 onlay Strattice® biological mesh layer (LifeCell, Branchburg, NJ) [7] after closure of the abdominal wall. After a 6-week follow-up no recurrence, SSI or incisional hernia occurred and the patient survived. The early terminated randomized controlled study (NCT01083472), found in the trial registry only, included 37 out of 200 participants [32]. Eighteen patients were randomized for intraperitoneal or retrorectus placement of Strattice®; one developed a superficial wound infection and three patients experienced recurrences (16.7%); no incisional hernia was found after an unclear period of follow-up. The remaining 19 patients received 'standard of care', consisting of primary suture closure or absorbable bridging mesh with no data provided per subpopulation. This group was subsequently excluded from analysis.

Mesh position

The mesh was reported to be sutured in the onlay position in 57 patients, 56 with a non-absorbable mesh (polypropylene) and 1 with an absorbable mesh (Strattice®) [7, 11]. A total of 103 patients were treated with intraperitoneally placed mesh: in 87 patients polypropylene mesh was used and polyester mesh was used in 16 patients [8, 14]. For 18 patients Strattice® mesh was used in either intraperitoneal or retrorectus position [32]. The inlay position was used for 53 patients, using polypropylene for 24, polyglactin for 17, Marlex® for seven and Prolene® for five patients [9, 10, 17, 30, 31]. The type of mesh, mesh position and definitive closure technique of all studies reporting on the use of mesh can be found in Table 3.

Primary suture closure

Primary suture closure remained a widely reported technique to treat AWD. Seven studies reported the use of primary suture closure with a total of 299 patients, treated from 1986 till 2015 [8, 10, 11, 14, 15, 18, 30]. Gislason et al. reported the use of 5 different suture materials, using

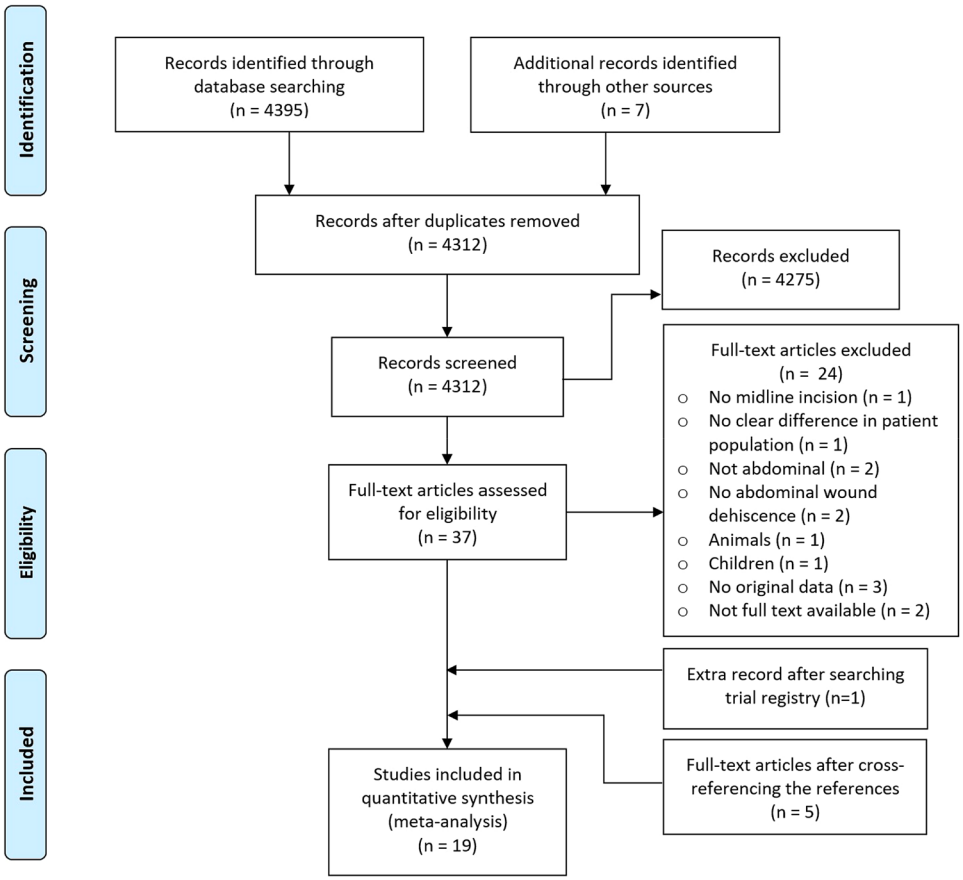

Fig. 1 Flow chart

polyglactin (Vicryl®) for 18 patients, polyglycolic acid (Dexon) for 17 patients, polyglyconate (Maxon™ loop) for 10 patients, polydioxanone (PDS®) for 2 patients and polyamide (Ethilon™) for 2 patients; 4 patients were treated with unknown material [18]. Polydioxanone was used in 5 studies to treat 143 patients in total [8, 10, 11, 14, 18]. Tilt et al. used Prolene® as a suture material to treat 43 patients [15]. Scholtes et al. and Petersson et al. used Vicryl® strings and polypropylene, respectively, but did not report patient numbers [8, 10].

Jakob et al. was the only group that reported on the applied suture to wound length ratio (SL: WL ratio) of 4:1 [14]. Time period, suture materials and technique of the included studies reporting on primary suture closure are presented in Table 4.

Alternative management methods

Vahedian et al. reported the use of nasogastric tubes (NGT) with an interrupted suture technique on 25 patients [33]. They used one ultraviolet sterilized black NGT (10 FG) and one Hemovac perforator. The NGTs were sutured with a simple interrupted suture technique, and the NGTs were tied. Each patient received 4–5 NGT sutures with the distance of 4–5 cm. Delayed skin closure by far-and-near suturing technique was used in patients if needed; otherwise, the skin was left to close by secondary intention. During the 1-month follow-up, no recurrence, mortality, SSI or incisional hernia occurred [33].

Dumanian et al. used strips of light-weight macroporous polypropylene mesh [13]. The mesh was cut into 2 cm-wide pieces in order to fabricate mesh strips. The mesh strips were placed in interrupted fashion and spaced 1 cm from each other. A total number of 48 patients were treated with this new technique, with a mean follow-up of 358 days (11.8 months). A SSI rate of 19.0% (9/47) was reported, of which seven had superficial infections. None of them required mesh strip removal [13]. One patient died during follow-up—unrelated to use of mesh strips—resulting in 47 surviving patients. Three patients (6.0%) developed recurrence and three (6.0%) an incisional hernia at their midline closure. Incisional hernia was defined as "any defect in the abdominal wall fascia as diagnosed by physical examination or CT scan", after a mean 11.8-month follow-up [13].

Morinaga et al. used intrawound continuous negative pressure and irrigation treatment (IW-CONPIT) with artificial dermis as a new technique to treat AWD [16]. Eighteen patients were treated between March 2007 and August 2016 using this technique, with an unknown period of follow-up. After complete debridement, artificial dermis PELNAC

Table 2 Patient characteristics

Study	Group (patients)	Median age, years (range)	Mean size of AWD, cm (range)	Diabetes type I, *n* (%)	Diabetes type II, *n* (%)	BMI, median (range)	Pulmonary lung diseases, *n* (%)	Smoking, *n* (%)		SSI, *n* (%)
								Active	Former	
McNeeley [17]*	Obstetric patients (18)	Mean: 25.8	NR	1 (5.6%)		32.7	2 (11.1%)	4 (22.2%)	NR	NR
	Gynaecologic patients (18)	Mean: 49	NR	1 (5.6%)		33.6	2 (11.1%)	3 (16.7%)	NR	NR
Gislason [18]	Suture (78)	70.5 (41–91)	NR	NR	NR	NR	NR	NR	NR	34 (43.6%)
Abbott [30]	Suture (27)	NR	NR	NR	NR	NR	NR	NR	NR	NR
	Mesh (10)	NR	NR	NR	NR	NR	NR	NR	NR	NR
Kelley [7]	Biological mesh (1)	31	25 cm (skin: 8 cm) (fascia: 5 cm)	NR	NR	NR	NR	NR	NR	NR
Scholtes [8]**	Suture (63)	61.3 (22–85)	NR	7 (11.1%)		18 > 30 kg/m^2 (28.6%)	12 (19.0%)	NR	NR	NR
	Mesh (51)	64.3 (22–86)	NR	7 (13.7%)		8 > 30 kg/m^2 (15.7%)	15 (29.4%)	NR	NR	NR
Bjørsum-Meyer [9]	VAWCM (18)	64 (29–90)	NR	1 (5.5%)		27 (18–40)	3 (16.7%)	9 (50.0%)	NR	NR
López-Cano [20] (Review)	–	–	–	–	–	–	–	–	–	–
NCT01083472 [32]	Biological mesh (18)	Mean: 70 (SD = 9.94)	NR	NR	NR	NR	NR	NR	NR	NR
	Suture or Mesh (19)	Mean: 67 (SD = 8.49)	NR	NR	NR	NR	NR	NR	NR	NR
Petersson [10]	Suture (22)	76.5 (60–90)	NR	3 (13.6%)		26.0 (18.1–32.7)	2 (9.1%)	NR	NR	NR
	Mesh (18)	73 (38–88)	NR	2 (11.1%)		26.4 (15.2–33.5)	3 (16.7%)	NR	NR	NR
	VAWCM (6)	76.5 (63–87)	NR	0 (0.0%)		19.5 (18.4–29.5)	1 (16.6%)	NR	NR	NR
Lord [31]	VAWCM (1)	57	+20 cm	NR	NR	> 30 kg/m^2	1 (100.0%)	-	1 (100.0%)	NR
López-Cano (Retro) [11]	Suture (35)	Mean: 71.7 (SD = 10.0)	NR	8 (22.9%)		NR	11 (31.4%)	NR	NR	7 (20.0%)
	Mesh (56)	Mean: 69.9 (SD = 12.8)	NR	9 (16.4%)		NR	15 (26.8%)	NR	NR	16 (29.1%)
Abo-Ryia [12]	Mesh (11)	49.3 (28–66)	NR	NR	NR	Mean: 34.2 (27–43.5)	NR	NR	NR	NR
Deleyto [36]	CWT (35)	NR	NR	NR	NR	NR	NR	NR	NR	NR
	NPWTi (11)	NR	NR	NR	NR	NR	NR	NR	NR	NR
Dumanian [13]	Mesh strips (48)	Mean: 62.2 (SD = 14.2)	10.5 cm (5–25 cm)	15 (31.3%)		Mean: 29.8 (SD = 7.7)	5 (10.4%)	5 (10.4%)	NR	NR
Vahedian [33]	NGT (25)	Mean: 71.12 (SD = 13.48)	NR	7 (28.0%)		NR	NR	NR	NR	0 (0.0%)

Table 2 (continued)

Study	Group (patients)	Median age, years (range)	Mean size of AWD, cm (range)	Diabetes type I, *n* (%)	Diabetes type II, *n* (%)	BMI, median (range)	Pulmonary lung diseases, *n* (%)	Smoking, *n* (%)		SSI, *n* (%)
								Active	Former	
Jakob [14]	Suture (49)	64 (IQR: 56–74)	NR	–	6 (12.2%)	28.1 (IQR: 23.6–34.9)	14 (28.6%)	12 (24.5%)	9 (18.4%)	NR
	Mesh (70)	66 (IQR: 58–74)	NR	1 (1.4%)	11 (15.7%)	25.8 (IQR: 22.9–29.1)	29 (41.4%)	21 (30.0%)	10 (14.3%)	NR
Tilt [15]	Suture (43)	Mean: 54 (SD = 15.4)	NR	10 (23.3%)		Mean: 31.9 (SD = 10.3)	NR	6 (14.0%)	18 (41.9%)	NR
López-Cano (EHS guidelines) [22]	–	–	–	–	–	–	–	–	–	–
Morinaga [16]	IW-CONPIT (18)	63 (41–84)	NR	NR	NR	NR	NR	NR	NR	NR

BMI body mass index, *SSI* surgical site infection, *NR* not reported, *SD* standard deviation, *IQR* interquartile range

*Characteristics of the 18 patients treated with synthetic mesh were not reported separately of the 36 patients

**Patient characteristics were not divided in open abdomen and fascial closure treated group

was attached to the exposed bowel. Two tubes were inserted into the sponge to provide continuous irrigation with saline (1–3 l/day). One tube was connected with a bottle containing saline solution, the other to a continuous suction unit. After complete epithelialization, intestinal resection was performed and the abdominal wall was reconstructed [16]. Morinaga et al. reported a 0.0% (0/18) mortality rate [16].

Meta-analysis

Comparisons were made for primary sutured group and synthetic mesh group only, as the numbers of relevant studies for other techniques were deemed too low.

The overall mortality rate for the primary sutured group was 15.9% (43/270 patients) compared to 11.7% (23/206 patients) for the synthetic mesh group [8, 10–12, 14, 15, 17, 18]. The mortality rate for patients treated with synthetic mesh in combination with VAWCM was 16.7% (4/24) [9, 10]. Mortality rates were not significantly higher for primary suture closure than for the synthetic mesh group ($p = 0.136$), odds ratio (OR) 1.85, [95% CI 0.91–3.76], $I^2 = 8.39$, see Fig. 2.

Overall SSI rate in the mesh group was 27.9% (41/147 patients) [10–12, 14, 17], resulting in mesh explantation for five patients [14, 17]. Jakob et al. compared the use of polypropylene and polyester mesh. 16 of the 45 patients (36%) treated with polypropylene mesh occurred to have SSI compared to eight of the 14 patients (57%) treated with polyester mesh. SSI resulted in partial mesh removal in 2/45 (4%) treated with polypropylene mesh and 2/14 patients treated with polyester mesh [14]. For primary suture closure, 27.6% (59/214 patients) had a SSI [9–12, 14, 15, 18], but this was not significantly different compared to the mesh group ($p = 0.103$), OR 0.65 (95% CI 0.23–1.81), $I^2 = 45.35$, see Fig. 3.

Overall recurrence rates were 2.7% (3/112 patients) in the synthetic mesh group versus 10.2% (21/206 patients) in the primary suture group [9–11, 15]; OR 1.81 (0.18; 17.80) $I^2 = 55.63$, see Fig. 4. Three of the 15 patients (20.0%) treated with synthetic mesh with VAWCM developed a recurrence [9]. In the group treated with synthetic mesh without VAWCM, no recurrence was reported (0/97 patients)[10–12, 30].

Incisional hernia occurred in 11.1% (19/171 patients) of all patients treated with synthetic mesh. Patients treated without VAWCM developed an incisional hernia in 10.2% (16/157 patients). The use of synthetic mesh in combination with VAWCM resulted in three incisional hernias out of 14 patients (21%) [8–12, 14].

Bjørsum-Meyer et al. reported three incisional hernias (3/14, 21%), after 1, 12 and 19 months [9]. Petersson et al. had a median follow-up of 405 days (40–953 days) and reported one incisional hernia (1/20, 5.0%) [34].

Table 3 Studies reporting on mesh: details of the type and position of the mesh

Author	Year	Group	No. patients	Type of mesh	Mesh position	Definitive closure technique
McNeeley [17]	1998	Synthetic mesh	7	Marlex® mesh	Inlay	
			4	Prolene® mesh	Inlay	
			7	Polyglactin mesh	Inlay	
Abbott [30]	2007	Synthetic mesh	10	Polyglactin mesh	Inlay	Skin graft
Kelley [7]	2010	Biological mesh	1	200-cm^2 Strattice® biological mesh (LifeCell, Branchburg, NJ)	Onlay	By passing #1 Quil™ SRS PDO suture perpendicular to the incision line
Scholtes [8]	2012	Synthetic mesh	33	Polypropylene mesh	Intraperitoneal	
Bjørsum-Meyer [9]	2013	VAWCM	18	Polypropylene mesh	Inlay	Delayed primary suture closure
NCT01083472 [32]	2013	Biological mesh	18	Strattice® mesh	Intraperitoneal or retrorectus	
Petersson [10]	2014	VAWCM	6	Polypropylene mesh	Inlay	2 Delayed primary suture closure 3 retromuscular polypropylene or polyvinylidene mesh 1 died
		Synthetic mesh	21	11 Polypropylene mesh 10 Polyvinylidene mesh	retromuscular	
Lord [31]	2015	VAWCM	1	Prolene® mesh	Inlay	Fascia with interrupted nylon sutures + skin grafting
López-Cano [11]	2015	Synthetic mesh	56	Polypropylene mesh	Onlay	
Abo-Ryia [12]	2017	Synthetic mesh	11	Polypropylene mesh	Inlay + Bridging	
Jakob [14]	2018	Synthetic mesh	54	Polypropylene mesh	Intraperitoneal	
			16	Polyester mesh	Intraperitoneal	

Table 4 Included studies primary suture group

Author	Year	Time period	No. patients	Suture materials	SL:WL ratio
Gislason [18]	1999	1986–1996	18	Polyglactin	NR
			17	Polyglycolic acid (Dexon)	NR
			10	Polyglyconate (Maxon™ loop)	NR
			2	Polydioxanone (PDS®)	NR
			2	Polyamide (Ethilon™)	NR
			4	Unknown material	NR
Abbott [30]	2007	1997–2005	27	Large diameter sutures 15 retention sutures	NR
Scholtes [8]	2012	2001–2009	45	PDS® loop 1 sutures or additional Vicryl® strings	NR
Petersson [10]	2014	2010–2012	12	0-0 or 2-0, polydioxanone or polypropylene	Not routinely measured
López-Cano [11]	2015	2006–2011	35	Running suture of polydioxanone material	NR
Jakob [14]	2018	2001–2015	49	Single running suture using loop 0-PDS®	4:1
Tilt [15]	2018	2011–2015	43	Vertical mattress sutures using Prolene®, with minimal deep suture placement	NR

NR not reported

López-Cano et al. followed 34 mesh group patients (34/56, 60.7%), six patients developed incisional hernia after a minimum follow-up of 12 months (6/34, 17.6%) [11].

Primary suture closure resulted in an incisional hernia rate of 30.7% (67/218 patients) [8, 10, 11, 14, 15, 18]. Gislason et al. reported a 43% incisional hernia rate (23/53 patients) with a median follow-up of 23 months (1–8 years), with different hernia rates for various suture materials [18]. Reported rates are included in Table 5. Petersson et al. had a median follow-up of 619 days (205–1042 days) and 53.3% developed an incisional hernia (8/15 patients) [10].

Incisional hernia rates were significantly higher for patient after primary suture closure [$p = 0.036$, OR 4.01 (95% CI 1.70–9.46), $I^2 = 22.60$] using Binary Random-Effects Model, see Fig. 5. No significant difference was

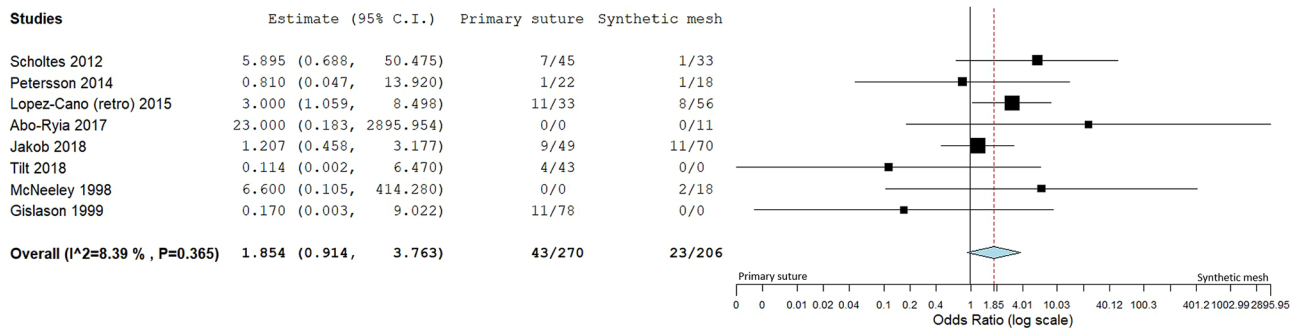

Fig.2 Forest plot mortality rate, Binary Random-Effects Model

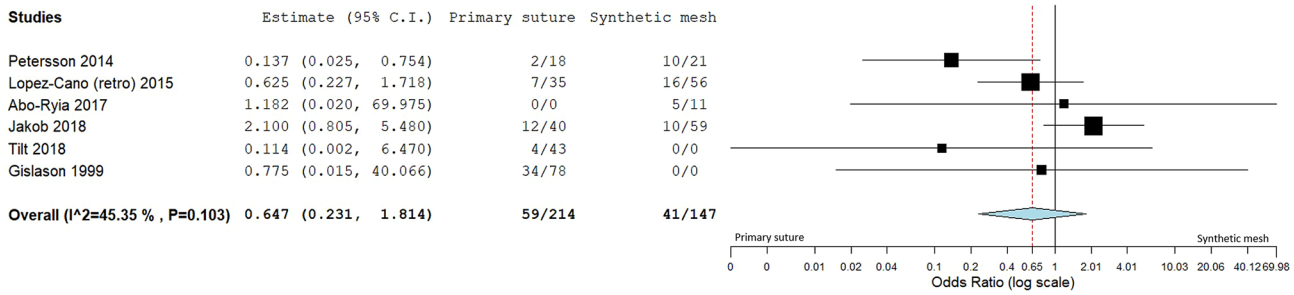

Fig. 3 Forest plot SSI, Binary Random-Effects Model

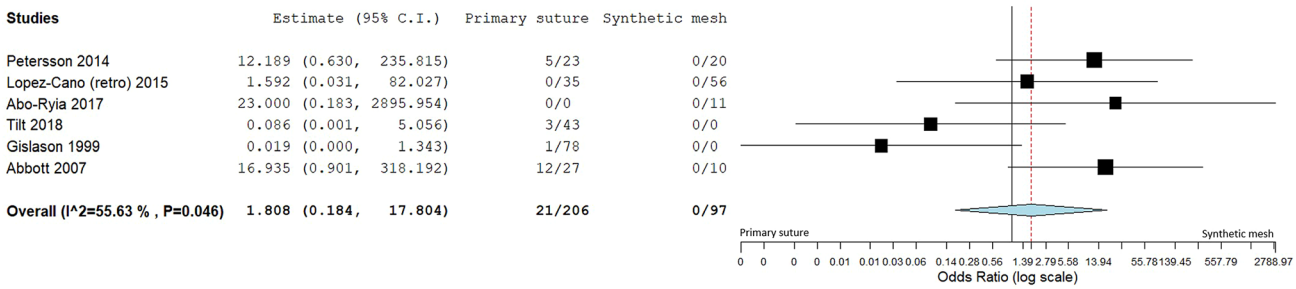

Fig. 4 Forest plot recurrence, Binary Random-Effects Model

Table 5 Incisional hernia rate, outcome reported by Gislason et al. [18]

Suture materials	Hernia rate (%)	Hernia/total
Polyglactin (Vicryl)	33	6/18
Polyglycolic acid (Dexon)	35	6/17
Polyglyconate (Maxon™ loop)	60	6/10
Polydioxanone (PDS®)	100	2/2
Polyamide (Ethilon™)	0	0/2
Unknown material	75	3/4

observed between primary suture closure and mesh group for SSI, recurrence and mortality.

Two studies received external funding [22, 32]; one study received an internal funding [13].

Discussion

This study provides an overview of the impact of mesh and other closing techniques on the core clinical outcomes of surgical site infection (SSI), recurrence and hernia formation as to be able to guide surgeons towards current best evidence. To date, only published retrospective studies were

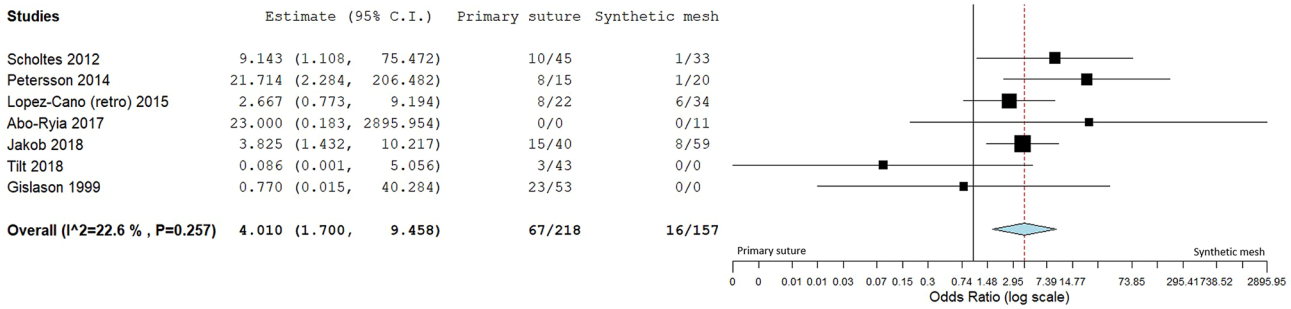

Fig. 5 Forest plot incisional hernia, Binary Random-Effects Model

found in the literature and only a few studies had considerable numbers of patients. Our meta-analysis showed that the use of synthetic mesh results in lower incisional hernia rates compared to primary suture closure, confirming previously published results [8, 10, 11, 14, 30]. This reinforces the statement that patients with a high risk for developing an incisional hernia should be treated with a synthetic mesh. There are various reports indicating that the use of a synthetic mesh results in higher SSI and SSO rates than primary suture closure [10, 11, 14]. In this meta-analysis, SSI were considerable in both groups, but there was no significant difference in favour of the primary suture group. Consequences of SSI may include mesh removal and prolonged treatment with antibiotics.

Lima et al. reported that AWD can be prevented in high-risk patients, using our previously developed risk score for AWD [4, 35]. They compared the use of a preventive polypropylene mesh in the onlay position to primary suture closure using slowly absorbable running sutures in high-risk patients undergoing emergency laparotomy [34]. In this randomized clinical trial, the use of a mesh prevented fascial dehiscence (0/63 patients) when compared to the 7 out of 52 patients (13.5%) in the suture group ($p = 0.003$). The use of mesh was not associated with significantly higher SSO rates, but some specific SSO (SSI, seroma and superficial wound dehiscence) were more frequently reported. SSO rates were 42.9% (27/63 patients) in the mesh group and 28.8% (15/52 patients) in the suture group. However, this study was based on prevention of AWD, not treatment [34].

Limitations of our study include the retrospective design of the studies that were included, with a considerable proportion of possible confounding variables not reported by the majority, such as wound class. Clean wounds could be closed with primary suture closure, although in the literature this is associated with higher recurrence rates [10, 19, 30]. The use of synthetic mesh is often associated with a decrease in incisional hernia rates, as confirmed in our meta-analysis [8, 10, 11, 14]. Mortality rates were lower for patients treated with synthetic mesh versus patients treated with primary suture closure, although statistically not significant and, possibly, a form of selection bias. This confirms previously published results [8, 11, 14]. Considering the sum of these outcomes, the use of synthetic mesh is slightly favourable over primary suture closure. The EHS clinical guidelines reported that the use of a mesh is related to an increased incidence of SSO, but a decreased incisional hernia rate and mortality rate. The EHS recommends the use of mesh reinforcement whenever fascial closure is possible [22]. Overall, the results by the EHS are comparable with results of our meta-analysis. As for clinical implications, surgeons will still need to assess the contamination degree of the wound and trade the risk of SSI for the benefit of decreased AWD with a synthetic mesh closure. In case of dirty wounds, the risk of mesh infection may be higher than the benefit from decreased hernia.

Our analysis included 11 studies published after 2010, providing a relevant update of recent literature regarding the management of AWD. VAWCM was published by Petersson, often proposed as a good alternative in cases with severe visceral swelling [35]. VAWCM is often associated with high material cost [36, 37]. With only three studies reporting on the use of VAWCM and outcomes limited to less than 25 patients, it is a technique that needs more exploration in terms of potential benefits in the setting of AWD [9, 10, 31]. We are aware that some surgeons use a strategy involving onlay slowly resorbable mesh in combination with negative pressure wound therapy, but we were unable to find any reports. Retention type sutures, like NGT presented by Vahedian et al. may provide an alternative for resource-limited countries [33]. Mesh strips, IW-CONPIT and biological meshes are newly presented alternatives with early promising results [7, 13, 16]. Dumanian et al. recommended mesh strips in contaminated wounds [13]. Mesh strips offer the durability of a planar mesh, while minimizing the total volume of material. Future studies on these new techniques are needed to compare the surgical outcomes of primary suture closure and synthetic mesh with the new techniques.

Conclusion

There is an overall lack of evidence in studies published regarding the management of abdominal wound dehiscence. The use of synthetic mesh shows the best outcomes with regard to incisional hernia rate, and inclusion of the latest studies showed no increase in SSI rates. Results reported in the EHS clinical guidelines correspond with our findings, confirming the recommendation to use mesh when fascial closure is possible. Methods like VAWCM, the use of synthetic mesh strips and the use of biological mesh have only been reported anecdotally.

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Compliance with ethical standards

Conflict of interest None of the authors reported a conflict of interest.

Ethical approval As this was a meta-analysis, no ethical approval was requested.

Human and animal rights This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent No informed consent is required.

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