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Damage Control Surgery in Patients with Non-traumatic Abdominal Emergencies: A Systematic Review and Meta-Analysis

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ABSTRACT

Background

After the successful implementation in trauma, damage control surgery (DCS) is being increasingly used in patients with non-traumatic emergencies. However, the role of DCS in the non-trauma setting is not well defined. The aim of this study was to investigate the effect of DCS on mortality in patients with non-traumatic abdominal emergencies.

Methods

Systematic literature search using PubMed. Original articles addressing non-trauma DCS were included. Two meta-analyses were performed, comparing (#1) mortality in patients undergoing non-trauma DCS vs. conventional surgery (CS) and (#2) the observed vs. expected mortality rate in the DCS group. Expected mortality was derived from APACHE, SAPS, and P-POSSUM scores.

Results

A total of five non-randomized prospective and 16 retrospective studies were included. Nontrauma DCS was performed in 1,238 and non-trauma CS in 936 patients. Frequent indications for surgery in the DCS group were (weighted proportions) hollow viscus perforation (28.5%), mesenteric ischemia (26.5%), anastomotic leak and postoperative peritonitis (19.6%), nontraumatic hemorrhage (18.4%), abdominal compartment syndrome (17.8%), bowel obstruction (15.5%), and pancreatitis (12.9%). In meta-analysis #1, including eight studies, mortality was not significantly different between the non-trauma DCS and CS group (risk difference [RD] 0.09, 95% CI -0.06/0.24). Meta-analysis #2, including 14 studies, revealed a significantly lower observed than

expected mortality rate in patients undergoing non-trauma DCS (RD -0.18, 95% CI -0.29/-0.06).

Conclusion

This meta-analysis revealed no significantly different mortality in patients undergoing nontrauma DCS vs. CS. However, observed mortality was significantly lower than the expected mortality rate in the DCS group, suggesting a benefit of the DCS approach. Based on these two findings, the effect of DCS on mortality in patients with non-traumatic abdominal emergencies remains unclear. Further prospective investigation into this topic is warranted.

Level of evidence: III, systematic review and meta-analysis

Keywords: abdominal emergency, damage control surgery, emergency general surgery, open abdomen treatment, meta-analysis

INTRODUCTION

Damage control surgery (DCS) is a well-known and widely used concept in trauma surgery.(1) In the trauma setting, DCS is performed in patients with hemorrhagic shock and subsequent physiologic derangements, including acidosis, hypothermia, and coagulopathy, that are known to adversely affect outcomes.(2)

In critically ill patients with non-traumatic abdominal emergencies, profound physiologic derangements have also been described(3), including acidosis, coagulopathy, endothelial leakage, vasodilatation and hypotension, myocardial depression, acute kidney injury, hepatic insufficiency, and multi-organ failure.(4-6) Furthermore, patients undergoing emergency abdominal surgery for non-traumatic emergencies are typically of older age and suffer from comorbidities.(7) In these frail patients, prolonged surgery in an attempt to perform a definitive repair and abdominal closure can further aggravate physiologic derangements and lead to worse outcomes.(8) It therefore seems reasonable to apply damage control principles to patients undergoing surgery for non-traumatic abdominal emergencies, especially in older patients with reduced physiological reserves.

However, although increasingly used, DCS remains controversial in non-trauma patients.(9, 10) The open abdomen (OA) treatment typically performed in DCS is a non-anatomical situation and associated with several potentially severe side effects, including fluid and protein loss, fistula formation, and incisional hernias. Furthermore, the required hospital resources are high in patients undergoing DCS with OA treatment.(9, 11, 12) Patients undergoing emergency laparotomy for non-traumatic emergencies are typically older and have more comorbidities than trauma patients.(13, 14) The above-named side-effects of DCS therefore may have a more significant

impact on mortality in non-trauma patients than in trauma patients.

Taking into account the increasing use of DCS in the non-trauma setting and ongoing debate about the rationale for this surgical strategy in patients with non-traumatic abdominal emergencies, a comprehensive assessment of the current evidence is warranted. To date, the impact of DCS in patients with non-traumatic abdominal emergencies has not yet been assessed in meta-analysis. The aim of the current systematic review and meta-analysis was, therefore, to investigate the effect of DCS in patients with non-traumatic abdominal emergencies on mortality. We hypothesized that the DCS approach decreases mortality in patients undergoing surgery for non-traumatic abdominal emergencies.

METHODS

This is a systematic literature review and meta-analysis investigating the effect of DCS on mortality in patients with non-traumatic abdominal emergencies. DCS was defined as emergency surgery that required a follow-up procedure for anatomical repair and/or abdominal closure. On-demand re-laparotomy after primary definitive repair was not considered DCS. PRISMA guidelines were followed throughout the systematic review and meta-analysis.(15) (*Supplemental Table 3*, http://links.lww.com/TA/C232) This study was registered at ClinicalTrials.gov (NCT Number 04448912).

Literature search

A systematic literature search was conducted using the National Library of Medicine's Medline database (PubMed).(16) The search strategy was based on the PICOS process(17) and was

structured as follows:

- ***P**opulation:* Patients undergoing emergency abdominal surgery for non-traumatic abdominal emergencies
- ***I**ntervention:* Non-trauma damage control surgery (DCS)
- ***C**omparison:* Non-trauma conventional surgery (CS)
- ***O**utcome:* Mortality (in-hospital and 30 day)
- ***S**tudy type:* Original scientific articles

The final literature search was performed in January 2021. Articles were assessed and data extracted by three reviewers (MF, OQ, and TH). Differences were resolved by consensus.

Inclusion criteria were as follows:

1. Articles on DCS in patients with non-traumatic abdominal emergencies, including abbreviated laparotomy, temporary abdominal closure, and open abdomen treatment
2. Reported in-hospital or 30-day mortality in patients undergoing DCS vs. CS or
3. Reported observed in-hospital or 30-day mortality vs. expected mortality based on outcome prediction scores in patients undergoing DCS
4. Articles published from 2000 to 2020
5. Articles including patients older than 18 years
6. Original research articles
7. Articles in English language

In studies that reported overall mortality or mortality not further specified, the reported mortality

rate was assumed to correspond to in-hospital mortality. Details of the literature search are outlined in *Supplemental Table 1,* http://links.lww.com/TA/C230.

Abstracts of articles found in the literature search were screened for inclusion based on the above-mentioned criteria. Full text articles of abstracts that met the inclusion criteria were assessed. Studies relevant to the topic that were cited in articles found through the literature search were also included.

Reporting of data

Extracted continuous variables were reported as weighted mean or median, extracted categorical variables as weighted proportions. Weighted values were calculated based on the number of patients included in the individual studies.

Meta-analysis

Two separate meta-analyses were performed, comparing (#1) mortality in patients undergoing DCS vs. CS and (#2) the observed vs. expected mortality rate in patients undergoing DCS.

Meta-analysis comparing the observed vs. expected mortality rate included studies that reported the observed mortality and expected mortality rate based on Acute Physiology And Chronic Health Evaluation (APACHE) scores, Portsmouth Physiological and Operative Severity Score for enUmeration of Mortality and Morbidity (P-POSSUM), or Simplified Acute Physiology Score (SAPS). Four studies did not report the expected mortality rate, but the SAPS II score.(18-21) For the current analysis, the expected mortality was calculated by the investigators using the SAPS II

score reported in these studies.

Meta-analyses were performed using a random-effect model. The estimated effect size of DCS vs. CS on mortality, as well as the observed vs. expected mortality rate were reported as risk differences (RD) with 95% confidence intervals (CI). Heterogeneity of included studies was assessed using Cochran Q statistic, I^2 and H^2. The interpretation of heterogeneity was based on the consensus-based recommendations by Gagnier et al.(22)

Statistical analysis was performed using STATA Version 16 (StataCorp, College Station, TX, USA).

Sensitivity analysis

Sensitivity analysis was performed by repeating the random-effect models on reduced study sets. For meta-analysis #1, sensitivity analysis was performed in the subgroups of non-matched and propensity score matched studies. For meta-analysis #2, sensitivity analysis included the subgroups of studies reporting APACHE, SAPS, or P-POSSUM scores.

Quality assessment and risk of bias

The quality and risk of bias of the studies included in meta-analysis were assessed using the Newcastle-Ottawa Scale (NOS) for cohort studies with mortality as outcome measure.(23) *(Supplemental Table 2,* http://links.lww.com/TA/C231*)*

RESULTS

Study selection and characteristics

Figure 1 outlines the systematic literature search and study selection process. Study characteristics are shown in *Table 1*. The literature search revealed 1,340 articles. Of these, 21 articles, published from 2004 to 2019, fulfilled the inclusion criteria.(5, 7, 18-21, 24-38) Included studies comprised a total of 2,174 patients with non-traumatic abdominal emergencies. DCS was performed in 1,238 patients and CS in 936 patients.

The study design was retrospective in 16(5, 7, 18-21, 24-28, 30-32, 35, 36) and prospective in five(29, 33, 34, 37, 38) studies. Two studies used a matched design.(24, 26) No randomized controlled trials were among the selected studies.

Frequently reported indications for DCS were abdominal compartment syndrome, abdominal hypertension, peritonitis, peritoneal contamination, non-traumatic hemorrhage, sepsis, inability to close the fascia, and planned second look.

Temporary abdominal closure was performed using vacuum-assisted closure techniques in 13 studies(5, 7, 19, 20, 24, 25, 27, 28, 30, 33, 34, 36, 37), vacuum-assisted wound closure with mesh-mediated fascial traction in tree studies(18, 20, 29), occlusive dressings with low-pressure suction in one study(21), and the Opsite™ sandwich or Bogota bag technique in one study(38). Two studies reported abdominal packing.(30, 32) Three studies did not report temporary abdominal closure techniques.(26, 31, 35)

Of the studies that reported outcome prediction scores, four reported APACHE II scores(5, 30, 33,

36), two APACHE IV scores(27, 31), four the SAPS II(18-21), one the SAPS III(29), and three P-POSSUM scores(32, 34, 38).

Patient characteristics and indications for emergency abdominal surgery

The weighted proportion of male patients was 58.6% in the DCS group and 52.9% in the CS group, respectively. In the DCS group, the weighted mean and median age was 60.8 and 66.7 years, while in the CS group it was 64.8 and 62.4 years, respectively. In three studies that reported the American Society of Anesthesiologists (ASA) physical status classification system score, the weighted proportion of patients with an ASA score ≥ 3 was 69.1 % in the DCS group and 66.7 % in the CS group, respectively.(7, 26, 28)

Indications for emergency abdominal surgery are presented in *Table 2*. Mesenteric ischemia, anastomotic leakage and postoperative peritonitis, non-traumatic hemorrhage, abdominal compartment syndrome, and pancreatitis were more frequent indications for emergency surgery in the DCS group, whereas hollow-viscus perforations and bowel obstructions were more common in the CS group.

Postoperative complications and length of stay

Postoperative complications are summarized in *Table 3*. Most complications, including surgical site infections, abscesses, cardiac complications, and respiratory complications were more frequent in the DCS group. Renal failure was more commonly reported in the CS group. Fistulas and abdominal wall hernias were only reported in the DCS group.

In the DCS group, the weighted median and mean hospital length of stay was 22.4 and 52.6 days, whereas it was 9.7 and 40.8 days in the CS group. The weighted median and mean Intensive Care Unit length of stay was 15.5 and 20.2 days in the DCS group while it was 3.4 and 10.2 days in the CS group.

Meta-Analysis #1: DCS vs. CS (Figure 2)

Eight studies comprising a total of 1,573 patients reported mortality in patients undergoing DCS (n=637) or CS (n=936) and were included in meta-analysis comparing these two surgical approaches.(7, 24-28, 35, 37) In this meta-analysis, mortality was not significantly different between the DCS and CS group (RD 0.09, 95% CI -0.06/0.24). Heterogeneity of all studies included was high (Cochran's Q $p<0.01$, I^2 89.0 %).

In sensitivity analysis, mortality was significantly higher in the DCS compared to the CS group in the subgroup of propensity score matched studies (RD 0.10, 95% CI 0.04/0.17). In the subgroup on non-matched studies, mortality was not significantly different between patients undergoing DCS vs. CS (RD 0.09, 95% CI -0.12/0.30).

Meta-analysis #2: Observed vs. expected mortality in DCS (Figure 3)

Fourteen studies including a total of 733 patients undergoing DCS were included in meta-analysis on the observed vs. expected mortality rate.(5, 18-21, 27, 29-34, 36, 38) Meta-analysis revealed a significantly lower observed than expected mortality rate (RD -0.18, 95% CI -0.29/-0.06) in patients undergoing DCS. Heterogeneity of all included studies was high (Cochran's Q $p<0.01$, I^2 79.9 %).

In sensitivity analysis, observed mortality was also significantly lower than the expected mortality rate in the subgroups of studies reporting APACHE and P-POSSUM scores (RD -0.19, 95% CI -0.31/-0.07 and RD -0.33, 95% CI -0.48/-0.17), but not the subgroup of studies reporting SAPS scores (RD -0.07, 95% CI -0.30/0.16).

Quality assessment

Overall, the quality of the studies included in the meta-analysis was satisfactory. Two studies received nine out of nine stars(24, 26), 13 studies eight stars(5, 18-21, 29-34, 36, 38), and six studies seven stars(7, 25, 27, 28, 35, 37). *(Supplemental Table 1*, http://links.lww.com/TA/C230*)*

DISCUSSION

This systematic literature review and meta-analysis aimed to assess the effect the DCS approach on mortality in patients with non-traumatic abdominal emergencies.

Meta-analysis comparing mortality in patients undergoing DCS vs. CS for abdominal emergencies revealed no significantly different mortality risk between the two groups. (*Figure 2*) The results of this meta-analysis have to be interpreted with care. Mesenteric ischemia(39), anastomotic leakage and postoperative peritonitis(40), abdominal compartment syndrome(41), and pancreatitis(42), which are known to be associated with poor outcomes, were more frequent indications for emergency surgery in patients undergoing DCS compared to CS. *(Table 2)* Furthermore, although only reported in three studies, ASA scores greater or equal to three, as an indicator for severe comorbidities(43), were more frequent in the DCS group. Based on these

different indications for emergency surgery and patient characteristics, it seems likely that patients undergoing DCS had a higher mortality risk compared to patients undergoing CS.

In sensitivity analysis including the two studies using a propensity-matched design(24, 26), patients undergoing DCS had a significantly higher mortality risk compared to patients undergoing CS. This is of importance, as the adjusted baseline characteristics in these studies allow a better comparison between the two study groups. However, both studies matched on only three variables. One study used the Mannheim peritonitis index, vasopressor requirements, and a lactate level for propensity score matching.(24) The other study matched for the International Classification of Disease (ICD)-10 code, number of risk factors, and presence of preoperative sepsis.(26) In clinical practice, the decision to perform DCS depends on various criteria, including the underlying disease, physiology of the patient, degree of contamination, technical considerations, and training level of the surgeon. Thus, despite the matching procedure, a selection bias cannot be excluded in these studies.

In meta-analysis comparing the observed and expected mortality rate, observed mortality was significantly lower than expected mortality in patients undergoing DCS with a mortality risk difference of -0.18. *(Figure 3)* In a recent study comparing APACHE II, SAPS II, and P-POSSUM scores in patients undergoing planned relaparotomy for secondary peritonitis, all three scores discriminated well between survivors and non-survivors with an area under the curve of 0.958, 0.955, and 0.931, respectively.(44) Considering the difficult direct comparison of DCS vs. CS as described above, the lower than expected mortality found this meta-analysis suggests a potential benefit of the DCS approach in patients with non-traumatic abdominal emergencies.

The high statistical heterogeneity found in both meta-analyses is mostly explained by clinical and methodological heterogeneity, i.e., the different groups of patients investigated in the studies included, different study designs, and different outcome prediction scores. *(Tables 1-3, Figure 2)* Accordingly, statistical heterogeneity was lower in the subgroups of studies using the same design and studies that applied the same outcome prediction score. *(Figures 2 and 3)*

In the studies included in this review, indications for DCS were highly heterogeneous, as previously reported by *Becher et al(7)* and *Godat et al*(45). *(Table 1)* In trauma patients with massive hemorrhage, the lethal triad of hypothermia, acidosis, and coagulopathy is associated with a high mortality rate and has been widely used as an indication for DCS.(46, 47) Other than in trauma patients, there are many different underlying pathologies and indications for surgery in patients with non-traumatic abdominal emergencies. Some authors therefore suggested that the decision to perform DCS in non-trauma patients should not only be made based on the factors that comprise the lethal triad, but rather factors specific for this patient population, i.e. comorbidities, advanced age, systemic inflammatory response, and the ASA Score.(7)

Indications for non-trauma DCS are provided by *Becher et al.* According to this study, best candidates for DCS are male patients older than 70 years with multiple comorbidities, elevated lactate levels with acidosis, and severe sepsis or septic shock.(7) The authors also state that patients without preoperative inflammation may not benefit from DCS. In their article on the evolution of DCS in trauma and non-trauma patients, *Beldowicz et al* suggested that patient selection should focus on patients that may benefit from DCS, but tolerate potential over-utilization, which is

associated with increased morbidity.(48) Ordonez et al., in a recently published cohort study including 290 patients, provided a decision-making algorithm for the management patients with severe non-traumatic peritonitis, taking into account the DCS approach.(49)

The higher reported incidence of surgical site infections, abscesses, cardiac complications, and respiratory complications in the DCS compared to the CS group may well be explained by the different characteristics of the two groups as described above.

The more frequent renal failure in the CS group may be explained by the potentially delayed resuscitation in the Intensive Care Unit in this group compared to the DCS group. Another explanation may be the effect of the peritoneal negative pressure wound therapy on the renal function. It has been shown in a porcine sepsis model that peritoneal negative pressure wound therapy compared to passive drainage alone was associated with higher urinary output, despite more fluids given in the passive drainage group.(50) On the other hand, a retrospective study including 251 acute care surgery patients undergoing temporary abdominal closure revealed higher negative pressure wound therapy fluid output as a risk factor for acute kidney injury.(51) However, as only two studies reported renal failure in patients undergoing DCS and CS(24, 25), these potential explanations remains highly speculative.

A considerable weighted proportion of abdominal wall hernias of 16.6 % in patients undergoing DCS was found in the current study. However, emergency laparotomy per se is a known risk factor for incisional hernias(52) and the proportion of abdominal wall hernias in the current study is not more frequent than the rate reported in a recent randomized controlled trial including patients

undergoing CS.(53) The fistula rate in patients undergoing DCS found in the current review is comparable to the rate reported in the International Register of Open Abdomen (IROA). Of note, in multivariable analysis using data from the IROA, the duration of OA treatment, but not negative-pressure therapy was identified as a predictor for enteroatmospheric fistulas.(12)

In this study, both the total hospital and Intensive Care Unit length of stay were substantially longer in the DCS group compared to the CS group. The longer length of stay in the DCS may be explained by the required relook laparotomies in DCS. However, in addition to that, the different distribution of indications for emergency abdominal surgery in the two groups, with mesenteric ischemia, anastomotic leakage, non-traumatic hemorrhage, abdominal compartment syndrome, and pancreatitis being more frequent in the DCS group, most likely also contributed to the longer duration of hospitalization.

This systematic literature review and meta-analysis has several limitations. First, as most studies included were retrospective, the overall level of evidence was low. Second, the different outcome prediction scores used in the studies included in meta-analysis comparing the observed vs. expected mortality may have affected the risk difference between the observed and expected mortality. Third, as stated above, heterogeneity of the studies included in meta-analysis was high. Fourth, only two studies reported outcome prediction scores in patients undergoing CS(25, 27). A comparison of the observed vs. expected mortality rate was therefore not feasible in this group. Fifth, as literature search was performed using the National Library of Medicine's Medline database only, other relevant publications may have been potentially missed.

Considering the increasing use of DCS principles in patients with non-traumatic abdominal emergencies(10), the results of the two meta-analyses and the above-mentioned limitations of the available literature, further prospective investigation into this topic is warranted. Currently, the multicenter randomized controlled *Closed Or Open after Laparotomy* (COOL) trial aims to investigate the OA management strategy vs. formal closure of the fascia in patients with severe complicated intra-abdominal sepsis.(54)

In conclusion, the current systematic review and meta-analysis revealed no significantly different mortality in patients undergoing DCS vs. CS. However, the distribution of indications for emergency abdominal surgery was different in the two groups. In patients undergoing DCS, observed mortality was significantly lower than the expected mortality rate. Based on these results, the effect of DCS on mortality in patients with non-traumatic abdominal emergencies remains unclear and the indication for DCS or CS must be made individually. Nevertheless, the lower observed than expected mortality rate in the DCS group suggests a potential benefit of the DCS approach in the non-trauma setting. Further prospective investigation comparing non-trauma DCS vs. CS in homogenous patient cohorts is warranted.

Disclosure

TH, MF, OQ, DC, and BS have no conflicts of interest or financial ties to disclose. No funding was received for this study.

Author contribution statement

Study design: TH, BS

Literature search: MF, TH, OQ

Extraction of data: MF, TH, OQ

Analysis: TH, MF

Interpretation of results: TH, MF, BS, DC

Writing: TH, MF, BS

Critical revision: BS, DC

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Figure legends

Figure 1:

DCS: damage control surgery, CS: conventional surgery

*One study in both meta-analyses

Figure 2:

DCS: damage control surgery, CS: conventional surgery, CI: confidence interval

Figure 3:

DCS: damage control surgery, APACHE: Acute Physiology And Chronic Health Evaluation score, SAPS: Simplified Acute Physiology Score, POSSUM: Physiologic and Operative Severity Score for the enumeration of Mortality and Morbidity, Cl: confidence interval

Supplemental Digital Content

Supplemental Table 1: Search terms

Supplemental Table 2: Quality assessment according to Newcastle-Ottawa Scale for cohort studies

Supplemental Table 3: PRISMA checklist

Figure 1 PRISMA Flow Diagram

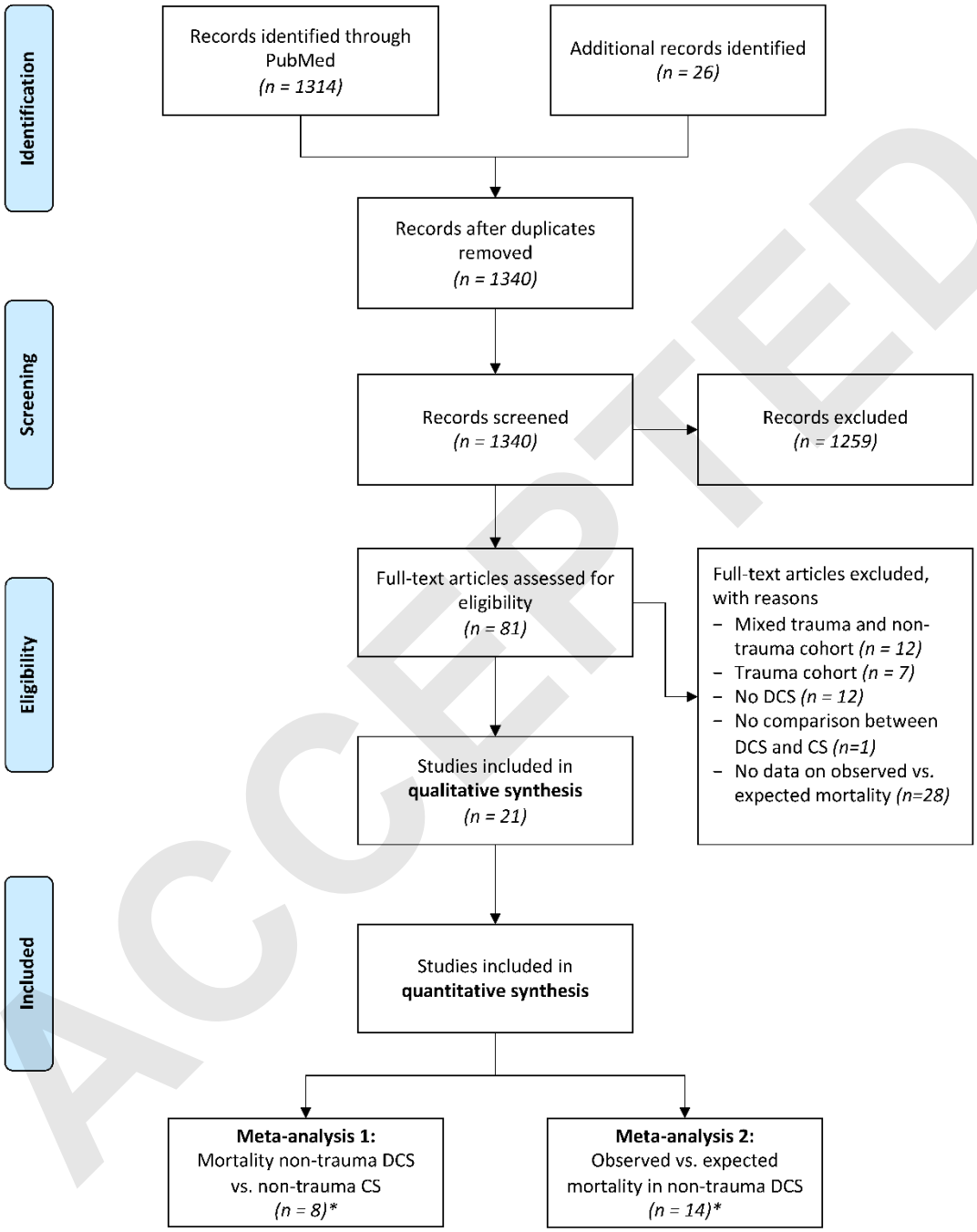

Figure 2: Mortality in patients undergoing non–trauma damage control surgery vs conventional surgery

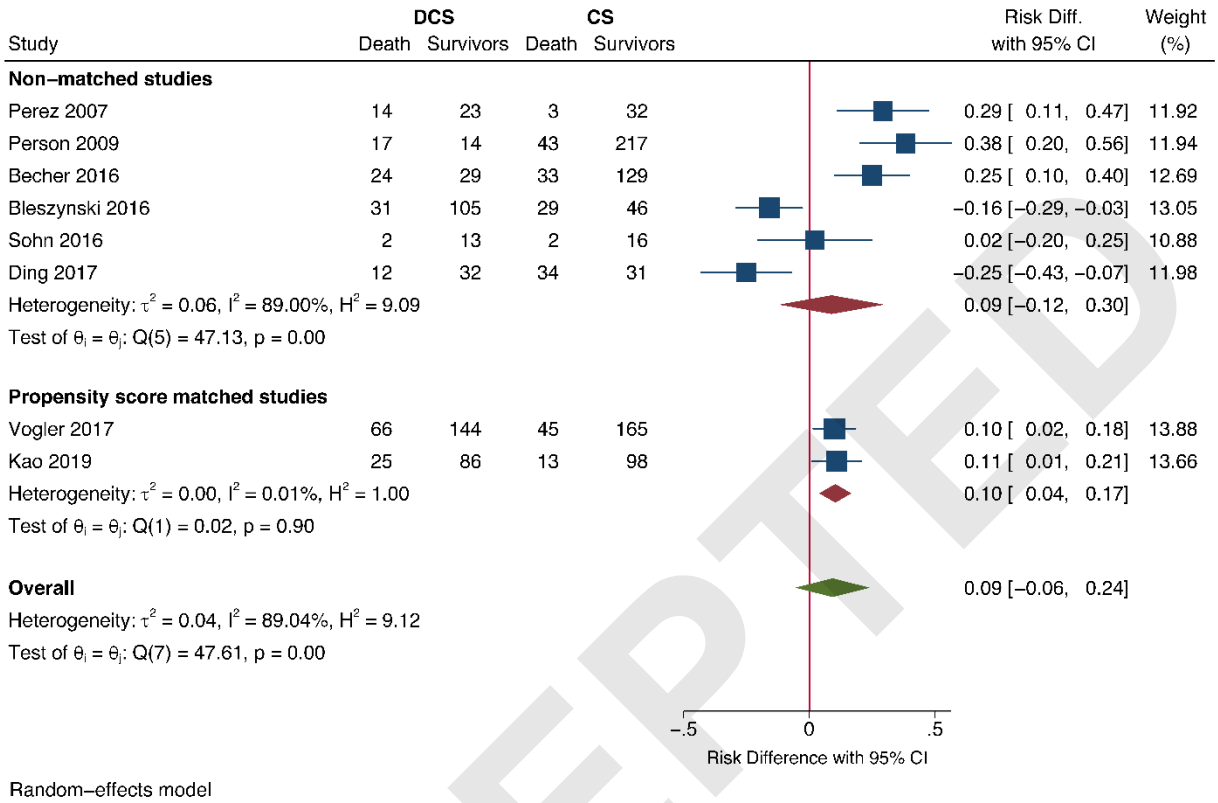

Figure 3: Observed vs. expected mortality in patients undergoing non-trauma damage control surgery

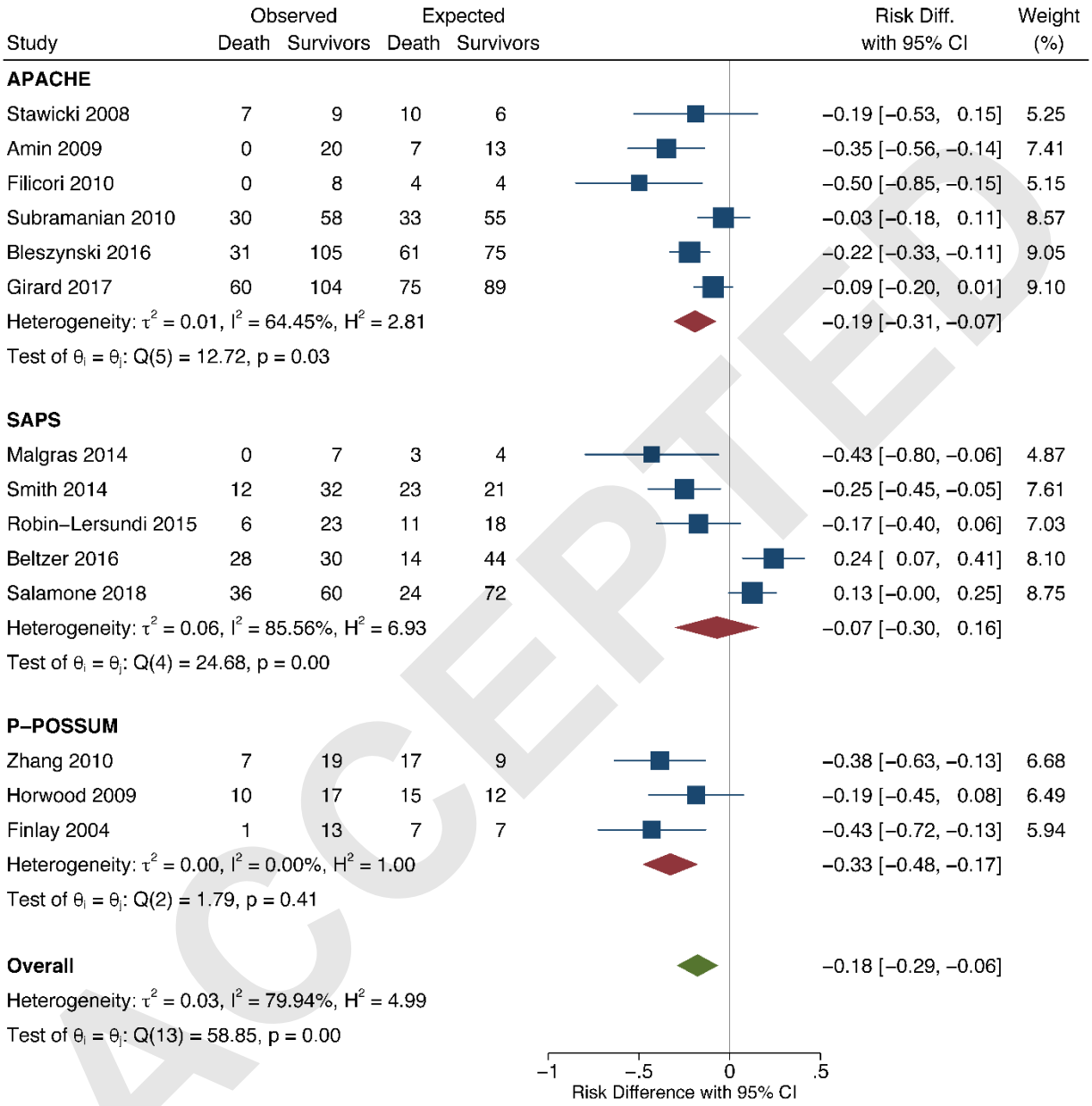

Table 1 Study characteristics

Author, Journal, Year	Patients	DCS	CS	Study type	Indications for non-trauma DCS	Temporary abdominal closure
	N	*N*	*N*			
Kao, *J Trauma Acute Care Surg* 2019	222	111	111	Retrospective	Vasopressors, contamination, intra-abdominal hypertension	VAWC
Salamone, *World J Surg* 2018	96	96	-	Retrospective	ACS, prophylactic, need for second look, full-thickness dehiscence	VAWCM, VAWC
Ding, *J Clin Gastroenterology* 2017	109	44	65	Retrospective	Peritonitis due to superior mesenteric artery occlusion	VAWC
Girard, *World J Surg* 2017	164	164	-	Retrospective	Hypotension, hypothermia, acidosis, coagulopathy	VAWC
Vogler, *Surgical Infections* 2017	420	210	210	Retrospective	Sepsis, gastric ulcer perforation, vascular disorder, bowel obstruction, bowel perforation, peritonitis, abscess	-
Becher, *World J Em Surg* 2016	215	53	162	Retrospective	Hypothermia, acidosis, coagulopathy, abdominal hypertension in non-trauma emergency abdominal surgery	VAWC
Beltzer, GMS *Interdiscip Plat Reconstr Surg* 2016	58	58	-	Retrospective	Secondary peritonitis, bowel obstruction, mesenteric Ischemia, intraabdominal abscess, ACS, AAA, pancreatitis	VAWCM
Bleszynski, *Am J Surg* 2016	211	136	75	Retrospective	Hemodynamic instability, bowel edema, gross peritoneal contamination, anticipated ACS, ongoing volume resuscitation, abdominal loss of domain	VAWC
Sohn, *Tech Coloproctol* 2016	37	19	18	Retrospective	Perforated diverticulitis with generalized peritonitis	VAWC
Robin-Lersundi, *Hernia* 2015	29	29	-	Prospective	Pancreatitis with intra-abdominal hypertension, abdominal sepsis requiring re-exploration or with high risk of ACS, major abdominal wall involvement	VAWCM
Malgras, *Am Surg* 2014	7	7	-	Retrospective	Peritonitis (GIT perforations), bleeding, ischemic colitis	VAWC

Smith, *J Trauma Acute Care Surg* 2014	44	44	-	Retrospective	Bowel viability, contamination, hemodynamic instability, abdominal hypertension at closing, significant bowel edema or distension at closure	Occlusive dressing with low-pressure suction
Filicori, *World J Surg* 2010	8	8	-	Retrospective	Severe hemorrhage during or after surgical procedures, acidosis, coagulopathy, hypothermia	Packing, VAWC
Subramanian, *Am J Surg* 2010	88	88	-	Retrospective	Planned second look, necrotic fascia, uncertain bowel viability, gross contamination, intra-abdominal hypertension, bowel edema or distension, hemodynamic instability	-
Zhang, *ANZ J Surg* 2010	26	26	-	Retrospective	Massive non-traumatic abdominal hemorrhage due to necrotizing pancreatitis, intestinal fistula, tumor	Abbreviated laparotomy with abdominal packing
Amin, *World J Gastroenterol* 2009	20	20	-	Prospective	Perforated viscus, anastomotic leak, iatrogenic bowel injury, pelvic inflammatory disease	VAWC
Horwood, *Ann R Coll Surg Engl* 2009	27	27	-	Prospective	Inability to close fascia, planned second look, ACS	VAWC
Person, *World J Em Surg* 2009	291	31	260	Retrospective	Peritonitis, mesenteric ischemia, intestinal obstruction, bleeding	-
Stawicki, *Injury* 2008	16	16	-	Retrospective	Abdominal sepsis, intraoperative bleeding, ischemic bowel, necrotizing pancreatitis	VAWC
Perez, *Am Coll Surg* 2007	72	37	35	Prospective	Severe abdominal sepsis, ACS	VAWC
Finlay, *Br J Surg* 2004	14	14	-	Prospective	Peritonitis (colon perforation, anastomotic leak, infarcted small bowel), hemorrhage (ruptured AAA, retroperitoneal), pancreatitis with ACS)	Opsite technique, Bogota Bag

DCS: non-trauma damage control surgery, CS: non-trauma conventional surgery, ACS: abdominal compartment syndrome, AAA: abdominal aortic aneurysm, GIT: gastro-intestinal tract, VAWC: vacuum-assisted wound closure, VAWCM: vacuum-assisted wound closure with mesh mediated fascial traction.

Table 2 Indications for emergency abdominal surgery

Author, Journal, Year	**Hollow viscus perforation**		**Mesenteric ischemia**		**Anastomotic leak/pos top. peritonitis**		**Non-traumatic hemorrhage**		**ACS**		**Bowel obstruction**		**Pancreatitis**	
Author, Journal, Year	**DCS**	**CS**	**DCS**	**CS**	**DCS**	**CS**	**DCS**	**CS**	**DCS**	**CS**	**DCS**	**CS**	**DCS**	**CS**
Weighted proportion (%)	28.5	34.5	26.5	17.9	19.6	9.3	18.4	3.1	17.8	0.0	15.5	35.2	12.9	0.9
Kao, *J Trauma Acute Care Surg* 2019	32 (28.8)	36 (32.4)	47 (42.3)	12 (10.8)	-	-	-	-	-	-	20 (18.0)	47 (42.3)	-	-
Salamone, *World J Surg* 2018	24 (25.0)	-	14 (14.6)	-	-	-	-	-	-	-	32 (33.)	-	18 (18.8)	-
Ding, *J Clin Gastroenterology* 2017	-	-	44 (100)	65 (100)	-	-	-	-	-	-	-	-	-	-
Girard, *World J Surg* 2017	21 (12.8)	-	68 (41.5)	-	23 (14.0)	-	14 (8.5)	-	52 (31.7)	-	-	-	28 (17.1)	-
Vogler, *Surgical Infections* 2017	65 (31.0)	65 (31.0)	-	-	-	-	-	-	-	-	34 (16.2)	34 (16.2)	-	-
Becher, *World J Em Surg* 2016	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Beltzer, GMS *Interdiscip Plat Reconstr Surg* 2016	-	-	5 (8.6)	-	27 (46.6)	-	-	-	3 (5.2)	-	7 (12.1)	-	2 (3.4)	-
Bleszynski, *Am J Surg* 2016	37 (27.2)	24 (32.0)	22 (16.2)	9 (12.0)	23 (16.9)	7 (9.3)	-	-	-	-	5 (3.7)	8 (10.7)	8 (5.9)	1 (1.3)
Sohn, *Tech Coloproctol* 2016	19 (100)	18 (100)	-	-	-	-	-	-	-	-	-	-	-	-
Robin-Lersundi, *Hernia* 2015	8 (27.6)	-	1 (3.4)	-	3 (10.3)	-	-	-	-	-	2 (6.9)	-	12 (41.4)	-
Malgras, *Am Surg* 2014	4 (57.1)	-	1 (14.3)	-	-	-	2 (28.6)	-	-	-	-	-	-	-

Smith, *J Trauma Acute Care Surg* 2014	17 (38.6)	-	11 (25.0)	-	-	-	-	-	-	-	8 (18.2)	-	-	-
Filicori, *World J Surg* 2010	-	-	-	-	-	-	8 (100)	-	-	-	-	-	-	-
Subramanian, *Am J Surg* 2010	19 (21.6)	-	11 (12.5)	-	11 (12.5)	-	2 (2.3)	-	4 (4.5)	-	10 (11.4)	-	11 (12.5)	-
Zhang, *ANZ J Surg* 2010	-	-	-	-	-	-	26 (100)	-	-	-	-	-		-
Amin, *World J Gastroenterol* 2009	9 (45.0)	-	-	-	8 (40.0)	-	-	-	-	-	-	-	-	-
Horwood, *Ann R Coll Surg Engl* 2009	16 (59.3)	-	1 (3.7)	-	7 (25.9)	-	-	-	1 (3.7)	-	-	-	1 (3.7)	-
Person, *World J Em Surg* 2009	-	-	10 (32.3)	9 (3.5)	-	-	3 (9.7)	8 (3.1)	-	-	2 (6.5)	151 (58.1)	-	-
Stawicki et al.(36), , *Injury* 2008	-	-	3 (18.8)	-	-	-	5 (31.3)	-	-	-	-	-	2 (12.5)	-
Perez, *Am Coll Surg* 2007	-	-	0 (0.0)	3 (8.6)	-	-	-	-	-	-	10 (27.0)	3 (8.6)	3 (8.1)	0 (0.0)
Finlay, *Br J Surg* 2004	4 (28.6)	-	1 (7.1)	-	3 (21.4)	-	5 (35.7)	-	-	-	-	-	1 (7.1)	-

Values are numbers (percentages) unless indicated otherwise.
ACS: abdominal compartment syndrome, DCS: non-trauma damage control surgery, CS: non-trauma conventional surgery.

Table 3 Postoperative complications

Author, Journal, Year	**Surgical site infection**		**Abscess**		**Cardiac complications**		**Respiratory complications**		**Renal failure**		**Fistula**		**Abdominal wall hernia**	
Author, Journal, Year	**DCS**	**CS**	**DCS**	**CS**	**DCS**	**CS**	**DCS**	**CS**	**DCS**	**CS**	**DCS**	**CS**	**DCS**	**CS**
Weighted proportion (%)	16.9	10.0	20.5	19.3	18.8	16.2	27.0	23.3	26.6	30.7	11.1	-	16.6	-
Kao, *J Trauma Acute Care Surg* 2019	12 (10.8)	5 (4.5)	-	-	29 (26.1)	18 (16.2)	30 (27.0)	21 (18.9)	31 (27.9)	19 (17.1)	-	-	-	-
Salamone, *World J Surg* 2018	-	-	-	-	-	-	-	-	-	-	-	-	19 (19.8)	-
Ding, *J Clin Gastroenterology* 2017	-	-	3 (6.8)	15 (23.1)	-	-	11 (25.0)	20 (30.8)	14 (31.8)	35 (53.8)	-	-	-	-
Girard, *World J Surg* 2017	-	-	-	-	-	-	-	-	-	-	-	-	27 (16.5)	-
Vogler, *Surgical Infections* 2017	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Becher, *World J Em Surg* 2016	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Beltzer, GMS *Interdiscip Plat Reconstr Surg* 2016	-	-	-	-	-	-	-	-	-	-	4 (6.9)	-	-	-
Bleszynski, *Am J Surg* 2016	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sohn, *Tech Coloproctol* 2016	4 (21.1)	4 (22.2)	1 (5.3)	1 (5.6)	-	-	-	-	-	-	-	-	-	-
Robin-Lersundi, *Hernia* 2015	10 (34.5)	-	-	-	-	-	1 (6.3)	-	-	-	-	-	-	-

Malgras, *Am Surg* 2014	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Smith, *J Trauma Acute Care Surg* 2014	-	-	17 (38.6)	-	-	-	-	-	-	-	4 (9.1)	-	-	-
Filicori, *World J Surg* 2010	3 (37.5)	-	4 (50.0)	-	1 (12.5)	-	4 (50.0)	-	-	-	1 (12.5)	-	-	-
Subramanian, *Am J Surg* 2010	8 (9.1)	-	14 (15.9)	-	9 (10.2)	-	26 (29.5)	-	19 (21.6)	-	11 (12.5)	-	12 (13.6)	
Zhang, *ANZ J Surg* 2010	-	-	-	-	-	-	15 (57.7)	-	-	-	4 (15.4)	-	-	-
Amin, *World J Gastroentero l* 2009	-	-	-	-	-	-	-	-	-	-	2 (10.0)	-	-	-
Horwood, *Ann R Coll Surg Engl* 2009	-	-	-	-	-	-	-	-	-	-	2 (7.4)	-	-	-
Person, *World J Em Surg* 2009	10 (32.3)	30 (11.5)	-	-	-	-	-	-	-	-	-	-	-	-
Stawicki et al.(36), , *Injury* 2008	4 (25.0)	-	6 (37.5)	-	3 (18.8)	-	7 (43.8)	-	5 (31.3)	-	7 (43.8)	-	-	-
Perez, *Am Coll Surg* 2007	-	-	-	-	-	-	-	-	-	-	1 (2.7)	-	-	-
Finlay, *Br J Surg* 2004	-	-	-	-	-	-	-	-	-	-	-	-	2 (14.3)	-

Values are numbers (percentages) unless indicated otherwise.
DCS: non-trauma damage control surgery; CS: non-trauma conventional surgery.

Supplemental Table 1 Search terms

PICOS	
Population	"non-traumatic" OR "non-trauma" OR "nontrauma" OR "abdominal emergency" OR "emergency general surgery" OR "peritonitis" OR "sepsis" OR "perforation" OR "ischemia" OR "obstruction" OR "compartment syndrome" OR "fascial dehiscence" OR "anastomotic leakage" OR "pancreatitis" OR "vascular emergency" OR "bleeding" OR "hemorrhage" OR "source control"
Intervention	“damage control surgery” OR "damage control" OR "abbreviated laparotomy" OR "open abdomen" OR "temporary abdominal closure" OR “vacuum-assisted wound closure” OR “vacuum-assisted wound closure and mesh-mediated fascial traction” OR “mesh mediated traction” OR “Bogota bag” OR “Opsite sandwich” OR “Wittmann patch”
Comparison	"conventional surgery" OR "definitive closure" OR "definitive abdominal closure
Outcome	“outcome" OR "mortality" OR "complication" OR "morbidity" OR "infection" OR "surgical site infection" OR "fistula" OR "incisional hernia"
Study type	"Journal Article"
PubMed Query	
("non-traumatic" OR "non-trauma" OR "nontrauma" OR "abdominal emergency" OR "emergency general surgery" OR "peritonitis" OR "sepsis" OR "perforation" OR "ischemia" OR "obstruction" OR "compartment syndrome" OR "fascial dehiscence" OR "anastomotic leakage" OR "pancreatitis" OR "vascular emergency" OR "bleeding" OR "hemorrhage" OR "source control") AND ("damage control surgery" OR "damage control" OR "abbreviated laparotomy" OR "open abdomen" OR "temporary abdominal closure" OR "vacuum-assisted wound closure" OR "vacuum-assisted wound closure and mesh-mediated fascial traction" OR "mesh mediated traction" OR "Bogota bag" OR "Opsite sandwich" OR "Wittmann patch") OR ("conventional surgery" OR "definitive closure" OR "definitive abdominal closure") AND ("outcome" OR "mortality" OR "complication" OR "morbidity" OR "infection" OR "surgical site infection" OR "fistula" OR "incisional hernia") AND ("Journal Article" [Publication Type]) Filters: Journal Article, English, Adult: 19+ years, from 2000/1/1 - 2020/12/31	

Supplemental Table 2 Quality assessment according to Newcastle-Ottawa Scale for cohort studies

Author, Journal, Year	**Selection**				**Comparability**	**Outcome**			**Total**
	Representative-ness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study		Assessment of outcome	Follow-up long enough for outcomes to occur	Adequacy of follow up of cohorts	
Kao, *J Trauma Acute Care Surg* 2019	*	*	*	*	**	*	*	*	9
Salamone, *WJS* 2018	*	-	*	*	**	*	*	*	8
Girard, *WJS* 2017	*	-	*	*	**	*	*	*	8
Ding, *J Clin Gastroenterology* 2017	*	*	*	*		*	*	*	7
Vogler, *Surgical Infections* 2017	*	*	*	*	**	*	*	*	9
Becher, *World J Em Surg* 2016	*	*	*	*		*	*	*	7
Beltzer, *GMS* 2016	*	-	*	*	**	*	*	*	8
Bleszynski, *AJS* 2016	*	*	*	*		*	*	*	7
Sohn, *Tech*	*	*	*	*		*	*	*	7

Coloproctol 2016									
Robin-Lersundi, *Hernia* 2015	*	-	*	*	**	*	*	*	8
Malgras, *AM Surg* 2014	*	-	*	*	**	*	*	*	8
Smith, *J Trauma Acute Care Surg* 2014	*	-	*	*	**	*	*	*	8
Filicori, *WJS* 2010	*	-	*	*	**	*	*	*	8
Subramanian, *AJS* 2010	*	-	*	*	**	*	*	*	8
Amin, *WJG* 2009	*	-	*	*	**	*	*	*	8
Horwood, *Ann R Coll Surg Engl* 2009	*	-	*	*	**	*	*	*	8
Person, *World J Em Surg* 2009	*	*	*	*		*	*	*	7
Stawicki, *Injury* 2008	*	-	*	*	**	*	*	*	8
Zhang, *ANZ J Surg* 2010	*	*	*	*	**	*	*	*	8
Perez, *J Am Coll Surg* 2007	*	*	*	*		*	*	*	7
Finlay, *BJS* 2004	*	-	*	*	**	*	*	*	8
Available at: http://www.ohri.ca/Programs/clinical_epidemiology/oxford.asp									

Supplemental Table 3 PRISMA Checklist			
Section/topic	**#**	**Checklist item**	**Reported on page #**
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Title page, abstract, 2
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	Abstract
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	1, 2
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	3
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	3
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	3, 4
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	3
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Suppl. Table 1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	3, 4
Data collection	10	Describe method of data extraction from reports (e.g.,	4, 5

process		piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	3, 4, Suppl. Table 1
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	6
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	4, 5
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	5, 6
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	6
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	5, 6
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Figure 1, 7
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Tables 1 and 2, 7, 8
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Suppl. Table 2, 10
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Figures 2 and 3, 9
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Figures 2 and 3, 9
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	Suppl. Table 2, 10
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see	Figures 2 and 3, 9

		Item 16]).	
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	11-16
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	15
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	15, 16
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	N/A