Med. J. Cairo Univ., Vol. 90, No. 8, December: 2435-2450, 2022
www.medicaljournalofcairouniversity.net

Using of Vacuum Assisted Closure System in Treatment of Post Sternotomy Mediastinitis Systematic Review and Meta-Analysis

MOHAMED MOHAMED ABD EL SAMEA SHALABY, M.Sc.; HANI ABD EL MAABOUD METWALLY, M.D.; YASSER MAHMOUD ELNAHAS, M.D. and RAMY MOHAMED REDA KHORSHID, M.D.

The Department of Cardiothoracic Surgery, Faculty of Medicine, Ain Shams University

Abstract

Background: The median sternotomy incision was first described for use in cardiac surgery by Julian and colleagues in 1957. They demonstrated discrete advantages of the median sternotomy incision for cardiac surgery, particularly, improved surgical efficiency, excellent exposure of the heart, great vessels and pulmonary hila, and reduced pulmonary trauma. This was a convincing argument for median sternotomy as the incision of choice for cardiac surgical procedures.

Aim of Study: The present study was the evaluation of the efficacy and safety of using of vacuum assisted closure system in treatment of post sternotomy mediastinitis.

Material and Methods: A search of the scientific literature was carried out querying electronic databases to identify relevant studies about VAC therapy and post sternotomy mediastinitis: PubMed, Embase, Cochrane Library, Dare, Sumsearch and Scirus.

Results: Application of inclusion and exclusion criteria to study abstracts yielded 8 articles. A total of 400 studies were identified from the database search. After review, a total of 11 studies were selected. This systematic review and meta-analysis conducted among 11 studies and aimed at evaluation for the efficacy and safety of VAC in treatment of sternal wound infection.

Conclusion: This meta-analysis concluded that VAC when used in treatment of DSWI, can lower mortality and ICU admission days. Diabetes and obesity were common among those who had deep sternal wound infection.

Key Words: *Vacuum – Sternotomy – Mediastinitis.*

Introduction

THE median sternotomy incision was first described for use in cardiac surgery by Julian and colleagues in 1957. They demonstrated discrete advantages of the median sternotomy incision for cardiac surgery, particularly, improved surgical efficiency, excellent exposure of the heart, great vessels and pulmonary hila, and reduced pulmonary trauma. This was a convincing argument for median sternotomy as the incision of choice for cardiac surgical procedures **[1]**.

Surgical site infection (SSI) following cardiovascular surgery is reported to occur in 1-10% of cases and can result in prolonged hospitalization and a higher mortality rate (9.8-14 %) **[2]**.

Patient related factors contributing to the risk of SSIs after cardiothoracic surgery have been well described in the literature and include obesity, renal insufficiency, diabetes mellitus, advanced age, gender, chronic obstructive pulmonary disease, smoking, steroid use, and length of hospitalization (>5 days) **[3]**.

Surgical risk factors include the use of 1 or 2 internal mammary artery (IMA) grafts (especially bilaterally and when using a pedicled IMA), duration of surgery and perfusion time, prolonged mechanical ventilation, post-operative bleeding, re-operation, sternal rewiring, extensive electrocautery, shaving with razors, and excessive use of bone wax **[4,5]**.

Complications may affect the superficial part of the wound, the sternum or the mediastinum. Classical techniques such as irrigation drainage, secondary closure or surgical reconstruction do not always produce the desired effect, and the infected wound remains a source of further complications **[6]**.

Vacuum-assisted closure (VAC) is a new technique that was originally developed for the needs of plastic and reconstructive surgery in the late 1990s. After a few years it found its place in the

Correspondence to: Dr. Mohamed M.A. Shalaby
E-Mail: mo7amed4shalapy@yahoo.com

treatment of chest wound infections. The VAC system is becoming more and more widespread as one of the elements of wound infection therapy [7].

Aim of the work:

The present study was the evaluation of the efficacy and safety of using of vacuum assisted closure system in treatment of post sternotomy mediastinitis.

Patients and Methods

Search strategy: A search of the scientific literature was carried out querying electronic databases to identify relevant studies about VAC therapy and post sternotomy mediastinitis: PubMed, Embase, Cochrane Library, Dare, Sumsearch and Scirus.

The keywords used to search for articles were connected with treatment and outcomes, as enumerated below: Keywords relating to disease: Mediastinitis; and Post sternotomy wound, keywords relating to treatment: Vacuum-assisted closure therapy; negative-pressure wound therapy; VAC and traditional therapy; VAC and standard moist wound therapy; and VAC and standard dressing, keywords relating to outcomes: Mortality, length of stay and hospital stay and the PubMed Related Articles function: which links each article to a list of references with similar content, was also used. Manual searching aimed to identify relevant studies from a reference list of articles.

Inclusion criteria: Studies published after 2011, adult patients 18- 65 years old and studies including follow-up for one month.

Exclusion criteria: Studies irrelevant to key words, small sample size or Underpowered studies (less than 50 patients) and case report studies.

Quality assessment: The methodology of each study was assessed independently by two authors who evaluated five potential sources of study bias. Disagreements were solved by consulting the third author by consensus, the method of allocation to study groups (random, 2; quasi-random, 1; and selected concurrent controls, 0). The data analysis and presentation of results (appropriate statistical analysis and clear presentation of results, 2; inappropriate statistical analysis or unclear presentation of results, 1; and inappropriate statistical analysis and unclear presentation of results, 0), the presence of baseline differences between the groups that were potentially linked to study outcomes (of particular importance for observational studies: no baseline differences present or appropriate statistical adjustments made for differences, 2; baseline differences present and no statistical adjustments made, 1; and baseline characteristics not reported, 0), the objectivity of the outcome (objective outcomes or subjective outcomes with blinded assessment, 2; subjective outcomes with no blinding but clearly defined assessment criteria, 1; and subjective outcomes with no blinding and poorly defined, 0); and the completeness of follow-up for the appropriate unit of analysis (90%, 2; 80e90%, 1; and 80% or not described, 0).

*Data extraction and data analysis:*We computed weighted estimates and 95% confidence intervals (CIs) of morbidity, intensive care unit duration, and hospitalization by random-effects meta-regression analysis. We computed χ^2 and I^2 statistics of heterogeneity. An I^2 value >50 was considered indicated the presence of heterogeneity. Pooled risk ratios were calculated using a random-effects model to obtain a robust estimate of morbidity, intensive care unit duration, and hospitalization. In contrast to classic regression, in meta-regression the smallest unit of observation is the individual study, not the individual patient. Random-effects modeling accounts for both within- and between-study variability and Higgins I-squared (I^2) statistical model was used to assess variations in outcomes of the included studies. I^2 less than 40% corresponded to low heterogeneity. Depending upon the strength of evidence for heterogeneity (p-value from the Chi-square analysis), I^2 of 41-74% indicated moderate (p=0.05) or moderate to severe (p=0.05), and I^2 of 75% or higher suggested substantial heterogeneity. Publication bias was illustrated graphically using a funnel plot. The methodological quality assessment of the included studies was performed using the Cochrane collaboration tool for the systematic review and meta-analysis, where each study was screened for five different types of bias (selection, performance, detection, attrition, and reporting bias). All statistical analysis was performed using the Digitize and the Cochrane Review Manager (RevMan) version 5.3.

Results

Study selection:

Application of inclusion and exclusion criteria to study abstracts yielded 8 articles. A total of 400 studies were identified from the database search. After review, a total of 11 studies were selected. The PRISMA flowchart can be seen in Fig. (1).

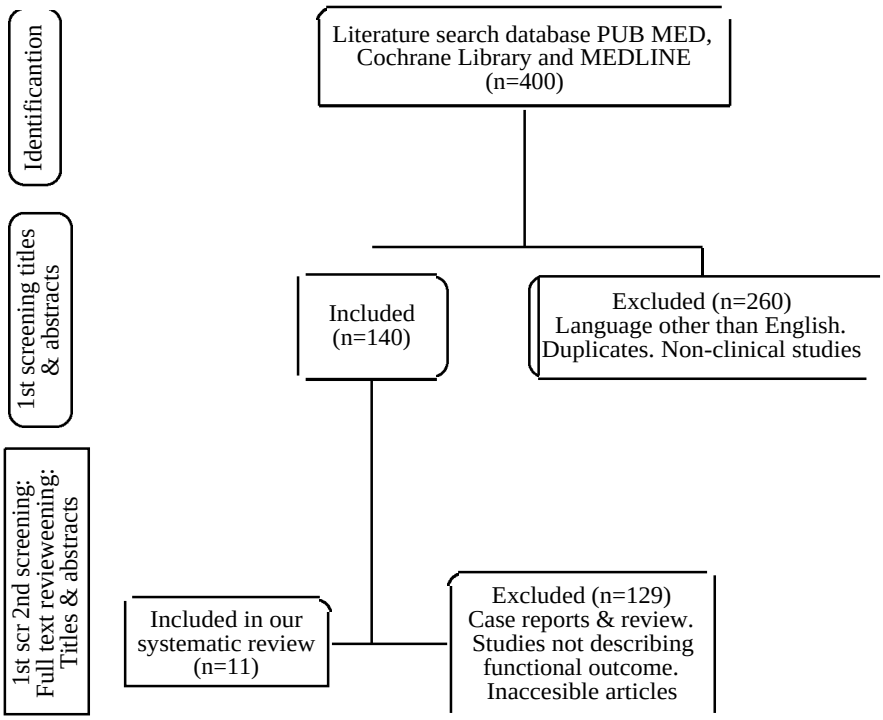

Fig. (1): PRISMA flow diagram of eligible studies.

Table (1): Summary of basic characteristics of the included studies included in our study.

First author	Year of publication	Type of study	Sample size (n)			Gender	
			Total	VAC	Non-VAC	Male	Female
Deniz	2012	A retrospective study	90	47	43	33	57
Fleck	2012	A retrospective study	524	326	198	61%	39%
Risnes	2012	A retrospective study	130	64	66	115%	15
Biefer	2012	A retrospective study	159	105	54	79.0%	21%
						85.2%	14.8%
Vos	2012	A retrospective analysis	132	89	43	87	45
Vos J.	2012	A retrospective analysis	113	89	24	80	33
Tarzia	2014	A retrospective study	152	45	107	109	43
Barbera	2019	A retrospective analysis	73	37	36	33	40
Pan	2020	A retrospective study	132	66	66	91	41
Hämäläinen	2021	A retrospective study	129	55	74	103	26
Myllykangas	2021	A retrospective analysis	125	55	60	NM	NM

The basic characteristics of the studies included in this systematic review were showed in Table (1). The included studies ranged in publication from 2012 to 2021. There were all retrospective studies included in our systematic review. There were 1759 participants included in this study. The sample size ranged from 73 to 529. Among them there were 978 treated by VAC.

Table (2): Age and obesity among the included studies.

First author	Year of publication	Study period	Age (years)		Obesity/BMI	
			VAC	Non-VAC	VAC	Non-VAC
Deniz	2012	Between January 2000 & December 2011	67.96±10.47	57.3±14.7	33 (70.2%)	22 (51.2%)
Fleck	2012	From 2002 to 2011	62±16	65±10	NM	NM
Risnes	2012	From January 1997 to October 2010	68.2 (±9.2)	63.3 (±10.2)		
Biefer	2012	Between January 1999 & December 2008	63.6±11.6	66.6±10.5	29.1 (±3.8)	28.1 (±4.1)
Vos	2012	Between January 2000 & January 2011	67.9±10.1	66.4±12.1	NM	NM
Vos J.	2012	Between January 1, 2000 & July 1, 2010	67.9±10.1	74.6±8.4	27.6±5.1	27.6±4.4
Tarzia	2014	Between January 2002 & June 2012	68±10	68±11	27.6±5.1	27.2±3.9
Barbera	2019	Between March 2005 & January 2018	68.3±11	68.3±11	13 (29%)	24 (22%)
Pan	2020	Between January 1, 2014 & June 1, 2018	60.2±11.7	59.0±11.2	13.7%	13.7%
Hämäläinen	2021	Between 2007 & 2016	40 to 87	40 to 87	27.1±4.0 15 (22.7%)	26.7±3.8 9 (13.6%)
Myllykangas	2021	Between the years 2006 & 2018	67.9±9.7	67.5±10.1	25 (45.5%) 30.6±5.6	28 (38.4%) 30.0±5.5

BMI: Body Mass Index. NM: Not Mentioned.

The included studies ranged in records from 1997 to 2018. The age ranging from 40 to 70 years among VAC group and ranging from 40 to 75 years among non-VAC group. The BMI ranging from 27 to 31 among VAC group while ranging from 26 to 28 among non-VAC group (Table 2).

Table (3): Diabetes and redo surgery among the included studies.

First author	Year of publication	Diabetes		Re-do surgery	
		VAC	Non-VAC	VAC	Non-VAC
Deniz	2012	15 (31.9%)	14 (32.6%)	4 (8.5%)	3 (6.9%)
Fleck	2012	25	20	NM	NM
Risnes	2012	25	20	NM	NM
Biefer	2012	31.7%	31.5%	NM	NM
Vos	2012	36 (40%)	16 (37%)	NM	NM
Vos J.	2012	36 (40.4%)	6 (25%)	NM	NM
Tarzia	2014	23 (51%)	32 (30%)	1 (2%)	7 (6%)
Barbera	2019	12 (16.4%)	12 (16.4%)	NM	NM
Pan	2020	26 (39.4%)	25 (37.9%)	NM	NM
Hämäläinen	2021	NM	NM	NM	NM
Myllykangas	2021	33 (60.0%)	28 (46.7%)	NM	NM

NM: Not Mentioned.

The diabetes was common among studies included in this systematic review **[8]** had 23 and 32 with diabetes among VAC and non-VAC groups respectively **[9]** had 15 and 14 with diabetes among VAC and non-VAC groups respectively **[10]** had 23 and 32 with diabetes among VAC and non-VAC groups respectively **[11]** had 26 and 25 with diabetes among VAC and non-VAC groups respectively **[12]** had 25 and 20 with diabetes among VAC and non-VAC groups respectively **[13]** had 31.7% and 31.5% with diabetes among VAC and non-VAC groups respectively (Table 3).

Table (4): Incidence of infection and bacterial strain among the included studies.

First author	Year of publication	Incidence of infection		Bacterial strain	
		VAC	Non-VAC	VAC	Non-VAC
Deniz	2012	NM	NM	S.aureus-methicillin resistant S.aureus	S.aureus-methicillin resistant S.aureus
Fleck	2012	3.2%	2.5%	Staphylococcus epidermidis-staphylococcus aureus-coagulase negative staphylococcus	Staphylococcus epidermidis-staphylococcus aureus-coagulase negative staphylococcus
Risnes	2012	NM	NM	Staphylococcus aureus-staphylococcus epidermidis	Staphylococcus aureus-staphylococcus epidermidis
Biefer	2012	2%	2%	Coagulase negative staphylococci-staphylococcus aureus	Coagulase negative staphylococci-staphylococcus aureus
Vos	2012	NM	NM	Staphylococcus aureus-coagulase negative staphylococcus	Staphylococcus aureus-coagulase negative staphylococcus
Vos J.	2012	NM	NM	Staphylococcus aureus or coagulase-negative staphylococcus strains	Staphylococcus aureus or coagulase-negative staphylococcus strains
Tarzia	2014	29 (64%)	47 (44%)	Staphylococcus aureus	Staphylococcus aureus
Barbera	2019	NM	NM	Coagulase-negative staphylococcus-S.aureus	Coagulase-negative staphylococcus-S.aureus
Pan	2020	23.3%	23.3%	Staphylococcus aureus-MRSA	Staphylococcus aureus-MRSA
Hämäläinen	2021	1.6%	1.6%	Coagulase negative staphylococci-staphylococcus aureus	Coagulase negative staphylococci-staphylococcus aureus
Myllykangas	2021	NM	NM	Staphylococcus epidermidis-staphylococcus aureus	Staphylococcus epidermidis-staphylococcus aureus

NM: Not Mentioned. S.aureus: Staphylococcus Aureus. MRSA: Methicillin Resistant Staphylococcus Aureus.

The incidence of infection after cardiac surgery was 1.5% and by **[8]** was 64% while it was 2% by **[13]** . The most common bacteria were coagulase negative staphylococci, Staphylococcus aureus and Staphylococcus epidermidis (Table 4).

Table (5): CABG and Euro score among the included studies.

First author	Year of publication	CABG		Euro Score	
		VAC	Non-VAC	VAC	Non-VAC
Deniz	2012	32 (68.1%)	29 (67.4%)	7.5±3.4	5.0±2.6
Fleck	2012	NM	NM	3	6
Risnes	2012	100%	100%	NM	NM
Biefer	2012	51%	51%	10.3±12.5	9.4±11.2
Vos	2012	76 (85%)	31 (72%)	NM	NM
Vos J.	2012	76 (85.4%)	19 (79.2%)	NM	NM
Tarzia	2014	NM	NM	NM	NM
Barbera	2019	40 (54.8%)	40 (54.8%)	NM	NM
Pan	2020	13 (19.7%)	15 (22.7%)	5.79±2.56	5.61±2.41
Hämäläinen	2021	52.3%	52.3%	NM	NM
Myllykangas	2021	40 (72.6%)	52 (86.7%)	3.4±2.3	4.83±6.6

NM: Not Mentioned.

The percentage of CABG and Euro score among the included studies were shown in Table (5). There were 85% and 72% had CABG by Vos et al., **[14,15]**. And it was 54% among both groups by Barbera et al., **[16]**. While **[12]** had included all participants who had CABG. Regarding Euro score, it ranged from 3 to 10.3 among VAC group while it ranged from 4.8 to 9.4 among non-VAC group (Table 5).

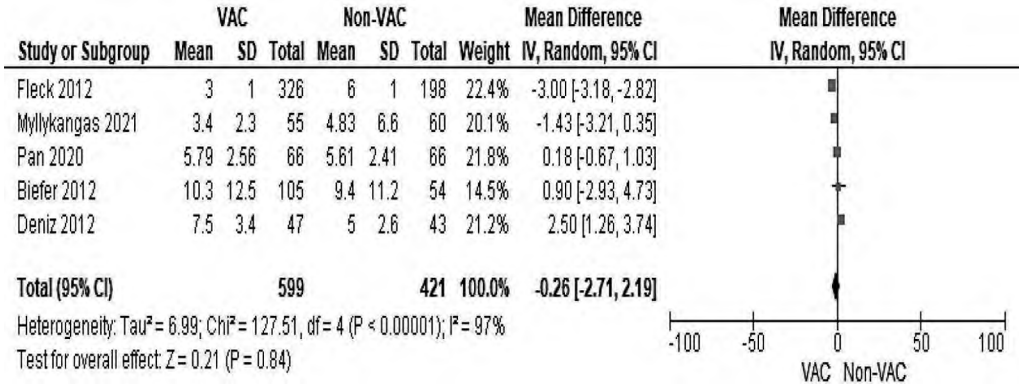

Fig. (2): Random-effects meta-analysis of the Euro score among included studies.

A total of 5 studies allowed for estimating the weighted risk ratio between Euro score among VAC and non-VAC groups. There was significant heterogeneity across studies (I^2=97%; p<0.001). The overall effect was not statistically significant (p=0.84). The pooled odds ratio was –0.26 (–2.71, 2.19) (Fig. 2).

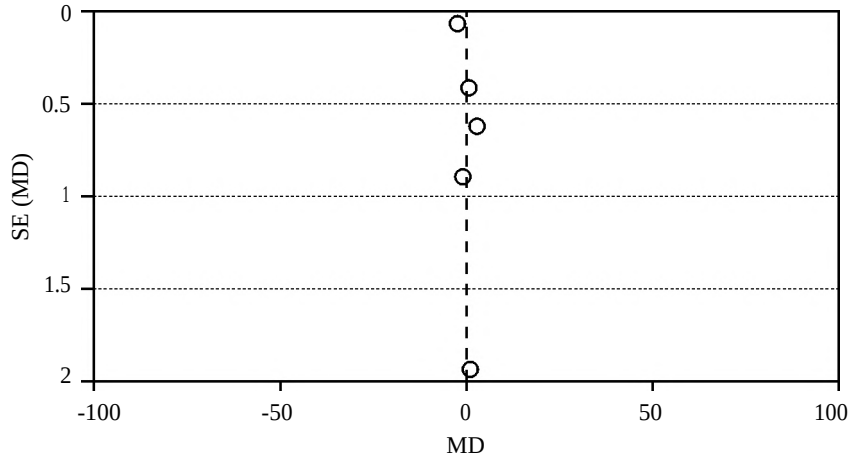

Fig. (3): Funnel plot showing possible publication bias across 5 studies.

On visual assessment of the funnel plots, publication bias was minimal for those 5 studies (Fig. 3).

Publication bias is the most well-known reporting bias. It results from the publication or non-publication of relevant trials, depending on the nature and direction of the results.

- X → BIAS

- γ → Sample size.

Table (6): Outcome mortality and ICU duration among the included studies.

First author	Year of publication	Mortality		ICU admission (d)	
		Non-VAC	VAC	Non-VAC	VAC
Deniz	2012	6	13	>2 days=19 (40.4)	20 (46.5%)
Fleck	2012	8.5%	34%	NM	NM
Risnes	2012	34.6%	28.8%	NM	NM
Biefer	2012	2 (1.9%)	3 (5.5%)	4.08±5.02	3.2±2.3
Vos	2012	28%	23 %	6.8± 14.4	4.8± 10.1
Vos J.	2012	12.4%	41.7%	6.8± 14.4	18.5±21.0
Tarzia	2014	0 (0%)	5 (11%)	5±7	9± 15
Barbera	2019	2.7%	19.2%	NM	NM
Pan	2020	11	0	3 (3-5)	4 (3-4)
Hämäläinen	2021	18 (23.6%)	13 (17.6%)	4	1
Myllykangas	2021	8 (14.5%)	0 (0%)	10.5± 13.4	6.9± 17.7

NM: Not Mentioned.

The mortality rate among the included studies ranging from 0 to 28 among VAC group and ranging from 0 to 68 among non-VAC group. The mean intensive care admission was ranging from 4 day to 11 days among VAC group and ranging from 3 to 20 days among non-VAC group (Table 6).

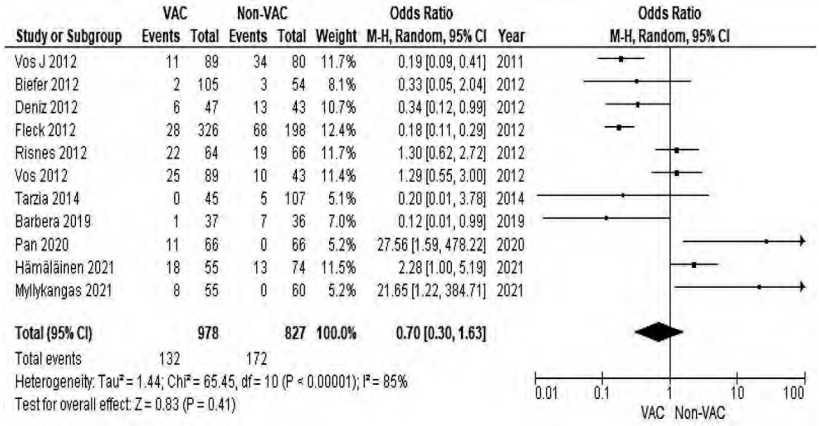

Fig. (4): Random-effects meta-analysis of the mortality rate among included studies.

All included studies allowed for estimating the weighted risk ratio between mortality rate among group 1 and 2. There was significant heterogeneity across studies (I^2=85%; p<0.001). The overall effect was not statistically significant (p=0.41). The pooled odds ratio for mortality rate was 0.70 (0.30, 1.63) (Fig. 4).

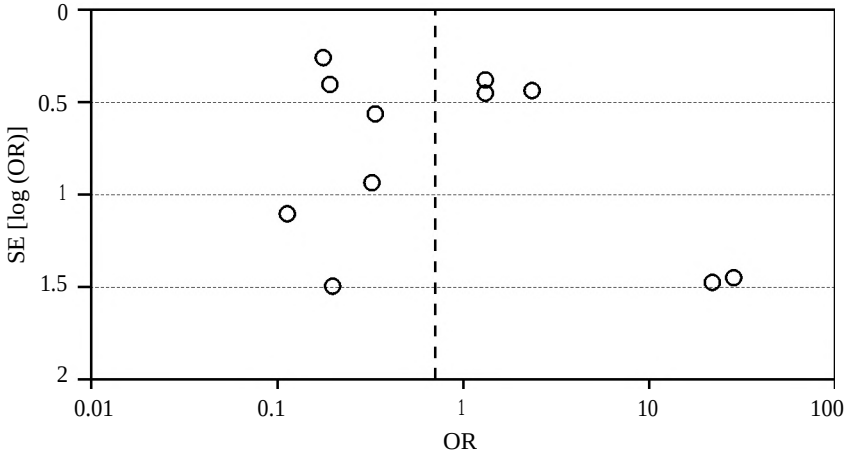

Fig. (5): Funnel plot showing possible publication bias across included studies.

On visual assessment of the funnel plots, publication bias was moderate for those studies (Fig. 5).

Publication bias is the most well-known reporting bias. It results from the publication or non-publication of relevant trials, depending on the nature and direction of the results.

- X → BIAS.

- y → Sample size.

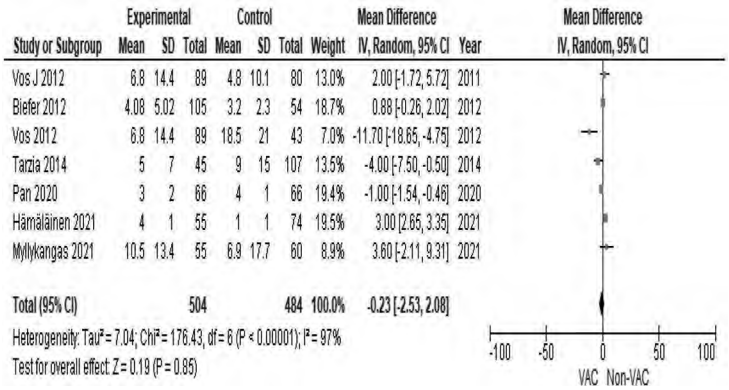

Fig. (6): Random-effects meta-analysis of the ICU admission duration among 8 studies.

A total of 7 studies allowed for estimating the weighted risk ratio between ICU admission duration among VAC (Experimental) and non-VAC (Control) groups. There was significant heterogeneity across studies (I^2=97%; p<0.0001) but the total overall effect was not statistically significant (Z= 0.19, p=0.85) (Fig. 6).

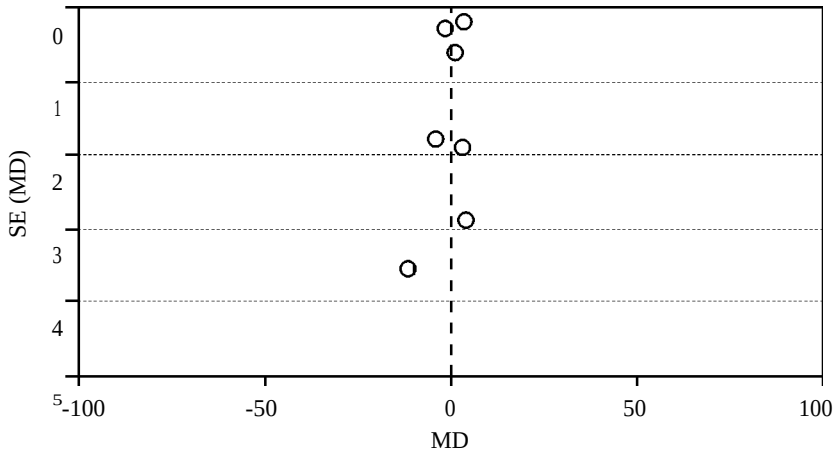

Fig. (7): Funnel plot showing possible publication bias across 6 studies.

On visual assessment of the funnel plots, publication bias was minimal for those 7 studies (Fig. 7). The vertical axis of the plot used the standard error to estimate the sample size of the study. The horizontal spread reflected that most studies were underpowered due to a wide CI of the effect size which not showed in our studies.

Publication bias is the most well-known reporting bias. It results from the publication or non-publication of relevant trials, depending on the nature and direction of the results.

- X → BIAS
- γ → Sample size.

Table (7): Length of hospitalization, recurrence, and complications among the included studies.

First author	Year of publication	Length of hospitalization		Recurrence		Complications	
		VAC	Non-VAC	VAC	Non-VAC	Non-VAC	VAC
Deniz	2012	26±8	31±9	1 (2.1 %)	2 (4.6%)	NM	NM
Fleck	2012	22±19	22±19	3.6%	10%	0	4
Risnes	2012	14	14	4 (6.3%)	14 (21.2%)	4	2
Biefer	2012	21.10±16.4	13.3±12.1	6 (5.0%)	2 (5.1%)	NM	NM
Vos	2012	74±61	45±38	NM	NM	NM	NM
Vos J.	2012	74±61	69±62	NM	NM	NM	NM
Tarzia	2014	27±14	30±22	NM	NM	18 (40%)	62 (57.9%)
Barbera	2019	16.9±4.9	16.9±4.9	0	0	9.6%	9.6%
Pan	2020	30 (22-47)	16 (14-23)	11 (1.7%)	6 (9.1%)	29	16
Hämäläinen	2021	38	18	7	1	NM	NM
Myllykangas	2021	36.8±28.1	25.6±38.7	NM	NM	25 (45.5%)	36 (60%)

NM: Not Mentioned.

The length of hospitalization was ranging from 14 days to 74 days among VAC group while ranging from 13 days to 69 days among non-VAC group. The largest hospitalization was 74±61 days among VAC group by **[14,15]**. The recurrence rate was ranging from 1 case to 11 patients among VAC group while it was ranging from I patient to 14 patients. The recurrence rare was zero by **[16]**. According to complications, **[8]** had 40% and 57.9% complications among Non-VAC group and VAC group. Also, **[17]** had 45.5% and 60% with complications among Non-VAC and VAC groups (Table 7).

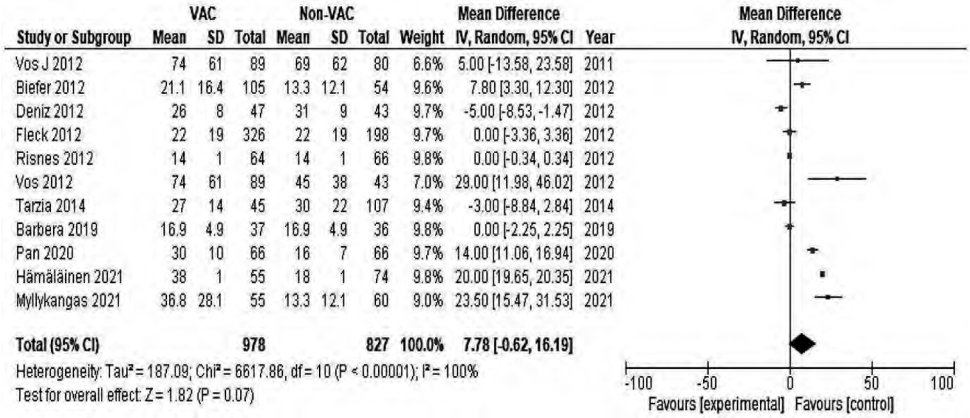

Fig. (8): Random-effects meta-analysis of length of hospitalization among VAC and non-VAC groups.

Estimating the weighted risk ratio between all studies regarding length of hospitalizations in days among VAC and non-VAC groups. There was significant heterogeneity across studies (I^2=100%; p<0.001). The overall effect was not statistically significant (Z=1.82, p=0.07) (Fig. 8).

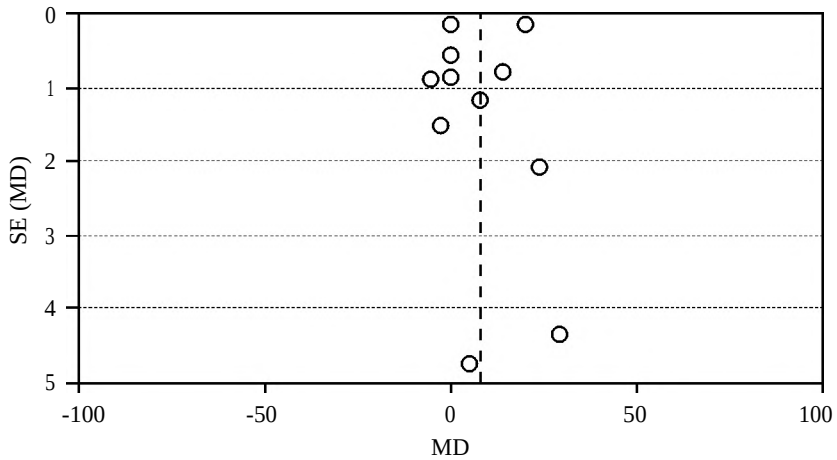

Fig. (9): Funnel plot showing possible publication bias across studies.

On visual assessment of the funnel plots, publication bias was minimal for those studies (Fig. 9).

Publication bias is the most well-known reporting bias. It results from the publication or non-publication of relevant trials, depending on the nature and direction of the results.

- X → BIAS.
- y → Sample size.

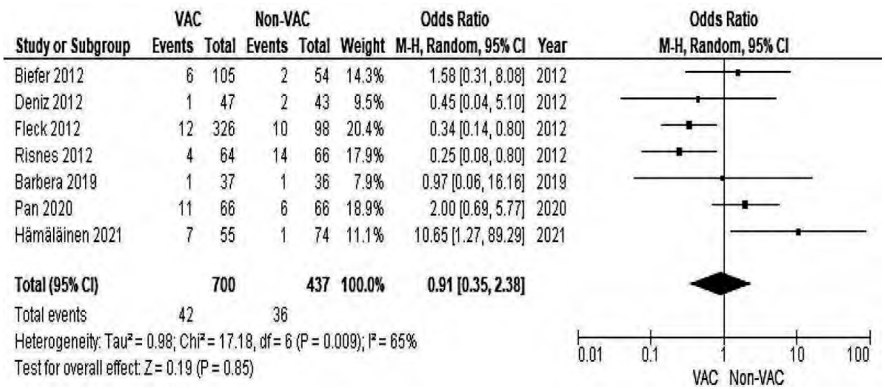

Fig. (10): Random-effects meta-analysis of recurrence among VAC and non-VAC groups.

Estimating the odds ratio between 7 studies regarding recurrence among VAC and non-VAC groups. There was significant heterogeneity across studies (I^2=65%; p=0.009). The overall effect was not statistically significant (Z=0.19, p=0.85) (Fig. 10).

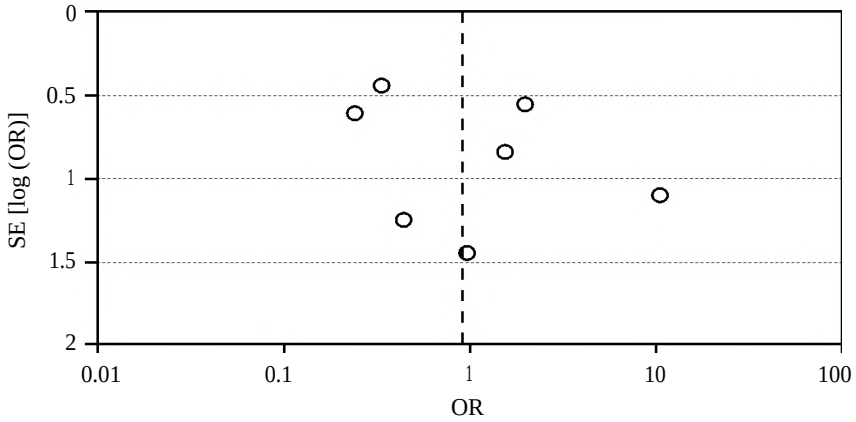

Fig. (11): Funnel plot showing possible publication bias across studies.

On visual assessment of the funnel plots, publication bias was minimal for those studies (Fig. 11).

Publication bias is the most well-known reporting bias. It results from the publication or non-publication of relevant trials, depending on the nature and direction of the results.

- X → BIAS.
- y → Sample size.

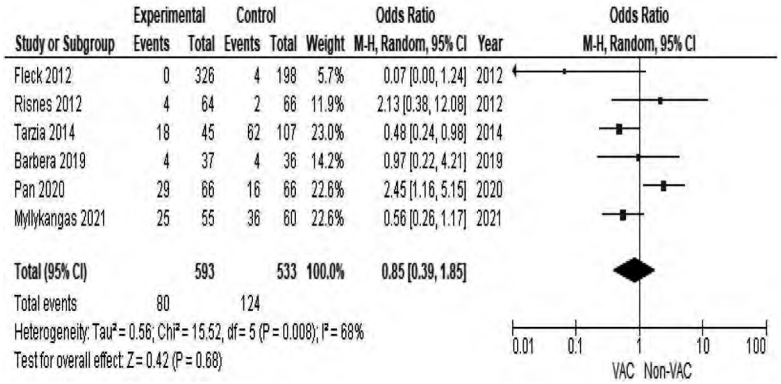

Fig. (12): Random-effects meta-analysis of complications among VAC and non-VAC groups.

Estimating the odds ratio between 6 studies regarding presence of complications among VAC and non-VAC groups. There was significant heterogeneity across studies (I^2=68%; p=0.008). The overall effect was not statistically significant (Z= 0.42, p=0.68) (Fig. 12).

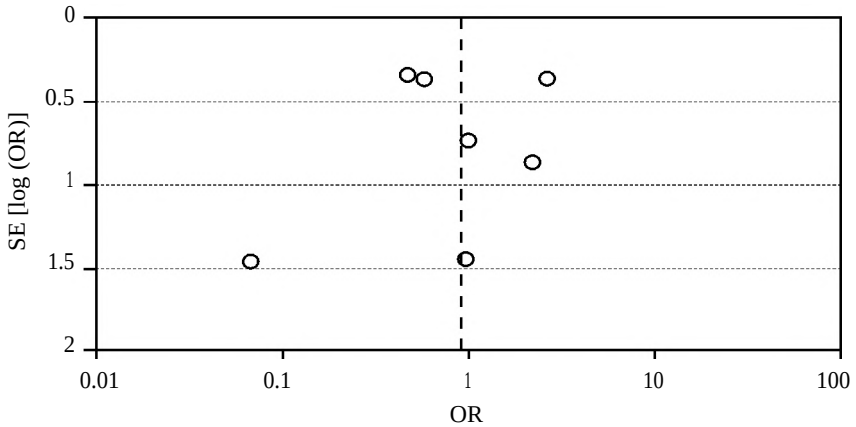

Fig. (13): Funnel plot showing possible publication bias across studies.

On visual assessment of the funnel plots, publication bias was moderate for those studies. (Fig. 13).

Publication bias is the most well-known reporting bias. It results from the publication or non-publication of relevant trials, depending on the nature and direction of the results.

- X → BIAS.
- y → Sample size.

Table (8): Literature appraisal using MINORS assessment tool.

First author	A clearly stated aim	Inclusion of consecutive patient	Prospective collection of data	Appropriate endpoints	Unbiased assessment of study endpoint	Appropriate follow-up period	Loss to follow-up less than 5%	Prospective calculation of study size	Total
Hämäläinen	2	2	0	1	2	2	2	0	11
Tarzia	2	2	0	2	1	1	2	0	10
Deniz	2	2	0	1	1	2	2	0	10
Fleck	2	2	0	2	2	2	2	0	12
Pan	2	2	0	2	2	2	2	0	12
Risnes	2	2	0	2	1	2	2	0	11
Biefer	2	2	0	2	2	2	2	0	12
Vos	2	2	0	2	2	2	1	0	11
Myllykangas	2	2	0	1	2	2	2	0	11
Vos J.	2	2	0	2	2	2	2	0	12
Barbera	2	2	0	1	2	2	2	0	11

Results of the quality assessment using the MINORS tool can be seen in Table (8). The MINORS score the 11 included studies ranging from 10 to 12 out of 16 (Table 8).

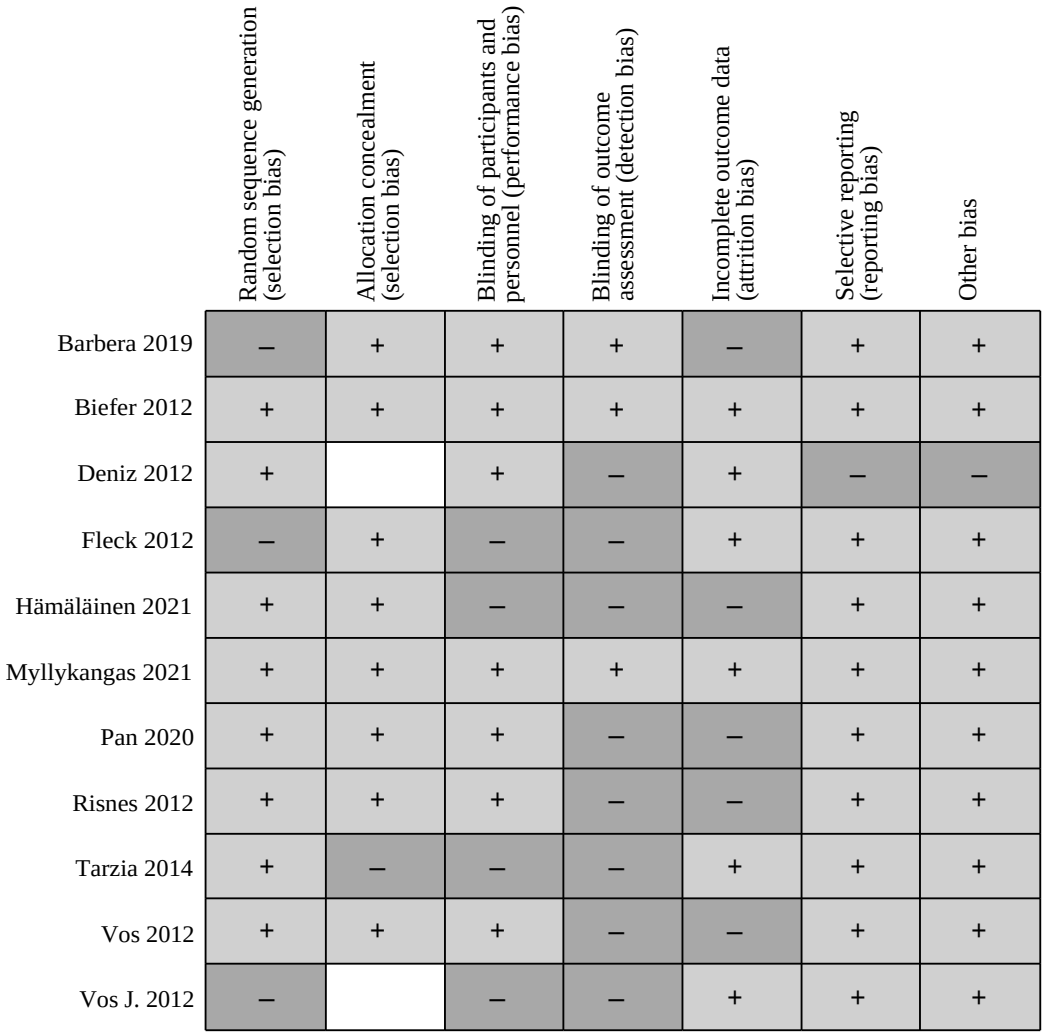

Fig. (14): Methodological quality assessment of the included studies.

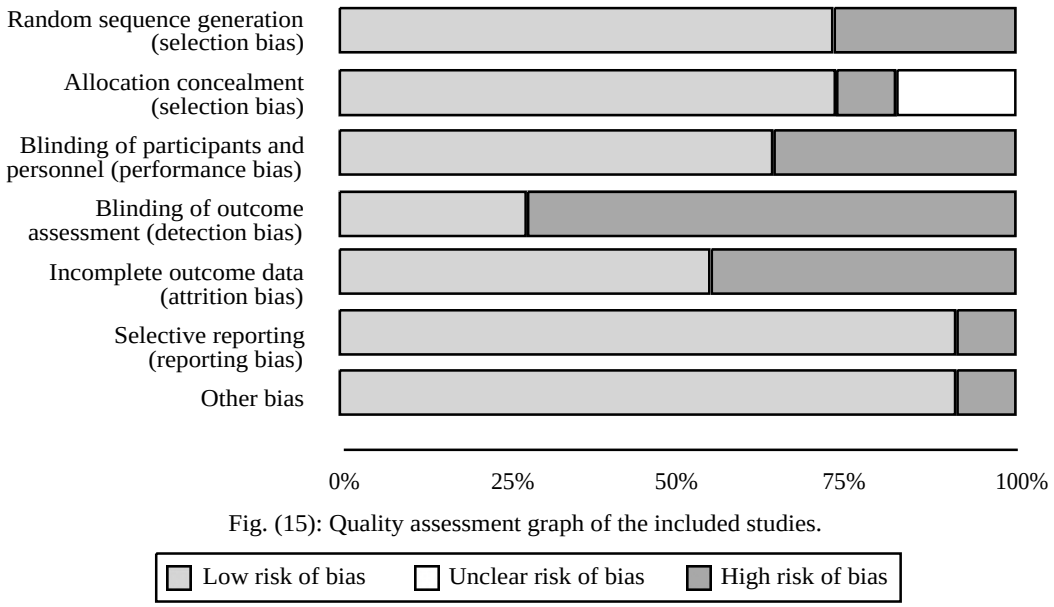

Fig. (15): Quality assessment graph of the included studies.

The overall quality of the included studies was high. Due to adequate randomization and allocation concealment, the risk of selection bias in studies was low. The risks of performance, attrition and detection bias were high because of inadequate blinding of participants and outcomes, respectively. Reporting bias across all studies was reduced due to an adequate description of the study results.

Discussion

Patients undergoing cardiac surgical procedures using sternotomy have significant risk of sternal wound infection (SWI). Superficial sternal wound infection (SSWI), which involves the skin, subcutaneous tissue and the pectoralis fascia, has an incidence of 0.5% to 8%, with an associated morbidity and mortality rate ranging from 0.5% to 9%. The incidence of deep sternal wound infection (DSWI), despite advances in prevention, still remains significant, and ranges between 0.5% and 6.8% **[18]**.

The median sternotomy is the most common surgical approach for cardiac surgery. Once the median sternotomy is infected, it eventually develops into deep sternal wound infection (DSWI). DSWI is a significant complication which occurs in 0.8-8% of patients after median sternotomy **[19]**.

The spectrum of sternal wound infections after cardiac surgery ranges from superficial infections to deep sternal infections known as mediastinitis. DSWI is one of the most challenging complications in cardiac surgery **[20]**.

Even though the incidence of DSWI has been reported to be very low, there is still significant mortality and morbidity associated with it. Conventional treatment of DSWI involves surgical debridement, closed irrigation followed by sternal reconstruction through the use of omentum or pectoral muscle flaps. In addition to the above, several dressing materials and techniques have been used **[21]**.

Over the past decades, cardiac surgeons have tried numerous methods of treating deep sternal wound infections after heart surgery, ranging from topical lavage and wound washing with antibiotics to aggressive surgical interventions such as reconstructive surgery with pectoral flaps or omental flaps **[22]**.

Vacuum-assisted closure (VAC) therapy has been widely used for the treatment of wound infection. VAC can improve healing of DSWI by increasing wound blood flow, reducing bacterial loads, enhancing formation of granulation tissue **[20]**.

VAC therapy has shown promising results in the treatment of DSWI after cardiac surgery comparison with other therapeutic options. And it has no standardized procedure, various strategies are being used. The basic principle of operation is debridement, administration of culture-specific antibiotics, wound closure therapy **[23]**.

This systematic review and meta-analysis conducted among 1 1 studies and aimed at evaluation for the efficacy and safety of VAC in treatment of sternal wound infection.

A variety of techniques were used for the management of DSWIs in the control groups of both the individual studies and between studies. As this clinical heterogeneity was expected, a random

effect model was selected for all comparisons prior to the implementation of the meta-analysis.

In this meta-analysis, the length of hospitalization was ranging from 14 days to 74 days among VAC group while ranging from 13 days to 69 days among non-VAC group. The largest hospitalization was 74±61 days among VAC group by **[14,15]**.

When estimating the weighted risk ratio between all studies regarding length of hospitalizations in days among VAC and non-VAC groups. There was significant heterogeneity across studies (I^2=100%; p<0.001). The overall effect was not statistically significant (Z=1.82, p=0.07).

In agreement with our findings, **[21]** performed a meta-analysis of six observational studies (n=321) and evaluated the difference in lengths of hospital stay and mortality rates. They found that VAC therapy, when compared with other more conventional forms of treatment reduced in-patient stay by 7.18 days [95% CI: 3.54, 10.82] without a significant impact on mortality (odds ratio (OR) 0.61 [95% CI: 0.29, 1.27]).

This goes in line with Falagas et al., **[25]** as Pooling of the outcomes of ten studies showed that there was no statistically significant difference in length of hospitalization between patients treated with VAC and those treated with a non-VAC therapy, [RR=22.25 (95% CI: 27.52, 3.02)].

Contrary to Simek et al., **[26]** who postulated a particular decrease in the in-hospital stay (p<0.05) in group treated by VAC in comparison to group treated by closed irrigation therapy.

In our study, we found that the mortality rate among the included studies ranging from 0 to 28 among VAC group and ranging from 0 to 68 among non- VAC group. All included studies allowed for estimating the weighted risk ratio between mortality rate among group 1 and 2. There was significant heterogeneity across studies (I^2=85%; p<0.001). The overall effect was not statistically significant (p=0.41). The pooled odds ratio for mortality rate was 0.70 (0.30, 1.63).

In agreement with our results, Feo et al., **[24]** studied 157 patients with post-sternotomy mediastinitis who had undergone VAC therapy after debridement or conventional treatment, which consisted of primary wound reopening, debridement, closed chest irrigation, topical application of granulated sugar and pectoralis musculocutaneous reconstruction.

They also found no difference in mortality but did find a reduction in length of hospital stay (p<0.05) in their patients treated with VAC therapy compared with those treated with closed irrigation in addition to granulated sugar and hyperbaric therapy (n=200). They also found that the rate of reduction in C-reactive protein was significantly faster in the VAC group (p<0.05) **[23]**.

In contrast with our results, Petzina et al., **[19]** also found a reduced mortality rate (p<0.05) as well as a tendency towards shorter lengths of hospital stay (p=0.08) when comparing the VAC group with conventionally treated patients who had drainage and irrigation, omentoplasty (when appropriate) and stabilization of the sternum (n=118).

They postulated that the increased number of operative procedures required for the VAC treatment (mean 5.5) compared with the conventionally treatment (mean 1) offered optimal infection control due to repeated debridement and microbiological testing .

In disagreement with our results, a meta-analysis by Falagas et al., **[24]** to examine the impact of VAC therapy on mortality of patients with sternal wound infections after cardiothoracic surgery. They suggested that the use of VAC therapy was associated with lower mortality than non-VAC therapy for the treatment of patients with DSWIs after cardiovascular surgery RR=0.40, (95% CI: 0.28, 0.57).

Contrary to our results, Simek et al., found that Topical negative pressure was associated with a significantly lower the 1-year mortality (p<0.05) in comparison with closed irrigation therapy **[25]**.

In the present meta-analysis, we demonstrated that the recurrence rate was ranging from 1 case to 11 patients among VAC group while it was ranging from I patient to 14 patients. The recurrence rare was zero by Barbera et al., **[16]**. When estimating the odds ratio between 7 studies regarding recurrence among VAC and non-VAC groups. There was significant heterogeneity across studies (I^2= 65%; p=0.009). The overall effect was not statistically significant (Z=0.19, p=0.85).

This goes in line with Steingrimsson et al., **[7]** showed that VAC therapy significantly reduced the early post-treatment recurrence of mediastinitis when compared with open packing and closed irrigation (n=43). However, they found no significant differences in length of stay, early or late mortality rates.

In contrast with our results, Segers et al., [26] also reported lower rates of recurring infection and therapeutic failure in their patients who had undergone VAC therapy compared with those who had closed drainage (p<0.05) (n=63). The small sample size and retrospective nature of the study encourage a careful interpretation of those results.

In disagreement with our results, Falagas et al., [25] analyzed data from 22 papers. Among them ten studies provided data on recurrence of DSWIs. Pooling of these studies showed that recurrence was less common among patients treated with VAC compared to those treated with a non-VAC therapy, [RR=0.34 (95% CI: 0. 19, 0.59)].

In the current meta-analysis, according to complications, Tarzia et al., [8] had 40% and 57.9% complications among VAC group and non-VAC group. Also, Myllykangas et al., [17] had 45.5% and 60% with complications among VAC and non-VAC groups. Only, 6 studies reported about complications. When estimating the pooled odds ratio between 6 studies regarding presence of complications among VAC and non-VAC groups. There was significant heterogeneity across studies (I^2=68%; p=0.008). The overall effect was not statistically significant (Z=0.42, p=0.68).

Data on complications by Falagas et al., [24] showed different types of complications in the individual studies including remote infections, sepsis, cardiovascular/neurological/gastrointestinal complications, renal failure, bleeding, multiple organ failure, fistula, empyema, dehiscence, skin graft requirement, skin necrosis, seroma, discharging sinus, partial flap loss, new atrial fibrillation. However, only one study presented the total number of complications patients in each treatment arm.

In the current meta-analysis, the mean intensive care admission was ranging from 4 day to 11 days among VAC group and ranging from 3 to 20 days among non-VAC group. A total of 8 studies allowed for estimating the weighted risk ratio between ICU admission duration among VAC and non-VAC groups. There was significant heterogeneity across studies (I^2=97%; p<0.0001) but the total overall effect was not statistically significant (Z=0.19, p= 0.85).

In a study conducted by Simek et al., [25] aimed to compare clinical outcomes of two different treatment modalities of deep sternal wound infection, topical negative pressure and the closed irrigation therapy. They demonstrated that Topical negative pressure was associated with a significantly lower failure rate of the primary therapy (p<0.05) and shortening of the intensive care unit stay (p<0.001).

In the present study, the diabetes was common among studies included in this systematic review. Tarzia et al., [8] had 23 and 32 with diabetes among VAC and non-VAC groups respectively. Deniz et al., [9] had 15 and 14 with diabetes among VAC and non-VAC groups respectively.

Fleck and Fleck [10] had 23 and 32 with diabetes among VAC and non-VAC groups respectively. Pan et al., [11] had 26 and 25 with diabetes among VAC and non-VAC groups respectively. Risnes et al., [12] had 25 and 20 with diabetes among VAC and non-VAC groups respectively. Biefer et al., [13] had 31.7% and 31.5% with diabetes among VAC and non-VAC groups respectively.

This goes in line with Kamel et al., [27] who showed that DM is common in patients with DSWI and mediastinitis (51.66% of patients were diabetic).

This agrees with a study conducted by Schroeyers et al., [28] in which the incidence of diabetes was 51%.

Similar findings were found in a retrospective study conducted by Simek et al., [25] in which the incidence of diabetes was 59% and Sha'aban et al., [29] reported that the incidence of diabetes in DSWI patients was 53.3%.

In this meta-analysis, The BMI ranging from 27 to 31 among VAC group while ranging from 26 to 28 among non-VAC group. The obesity was common among the studies included in our study. There were 45% and 38% had obesity among VAC and non-VAC groups.

There were 29% and 22% had obesity among both groups respectively in a study conducted by Tarzia et al., [8]. Deniz et al., [9] had 70% and 51% with obesity while Pan et al., [11] had 22.7% and 13.6% among both groups respectively.

To add to our results Kamel et al., [27] shows that obesity is common in patients with DSWI (58.33% of patients were obese). This agrees with a study conducted by Sha'aban et al., [29] reported that the incidence of obesity in DSWI patients was 70%.

This meta-analysis limited by those included studies which comparing VAC with non-VAC were all retrospective in nature. The great variability in what the non-VAC arms of the studies must be taken into account when considering the evidence combined. No randomized controlled trial has been

published yet. This reinforces the need for randomized controlled trials in order to more accurately establish differences in outcomes between VAC and non-VAC.

Conclusion:

This meta-analysis concluded that VAC when used in treatment of DSWI, can lower mortality and ICU admission days. Diabetes and obesity were common among those who had deep sternal wound infection.

References

1- JULIAN O.C., LOPEZ-BELIO M., MOOREHEAD D. and LIMA A.: Dieect surgical procedures on the coronary arteries: Experimental studies. Journal of Thoracic Surgery, 34 (5): 654-660, 1957.

2- HOLLENBEAK C.S., MURPHY D.M., KOENIG S., WOODWARD R.S., DUNAGAN W.C. and FRASER V.J.: The Clinical and Economic Impact of Deep Chest Surgical Site Infections Following Coronary Artery Bypass Graft Surgery. Chest, 118 (2): 397-402, 2000.

3- OLSEN M.A., LOCK-BUCKLEY P., HOPKINS D., POLISH L.B., SUNDT T.M. and FRASER V.J.: The risk factors for deep and superficial chest surgical-site infections after coronary artery bypass graft surgery are different. The Journal of Thoracic and Cardiovascular Surgery, 124 (1): 136-145, 2002.

4- ROY M.-C.: Surgical-Site Infections After Coronary Artery Bypass Graft Surgery: Discriminating Site-Specific Risk Factors to Improve Prevention Efforts. Infection Control & Hospital Epidemiology, 19 (4): 229-233, 1998.

5- ZACHARIAS A. and HABIB R.H.: Factors Predisposing to Median Sternotomy Complications. Chest, 110 (5): 1173-1178, 1996b.

6- ZEITANI J., BERTOLDO F., BASSANO C., PENTA DE PEPPO A., PELLEGRINO A., EL FAKHRI F.M. and CHIARIELLO L.: Superficial wound dehiscence after median sternotomy: Surgical treatment versus secondary wound healing. The Annals of Thoracic Surgery, 77 (2): 672-675, 2004.

7- STEINGRIMSSON S., GOTTFREDSSON M., GUDMUNDSDOTTIR I., SJÖGREN J. and GUDBJARTSSON T.: Negative-pressure wound therapy for deep sternal wound infections reduces the rate of surgical interventions for early re-infections. Interactive Cardiovascular and Thoracic Surgery, 15 (3): 406-410, 2012.

8- TARZIA V., CARROZZINI M., BORTOLUSSI G., BURATTO E. and BEJKO J.: Impact of vacuum-assisted closure therapy on outcomes of sternal wound dehiscence†, 19 (April), 70-75, 2014.

9- DENIZ H., GOKASLAN G., ARSLANOGLU Y., OZCALISKAN O., GUZEL G., YASIM A. and USTUNSOY H.: Treatment outcomes of postoperative mediastinitis in cardiac surgery; negative pressure wound therapy versus conventional treatment. Journal of Cardiothoracic Surgery, 7, 67, 2012..

10- FLECK T. and FLECK M.: Negative pressure wound therapy for the treatment of sternal wound infections after cardiac surgery, 1-7, 2012.

11- PAN T., LI K., FAN F.-D., GAO Y.-S. and WANG D.-J.: Vacuum-assisted closure vs. bilateral pectoralis major muscle flaps for deep sternal wounds infection. Journal of Thoracic Disease, 12 (3): 866-875, 2020.

12- RISNES I., ABDELNOOR M., VEEL T., SVENNEVIG J.L. and RYNNING S.E.: Mediastinitis after coronary artery bypass grafting: The effect of vacuum-assisted closure versus traditional closed drainage on survival and reinfection rate, 1-7, 2012.

13- BIEFER C., RODRIGUEZ H., SÜNDERMANN S.H., EMMERT M.Y., RANCIC Z., SALZBERG S.P., GRÜNENFELDER J., FALK V. and PLASS A.R.: Negative microbiological results are not mandatory in deep sternal wound infections before wound closure†, 42 (October 2011): 306-310, 2012.

14- VOS R.J., YILMAZ A., SONKER U., KELDER J.C. and KLOPPENBURG G.T.L.: Vacuum-assisted closure of post-sternotomy mediastinitis as compared to open packing. Interactive Cardiovascular and Thoracic Surgery, 14 (1): 17-21, 2012b.

15- VOS R.J., YILMAZ A., SONKER U., KELDER J.C. and KLOPPENBURG G.T.L.: Primary closure using Redon drains vs vacuum-assisted closure in post-sternotomy mediastinitis, 42 (January 2011): 53-57, 2012a.

16- BARBERA F., LORENZETTI F., MARSILI R., LISA A., GUIDO G. and PANTALONI M.: The Impact of Preoperative Negative-Pressure Wound Therapy on Pectoralis Major Muscle Flap Reconstruction for Deep Sternal Wound Infections. Annals of Plastic Surgery, 83 (2): 195-200, 2019.

17- MYLLYKANGAS H., BERG L.T., HUSSO A. and HALONEN J.: Negative pressure wound therapy in the treatment of deep sternal wound infections – a critical appraisal. Scandinavian Cardiovascular Journal, 0 (0): 1-6, 2021.

18- YU A.W., RIPPEL R.A., SMOCK E. and JARRAL O.A.: In patients with post-sternotomy mediastinitis is vacuum-assisted closure superior to conventional therapy? Interactive Cardiovascular and Thoracic Surgery, 17 (5): 861-865, 2013.

19- PETZINA R., HOFFMANN J., NAVASARDYAN A., MALMSJÖ M., STAMM C., UNBEHAUN A. and HETZER R.: Negative pressure wound therapy for post-sternotomy mediastinitis reduces mortality rate and sternal re-infection rate compared to conventional treatment. European Journal of Cardio-Thoracic Surgery, 38 (1): 110-113, 2010.

20- DAMIANI G., PINNARELLI L., SOMMELLA L., TOCCO M.P., MARVULLI M., MAGRINI P. and RICCIARDI W.: Vacuum-assisted closure therapy for patients with infected sternal wounds: A meta-analysis of current evidence. Journal of Plastic, Reconstructive & amp; Aesthetic Surgery, 64 (9): 1119-1123, 2011.

21- KOTNIS-GASKA, A., MAZUR P., OLECHOWSKA-JARZAB A., STANISZ A., BULANDA M. and UNDAS A.: Sternal wound infections following cardiac surgery and their management: a single-centre study from the years 2016-2017. Kardiochirurgia i Torakochirurgia Polska

= Polish Journal of Cardio-Thoracic Surgery, 15 (2): 79-85, 2018.

22- YUMUN G., ERDOLU B., TOKTAS F., ERIS C., AY D., TURK T. and AS A.K.: Deep Sternal Wound Infection after Coronary Artery Bypass Surgery: Management and Risk Factor Analysis for Mortality. The Heart Surgery Forum, 17 (4): 212, 2014.

23- FEO M. DE, VICCHIO M., SANTÈ P., CERASUOLO F. and NAPPI G.: Evolution in the treatment of mediastinitis: Single-center experience. Asian Cardiovascular and Thoracic Annals, 19 (1): 39-43, 2011.

24- FALAGAS M.E., TANSARLI G.S., KAPASKELIS A. and VARDAKAS K.Z.: Impact of vacuum-assisted closure (VAC) therapy on clinical outcomes of patients with sternal wound infections: A meta-analysis of non-randomized studies. PloS One, 8 (5): e64741-e64741, 2013.

25- SIMEK M., HAJEK R., FLUGER I., MOLITOR M., GRULICHOVA J., LANGOVA K., TOBBIA P., NEMEC P., ZALESAK B. and LONSKY V.: Superiority of topical negative pressure over closed irrigation therapy of deep sternal wound infection in cardiac surgery. The Journal of Cardiovascular Surgery, 53 (1): 113-120, 2012.

26- SEGERS P., DE JONG A.P., KLOEK J.J. and DE MOL B.A.J.M.: Poststernotomy mediastinitis: Comparison of two treatment modalities. Interactive CardioVascular and Thoracic Surgery, 4 (6): 555-560, 2005.

27- KAMEL W.A. and ELHENDAWY S.A.K.: Vacuum Assisted Closure Versus Conventional Surgical Techniques in Treatment of Post-Sternotomy Mediastinitis. The Egyptian Journal of Hospital Medicine, 83 (1): 1173-1176, 2021.

28- SCHROEYERS P., WELLENS F., DEGRIECK I., DE GEEST R., VAN PRAET F., VERMEULEN Y. and VANERMEN H.: Aggressive primary treatment for poststernotomy acute mediastinitis: Our experience with omental- and muscle flaps surgery. European Journal of Cardio-Thoracic Surgery, 20 (4): 743-746, 2001.

29- SHA'ABAN K., FARGHALY A., ALLAMA A. and NASHY M.: Impact of vacuum-assisted closure device in the treatment of sternal wound infection. Menoufia Medical Journal, 30 (2): 405, 2017.

استخدام نظام الضغط السالب فى علاج عدوى جروح عظمة القص مراجعة منهجية وتحليلية

خلفية البحث : تم الشق الصدرى المتوسط لأول مرة للاستخدام فى جراحة القلب من قبل جوليان وزملاؤه فى ١٩٥٧عام . أظهروا الشق الصدرى المتوسط مزايا عديدة منها تحسين الكفاءة الجراحية، والكشف الجيد للقلب، والأوعية الرئوية الكبيرة ونقير الرئتين وتقليل الصدمات الرئوية. كانت هذه حجة مقنعة للشق الصدرى المتوسط باعتباره الشق المفضل لعمليات جراحات القلب.

الهدف من الدراسة : الدراسة الحالية هى تقييم فعالية وسلامة استخدام نظام الضغط السالب فى علاج التهاب عظمة القص.

المواد وطرق العلاج : تم إجراء بحث فى الأدبيات العلمية للاستعلام عن قواعد البيانات الإلكترونية لتحديد الدراسات ذات الصلة حول علاج الضغط الساب والتهاب عظمة القص ما بعد الشق الصدرى المتوسط: PubMed و Embase و Cochrane Library و Dare و Sumsearch و Scirus.

النتائج : أسفر تطبيق معايير التضمين والاستبعاد لدراسة الملخصات عن ٨ مقالات. تم تحديد ما مجموعة ٤٠٠ دراسة من البحث فى قاعدة البيانات. بعد المراجعة، تم اختيار ما مجموعة ١١ دراسة. أجريت هذه المراجعة المنهجية والتحليل التلوى من بين ١١ دراسة وتهدف إلى تقييم فعالية وسلامة الضغط السالب فى علاج عدوى جروح عظمة القص.

الخلاصة : خلص هذا التحليل التلوى إلى أن الضغط السالب عند استخدامه فى علاج عدوى جروح عظمة القص، يمكن أن يخفض معدل الوفيات وأيام الحجز فى وحدة العناية المركزة. كان مرض السكرى والسمنة شائعين بين أولئك الذين أصيبوا بعدوى جروح القص العميقة.