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Effect of Active Aspiration Drainage System Use on Postoperative Outcomes After Cardiac Surgery

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Abstract:

Objective: Postoperative drainage systems are essential for maintaining hemodynamic stability and enabling early detection of complications after cardiac surgery. This study aimed to evaluate the impact of an active suction drainage system applying negative pressure on postoperative morbidity and mortality.

Methods: This single-center retrospective study included 153 patients who underwent open-heart surgery between August 2023 and August 2024. Patients were divided into two groups based on the drainage method: active suction drainage (n=69) and conventional drainage (n=84). Postoperative drainage volume, cardiac tamponade, re-exploration for bleeding, mortality, and postoperative complications such as acute kidney injury and wound infection were evaluated. Univariate logistic regression analyses were performed to assess potential confounding factors.

Results: Cardiopulmonary bypass time, aortic cross-clamp time, and total operative duration were significantly longer in the active suction group (P=0.007, p=0.009 and pP=0.010, respectively), while local hemostatic agent use was higher in the conventional group (P<0.001). Despite these differences, postoperative drainage volume, re-exploration rates, incidence of cardiac tamponade, acute kidney injury, wound infection, and mortality were comparable between groups (all P>0.05). Length of hospital stay was significantly longer in the active suction group. Univariate regression analyses did not identify any independent predictors of re-exploration or cardiac tamponade (P>0.05 for all variables).

Conclusion: Active suction drainage was not associated with significant differences in major postoperative outcomes compared with conventional drainage methods. Although operative variables differed between groups, these factors did not demonstrate an independent effect on clinical outcomes. A numerically higher incidence of cardiac tamponade in the active suction group did not reach statistical significance and should be interpreted cautiously. Further large-scale prospective studies are warranted.

Keywords: Active Suction System, Cardiac Surgery, Negative Pressure Drainage, Re-Exploration

Bleeding following cardiac surgery is a common complication that is usually controllable; however, if not recognized and managed promptly, it may lead to life-threatening and catastrophic outcomes [1–3]. Reported rates of postoperative re-exploration range from 2% to 6%,

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with more than half of these cases revealing an active surgical bleeding source requiring intervention [4–6]. Several risk factors have been associated with an increased need for re-exploration, including advanced age, emergency procedures, low body surface area, reoperative surgery, preoperative antiplatelet therapy, and prolonged cardiopulmonary bypass duration. Blood loss and its related complications remain major determinants of postoperative morbidity and mortality in cardiac surgery. Therefore, the use of an effective drainage system is crucial for early detection of bleeding and prevention of associated complications [7].

In the early postoperative period, bleeding can often be diagnosed clinically. However, another critical complication following cardiac surgery is pericardial tamponade. This condition, characterized by reduced cardiac output and requiring urgent intervention, has been reported with an incidence of up to 8.4% in some series [8–10].

To prevent bleeding and tamponade, various drainage tube designs and systems have been developed in recent years. Chest drainage systems have been shown to reduce morbidity and mortality associated with postoperative tamponade [11]. In addition, recently introduced digital drainage systems have been associated with shorter drainage duration, reduced length of hospital stay, and improved postoperative recovery [12].

With the increasing number of cardiac surgical procedures, the prevention, early detection, and timely management of postoperative complications have become increasingly important. In this context, the present study aimed to compare early postoperative outcomes between patients managed with negative pressure mediastinal and thoracic drainage systems and those followed with conventional drainage methods.

METHODS

Study Population

This study was designed as a single-center, retrospective observational analysis. Ethical approval was obtained from the Scientific Research Ethics Committee of the University of Health Sciences, Trabzon Faculty of Medicine (Decision No: 2025/165; Date: February 4, 2025). The study was conducted in accordance with the Declaration of Helsinki.

A total of 153 patients who underwent open-heart surgery at our institution between August 2023 and

TABLE 1. Baseline Demographic and Clinical Characteristics of the Study Population COPD: Chronic Obstructive Pulmonary Disease.

Variable	Active suction drainage (n=69)	Conventional drainage (n=84)	P-value
Age (years)	63.03±11.22	62.81±9.99	0.898
Sex			
Female, n (%)	22 (31.9%)	19 (22.6%)	
Male, n (%)	47 (68.1%)	65 (77.4%)	0.198
Height (cm)	166.46±10.76	164.83±10.00	0.334
Weight (kg)	82.64±12.62	79.73±15.07	0.203
Body surface area (m²)	1.92±0.19	1.87±0.18	0.114
EuroSCORE II	1.53±1.16	1.61±1.23	0.698
Diabetes mellitus, n (%)	24(34.8%)	32(38.1%)	0.672
Hypertension, n (%)	51 (73.9%)	57 (67.9%)	0.413
COPD, n (%)	6 (8.7%)	8 (9.5%)	0.860
Chronic kidney disease, n (%)	1 (1.4%)	4 (4.8%)	0.379
Peripheral artery disease, n (%)	10 (14.5%)	13 (15.5%)	0.866
Thyroid disease, n (%)	2 (2.9%)	3 (3.6%)	1.000

August 2024 were included. Patients who required chest tube placement for non-cardiac indications were excluded.

Demographic characteristics, laboratory findings, operative data, and postoperative clinical outcomes were retrospectively collected from the hospital information management system and patient records. Preoperative mortality risk was assessed using EuroSCORE II, and left ventricular ejection fraction was evaluated using the modified Simpson method.
The study population was divided into two groups: patients managed with an active suction drainage system (active suction drainage group) and those followed with conventional drainage (conventional drainage group).

Surgical Procedure

In all patients, one chest drainage tube was placed into each anatomical cavity opened during surgery prior to completion of the procedure. In the active suction drainage group, continuous negative pressure was applied to enhance drainage efficiency, based on routine clinical practice without predefined selection criteria. The use of local hemostatic agents during surgery was left to the discretion of the operating surgeon. Chest drains were generally removed on postoperative day 2, provided that hourly drainage decreased below 50 mL and hemodynamic stability was achieved.

Cardiac tamponade was defined as the presence of clinical signs of hemodynamic compromise (such as hypotension, tachycardia, or elevated central venous pressure) associated with echocardiographic evidence of pericardial effusion requiring therapeutic intervention.

Re-exploration for bleeding was defined as the need for surgical re-intervention due to excessive postoperative bleeding or cardiac tamponade. Excessive bleeding was considered in cases with persistent chest tube drainage exceeding 200 mL per hour for consecutive hours or clinical evidence of ongoing hemorrhage requiring surgical intervention. Acute kidney injury (AKI) was defined according to the Kidney Disease: Improving Global Outcomes (KDIGO) criteria [13]. Wound infection was defined as the presence of clinical signs of infection (including erythema, swelling, purulent discharge, or positive microbiological culture) at the surgical site requiring medical or surgical treatment.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 22.0 (SPSS Inc., Chicago, IL, USA). Sample size estimation was conducted using Cohen's power analysis model. Categorical variables were expressed as numbers and percentages and compared using the chi-square or Fisher's exact test, as appropriate. The distribution of continuous variables was assessed using the Kolmogorov–Smirnov test. Normally distributed continuous variables were presented as mean ± standard deviation and compared using Student's t-test. Logistic regression analyses were conducted to assess potential factors associated with re-exploration and cardiac tamponade. As no variables were found to be significant in the univariate analysis, multivariate analysis was not undertaken.

TABLE 2. Preoperative Clinical and Laboratory Characteristics of the Study Population

Variable	Active suction drainage (n=69)	Conventional drainage (n=84)	P-value
LVEF (%)	54.36±7.06	56.32±7.00	0.086
Creatinine (mg/dL)	0.94±0.25	1.16±0.92	0.061
ALT (U/L)	29.79±23.68	27.89±18.55	0.578
AST (U/L)	31.98±24.20	28.34±18.50	0.294
Hematocrit (%)	39.69±4.78	39.64±4.94	0.944
Platelet count (×10³/µL)	236.86±75.43	236.74±82.63	0.993
hs-Troponin I (ng/L)	853.62±3224.83	646.17±4810.97	0.760

ALT, alanine aminotransferase; AST, aspartate aminotransferase; LVEF, left ventricular ejection fraction.

TABLE 3. **Operative Characteristics and Intraoperative Hemostatic Agent Use**

Variable	Active suction drainage (n=69)	Conventional drainage (n=84)	P-value
Tranexamic acid, n (%)	30 (43.5%)	43 (51.2%)	0.342
CPB time (min)	162.14±46.43	143.52±37.70	0.007
Aortic cross-clamp time (min)	125.13±45.29	107.80±36.29	**0.009**
Total operative time (min)	340.29±61.18	314.70±59.51	**0.010**
Intravenous fibrinogen, n (%)	1 (1.4%)	0 (0%)	0.451
Local hemostatic agents, n (%)	29 (42%)	62 (73.8%)	**<0.001**
Temporary pacemaker, n (%)	5 (7.2%)	3 (3.6%)	0.469
Antegrade cardioplegia, n (%)	33 (47.8%)	45 (53.6%)	0.479
Combined cardioplegia, n (%)	36 (52.2%)	39 (46.4%)	0.479

Data are shown as mean±standard deviation or n (%) where appropriate. CPB, cardiopulmonary bypass.
Statistically significant P-values are shown in bold

Survival analyses were performed using the Kaplan–Meier method, and survival curves were compared using the log-rank test. A P-value of <0.05 was considered statistically significant.

RESULTS

A total of 153 patients were included in the study, of whom 69 (45.1%) were managed with an active suction drainage system and 84 (54.9%) with conventional drainage.

The two groups were comparable in terms of demographic, preoperative clinical, and laboratory characteristics (Tables 1 and 2). Cardiopulmonary bypass time, aortic cross-clamp time, and total operative duration were significantly longer in the active suction drainage group compared with the

TABLE 4. Distribution of Surgical Procedures

Procedure	Active suction drainage (n=69)	Conventional drainage (n = 84)	P-value
CABG	47 (68.1%)	57 (67.9%)	0.973
AVR	6 (8.7%)	7 (8.3%)	0.936
MVR	5 (7.2%)	6 (7.2%)	1.000
Tricuspid annuloplasty	1(1.4%)	0 (0%)	0.451
ASD closure	1 (1.4%)	0 (0%)	0.451
Ascending aortic surgery	0 (0%)	2 (2.4%)	0.502
AVR + ascending aortic surgery	2 (2.9%)	3 (3.6%)	1.000
AVR + aortic root enlargement	1 (1.4%)	0 (0%)	0.451
CABG + additional procedure	4 (5.8%)	5 (6%)	1.000
Bentall procedure	1 (1.4%)	2 (2.4%)	1.000
David procedure	1 (1.4%)	2 (2.4%)	1.000

AVR, aortic valve replacement; ASD, atrial septal defect; CABG, coronary artery bypass grafting; MVR, mitral valve replacement.

TABLE 5. Postoperative Laboratory Parameters and Clinical Outcomes

Variable	Active suction drainage (n=69)	Conventional drainage (n=84)	P-value
Creatinine (mg/dL)			
Day 0	0.94±1.11	1.03±0.82	0.540
Day 1	1.06±0.30	1.36±1.09	0.018
Day 2	1.13±0.41	1.35±0.99	0.076
ALT (U/L)			
Day 0	31.71±24.61	31.09±20.19	0.865
Day 1	53.89±130.26	37.46±22.87	0.258
Day 2	60.78±169.17	35.65±41.37	0.190
AST (U/L)			
Day 0	70.56±106.95	54.29±35.02	0.192
Day 1	83.97±126.98	70.75±59.65	0.398
Day 2	126.72±318.63	63.19±42.25	0.105
Hematocrit (%)			
Day 0	29.25±3.76	29.19±3.38	0.923
Day 1	29.92±3.45	30.10±3.22	0.737
Day 2	26.31±2.53	26.62±2.76	0.480
Platelet count (×10³/µL)			
Day 0	136.81±46.66	151.98±62.81	0.098
Day 1	172.49±49.29	184.63±70.34	0.228
Day 2	153.23±53.78	158.85±57.84	0.539
hs-Troponin I (ng/L)			
Day 0	9388.08±56819.23	4149.98±11904.39	0.411
Day 1	9738.50±42921.97	7033.36±14473.02	0.589
Day 2	5979.54±24373.90	3075.76±4130.20	0.285
Drainage volume (mL)			
Day 0	572.46±423.09	492.86±280.18	0.183
Day 1	361.96±165.75	338.69±207.00	0.451
Day 2	98.55±147.52	105.95±189.22	0.791
Total blood product use (units)	1.87±1.74	1.57±1.54	0.265
Red blood cell transfusion (units)	1.03±0.90	0.94±0.96	0.562
Fresh frozen plasma (units)	0.51±0.77	0.44±0.62	0.558
Whole blood (units)	0.32±0.55	0.19±0.39	0.109
Platelet transfusion (units)	0.01±0.12	0.01±0.10	0.889
Re-exploration, n (%)	6 (8.7%)	5 (6%)	0.545
Cardiac tamponade, n (%)	3 (4.3%)	1 (1.2%)	0.328
Acute kidney injury, n (%)	5 (7.2%)	5 (6%)	0.755
Wound infection, n (%)	8 (11.6%)	7 (8.3%)	0.500

Data are shown as mean±standard deviation or n (%) where appropriate. ALT, alanine aminotransferase; AST, aspartate aminotransferase.

TABLE 6. **Postoperative Time Intervals**

Variable	Active suction drainage (n=69)	Conventional drainage (n=84)	P-value
ICU stay (days)	3.68±1.85	3.43±0.89	0.273
Length of hospital stay (days)	11.10±7.13	8.71±4.59	0.018
Duration of mechanical ventilation (min)	540.96±239.43	496.01±248.10	0.259

Data are shown as mean±standard deviation. ICU, intensive care unit.

TABLE 7. **Postoperative Mortality**

Variable	Active suction drainage (n=69)	Conventional drainage (n=84)	P-value
Mortality, n (%)	0 (0%)	2 (2.4%)	0.502

conventional drainage group. In contrast, the use of local hemostatic agents was significantly higher in the conventional drainage group (Table 3). No statistically significant difference was observed between the groups regarding the distribution of surgical procedures (Table 4).

On postoperative day 1, serum creatinine levels were significantly higher in the conventional drainage group (P=0.018), whereas no differences were observed at other time points. Liver function tests, hematocrit, platelet count, and high-sensitivity troponin I levels were similar between the groups. Postoperative drainage volumes, total blood product use, and individual blood components were also comparable (all P>0.05). Additionally, no significant differences were found between the groups in terms of re-exploration, cardiac tamponade, acute kidney injury, or wound infection rates. Overall, postoperative parameters and clinical outcomes were comparable between the groups (Table 5).

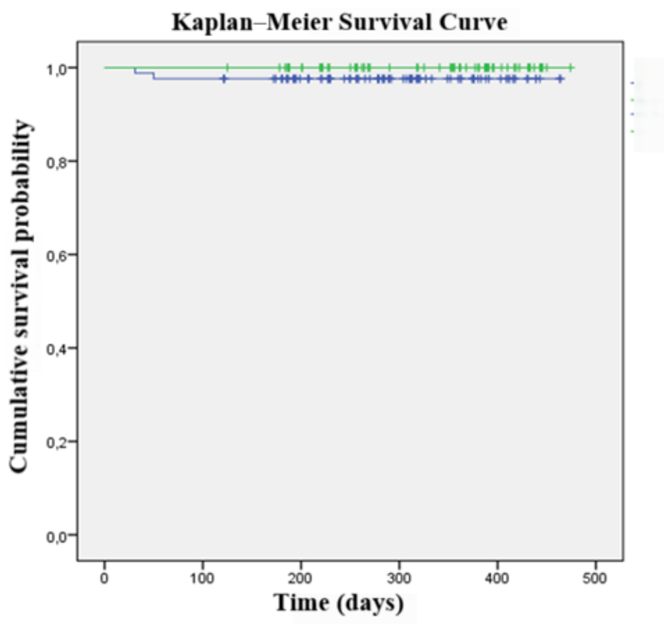

FIGURE 1. **Kaplan–Meier survival curves comparing patients managed with active suction drainage and conventional drainage. Green: active suction drainage; blue: conventional drainage (log-rank P=0.199).**

TABLE 8. **Tamponade and Wound Infection in Patients Undergoing Re-Exploration**

Variable	Active suction drainage (n=69)	Conventional drainage (n=84)	P-value
Cardiac tamponade, n (%)	3 (50%)	1 (20%)	0.545
Wound infection, n (%)	2 (33.3%)	0 (0%)	0.455

Length of hospital stay was significantly longer in the active suction drainage group (P=0.018) (Table 6), while no significant differences were observed in other postoperative variables.

Mortality rates were similar between the groups (Table 7). Kaplan–Meier survival analysis demonstrated no significant difference (P=0.199). According to life-table analysis, two deaths occurred in the conventional drainage group within the first 60 postoperative days, whereas no mortality was observed in the active suction group during follow-up. No in-hospital mortality was observed in either group (Figure 1).

Among patients undergoing re-exploration, no significant differences were found between the groups in terms of tamponade or sternal wound infection rates (Table 8).

In patients requiring re-exploration, the use of blood products—except for platelet transfusion—was significantly higher. In addition, the duration of mechanical ventilation was significantly longer in this group (P=0.001). However, mortality rates did not differ significantly between the groups (Table 9).

Univariate logistic regression analyses were performed to identify factors associated with re-exploration and cardiac tamponade. Cardiopulmonary bypass time, aortic cross-clamp time, operative duration, and local hemostatic agent use were included in the analysis. None of these variables were found to be significantly associated with either re-exploration or cardiac tamponade (Tables 10 and 11). The odds ratios were close to 1 with wide confidence intervals, suggesting no strong independent effect of these variables.

DISCUSSION

In this study, active suction drainage and conventional drainage systems were compared, and no significant differences were observed between the two approaches in terms of major postoperative outcomes. Although a numerical increase in the incidence of cardiac tamponade was observed in the active suction group, this finding did not reach statistical significance. This necessitates a cautious interpretation

TABLE 9. **Clinical Characteristics Associated with Re-Exploration**

Variable	Re-exploration (+) (n=11)	Re-exploration (–) (n=142)	P-value
Total blood product use (units)	4.64±1.91	1.48±1.38	**0.001**
Red blood cell transfusion (units)	2.09±0.94	0.89±0.88	**0.001**
Fresh frozen plasma (units)	1.36±1.02	0.40±0.62	**0.011**
Whole blood (units)	1.09±0.53	0.18±0.406	**0.001**
Platelet transfusion (units)	0.09±0.30	0.01±0.08	0.379
Duration of mechanical ventilation (min)	850.91±268.09	490.36±223.42	**0.001**
Wound infection, n (%)	2 (18.2%)	13 (9.2%)	0.294
Mortality, n (%)	0 (0%)	2 (1.4%)	1.000

Data are shown as mean±standard deviation or n (%) where appropriate.
Statistically significant P-values are shown in bold.

TABLE 10. Univariate Logistic Regression Analysis of Factors Associated With Re-Exploration

	Univariate logistic regression analysis		
	P-value	Exp(B) Odds ratio	95% CI Lower-Upper
Local hemostatic agent	0.730	0.805	0.234-2.762
CPB time (min)	0.157	0.988	0.971-1.005
Cross-clamp time (min)	0.383	0.993	0.977-1.009
Operative time (min)	0.735	1.002	0.992-1.012

CI, confidence interval; CPB, cardiopulmonary bypass.

of any potential contribution of active suction systems to the early detection of tamponade. Given the low number of events, this observation requires confirmation in larger studies.

Previous studies have identified several predictors of cardiac tamponade following cardiac surgery, including anticoagulation, early reoperation, and red blood cell transfusion [14]. In our study, although a numerically higher incidence of tamponade was observed in the active suction group, this difference did not reach statistical significance. Therefore, any potential association between drainage strategy and tamponade detection should be interpreted with caution. Given the limited number of events, our findings do not allow for definitive conclusions regarding causality, and further prospective studies are required to clarify this relationship.

The significant differences in cardiopulmonary bypass time, aortic cross-clamp time, operative duration, and local hemostatic agent use may reflect differences in surgical complexity between the groups. Therefore, these variables were considered potential confounders. However, univariate logistic regression analyses showed no significant association between these factors and re-exploration or cardiac tamponade. These findings suggest that the observed group differences in operative variables did not clearly translate into differences in the primary clinical outcomes. Nevertheless, due to the limited number of events, these results should be interpreted cautiously.

Topical hemostatic agent use, which we considered a potential confounding factor, was higher in the conventional drainage group. Although previous studies have reported that next-generation topical hemostatic agents may improve intraoperative hemostasis [15], this difference did not translate into significant differences in postoperative drainage volume or re-exploration rates in our study. This observation may suggest that the clinical impact of these agents is limited in this context. However, given the non-randomized study design and the unequal distribution between groups, the potential confounding effect of hemostatic agent use should be taken into account when interpreting the results.

TABLE 11. Univariate Logistic Regression Analysis of Factors Associated with Cardiac Tamponade

	Univariate logistic regression analysis		
	P-value	Exp(B) Odds ratio	95% CI Lower-Upper
Local hemostatic agent	0.192	0.219	0.022-2.151
CPB time (min)	0.488	0.991	0.964-1.017
Cross-clamp time (min)	0.801	0.997	0.972-1.022
Operative time (min)	0.096	1.012	0.998-1.026

CI, confidence interval; CPB, cardiopulmonary bypass.

Previous studies have shown that re-exploration for bleeding is associated with prolonged intensive care unit stay [16]. Although no significant difference in intensive care unit duration was observed in our cohort, the longer hospital stay in the active suction group may reflect a higher clinical burden, potentially related to increased rates of tamponade or re-exploration.

Meszaros *et al*. [17] reported that operative duration, surgical complexity, and re-exploration are significant risk factors for sternal wound infection following cardiac surgery. However, our findings demonstrated no significant difference in wound infection rates between the groups, even in the presence of a higher incidence of re-exploration, suggesting that active suction drainage does not increase infection risk.

In our study, patients undergoing re-exploration required significantly more blood product transfusion and had longer durations of mechanical ventilation. Previous studies have demonstrated that increased red blood cell transfusion is associated with adverse outcomes, including both early and long-term mortality, as well as renal failure, systemic infection, and prolonged ventilation [18]. Similarly, restrictive transfusion strategies have been shown not to increase mortality or major complications compared with liberal approaches [19].

Despite these associations reported in the literature, we did not observe a significant relationship between increased transfusion and mortality or wound infection in our cohort. This discrepancy may be related to the relatively small sample size and low number of events, which may limit the ability to detect differences in clinical outcomes.

Strengths and Limitations

The present study has several strengths. First, it provides real-world comparative data regarding the use of active suction drainage systems in cardiac surgery, an area with limited clinical evidence in the current literature. Second, important postoperative outcomes, including re-exploration, cardiac tamponade, acute kidney injury, wound infection, and mortality, were evaluated comprehensively rather than focusing solely on drainage volume. Third, the study population consisted of patients treated at a single center with relatively standardized surgical and postoperative management protocols, which increased cohort homogeneity. In addition, potential confounding operative variables were further evaluated using regression analyses.

This study has several limitations. First, its retrospective and non-randomized design introduces a potential risk of selection bias. Second, the absence of predefined criteria for group allocation may have resulted in differences in surgical complexity between groups. Third, the relatively small sample size and low number of clinical events limit the statistical power, particularly for rare outcomes such as cardiac tamponade and mortality.

CONCLUSION

In conclusion, active suction drainage was not associated with significant differences in major postoperative outcomes, including re-exploration, cardiac tamponade, and mortality, compared with conventional drainage. Although certain operative variables differed between groups, these factors did not show an independent effect on clinical outcomes. A numerically higher incidence of tamponade in the active suction group did not reach statistical significance and should be interpreted cautiously. Further large-scale prospective studies are needed to clarify these findings.

Ethics Approval and Consent to Participate

This study was approved by the University of Health Sciences, Trabzon Faculty of Medicine Scientific Research Ethics Committee. (Decision No: 2025/165; date: 04.02.2025). All procedures were conducted in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments. Given the retrospective design and the use of fully anonymized data, the requirement for written informed consent was waived by the ethics committee.

Data Availability

All data generated or analyzed during this study are included in this published article. The data that support the findings of this study are available on request from the corresponding author, upon reasonable request.

Authors' Contribution

Study Conception: MCS, MOH; Study Design: MCS, MA, ET; Supervision: MOH; Funding: N/A; Materials: MCS, MA, ET; Data Collection and/or Processing: MCS, MA, ET; Statistical Analysis and/or Data Interpretation: MCS, MA; Literature Review: MCS; Manuscript Preparation: MCS, MA, ET; and Critical Review: MOH.

Conflict of Interest

The author(s) disclosed no conflict of interest during the preparation or publication of this manuscript.

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Editor's Note

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