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ORIGINAL STUDY

Mediastinal packing for massive bleeding following acute ascending aortic dissection surgery: Outcomes and risk factors analysis

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Abstract

Background: **Surgery for acute ascending aortic dissection (AAAD) is often complicated by severe perioperative coagulopathy and critical bleeding. Mediastinal packing (MP) is a widely recognized technique used to manage and control this complication. This retrospective study aims to analyze early outcomes and potential risk factors for patients subjected to MP after AAAD surgery.**

Methods: **352 consecutive patients who had undergone AAAD surgery were studied at the National Heart Institution between February 2014 and March 2023. These patients were divided into two groups: the MP with delayed closure group ($n = 53$; 15.05%) and the primary closure group ($n = 299$; 84.94%). The study aimed to compare the clinical characteristics, surgical details, postoperative complications, and short-term outcomes between the two groups. A multivariate logistic regression analysis was conducted to recognize the independent risk factors for patients who had undergone MP with delayed closure.**

Results: **The MP group exhibited a greater incidence of preoperative hemopericardium and malperfusion. This group was also linked to extended periods of cardiopulmonary bypass (CPB) and aortic clamping times. Additionally, the MP group had higher rates of prolonged intraoperative CPB support. Moreover, other parameters as blood product transfusion and rate of re-exploration were significantly higher in the MP group. However, the in-hospital mortality rates (20.75% vs. 12.70%; $P = 0.267$), Deep sternal wound infection rates (5.66% vs. 2.67%; $P = 0.091$), and total Hospital stay (days) (28.8 ± 32.4 vs. 24.8 ± 28.5; $P = 0.161$), were comparable between both groups. Multivariate analysis revealed that hemopericardium, preoperative malperfusion, and prolonged intraoperative CPB support were risk factors for undergoing MP procedures.**

Conclusion: **MP is an effective technique to stabilize patients who are experiencing uncontrollable bleeding following surgery for AAAD. This technique has been shown to result in satisfactory postoperative outcomes. It is recommended that patients with uncontrollable bleeding should have prompt consideration for implementing MP with delayed closure.**

Keywords: Acute ascending aortic dissection, Bleeding, Mediastinal packing

1. Introduction

Acute ascending aortic dissection (AAAD) is a life-threatening condition that necessitates emergency surgical intervention and is associated with significant rates of mortality and morbidity [1,2]. Excessive bleeding after surgery and the need for re-intervention are among the most concerning complications [3–5].

During AAAD surgery, a common complication is the development of consumption coagulopathy, which is a result of continuous systemic activation of the coagulation system. The presence of an aortic dissecting flap causes intravascular coagulation, consuming blood clotting factors [5]. Nevertheless, surgery for acute aortic dissection is a complex and demanding operation, the prolonged operative time, excessive tissue trauma, and profused blood

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transfusion all add to the possibility of coagulopathy after surgery.

The mediastinal packing (MP) technique was frequently used to manage difficult intraoperative bleeding. This technique was especially effective in stabilizing the bleeding risk after complex surgeries involving the heart and proximal aorta [6–8]. However, previous studies have not provided a thorough analysis of the results and potential risk factors associated with this technique in AAAD patients. We performed a retrospective investigation using the database from our National Heart Institute which specializes in aortic surgery. This analysis aimed to compare patient characteristics and the early outcomes of patients who underwent MP and primary closure after AAAD surgery.

2. Patients and methods

After approval of the ethical committee, 352 adult emergency patients who suffered AAAD and were subjected to AAAD surgery were studied retrospectively at the National Heart Institute of Egypt between February 2014 and Mars 2023, Data were collected through our institute database of aortic dissection. The diagnosis of acute aortic dissection condition was performed using clinical assessment, trans-esophageal echocardiograph, and computed tomography angiography of the aorta at the emergency unit of our institute. After the diagnosis of AAAD was confirmed candidates were prepared and underwent AAAD surgery on an emergency basis.

The study included 352 patients who were divided into two groups, namely the MP group ($n = 53$; 15.05%) and the primary closure group ($n = 299$; 84.94%). The division was based on whether MP was applied during surgery to control severe bleeding that could not be managed otherwise. Fig. 1 displays the yearly incidence rates of the entire cohort, AAAD, MP, and Primary closure groups throughout the research period.

Intravenous beta-blockers were administered to stabilize the preoperative hemodynamics of the patients. This was done to maintain a systolic blood pressure of less than 120 mmHg, and a heart rate of 60–70 bpm, by recent guidelines [9]. resuscitation procedures were administered to patients who arrived in a state of shock, following standardized protocols [10,11].

2.1. Aortic dissection surgery technique

Earlier research has already covered the technical aspects of AAAD surgery [12,13]. A frequently employed approach for patients with a stable preoperative state was to use double artery cannulation via a combination of right axillary and femoral arterial access, along with the antegrade cerebral perfusion strategy. On the other hand, when dealing with patients who exhibited an unstable condition, the preferred method was to use isolated femoral artery cannulation with retrograde cerebral perfusion.

After the sternum was cut open, a venous cannula was inserted into either the right atrium or vena cava, and cardiopulmonary bypass (CPB) with systemic hypothermia was started. Typically, the damaged aorta was replaced with prosthetic grafts made of albumen-coated Dacron tube. Usually, the dissected ascending aorta was removed, and the

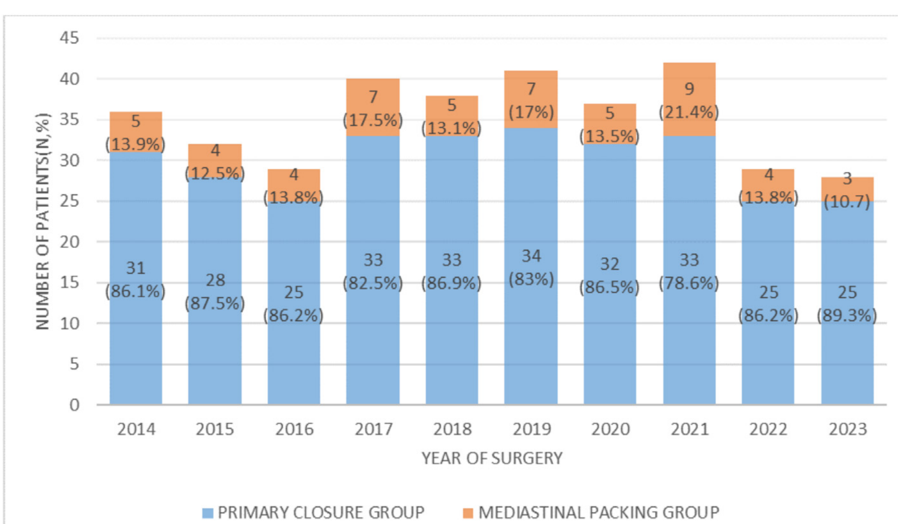

Fig. 1. Distribution of patients by year of surgery for overall AAAD, mediastinal packing, and primary closure groups during the study period. AAAD, acute ascending aortic dissection.

proximal anastomosis was done first. After that, the distal anastomosis was performed while the patient was under deep hypothermic circulatory arrest, at a temperature between 18 and 22 °C. The anastomoses of the graft aorta were strengthened with pericardial strips. When the circulatory arrest was established, the flow of the femoral artery was kept to the minimum, and either selective antegrade cerebral perfusion through the right axillary artery or retrograde cerebral perfusion through the superior vena cava was used based on the cannulation strategy chosen. In cases where the aortic dissection involved both the aortic root and descending thoracic aorta, a frozen elephant trunk technique was performed. Following the AAAD surgery, all patients were transferred to the ICU for post-operative treatment and observation.

2.2. Mediastinal packing and delayed sternal closure procedures

Before discontinuing CPB, we thoroughly inspected the graft-aorta anastomoses, cannulation sites, and rough tissue surfaces for any active bleeding. Any bleeding points found were then reinforced with compression sutures containing pledgets. Patients who were weaned from CPB and received protamine, along with maximal surgical hemostasis, were evaluated for intractable perioperative bleeding based on any of the following 4 criteria: if bleeding exceeded 500 ml within 30 min, if more than 8 units of red blood cells were required, if the bleeding was uncontrolled from inaccessible bleeding sites, or if hemodynamic instability was observed during attempted sternal closure. Before the decision of mediastina packing was taken intraoperative haematological studies were done to exclude the possibility of disseminated intravascular coagulopathy (DIC).

Sterile gauzes were utilized to apply extensive pressure on the noncontrollable sites of bleeding. The prosthetic aortic graft was compressed with sterile gauze in a surrounding manner, after which the remaining mediastinal space was packed. The pericardium and sternum were left open, and a sterile plastic patch was used to cover the chest.

To protect against infection, immediate administration of broad-spectrum intravenous antibiotics was carried out according to ICU policies. Fresh blood and fresh frozen plasma were used to manage any observed blood coagulopathy. Changing packs every 6–12 h to evaluate bleeding and avoid cardiac tamponade was performed either in the ICU or in the operating room under completely sterile conditions. If the mediastinal packs were socked with blood re-packing was considered at shorter intervals. If the patient's hemodynamics were stable and bleeding tendency improved (blood loss from chest tubes <600 ml and transfusion of red blood cells <4 units for at least 12 consecutive hours), mediastinal re-exploration was typically performed within 24–48 h in the operating theatre. During the procedure, all blood clots were removed, and the identified bleeders were carefully examined once more. If hemostasis had been achieved, patients were closed in layers. They were given prophylactic broad-spectrum intravenous antibiotics for at least 1–2 weeks, with careful monitoring against any signs of infection.

2.3. Statistical analyses

Data were collected, revised, coded, and entered into the Statistical Package for Social Science (IBM SPSS Company name: IBM, State: Chicago, IL, Country: U.S.A, Product: statistical software) version 20. Qualitative data were presented as numbers and percentages while quantitative data with parametric distribution were presented as mean, standard deviations, and ranges. Comparison between the two groups regarding qualitative data was done using the χ^2 test, and a comparison between the two independent groups regarding quantitative data with parametric distribution was done using the Independent *t*-test.

The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the *P* value was considered significant as follows: *P* greater than 0.05: nonsignificant, *P* less than 0.05: significant, *P* less than 0.01: highly significant. To determine the independent risk factors for patients who underwent MP, a multivariate logistic regression analysis was conducted. Initially, the univariate logistic regression analysis was applied to the preoperative and surgical variables listed in Tables 1 and 2. The variables with a *P* value less than 0.05 in the univariate logistic regression analysis were then further examined using multivariate logistic regression analysis.

3. Results

3.1. Patient demographics

There were no statistically significant differences detected between the two groups as regards age, sex, comorbidities, and preoperative conditions. The mean age of the studied cohort was 57.6 ± 13.5 years, the female gender represented 30.39% of participating patients, and chest pain was the commonest representation of AAAD and was around 74% in all patients significantly increased

Table 1. Preoperative characteristics.

Parameters	Total	MP	PC	P value
	n = 352	n = 53	n = 299	
Clinical demographics				
Age (years)	57.6 ± 13.5	57.6 ± 14.1	56.1 ± 13.2	0.713
Sex (female, n-%)	107–30.39	17–32	90–30.1	0.844
Hypertension (n-%)	255–72.45	38–71.69	217–72.57	0.354
Diabetes mellitus (n-%)	47–13.35	5–9.43	42–14.04	0.343
Creatinine (mg/dl)	1.4 ± 1.3	1.6 ± 1.2	1.4 ± 1.3	0.156
Renal failure (n-%)	6–1.704	1–1.88	5–1.67	0.497
Preoperative condition				
Systolic blood pressure (mmHg)	98.6 ± 18.7	97.7 ± 20.2	98.8 ± 18.4	0.602
Systolic blood pressure <90 mmHg (n-%)	81–23.01	15–28.3	66–22.07	0.334
Cardiopulmonary resuscitation (n-%)	6–1.7	1–1.88	5–1.67	0.397
Ventilator support (n-%)	19–5.39	5–9.43	14–4.68	0.072
Clinical presentation				
DeBakey type II (n-%)	34–9.65	5–9.43	29–9.69	0.851
Intramural hematoma (n-%)	66–18.75	11–20.75	55–18.39	0.882
Chest/back pain (n-%)	262–74.43	41–77.35	221–73.91	0.683
Hemopericardium (n-%)	118–33.52	24–45.28	94–31.43	0.023
Aortic regurgitation > moderate (n-%)	62–17.61	13–24.52	49–16.38	0.974
Malperfusion[a] (n-%)	54–15.34	14–26.41	40–13.37	<0.001
Acute myocardial infarction (n-%)	7–1.98	2–3.77	5–1.67	0.052
Cerebral infarction (n-%)	14–3.97	4–7.54	10–3.34	0.019

MP, mediastinal packing group; PC, primary closure group.

[a] presence of preoperative limb ischemia, cerebral infarction, paraplegia, coronary artery occlusion, and mesenteric ischemia.

Table 2. Surgical details.

Parameters	Total	MP	PC	P-value
	n = 352	n = 53	n = 299	
Femoral artery cannulation (n-%)	333–94.60	51–96.22	282–94.31	0.898
Axillary artery cannulation (n-%)	38–10.79	6–11.32	32–10.70	0.806
Aortic cannulation (n-%)	1–0.28	0	1–0.33	0.667
Aortic surgery procedures				
Root replacement (n-%)	256–72.72	35–66.03	221–73.91	0.229
Isolated supra-coronary conduit (n-%)	96–27.27	18–33.96	78–26.08	0.079
Arch replacement (n-%)	38–10.79	6–11.32	32–10.702	0.963
Partial arch replacement (n-%)	26–7.38	4–7.54	22–7.35	0.752
Total arch replacement (n-%)	12–3.40	2–3.77	10–3.34	0.730
Frozen elephant trunk (n-%)	3–0.85	1–1.88	2–0.66	0.224
Cardiopulmonary bypass time (min)	257.0 ± 76.6	277.4 ± 87.7	252.9 ± 74.2	0.001
Aortic cross-clamp time (min)	167.4 ± 53.4	182.8 ± 64.2	162.6 ± 52.4	0.008
Circulatory arrest time (min)	51.8 ± 23.2	53.8 ± 25.1	51.4 ± 22.7	0.359
Hypothermia temperature (°C)	20.6 ± 2.4	20.3 ± 2.3	20.3 ± 2.6	0.433
Antegrade cerebral perfusion (n-%)	39–11.07	6–11.32	33–11.03	0.184
Retrograde cerebral perfusion (n-%)	313–88.92	47–88.67	266–88.96	0.186
Prolonged CBP support (n-%)	12–3.40	6–11.32	6–2.0	<0.001

MP, mediastinal packing group; PC, primary closure group.

proportions of patients with hemopericardium (45.28% vs. 31.43%; $P = 0.023$), malperfusion (26.41% vs. 13.37%; $P < 0.001$), and cerebral infarction (7.54% vs. 3.4%; $P = 0.019$) were observed in the MP group (Table 1).

3.2. Surgical details

The surgical information is shown in (Table 2), there were no statistically significant differences regarding the arterial cannulation sites or aortic surgery procedures between the two groups, significantly longer bypass and cross-clamp times were observed in the mediastinal group when compared with the primary closure group (277.4 ± 87.7 vs. 252.9 ± 74.2 min; $P = 0.001$), (182.8 ± 64.2 vs. 162.6 ± 52.4 min; $P = 0.008$), respectively. A higher rate of prolonged intra-operative CPB support (11.32% vs. 2.0%; $P < 0.001$) was observed in the MP group.

3.3. Postoperative morbidity and mortality

The in-hospital mortality was (20.75% vs. 12.70%; $P = 0.267$), respectively, with no significant difference between the two groups, other parameters as blood product transfusion and rate of re-exploration were significantly higher in the MP group. Nevertheless, the MP group showed increased proportions of postoperative morbidity as a new onset of renal failure, mesenteric ischemia, pneumonia, and prolonged ventilation support. Also, the extent of ICU and total hospital stays were longer in the MP group but it did not reach the statistically significant values (Table 3).

3.4. Risk factors associated with mediastinal packing

The scores of logistic regression analyses for patients at risk of undergoing MP are demonstrated in (Table 4).

3 significant risk factors for MP were detected: preoperative hemopericardium (odds ratio [OR], 1.66; 95% confidence interval [CI] 1.08–2.56; $P = 0.022$),

Table 3. Mortality and morbidity after surgery.

Parameters	Total $n = 352$	MP $n = 53$	PC $n = 299$	*P*-value
In-hospital mortality (*n*-%)	49–13.92	11–20.75	38–12.70	0.267
Bleeding (*n*-%)	28–7.95	8–15.09,	20–6.68	0.243
Myocardial failure (*n*-%)	21–5.96	3–5.66	18–6.02	0.834
Brain stem insult (*n*-%)	9–2.55	2–3.77	7–2.34	0.432
Sepsis (*n*-%)	10–2.84	2–3.77	8–2.67	0.567
Transfusion within 24 h after surgery				
RBC[a] (units)	8.8 ± 7.8	13.8 ± 11.9	8.1 ± 6.2	<0.001
Plasma[b] (units)	7.8 ± 6.9	12.7 ± 9.8	7.2 ± 5.5	<0.001
Platelet (units)	19.3 ± 13.3	29.2 ± 19.7	17.3 ± 11.1	<0.001
Re-exploration for bleeding (*n*-%)	51–14.48	20–37.73	31–10.36	<0.001
Delirium (*n*-%)	63–17.89	10–18.86	53–17.72	0.932
Seizure (*n*-%)	27–7.67	3–5.66	24–8.02	0.353
Brain stroke (*n*-%)	58–16.47	11–20.75	47–15.71	0.156
Brain Infarction (*n*-%)	48–13.63	8–15.09	40–13.37	0.483
Brain Hemorrhage (*n*-%)	11–3.12	3–5.66	8–2.67	0.091
New onset Renal failure (*n*-%)	33–9.37	8–15.09	25–8.36	0.038
Mesenteric ischemia (n,%)	9,2.55	3,5.66	6,2.0	0.032
Limb ischemia (*n*-%)	10–2.84	2–3.77	8–2.67	0.567
Pneumonia (*n*-%)	43–12.21	10–18.86	33–11.03	0.007
Deep sternal wound infection (*n*-%)	11–3.12	3–5.66	8–2.67	0.091
Extubation time (h)	97.8 ± 258.5	155.2 ± 479.9	88.2 ± 192.1	0.143
Ventilator support >72 h (*n*-%)	113–32.10	26–49.05	87–29.09	<0.001
ICU stay (days)	7.5 ± 13.8	10.7 ± 20.7	6.8 ± 12.2	0.073
Hospital stay (days)	25.4 ± 29.1	28.8 ± 32.4	24.8 ± 28.5	0.161

ICU, intensive care unit; MP, mediastinal packing group; PC, primary closure group.
[a] Red blood cell transfusion including the amount of all fresh blood and packed red blood cell concentrate.
[b] Plasma transfusion including the amount of fresh-frozen plasma and cryoprecipitate.

Table 4. Logistic regression analyses for mediastinal packing.

Parameters	β-coefficient	Standard error	Odds ratio, 95% CI	*P* value
Univariate logistic regression				
Hemopericardium	0.487	0.212	1.62 (1.08–2.48)	0.023
Malperfusion	0.848	0.249	2.34 (1.45–3.78)	0.001
Cerebral infarction	0.952	0.417	2.58 (1.14–5.84)	0.023
Cardiopulmonary bypass time	0.005	0.002	1.01 (1.00–1.02)	0.002
Aortic cross-clamp time	0.007	0.003	1.01 (1.00–1.01)	0.002
Prolonged CPB time	1.697	0.432	5.46 (2.35–12.71)	<0.001
Multivariate logistic regression				
Hemopericardium	0.504	0.221	1.66 (1.08–2.56)	0.022
Malperfusion	0.708	0.295	2.04 (1.15–3.66)	0.018
Prolonged CPB support	1.466	0.477	4.32 (1.71–11.06)	0.002

CI, confidence interval.

preoperative malperfusion (OR, 2.04; 95% CI 1.15–3.66; $P = 0.018$), and intraoperative prolonged CPB support (OR, 4.32; 95% CI 1.71–11.06; $P = 0.002$).

4. Discussion

MP was first introduced in the early 1980s as a technique to be used after open heart surgeries [14]. It has since become a well-known life-saving measure for complex cardiovascular procedures when massive bleeding is a complication [6–8]. Despite this, there have been few reports in previous studies about the outcomes and associated risk factors of MP in AAAD patients.

We conducted a retrospective study on a group of 352 patients who underwent AAAD surgery at our institute, out of which, 53 were subjected to MP and 299 were closed primarily. Our study revealed some important findings. Firstly, we observed an increased incidence of MP population (15.05%) among the AAAD patients. This can be attributed to the pathophysiological nature of the disease, which is characterized by increased coagulopathy. Additionally, the complexity of the surgical procedures may add to these challenges. Secondly, the MP group had acceptable short-term outcomes in patients who were carefully selected when compared with those with Primary sternal closure. Thirdly, patients who had preoperative hemopericardium, low cardiac output, and prolonged intraoperative CPB support are more prone to massive bleeding and should be assessed thoroughly before considering MP.

Patients who undergo AAAD surgery frequently display a dysfunction in their coagulation system, which is a commonly observed phenomenon in acute aortic dissection cases. Multiple factors share this pathology and associated mechanisms including the activation of the coagulation and fibrinolytic systems that cause intravascular thrombosis in the lumen of the dissected aortic flap, which results in a state of consumption coagulopathy. Additionally, coagulopathy is also associated with prolonged CPB time and excessive tissue damage due to the complex aortic surgery, this was found to be consistent with our study as we identified prolonged CBP support as one of the risk factors for MP [5].

Re-exploration due to high drainage still poses a significant risk despite the advancements in management protocols, surgical procedures, and CPB strategies in recent decades. According to various international data records, the incidence of reopening for high drainage ranges from 9 to 20% for AAAD patients [15–17].

The coagulopathy related to acute aortic dissection requires a recovery period that may last over 24 h from the onset of the condition [3]. Thus, MP is considered the treatment of choice as a life-saving measure to decrease blood loss and maintain a patient's hemodynamics.

In our study, despite similar in-hospital mortality rates observed between the two studied groups, the MP group had higher postoperative complication rates compared with the Primary closure group. These complications included massive blood transfusion, reopening for high drainage, acute renal failure, and extended ventilator support and ICU stay. It is possible to interpret these findings in different ways. For instance, despite using pressurized packing to reach inaccessible bleeding sites, there may still be some minor bleeding from the needle holes and fragile tissue. Moreover, the impaction of gauze has reduced the residual pericardial space, which, in turn, may decrease the heart's ability to handle cardiac tamponade. It is recommended that patients who continue to experience bleeding or show signs of cardiac tamponade after undergoing MP procedures should undergo a more assertive re-exploration strategy. Additionally, it is imperative to avoid postoperative hypothermia, and metabolic imbalances, and provide adequate fresh blood transfusions to address any coagulation defects.

On the other hand, large blood transfusion volumes may cause significant harm to organs. Our research has shown that the MP group had higher transfusion quantities of all blood products, which may indicate significant bleeding and systemic hypo-perfusion status. This condition could result in organ failure.

As per the findings conveyed by Wu and Helgason *et al.* in their previous research, the administration of massive blood transfusion was identified as a key risk factor contributing to the development of postoperative acute renal failure and the need for renal hemodialysis therapy [18,19]. A similar result was shown in the current research. At our institute, if acute renal failure occurs after AAAD surgery, renal dialysis is quickly initiated in line with the Acute Kidney Injury Network criteria to minimize the adverse effects of fluid overload, metabolic acidosis, and electrolyte imbalance [20] Finally, as previously mentioned, regarding the increased incidence of postoperative complications accompanying the MP group, one should also expect increase in the mechanical ventilation intervals and overall ICU stay period.

One great challenge associated with patients undergoing MP procedures is the increased risk of wound and mediastinal infections. Yet, a study done by Fanning and Boeken *et al*. showed comparable rates of infection regarding MP and primary closed groups [21,22]. These findings go hand in hand with our study, patients in both groups showed similar incidences of deep sternal wound infections. However, we believe that the MP group of patients must have an aggressive postoperative monitoring system together with routine prophylactic antibiotics to detect and treat any early signs of wound infection.

4.1. Limitations

Limitations to this study include the loss of homogeneity between the study groups with possible bias as a result of being a retrospective non-randomized control study. Also, the rules of applying the MP technique were yielded to our institutional consensus. However, the final decision was taken by the operating surgeon considering the severity of each case individually. As a result, some patients with higher risk factors for bleeding may be subjected to the MP technique more frequently than others, for example, patients with a fragile aorta, perioperative leaking aortic dissection or patients on anticoagulation therapy. Lastly, the relatively few number of studied patients and lack of patient follow-up may add to the limitations of our study.

4.2. Conclusions

The MP procedure is crucial in managing AAAD patients with uncontrollable bleeding, it is a lifesaving technique with comparable short-term results to standard primary closure procedures.

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Ethical statement

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Author contribution

Ahmed Shafeek Ali El Naas: The principal investigator (PI), performs surgical operations, writes the research, and puts project protocol. Mostafa Abd Al Salam Mohamed Ghazi: Perform surgical operations, and revise the final research. Mahmoud Maher Abdou Ibrahim: Data collection, statistical analysis, and revision. Haitham Alshahat Ramadan: Data collection, statistical analysis, and revision.

Institutional Review Board (IRB) Approval Number

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Conflict of interest

There are no conflicts of interest.

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