Long-term outcomes of surgical or endovascular treatment of adult with midaortic syndrome: A single-center retrospective study over a 14-year period

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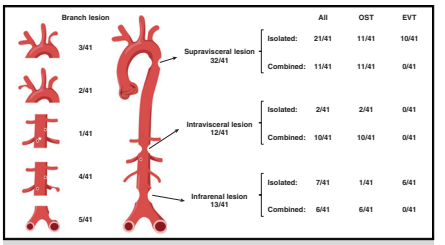
ABSTRACT

Objective: Midaortic syndrome is a rare clinical condition that has been mainly studied in juveniles through case reports and series. This study aims to report the anatomic characteristics and long-term outcomes of 41 adult patients with midaortic syndrome who received open surgical treatment or endovascular treatment over a 14-year period.

Methods: A consecutive cohort of 41 adult patients diagnosed with midaortic syndrome at our center between January 2008 and November 2021 were enrolled in the study. Patients' baseline and anatomic characteristics were collected and analyzed. Primary follow-up outcomes included death and reintervention. Other follow-up outcomes included hypertension and complications.

Results: The study enrolled 41 adult patients with midaortic syndrome with a mean age of 37.5 ± 13.4 years. Twenty-five patients received open surgical treatment, and 16 patients received endovascular treatment. Isolated infrarenal lesions were more likely to be found in the endovascular treatment group ($P = .005$), whereas patients with multiple ($P = .002$) or intravisceral involvement ($P = .001$) were more likely to be found in the open surgical treatment group. The open surgical treatment group was more likely to have a lower postoperative peak systolic pressure gradient ($P = .020$). The 5- and 10-year reintervention-free survivals were 87.7% and 71.7% in the open surgical treatment group and 92.3% and 79.1% in the endovascular treatment group, respectively.

Conclusions: Both open surgical treatment and endovascular treatment showed satisfactory long-term efficacy outcomes for adult patients with midaortic syndrome. Given the patients' relatively young age and long life expectancy, strict and regular lifelong follow-up is necessary. (JTCVS Open 2024;19:1-8)



Reintervention-free survival of all adult patients with MAS.

CENTRAL MESSAGE

Most patients had isolated supravisceral lesions. The OST group was more likely to achieve lower postoperative peak systolic pressure gradient. Long-term outcomes were similar between the 2 groups.

PERSPECTIVE

The current study enrolled 41 adult patients with MAS. The findings suggest that both OST and EVT showed similar outcomes with 10-year reintervention-free survival of 70% or more. Considering the patients' relatively young age and long life expectancy, strict and regular lifelong follow-up is necessary.

Midaortic syndrome (MAS) is a rare clinical condition characterized by stenosis between the arch and the bifurcation of the abdominal aortic aorta, and it accounts for only 0.5% to 2% of all aortic coarctations.[1,2] Although idiopathic MAS accounts for the majority of cases (~64%), it also may result from inflammatory aortitis,

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The study design was approved by the Ethics Committee of Zhongshan Hospital, Fudan University, Shanghai, China (Approval No: B2019-231R, approval date: September 18, 2019). All included patients were informed about the nature of the study and gave their written informed consent for publication.

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Abbreviations and Acronyms

AA = abdominal aorta
CTA = computed tomography angiography
DTA = descending thoracic aorta
EVT = endovascular treatment
LSA = left subclavian artery
MAS = midaortic syndrome
OST = open surgical treatment
PTA = percutaneous transluminal angioplasty
TA = Takayasu's arteritis

neurofibromatosis, and other conditions.[3] The classic symptoms of MAS include hypertension and claudication, and patients often are admitted for refractory hypertension. Medical management of hypertension in MAS has been largely unsuccessful, and invasive intervention is often necessary to achieve ideal blood pressure control and prevent end-organ damage. Invasive interventions for MAS include open surgical treatment (OST) such as aortic bypass and interposition aortic graft, and endovascular treatment (EVT) such as stent implantation and percutaneous transluminal angioplasty (PTA).

However, because of its rarity, studies focusing on MAS are mainly limited to case reports or series involving juveniles, and there is a lack of long-term follow-up results.[4-6] In this retrospective study, we aimed to report the anatomic characteristics and long-term outcomes of 41 adult patients with MAS who received OST or EVT at our center over a 14-year period.

MATERIAL AND METHODS

The study protocol was approved by the Ethics Committee of Zhongshan Hospital affiliated with Fudan University (No. B2019-231R, approval date: September 18, 2019) and was conducted in accordance with the principles outlined in the World Medical Association's Declaration of Helsinki. Written informed consent for publication was obtained from all participants before inclusion in the study.

Patients and Baseline Data Collection

A total of 41 adult patients diagnosed with MAS and treated with OST or EVT at our center between January 2008 and November 2021 were retrospectively enrolled in this study. MAS was diagnosed on the basis of findings from computed tomography angiography, magnetic resonance angiography, or digital subtraction angiography, and was defined as stenosis or occlusion of the aorta between the arch and abdominal aortic bifurcation. Patients were classified into 2 groups based on the type of intervention they received: OST or EVT.

Baseline characteristics, including age and gender, were collected, and anatomic details of the lesions were obtained from preoperative computed tomography angiography, magnetic resonance angiography, or digital subtraction angiography. The MAS lesions were classified into 3 types: supravisceral (from aortic arch to celiac trunk), intravisceral (from celiac trunk to renal artery), and infrarenal (from renal artery to abdominal aortic bifurcation).[1]

Preoperative Medication

Patients diagnosed with Takayasu's arteritis (TA) were required to visit the outpatient department of rheumatology to control the activity of the primary disease before undergoing any intervention. Additionally, all patients with hypertension were prescribed antihypertensive drugs.

Interventions

Indications for interventions included preoperative transcatheter peak systolic pressure gradient greater than 40 mm Hg, refractory hypertension, or symptoms related to end-organ damage such as renal failure or claudication. The choice of OST or EVT was made according to the judgements of 3 experienced surgeons and preference of patients. OST for MAS primarily involved aortic bypass procedures, including left subclavian artery (LSA)-descending thoracic aorta (DTA), LSA-abdominal aorta (AA), DTA-DTA, DTA-AA, and AA-AA bypass. The choice of bypass depended on the anatomic characteristics of the lesion. Knitted Dacron was the preferred conduit for aortic bypass, and autologous saphenous vein was used for aorto-renal bypass. EVT for MAS involved covered stent implantation, bare stent implantation, and PTA. Covered stents were primarily used in the DTA and infrarenal AA segments, whereas bare stents were used to increase the radial support force of covered stents or in the intravisceral segment.

Technique success was defined as successful performance of bypass or stenting with a postoperative peak systolic pressure gradient of 40 mm Hg or less or an instant postoperative ankle-brachial index of 0.9 or higher. Clinical success was defined as technique success without death during admission. Complications included procedural complications such as stent migration, acute cerebrovascular accidents, and hemothorax, as well as vascular complications such as femoral pseudoaneurysm/dissection and retroperitoneal hemorrhage.

Follow-up Outcomes

The primary follow-up outcomes were death and reintervention. Reintervention was defined as intervention for complications related to OST/EVT or unrelieved symptoms. Other outcomes included hypertension control and complications. Hypertension control was divided into 3 categories: cured hypertension (normotensive without taking any antihypertensive drugs), improved hypertension (normotensive with <3 types of antihypertensive drugs), and unchanged hypertension (normotensive with ≥ 3 types of antihypertensive drugs or hypertension could not be well controlled). Complications included recoil, pseudoaneurysm formation, and aortic tear. All patients were required to pay regular outpatient follow-up in 1 month, 6 months, and annually after discharge. Telephone follow-up was used as an alternative if the patient could not pay for the clinical visit.

Statistical Analysis

The quantitative data, which were compared using Student t test, are shown as the mean $\pm$ SD or as the median with the interquartile range, depending on their distribution. Categorical variables, presented as frequencies and percentages, were compared using the chi-square test or Fisher exact test. The reintervention-free survival was analyzed by a Kaplan–Meier analysis. All statistical tests were performed using a 2-sided α of 0.05. All tests were performed using PASW software, version 19 (IBM Corporation).

RESULTS

Patient Characteristics

From January 2008 to November 2021, 41 adult patients with MAS were enrolled with a mean age of 37.5 $\pm$ 13.4 years (range, 20-59 years). Of the patients,

TABLE 1. Preoperative demographic characteristics

Characteristics	All patients (n = 41)	OST group (n = 25)	EVT group (n = 16)	*P* value
Age, y, mean ± SD	37.54 ± 13.43	36.96 ± 12.04	38.35 ± 15.54	.749
Gender (male/female)	13/28	7/18	6/10	.524
Cause of MAS, n (%)				
Idiopathic	24 (58.5)	14 (64.0)	10 (62.5)	.680
Inflammatory	17 (41.5)	11 (44.0)	6 (37.5)	
Takayasu's arteritis	14 (34.2)	10 (40.0)	4 (25.0)	.323
Atherosclerosis	3 (7.3)	1 (4.0)	2 (12.5)	.308
Symptoms, n (%)				
Asymptomatic	11 (26.8)	5 (20.0)	6 (37.4)	.217
Dyspnea	7 (17.1)	5 (20.0)	2 (12.5)	.534
Claudication	7 (17.1)	4 (16.0)	3 (18.8)	.819
Headache	8 (19.5)	6 (24.0)	2 (12.5)	.365
Nausea/vomiting	7 (17.1)	4 (16.0)	3 (18.8)	.819
Stroke	1 (2.4)	1 (4.0)	0 (0.0)	.418
Basic diseases, n (%)				
Refractory hypertension	33 (80.5)	20 (80.0)	13 (81.3)	.922
Cardiovascular disease	5 (12.2)	3 (12.0)	2 (12.5)	.962
Cerebrovascular disease	2 (4.9)	2 (8.0)	0 (0.0)	.246
Cardiac insufficiency	2 (4.9)	2 (8.0)	0 (0.0)	.246
Renal insufficiency	1 (2.4)	1 (4.0)	0 (0.0)	.418
Anatomic characteristics, n (%)				
Involved aortic segment				
Supravisceral	21 (51.2)	11 (44.0)	10 (62.5)	.248
Intravisceral	2 (4.9)	2 (8.0)	0 (0.0)	.246
Infrarenal	7 (17.1)	1 (4.0)	6 (37.5)	.005
Supravisceral + intravisceral	5 (12.2)	5 (20.0)	0 (0.0)	.056
Supravisceral + infrarenal	1 (2.4)	1 (4.0)	0 (0.0)	.418
Intravisceral + infrarenal	0 (0.0)	0 (0.0)	0 (0.0)	-
Supravisceral + intravisceral + infrarenal	5 (12.2)	5 (20.0)	0 (0.0)	.056
Single segment	30 (73.2)	14 (56.0)	16 (100.0)	.002
Multiple segment	11 (26.8)	11 (44.0)	0 (0.0)	
Aortic branch lesions				
Left subclavian artery	3 (7.3)	2 (8.0)	1 (6.3)	.834
Right subclavian artery	2 (4.9)	2 (8.0)	0 (0.0)	.246
Superior mesenteric artery	1 (2.4)	1 (4.0)	0 (0.0)	.418
Renal artery	4 (9.8)	2 (2.0)	2 (12.5)	.636
Iliac artery	5 (12.2)	0 (0.0)	5 (31.3)	.003

The data presented are numbers (%) or the means ± SD. *OST*, Open surgical treatment; *EVT*, endovascular treatment; *MAS*, midaortic syndrome; *IQR*, interquartile range.

25 (7 male and 18 female) received OST and 16 (6 male and 10 female) received EVT. The majority of MAS cases were idiopathic (58.5%, 24/41), whereas the remainder were inflammatory MAS (14 TA and 3 atherosclerosis). Eleven patients were admitted without clinical symptoms, and the rest presented with dyspnea (7/41), claudication (7/41), headache (8/41), nausea/vomiting (7/41), and stroke (1/41). Refractory hypertension was present in more than 80.0% (33/41), whereas the frequency of other cardiocerebrovascular risk factors was low. Table 1 provides a more detailed summary of the baseline characteristics of the patients.

Anatomic Details

The majority of patients had supravisceral lesions (78.0%, 32/41), whereas only 2 patients (4.9%, 2/41) had isolated intravisceral lesions. Isolated infrarenal lesions were more common in the EVT group (6/16 vs 1/25, $P = .005$). Patients in the OST group were more likely to have multiple segmental lesions (11/25 vs 0/16, $P = .002$) or intravisceral segment involvement (12/25 vs 0/16, $P = .001$). Concurrent aortic branch lesions were observed in 12 patients, including LSA, right subclavian artery, superior mesenteric artery, renal artery, and iliac artery (Figure 1). Patients with iliac lesions were more common

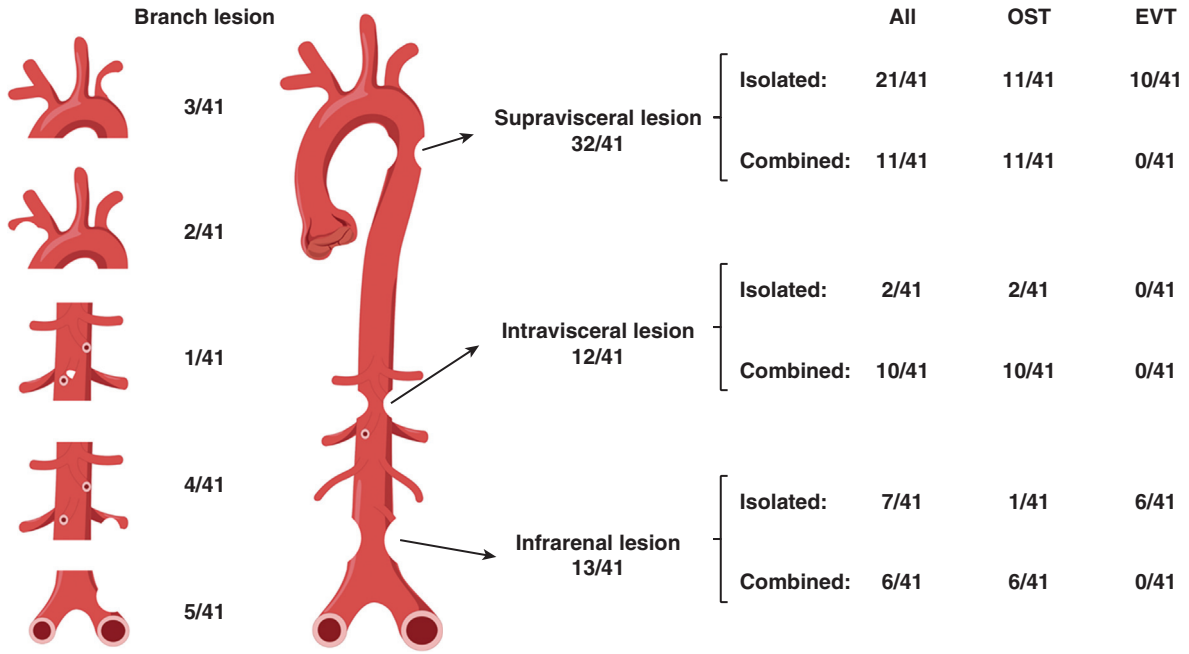

FIGURE 1. Anatomic characteristics of all adult patients with MAS who received OST or EVT. *OST,* Open surgical treatment; *EVT,* endovascular treatment.

in the EVT group ($P = .003$). More detailed anatomic information is shown in Table 1.

Interventions

In the majority of OST patients (24/25, 96.0%), aortic bypass was performed, which included 17 aorto-aortic bypasses (2 DTA-DTA, 14 DTA-AA and 1 AA-AA bypass) and 7 LSA-aorta bypasses (4 LSA-DTA and 3 LSA-AA bypasses). One patient (4.0%) with a short-segment DTA lesion received an aorto-aortic interposition graft. All EVT patients underwent stent implantation, with 2 receiving bare stent implantation for infrarenal lesion, 7 receiving a covered stent (4 self-expandable, 2 balloon-expandable and 1 both) for supravisceral lesion, and 2 receiving a covered stent (1 self-expandable and 1 balloon-expandable) for infrarenal lesion. Five patients received both bare and covered stent implantation (2 with supravisceral lesion, 2 with infrarenal lesion, and 1 with both lesions). Additional PTA was used in 50.0% of patients (8/16). Aortic branch revascularization was performed in 7 patients, including 1 OST patient who received AA-AA and concurrent aorto-renal bypass, 1 EVT patient who received renal artery stent implantation, and 5 EVT patients who received iliac artery stent implantation. More detailed information on patients' characteristics of intervention is shown in Table 2.

Transcatheter peak systolic pressure gradient measurements were performed on 16 OST patients and all EVT patients. Although there was no significant difference in preoperative peak systolic pressure gradient between the 2 groups (OST 72.1 $\pm$ 26.3 mm Hg vs EVT 62.4 $\pm$ 13.0 mm Hg, $P = .874$), lower postoperative peak systolic pressure gradient seemed to be more likely to be found in the OST group (OST 5.6 $\pm$ 6.2 mm Hg vs EVT 12.9 $\pm$ 11.0 mm Hg, $P = .027$) (Table 2). Furthermore, a postoperative peak systolic pressure gradient of 20 mm Hg or greater was observed in 3 EVT patients.

In the OST group, postoperative hemothorax was observed in a patient who died of respiratory and circulatory failure 13 days after the operation. Postoperative hydrothorax occurred in 2 patients, and concurrent postoperative paraplegia was observed in 1 of them. The muscle strength in the patient's lower limbs was improved with conservative treatment before discharge. Postoperative stroke occurred in 1 patient.

In the EVT group, no vascular complications were observed. Postoperative stroke occurred in 1 patient. One patient who received a balloon-expandable covered stent implantation had intraoperative stent migration.

The technical success rate was 100.0% in the OST group and 93.8% in the EVT group. Clinical success was 96.0% in the OST group and 93.8% in the EVT group. Compared with OST patients, EVT patients were more likely to have a shorter hospital stay (11 [8-15] days vs 22 [13-37] days, $P = .012$).

Follow-up Outcomes

Except for 1 OST patient who died during admission and 1 OST patient who was lost at 3 months after intervention, the remaining patients all completed a 12-month or longer

TABLE 2. Characteristics of operation and perioperative complications

Characteristics	All patients (n = 41)	OST group (n = 25)	EVT group (n = 16)	*P* value
Peak systolic pressure gradient before operation,* mm Hg, median (IQR)	64 (54-78)*	71 (51-89)*	64 (56-72)	.874
Open surgical treatment, n (%)				
Aorto-aortic bypass	-	17 (68.0)	-	-
DTA-DTA	-	2 (8.0)	-	-
DTA-AA	-	14 (56.0)	-	-
AA-AA	-	1 (4.0)	-	-
LSA-DTA bypass	-	4 (16.0)	-	
LSA-AA bypass	-	3 (12.0)	-	
Aorto-aortic interposition graft	-	1 (4.0)	-	
Aorto-renal bypass	-	1 (4.0)	-	-
EVT, n (%)				
Stent implantation	-	-	16 (100.0)	-
Covered stent	-	-	14 (92.0)	-
Self-expandable	-	-	10 (62.5)	-
Fluency	-	-	5 (31.3)	-
Talent	-	-	1 (6.3)	-
Excluder	-	-	1 (6.3)	-
Captivia	-	-	1 (6.3)	-
cTAG	-	-	1 (6.3)	-
Viabhan	-	-	1 (6.3)	-
Balloon-expandable	-	-	5 (31.3)	-
Lifestream	-	-	3 (18.8)	-
Cheatham-Platinum	-	-	2 (12.5)	-
Bare stent	-	-	7 (43.8)	-
Self-expandable	-	-	4 (25.0)	-
Balloon-expandable	-	-	3 (18.8)	-
PTA	-	-	8 (50.0)	-
Concurrent aortic branch intervention	7 (17.1)	1 (4.0)	6 (37.5)	-
Peak systolic pressure gradient after operation,* mm Hg, median (IQR)	10 (0-16)*	3 (0-10)*	14 (0-26)	.020
Perioperative complication, n (%)	7 (17.1)	6 (24.0)	1 (6.3)	.141
Death	1 (2.4)	1 (4.0)	0 (0.0)	.418
Stroke	2 (4.9)	1 (4.0)	1 (6.3)	.744
Paraplegia	1 (2.4)	1 (4.0)	0 (0.0)	.418
Hydrothorax	3 (7.3)	3 (12.0)	0 (0.0)	.150
Hospital stays, d, median (IQR)	15 (11-24)	22 (13-37)	11 (8-15)	.012

The data presented are numbers (%) or median (IQR). *OST,* Open surgical treatment; *EVT,* endovascular treatment; *IQR,* interquartile range; *DTA,* descending thoracic aorta; *AA,* abdominal aorta; *LSA*, left subclavian artery; *PTA,* percutaneous transluminal angioplasty. *A total of 16 OST patients and all EVT patients received peak systolic pressure gradient measurement.

follow-up with a mean period of 94.3 ± 46.1 (range, 13-178) months. During the follow-up, symptoms at admission were relieved in 30 patients, and death occurred in 3 patients (2 due to cardiac disease and 1 of unknown reason). Stroke was observed in 1 EVT patient in 41 months (Table 3).

In the OST group, hypertension was cured in 8 patients, improved in 10 patients, and unchanged in 2 patients of the 20 with refractory hypertension at last follow-up. In the EVT group, hypertension was cured in 3 patients, improved in 9 patients, and unchanged in 1 patient of the 13 with refractory hypertension. Reintervention was used in 3

TABLE 3. Follow-up outcomes and complications

Outcomes/Complications	All patients (n = 41)	OST group (n = 25)	EVT group (n = 16)	*P* value
Follow-up time, d, mean ± SD (range)	94.3 ± 46.1* (13-178)	96.8 ± 47.2* (19-178)	90.9 ± 45.9 (13-148)	-
Death, n (%)	3 (7.3)	2 (8.0)	1 (6.3)	.834
Reintervention, n (%)	4 (9.8)	3 (12.0)	1 (6.3)	.545
Pseudoaneurysm	2 (4.9)	2 (8.0)	0 (0.0)	.246
Uncontrolled hypertension	2 (4.9)	1 (4.0)	1 (6.3)	.744
Aortic tear, n (%)	1 (2.4)	0 (0.0)	1 (6.3)	.206
Stroke, n (%)	1 (2.4)	0 (0.0)	1 (6.3)	.206

The data presented are numbers (%) or mean ± SD. *OST,* Open surgical treatment; *EVT,* endovascular treatment. *One OST patient who died during the perioperative period and 1 lost OST patient were not counted.

patients: Renal artery stent implantation was used in 1 OST patient and 1 EVT patient for incompletely improved hypertension; 1 TA patient who received LSA-DTA bypass received covered stent implantation for aortic pseudoaneurysm at the distal anastomosis in 93 months after intervention, whereas a new proximal anastomotic aortic pseudoaneurysm occurred in 105 months (Figure 2). Stent-induced aortic tear was observed in 1 patient in 4 months. Considering the tear remained stable at last follow-up, the patient received conservative treatment (Figure 3). No recoil was observed.

The 5- and 10-year reintervention-free survivals were 87.7% and 71.7% in the OST group and 92.3% and 79.1% in the EVT group, respectively. However, no significant difference was observed between the 2 groups (log-rank test, $P = .529$) (Figure 4).

DISCUSSION

Stenosis of the AA was first reported in 1848, whereas MAS was first described by Sen and colleagues in 1963.[1,7] Patients with untreated MAS are typically associated with a poor prognosis, with a mortality of 30% to 45% before 34 years of age.[6] MAS is typically diagnosed in late childhood or young adulthood, with an average age of onset of 9 years old.[3] Although most lesions are treated soon after birth or in childhood, there have been few studies in terms of the management and treatment of adults with MAS. This study reports the anatomic characteristics and long-term outcomes of 41 adult MAS patients who received OST or EVT at our center.

Lesions above the visceral zone were reported to be the most common anatomic type of MAS, followed by the visceral zone and infrarenal segment involved.[2] In the current study, the majority of cases were with isolated supravisceral lesion (21/41), whereas isolated intravisceral lesion (2/41) and isolated infrarenal lesion (7/41) were less common. Multiple segmental lesions were observed in 11 patients, all of whom had supravisceral segment involvement. Porras and colleagues[2] suggested that invasive intervention should be performed when the aortic stenosis degree is more than 60% or when symptoms related to end-organ damage are present, such as renal failure or

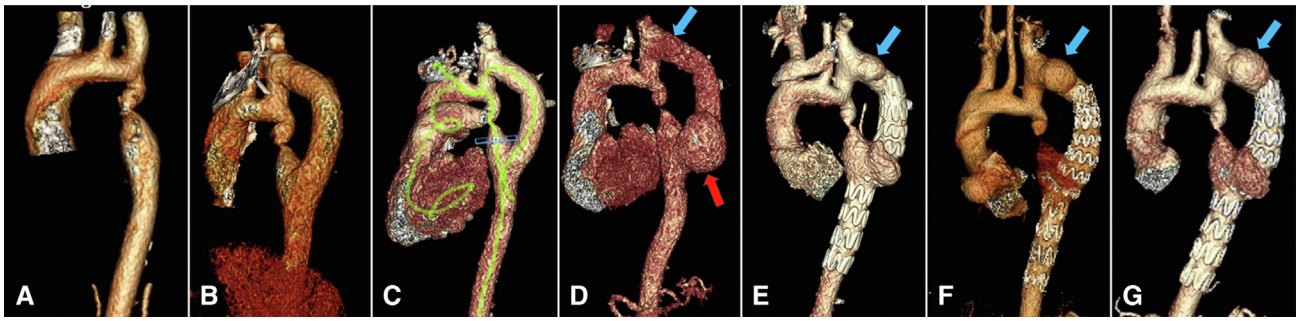

FIGURE 2. In 2013, an adult patient with MAS with a supravisceral lesion (A) was admitted and received LSA-DTA bypass. Postoperative 1-year (B) and 5-year (C) follow-up CTA showed satisfactory outcomes, whereas pseudoaneurysms at the proximal (*blue arrow*) and distal anastomosis (*red arrow*) were found in the postoperative 93-month CTA (D). The patient received reintervention of covered-stent implantation to isolate the distal pseudoaneurysm. In 3 months (E), 15 months (F), and 27 months (G) after reintervention, distal pseudoaneurysm remained stable though type II endoleak from lesioned aorta was observed, whereas the proximal pseudoaneurysm gradually increased (*blue arrow*). *MAS,* Midaortic syndrome; *LSA,* left subclavian artery; *DTA,* descending thoracic artery; *CTA,* computed tomography angiography.

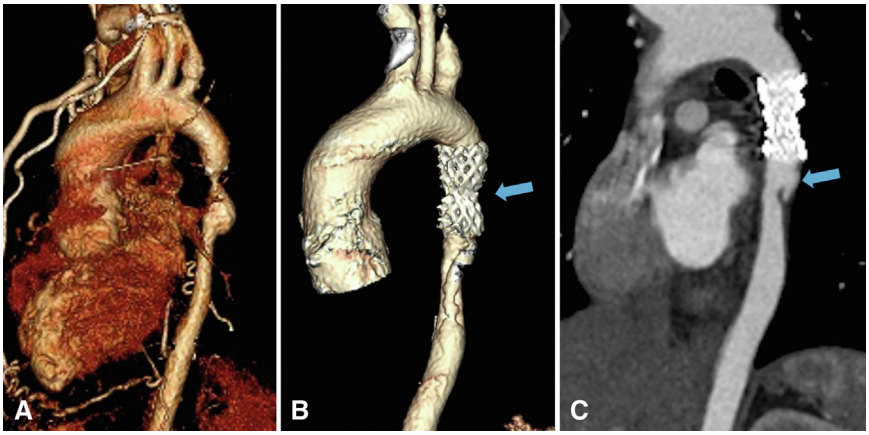

FIGURE 3. An adult patient with MAS with a supravisceral lesion (A) was admitted and received CP covered-stent implantation. Postoperative 4-month follow-up CTA showed stent-induced distal aortic tear (B and C; *blue arrow*). *MAS*, Midaortic syndrome; *CTA,* computed tomography angiography.

claudication. In this study, indications for intervention included not only symptoms related to end-organ damage but also a transcatheter peak systolic pressure gradient greater than 40 mm Hg instead of morphological indicators. Intervention methods included both OST and EVT, and both were found to be reliable methods for treating MAS with satisfactory short- and mid-term follow-up outcomes.[5,8,9] However, specific guidelines for the treatment of MAS are still lacking, and the choice of intervention is highly individualized.

It is commonly agreed that EVT may achieve better outcomes in terms of morbidity and perioperative complications than OST, and MAS with diffuse lesion or intravisceral lesion involvement is suitable for OST. The 2 most commonly used OST procedures are patch aortoplasty and bypass, with the latter being the main treatment for MAS with concurrent visceral artery stenosis.[8] In this study, OST was more likely to be performed in patients with intravisceral lesions ($P = .001$) or multiple segmental lesions ($P = .002$). Most OST patients in this study received bypass, whereas only 1 patient with a short supravisceral lesion received coarctectomy and interposition graft. Results of the current study indicate that both OST and EVT can yield satisfactory outcomes for isolated supravisceral and infrarenal lesions. EVT demonstrates superiority over OST because of its less invasive nature, reduced perioperative complications, and shorter hospital stays. Conversely, for intravisceral and multiple lesions, OST appears to be the preferred option because it can address multiple lesions with a single bypass without compromising visceral blood flow. In contrast, EVT for multiple lesions typically requires multiple stent-grafts and carries an increased risk of spinal cord ischemia.

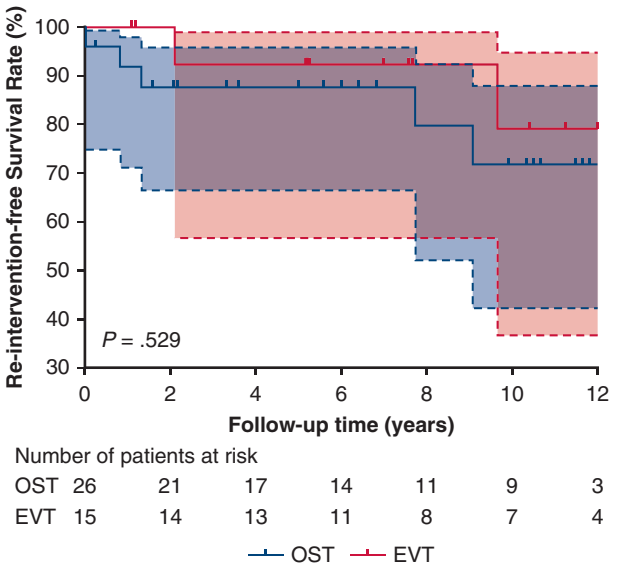

FIGURE 4. Kaplan–Meier curves showing the probabilities of reintervention-free survival rates (with 95% CI) of OST group or EVT group (log-rank test, $P = .529$), respectively. *OST*, Open surgical treatment; *EVT,* endovascular treatment.

The most commonly reported adverse events for MAS after OST included dissection and pseudoaneurysm formation.[8] No dissection was observed in the OST group in the current study. Pseudoaneurysms were observed in 2 OST patients, 1 in the internal thoracic artery and 1 in the anastomosis. The former patient received coil embolization, and the latter patient received a covered stent implantation. However, pseudoaneurysm at anastomosis might be difficult to completely isolate by a covered stent, because the original lesion aorta might be a natural source of type II endoleak, as in the patient described in the current study. In a study involving 33 patients with TA who underwent surgical repair for MAS, the cumulative incidence of anastomotic pseudoaneurysms at 10, 20, and 30 years were 12.2%, 21.2%, and 37.3%, respectively.[10]

For EVT patients, one of the most common complications reported was aneurysm, which was induced by fracturing the intima and media of the aortic wall as well as the surrounding normal tissue during the progress of PTA or stent implantation.[11] However, with the application

of covered stents, the incidence rate of aneurysm significantly decreased. Covered stents could not only support the integrity of the vessel wall after balloon dilation by opposing the recoil of the elastic vascular stenosis but also reapply the torn intima to the media with the membrane. This could minimize the extension of wall tears and subsequent dissection or aneurysm formation that could occur after PTA or bare stent implantation.[12] In the current study, stent-induced aortic tears were observed in 1 patient who received a CP stent (Figure 3). Unlike other covered stents used in this study, CP and Fluency stents had a certain portion of bare metal stent at not only the proximal but also the distal end, which was likely to induce new aortic tears within the progress of aortic oscillation. Considering that the patients are relatively young and have long life expectancy, strict and regular lifelong follow-up is needed.

The primary goal of MAS treatment traditionally has been the complete relief of a pressure gradient.[13] In this study, baseline and postoperative peak systolic pressure gradients were measured in all EVT patients and most (16/25) OST patients. Although no difference observed, a lower postoperative gradient was more likely to be found in the OST group ($P = .020$). Notably, 3 EVT patients still had a postoperative peak systolic pressure gradient of 20 mm Hg or greater, indicating that gradients frequently persist even after successful stenting, which is a common and concerning complication.[4] A successful intervention is typically defined as a pressure gradient less than 20 mm Hg,[14] and a meta-analysis found that postoperative pressure gradient less than 20 mm Hg could be achieved in 99.5% of patients who received stent implantation.[15] However, it is worth noting that the meta-analysis only included patients with aortic coarctation with a mean baseline pressure gradient of 45.41 mm Hg, whereas the patients enrolled in the current study had a higher baseline gradient (64 [54-78] mm Hg), which was caused by not only aortic coarctation but also idiopathic, atherosclerosis, and TA. Thus, the relatively low rate of patients with postoperative pressure gradient less than 20 mm Hg may be partly explained.

Study Limitations

There were several limitations to this study. First and foremost, it was a retrospective study with a limited cohort. However, given the rarity of adult MAS cases, the cohort in this study was relatively large. Second, the study covered a long period during which treatment techniques and devices have evolved, which may have compromised intragroup consistency. Third, intergroup baseline characteristics were inconsistent, which limited comparability between the 2 treatment groups. A randomized clinical trial with a larger cohort will be necessary in the future to more comprehensively compare the 2 treatment methods and guide the management of MAS.

CONCLUSIONS

Both OST and EVT showed satisfactory long-term efficacy outcomes for adult patients with MAS with 5-year reintervention-free survivals of 87.5% and 92.9%, respectively. Patients with multiple segmental lesions or intravisceral segment involved were more likely to be found in OST group, whereas higher postoperative peak systolic pressure gradient was more likely to be found in the EVT group. Considering patients' long life expectancy, strict and regular lifelong follow-up is needed.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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