ORIGINAL ARTICLE

VASCULAR

Outcomes in the treatment of aberrant subclavian arteries using the hybrid approach

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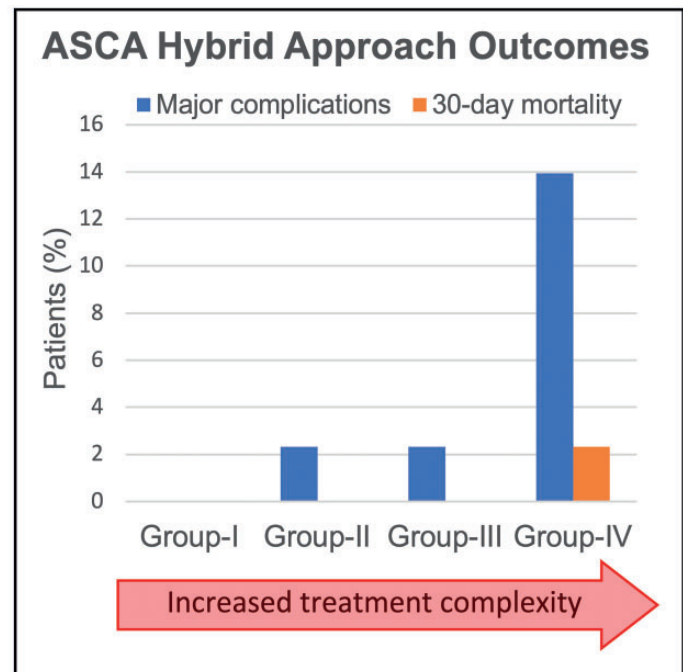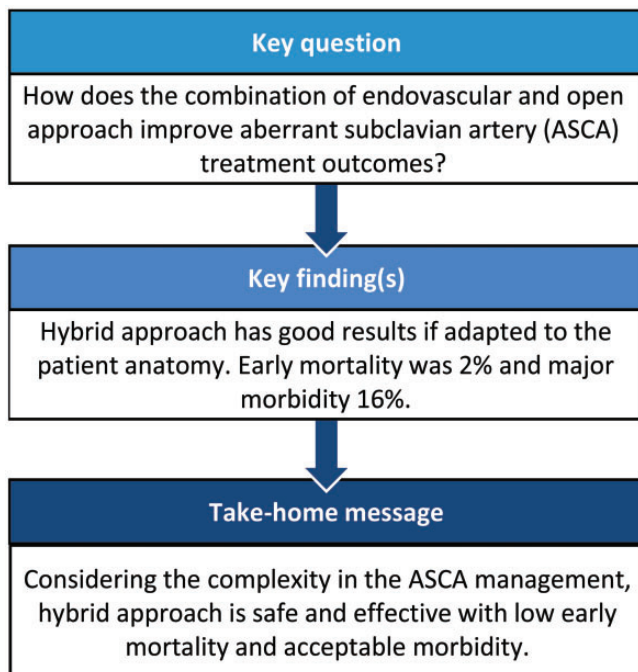[e] Service de Chirurgie Vasculaire, CHU Clermont-Ferrand, Clermont-Ferrand, France
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Key question

How does the combination of endovascular and open approach improve aberrant subclavian artery (ASCA) treatment outcomes?

Key finding(s)

Hybrid approach has good results if adapted to the patient anatomy. Early mortality was 2% and major morbidity 16%.

Take-home message

Considering the complexity in the ASCA management, hybrid approach is safe and effective with low early mortality and acceptable morbidity.

ASCA Hybrid Approach Outcomes
■ Major complications ■ 30-day mortality
Increased treatment complexity

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Abstract

OBJECTIVES: Aberrant subclavian artery (ASCA) occurs rarely but is one of the most frequent anatomical variations of the supra-aortic trunks. No consensus has been established on its best treatment. The goal of this study was to report the outcomes of ASCA treated by the hybrid approach.

METHODS: This non-interventional retrospective multicentre analysis included patients treated for ASCA by the hybrid approach in 12 French university hospitals between 2007 and 2019. The hybrid approach was defined as an endovascular procedure combined with open surgery or a hybrid stent graft. Patients were divided in 4 groups (from less to more complex treatment). The primary end point was 30-day mortality. The secondary end points were 30-day complications and late mortality.

RESULTS: This study included 43 patients. The mean age was 65 (SD, standard deviation: 16) years. Symptoms were found in 33 patients. Subclavian revascularization combined with aberrant subclavian artery occlusion was undertaken in 13 patients. Unilateral and bilateral subclavian revascularization combined with a thoracic aortic stent graft was undertaken in 11 and 6 patients, respectively. Total aortic arch repair combined with a thoracic aortic stent graft was undertaken in 13 patients. Thirty-day mortality was 2.3% with a technical success rate of 95.3%. The 30-day major postoperative complication rate was 16.3%: 4 strokes, 2 tamponades, 1 acute respiratory distress syndrome. Mean follow-up was 56.3 (SD: 44.7) months. The late mortality was 18.6%.

CONCLUSIONS: The ASCA hybrid approach is feasible, safe and effective with low early mortality. Morbidity is rather high. However, it increases with the complexity of the hybrid approach, which should be kept as simple as possible if the anatomical morphology allows.

Keywords: Aberrant subclavian artery • Kommerell's diverticulum • Hybrid approach • Surgical treatment • Endovascular treatment • ARDS • Acute respiratory distress syndrome

ABBREVIATIONS	
ARDS	Acute respiratory distress syndrome
ASCA	Aberrant subclavian artery
CT	Computed tomography
KD	Kommerell's diverticulum
SCA	Subclavian artery
SAT	Supra-aortic trunks
SD	Standard deviation
TEVAR	Thoracic endovascular aortic repair

INTRODUCTION

Aberrant subclavian artery (ASCA), also named "arteria lusoria", is the most frequent anatomical variation of the supra-aortic trunks (SAT). Currently, its prevalence varies between 0.2% and 2.5% [1] in cadaveric series and 0.5 to 0.8% [2, 3] in imaging series. ASCA was first described by Hunauld in 1735 [4]. The first surgical treatment was performed by Gross in 1964 [5]. ASCA can be isolated or associated with other anatomical variations of the SAT.

ASCA is usually asymptomatic. Dysphagia is the most common symptom in adults [6, 7]. It is related to the extrinsic compression of the posterior part of the oesophagus by ASCA. Dyspnoea, retrosternal pain, cough and weight loss are also commonly reported [8]. Other symptoms include thromboembolic events such as acute upper limb ischaemia or vertebrobasilar strokes.

ASCA treatment is indicated in case of symptoms, aneurysmal degeneration (mean diameter ≥3 cm) or Kommerell's diverticulum (KD) (mean diameter ≥5.5 cm) due to the risk of rupture and dissection [9]. Because there is a lack of randomized data, guidelines and consensus on this entity, there are no clear therapeutic indications [10]. In particular, no consensus is available regarding the KD size measurement [9]. Endovascular, hybrid and open aortic arch and subclavian artery (SCA) repair has been discussed in selected cases [10]. The goal of treatment is to exclude ASCA and revascularize the homolateral upper limb. Despite recent advances in vascular and endovascular surgery, there are no

standardized approaches for treating ASCA [10]. In past decades, open surgery was the preferred treatment. The largest available cohort (33 patients) was that reported by Kieffer *et al.* in 1994 [11]. Advances in endovascular techniques have changed the management of ASCA, potentially improving perioperative outcomes compared with conventional open repair techniques. This situation is of particular importance for older patients whose multiple comorbidities are deemed at high risk for open repair. This preferred method for such cohorts comprises a combination of SAT debranching and thoracic endovascular aortic repair (TEVAR) and ASCA [10, 12] exclusion. The advantage of the hybrid treatment is the avoidance of cardiopulmonary bypass and hypothermic circulatory arrest [10]. ASCA hybrid treatment was first described in 2003 by Lacroix *et al.* [13]. Some authors [14] advocate hybrid treatment as the best choice to treat ASCA. Current literature provides limited data [10], mainly comprising case series with short follow-up periods [15]. The hybrid approach seems to be a good option with good outcomes and lower mortality and morbidity compared with open surgery [16].

The goal of this study was to report the outcomes of ASCA treatment using the hybrid approach.

MATERIAL AND METHODS

Ethical statement

Local ethical approval was obtained at each centre. Ethical approval of the coordinating centre with mutual agreement of all the participating centres was obtained (ID: IRB1672021/CHUSTE dated 16 December 2021).

We performed a retrospective analysis of consecutive patients treated for ASCA by the hybrid approach in 12 vascular surgery departments of French university hospitals (Nancy, Toulouse, Paris Mondor, Clermont-Ferrand, Saint-Etienne, Nice, Caen, Nantes, Besançon, Lyon, Marseille, Paris Ambroise-Paré) between January 2007 and June 2019. All centres were members of the AURC (Association Universitaire pour la Recherche en Chirurgie) and agreed to participate in the study. During the study period,

no open procedures other than hybrid stent grafts were performed to treat this condition.

The hybrid approach was defined as an endovascular procedure combined with open surgery or a hybrid stent graft inserted simultaneously or in a staged manner. The choice between simultaneous or staged treatment was left to the discretion of each centre.

Patients were included in the order in which they were treated at each centre. Inclusion criteria were adults $\geq$18 years of age, symptomatic ASCA, aneurysmatic ASCA (30$\leq$mean diameter < 55 mm) and KD (mean diameter $\geq$55 mm).

The ASCA hybrid approach was divided into 4 groups from less to more complex approaches. Group I had 1 cervical subclavian revascularization combined with an ASCA occlusion. Group II had 1 subclavian revascularization combined with ASCA coverage by TEVAR. Group III had revascularization and TEVAR coverage of both SCAs. Group IV had complex hybrid reconstruction of the aortic arch including hybrid stent grafts (frozen elephant trunk). The minimum accepted landing zone for TEVAR was 15 mm, except in a salvage procedure.

The primary end point was 30-day mortality after a complete hybrid approach. Secondary end points were in-hospital (during the hospital stay) deaths, late deaths, early (<30 days) and late (>30 days) complications, secondary procedures rates and dysphagia relief.

Minor complications were defined as wound bleeding or lymphocele, nerve injury, transient renal failure and pulmonary infection. Major complications were defined as cardiac complications (tamponade, arrythmia, myocardial infarction, congestive heart failure), stroke, acute respiratory distress syndrome (ARDS) and multiorgan failure. Secondary procedures were defined as any additional surgical or endovascular procedures performed after the hybrid approach to treat endoleaks, migration, kinking, stenosis or occlusion.

The technical success rate was defined as uncomplicated arterial revascularization/transposition, successful plug occlusion of targeted arteries and successful deployment of the stent graft and endograft without angiographic complications during the procedure.

During follow-up, all patients had clinical and computed tomography (CT) scan evaluations every year. The modalities were left to the discretion of each centre, but all patients had at least 1 CT scan and 1 clinical evaluation every year for follow-up. The last follow-up was the last clinical and CT-scan evaluation. Follow-up ended in June 2020.

Data were collected anonymously. The Ishimaru classification [17] of landing zones was used in patients who required TEVAR.

Statistical analyses were performed using Stata version 13 software (StataCorp LP, College Station, TX, USA). Quantitative variables were reported by mean ± standard deviation or median [interquartile range]. Categorical variables were reported as frequencies and percentages. The Shapiro-Wilk test was used to assess the normality of continuous variables. Variables with more than 25% of their values missing were omitted. Survival and intervention-free survival were reported using Kaplan–Meier methods.

RESULTS

The intention-to-treat hybrid approach was undertaken in 43 patients. The mean age was 65 years [standard deviation (SD): 16]. Patient characteristics are shown in Table 1.

Of the 33 patients who exhibited symptoms, 5 patients each had 2 symptoms. Dysphagia was found in 18 patients. Among the latter, 2 patients had a KD and 7 had an aneurysmatic ASCA.

Table 1: Patient characteristics and comorbidities

Patient characteristics	Number	Percentage
Male	24	55.8
Tobacco (active)	17	39.5
Dyslipidaemia	14	32.6
Diabetes	8	18.6
Hypertension	29	67.4
Rhythmic cardiopathy	6	13.9
Ischaemic cardiopathy	6	13.9
Chronic obstructive pulmonary disease	4	9.3
Chronic respiratory failure	1	2.3
History of stroke	10	23.3
History of peripheral artery disease	1	2.3
ASA 1	3	7.0
ASA 2	16	37.2
ASA 3	24	55.8

ASA: American Society of Anesthesiologists.

Seven patients experienced embolic events. Among them, 2 had acute upper limb ischaemia, 1 had vertebral artery occlusion and 4 had a posterior fossa stroke. Dyspnoea was observed in 3 patients, dysphonia in 3. Seven patients experienced acute thoracic pain: 3 KD ruptures, 3 type-B aortic dissections with primary entry tear facing the KD and 1 descending thoracic aortic haematoma.

Ten patients were asymptomatic. Among them, 5 had an aneurysmatic ASCA and 2, a KD. ASCA was associated with another aortic disease in the 3 other cases: 2 descending thoracic aortic aneurysms and 1 total thoracic aortic aneurysm.

Symptom repartition, ASCA anatomical characteristics and hybrid procedure characteristics are summarized in Table 2. The detailed hybrid approach is described in Table 3 for groups I to III and in Table 4 for group IV.

The intention-to-treat technical success rate was 95.3%. TEVAR placement failed in 2 patients. One 65-year-old woman in group III had multiple unsuccessful attempts to place the TEVAR in zone 2 because of a complex anatomy, and TEVAR was not deployed. She therefore experienced a postoperative embolic occipital stroke with regressive aphasia and regressive paresis but persistent visual disorders. She refused secondary procedures. One 74-year-old man in group II had an intraoperative type I endoleak treated by TEVAR extension in zone 3 the day after the operation because the endograft was not available in the centre at the time of the treatment.

The intraoperative complication rate was 2.3% (1/43). One patient in group III had an iliac occlusion caused by dissection related to the TEVAR introducer sheath. He was treated with a femoro-femoral cross-over bypass.

The 30-day and intrahospital mortality rates were 2.3% (1/43) and 4.6% (2/43), respectively. Both patients were in group IV and had hybrid stent grafts. One was a 59-year-old man who had an ASCA associated with a type B aortic dissection. A postoperative major stroke occurred after the second stage, and he died on postoperative day 4. The second was an 83-year-old man. He had a reintervention for a postoperative tamponade 8 days after the second stage. Then, he had ARDS caused by pneumopathy and died on postoperative day 40 of multiorgan failure.

The mean hospital stay was 9.7 days (4–21) when the hybrid approach was performed simultaneously and 20.2 days (6–45) for both stages when it was staged.

Table 2:   Symptom repartition, aberrant subclavian artery anatomical characteristics, stages and delay between stages of the hybrid approaches for each group

	Group I	Group II	Group III	Group IV	Total
Patients, n (%)	13 (30.2)	11 (25.6)	6 (13.9)	13 (30.2)	43 (100)
Gender, n	4 men, 7 women	7 men, 4 women	3 men, 7 women	10 men, 3 women	24 men, 19 women
Mean age, years (SD)	56 (20)	68.5(14)	66.2 (12)	70.5 (10.2)	65 (16)
Symptomatic patients, n	12	6	5	10	33
Anatomical Characteristics					
Aneurysmatic ASCA, n	1	6	4	7	18
Mean diameter of aneurysmatic ASCA, mm (SD)	34	38.7 (4.5)	34.4 (4.5)	39.3 (9.1)	37.7 (7.1)
Kommerell's diverticulum, n	0	2	1	4	7
Mean diameter of Kommerell's diverticulum, mm (SD)	NA	60 (7.1)	55	65 (7.1)	63.3 (7)
Mean length between the ASCA and the contralateral SCA, mm (SD)	10.7 (8.8)	18 (7.4)	11.6 (5.9)	12.1 (8.9)	13.3 (8.4)
Length between the ASCA and the contralateral SCA $\geq$ 20 mm, n	2	5	1	3	11
Left ASCA associated with the right aortic arch, n	1	2	1	2	6
Right ASCA, n	12	9	5	11	37
Bicarotid trunk, n	8	3	2	4	17
Type B aortic dissection, n	0	0	1	3	4
Thoracic aortic aneurysm, n	1	1	1	4	7
Abdominal aortic aneurysm, n	1	2	1	0	4
Hybrid procedure characteristics					
Staged procedures, n	0	4	5	8	17
Mean delay between both stages, days (SD)	NA	42.2 (38)	34.0 (56)	66.0 (58.5)	51.8 (52.2)

ASCA: aberrant subclavian artery; NA: not applicable; SCA: subclavian artery; SD: standard deviation.

Table 3:   Detailed hybrid approach for groups I, II and III

		Group I	Group II	Group III
SAT open repair				
ASCA transposition on the ipsilateral common carotid artery		10	3	0
Carotid-subclavian bypass		3	8	0
Double carotid-subclavian transposition		0	0	1
Double carotid-subclavian bypass		0	0	2
Carotid-subclavian transposition and bypass		0	0	1
SAT open and endovascular repair				
ASCA bypass and contralateral subclavian chimney		0	0	1
ASCA transposition and retro-oesophageal periscope		0	0	1
ASCA plug occlusion[*]	Ostium	10	4	0
	Prevertebral segment	2	5	0
	Ostium and prevertebral segment	1	0	0
Thoracic aorta endovascular repair				
TEVAR	Zone 2 coverage	0	0	6
	Zone 3 coverage	0	11	0

*All procedures were performed using AMPLATZER Vascular Plugs (St. Jude Medical, St Paul, MN, USA).
ASCA: aberrant subclavian artery; SAT: supra-aortic trunk; TEVAR: thoracic endovascular aortic repair.

With a follow-up of 56.3 (SD: 44.7) months (Fig. 1), the late mortality rate was 18.6% (8/43) and was not related to the ASCA hybrid approach. The cause of death was cardiac in 3 patients (at 6 months and 7 and 10 years), neoplasia in 2 (at 22 and 64 months), type A aortic dissection in 1 (at 10 years) and ARDS in 2 (at 2 months caused by severe pneumonia and at 8 years caused by sepsis).

A total of 13 complications (30.2%) occurred in 11 patients (Table 5), 25.6% of which were early and 4.6% of which were late. One patient had 3 complications: 2 early and 1 late. The early major complication rate was 16.3% and occurred mainly in group IV (71.4%, 5/7). The minor early complication rate was 9.3% and occurred mainly in group III (75%, 3/4). One late major complication (2.3%) occurred in the patient who had ARDS; it led to lethal multiorgan failure (group IV). Access-related complications occurred in 2 patients (1 early and 1 late) who required open surgical treatment. Two patients had cardiac tamponade following a sternotomy and required surgical revision. The rate of complications increased with the increasing complexity of the hybrid approach: from 0% in group I, to 9.1% (1/11) in group II, to 66.6% (4/6) in group III and to 69.2% (9/13) in group IV (Table 5). The rate of major complications also increased with

Table 4: Detailed hybrid approach in group IV

	One stage or stage 1	Stage 2	TEVAR landing zone
Patient 1	CCA to right SCA bypass ASCA plug occlusion	Hybrid stent graft[*]	
Patient 2	CCA to right SCA bypass	Aortic arch open debranching TEVAR	3
Patient 3	CCA to left SCA bypass Right and left CCA chimneys ASCA plug occlusion TEVAR		0
Patient 4	SAT debranching on aortic arch TEVAR		0
Patient 5	Carotid to carotid bypass Left SCA to CCA transposition	TEVAR	1
Patient 6	Right and left SCA to left CCA bypass TEVAR		1
Patient 7	Left SCA to left CCA transposition	Ascending aortic to right and left CCA TEVAR	0
Patient 8	Bilateral carotid SCA bypass	ASCA plug occlusion Fenestrated stent graft on bicarotid trunk TEVAR	0
Patient 9	Carotid to left SCA bypass	Hybrid stent graft[**]	
Patient 10	Carotid to SCA bypass ASCA plug occlusion	Hybrid stent graft[**]	
Patient 11	Ascending aorta to bicaridid trunk bypass SCA to right CCA transposition	TEVAR	0
Patient 12	Carotid to carotid bypass Right SCA to right CCA bypass ASCA ligation Left SCA periscope TEVAR		1
Patient 13	Hybrid stent graft[**]		

*Thoraflex hybrid stent graft.
**E-vita Open hybrid stent graft.
ASCA: aberrant subclavian artery; CCA: common carotid artery; SAT: supra-aortic trunks; SCA: subclavian artery; TEVAR: thoracic endovascular aortic repair.al
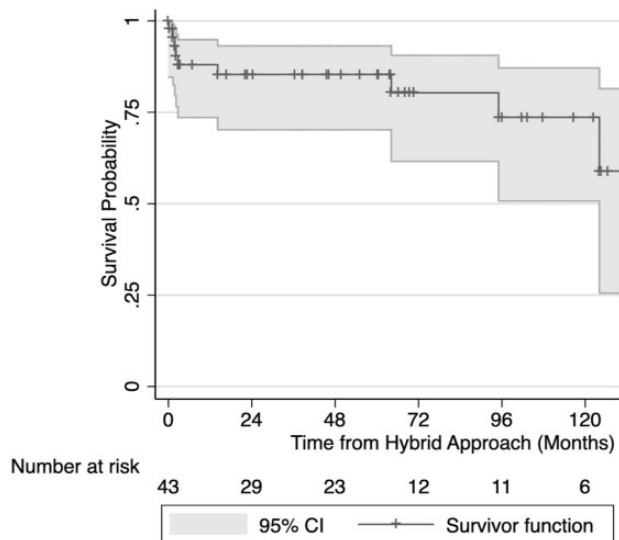
Figure 1: Kaplan–Meier graph showing the survival among patients. CI: confidence interval.

increasing complexity of the hybrid approach: from 0% in group I, to 9.1% (1/11) in group II, to 16.7% (1/6) in group III and to 53.8% (7/13) in group IV (Table 5).

Four patients underwent 4 secondary procedures (9.3%): 2 early (<30 days) and 2 late (>30 days). Both early secondary procedures occurred in group II. TEVAR extensions (1 in zone 3 and 1 in zone 2) were performed to treat a type I endoleak on postoperative days 1 and 8. One late secondary procedure occurred at 5 months in a group I patient. His postoperative CT scan showed an endoleak caused by a failure of an ASCA plug occlusion. He had a right carotid subclavian bypass and prevertebral plug occlusion of a right ASCA. A left carotid subclavian bypass combined with zone 2 coverage by TEVAR was therefore performed. The second late secondary procedure was a TEVAR extension in zone 2 to treat a type I endoleak at 13 months in a group II patient.

The Kaplan–Meier reintervention-free survival was 78.5% at 12 months and 73% at 60 months (Fig. 2).

Among the 18 patients who had dysphagia, 77.8% (14/18) became asymptomatic early after hybrid treatment. Three patients with persistent dysphagia had plug migration behind the

Table 5: Complications after the aberrant subclavian artery hybrid approach

Complications	Group I (n)	Group II (n)	Group III (n)	Group IV (n)	Total (n)
Early complications (< postoperative day 30)		1	4	6	11
Stroke*		1	1	2**	4
ARDS*				1	1
Cardiac tamponade*				2***	2
Acute renal failure			1		1
Peripheral neurological			1		1
Femoral access haematoma			1		1
Pneumopathy				1	1
Late complications (> postoperative day-30)				2	2
Multiorgan failure*				1***	1
Lymphocele				1	1

*Major complications.

**One of them was lethal on postoperative day 3.

***One patient had cardiac tamponade and ARDS that led to multiorgan failure and death on postoperative day 40.
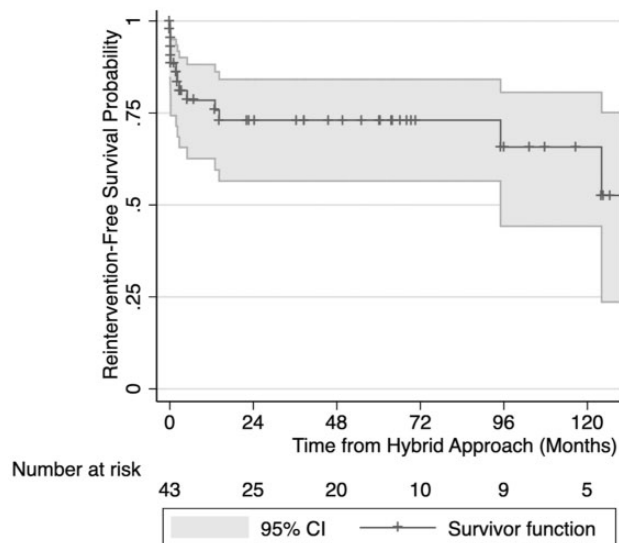
ARDS: acute respiratory distress syndrome

Figure 2: Kaplan–Meier graph showing the reintervention-free survival among patients. CI: confidence interval

oesophagus, although it was positioned at the ASCA ostium during the hybrid procedure. One patient had transient improvement of dysphagia for a few weeks, probably related to the persistent compression of the oesophagus by a plug occlusion.

All SAT revascularizations remained patent during the follow-up period.

DISCUSSION

This multicentre study presents a large series of patients who had an ASCA hybrid approach. In this 43-patient study, with 76.7% symptomatic patients, different hybrid approaches were classified into 4 groups from less to more complex approaches. Intrahospital deaths and major complications occurred mainly with the most complex approaches (groups III and IV).

ASCA surgical treatment carries a high mortality of 9 to 25% and a high morbidity rate of 20 to 60% [15]. Endovascular ASCA treatment showed fewer deaths and lower complication rates.

However, a secondary open surgical procedure may often be necessary to allow or maintain an effective treatment result. The hybrid approach is also a good alternative for the treatment ASCA.

The number of deaths associated with the hybrid treatment varies between 0 and 10% [14–16]. In a series of 21 patients with aneurysmal ASCA, Verzini et al. reported 7% perioperative mortality (1/15) in the hybrid group [14]. In his review, Yang et al. reported 8% mortality in patients who underwent hybrid treatment [15]. Our study showed 4.6% intrahospital mortality, in accordance with the available literature. Both deaths in our series occurred in patients treated with complex hybrid procedures.

In this study, the complication rate increased as the complexity of the hybrid approach increased: from 0% in group I to 69% in group IV. The complication rate after the hybrid treatment varies between 0 and 23% in the literature [14, 16, 18]. In the series of Wooster et al., no major complications occurred after the hybrid treatment [16]. Vucimello et al. reported 22% complications, mainly ipsilateral upper limb ischaemia [18]. The major complication rate of our series was in accordance with that in the literature. Complications mainly occurred in patients who had the complex hybrid approach. When total aortic arch repair was necessary, higher mortality risks and more complications were observed. The hybrid approach to treat ASCA should also be kept as simple as possible if anatomical morphology allows.

In this series, the secondary procedures were all related to the endovascular stage. They were mainly related to a type-1 endoleak. Verzini et al. reported 2 cases with endoleaks [14]. Regarding the aetiology of the endoleaks in our series, the proximal landing zone in zone 3 of TEVAR was too short. Indeed, the mean length between the ostia of the SCAs was less than 20 mm. In their analysis of 180 CT scans in patients with a right ASCA, Settembre et al. reported that the mean length between the ostia of the SCAs was 5.4 mm ± 4.3 mm [19]. Conventional TEVAR requires a landing zone of at least 20 mm to minimize the risk of a type 1 endoleak. If this condition is not verified, coverage of the SAT combined with revascularization by open surgery or complex endografting with fenestrations, chimneys or periscopes is possible. However, these latter bear the risk of gutter endoleaks and reintervention during the follow-up period.

In all cases in this series, maintenance of the patency of both SCAs was performed whenever possible. Prophylactic bypassing of the left SCA before coverage with an endograft is still a matter of debate. Despite controversial results in the literature, the Society for Vascular Surgery practice guidelines recommend routine prophylactic revascularization in elective TEVAR procedures [20]. Because ASCA is a complex disease, patients with ASCA coverage without revascularization are at a higher risk of neurological complications (posterior stroke and ischaemic spinal cord damage) than patients with subclavian revascularization [7].

However, the risk of embolic stroke remains despite revascularization of the SCAs. The 4 postoperative strokes that occurred in this series (9.3%) were related to embolic events, 3 of which occurred after complex repair. In the literature, postoperative stroke rates varied between 2.6 and 16% and were likely related to aortic arch and SAT manipulations and/or to endovascular wires and device-related injuries [21–23]. Other studies do not report a postoperative stroke after ASCA hybrid repair [14, 16]. Given the severity and the dreadful complications of aneurysmatic ASCA and KD, the perioperative stroke rates after an ASCA hybrid repair reported in this series are satisfactory.

A hybrid approach to ASCA is feasible. Indeed, the technical success rate was 100% in Verzini *et al.*[14] and 95.3% in our series. One technical failure was related to the patient's complex anatomy. The latter can make the endovascular stage of the hybrid approach challenging.

In this study, the main clinical indication for ASCA treatment was dysphagia. A decrease in pressure of the retro-oesophageal ASCA by the hybrid approach decreases the compression by ASCA and should improve the dysphagia. In the 10-patient series of Wooster *et al.*, dysphagia disappeared in all patients and in 77.8% of the patients in this series [16]. Despite oversizing, we observed plug migration from the ASCA ostium to the prevertebral portion in 3 cases. Occlusion plug placement is crucial in the treatment of ASCA but may be challenging. Precise preoperative planification and good quality imaging during the procedure in the operating room may improve the immediate technical success, relief of symptoms and the long-term outcomes.

No consensus on the optimal treatment for ASCA is available. The hybrid procedure seems to be a good alternative to total open surgery, with lower mortality and morbidity. However, data are scarce in the literature. Kieffer *et al.* proposed a classification to help physicians choose the optimal surgical treatment, depending on the ASCA presentation [11]. Yang *et al.* modified this classification to include other symptomatic types of ASCA, such as aortic dissection originating from the ASCA and iatrogenic injury of the ASCA [15]. Ascending or descending thoracic aortic aneurysms, aortic arch aneurysms and aortic dissections below the contralateral SCA are not rare in the presence of ASCA. However, they are not included in the classifications. They also require a complex specific hybrid approach. Total endovascular repair including the use of fenestrations, chimneys or periscopes could also be an alternative to the hybrid treatment and avoids a sternotomy in the treatment of complex ASCA. Gafoor *et al.* described the first fully endovascular exclusion of a right ASCA and thoracic aortic aneurysm with good outcomes [24]. Total endovascular repair could decrease mortality and morbidity in cases requiring challenging complex ASCA treatment.

This retrospective study has several limitations. The data were collected from different centres with heterogeneous patient selection and heterogeneous choice of treatment. Follow-up was also not homogeneous with different protocols in each centre that impact the analysis of the outcomes. The small number of patients in each group makes statistical analysis not feasible.

No consensus has been established as to the best treatment of this rare SAT anomaly. The results of this study provide insights into the ASCA hybrid approach despite the variability in practice among centres. The ASCA hybrid approach deserves further study to assess its long-term effectiveness and safety.

CONCLUSION

A hybrid approach to the treatment of ASCA is feasible, safe and effective. The early mortality rate is low. Morbidity is rather high, and it increases with the complexity of the hybrid approach. When total aortic repair was necessary, higher mortality risks and more complications were observed. The hybrid approach to treat ASCA should be kept as simple as possible if the anatomical morphology allows.

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Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

Author contributions

Sabrina Ben Ahmed: Conceptualization; Data curation; Formal analysis; Methodology; Validation; Writing−original draft; Writing−review & editing. **Nicla Settembre**: Data curation; Formal analysis; Validation; Writing−original draft; Writing−review & editing. **Jospeh Touma**: Formal analysis; Supervision; Writing−original draft; Writing−review & editing. **Anthony Brouat**: Data curation; Formal analysis; Methodology; Writing−original draft. **Jean-Pierre Favre**: Conceptualization; Supervision; Validation; Writing−review & editing. **Elixene Jean Baptiste**: Supervision; Validation; Writing−original draft. **Xavier Chaufour**: Supervision; Validation; Writing−original draft; Writing−review & editing. **Eugenio Rosset**: Conceptualization; Formal analysis; Supervision; Validation; Writing−original draft; Writing−review & editing.

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