The fate of spinal arteries after the stent-assisted balloon-induced intimal disruption and relamination in aortic dissection repair technique: a case series

Alice Lopes, MD,[a,b,c] Ryan Gouveia e Melo, MD,[a,b,c] João Leitão, MD,[b,d] Carlos Mendonça, MD,[d] Mariana Moutinho, MD,[a] *and* Luís Mendes Pedro, MD, PhD, FEBVS,[a,b,c] *Lisbon, Portugal*

ABSTRACT

Objective: We evaluated the patency of the spinal arteries (intercostal and lumbar) after the STABILISE (stent-assisted balloon-induced intimal disruption and relamination in aortic dissection repair) technique.

Methods: A retrospective analysis of all patients with aortic dissection treated with the STABILISE technique between April 2018 and July 2021 was performed. Imaging analysis of the spinal cord vascular supply was accomplished using multiplanar and maximum intensity projection reconstructed images of pre- and postoperative computed tomography angiograms at 1 month, 12 months, and annually thereafter.

Results: Twelve patients were treated for complicated aortic dissection. Primary technical success was 100% and mid-term clinical success, at a mean follow-up of 27 ± 12 months, was 90%. No cases of spinal cord ischemia were identified. One patient died after 1 year (non−aortic related), and one patient was lost to follow-up. A significant decrease was found in the mean number of patent spinal arteries in the stent graft area at 1 month ($P < .001$), 1 year ($P < .001$), and 2 years ($P = .004$). However, no significant reduction was found in the number of spinal arteries in either the bare metal stented or nonstented aorta ($P > .05$).

Conclusions: Use of the STABILISE technique decreased intercostal artery patency in the thoracic stent graft area, but spinal artery patency was not significantly affected by the bare metal stent nor its aggressive ballooning. These findings constitute a step toward a better understanding of the safety of this technique. (J Vasc Surg Cases Innov Tech 2023;9:1-7.)

Keywords: Aortic dissection; Bare metal stent; Endovascular repair; Spinal cord ischemia; STABILISE; Stent graft

Endovascular treatment has emerged during the past decade as the standard of care for complicated acute type B aortic dissection, and the first step is usually deployment of a thoracic endograft (thoracic endovascular aortic aneurysm repair [TEVAR]) with the aim of covering the entry tear. TEVAR might be enough to fix most malperfusion syndromes but is frequently associated with late aortic dilatation and unfavorable remodeling.[1,2] The failure of simple TEVAR to solve malperfusion syndromes led to the development of adjunctive techniques such as direct stenting of the occluded arteries, fenestration of the lamella or the use of a self-expandable bare metal stent (BMS) deployment across the visceral and renal arteries to increase the true lumen diameter and improve perfusion of those arteries. This procedure was called the PETTICOAT (provisional extension to induce complete attachment) technique.

The STABILISE (stent-assisted balloon-induced intimal disruption and relamination in aortic dissection repair) technique was described in 2012 by Hofferberth et al[3] and aims for complete remodeling of the thoracoabdominal aorta. The first steps are similar to those in the PETTICOAT procedure (TEVAR plus BMS deployment) but are followed by dilatation of the dissection stent graft and BMS to reappose the lamella to the peripheral aortic wall and induce complete false lumen thrombosis and re-create a single-channel aorta.[3]

Despite the encouraging results and reported low complication rate, the STABILSE technique remains under investigation. Currently, one of the risks to which we must be most alert is spinal cord ischemia (SCI), with a rate that can reach 10%, according to the series reported to date.[4,5]

Although the pathophysiology of SCI after TEVAR is multifactorial and not completely understood, coverage of the intercostal arteries certainly plays a role.[6-10] The STABILISE procedure implies covering some extent of the descending aorta and, thus, compromising direct flow to the first pairs of the intercostal arteries. However, in the area of the BMS, which is aggressively ballooned, the fate of the intercostal and lumbar arteries is unclear

From the Heart and Vessels Division, Vascular Surgery Department, Hospital de Santa Maria[a]; the Faculty of Medicine,[b] and Cardiovascular Center,[c] University of Lisbon; and the General Radiology Department, Hospital de Santa Maria.[d]

Author conflict of interest: none.

Correspondence: Alice Lopes, MD, Heart and Vessels Division, Vascular Surgery Department, Hospital de Santa Maria, Ave Professor Egas Moniz, Lisbon 1649-035, Portugal (e-mail: alicerclopes@gmail.com).

The editors and reviewers of this article have no relevant financial relationships to disclose per the Journal policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

2468-4287

https://doi.org/10.1016/j.jvscit.2023.101183

and has not been previously assessed, to the best of our knowledge.

In the present study, we evaluated the patency of the intercostal and lumbar arteries after the STABILISE technique for aortic dissection repair.

METHODS

The study followed the reporting guidelines from the STROBE (strengthening the reporting of observational studies in epidemiology) statement for cohort studies.[11]

Study design, setting, and participants. A retrospective analysis of prospectively collected data for all patients treated during a 3-year period (April 2018 to July 2021) with the STABILISE technique in a tertiary referral center was performed. Only patients with complicated aortic dissections (malperfusion syndrome, acute aortic dilatation, refractory hypertension, and/or refractory pain) were included. Most patients were treated for type B aortic dissections, except for one patient who was treated for a type A aortic dissection with distal extension. We included patients treated in the acute, subacute, and early chronic phases. Patients treated using the STABILISE technique, in addition to other adjunctive techniques, such as target vessel stenting, distal covered endovascular reconstruction of the aortic bifurcation, and/or iliac artery stenting, were included in the present study. Patients with an overall aortic diameter >42 mm and patients in whom the dissection had progressed deeply into the SMA and renal arteries were excluded, because we do not use the STABILISE technique for such patients.

According to our standard practice, all the patients underwent preoperative computed tomography angiography (CTA). During the follow-up period, postoperative CTA was performed at 1 month and 12 months and annually thereafter.

STABILISE technique. A very careful analysis of the CTA images was always performed to identify the path to the true lumen. The procedure started with femoral access via artery cutdown, followed by catheterization of the true lumen with a hydrophilic wire, which was changed to a stiff wire, positioned in the ascending aorta. Next, a 6F flexor sheath was advanced over the stiff wire, and small, sequential contrast injections were performed from the top to the bottom of the aorta to confirm true lumen catheterization at all levels. The chosen endograft was positioned in the proximal landing zone and deployed. At this step, a systolic blood pressure of <70 mm Hg was achieved by the anesthesiology team. We used Zenith TX2 dissection endovascular grafts (Cook Medical Inc), with maximum 10% oversizing for the proximal endograft. However, in a few urgent cases, a Zenith Alpha thoracic endograft (Cook Medical Inc) was used because of off-the-shelf availability at our department. After stent graft deployment, an angiogram was obtained to assess the patency of the true lumen and collateral arteries. Dissection stents were then deployed and extended to the infrarenal aorta. In cases in which two BMSs were needed, we avoided overlapping them in the visceral area to expedite target vessel catheterization in the present or future procedures. If needed, catheterization of the visceral and/or renal arteries arising from the false lumen was performed, and a 6F flexor sheath was introduced. Finally, dilatation of the distal two thirds of the stent graft with compliant balloons was achieved, followed by dilation of the full length of the BMS with noncompliant balloons (sized according to the total aortic diameter at each level). After completing the STABILISE technique, the previously catheterized visceral arteries originating from the false lumen were stented, if deemed necessary.

Variables, data sources, and measurement. All the patients underwent a thorough clinical examination at admission, and the demographic variables, comorbidities, indication for treatment, extent of aortic repair, and imaging and clinical data were collected prospectively and analyzed retrospectively. This information and the follow-up data were obtained from case report forms completed prospectively at the following stages: preoperatively (at admission), perioperatively, postoperatively in the hospital, and during outpatient follow-up.

Imaging analysis of the spinal cord vascular supply was performed by the same experienced radiologist, with >30 years' professional experience, whose clinical focus was the vascular anatomy. Images were stored and analyzed using the Sectra picture archiving and communications system (Sectra AB) of our hospital. All examinations were performed using 64-slice Philips Extended Brilliance computed tomography scanner with a slice thickness of 1 mm. Multiplanar reconstruction images, maximum intensity projection images, and three-dimensional reconstructed images of pre- and postoperative CTA were available for all patients.

End points and definitions. The entire aorta was analyzed, looking specifically at the origin and main branches of the spinal arteries—intercostal and lumbar—in the true or false lumen. The aorta was then divided into three levels according to where the endografts were placed (covered stent graft, bare metal dissection stent, and nonstented aorta). A quantitative assessment of the patency of the intercostal and lumbar arteries was determined at each level. Patency was defined as the presence of contrast opacification up to the aortic wall. The number of patent intercostal and lumbar arteries on pre- and postoperative imaging was also compared regarding the different areas of the aorta:

Table I. Clinical characteristics and indications for stent-assisted balloon-induced intimal disruption and relamination in aortic dissection repair (STABILISE)[a]

Pt. No.	Sex	Age, years	Temporal phase	Time since diagnosis, days	Indication for STABILISE
1	Male	71	Subacute	26	Visceral malperfusion
2	Male	69	Chronic	144	Lower limb ischaemia
3	Male	42	Chronic	98	Acute aortic dilatation
4	Male	34	Acute	6	Renal malperfusion; lower limb ischemia
5	Male	59	Subacute	16	Lower limb ischaemia; refractory hypertension
6	Male	49	Acute	5	Visceral malperfusion
7	Male	53	Acute	10	Visceral malperfusion
8	Male	74	Subacute	22	Acute aortic dilatation
9	Male	53	Acute	7	Acute aortic dilatation; lower limb ischemia
10	Male	52	Subacute	16	Renal malperfusion; lower limb ischemia
11	Male	61	Subacute	32	Lower limb ischaemia
12	Female	68	Subacute	25	Lower limb ischaemia

Pt. No., Patient number.
[a]All patients were treated for type B aortic dissection.

Table II. Patient demographics and risk factors and procedures associated with the stent-assisted balloon-induced intimal disruption and relamination in aortic dissection repair (STABILISE) technique

Risk factor	Value
Age, years	57.2 ± 11.7
Male sex	11 (91.7)
TBAD	11 (91.7)
Hypertension	12 (100)
Dyslipidemia	3 (25)
Diabetes	0 (0)
Active smoking	8 (66.7)
Prior aortic surgery	2 (16.7)
Connective tissue disease	0 (0)
Associated procedure	
Hybrid TAAD repair	1 (8.3)
Left carotid–subclavian bypass	6 (50)
Visceral artery stenting	
SMA	1 (8.3)
RRA	5 (41.7)
LRA	1 (8.3)
Iliac artery stenting	3 (25)
CERAB	1 (8.3)

CERAB, Covered endovascular reconstruction of aortic bifurcation; *LLR*, left renal artery; *RRA*, right renal artery; *SMA*, superior mesenteric artery; *TAAD*, type A aortic dissection; *TBAD*, type B aortic dissection.
Data presented as mean ± standard deviation or number (%).

covered stent graft, BMS, and nonstented aorta. The main end point was the variation in spinal artery patency at the different levels of the aorta after the procedure and during follow-up.

Statistical analysis. Descriptive statistics are presented for the demographic and baseline variables as absolute and relative frequencies. Continuous variables are presented as the mean ± standard deviation if normally distributed and the median and interquartile range (IQR) if not. Categorical variables are presented as frequencies and percentages.

To study the patency of the spinal arteries across time in the different aortic segments, the Mann-Whitney *U* test was used. The Pearson χ^2 test or Fisher exact test was used to compare the categorical variables. The latter was used when the event rates were low (<10 events). Statistical significance was set at $P < .05$. Statistical analysis was performed using Stata, version 16.0, for Mac (StataCorp LP).

All the patients provided written informed consent before treatment. The institutional review board waived the requirement for approval for the present study.

RESULTS

Patient demographics and descriptive data

During the study period, 12 patients (mean age, 57.2 ± 11.7 years; 91.7% male) underwent treatment of complicated type B aortic dissection using the STABILISE technique. Of these 12 patients, 4 were treated for management of acute, 6 for subacute, and 2 for early chronic aortic dissection. The indication for repair was visceral malperfusion (n = 3), renal malperfusion (n = 2), lower limb ischemia (n = 7), acute aortic dilatation (n = 2) in the entry tear region, and refractory hypertension (n = 1). Four patients had had more than one criterion for surgery (Table I). One patient had previously undergone ascending aorta/arch repair with an E-vita open hybrid graft (Jotec GmbH) for type A aortic dissection.

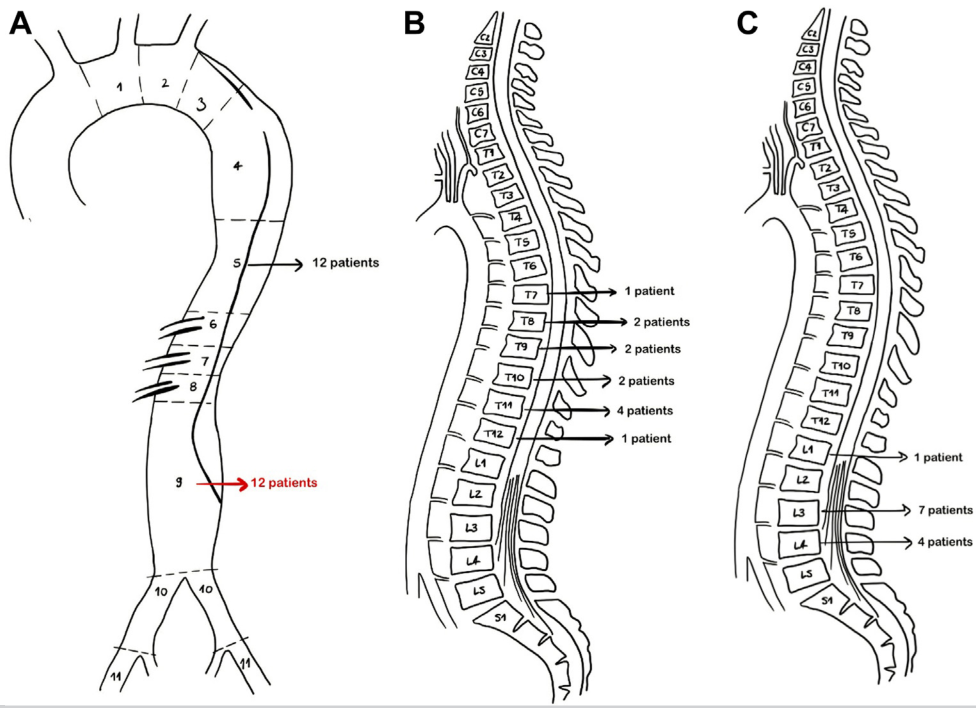

Fig 1. **A,** Anatomic location, according to the Aortic Dissection Classification System, of the distal landing zone of the thoracic stent graft (*black arrow*) and dissection bare metal stent (BMS; *red arrow*). **B and C,** Spinal level of distal landing zone of thoracic endovascular aortic aneurysm repair (TEVAR) and BMS.

The preoperative patient demographics and risk factors are detailed in Table II.

Surgical treatment outcomes

Primary technical success was achieved in all patients with no conversion to open repair or reinterventions required during the follow-up period (27 ± 12 months). The proximal landing zone was in aortic zone 3 (Society for Vascular Surgery/Society of Thoracic Surgeons classification system), maintaining left subclavian artery patency without debranching, in five patients. One patient underwent simultaneous aortic arch replacement for type A aortic dissection, and six underwent staged left carotid–subclavian bypass before the STABILISE technique for zone 2 deployment. The anatomic location of the distal landing zones of both stent grafts and bare metal dissection stents is illustrated in Fig 1. The median number of devices deployed per patient was 3 (range, 2-4), with a median of 1 stent graft (range, 1-2) and 2 dissection BMSs (range, 1-2). The left subclavian artery and both internal iliac arteries remained patent in all patients. All associated procedures are presented in Table II. The median length of the covered aorta by the stent graft was 202.5 mm (IQR, 67 mm; range, 113-334 mm).

Mid-term clinical success, at a mean follow-up of 27 ± 12 months, was obtained in 10 patients (83.3%). One patient had died at 1 year of follow-up from a non–aortic-related cause, and one patient was lost to follow-up because he had returned to his country of birth. No case of pre- or postoperative SCI occurred in our cohort. In two cases, the false lumen remained patent in the transition zone between TEVAR and the BMS and in the corresponding spinal artery. In another patient, the false lumen remained patent in the aortic zone 4 on the first month postoperative CTA (reentry flow) but was occluded on the 6-month follow-up CTA, with positive aortic remodeling and complete false lumen thrombosis. No difference was found in the occlusion rate regarding the origin of the spinal arteries in the true or false lumen.

Patency of spinal arteries before and after STABILISE technique

A quantitative analysis of the patent spinal arteries in the various segments of the aorta over time is shown in Tables III and IV. The median change over time is shown in Fig 2.

Stent graft area. The median number of patent spinal arteries in the stent graft area was 15 (IQR, 6). At 1 month, 1 year, and 2 years after the STABILISE technique, the median number in the stent graft area was 6 (IQR, 4.5), 8 (IQR, 7), and 7 (IQR, 3.5), respectively. This decrease in spinal artery patency was significant compared with the baseline value at 1 month ($P < .001$), 1 year ($P < .001$), and 2 years ($P = .004$).

BMS area. The median number of patent spinal arteries in the area where a BMS was placed was 10 (IQR, 4.5); however, at 1 month, 1 year, and 2 years after the

Table III. Number of patent spinal arteries stratified by timing of computed tomography angiography (CTA) in aortic segments

		Stent graft				BMS				Nonstented aorta			
			Postoperative				Postoperative				Postoperative		
Pt. No.	SA	Preop	1 M	1 Y	2 Y	Preop	1 M	1 Y	2 Y	Preop	1 M	1 Y	2 Y
1													
	IC	21	6	3	3	2	1	1	1	–	–	–	–
	L	–	–	–	–	6	6	6	6	2	2	2	2
2													
	IC	22	8	8	8	2	1	1	1	–	–	–	–
	L	–	–	–	–	6	5	5	5	4	2	2	2
3													
	IC	17	6	6	6	6	6	5	4	–	–	–	–
	L	–	–	–	–	6	6	6	6	4	4	4	4
4													
	IC	17	5	2	–	6	5	5	–	–	–	–	–
	L	–	–	–	–	2	2	2	–	6	6	6	–
5													
	IC	14	8	8	8	–	–	–	–	–	–	–	–
	L	–	–	–	–	6	5	5	5	2	2	2	2
6													
	IC	14	2	–	–	8	6	–	–	–	–	–	–
	L	–	–	–	–	8	8	–	–	–	–	–	–
7													
	IC	22	14	14	–	2	2	2	–	–	–	–	–
	L	–	–	–	–	6	6	6	–	2	2	2	–
8													
	IC	15	11	10	–	2	2	2	–	–	–	–	–
	L	–	–	–	–	8	8	8	–	–	–	–	–
9													
	IC	11	4	4	–	10	8	8	–	–	–	–	–
	L	–	–	–	–	8	8	7	–	–	–	–	–
10													
	IC	15	5	–	–	7	2	–	–	–	–	–	–
	L	–	–	–	–	6	6	–	–	2	2	–	–
11													
	IC	20	10	–	–	4	4	–	–	–	–	–	–
	L	–	–	–	–	8	8	–	–	–	–	–	–
12													
	IC	15	4	–	–	4	3	–	–	–	–	–	–
	L	–	–	–	–	6	4	–	–	2	2	–	–

BMS, Bare metal stent; *IC*, intercostal; *L*, lumbar; *M*, month; *Preop*, preoperative; *Pt. No.*, patient number; *SA*, spinal artery; *Y*, year.

STABILISE technique, the median number of patent spinal arteries was 8 (IQR, 5), 7 (IQR, 4), and 6.5 (IQR, 3), respectively. On the first postoperative computed tomography scan, the number of patent intercostal and lumbar arteries remained unchanged in 33% of the patients. For 59% of the patients, patency of one to two intercostal arteries and/or one to two lumbar arteries was lost, and in 8%, a loss of patency of more than two intercostal arteries was observed. The decrease in spinal artery patency was not significant compared with the baseline value at 1 month ($P = .24$), 1 year ($P = .44$), and 2 years ($P = .47$).

Table IV. Evolution of spinal arteries on computed tomography angiography (CTA)

Area	Baseline	Postoperative					
		1 Month	*P* value	1 Year	*P* value	2 Years	*P* value
Covered endograft	15 (6)	6 (4.5)	<.001	8 (7)	<.001	7 (3.5)	.004
BMS	10 (4.5)	8 (5)	.24	7 (4)	.44	6.5 (3)	.47
Nonstented	2 (3)	2 (2)	.62	2 (4)	.79	2 (2)	.89

BMS, Bare metal stent.
Data presented as median (interquartile range).

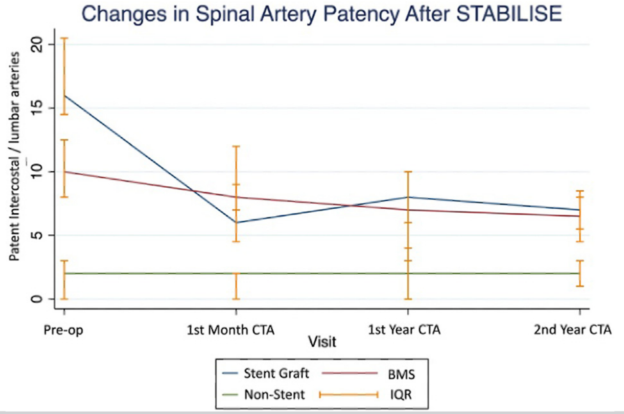

Fig 2. Median change and interquartile range (IQR) of spinal artery patency after stent-assisted balloon-induced intimal disruption and relamination in aortic dissection repair (STABILISE) over time. *BMS,* Bare metal stent; *CTA,* computed tomography angiography; *Pre-op,* preoperatively.

Nonstented area. The median number of spinal arteries in the nonstented area was 2 (IQR, 3). At 1 month, 1 year, and 2 years after the STABILISE technique, the median number of patent spinal arteries was 2 (IQR, 2), 2 (IQR, 4), and 2 (IQR, 2), respectively. This decrease in spinal artery patency was not significant compared with the baseline value at 1 month ($P = .62$), 1 year ($P = .79$), and 2 years ($P = .89$).

DISCUSSION

To the best of our knowledge, the present study is the first to analyze the patency of the spinal arteries after the STABILISE technique. Our main findings showed that the number of patent intercostal and lumbar arteries decreased significantly in the covered portion of the aorta after STABILISE repair. This was an expected finding, primarily observed on the first postoperative computed tomography scan, which remained relatively stable over time.

In the uncovered BMS area, the number of patent intercostal and lumbar arteries remained unchanged at the first postoperative follow-up visit in one third of the cases. However, a slight decrease in patent intercostal and lumbar arteries was observed in 59% of the cases, and, in 8%, more than two were lost. Overall, this difference was not statistically significant. No clinical effects from these findings were observed in this small cohort.

SCI remains the Achilles' heel of both open and endovascular repair of thoracic and thoracoabdominal aortic pathologies. In a recent review, Uchida[10] showed an average SCI rate of 4.5% (range, 0%-10.3 %) in 7309 TEVAR patients, suggesting that endoluminal procedures are not superior to the open approach, especially compared with the rate at aortic centers performing a high volume of open repairs.[9,12-14] Endoluminal approaches avoid aortic cross-clamping and most of the intraoperative hemodynamic changes but prevent reimplantation of the intercostal arteries covered by the stent graft.

Although the pathogenesis of SCI is not yet fully understood, it is certainly a multifactorial phenomenon. One of the causes of SCI after TEVAR is coverage of the origin of the lower intercostal arteries and the Adamkiewicz artery (AKA), which reduces the blood supply to the spinal cord. The AKA, discovered in 1882 and also known as the magna anterior radicular artery, usually arises from T8 to T12, and is considered the most important input to the anterior spinal artery in the thoracolumbar area.

The use of the STABILISE technique to manage complicated aortic dissections leads to obstruction of the origin of the aortic side branches in the region of the covered stent. However, the fate of these arteries across the BMS area is not known. Additionally, dissected aortas are usually different from degenerative aneurysms in which aortic wall atherosclerosis and thrombus are common, leading to chronic occlusion of several intercostal and lumbar arteries. Patients with dissection are often younger, with no or scarce atherosclerotic involvement and, theoretically, are more prone to develop SCI after large endovascular aortic coverage.

An important finding of our study is that vigorous dilatation of the BMS dissection to reappose the lamella, thus restoring the single aortic lumen, led to a slight and nonsignificant reduction of the patent intercostal and lumbar arteries, which remained considerably stable at each follow-up period after STABILISE. The mechanism of postoperative occlusion of these arteries could be twofold. One is the mismatch between the ostia and the corresponding lamella orifice after reapposition of the flap when they arise from the false lumen. The second is that it might result from previous involvement of the spinal arteries by the dissection process, further compromised by the dilatation.

In our study, despite an overall reduction of patent intercostal arteries after the procedure, no cases of SCI occurred. This is in line with the current concept of a collateral blood supply to the spinal cord, which relies more on a collateral network than on single segmental arteries, such as the AKA.[15] Kawaharada et al[15] found that although there was a trend toward a higher risk of a neurologic deficit in patients with occlusion of the intercostal artery to the AKA after TEVAR, in most patients, SCI did not occur, supporting the concept that the total amount of blood flow to the spinal cord is more important than any single artery. However, it is essential to recognize the importance of the intercostal and lumbar arteries, as well as the vertebral, subclavian, and hypogastric territories. In our series, these arteries were preserved in all 12 patients.

Our study has the limitation of a small sample size with only 12 patients and the absence of SCI cases, limiting the analysis of potential risk factors. However, to the best of our knowledge, this is the first study to evaluate the effect of the STABILISE technique on the patency of spinal arteries. Despite awareness of the myriad of potential causes for its development, the absence of a significant reduction in patent spinal arteries in the BMS area constitutes a step toward establishing the safety of this technique.

CONCLUSIONS

The STABILISE technique decreased intercostal artery patency in the area of the thoracic stent graft; however, spinal artery patency was not significantly affected by aortic coverage with the BMS nor by its aggressive ballooning to reappose the intimal lamella. These findings constitute a step toward a better understanding of the safety of this technique.

REFERENCES

1. Fattori R, Montgomery D, Lovato L, et al. Survival after endovascular therapy in patients with type B aortic dissection: a report from the International Registry of Acute Aortic Dissection (IRAD). JACC Cardiovasc Interv 2013;6:876-82.
2. Faure EM, Canaud L, Agostini C, et al. Reintervention after thoracic endovascular aortic repair of complicated aortic dissection. J Vasc Surg 2014;59:327-33.
3. Hofferberth SC, Nixon IK, Boston RC, McLachlan CS, Mossop PJ. Stent-assisted balloon-induced intimal disruption and relamination in aortic dissection repair: the STABILISE concept. J Thorac Cardiovasc Surg 2014;147:1240-5.
4. Melissano G, Bertoglio L, Rinaldi E, et al. Satisfactory short-term outcomes of the STABILISE technique for type B aortic dissection. J Vasc Surg 2018;68:966-75.
5. Faure EM, El Batti S, Abou Rjeili M, Julia P, Alsac JM. Mid-term outcomes of stent assisted balloon induced intimal disruption and relamination in aortic dissection repair (STABILISE) in acute type B aortic dissection. Eur J Vasc Endovasc Surg 2018;56:209-15.
6. Buth J, Harris PL, Hobo R, et al. Neurologic complications associated with endovascular repair of thoracic aortic pathology: incidence and risk factors. a study from the European Collaborators on Stent/Graft Techniques for Aortic Aneurysm Repair (EUROSTAR) registry. J Vasc Surg 2007;46:1103-10.
7. Feezor RJ, Lee WA. Strategies for detection and prevention of spinal cord ischemia during TEVAR. Semin Vasc Surg 2009;22:187-92.
8. Jonker FH, Verhagen HJ, Lin PH, et al. Outcomes of endovascular repair of ruptured descending thoracic aortic aneurysms. Circulation 2010;121:2718-23.
9. Chiesa R, Melissano G, Marrocco-Trischitta MM, Civilini E, Setacci F. Spinal cord ischemia after elective stent-graft repair of the thoracic aorta. J Vasc Surg 2005;42:11-7.
10. Uchida N. How to prevent spinal cord injury during endovascular repair of thoracic aortic disease. Gen Thorac Cardiovasc Surg 2014;62:391-7.
11. von Elm E, Altman DG, Egger M, et al. The Strengthening the reporting of Observational studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Int J Surg 2014;12:1495-9.
12. Awad H, Ramadan ME, El Sayed HF, Tolpin DA, Tili E, Collard CD. Spinal cord injury after thoracic endovascular aortic aneurysm repair. Can J Anaesth 2017;64:1218-35.
13. Coselli JS, Bozinovski J, LeMaire SA. Open surgical repair of 2286 thoracoabdominal aortic aneurysms. Ann Thorac Surg 2007;83:S862-4; discussion: S890-2.
14. Etz DC, Luehr M, Aspern KV, et al. Spinal cord ischemia in open and endovascular thoracoabdominal aortic aneurysm repair: new concepts. J Cardiovasc Surg (Torino) 2014;55(2 Suppl 1):159-68.
15. Kawaharada N, Morishita K, Kurimoto Y, et al. Spinal cord ischemia after elective endovascular stent-graft repair of the thoracic aorta. Eur J Cardiothorac Surg 2007;31:998-1003; discussion: 1003.

Submitted Jan 24, 2023; accepted Mar 28, 2023.