Technical and clinical success after endovascular therapy for chronic type B aortic dissections

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Objective: **To analyze early technical success and late clinical success after endovascular entry sealing for chronic type B dissection with special emphasis on reintervention, false lumen thrombosis, and aortic remodeling.**
Methods: **Retrospective analysis of a prospective database. From September 1999 to January 2011, 19 patients with chronic type B dissections were treated by endovascular entry sealing. Median age was 60 years. Median time between onset of acute dissection and surgical intervention was 36 (1 to 60) months. Median follow-up was 13 months (1 to 124).**
Results: **The endografts used were: Medtronic Captivia (5), Medtronic Valiant (5), Gore TAG (6), Gore C-TAG (2), and Cook Zenith (1). In four patients, revascularization of the left subclavian artery was performed prior to entry sealing. Primary technical success rate (entry sealing, absence of type I leak) was 18/19 (94.7%). In-hospital mortality was 0%. Spinal cord injury with persistent paraplegia occurred in 1/19 (5.2%) patients. After a maximal follow-up of 124 months, reinterventions in 9/19 (47.3%) were necessary: distal/proximal extension of stent graft (8), replacement of the aortic arch due to retrograde dissection (1), and open infrarenal aneurysm repair (1). During follow-up, none of the patients died due to stent-related complications.**
Conclusion: **Endovascular treatment (EVT) in chronic type B dissections has a high technical success rate and low mortality/morbidity. However reintervention rates are not negligible which might reduce the *clinical* success of EVT. Future investigations should aim at identifying patients who benefit from EVT at better defining the timing of EVT and at determining if entry sealing alone is sufficient. (J Vasc Surg 2011;54:1303-9.)**

Aortic dissection is a complex aortic pathology with an incidence of three to eight cases per 100,000 people.[1] As for type B dissections, three situations are set apart: (1) acute uncomplicated, (2) acute complicated, and (3) chronic. Currently, there is consensus that acute uncomplicated type B dissections are managed medically, whereas acute complicated, eg, malperfusion or refractory pain, are treated interventionally by endovascular entry sealing.[2] Chronic dissections (>14 days) are managed surgically in case of expansion >6 cm or >1 cm/year[2]. As endovascular treatment (EVT) of thoracic aortic pathologies has evolved during the last decade, the preferred technique with low mortality and morbidity is endovascular closure of the primary entry tear.[3] This method has been proven to be effective with high technical success.[4,5] Published series and international registries include outcomes of acute, chronic, and asymptomatic patients after open or endovascular treatment.[6-9] Hence, the indication, the timing, and the results, particularly in the long term, of endovascular treatment of type B dissections are still under debate. The success of endovascular entry sealing is not only determined by the technical success but also by the clinical success, ie, freedom from rupture and/or reintervention in the long-term. There are hardly any data concerning this specific issue of long-term outcome after endovascular treatment of chronic type B aortic dissections. For this reason, the aim of this article was to analyze our patient data after endovascular entry sealing for chronic type B dissection in terms of early *technical* success and late *clinical* success with special emphasis on reintervention, false lumen thrombosis, and aortic remodeling.

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METHODS

Data analysis. We retrospectively analyzed a prospective database of consecutive patients that were treated due to chronic aortic dissection type B in our department. From September 1999 to January 2011, 71 patients with acute (complicated and uncomplicated) and chronic aortic dissection type B were admitted to our department. For the purpose of this analysis, we focused on patients with chronic dissection who underwent endovascular entry sealing due to expansion or rapid increase of the thoracic aortic diameter.

Routine surveillance. All patients with uncomplicated aortic dissection undergo routine computed tomography (CT) scans at 3 and 6 months, and annually thereafter.

Indication for endovascular therapy. We see the indication for entry sealing in chronic type B dissections if: (1) the maximum diameter of the thoracic aorta exceeds 6 cm, and (2) if there is rapid expansion of >1 cm/y.

Definitions. Aortic type B dissection is defined as chronic after 14 days after onset of acute symptoms. According to the *Reporting Standards For Thoracic Endovas-*

Table I. Overview of the index procedures and reinterventions

n	*Index procedure*	*Reintervention*	*Time between procedures*
1	2 × Medtronic Talent 38-160/40-100	Medtronic Valiant 40-40-200	19
2	Medtronic Captivia 36-100		
3	Medtronic Valiant 42-150	Medtronic Captivia 44-200	25
4	Medtronic Valiant 42-150		
5	Medtronic Valiant 38-100	Medtronic Captivia 38-200	21
6	Gore TAG 37-200	Medtronic Captivia 38-150	58
7	Gore TAG 40-150	Jotec Evita 44-33-150	53
8	Medtronic Valiant 44-150		
9	Medtronic Captivia 34-150		
10	Gore TAG 40-100		
11	Medtronic Talent 36-118	Gore TAG 40-100	59
12	Gore TAG 37-150		
13	Gore TAG 37-150	Gore TAG 37-150/aortic arch repair	7
14	2 × Gore TAG 37-150/40-200	Open infrarenal repair	11
15	COOK Zenith 34-34-130		
16	Medtronic Captivia 30-30-150		
17	Gore C-TAG 37-100	Gore C-TAG 36-200	6
18	Gore C-TAG 37-100		
19	Medtronic Captivia 42-150		

Time between procedures is given in months.

cular Aortic Repair[10] technical success was defined as complete coverage of the primary entry tear without a type I leak at the end of the procedure. False lumen thrombosis was defined as presence of thrombus without blood flow in the false lumen. Partial false lumen thrombosis was defined as the concurrent presence of both blood flow (via distal re-entries) and thrombus in the false lumen. Aortic remodeling is considered reattachment of the dissection membrane to the aortic wall so that only a true lumen is shown on CT scan.

Surgical procedure. All procedures were elective endovascular procedures. Access to the true lumen and the aortic arch could be achieved in all cases via the femoral arteries. All endografts were deployed under guidance of a C-arm image intensifier (OEC 9600 Vascular; GE Healthcare, Munich, Germany); transesophageal echocardiography (TEE) was applied in all cases to verify exact positioning of the guidewire in the true lumen. To confirm exact position and absence or presence of endoleaks, a final angiogram was routinely performed, including delayed angiographic series to evaluate distal reperfusion. For 19 patients, 21 stent grafts were used, including 7 Gore TAG (W. L. Gore & Associates, Flagstaff, Ariz), 2 Gore C TAG (W. L. Gore & Associates), 4 Medtronic Captivia (Medtronic World Medical), 7 Medtronic Valiant (Medtronic World Medical), and 1 COOK Zenith (Cook Inc, Bloomington, Ind). For overview, see Table I. Seventeen patients had one graft, two patients had two grafts, one patient had two Medtronic stent grafts (36-160 and 40-100), and the other patient two Gore stent grafts (37-150 and 40-200). In nine patients, the left subclavian artery (LSA) was intentionally overstented. In five patients, supra-aortic trunks were revascularized: in two patients, only the LSA were reconstructed. One patient underwent complete revascularization of all supra-aortic vessels, one patient received revascularization of the left common carotid artery, and one patient of the left common carotid artery together with the LSA. In one case (LSA reconstruction), the revascularization was performed prior to reintervention (distal stent graft extension). Median operative time was 68 minutes (55 to 83 minutes); median contrast medium used was 80 mL (60-140 mL), with a concentration of 300 mg/mL iodine. Postoperatively, patients were routinely transferred to the intermediate care where they were monitored (blood pressure, heart rate, pain level, neuro check, spinal drain, urine production, blood values like hemoglobin, creatinine, and lactate) overnight. On postoperative day 1, patients were transferred to the surgical ward. Before discharge, a CT scan was done to document graft positioning, presence or absence of endoleaks, and thrombosis of the false lumen (Fig 1, *A-F*). Further scans were done at 3 and 6 months and then annually with multislice dual-phase (arterial and venous) CT.

Statistical analysis. The statistical analysis was performed in collaboration with the local Institute of biometry. For discrete variables, absolute and relative frequencies are given. For continuous variables, median values and range are applied. To calculate significant differences of length and diameter of the stent grafts used at primary intervention, the analysis of variance (ANOVA) test was applied; to calculate differences of length and diameter of the stent grafts used at index procedure and reintervention Mann-Whitney U was applied. P values $<.05$ were regarded to be significant.

RESULTS

Patient data. During the observation period, we had 19 patients with a median age of 60 years who underwent endovascular closure of the primary entry tear. Median time between onset of acute symptoms and treatment in these patients was 36 months (1 to 60); median follow-up was 13 months (1 to 124).

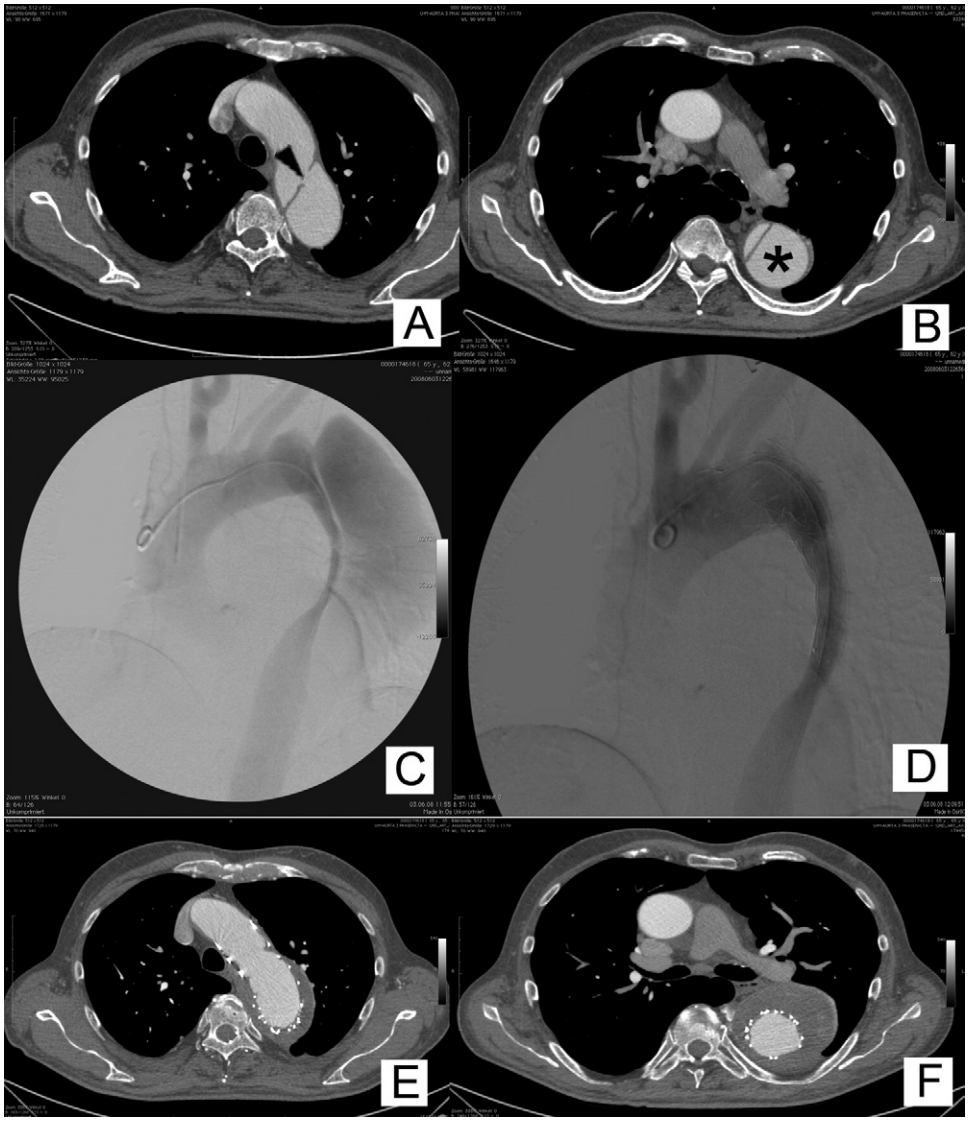

Fig 1. A, Preoperative computed tomography (CT) angiography showing entry (*arrowhead*). **B,** True and false lumen (*asterisk*). **C,** Intraoperative angiography before graft deployment. **D,** Intraoperative angiography after successful graft deployment. **E,** Postoperative CT angiography showing entry sealing. **F,** Postoperative CT angiography showing patent graft with thrombosis of the false lumen.

Detailed overview over demographic data is given in Table II. The majority of the patients (94.7%) suffered from arterial hypertension; moreover, 47.3% had a history of smoking or were active smokers. In one patient, Marfan's Syndrome was the underlying disease that led to aortic dissection.

Perioperative outcome. Detailed overview in terms of perioperative outcome is given in Table III. None of the patients died during the hospital stay. There were no major complications such as stroke, heart, or respiratory failure. One patient each experienced transient and persistent spinal cord ischemia, respectively. The patient with persistent ischemia had had LSA transpositioning prior to endografting. On postoperative CT scan control, we had one patient with proximal type I endoleak which was treated immediately with proximal stent graft extension. In three cases, type II leaks (retrograde perfusion via the overstented LSA) were seen; these patients undergo close CT surveillance. We consider treatment of type II leaks necessary only in case of aneurysm sac expansion.

Outcome on follow-up. In nine patients (47.3%), reinterventions were necessary during follow-up due to increase of the aortic diameter in seven patients, progredient perfusion of the false lumen in one patient and due to a type I leak in one patient. Median time to reintervention from the index procedure was 23 (6 to 59) months (Fig 2);

Table II. Demographic data of the 19 patients

Age	60 (31-77) years
Gender M/F	17:2
Follow-up	13 [1-124] months
Arterial hypertension	18/19 (94.7%)
Smoking	9/19 (47.3%)
Renal insufficiency	6/19 (31.5%)
COPD	4/19 (21%)
CAD	4/19 (21%)
ASA score	II: 1/19 (5.3%)
	III: 17/19 (89.4%)
	IV: 1/19 (5.3%)

ASA, American Society of Anesthesiologists; *CAD,* coronary artery disease; *COPD,* chronic obstructive pulmonary disease.
Data are presented as median [range].

Table III. Perioperative outcome of the 19 patients

In-hospital mortality	0%
Stroke	0%
Heart/respiratory failure	0%
Transient SCI	1/19 (5.2%)
Persistent SCI	1/19 (5.2%)
CT on discharge	
No endoleak	16
Type II Leak	3
Type I Leak	0

CT, Computed tomography; *SCI,* spinal cord ischemia.

the majority of the patients underwent distal stent graft extension (Table IV). The extent of distal coverage is determined by preoperative CT and sufficient overlap in order to prevent type III endoleak. As for endografts, a variety were used, including Gore TAG (2), Gore C TAG (1), Medtronic Captivia (3), Medtronic Valiant (1), and Jotec Evita (1) (Jotec GmbH, Hechingen, Germany). For overview, see Table I. The stent grafts used at reinterventions were longer than those at index procedure (P = .052).

We see the indication for stent graft extension if the aneurysm sac shows an increase in diameter with or without presence of endoleak on CT scan despite presence of thrombus in the descending part of the aorta. In one patient, aortic arch repair due to retrograde dissection was necessary. This patient showed a persistent type I leak, so 7 months after primary intervention, the reintervention took place. During placement of the 37 to 150 Gore TAG stent graft, a retrograde dissection occurred. Immediately aortic arch repair with stent graft explantation under deep hypothermia and heart-lung-machine were performed. The postoperative course was unremarkable.

Patients with stent graft extension showed no perioperative complications; the patient with the open infrarenal replacement died 5 years after the reintervention due to myocardial infarction.

CT findings on follow-up. During follow-up, we found complete false lumen thrombosis, including the abdominal aorta only in one patient. This patient had had endovascular sealing of distal re-entries as initial therapy prior to primary entry sealing. All other 18 patients showed only partial false lumen thrombosis and distal reperfusion of the false lumen at the level of the diaphragm via pre-existing re-entries (Fig 3). Aortic remodeling defined as reattachment of the dissecting membrane was seen only in the above-mentioned patient that had had re-entry sealing prior to entry sealing. As for the thoracic aortic diameter, seven patients out of nine that required stent graft extension showed an increase from 2-mm (mean, 6 mm) compared with baseline diameter at the index procedure. In 12 patients, the aortic diameter was constant or decreased, respectively (Table V).

DISCUSSION

Uncomplicated acute type B dissections are managed medically. Acute complicated type B dissections undergo endovascular entry sealing as mortality rates in this setting are significantly lower compared with open repair.[11] In chronic type B dissections, surgery is indicated for late complications such as aortic dilatation (>6 cm) and further dissection.[12] The preferred technique to treat chronic expansion after dissection is the endovascular approach with low morbidity and mortality rates.[3] The value of endovascular entry sealing in chronic B dissections is still under debate.[6,13] Particularly, the long-term durability of the endovascular approach is undefined, and there are hardly any data on mid- and long-term outcomes after endovascular entry sealing in chronic type B dissections.[14,15] Therefore, we analyzed our data of endovascular entry sealing in chronic type B aortic dissections focusing on technical and clinical success, the latter being determined by the rate of reintervention, false lumen thrombosis, and aortic remodeling. According to the reporting standards for thoracic endovascular aortic repair[10] supposed by the Society for Vascular Surgery and the American Association for Vascular Surgery, technical success is defined as successful deployment of the endograft without type I leak. According to that definition, the technical success in our series was 94.7%; in other published series, success rates vary from 77% to 100% with higher rates in chronic dissections.[3,13,14,16] These high rates of endovascular entry sealing demonstrate that EVT has emerged as an acceptable treatment modality also in aortic dissections. Not finally clarified is whether the definition of technical success in aortic dissection is appropriate. In our series, nearly all patients that needed reintervention had expansion of the false lumen. This arose from distal re-entries that were let uncovered. Consequently, a better definition of technical success in aortic dissection should include the following parameter: absence of type I leak after EVT, the aortic diameter, and reattachment of the dissected membrane. One issue of debate in this context is the timing of endovascular intervention in type B dissections. Some investigators favor intervention within 2 weeks of the initial diagnosis with good results, whereas others have reported higher mortality rates in the acute phase.[6,17] The published mortality rates in series summarizing acute and chronic dissections range from 0% to 15%;[11,18-20] in series focusing on

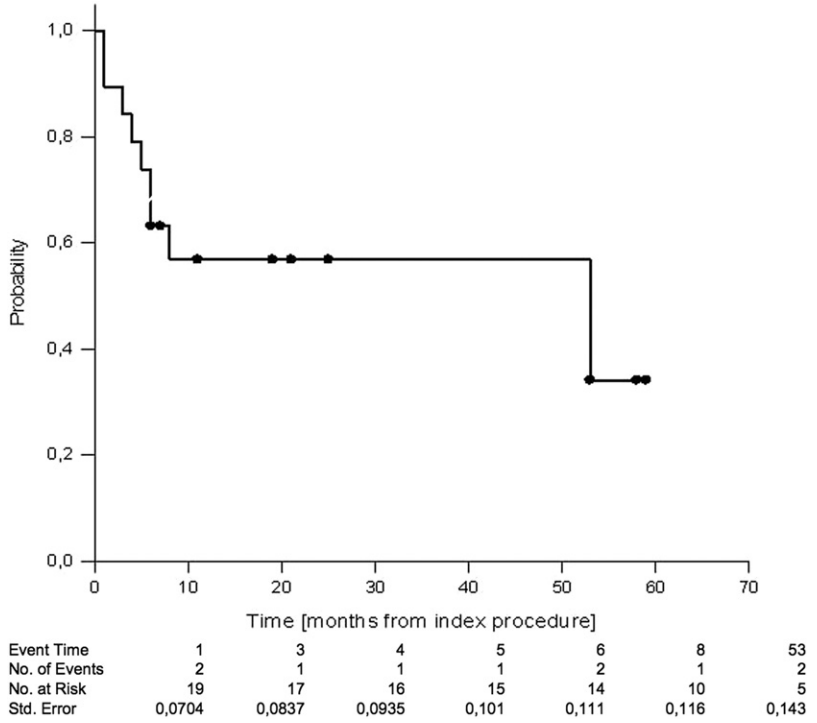

Fig 2. Freedom from reintervention from index procedure; median time to reintervention.

Table IV. Reinterventions during follow-up

Reintervention	*9/19 (47.3%)*
Stent graft extension (distal/proximal)	7
Open infrarenal repair	1
Aortic arch repair	1

chronic dissections, mortality rates appear to be lower.[3,21] It is speculated that morphologic changes of the initially fragile dissecting membrane to a more fibrotic membrane with an aortic wall less vulnerable to manipulations by catheters and wires in the chronic phase is critical.[22] As a result, in our series of chronic type B dissections the in-hospital mortality was 0% as well. As for perioperative complications, we had one patient with delayed onset of spinal cord ischemia after 36 hours that persisted after insertion of cerebrospinal fluid drainage; prior to surgery this patient had had revascularization of the LSA. Probably this delayed spinal cord ischemia (SCI) was due to thrombosis of spinal arteries originating from the false lumen, which also partially thrombosed after successful sealing of the primary entry tear. The SCI rates after endografting of dissections range from 0%[14] to 5.5%;[16] risk for SCI in thoracic endografting depends on prior aortic surgery and length of covered aortic segment. To overcome this problem, adjunctives such as cerebrospinal fluid drainage and revascularization of the left subclavian artery, were performed. Using these adjunctives, the overall paraplegia rate in our series was 5.2%. For EVT of aortic dissection, there is no evidence that cerebrospinal fluid drainage can reduce the occurrence of neurologic complications. It seems reasonable to use in patients with prior aortic surgery.

Aortic remodeling in dissections refers to the thrombosis of the false lumen (compete or partial) and reattachment of the dissection membrane.[4] Only this reattachment together with complete false lumen thrombosis would result in stabilization of the aortic wall with reduction of risk of rupture. As for aortic remodeling, after entry sealing we had immediate partial false lumen thrombosis in the grafted segment of the thoracic aorta in all patients. In the distal segment, all patients, except one, showed reperfusion of the false lumen via re-entries. This persisting perfusion might be the origin for a resulting increase of the aortic diameter which may lead to reinterventions. On the other hand, these re-entries might be necessary for the perfusion of visceral or renal arteries originating from the false lumen.

In our department, all patients undergo CT scan before discharge. These scans documented three suspected type II endoleaks. In our series, during follow-up of a maximum of 11 years, 9/19 (47%) required reinterventions: retrograde dissection (one patient), progressive infrarenal aneurysm formation (one patient), and increase in thoracic aneurysm sac diameter (seven patients); the latter were successfully treated by distal stent graft extension; the patient with retrograde dissection required aortic arch replacement and the patient with infrarenal aneurysm formation underwent open infrarenal repair. As for reinterventions after endovascular treatment of type B dissections, there are hardly any

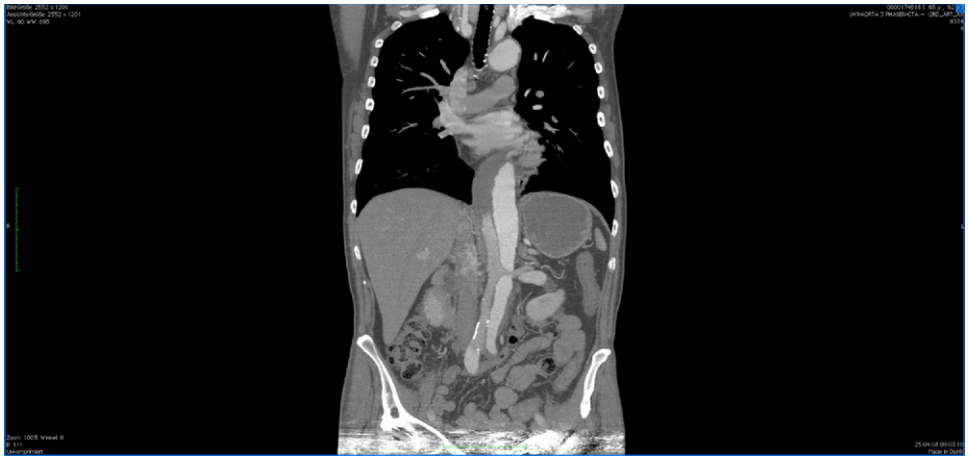

Fig 3. Computed tomography (CT) angiography of chronic expansion after aortic dissection after entry sealing and prior to distal stent graft extension; antegrade flow in the true (T) lumen and reperfusion of the false (F) lumen via re-entries.

Table V. Computed tomography findings in the follow-up

False lumen thrombosis on follow-up	
Partial	18
Complete	1
Aortic remodelling	
Yes	1
No	18
Thoracic aortic diameter (compared with index procedure)	
Increase	7
Constant	7
Decrease	4
Not available	1

data. Manning and coworkers reported about reintervention rates of 70% after maximum follow-up 86 months.[2] The reason for reintervention (distal stent graft extension) was erosion of the dissection membrane that had resulted in endoleak with false lumen reperfusion. In our seven patients that required distal graft extension, we had development of distal erosion in one patient; the remaining six showed an increase in sac diameter from 2 to 8 mm. The high reintervention rates series of Manning and co-workers[23] and in our own series brings up the question if endovascular entry sealing alone represents a procedure extensive enough to treat the complex pathology of aortic dissections. Potentially, the problem arises from the fact that entry sealing results in partial thrombosis of the false lumen, but not in thrombosis of the distal abdominal segment which is usually reperfused via re-entries. As a consequence, there is no distal remodeling setting the stage for later complications such as formation of distal endoleaks or sac progression despite successful entry sealing. This unresolved problem has led to the proposal of the PETTICOAT concept (endovascular entry sealing with a covered graft and distal extension with an uncovered stent) by Nienaber and coworkers[24] "to abolish true lumen collapse and enhance aortic remodelling." Yet, experience with this technique is limited. Nonetheless, our high rate of reintervention confirms the underlying theory of sustained distal false lumen flow and pressurization despite successful sealing of the thoracic entry tear. As a consequence, the practice in management of chronic type B dissection in our department has changed to extend the coverage of the dissected aorta to the celic trunk.

CONCLUSION

In summary, endovascular entry sealing in patients with chronic type B dissections has a high technical success and low morbidity and mortality rates; however, after entry sealing only partial false lumen thrombosis can be achieved and the distal aortic segment remains perfused, a problem from which later sac progression may arise. As a consequence, reintervention rates after EVT in chronic type B dissections are high. Possible entry sealing and distal extension with an uncovered stent, as proposed by Nienaber, might be promising to induce aortic remodeling and reduce the rate of reinterventions.

To better define the role of EVT in type B dissections, more patients and more information about clinical and morphologic outcomes is needed. Maybe prospective registries such as International Registry of Acute Aortic Dissections, EUROpean collaborators on Stent-graft Techniques for abdominal aortic Aneurysm Repair, and VALIANT Thoracic Stent Graft Evaluation For the Treatment of Descending Thoracic Aortic Dissections will provide more detailed results regarding these issues. Apart from that, comparative clinical trials should be initiated to answer the questions of timing of endovascular treatment, endografts used, and extension of aortic coverage.

AUTHOR CONTRIBUTIONS

Conception and design: AO, BM
Analysis and interpretation: AO, PW, BM

Data collection: AO, PW, HS, KO, BM
Writing the article: AO, BM
Critical revision of the article: AO, PW, HS, KO, BM
Final approval of the article: AO, PW, HS, KO, BM
Statistical analysis: AO, BM
Obtained funding: AO, BM
Overall responsibility: AO, BM

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