CURRENT OPINION

Surgical and anesthetic considerations for the endovascular treatment of ruptured descending thoracic aortic aneurysms

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Purpose of review

Ruptured descending thoracic aortic aneurysm (rDTAA) is a life-threatening disease. In the last decade, thoracic endovascular aortic repair (TEVAR) has evolved as a viable option and is now considered the preferred treatment for rDTAAs. New opportunities as well as new challenges are faced by both the surgeon and the anesthesiologist. This review describes the impact of current developments and new modalities for the surgical and anesthetic management of rDTAAs.

Recent findings

A collaborative approach between the anesthesiologist and surgeon during critical moments such as induction, moment of aortic occlusion and placement of the aortic stent-graft is mandatory. Important issues to consider on preoperative imaging evaluation are correct sizing of the aortic stent-graft and localization of the artery of Adamkiewicz. Emergency TEVAR should preferentially be started under local anesthesia and could be switched to general anesthesia after stent placement. Patients should be kept in permissive hypotension preoperatively and during the intervention before stent-graft deployment and relative hypertension after deployment. The use of a proactive spinal cord protection protocol could decrease the risk of spinal cord ischemia and/or paraplegia and consists of permissive hypertension after stent deployment, cerebrospinal fluid drainage to maintain adequate spinal cord perfusion, relative hypothermia and possibly use of mannitol.

Summary

In order to improve outcomes of TEVAR for rDTAA, a close communication between the anesthesiologist and the surgeon and a thorough understanding of the events during the procedure is mandatory. The use of a proactive spinal cord protection protocol may decrease the rates of devastating spinal cord ischemia.

Keywords

anesthesia, ruptured descending thoracic aortic aneurysms, spinal cord, thoracic endovascular aortic repair

INTRODUCTION

Rupture of the thoracic aorta is a rare but life-threatening emergency with an annual incidence of five per 100 000 people and with reported overall mortality rates up to 97%. Ruptured descending thoracic aortic aneurysms (rDTAAs) account for approximately 30% of all thoracic aortic ruptures, and only 41% of these patients arrive at the hospital alive [1].

Considering the fact that untreated patients reach nearly 100% mortality, 'no treatment' is not a viable option. A team effort of both the anesthesiologist and vascular surgeon is vital to successful management of the case. Open repair of rDTAAs with an interposition graft has been the traditional treatment for decades. However, this procedure requires a large open thoracotomy as well as placement of a high-level aortic cross-clamp with or without the use of left atrial-femoral bypass. Therefore, the open repair of rDTAA registers a high

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KEY POINTS

- In order to improve outcomes of TEVAR for rDTAA, a close communication between the anesthesiologist and the surgeon and a thorough understanding of the events during the procedure as well as their inherent risk factors is mandatory.
- The use of a proactive spinal cord protection protocol may decrease the rates of devastating SCI and/or paraplegia.
- Spinal cord NIRS represents a promising noninvasive technology that could be utilized in high-risk individuals undergoing emergency TEVAR and provides real time information regarding SCI.
- Important issues to consider on preoperative imaging evaluation are correct sizing of the aortic stent graft and localization of the artery of Adamkiewicz.
- New endovascular techniques, such as the chimney technique, have shown good early results for the treatment of emergency situations, with low neurological complication rates.

morbidity and mortality. During the last decade, thoracic endovascular aortic repair (TEVAR) has evolved as a viable option for the treatment of rDTAAs. Short-term results are considered good and include a 30-day mortality of 19% (vs. 33 for open repair) and low 30-day complication rates, including myocardial infarction (3.5 vs. 11.1%, open repair) and stroke (4.1 vs. 10.2%, open repair). TEVAR is now considered as the first-choice treatment in patients with rDTAA [2]. Furthermore, the feasibility of TEVAR is described for hemodynamically stable and unstable patients with ruptured aneurysms [3]. Unlike the risks of stroke and myocardial infarction, which are significantly decreased, the risks of spinal cord ischemia (SCI) and/or paraplegia are still high (3.9 vs. 5.5%, open repair) for both patients with ruptured and nonruptured thoracic aneurysms after TEVAR [4,5]. Prevention of SCI has become one of the most important objectives during TEVAR and strategies for protection of the spinal cord are still evolving.

Considering the low incidence of rDTAAs and the emergency setting of this highly fatal condition, large studies describing the optimal anesthetic protocol for rDTAAs are lacking. The purpose of this review is to evaluate the most recent and relevant literature on the surgical and anesthetic considerations for the interventional treatment of rDTAA with a special focus on prevention of SCI. Knowledge of new modalities of spinal cord protection is important to decrease the morbidity and mortality in patients with rDTAAs. Furthermore, the importance of preoperative imaging, spinal cord protective protocols and different types of anesthetic techniques will be discussed.

PREOPERATIVE CONSIDERATIONS

The descending thoracic aorta is considered to start distal to the left subclavian artery (LSA) and to end at the diaphragm and is anatomically more amendable to endovascular repair than the abdominal aorta given the absence of major side branches. However, a good postoperative outcome relies on a thorough understanding of some important preoperative considerations for TEVAR.

Preoperative imaging

First and most important, in rDTAA, every second counts, and there is no time for extensive preoperative imaging to explore the anatomy of the thoracic aorta. Preoperative imaging for TEVAR is particularly important to investigate the curvature and the diameter of the thoracic aorta and the involvement of any of the vital aortic arch side branches. If the patient is stable and imaging is performed, ECG-gated computed tomography angiography (CTA) is recommended. The CTA allows for a dynamic imaging of the thoracic aorta and cardiac structures and function, including the coronary arteries. Additionally, this could help improve stent-graft sizing, reduce risk of false detection of a dissection flap due to motion artifact of the aortic wall, and simultaneously allows preoperative cardiac risk stratification, which could positively impact anesthetic care [6]. More importantly, identification of the exact location of the artery of Adamkiewicz is useful in evaluating the operative risk of SCI.

Preoperative imaging should be focused, to prevent delay in therapeutic care of the ruptured thoracic aorta. First, computed tomography (CT) imaging should always extend from the supra aortic vessels to the common femoral arteries. Time for complex imaging reformatting, including multiplanar reformatting, 3D rendering and center-line measurements, is often not available in the emergency setting. However, one must ensure to have imaging available at least 10 mm proximal and 10 mm distal to the affected aortic territory (in some instances more) in order to evaluate for adequate graft landing zones. To ensure a good sealing in highly angulated anatomy, more length is frequently required [7].

Stent graft sizing

Due to the hypotension induced by bleeding from the ruptured aneurysm with a subsequent decreased pressure on the thoracic aortic wall, the aortic dimensions measured on CTA could be smaller than under normotensive conditions. As a result, an oversizing of the stent graft should be performed to compensate for the enlargement of the aorta to its normal dimensions. Generally, 15–20% oversizing is recommended to guarantee an optimal seal, prevent endoleaks and graft migration under normotensive conditions [8]. However, too much oversizing should also be avoided. In a study evaluating the incidence of collapsed GORE TAG Thoracic Endoprosthesis (W.L. Gore and Associates, Flagstaff, Ariz, USA), which included 33 289 deployed devices, excessive oversizing was one of the main risk factors for graft collapse [9].

Preoperative anesthetic considerations

In emergency situations, the main therapeutic goal is to minimize the time between arrival at the hospital and surgical repair. Time is often not available for extensive preoperative evaluation and optimizing the patient for the intervention. Patients with ruptured aneurysms should be kept in a permissive hypotension preoperatively, with SBPs between 50 and 100 mm Hg while maintaining consciousness [10]. Immediate availability of blood products as well as obtaining patient's consent for transfusion should be a priority.

Furthermore, the intervention should preferentially be performed in a dedicated hybrid /endovascular suite with excellent fluoroscopic imaging and with capabilities for potential conversion to traditional open surgery with thoracotomy [11].

INTRAOPERATIVE CONSIDERATIONS

The overall intraoperative anesthetic goals are represented by establishing a stable hemodynamic environment, optimal for a secure stent deployment while maintaining good cardiac function as well as adequate blood flow to the spinal cord and abdominal vital organs.

Type of anesthesia

With the previously described goals set forward, local, regional or general anesthesia have all been successfully used in patients undergoing emergency TEVAR [12–14]. There are, however, no large comparative studies showing superiority of one technique over the other. In a recent study by Carmona *et al.* [15▪], successful deployment of the Talent or Valiant stent graft (Medtronic Inc., Fridley, Minnesota, USA) was achieved in all 25 patients with rDTAAs. In this study population, 32% of patients received only epidural anesthesia with no significant difference in outcome being reported.

It is the authors' experience that in certain patient populations with multiple preoperative coexisting diseases and mild hemodynamic instability, the TEVAR for rDTAA should be performed under local anesthesia. The advantage of such an anesthetic choice is the fact that there are minimal perturbances in blood pressure, which are commonly encountered during general anesthesia induction, and that the need for mechanical ventilation is obviated. In a large study of more than 6000 patients who underwent endovascular abdominal aortic repair (EVAR) for diseases of the abdominal aorta, general anesthesia was associated with an increased postoperative hospitalization period and increased pulmonary morbidity, when compared with local anesthesia. In contrast, employment of local anesthetic techniques was associated with decreased length of hospitalization, reduced postoperative morbidity and lower overall costs [16]. Although this study was for abdominal aortic aneurysms (AAAs), the results are likely applicable for patients with thoracic aortic aneurysms as well. However, patient co-operation is a mandatory prerequisite in cases performed under local anesthesia given the necessity of a motionless field during deployment of the stent graft. It must be mentioned that this may not be an attainable goal especially in emergency situations when patients are in pain and stress.

There are no clear guidelines pertaining to the type of anesthesia employed in interventions for rDTAAs. TEVAR could be started under local anesthesia, and once control of the ruptured thoracic aorta has been obtained via stent deployment, the need for general anesthesia could be re-evaluated [17]. If additional interventions are required (carotid stent or carotid subclavian bypass) then induction of general anesthesia should be considered. However, in situations of cardiovascular collapse due to major hemorrhage, general anesthesia should be induced and the airway controlled. As level one evidence studies are lacking, the type of anesthesia should be discussed between the anesthesiologist and the vascular surgeon, and the plan should be tailored to the patient's disease, indication and setting of the intervention.

Intraoperative monitoring

The surgical team should ideally prepare and drape prior to induction of anesthesia. Standard ASA monitors should be immediately employed. Adequate large intravenous access should be obtained as soon as possible. Arterial access should be obtained on the right arm, as left brachial access could be necessary for additional stent grafting or the thoracic aortic stent graft may cover the LSA take-off. However, placement of the arterial line should not delay the commencement of the TEVAR.

In situations in which general anesthesia is used, placement of a transesophageal echocardiography (TEE) probe is extremely useful. The utility of TEE is multifold. First and foremost, TEE confirms the aortic disease as well as the extent of the disease process. This fact becomes of paramount importance in emergency situations wherein the hemodynamic instability of the patient precluded the possibility of obtaining a CTA. In addition, the use of intraoperative TEE allows for a continuous assessment of the cardiac function, especially at the time of aortic occlusion, and represents a reliable monitor of intravascular volume status. Post stent deployment, in addition to angiography, TEE can be used to identify various endoleaks [18].

A cerebral oximeter using near-infrared spectroscopy (NIRS) could be useful in such cases as it has the capacity of monitoring cerebral regional oxygen saturation. Several reports have identified that decreased cerebral oxygen saturation during cardiovascular surgery is associated with insufficient cerebral perfusion [19]. Although not presently reported in the literature, this monitoring device could be useful in alerting the clinician about inadequate cerebral flow in situations wherein the proximal landing zone of the stent impinges on the left carotid take-off.

Because of the devastating outcomes of SCI, monitoring the spinal cord should be of prime importance in these cases. To date, the best available devices for spinal cord function monitoring are represented by registering the somato-sensory evoked potentials and the motor-evoked potentials (MEPs). However, these monitoring techniques require special equipment and trained personnel which may not be readily available at the time the emergency rDTAA arrives to the open repair. Interestingly, a recently published case series identified the use of spinal cord NIRS as a very good monitoring alternative to the traditional MEPs. The authors have placed the NIRS probes midline over the spinous processes of vertebrae T1-T3 (control zone) and T8-T10 (at risk zone). They have identified that in each case the NIRS correlated well with changes in the MEPs. The authors concluded that spinal cord NIRS might provide real time information regarding SCI [20]. The utility of NIRS as a spinal cord monitoring device remains to be tested in large trials. However, it represents a promising noninvasive technology that could be utilized in high-risk individuals undergoing emergency TEVAR.

Management of the spinal cord

As previously mentioned, despite the absence of aortic cross-clamping during TEVAR, paraplegia due to SCI remains a devastating complication of this procedure.

The cause of SCI is not clearly elucidated but it most likely is multifactorial. The main issue is related to inadequate blood flow to the arteries providing direct or collateral vascularization of the spinal cord. The blood supply of the spinal cord consists of an extensive network of collaterals. Probably, the most important cause is represented by the complete coverage of a varying number of intercostal arteries by the stent graft. The largest anterior segmental medullary artery providing the main blood supply to the spinal cord is the artery of Adamkiewicz. In 75% of people, the artery of Adamkiewicz originates between the T8 and L1 vertebral segments. Recently, the importance of identifying the artery of Adamkiewicz was investigated in patients with type B aortic dissection. Patients in whom the artery of Adamkiewicz was localized were treated with longer stent devices capable to provide a better structural stability to the affected aorta yet without covering the artery of Adamkiewicz. Furthermore, 0% of these patients developed paraparesis compared with 2.1% of patients in which the artery was not located [21]. More importantly, while during the open procedure the intercostal arteries can be reimplanted, during TEVAR this procedure is not possible. A second important cause contributing to the cause of SCI is graft coverage of the LSA, which gives rise to the left vertebral artery, which in turn gives rise to posterior spinal arteries. The hypogastric and pelvic arteries also provide collateral circulation to the anterior spinal artery. As such, patients who have undergone an abdominal aortic aneurysm repair have this vascular network damaged, and are therefore at higher risk of SCI. In addition to stent coverage of the origin of the main or collateral blood supply of the spinal cord, the flow is also compromised by embolization of debris material dislodged from the aortic wall during catheter manipulation.

In summary, factors that contribute to a higher risk of SCI either reduce direct or collateral blood supply or lower the spinal cord perfusion pressure (SCPP) (Table 1) [22]. The goal of spinal cord protection during TEVAR for rDTAAs is to optimize the oxygen delivery to the spinal cord and to minimize the oxygen demand of the spinal cord. The SCPP is equal to mean aortic pressure (MAP) minus the higher of the two pressures: cerebrospinal fluid pressure (CSFP) or central venous pressure (CVP) ($SCPP = MAP - CSFP$) [23]. On the basis of this physiology, current recommendations are to maintain

Table 1. Risk factors associated with development of spinal sord ischemia after thoracic endovascular aortic repair

Demographics	Age
	Male sex
	Lower BMI
	Preoperative renal failure
	Prior abdominal aortic aneurysm repair
Anatomical	Prior distal aortic vascular graft
	Thoracic aortic disease
	Extent of thoracic or thoracoabdominal aneurysm
	Number of patent lumbar arteries
Perioperative	
Preoperative	Emergency operation
Intraoperative	General anesthesia
	Procedure duration
	Endovascular stent coverage
	Total length of aortic coverage
	Extent of uncovered distal aorta
	Coverage of LSA
	Number of thoracic stents used
	Concomitant open abdominal aortic surgery
	Hypotension
	Hypogastric artery occlusion
	Arterial access site injury
	Bleeding
Postoperative	Hypotension
	Postoperative renal failure

LSA, left subclavian artery.
(Adapted from Ullery Semin Cardiothorac Vasc Anesth 2011).

MAP between 90 and 110 mmHg after stent deployment, and the CSFP and CVP below 10 mmHg.

Several techniques have been described and successfully used to reverse recurrent SCI following TEVAR for a descending thoracic aortic aneurysm [24]. Although this reactive approach to treat SCI could be successful, prevention of SCI is better than treatment afterwards. Bobadilla *et al.* [25■■] have successfully used a proactive SCI protection protocol in 94 consecutive TEVARs, most of which were acute. They observed a paraplegia rate of 1.1%, much lower than other reported series. This spinal cord protection protocol included routine spinal drainage in all patients to maintain a spinal fluid pressure of 8 mmHg intraoperatively and 10 mmHg postoperatively. Secondly, all patients received methylprednisolone and mannitol, resulting in further reduction of CSFPs. Lastly, a moderate intraoperative hypothermia between 32 and 35°C was allowed to help reduce the metabolic activity of the spinal cord and thus decrease oxygen requirements. During the entire procedure, the MAP was kept above 85 mm Hg. This study suggests that proactive approaches, instead of reactive, could result in a better long-term outcome to prevent SCI after TEVAR in the elective and emergency setting. Their results are amplified by another recent study, focusing on accurate hemodynamic control, represented by high-normal perioperative blood pressure, and this seems to protect against severe postoperative complications [26]. However, a balance should be maintained between hypothermia and normothermia, as it has been described that hypothermia is a risk factor for mortality after ruptured AAA repair. It should be noted that the temperature for patients treated with open repair was lower than for patients undergoing EVAR, and that efforts to correct hypothermia are more frequently successful in patients undergoing EVAR. Therefore, a body temperature around 35.5°C (96°F) is recommended to decrease both mortality and the risk of paraplegia [27]. If time does not allow placement of a spinal drain, such as in unstable patients actively bleeding, the spinal drain should be placed as soon as the situation permits [28].

Another recent study focused on the neuroprotective impact of intrathecal papaverine in patients who underwent descending thoracic aneurysm and thoracoabdominal aortic aneurysm repair. There was no difference between postoperative mortality and stroke, but permanent paraplegia (3.6 vs. 7.5%) and paraparesis (1.6 vs. 6.3%) were significantly lower in the intrathecal papaverine group, and the authors concluded that intrathecal papaverine may enhance spinal cord perfusion and provide additional spinal cord protection [29]. Larger studies should assess the long-term risks and benefits before the clinical implementation of intrathecal papaverine.

A flow chart presenting a perioperative management strategy designed to prevent and treat SCI is represented in Fig. 1 [30].

INTRAOPERATIVE SURGICAL CONSIDERATIONS

Custom-made, branched stent-grafts have been used for the treatment of rDTAAs, but applicability of these devices is less feasible in emergency

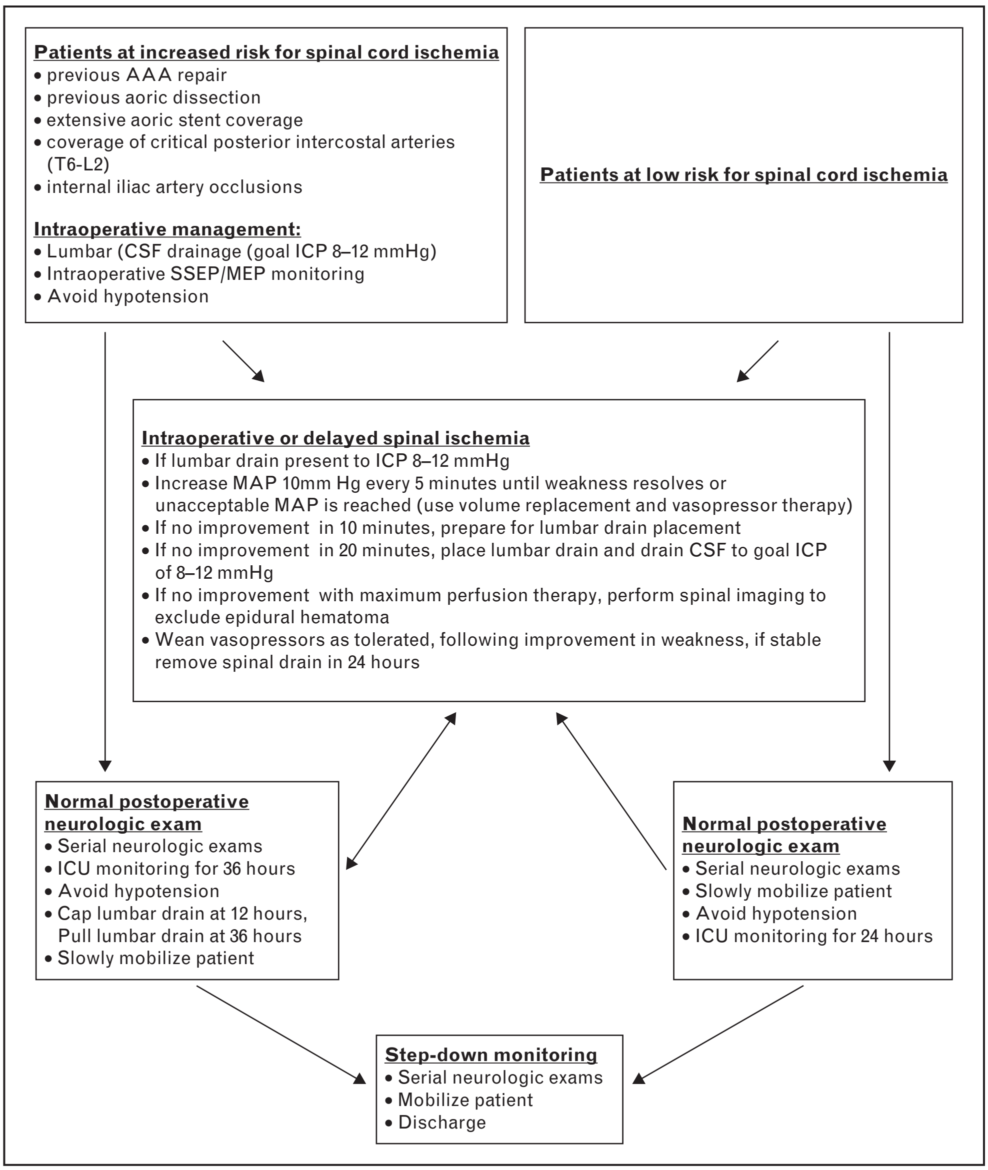

FIGURE 1. Perioperative management strategies to prevent and treat SCI in patients undergoing TEVAR (adapted from [30]). AAA, abdominal aortic aneurysm; CSF, cerebrospinal fluid; ICP, intracranial pressure measured through the lumbar cerebrospinal fluid drain; MAP, mean arterial pressure; MEP, motor-evoked potential; SCI, spinal cord ischemia; SSEP, somatosensory-evoked potential; TEVAR, thoracic endovascular aortic repair. (Adapted with permission from [30]) Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

situations as they are not available ‘off the shelf’. However, the goal of endovascular treatment is to perform a minimally invasive procedure to repair rDTAA. The use of heparin is recommended for endovascular repair in patients with rDTAA, but at a lower dose than in elective TEVAR [17].

To provide a good proximal seal, a proximal landing zone of sufficient length has to be established, but involvement of the LSA and left common carotid artery (LCCA) can thwart this good proximal landing zone. Thus, coverage of the LSA or LCCA may be required to obtain adequate proximal seal. However, the LSA supplies blood flow to the left arm, left vertebral artery (important for spinal cord perfusion) and left internal mammary artery (important in case of previous coronary artery bypass graft with grafting of the left anterior descending coronary artery), and may require an additional revascularization procedure in approximately 10% of patients. Indications for LSA revascularization include absent right subclavian artery, functional left arm arteriovenous shunt, patent left internal mammary artery coronary bypass graft, left axillary-femoral bypass graft and extensive thoracic aortic coverage with a history of prior abdominal aortic replacement. Options to preserve flow in the LSA, in situations wherein it needs to be covered, include carotid-LSA bypass. Similarly, carotid-carotid-LSA bypass can be performed if both the LCCA and the LSA are covered [31]. This is particularly important to prevent a steal phenomenon, which is caused by collateral flow from the left vertebral artery in retrograde direction to the LSA, causing ‘stealing’ of blood from the brain to the left arm [32]. Innovations to improve the proximal seal with a complete minimally invasive approach are currently underway. The Valiant Mona LiSA (Medtronic, Inc., Minneapolis, Minnesota, USA) is a new device based on the Valiant Captivia thoracic stent graft (Medtronic, Inc., Minneapolis, Minnesota, USA) and is currently being evaluated by the Food and Drug Administration’s Early Feasibility Pilot Program. This new device features an integrated branch-graft for the LSA and should make a complete minimally invasive approach with preserving the LSA available for patients worldwide. Another option to maintain the blood flow into the vital aortic arch side branches is the use of a chimney graft, which involves placement of stents in side branches of the aorta alongside the main endovascular stent graft (Fig. 2). A recent meta-analysis showed good short-term results with technical success in 98% of patients and 100% patency of chimney grafts after a mean follow-up of 11 months [33▪]. The chimney technique is a viable option for patients with rDTAA. However, a considerable percentage of these patients develop postoperative stroke (5%) and/or endoleaks, a fact that deserves attention. In case the proximal landing zone needs to be extended and is covering or impinging on the take-off of the LCCA, the chimney technique could also be a viable option. Patency described in this meta-analysis [33▪] is 100% after a mean follow-up of 11 months. However, the risk for complications is higher if the LCCA is covered compared with coverage of just the LSA. Total complications after chimney stenting are 27% for LCCA vs. 9.1% for LSA [33▪]. A possible explanation is that the LCCA perfuses more vital areas, such as the brain, that are less ‘forgiving’ than the areas perfused by the LSA. Another option is to perform a carotid-carotid bypass to preserve flow into the LCCA. However, a recent study comparing several techniques for

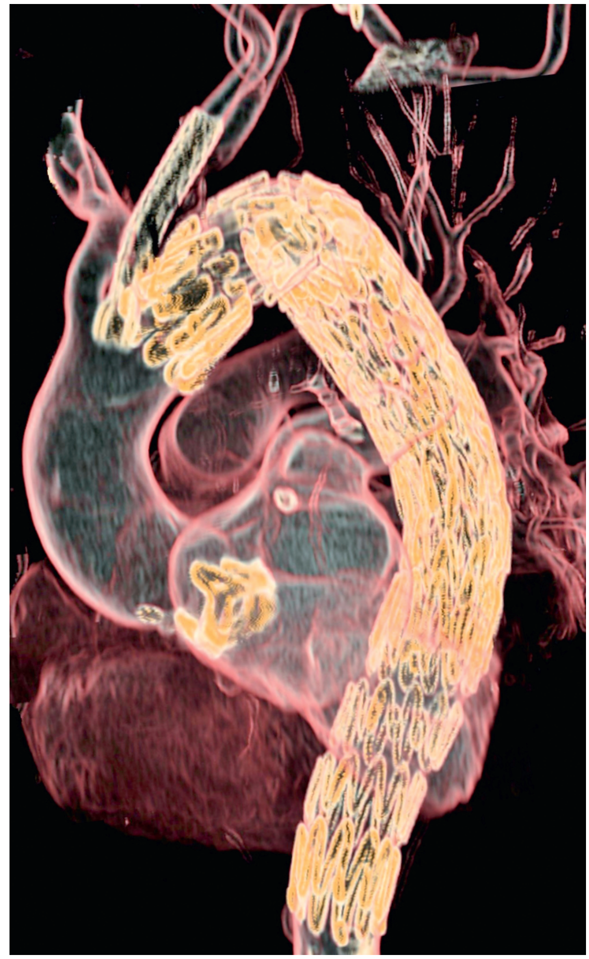

FIGURE 2. CTA shows a patent stent graft after successful TEVAR of an rDTAA with placement of a chimney stent in the LCCA. CTA, computed tomography angiography; LCCA, left common carotid artery; rDTAA, ruptured descending thoracic aortic aneurysm; TEVAR, thoracic endovascular aortic repair.

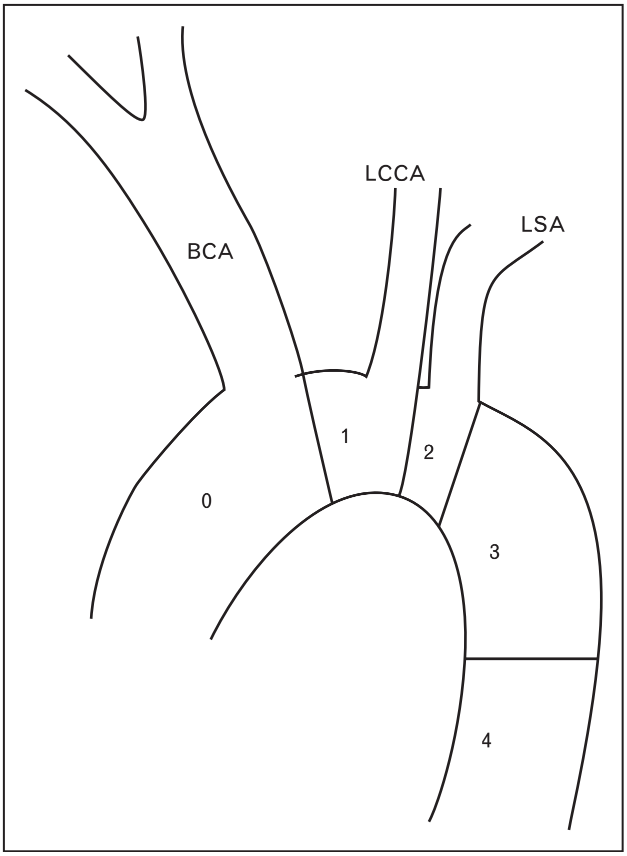

FIGURE 3. Zones in aortic arch. BCA, brachiocephalic artery; LCCA, left common carotid artery; LSA, left subclavian artery.

revascularization for vascular diseases in zone 0 and 1 (Fig. 3) of the aortic arch showed that carotid-carotid bypass has more complications compared with the chimney-technique [34]. Independent of the technique employed, postoperative angiography is of critical importance to evaluate the patency of the stents and prevent major complications.

POSTOPERATIVE CONSIDERATIONS

The use of EVAR and TEVAR has led to a decrease of patients with postoperative delirium. In a study with 256 patients with abdominal and thoraco-AAAs, 29% of patients in the open repair group vs. 13% of patients in the endovascular group developed postoperative delirium. To highlight this difference even more, the patients in the endovascular group were significantly older, and it is well known that age is an independent risk factor for delirium [35].

In order to employ a timely treatment of SCI, at the end of the procedure every attempt should be made to obtain a neurologic examination in the operating room. Even if the decision is made to maintain the patient intubated and sedated, the anesthetic agents should be decreased in order to allow for a thorough neurologic evaluation. In the intensive care unit, if the patient is hemodynamically unstable or has other comorbidities that require mechanical ventilation, the patient should continue to be routinely evaluated neurologically every hour.

Furthermore, attention should be paid to the analysis of laboratory results, as these are a good predictor for the survival of patients treated for ruptured aneurysms. Higher international normalized ratio and activated partial thromboplastin time and lower values of pH and bicarbonate concentration are associated with a higher rate of mortality. In patients with these impaired markers, extra attention should be paid to prevent postoperative mortality. Furthermore, patients with a higher intraoperative diuresis and first postoperative day diuresis were more likely to survive their intensive care unit hospitalization after ruptured aneurysm repair [36].

Apart from all the advantages of TEVAR, it should be noted that there are disadvantages for the patient, anesthetist and surgeon. One of these problems is the cumulative radiation exposure, which has been recently investigated by researchers from Milan, Italy. Overall radiation exposure was predicted by estimating the life-expectancy of the patients treated with TEVAR and the total number of required CT-scans. Three postoperative CT-scans in the first year with a yearly evaluation thereafter and a life expectancy of 15 years is estimated to increase the lifetime risk in radiation-induced leukemia and solid-tumor cancer by more than 2.7%. Obese patients had significantly higher radiation exposure, and therefore, the risks of cumulative radiation exposure must be balanced with the expected reduction in morbidity and mortality for patients treated with TEVAR, especially for younger or obese patients [37].

CONCLUSION

Endovascular treatment of rDTAAs is a challenging team effort for both the anesthesiologist and the surgeon. Limited time is available to prepare the patient for this intervention, and the preoperative evaluation should be focused. Close communication during the intervention between the anesthesiologist and the surgeon is required, especially during the critical moments including induction and during placement of the aortic stent graft. During TEVAR, patients should be kept in permissive hypotension prior to stent deployment, while maintaining sufficient spinal cord perfusion. After stent deployment in order to decrease the risk for

SCI, the MAP should be increased, and the CSFP should be decreased by actively draining fluid. The use of proactive spinal cord protection protocols could lead to a decrease of paraplegia rates. Future studies should focus on outcomes after different anesthetic techniques and spinal cord protective measures are employed.

Acknowledgements

None.

Conflicts of interest

B.E.M. is a Principal Investigator for Cook, Gore, and Medtronic and is a consultant for Cook.

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