A review of endovascular treatment of thoracic aorta disease

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ABSTRACT

INTRODUCTION The development of thoracic endovascular aortic repair has altered the approach and reduced the risk of treating the majority of descending thoracic aortic conditions. Primarily developed for the exclusion of thoracic aortic aneurysms, it is now used in place of open repair surgery for most descending thoracic aortic diseases, and has also been used to treat aortic arch diseases in selected cases.

METHODS A literature search was conducted of Medline and Embase databases from January 2007 to February 2017, using the key words 'aortic disease', 'thoracic aorta' and 'endovascular repair'; 205 articles were identified, of which 25 studies were selected for review based on their relevance.

FINDINGS The key findings of the indications, techniques, outcomes, complications and comparisons with open surgical repair were extracted from the published studies and are summarised in this review. Thoracic endovascular aortic repair is the preferred choice of intervention for patients with descending thoracic aortic disease. With time, it has improved to be safer and has the potential to expand aortic treatment choices in future.

KEYWORDS

Aortic disease – Thoracic aorta – Endovascular repair

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Introduction

Thoracic endovascular aortic repair (TEVAR) is a minimally invasive technique. It is now the preferred treatment, replacing the traditional method of open replacement of the descending thoracic aorta for the majority of descending thoracic aortic disease.¹ It has been shown to have lower morbidity and mortality rates, especially among high-risk groups.² Initially, it was used in the treatment of aortic aneurysm, but indications have expanded to include treatment of aortic dissections, traumatic aortic transections and penetrating aortic ulcers.³ Despite promising results from recent publications, there remains a lack of strong evidence to support the improvement of long-term survival for patients who were treated with TEVAR. However, the vastly improved early results with TEVAR makes it difficult to conduct randomised controlled trials comparing it with conventional open surgery at the present time. The results of TEVAR have also improved with better stent-graft technologies and implantation techniques.⁴

Methods

The literature search was performed for all published studies between January 2007 and February 2017. The Medline and Embase databases were searched using the key words 'aortic disease', 'thoracic aorta' and 'endovascular repair', which were combined using the Boolean function 'AND'. Searches were adapted to each database and performed using the specific controlled vocabulary accordingly if available. References from the retrieved papers were searched manually for any relevant and additional articles for this review. Only English language studies involving humans were included for selection. Titles of papers were initially screened, followed by abstracts, with full text obtained for relevant papers, followed by removal of duplicates. Papers were excluded where non-primary data were reported or if the data series presented were reported concurrently in a separate paper. Studies having patient sample sizes of less than 50 were also excluded from this review. A total of 205 articles were identified, of which 25 were selected for their relevance. Data regarding TEVAR

indications, selection criteria, techniques, intervention outcomes, complications and comparison with other methods were summarised.

Findings

A PRISMA flow diagram showing the selection process of articles is presented (Fig 1).

Indications

The introduction of endovascular aortic stent grafting for the treatment of thoracic aortic diseases has increased the intervention rates for patients who would previously have been considered too high risk for surgery. Clinical practice guidelines have identified general indications for both elective and emergency TEVAR, which include descending thoracic aortic aneurysms, acute and chronic descending thoracic aortic dissections, pseudoaneurysms, traumatic aortic transections, penetrating aortic ulcers and embolising lesions, among others.^{5–8} Patients with acute Stanford type B aortic dissections and acute traumatic aortic transections appear to benefit the most from TEVAR.⁹

Aortic aneurysms

Indications for intervention in descending thoracic aneurysms are dependent on the size of the aneurysm and the presence or absence of connective tissue diseases. Intervention is indicated when the aortic diameter size exceeds 6 cm in the presence of connective tissue diseases, while the threshold is 6 cm in its absence. These aortic diameters are the cut-off threshold whereby the risk of repair is lower than the risk of aortic rupture with non-intervention.¹⁰ A 2012 study compared early and midterm outcomes for TEVAR with open elective repair of descending thoracic aneurysms.¹¹ Patients who underwent TEVAR had favourable early outcomes; however, there was a decrease in midterm survival average of 73.5% compared with open repair at 77.5% within a timeframe of 6–24 months (Table 1).

Traumatic aortic transections

Aortic transection generally occurs at the level of the thoracic aorta in the region of the ligamentum arteriosum, just distal to the origin of the left subclavian artery. It is usually seen with rapid deceleration injuries that often lead to concomitant head, neck and chest trauma. In contained transections, endovascular repair has significantly

Figure 1 Preferred reporting items for systematic reviews flow chart of study selection.

Table 1 Overview of comparisons of outcomes and complications between thoracic endovascular aortic repair (TEVAR), open repair and hybrid repair.

Measure	TEVAR	Open repair	Hybrid repair
<i>Outcome</i>			
Mid-term survival (%):	68–79 ^(11,22)	72–83 ^(11,22)	–
6 months (%)	79	83	–
12 months (%)	71	79	–
24 months (%)	68–78	72–76	–
Mortality at 30 days (%)	2.1–10.2 ^(11,12,22,25,34,35) mean 6.15	10.3–23.5 ^(11,12,22,25,34,35) mean 16.9	5.7 – 14.9 ⁽¹⁷⁾ mean 10.3
Length of hospital stay (days)	7.4–21 ^(12,22,35) mean 14.2	14.4 – 28.1 ^(12,22,35) mean 21.25	8 ⁽¹⁷⁾
<i>Complications</i>			
Stroke (%)	1.7–7.1 ^(11,25,35) mean 4.4	0.3 – 12.5 ^(11,25,35) mean 6.4	4.6 ⁽¹⁷⁾
Paralysis (%)	0.9–3.6 ^(11,25) mean 2.25	0.8–3.4 ^(11, 25) mean 2.1	1.2 ⁽¹⁷⁾
Paraplegia (%)	0.8–3 ^(12,22) mean 1.9	2.9–14 ^(12,22) mean 8.45	1.2 ⁽¹⁷⁾
Myocardial infarction (%)	0 – 0.9 ^(22,25) mean 0.45	0 – 1.1 ^(22,25) mean 0.55	1.2 ⁽¹⁷⁾
Acute renal failure (%)	0 – 8.3 ^(11,12,22,25) mean 4.15	10.1–13.8 ^(11,12,22,25) mean 11.95	6.9 ⁽¹⁷⁾
Wound infection (%)	0–4 ^(11,22,25) mean 2	4.5–11 ^(11, 22, 25) mean 7.75	–
Sepsis (%)	3.6 ⁽¹¹⁾	6.9 ⁽¹¹⁾	–
Reoperation for bleeding (%)	0 – 0.9 ^(11,5) mean 0.45	3.1–20.7 ^(11, 5) mean 11.9	–
Atrial fibrillation (%)	10.7 ⁽¹¹⁾	17.2 ⁽¹¹⁾	–
Pneumonia (%)	31.5 ⁽¹²⁾	35.8 ⁽¹²⁾	–
Deep vein thrombosis (%)	4.1 ⁽¹²⁾	6 ⁽¹²⁾	–
Respiratory failure (%)	4 – 7.1 ^(22,25) mean 5.55	14.2–20.4 ^(22, 25) mean 17.3	–
Gastrointestinal complications (ileus, bowel ischemia or bowel obstruction) (%)	2 ⁽²²⁾	6 ⁽²²⁾	–
Urinary tract infection (%)	1.7–1.8 ⁽²⁵⁾	2.7–3.7 ⁽²⁵⁾	–

lowered morbidity (42.4%) and mortality (7.2%) compared with open repair (50% and 23.5%, respectively), even among the younger patient population.¹²

Acute descending thoracic aortic dissections

Acute descending thoracic aortic dissections are generally managed medically with control of blood pressure. However, in complicated descending thoracic aortic dissections, intervention is needed and has been shown to improve outcomes. Continued surveillance with imaging by computed tomography (CT) or magnetic resonance imaging (MRI) is vital as dissection-related complications continue to happen throughout the follow-up period.¹⁵ The preferred intervention today is by TEVAR whenever possible

rather than by open repair, as observed in complicated acute type B aortic dissections. Complications include persistent or recurrent pain, uncontrolled hypertension despite full medication, early aortic expansion, malperfusion and signs of rupture such as haemothorax and haematoma.⁷

Penetrating aortic ulcer and intramural haematoma

Penetrating aortic ulcers is characterised by an ulcerated atheromatous plaque that extends into the aortic media, whereas an intramural haematoma is characterised by haemorrhage within the aortic wall without a clear intimal disruption. Penetrating aortic ulcers with a depth greater than 10 mm or wider than 20 mm are at a higher risk of progression and should be considered for repair.

Indications for intervention include rupture, saccular aneurysm, or symptoms.¹⁴

Technique

Principles of TEVAR

The principle of TEVAR is the exclusion of an aneurysm or dissection with the use of a self-expanding covered stent (Fig 2). Placement of this stent is through the femoral artery, in most cases under imaging guidance, and requires an adequate landing zone for the stent graft, proximal to the aortic lesion.

Hybrid aortic arch repair

Hybrid aortic arch repair is an extension of TEVAR into the aortic arch and also ascending aorta with extra anatomical bypass of the left subclavian artery, left carotid artery and/or brachiocephalic artery as needed.^{15,16} Hybrid repair of the transverse aortic arch may be a treatment option in patients considered too high risk for conventional aortic arch replacement surgery. Andersen *et al.*¹⁷ described an algorithmic approach to hybrid arch repair, based on the extent of aortic disease and patient comorbidities (Fig 3).

Frozen elephant trunk techniques

The conventional 'elephant trunk' technique has been used to treat complex aortic diseases involving the aortic arch and the descending aorta. It involves replacement of the aortic arch and leaving a length of the tube graft in the

descending aorta (the elephant trunk), which would facilitate descending thoracic aortic repair subsequently. More recently, the frozen elephant trunk technique has been used. It involves placing a stent graft down the descending thoracic aorta (the frozen elephant trunk) at the time of open aortic arch replacement. Short- and mid-term results are good with this technique.¹⁸ In selected patients with combined aortic arch and descending aortic aneurysms limited to the proximal descending aorta, the frozen elephant trunk technique potentially allows for single-stage therapy, whereas a second-stage operation is inevitable with the standard elephant trunk technique.¹⁹

Left subclavian artery coverage

Left subclavian artery coverage during TEVAR is often necessary owing to anatomical factors (when the diseased aortic segment is too close to the origin of the left subclavian artery) and is performed in approximately 40% of procedures. Left subclavian artery coverage is associated with an increased 30-day risk of stroke in multivariable modeling.²⁰ It is now recommended that where coverage of the left subclavian artery is necessary, anatomical bypass of the left subclavian artery should also be performed.²¹

Outcome studies

TEVAR has an excellent track record and technical success rate of up to 98%.²² There is lower perioperative mortality than open repair surgery, with endovascular repair

Figure 2 Principles of thoracic endovascular aortic repair approach.

mortality rates of 1.9–2.1% compared with open repair at 5.7–11.7%.²³ Desai *et al.*⁵ conducted a study on 502 operations performed using thoracic aortic stent grafts. Patients with stent grafting for type B dissection had higher survival rates than those with stent grafting for aneurysms or other indications. Thoracic aortic stent grafting has evolved to be a feasible option to complement, improve and even replace traditional treatments for aortic disease.⁵ Knowles *et al.*²⁴ stated that endovascular thoracic aortic repair is a safe and effective treatment option for a variety of thoracic pathology including both elective and emergent cases. Off-label use of the procedure is associated with a much higher risk of mortality and spinal cord ischaemia, both at 10.5%, compared with 0% for on-label use.²⁴

A nationwide study of 1661 patients compared the outcomes between TEVAR and open surgery in type B aortic dissection. The results had demonstrated that patients with TEVAR had less respiratory failure at 7.1% compared with open repair at 20.4% and fewer wound complications at 0% than those with open repair at 5.3% under propensity score matching.²⁵

A 2011 study reviewed the six-year results of the endovascular repair of descending thoracic aortic pathologies, reporting the early perioperative outcomes and the mid-term follow-up of the treated patients.²⁶ It concluded that stenting of the thoracic aorta may offer a better solution for patients suffering from these pathological conditions.

In the literature, analyses of post-TEVAR outcomes appropriately stratified by aortic disease are limited. Schaffer *et al.*²⁷ described that patients with aortic rupture, acute aortic dissection and aortic trauma had the highest early incidence of death, whereas late survival was highest in patients with acute aortic dissection, aortic trauma and isolated thoracic aortic aneurysm. The late incidence of death remains high in TEVAR recipients, although acute aortic dissection, aortic trauma and isolated thoracic aortic aneurysm were associated with improved late survival.²⁷

Complications

Endoleaks are defined as leakage of blood into an aneurysm sac after stent-graft placement procedures and are the

most common type of endovascular complications, which may progress to aneurysmal ruptures.²⁸ A 2009 study had suggested that the clinical impact of type 2 endoleaks after TEVAR should not be overlooked. Type 2 endoleaks describes the reflux of blood into the aneurysmal sac through collateral vessels, most commonly lumbar or inferior mesenteric arteries.²⁹ It is associated with a significant reintervention rate, particularly in those cases involving the left subclavian artery with increasing aortic diameter or extensive leakage.³⁰

Neurological complications include permanent complete or incomplete paraplegia, reversible spinal cord ischemia, transient stroke and permanent stroke. Careful patient selection together with a strategy to reduce embolisation before endo-graft deployment may be beneficial.³¹

It is vital to assess early and midterm mortality and major complications in patients with aortic disease. Stroke, spinal cord ischemia, retrograde dissections and death are some of the complications that may occur. An endovascular procedure might also be a valid alternative to open surgery in average-risk patients with aortic arch diseases when morphologically viable.³²

Comparison with open repair

The role of hybrid repair in the management of aortic arch diseases and long-term outcomes with these techniques remains unclear. Hybrid aortic arch repair remains a feasible option for higher-risk patients with transverse arch pathology with perioperative outcomes and long-term aorta-specific survival similar to open repair, although with the need of increased reintervention.³³ Canaud *et al.*⁵⁴ compared the outcomes of open and endovascular repair of acute traumatic rupture of the thoracic aorta. Endovascular repair of traumatic thoracic aortic rupture is associated with a lower death rate at 2.5% than with open repair at 11.4%.³⁴ TEVAR for type B aortic dissection has less perioperative mortality, a shorter length of hospitalisation, a higher midterm survival rate, less postoperative respiratory failure, and fewer wound complications, as summarised in Table 1.^{25,55} Thoracic endovascular repair for isolated thoracic aortic disease have comparable results to open repair. However, the potential for endoleak or rupture remains as an obstacle that needs to be tackled in the future.³⁶

Conclusion

In conclusion, TEVAR is the preferred choice of intervention for patients with descending thoracic aortic conditions. Sufficient seal zones, safe preoperative planning and suitable device sizing are important to obtain good results and reduce complications. Hybrid repair approaches may further increase the group of patients who can receive benefits from this treatment. With the accumulation of expertise and improvement of device imaging technologies, TEVAR has improved to be safer and has the potential to expand treatment choices to include ascending and arch pathologies in future.

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