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Thoracic Endovascular Aortic Repair for Type B Aortic Dissection

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ABSTRACT

The incidence of aortic dissection (AD) is estimated to be 1 in 100,000 per year. The onset and progression of AD are rapid. Failure to receive appropriate treatment might lead to death in a short time. Even following active treatment, patients might develop low cardiac output syndrome, severe infection, and hemorrhage, which lead to death. Interventional therapy is a surgical method that has been widely used in Stanford type B AD recently. It is characterized by minimal invasiveness, low incidence of postoperative complications, and low cost. This article will review the interventional treatments for AD and will guide the selection of treatment options.

1. Introduction

Aortic dissection (AD) is a fatal vascular disease that occurs when blood leaks through an intimal tear in the aorta, passes into the artery wall and eventually forms a dissected hematoma, where true lumens (TLs) and false lumens (FLs) expand along the long axis of the artery [1]. The occurrence of AD is mainly associated with hypertension, which induces long-term oxidative stress in the arterial wall, resulting in cystic degeneration or necrosis of the elastic fibers, and the formation of dissection [2]. If AD is not diagnosed or treated appropriately, the early (within 1 h) fatality rate of patients with AD could reach 1%. Timely surgical treatment and the administration of medications significantly improved the survival rate of patients with AD, with a decrease in the case fatality rate from 27% to 18% [3]. Stanford type B AD includes dissections that originate in the descending thoracic aorta, abdominal aorta, and iliac artery, which account for 25%–40% of all AD cases. Approximately 75% of type B AD is noncomplicated AD [4]. Thoracic endovascular repair of

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the thoracic aorta (TEVAR), which is known as thoracic aortic interventional therapy, is a minimally invasive surgical method that is used for the treatment of critically ill patients with AD and is superior to open surgery in some aspects [5,6]. Due to the advances in medical technology and equipment, TEVAR has been applied gradually for the clinical treatment of Stanford type B AD. This article will review the interventional treatments for Stanford type B AD and will provide guidance on the selection of interventional therapies.

2. Indications and Contraindications of Interventional Therapy

In interventional therapy, endovascular stents or covered endovascular stents are commonly used to close the tear and FLs, and therefore, restore the patency of the TLs. Aortic intima fenestration and stent implantation are performed to restore blood perfusion in ischemic areas [7]. Interventional therapy is suitable for patients with chronic heart failure, chronic kidney insufficiency, and chronic pulmonary insufficiency, and those who have previously been treated with thoracotomy [8]. The indications for interventional therapy for patients with early-stage AD are: (1) duration of chronic type B AD > 3 weeks and (2) length of the neck hemangioma is > 1.5 cm [9]. Due to the advances in medical equipment and technology recently, the indications for interventional therapy have changed. Patients who are diagnosed with acute type B AD with possible aortic rupture, branch organ ischemia, aortic aneurysm formation, intractable severe pain, or hypertension might qualify for interventional therapy.

The optimal treatment for acute type B AD remains controversial. Some researchers found that the early and medium-term mortality of patients with thoracic aortic disease that were treated with interventional therapy was lower than those who received other treatments, in particular, conservative medical treatment. Therefore, currently, the indications for TEVAR for the treatment of AD are: (1) rupture and bleeding of a dissected aorta; (2) diameter of the dissected aorta increases rapidly (≥ 10 mm/year); (3) ischemia occurs in vital aortic branches; (4) persistent and unrelieved pain; (5) formation of intramural hematomas and aortic ulcer; and (6) formation of an aneurysm with an approximate diameter of 50–60 mm [10].

Although TEVAR has been widely used to treat AD, it is not recommended for patients with systemic infection, an inappropriate vascular approach, or inadequate anchoring area.

3. The Main Surgical Approaches in Interventional Therapy

TEVAR procedures mainly include aortic covered stent implantation, aortic fenestration, chimney technology, and branch stent technology. Aortic covered stent implantation was first performed in Argentina in 1990 to treat abdominal aortic aneurysms. Percutaneous transluminal aortic stent implantation was first used in 1994 to treat thoracic aortic aneurysm and descending AD. In this surgery, a covered stent is placed in the TLs to block the rupture of the dissection, reduce the blood flow through the FLs, induce thrombosis, and decrease the pressure in the FLs, and therefore, decrease the risk of aortic dilatation and rupture. In addition, the expansion of the TLs improves branch vascular perfusion and stabilizes the dissection. The aortic stent implantation shortens the operation time and reduces trauma, and significantly decreases the incidence of complications and mortality in patients with AD [11]. Zhou et al. [12] investigated the effect of stent-graft implantation for the treatment of patients with acute or subacute Stanford type B AD. The clinical data for 38 patients (31 males, 7 females) who presented with Stanford type B AD and received TEVAR treatment were retrospectively analyzed, which included 22 cases in the acute stage and 16 cases in the subacute stage. The average diameter of the TLs and FLs within the dissection before and after TEVAR, and the maximum aortic diameter, were measured. Seven patients (18.4%) had endoleaks following treatment. There were no perioperative deaths in this cohort. The results of computed tomography angiography at baseline showed that there was no significant difference in the maximum aortic diameter, or the diameter of TLs or FLs before TEVAR between the acute and subacute groups ($p = 0.193$, $p = 0.301$, and $p = 0.067$, respectively). After TEVAR treatment, significant differences were observed in the maximum aortic diameter and the diameter of FLs between both groups ($p = 0.005$ and $p = 0.012$, respectively), but not in the diameter of TLs ($p = 0.069$). The diameter of the TLs increased, and that of the FLs in the acute and subacute groups decreased significantly following TEVAR ($p<0.001$, $p<0.001$, $p<0.001$, and $p = 0.007$, respectively). The maximum aortic diameter in the acute group significantly decreased ($p<0.001$), but no significant changes were observed in the subacute group ($p = 0.121$). These findings suggested that the short-term prognosis for patients who received TEVAR in the acute stage was similar to that of the subacute group, although better outcomes were observed in patients with acute AD.

In aortic fenestration, the fenestration position and fenestration diameter of the branch arteries are determined by imaging examination. Holes and fenestrations are made on the inner membrane to separate TLs and FLs, decompressing the hypertensive FLs, and therefore, restoring blood supply. Aortic fenestration is used to increase the length of the stent; therefore, the anchoring area of the stent has a better fit on the aortic wall [13], which makes it suitable for AD patients with complications, such as visceral or lower limb ischemia. In addition, fenestration is performed in patients with ischemic manifestations, such as gastrointestinal ischemia, acute renal failure, claudication, or pulseless limbs [14]. Fenestration relieves ischemic symptoms in approximately 85%–93% of patients, stabilizes AD, and increase the time for elective surgery or stent intervention, and therefore, improves the prognosis of patients with AD [15]. Kuo et al. [16] evaluated the efficacy and safety of a handmade fenestrated stent-graft over an aortic stent graft to preserve the left subclavian artery (LSA) in TEVAR. A total of 32 patients with various thoracic aortic pathologies were included. There were 24 patients (75.00%) with AD, 5 patients (15.63%) with thoracic aortic aneurysm, and 2 patients (6.25%) with penetrating aortic ulcer. One patient (3.13%) required re-TEVAR due to the endoleak and sac expansion from previous TEVAR for a thoraco-abdominal aneurysm.They were treated with TEVAR, in which handmade fenestration over a thoracic aortic stent-graft was used for the LSA. TEVAR on zone 2 landings with single fenestration for the LSA was performed in 26 patients (81.25%); TEVAR on zone 1 landing with double fenestration for LSA and left common carotid artery was performed in 5 patients (15.63%); TEVAR on zone 1 landing with single fenestration for the LSA and a chimney graft for the left common carotid artery was performed in 1 patient (3.13%). The technical success rate, defined as the successful alignment of fenestration to the LSA, was 93.75%.At a mean follow-up of 17.3 months, four cases of endoleak and two cases of stent graft-induced new entry were observed; three of them were treated endovascularly. The ability to preserve blood flow in the LSA using a handmade stent-graft fenestration might justify the use of TEVAR in emergency cases. In addition, fenestration surgery can be used as adjuvant therapy in emergency treatment or stent implantation to reduce the incidence of ischemic complications. Recently, fenestration and branch endovascular stent implantation have shown promising clinical results for the treatment of branch vascular ischemia.

During transluminal therapy that uses the chimney technique, the vital branch vessels, such as the LSA, are intentionally or inadvertently covered due to the inadequate anchoring area. Bare stents and covered stents are often anchored together to preserve the branch vessels [17]. This technique was first proposed by R. K. Greenberg and then applied to TEVAR. The chimney technique is not performed as a routine surgical approach for complex Stanford type B AD, it is used in patients who cannot tolerate hybrid surgery or open surgery, or in an emergency [18]. Since this technique preserves vital branch vessels and maintains the blood supply to vital organs, it might replace bypass or open vascular repair in the near future. Zhao et al. [19] analyzed the effects of different chimney techniques that were applied to different positions on the aortic arch and provided guidance to reduce the complications from chimney thoracic endovascular aortic repair (cTEVAR). In this study, 234 patients with AD that involved the arch branches were treated with cTEVAR. There were 156 cases (66.7%) with single chimney (SC), 48 (20.5%) with double chimney (DC), and 30 (12.8%) with triple chimney (TC). A total of 342 chimney grafts were used. The results showed that all chimney grafts were successfully implanted, and no migration or occlusion was observed during follow-up. The postoperative mortality rate was 1.7% (4/234) and the occurrence of cerebrovascular events was 1.3% (3/234). In addition, 75 cases (75/234, 32.1%) had type I intimal leakage during the operation. The leakage in 27 patients (27/75, 36.0%) disappeared during follow-up; 33 patients (33/75, 44.0%) had stable FLs; 15 (15/75, 20%) had FLs expansion and were successfully treated with endovascular embolization. Patients with a proximal tear that was located in zone 0 had a higher instant endoleak rate than those with the tear located in zones 1, 2, and 3 (p = 0.041, p = 0.042, and p = 0.009, respectively). Patients with TC had increased instant endoleak than those with SC (p<0.001) and DC (p = 0.012). However, during follow-up, there was no significant difference in instant endoleak between the groups. These data showed that the SC technique achieved satisfactory results.

A retrospective study on 234 patients with aortic arch disease was performed to evaluate the feasibility, effectiveness, and safety of chimney, fenestration, and in situ fenestration techniques [20]. Among them, 126 patients received cTEVAR (98 cases with SC, 24 cases with DC, and 4 cases with TC); 102 patients (102/234) were treated with surgical fenestration (92 cases with single fenestration, 9 cases with double fenestration, and 1 case with double fenestration and innominate arterial chimney); the remaining 6 received in situ acupuncture fenestration. The indications included AD (99/234), aortic arch aneurysm

(60/234), penetrating aortic ulcer (72/234), and re-intervention (3/234). There were five early all-cause deaths. The technical success rate was 99.6% and the patency rate of all branches was 99.6%. There were 15 cases with type Ia intestinal leakage; 14 cases (11.1%) in the chimney group and 1 case (1%) in the table fenestration group. Five patients underwent re-intervention. The median follow-up for all patients was 28 months (range: 16–41 months), which indicated that chimney, table fenestration, and needle fenestration techniques were feasible, effective, and safe methods for the treatment of aortic arch lesions.

The Castor branched aortic stent, which was produced in China in June 2017, is a new type of thoracic aortic stent that has been used globally. This stent has a unique integrated structure, which better fits with the blood vessels of Chinese patients and shows improved stability and a low risk of long-term displacement. It allows precise positioning, separates TLs and the FLs, and avoids the use of hybrid technique and staged operation to reduce the pain of patients. The origin of the LSA can be intentionally covered by a stent-graft to provide an adequate proximal landing area during the endovascular repair of the Stanford B AD. Jing et al. [21] retrospectively analyzed 73 patients with Stanford type B AD who were treated with the Castor stent-graft in 11 tertiary hospitals in China. There were 50 cases with acute AD (<2 weeks [68.5%]) and 23 cases with chronic AD (>2 weeks [31.5%]). The results showed that the surgical success rate was 97% (n = 71/73). Two of the failures were caused by partial occlusion of the branches of the stent-graft. Four patients had intraoperative endoleaks (type Ia: n = 2, type B from the LSA: n = 2) and the endoleak rate was 5% (n = 4/73). One patient died in the hospital and the rest had no major complications. The mortality rate within 1 year of postoperative follow-up was 5% (n = 4/73) and the mortality rate within 6 years was 7% (n = 5/73). The cause of death in two patients was unknown. The deaths of three patients were not related to the aorta. Two patients had a new breach at the proximal or distal edge of the stent-graft and underwent endovascular repair. The branches where the Castor stent was deployed were partially occluded in 6 patients, and the follow-up patency rate of the branches was 93% (n = 63/68). In two cases with intraoperative endoleaks that were not treated, the endoleaks disappeared during follow-up. These findings suggest that endovascular treatment that used the Castor single-vessel stent graft was an easy-to-operate, safe, and effective treatment option for TBAD patients whose stents needed to be anchored near the origin of the LSA. The intraoperative reconstruction of the LSA resulted in a better blood supply and fewer complications.

4. Complications of Interventional Therapy

The complications from interventional therapy include internal leakage, distal new rupture, stent displacement, vascular injury, and thrombus exfoliation. Internal leakage, which is the most common complication, occurs when the covered stent implantation in the aorta does not completely isolate the aneurysm cavity from the arterial blood flow [22]. The incidence of internal leakage with stent treatment of AD was 3%–44% [23], which was related to the physical condition of the patient, type of the stent, anatomical condition of the aortic aneurysm, and the experience of the operator. Approximately 50% of the internal leakage disappeared spontaneously. However, it might expand to form an aneurysm and could lead to the rupture of the aneurysm cavity. In this case, re-implantation of the stent is required.

Stent displacement is a common complication in interventional therapy that mainly occurs due to intra-aortic blood flow and pulsation after stent implantation. Stent displacement increases the risk of internal leakage and might cause serious consequences, such as aortic rupture. Therefore, during the operation, it is important to ensure that there is no dilation or lesion at the anchorage site of the aorta and stent [24]. To prevent stent displacement it is important to select an appropriate stent, the diameter of the proximal and distal stent should be 3 mm ~ 4 mm larger than the diameter of the hemangiomas, to avoid stent distortion and angulation [25].

The incidence of new distal rupture is 3.4%–27.8% and the mortality rate is 26.1% [26]. When the length of the stent is >145 mm, the incidence of fracture significantly decreases. The oversizing area is closely related to the risk of stent-derived rupture. The stress between the stent and the aortic wall is the main factor that affects the distal aorta. To prevent distal rupture, lengthening the stent has been suggested, reducing the oversizing area, and the stress between the stent and the aortic wall, and protecting the edematous vascular wall in the acute stage [27].

5. Summary

The clinical significance of interventional therapy for the treatment of AD has been increasingly recognized.

Stent therapy could replace traditional surgical treatment in most cases. In addition, it could be performed in patients who cannot tolerate surgery. Due to the development of technologies and materials, the suture-free elephant trunk stent with artificial vessels and branch vessels has been used in type B AD with ascending and arch expansion. New stent materials, such as Ni-Ti alloy extruded stent and Ni-Ti memory alloy have been gradually used in clinical practice. New interventional guidance, such as visual guidance, virtual reality imaging technology, magnetic navigation guidance, and esophageal ultrasound guidance, shows the internal structure of the cardiovascular system and provides real-time monitoring for physicians during an operation. In addition, blood transfusion is not required in interventional therapy, which decreases the operation time and reduces operative morbidities and costs. The use of new dynamic imaging technology might facilitate the exploration of the morphology and dynamics of the aorta; therefore, new stents could be designed for patients with AD for a better prognosis.

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Disclosure of Interest

The authors report no conflicts of interest.

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