Advances in thoracic aortic surgery: Arch replacement with axillary cannulation and thoracic stent grafts

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During the past decade, significant advances in thoracic surgery have contributed to a decrease in the morbidity and mortality linked to surgery of the thoracic aorta. Drawing from the experiences at the Quebec Heart Institute, the present article focuses on the improvements in surgery of the aortic arch, mainly the use of the ‘arch-first technique’ and arterial cannulation through the right axillary artery. Furthermore, advances in the treatment of diseases of the descending aorta using thoracic stent grafts are delineated. The importance of establishing dedicated multidisciplinary teams and follow-up clinics to ensure good outcomes in the treatment of these complex diseases is stressed.

Key Words: Aorta; Axillary cannulation; Cerebral protection; Surgery; Thoracic stent-graft

Although attempts at surgical treatment of the thoracic aorta were performed in the 19th century, it was not until the pioneer experimental work of Alexis Carrel (1) on vascular anastomosis that the modern era of aortic surgery began. With the advent of cardiopulmonary bypass, tremendous innovation and progress took place in the management of diseases of the thoracic aorta. Work on deep hypothermia by Bigelow et al (2) initiated the development of complex surgical strategies to treat aortic arch pathologies while preserving brain function. Although high mortality and morbidity rates were initially reported, better patient selection and advancements in surgical technique, brain and spine protection, and perioperative care have led to acceptable outcomes (3,4).

During the past decade, the establishment of dedicated multidisciplinary teams and better understanding of the principles of cerebral protection have further improved the outcomes of open arch reconstruction (5). On the other hand, open operative repair of the descending aorta remains a major undertaking, especially in patients with severe comorbidities when operated emergently. The introduction of thoracic aortic stent grafts has contributed to a decrease in perioperative risks and enhanced early survival in this subset of patients (6). Drawing from the experiences of the Quebec Heart Institute, the present article focuses on establishing the current standards in the open operative approach to the aortic arch, and summarizes the indications and results of thoracic stent grafting.

ARCH REPLACEMENT WITH AXILLARY CANNULATION

Various surgical techniques have been introduced to replace the diseased aortic arch. The use of deep hypothermic circulatory arrest (DHCA) as a sole modality of brain protection was initially proposed (7). Although successful reports have assessed the safety of DHCA, significant cerebral morbidity has been reported (8). The safe duration of DHCA remains controversial and appears to be related to the patient’s age and the level of hypothermia. Even at systemic temperatures of 12°C to 15°C, a duration of DHCA longer than 30 min raises concern. McCullough et al (9) demonstrated that the cerebral metabolic rate was still 17% of baseline at a systemic temperature of 15°C. Furthermore, the prolonged period of cardiopulmonary bypass often required with DHCA is linked to significant coagulopathy and renal morbidity (10).

To shorten the duration of DHCA, various adjunctive measures have been proposed and clinically evaluated. Ueda et al (11) proposed the use of retrograde cerebral perfusion (RCP) to enhance brain protection during the period of DHCA. The literature on RCP yields conflicting results; however, most authors believe that RCP does not prolong the safe duration of DHCA. On the other hand, RCP may be effective at minimizing particular embolization to the brain (12). Thus, RCP is reserved for patients with a high atherosclerotic burden in the aortic arch.
The use of selective cerebral perfusion (SCP) through direct cannulation of the arch vessels has been championed by Bachet et al (13) and Kazui et al (14). Various techniques have been proposed to induce SCP: direct arch vessel cannulation; arch vessel island patch with subsequent perfusion through the graft; and selective arch branch vessel grafts with perfusion through the axillary artery. SCP shortens the duration of DHCA in arch replacement procedures by initially reperfusing the arch (‘arch-first technique’), followed by distal anastomosis and, subsequently, proximal aortic reconstruction. In aortic arch operations, SCP in combination with DHCA has been shown to reduce cerebral injury compared with DHCA alone (15).

During arch surgery, the arterial cannulation site for cardiopulmonary bypass initiation was traditionally the common femoral artery. In such circumstances, the risk of retrograde brain embolization during DHCA is significantly increased. Use of the axillary artery has been suggested to minimize this risk of retrograde embolization (16). Axillary cannulation has been shown to decrease the risk of stroke in patients undergoing procedures necessitating DHCA (17). Furthermore, axillary cannulation facilitates the initiation of SCP and avoids the risk of dislodging emboli during selective arch vessel cannulation.

At the Quebec Heart Institute, arch replacements have been performed in 54 patients since 2001 using axillary cannulation and the arch-first technique. The mean age of patients was 64.7±15.6 years (range 18 to 86 years) and 23% of the procedures were reoperations. The operative technique is summarized as follows. The right axillary artery is cannulated with an 8 mm Dacron side branch. Operative monitoring includes the use of the INVOS Cerebral Oximeter system (Somanetics Corporation, USA) and bilateral radial artery monitoring to exclude preferential perfusion of the right arm. In such circumstances, the right axillary artery distal to the side-branch graft is snared. A single, two-stage venous cannula positioned in the right atrium is used for venous return. Systemic temperature is decreased to 20°C to 24°C nasopharyngeal temperature. On initiation of DHCA, the arch vessels are dissected and transected in areas of minimal atheroma. Subsequently, selective perfusion through the right axillary graft is initiated at 10 mL/kg to 15 mL/kg, and the arch vessels are individually clamped. SCP is monitored by the left radial artery and the INVOS system. Previously, the arch vessels were anastomosed to a single graft before reinitiating perfusion through the right axillary artery; however, at present, each arch vessel, beginning with the left subclavian artery, is sequentially anastomosed using either a commercial three-branch graft or a tripod custom-made graft (Figure 1). Once the arch vessel anastomoses are completed, the distal anastomosis is performed using an elephant trunk technique when appropriate. Using a bifurcated line on the arterial tubing, the lower extremities are reperfused and systemic rewarming is begun. The proximal anastomosis at the level of the ascending aorta is subsequently performed with or without root reconstruction and replacement. The arch vessel graft is connected to the main ascending aortic graft to complete the operation (Figure 2). The axillary graft is ligated close to the native artery to minimize the length of the residual stump.

Using this technique, the mean duration of SCP was 20.3±18.2 min. Two patients died (3.7% in-hospital mortality). The incidence of new neurological deficits was 3.5%. A reoperation for bleeding was required in 14.0% of patients. No deep sternal infection was observed; however, it was necessary to remove the axillary artery stump in one patient due to infection. Renal failure, defined as a postoperative increase in creatinine of 100 μmol/L from the baseline value, was encountered in 7.4% of patients. The mean duration of intensive care unit and hospital stays was 3.3±3.0 days and 11.6±8.6 days, respectively.

THORACIC STENT GRAFTING

Historically, conventional open surgery has been the mainstay of therapy for diseases of the descending aorta. Although authors (18,19) report an operative mortality in the range of 4% to 9%, morbidity and mortality increase substantially in patients with severe comorbidities or who undergo emergent surgery (18,19). Complications of an open approach are mainly related to paraplegia, myocardial infarction, and respiratory and renal failure. Dake et al (6) were the first to design custom-made thoracic stent grafts to treat aneurysmal disease in...
patients at high risk for an open procedure. Since then, many authors (20,21) have demonstrated the technical feasibility of this technique. In addition to aneurysms, a wide variety of diseases of the thoracic aorta have been treated with thoracic stent grafts: blunt traumatic aortic ruptures, complicated penetrating ulcers, acute and chronic type B dissections, mycotic aneurysms, iatrogenic aortic ruptures and other miscellaneous diseases (22-25). Procedural success rates are greater than 95%, while in-hospital mortality is mainly linked to the severity of the patient’s comorbidities (26,27). Baumgart et al. (28) reported dismal early survival in patients with a poor clinical status (American Society of Anesthesiologists’ classification higher than class 3). Paraplegia is reported to occur in up to 5% of patients, with increasing risks with extensive stenting of the descending aorta, including the distal one-third, especially when coverage of the left subclavian artery cannot be avoided or in the absence of a patent internal iliac artery circulation (29). Midterm results appear to be related more to the patient’s comorbidities than to aortic-related problems (30). The presence of an unresolved type 1 endoleak at follow-up portends a poor outcome, thus mandating a regular imaging follow-up (31). Additional stent-graft procedures are required in 10% to 15% of cases and seem to increase with time, thus mandating lifelong surveillance (30). Complex hybrid procedures, including extra-anatomical revascularization of visceral arteries followed by extensive stent grafting, have been reported by the authors (32) and others (33).

At the Quebec Heart Institute, the thoracic stent-graft program was initiated in May 2001. Since then, 73 patients (mean age 63.8±16.5 years; 78.5% men) have been treated with thoracic stent grafts. Indications to implant a thoracic stent graft as opposed to performing an open operation were based on the presence of significant comorbidities in 89.0% of patients. Eight patients selected a stent graft after receiving an explanation of the advantages and disadvantages of the open and endovascular approaches. Symptoms were present in 64.3% of patients. Indications were aneurysmal disease in 34.2% of patients, complicated penetrating ulcer in 24.6%, blunt traumatic rupture in 24.6%, acute type B dissection in 12.3% and miscellaneous indications in the residual 4.3% of patients. The stent graft was inserted through the common femoral artery in 82.2% of patients. Other vascular access sites were the common iliac artery, the abdominal aorta and novel vascular access sites, such as the distal descending aorta and the ascending aorta (34). A mean of 1.9±1.0 stent-grafts per patient was required to treat the thoracic aortic disease; the procedural success rate was 100%. The left subclavian artery required partial or complete coverage in 34.2% of patients. The left subclavian artery was bypassed only in the presence of a left dominant vertebral artery, a patent mammary graft on the left anterior descending artery or a significant stenosis in another arch vessel. No patient without preoperative revascularization of the left subclavian artery required a bypass at follow-up. Either the Talent Thoracic Stent-Graft System (Medtronic Inc, USA) or the Valiant Thoracic Stent Graft System (Medtronic Inc, USA) was used in 94.5% of patients. In-hospital mortality was 9.5%, and two patients developed transient paraparesis. Follow-up was 98.6% complete at a mean of 22.1±17.9 months. At 48 months, overall survival was 56.7%; freedom from a type 1 endoleak was 85.8%, and freedom from stent graft- or aortic-related death was 91.3%. Univariate and multivariate analyses were performed to evaluate the predictors of poor outcome, defined as the presence of at least one of the following: in-hospital death, paraparesis or paraplegia, type 1 endoleak or late aortic-related death. On univariate analysis, only the presence of chronic obstructive pulmonary disease (P=0.02), renal failure (P=0.06), aneurysmal disease (P=0.04) and an operator who had performed fewer than five procedures (P=0.01) were significantly associated with a poor outcome. On multivariate analysis, only the presence of chronic obstructive pulmonary disease (OR 4.5; 95% CI 1.3 to 15.9) and an operator who had performed fewer than five procedures (OR 17.2; 95% CI 1.6 to 190.4) were significantly associated with a poor outcome.

CONCLUSION

Significant advances in the treatment of diseases of the thoracic aorta have occurred during the past decade. The establishment of dedicated multidisciplinary teams has contributed to this development. Arch replacement can now be performed with an acceptable rate of cerebral complications and early mortality. Thoracic stent grafts have been shown to be effective in decreasing mortality and morbidity, especially in patients with significant comorbidities and acute pathologies of the descending aorta. Better characterization of the natural history of chronic diseases of the descending aorta will allow better definition of the indications for and timing of stent-graft implantation. Early and midterm results are further dependent on patient selection, the expertise of the operator and a thorough follow-up protocol. Developments in stent-graft technology will result in lower early complication rates. The establishment of dedicated follow-up clinics is essential to recognize stent-graft complications or progression of the disease to new aortic segments.

REFERENCES