Open and endovascular repair of the nontraumatic isolated aortic arch aneurysm

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Objective: **Repair of isolated aortic arch aneurysms (nontraumatic) by either open (OAR) or endovascular (TEVAR) methods is associated with need for hypothermic circulatory arrest, complex debranching procedures, or use of marginal proximal landing zones. This study evaluates outcomes for treatment of this cohort.**
Methods: **Of 2153 patients undergoing arch repair (1993-2013), 137 (mean age, 60 years) were treated with isolated arch resection for nontraumatic aneurysms. Treatment was by open (n = 93), hybrid (n = 11), or TEVAR (n = 33) methods, with the last two approaches reserved for poor OAR candidates. Treatment was predominantly for saccular (n = 53) or fusiform (n = 30) aneurysms or dissection (n = 15). Rupture was present in 15%. Prior aortic repair was performed in the ascending (n = 30), arch (n = 40), descending (n = 24), or abdominal (n = 9) aorta. Propensity score adjustment was performed for multivariable analysis to account for baseline differences in patient groups as well as treatment selection bias.**
Results: **Early mortality was seen in nine patients (7%). Morbidity included stroke (n = 9), paraplegia (n = 1), and need for dialysis (n = 5) or tracheostomy (n = 10). A composite outcome of death and stroke was independently predicted by advancing age ($P = .055$) and performance of a hybrid procedure ($P = .012$). The 15-year survival was 59%, with late mortality predicted by increasing age, presence of peripheral vascular disease, and perioperative stroke (all $P < .05$). The 10-year freedom from aortic rupture or reintervention was 75% and was higher after OAR (2-year OAR, 94% vs TEVAR or hybrid, 78%; $P = .018$). After propensity-adjusted Cox regression analysis, both prior abdominal aortic aneurysmectomy ($P = .017$) and an endovascular or hybrid procedure ($P = .001$) independently predicted late aortic rupture or need for reintervention.**
Conclusions: **Isolated arch repair remains a high-risk procedure occurring frequently in the reoperative setting. Despite being performed in a higher risk group, endovascular strategies yielded similar outcomes but with an increased risk for aorta-related complications. These data support ongoing efforts to develop branched endografts specifically tailored for arch disease to potentially reduce morbidity related to currently available approaches. (J Vasc Surg 2014;60:57-63.)**

Since the first reported attempts at arch aneurysm repair by Michael DeBakey, morbidity rates have improved dramatically.[1-3] Whereas the majority of arch aneurysms exist as distal extensions of more proximal aortic disease or proximal extensions of descending aortic disease, the isolated nontraumatic arch aortic aneurysm represents a unique entity with its associated challenges. Exposure for traditional open aortic repair (OAR) of this pathologic process is through a median sternotomy or a thoracotomy, depending on the relative location of the arch to the midline of the chest. OAR also frequently requires adjunctive use of hypothermic circulatory arrest with its attendant increased morbidity, particularly if it is performed from a thoracotomy.[4] The associated pathologic process often either is a saccular aneurysm arising from a penetrating ulcer with its high associated atherosclerotic burden (Fig 1) or occurs in the reoperative setting of prior incomplete proximal or distal aneurysm resection, both of which contribute to increased morbidity.

In the last decade, endovascular options have been used to reduce the morbidity of thoracic aortic repair.[5] Thoracic endovascular aortic repair (TEVAR) has several limitations when it is extended to the arch aorta. These include the higher risk of stroke and the presence of inadequate landing zones due to arch branch vessel proximity or arch curvature.[6,7] In an effort to overcome these anatomic constraints, complex extra-anatomic arch vessel bypasses are constructed to extend proximal landing zones. These hybrid procedures have been evaluated in prior studies and have also been associated with significant morbidity.[8-14] However, these reports have often included large numbers of patients in whom the arch is modified to facilitate a repair of a predominantly descending thoracic aneurysm rather than solely focusing on an isolated arch aortic aneurysm. With the advent of these newer approaches, we undertook this 20-year study to evaluate both early and late outcomes associated with treatment of isolated arch aortic disease.

METHODS

This study was approved by the Institutional Review Board of the University of Michigan Hospitals (IRB HUM00044262; informed consent waived). Data from

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Fig 1. This three-dimensional reconstruction is an example of the typical saccular aneurysm evaluated in this study and probably arose from a penetrating ulcer in a 79-year-old ex-smoker who had associated coronary artery disease. This patient underwent subsequent total arch debranching with thoracic endovascular aortic repair (TEVAR) and concomitant left internal mammary artery bypass grafting to the left anterior descending coronary artery.

all patients who underwent operative therapy for nontraumatic, isolated aortic arch aneurysms at the University of Michigan from 1993 to 2013 were retrospectively collected and analyzed.

Of 2153 patients undergoing arch repair from 1993 to 2013, 137 (mean age, 60 years) were treated with isolated arch resection for nontraumatic aneurysms. Patients with ascending aneurysms extending into the arch or descending aneurysms that began in the arch and extended distally beyond the level of the left pulmonary artery were excluded. Indications for treatment were predominantly saccular aneurysm (n = 53), fusiform aneurysm (n = 30), or type B dissection (n = 15). Rupture was present in 15% of patients (n = 21), and a prior aortic repair had been performed in the ascending (n = 30; 22%), arch (n = 40; 29%), descending (n = 24; 18%), or abdominal (n = 9; 7%) aorta.

Determination of type of aortic repair was at the discretion of a surgeon experienced in aortic reconstruction. In general, evaluation for TEVAR or hybrid strategies was performed in a multidisciplinary fashion and reserved for poor OAR candidates who had complex aortic arch aneurysms.

OAR was performed in 93 patients. All open repairs were performed with extracorporeal perfusion support (mean perfusion times, 177 ± 59 minutes). Left-sided heart bypass was used in 13 patients. The remaining 80 patients had adjunctive use of deep hypothermic circulatory arrest (mean, 47 minutes), as previously described.[3,4]

For those patients undergoing an endovascular strategy, stent graft sizing and procedural technique were performed as previously described.[5] Our institutional preference employed a "bypass all" strategy of left subclavian artery revascularization unless a patient presented with frank rupture and hemodynamic instability. Forty-four patients were treated with an endovascular strategy classified according to Ishimaru.[15] Treatment into Ishimaru zone 2 (ie, proximal extent of therapy to distal origin of left carotid artery but not including it) was performed in 33 patients. Of this group, 25 patients underwent adjunctive left carotid to left subclavian arterial bypass; eight were treated without branch vessel revascularization because of marginal hemodynamic presentation. Finally, 11 patients underwent a hybrid endovascular procedure with arch vessel debranching, followed by TEVAR, with extension into zone 0 (treatment to include innominate artery and proximally). One patient had repair that extended only into zone 1. The arch vessel debranching usually consisted of initial left carotid to left subclavian arterial bypass, followed by median sternotomy and construction of ascending aorta to innominate artery and left carotid artery bypasses with a prefabricated Dacron prosthesis in nine patients. In two patients, replacement of the ascending aorta was needed to construct an appropriate proximal landing zone. This two-stage process was completed in the same hospitalization for seven patients and in a more delayed fashion in two patients. Ten patients had concomitant antegrade stent graft delivery; the remaining patient underwent delayed transfemoral delivery. Concomitant procedures included coronary artery bypass grafting and aortic valve replacement in four patients and in one patient, respectively.

In patients who were treated with an endovascular strategy, devices included TAG (W. L. Gore, Flagstaff, Ariz [n = 31]), TX2 (Cook, Bloomington, Ind [n = 12]), and Relay (Bolton Medical, Sunrise, Fla [n = 1]).

Preoperative lumbar drains were placed in hemodynamically stable patients at the discretion of the surgeon. Drains were placed in 52 patients (OAR 60% vs TEVAR or hybrid 11%; $P < .001$). Postoperative prevention of spinal cord ischemia was undertaken for patients whose aneurysms were of the distal arch and in whom the extent of treatment involved a component of the proximal descending aorta. In these patients, for all modalities of treatment, postoperative management was conducted as previously described.[4,5]

The primary outcome of this study was all-cause late mortality. Important additional outcomes included composite outcomes of death and stroke as well as death and major morbidity (stroke, spinal cord ischemia, dialysis requirement, and need for tracheostomy) and, finally, an evaluation of treatment efficacy. Data were collected from clinic visit notes, hospital charts, and imaging studies, and mortality was verified by interrogation of the Social Security Death Index.[2] Follow-up was 100% complete for the primary outcome as of September 2013 (mean follow-up, 66 ± 52 months).

Statistical analysis. Data were analyzed with SPSS software (SPSS, Chicago, Ill). All data are expressed as mean ± standard deviation where applicable. Dichotomous variables were evaluated by χ^2 analysis, continuous variables by one-way analysis of variance. A propensity score