

From the Society for Vascular Surgery

Assessment of aortic wall thrombus predicts outcomes of endovascular repair of complex aortic aneurysms using fenestrated and branched endografts

Mauricio Ribeiro, MD, PhD,^{a,b} Gustavo S. Oderich, MD,^a Thanila Macedo, MD,^c Terri J. Vrtiska, MD,^c Jan Hofer, RN,^a Julia Chini,^a Bernardo Mendes, MD,^a and Stephen Cha, MS,^d Rochester, Minn; and São Paulo, Brazil

ABSTRACT

Objective: The goal of this study was to investigate the correlation between atherothrombotic aortic wall thrombus (AWT) and clinical outcomes in patients treated by fenestrated-branched endovascular aortic repair (F-BEVAR) and present a new classification system for assessment of AWT burden.

Methods: The clinical data of 301 patients treated for pararenal and thoracoabdominal aortic aneurysms (TAAAs) by F-BEVAR was reviewed. The study excluded 89 patients with extent I to III TAAA because of extensive laminated thrombus within the aneurysm sac. Computed tomography angiograms were analyzed in all patients to determine the location, extent, and severity of atherothrombotic AWT. The aorta was divided into three segments: ascending and arch (A), thoracic (B) and renal-mesenteric (C). Volumetric measurements (cm^3) of AWT were performed using TeraRecon software (TeraRecon Inc, Foster City, Calif). These volumes were used to create an AWT index by dividing the AWT volume from the total aortic volume. A classification system was proposed using objective assessment of the number of affected segments, thrombus type, thickness, area, and circumference. Clinical outcomes included 30-day mortality, neurologic and gastrointestinal complications, renal events (Risk, Injury, Failure, Loss of kidney function, End-stage renal disease [RIFLE]), and solid organ infarction.

Results: The study included 212 patients, 169 men (80%) and 43 women (20%), with a mean age of 76 ± 7 years. A total of 700 renal-mesenteric arteries were incorporated (3.1 ± 1 vessels/patient). AWT was classified as mild in 98 patients (46%) and was considered moderate or severe in 114 (54%). There was one death (0.5%) at 30 days. Solid organ infarction was present in 50 patients (24%), and acute kidney injury occurred in 45 patients (21%) by RIFLE criteria. An association with higher AWT indices was found for time to resume enteral diet ($P = .0004$) and decline in renal function ($P = .0003$). Patients with acute kidney injury 2 by RIFLE criterion had significantly higher ($P = .002$) AWT index scores in segment B. Spinal cord injury occurred in three patients (1.4%) and stroke in four (1.9%), but were not associated with the AWT index. Severity of AWT using the new proposed classification system correlated with the AWT index in all three segments ($P < .001$). Any of the end points occurred in 35% of the patients with mild and in 53% of those with moderate or severe AWT ($P = .016$).

Conclusions: AWT predicts solid organ infarction, renal function deterioration, and longer time to resume enteral diet after F-BEVAR of pararenal and type IV TAAAs. Evaluation of AWT should be part of preoperative planning and decision making for selection of the ideal method of treatment in these patients. (J Vasc Surg 2017;■:1-13.)

Endovascular repair of complex aortic aneurysms (EVAR) can be done using fenestrated or branched devices (F-BEVAR) or parallel stent grafts. These techniques require significant device and catheter manipulations that can result in embolic events and vessel injury.^{1,2} Microembolization of cholesterol fragments or

macroscopic particles of thrombus and plaque can result in end-organ damage and loss of renal function, bowel infarction, spinal cord injury (SCI), or stroke.³⁻⁶ The presence of aortic thrombus has been associated with mesenteric and renal ischemia in patients treated by fenestrated endografts.⁷ Irregular thrombus or debris

From the Advanced Endovascular Aortic Research Program, Division of Vascular and Endovascular Surgery,^a Department of Radiology,^c and Department of Epidemiology and Biostatistics,^d Mayo Clinic, Rochester; and the Division of Vascular and Endovascular Surgery, Department of Surgery and Anatomy, Ribeirão Preto Medical School, University of São Paulo, São Paulo.^b This work received a research grant from Cook Medical and W. L. and Associates Gore paid to Mayo Clinic.

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Correspondence: Gustavo S. Oderich, MD, Gonda Vascular Center, Mayo Clinic, 200 First St, SW, Rochester, MN 55905 (e-mail: oderich.gustavo@mayo.edu).

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in the thoracic and abdominal aorta has been identified as a predictor of renal deterioration.^{8,9}

Although aortic thrombus is routinely assessed as part of preoperative planning, a standardized classification has not been reported to evaluate the severity of aortic wall thrombus (AWT) and its effect on specific events. The aim of this study was to correlate measurements of atherothrombotic AWT using objective volume assessment with clinical outcomes in a cohort of patients treated by F-BEVAR and to present a novel classification system that could be useful in clinical practice.

METHODS

The study was approved by the Mayo Clinic Institutional Review Board. All patients consented for participation in this research study. The clinical data of 301 patients treated for pararenal (PRA) and thoracoabdominal aortic aneurysms (TAAAs) with F-BEVAR was entered into a prospective database (2007-2015). The analysis excluded 89 patients with extent I to III TAAAs because of extensive laminated aortic thrombus within the thoracic and visceral segments of the aorta, which precluded assessment of atherosclerotic aortic debris in these segments. We therefore included patients with PRA or extent IV TAAAs who had normal or relatively normal aortic segments in the arch, thoracic aorta, and above the renal arteries.

The clinical data were retrospectively reviewed for demographics, clinical characteristics, cardiovascular risk factors, comorbidity scores, operative details, and outcomes. Early outcomes were defined as occurring within the first 30 days or within the hospital stay if >30 days. Predissmissal computed tomography angiograms (CTAs) were reviewed for evidence of infarction within the hepatic, splenic, or renal parenchyma. Renal infarctions caused by inadvertent occlusion of a main renal artery or accessory renal artery were excluded from analysis.

Assessment of atherothrombotic AWT. Volumetric measurements were performed using CTA and TeraRecon Software (TeraRecon Inc, Foster City, Calif; Fig 1) in nonaneurysmal aortic segments (≤ 4 cm) of the ascending aorta and arch (segment A), descending thoracic aorta (segment B), and renal-mesenteric aorta (segment C). An index was calculated using the TeraRecon automated software volumetric tool with manual correction of tracing of the aortic wall and thrombus to measure AWT burden in the three segments and in the entire length of aorta starting at the aortic annulus and extending 1 cm below the renal arteries. Measurements of AWT volume were performed by an experienced investigator without knowledge of the patient's clinical characteristics and postoperative outcomes.

The infrarenal aorta, which was typically affected by large aneurysm and extensive laminated thrombus, was not measured. Because measuring the volume of

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective single center cohort study
- **Take Home Message:** In 212 patients who underwent fenestrated and branched endovascular aortic repair, aortic wall thrombus volume and quality predicted solid organ infarction, renal function deterioration, and longer time to resume enteral diet.
- **Recommendation:** The study suggests that a qualitative grading system of aortic wall thrombus predicts thromboembolic complications with clinical consequences after fenestrated and branched endovascular aortic repair.

the thin-walled intima, media and adventitia is not possible, an AWT index was calculated by subtracting the volume of the aortic lumen from the total aortic volume, which includes the aortic lumen, any AWT, and the intima, media, and adventitia. A similar volume measurement protocol has been previously validated.¹⁰ Therefore, the AWT index was representative of the solid portion of the aortic wall after excluding the blood volume. The AWT index was presented as a percentage value (AWT index = [total aortic volume – aortic lumen volume/total aortic volume] $\times$ 100). Data were presented as the index to provide a representation relative to the entire aortic wall volume and to take into considerations differences in aortic length and diameter between patients.

AWT classification. To facilitate assessment of AWT in clinical practice, a novel classification was proposed to measure thrombus surface (irregular vs smooth) and extent. To assess thrombus objectively, we used a 0 to 10 scale to score thrombus type, thickness, area of involvement, circumference, and number of affected segments (Fig 2). For purposes of this classification, we analyzed the most severely affected segment of the aorta using axial cuts (Fig 3). The area was selected after examination of the entire length of the aorta. The final score was correlated with the AWT volume index measured in the three aortic segments and in the entire aorta to validate the proposed classification. To minimize inter-rater variability, measurements were done by two investigators in 50 consecutive patients.

Statistical analysis. Data were managed and stored in a MEDIDATA Rave (New York, NY) database and analyzed using SAS 9.1 software (SAS Institute, Inc, Cary, NC). The reporting standards of the Society for Vascular Surgery for endovascular aortic and thoracic repair were used to define stent graft-related outcomes.¹¹ Primary end points were 30-day mortality, neurologic (stroke, SCI), renal (acute kidney injury [AKI] by Risk, Injury, Failure, Loss of kidney function, End-stage renal disease [RIFLE]

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