From the Society for Vascular Surgery

Lower extremity weakness after endovascular aneurysm repair with multibranched thoracoabdominal stent grafts

Julia D. Sobel, BS, Shant M. Vartanian, MD, Warren J. Gasper, MD, Jade S. Hiramoto, MD, Timothy A. M. Chuter, DM, and **Linda M. Reilly, MD,** *San Francisco, Calif*

Objective: **We conducted our study to describe the incidence, presentation, management, risk factors, and outcomes of lower extremity weakness (LEW) after elective endovascular aneurysm repair with multibranched thoracoabdominal stent grafts.**

Methods: **Excluding symptomatic patients and those with aortic dissection, between July 2005 and October 2013, 116 patients with aortic aneurysms were treated in a prospective, single-center trial of multibranched endovascular aneurysm repair. LEW that resolved within 30 days of operation was classified as transient. Persistent LEW was defined as inability to walk or stand 30 days after surgery. Perioperative spinal cord protection measures included bypass as needed to maintain flow to the subclavian and internal iliac arteries, cerebrospinal fluid drainage, and permissive hypertension.**

Results: **Postoperative LEW occurred in 24 of 116 patients (20.6%). In 15 (12.9%), LEW was transient with full recovery. Nine patients (7.7%) had persistent LEW, three with paraparesis and six with paraplegia. Five of 24 patients (21%) awoke from anesthesia with LEW. Symptoms of LEW developed within 72 hours of operation in 14 of 24 (58%). Late-onset LEW (≥72 hours postoperatively) always occurred in the presence of a precipitating hypotensive event (5 of 24; 21%). Univariate analysis showed no association between LEW and Crawford type, staged repair, aneurysm extent, or postoperative endoleak. Baseline glomerular filtration rate <30 mL/min/1.73 m^2 (odds ratio [OR], 4.2; 95% confidence interval [CI], 1.2-14.6; $P = .03$), fluoroscopy time >190 minutes (OR, 3.6; 95% CI, 1.0-12.7; $P = .04$), and sustained hypotension (OR, 2.9; 95% CI, 1.1-7.7; $P = .04$) were identified as independent risk factors for LEW in multivariate analysis.**

Conclusions: **Most episodes of LEW after multibranched endovascular aneurysm repair are transient and do not occur in the operating room. Adjunctive strategies to maintain spinal perfusion, including cerebrospinal fluid drainage and permissive hypertension, may help prevent permanent LEW. (J Vasc Surg 2015;61:623-9.)**

Spinal cord ischemia (SCI) is a serious complication of surgical treatment of the thoracoabdominal aorta. The consequences of SCI include loss of independence, diminished quality of life, need for long-term assistance, risk for development of late infectious complications, and, for those with paraplegia, an abbreviated life expectancy.[1,2] Open surgical repair of thoracoabdominal aortic aneurysms (TAAAs) is associated with variable rates of SCI, with patient-specific factors, such as aneurysm extent and comorbid conditions, being major determinants of SCI risk.[3,4] High-volume centers using contemporary spinal protection techniques report SCI rates approaching 4% after open surgical treatment of extensive TAAAs.[5,6] However, population-based studies suggest that the morbidity and mortality of open surgical repair are substantially higher.[7,8]

Theoretical advantages of endovascular repair of TAAA include no interruption of aortic or visceral perfusion, less hypotension, less blood loss, and lower rates of cardiopulmonary complications.[9,10] Although SCI is a recognized complication of endovascular TAAA repair, most of what is known about the risks of SCI and its management is extrapolated from endovascular treatment of thoracic aortic aneurysms.[11,12] Unlike an isolated, proximal thoracic aortic aneurysm treated with shorter stent grafts, TAAAs are typically longer and require coverage of segmental arteries to the lower thoracic and upper lumbar spine.

During the last 8 years, we have been treating extensive aortic aneurysms in a prospective clinical trial using a multibranched aortic endograft technique. Because SCI is manifested clinically as lower extremity weakness (LEW), our objective was to describe the incidence, presentation, management, and clinical outcomes of LEW. We also sought to identify risk factors for LEW after multibranched endovascular repair.

From the Division of Vascular and Endovascular Surgery, University of California, San Francisco.

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Reprint requests: Julia D. Sobel, BS, Division of Vascular and Endovascular Surgery, University of California, San Francisco, 400 Parnassus Ave, Ste A-581, Box 0222, San Francisco, CA 94143 (e-mail: julia.sobel@ucsfmedctr.org).

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METHODS

Between July 2005 and October 2013, 127 patients were enrolled into a prospective clinical trial of repair of thoracoabdominal and pararenal aortic aneurysms with a modular multibranched aortic endograft (Cook Australia, Brisbane, Australia). A physician-sponsored investigational device exemption was approved by the Food and Drug Administration and the Committee on Human Research at the University of California, San Francisco. All patients gave informed consent. The inclusion criteria and surgical technique have been previously described.[13-15] Briefly, modular aortic components are placed through an open femoral exposure. Four fixed cuffs are bridged with stent grafts to the visceral and renal arteries inserted through a brachial approach. The cuffs allow continued prograde perfusion of the aneurysm, viscera, and segmental spinal arteries until the final branch is deployed. Patients without suitable arterial anatomy for repair or those with an abbreviated life expectancy were excluded from the study. As emergent repair is a known risk factor for LEW, 11 patients who presented with rupture, symptomatic aneurysms, or dissection were excluded from the analysis.[16,17]

Patient demographics, comorbid conditions, previous surgical history, biochemical profile, imaging results, procedural details, and adverse events were recorded prospectively. LEW was a predefined adverse event and was assessed at all postoperative visits. *Paraplegia* was defined as the inability to stand without assistance, despite motor function against gravity when supine. Patients who required assistance to stand or to walk were defined as having *paraparesis*. The onset of LEW was defined as *intraoperative* if the patient awoke from anesthesia with a neurologic deficit or *postoperative* if the patient had a normal finding on lower extremity neurologic examination on awakening from anesthesia. The duration of LEW was considered *transient* if the neurologic deficit resolved within 30 days from the day of surgery or *persistent* if any neurologic deficit, regardless of severity, lasted beyond 30 days.

Our spinal protection protocol includes preoperative permissive hypertension and intravenous hydration the night before the procedure. Permissive hypertension is induced by reducing antihypertensive medication to aim for a systolic blood pressure of 180 mm Hg with preservation of beta blockade if the patient is taking this medication chronically. If the planned aneurysm repair requires covering the origin of the subclavian or hypogastric vessels, prograde flow is preserved by performing a bypass to the vessel in a staged fashion whenever possible. A spinal drain is placed preoperatively to drain cerebrospinal fluid (CSF) at 10 mL/h intraoperatively, with an additional 10 mL of drainage just before the insertion of the final branch of the stent graft. CSF is drained at 10 mL/h for at least the first 24 hours postoperatively. Permissive hypertension is preserved for the first 3 months postoperatively by titration of antihypertensive medications.

Patients identified with LEW are treated with prompt additional CSF drainage (10-20 mL) that is titrated to clinical effect. Patients without an improvement in their examination findings within 5 minutes are treated with additional CSF drainage (up to 40-50 mL during 60 minutes) until symptoms improve or the onset of headache. If hypotension is present, it is concomitantly corrected with administration of intravenous fluids. Vasopressors (Neo-Synephrine) are administered only if the patient remains both symptomatic and hypotensive despite these maneuvers, with a target systolic blood pressure of 180 mm Hg.

Follow-up for all patients included a clinical evaluation with computed tomography angiography imaging at 1 week, 6 months, and 12 months postoperatively, then yearly thereafter. A comparison between the preoperative computed tomography angiography image and the first postoperative study was used to calculate the extent of endograft coverage. With three-dimensional reconstructive software, a single centerline measurement from the left subclavian artery orifice to the aortic bifurcation was obtained and compared against centerline measurements of the endograft length to the aortic bifurcation (OsiriX MD; Pixmeo, Bernex, Switzerland). In patients with previous aortic repair, we measured both length of the remaining untreated native aorta and length of the surgically repaired aorta separately. Extent of coverage is presented as length of endograft (millimeters), the ratio of endograft length to total aortic length, and length of uncovered native aorta.

Statistical analysis was performed with Stata/SE 13.1 (StataCorp LP, College Station, Tex). Nominal variables were analyzed with a Pearson χ^2 test unless the number of observations mandated use of a Fisher exact test. Interval variables were analyzed by a one-way analysis of variance. Nonparametric analysis of ordinal variables was performed with Wilcoxon rank sum test. A P value $< .05$ was considered statistically significant. Logistic regression was used to test for predictors of LEW. Continuous variables were dichotomized by the top quartile of each variable's range. Predictors on univariate analysis that were found to be significant ($P < .10$) were included in a stepwise logistic regression model using forward selection.

RESULTS

Patient demographics. The mean age for this cohort of patients (N = 116) was 72 years (range, 42-87 years), and 74% (86 of 116) were male. Common comorbid conditions included pulmonary disease (57 of 116; 49%), renal insufficiency (glomerular filtration rate [GFR] <30 mL/min/1.73 m^2, 24 of 116; 21%), and cardiovascular disease (65 of 116; 56%; Table I). Nearly half of all patients had previous aortic surgery (51 of 116; 44%), most with open surgical repair (41 of 116; 35%).

Anatomy and procedural characteristics. Forty-one percent of patients had aneurysms that required extensive coverage of the thoracic aorta (extent I, II, III, and V; 47 of 116; Table II). Most procedures were performed under general anesthesia (96 of 116) with preoperative placement of a CSF drain (112 of 116). All four patients without a CSF drain had paravisceral aneurysms, and none