A contemporary experience of open aortic reconstruction in patients with chronic atherosclerotic occlusion of the abdominal aorta

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Objective: **To examine and report surgical results from a contemporary experience of open abdominal aortic reconstruction in patients with chronic atherosclerotic abdominal aortic occlusion (CAAAO).**
Methods: **Between January 1999 through May 2010, 54 patients with CAAAO were identified and retrospectively reviewed. CAAAOs were categorized into infrarenal aortic occlusions (IRAOs) and juxtarenal aortic occlusions (JRAOs) based on superior extension of thrombus and requirement for supra-renal aortic clamping to repair. Morbidity, mortality, hospital stay, and operative variables were assessed. The χ^2 or Fisher test and the Wilcoxon rank sum test were used to compare demographic and operative variables between two aortic occlusion groups (IRAO and JRAO). Univariate and multivariate analyses were performed to assess factors associated with surgical outcomes and hospital stay. The Kaplan-Meier method was used to calculate survival and patency rates.**
Results: **Fifty patients underwent aortic reconstructions with aorto-bifemoral or iliac bypass, and three underwent a remote axillo-femoral bypass procedure. There were 35 (64.8%) males, and 19 (35.2%) females. Median age was 51.9 years (range, 32-72 years). Of the two CAAAO groups, there were 20 IRAOs and 33 JRAOs. Aorto-renal thromboendartectomy was performed in 26 (49.1%) patients; 26 (75.8%) among JRAOs versus 1 (5%) of IRAOs ($P < .01$). Proximal aortic clamps were required in 28 (85%) of JRAOs and 3 (15%) of IRAOs ($P < .01$). Thirty-day and in-hospital mortality was zero. Median length of hospital stay was 7 days (range, 4 to 66 days), and median intensive care unit length of stay was 3 days (range, 1-22 days). Complications included cardiopulmonary dysfunction in four (8%), postoperative renal insufficiency in 10 (18.9%), and other postoperative complications in 15 (28.3%). All 10 with renal insufficiency recovered renal function to baseline creatinine or a creatinine value <1.1 mg/dL. Mean increases in right and left ankle-brachial indices were 0.54 ± 0.25 and 0.59 ± 0.22, respectively. On univariate analysis, coronary artery disease and African American race were predictors of postoperative complications ($P = .048$). Age was significantly associated with total complications. Patients with postoperative complications and/or renal insufficiency were older than those without such complications ($P = .02$) Independent predictors of prolonged hospital stay were intraoperative blood replacement ($P = .003$), postoperative complications ($P < .01$), and postoperative renal insufficiency ($P < .01$). Prolonged intensive care unit stay was predicted by JRAO ($P = .04$), postoperative complications ($P = .02$), and postoperative renal insufficiency ($P = .013$). Survival at 3, 5, and 7 years were 86.6%, 76.5% and 50.9%, respectively. The reduced survival rates were predicted by previous myocardial infarction and existing coronary artery disease ($P < .01$).**
Conclusion: **Abdominal aortic reconstruction is a safe method for treating CAAAO with low associated morbidity and mortality. Aorto-renal thromboendartectomy with supra-renal aortic clamping and aortic replacement remains an effective treatment for those with significant pararenal aortic disease, and can be performed without significant renal impairment. (J Vasc Surg 2010;52:1164-72.)**

Chronic atherosclerotic abdominal aortic occlusion (CAAAO) is a rare form of aortic disease usually found in patients with a history of heavy tobacco use.[1,2] This condition was first described by Leriche[3] in 1923, which culminated in a series of reports followed by description of the particular syndrome.[3-5] Patients with CAAAO commonly present with severe claudication and occasionally with more advanced lower extremity ischemia.[6,7] Of greatest concern are the less common, but potentially fatal, complications of progressive ascending aortic thrombosis in the untreated.[8,9]

Historically, direct open surgical approaches to the abdominal aorta have been advocated to relieve lower extremity ischemia and eliminate the risk of aortic thrombus propagation into the paravisceral aortic segment.[10-13] Alternatives to direct abdominal aortic reconstruction have been proposed with the use of remote bypass procedures and other inflow sources to treat patients with abdominal aortic occlusion.[14-16] Successful reports of these techniques have brought into question the true risk of ascending aortic thrombosis in the setting of chronic aortic occlusion

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(CAO).[16] Thus far, endovascular approaches have been reported but are currently not well established as a credible treatment option.[17]

Controversy surrounding ascending aortic thrombosis in CAO and the most appropriate surgical management still remains. Few series are available that provide a current review of techniques and outcomes from direct abdominal aortic reconstruction. Thus, we sought to describe our contemporary experience and report early surgical results.

METHODS

Between January 1, 1999 and May 2010, clinical records of all patients with CAAAO at Louisiana State University Health Science Center in Shreveport, LA were reviewed and retrospectively analyzed after approval from the Institutional Review Board. Patients with CAAAO were identified using procedure code identifiers 39.35 and International Classification of Diseases, Ninth Revision codes 444.0 and 444.1. Manual medical chart review and electronic record queries were performed and all clinical data were entered into a Microsoft Access data base (2007, Microsoft, Redmond, Wash). For all patients, the diagnosis of CAAAO was determined by clinical evaluation and confirmed by either digital subtraction angiography or computed tomography. Those with acute embolic/thrombotic aortic occlusion and aortic aneurysms were excluded. Patients were followed up at mean of 42.9 months (range, 2.5-116.7 months) by routine clinic visits and telephone interviews. The State of Louisiana Department of Health and Hospitals Center for Health Statistics provided the survival status on missing subjects. Primary end points include in-hospital and 30-day mortality. Secondary endpoints include cardiopulmonary and renal morbidity, postoperative complications, combined adverse event rate and length of stay (intensive care unit [ICU] and hospital), graft patency, and survival. Significant predictors of adverse outcomes were determined among patient characteristics and operative variables.

Patterns of CAAAO: infrarenal aortic occlusion and juxtarenal aortic occlusion

Patient categories/definitions. CAAAOs were characterized as either infrarenal aortic occlusion (IRAO) or juxtarenal aortic occlusion (JRAO), based on the level of proximal extension of chronic athero-thrombotic material and level of disruption of the contrast column on computed tomographic angiogram (CTA) or standard digital subtraction angiography. IRAOs were defined as athero-thrombotic occlusion at the terminal aortic level (between the aortic terminus and inferior mesenteric artery) or in the mid abdominal aorta that permitted infrarenal clamping above the occlusion level. IRAOs were performed with infrarenal aortic clamps in most cases, but in some cases, the presence of juxtarenal atherosclerosis extending above the level of occlusive thrombus mandated suprarenal clamping. Patients were identified as JRAOs when the occlusive process encroached to the level of one or both main renal arteries requiring proximal aortic clamping.

Preoperative variables/patient characteristics. Baseline variables collected include: age, gender, ethnicity, and CAAAO type. Preoperative comorbodities were coronary artery disease (CAD), defined as previous myocardial infarction (MI), cardiac stress testing evidenced by demonstrable defects on nuclear imaging, electrocardiogram evidence of MI confirmed by staff cardiologist, previous coronary bypass and grafting or Percutanueous transluminal coronary angioplasty procedure. Chronic obstructive pulmonary disease or pulmonary insufficiency was present in all patients requiring supplement oxygen at home, those on scheduled bronchodilator inhalers, with a diagnosis of chronic lung disease, and documented abnormal pulmonary function test. Congestive heart failure was present in all those with cardiac testing with an associated ejection fraction less than <30%. Other baseline variables observed on the patients were preoperative renal insufficiency, defined as a serum creatinine (Cr) level >1.5 mg/dL, smoking (current or past in pack-years), diabetes, hypertension (diastolic blood pressure greater than 90 mm Hg or on one or more antihypertensive medications), hyperlipidemia, history of deep vein thrombosis, malignancy, and chronic renal failure. Severe claudication was present in those with pain on exercise or walking in the lower extremities relieved by rest, which was considered lifestyle-limiting to the patient. Advanced ischemia was defined as non-healing wounds or ulcerations, gangrene, or rest pain in those with an ankle-brachial index (ABI) <0.5 or an absolute ankle pressure <70 mm Hg. Demographic data are summarized in Table I.

Operative variables/procedures. Aortic reconstruction included aorto-femoral or iliac bypasses (ABF-I) using gelatin sealed polyester prosthesis. Fourteen × 7 mm bifurcated grafts were employed in most operations. Procedures consisted of 1) ABF-I only and 2) ABF-I with pararenal thrombectomy with or without aortorenal thromboendarterectomy (AR-TEA) noted in Table II. Aortic clamp positions and ischemic intervals in minutes were recorded. Aortic clamping was infrarenal (IRC); interenal, defined as above one of the other main renal arteries; supra-renal, defined as above both renal arteries; supra-mesenteric, or supra-celiac. Interenal clamps were considered as suprarenal clamps. Early in the experience, manual suprarenal aortic occlusion and thrombectomy extraction was employed in five patients with juxtarenal aortic occlusion. Three patients were deemed high risk for aortic reconstruction and were treated with extra anatomic axillo-femoral bypasses. In one, a large lower extremity wound infection precluded aortic grafting. Two were considered high risk for open surgery as a result of severe cardiac disease. Operative times were recorded in minutes. Intraoperative transfusions were accounted for in units transfused (cell saver and banked blood) during the procedure.

Exposure, reconstructive techniques, and operative management

Exposure was through a midline xipho-pubic incision followed by an infracolic aortic approach. Pararenal aortic

Table I. Patient characteristics: comparisons[a] between juxtarenal and infrarenal aortic occlusion patients – number (%) or median, mean ± SD

Variable	*All (n = 54)*	*IRAO (n = 20)*	*JRAO (n = 34)*	P *value*
Demographics				
Age (years)	51.9, 51.0 ± 8.4	51.0, 51.3 ± 8.2	52.3, 52.1 ± 8.6	.70
Gender (male)	35 (64.8)	12 (60.0)	23 (67.6)	.57
Ethnicity				.74
African American	12 (22.2)	5 (25.)	7 (20.6)	
Caucasian	42 (77.8)	15 (75.0)	27 (79.4)	
Smoking (preoperative)	54 (100)	20 (100.0)	34 (100.0)	N/A
Hypertension	47 (87.0)	16 (80.0)	31 (91.2)	.40
Hyperlipidemia	26 (51.0)	12 (60.0)	14 (45.2)	.30
Diabetes	8 (15.1)	3 (15.0)	5 (15.2)	.99
Coronary artery disease	28 (51.8)	10 (50.0)	18 (52.9)	.83
Previous myocardial infarction	18 (33.3)	6 (30.0)	12 (35.3)	.69
Chronic obstructive pulmonary disease	11 (20.4)	3 (15.0)	8 (23.5)	.51
Renal insufficiency	2 (3.7)	0 (0.0)	2 (5.9)	.52
Congestive heart failure	3 (5.6)	0 (0.0)	3 (0.0)	.29
Deep venous thrombosis	1 (1.8)	0 (0.0)	1 (2.9)	.99
Infrainguinal occlusive disease	16 (30.8)	5 (25.0)	11 (34.4)	.48
Claudication	36 (66.0)	17 (85.0)	19 (97.1)	.99
Critical limb ischemia	18 (33.0)	3 (15.0)	15 (44.1)	.04[b]
Critical limb ischemia type				.21
Rest pain	9 (50.0)	3 (100.0)	6 (40.0)	
Non-healing wound	9 (50.0)	0 (0.0)	9 (60.0	
Hemodynamics				
Preoperative ABI (right)	0.40, 0.39 ± 0.17	0.46, 0.44 ± 0.12	0.34, 0.37 ± 0.19	.13
Preoperative ABI (left)	0.45, 0.39 ± 0.18	0.48, 0.43 ± 0.16	0.37, 0.36 ± 0.19	.26
Postoperative ABI (right)	1.0, 0.92 ± 0.22	1.00, 0.96 ± 0.14	1.01, 0.90 ± 0.26	.91
Postoperative ABI (left)	1.0, 0.96 ± 0.19	1.02, 0.96 ± 0.24	1.00, 0.96 ± 0.16	.59

ABI, Ankle-brachial index; *IRAO,* infrarenal occlusion patients; *JRAO,* juxtarenal aortic occlusion.
[a]Calculated on non-missing values.
[b]Significant at 5% level (.01 < *P* value < .05).

dissections consisted of complete left renal vein mobilization, sharp exposure of all renal arteries, and incising the anterior aortic neural and lymphatic tissue encasing the superior mesenteric artery with bilateral division of the diaphragmatic crura.[18] Circumferential mobilization of the superior mesenteric artery with supramesenteric clamping was necessary in instances of extensive pararenal thrombus or in cases when more detailed renal endarterectomy beyond the renal artery origin was anticipated. AR-TEA was utilized to remove chronic adhesive thrombus from the aortic wall surface and lumen.

IRAOs underwent sub-renal aortic anastomosis within 1.5 to 3 cm from the immediate infrarenal clamp position after excision of short segment of infrarenal aorta avoiding the need for thrombectomy. In JRAOs, reconstructions were performed either end-to-end to the infrarenal aorta, the juxtarenal aorta after AR-TEA, or to the infrarenal aorta after longitudinal aortotomy, AR-TEA and primary aortic closure. Grafts sewn directly to the juxtarenal aorta were sewn within 1.0 to 2.0 cm of the lowest main renal artery, and frequently, sutures were placed either into or around the renal artery orifices. With the later technique, the aortotomy was extended up to the base or beyond the superior mesenteric artery origin on the left lateral side of the aortic wall followed by AR-TEA. Aortic primary closure was routinely performed with 4-0 polyprolene; the suture-line was discontinued at a level directly below the renal vein, allowing a safe clamp transition and optimal exposure for reconstruction. In some JRAOs, engraftment to the infrarenal aorta was performed after manual thrombectomy and or thromboendarterectomy. In these, if the clamp could be moved for an infrarenal anastomosis. The preferred method of treatment was to divide the aorta just beneath the renal arteries with a suprarenal clamp facilitating AR-TEA and aortic replacement.

An important technical goal in JRAOs was to completely remove all adherent chronic thrombus from the pararenal aorta. In patients with chronic aortic thrombus impinging on the renal artery margins, AR-TEA was sufficient in removing adherent thrombus around the renal orifices. When thrombus and or atherosclerotic plaque extended further out into the renal arteries, an extended AR-TEA as part of the aortic wall or renal artery bypass was required and considered as a renal revascularization procedure.

Intraoperatively, continuous cell saver auto-transfusion was employed. Prior to aortic clamping, all patients were administered 70 to 100 U/kg of intravenous heparin. Renal function protection routinely included 12.5 to 25 g of Mannitol, followed by 40 to 60 mg of Lasix administered intravenously to induce diuresis 10 to 15 minutes prior to suprarenal cross-clamping. The renal arteries were intermittently flushed with cooled heparin saline (4 U/cc).

Table II. Operative variables: comparisons[a] between juxtarenal and infrarenal aortic cclusion patients – number (%) or median, mean ± SD, range*

Variable	*All (n = 53)*	*IRAO (n = 20)*	*JRAO (n = 33)*	P *value*
Operative procedure				<0.01**
Aorto-femoral bypass (pararenal thrombectomy)	30 (56.6)	1 (5.0)	29 (87.9)	
Aorto-femoral bypass (alone)	20 (38.0)	19 (95.0)	1 (3.0)	
Axillo-bifemoral bypass	3 (5.7)	0 (0.0)	3 (9.1)	
Aorto-renal thromboendarterectomy	26 (49.1)	1 (5.0)	25 (75.8)	<0.01**
Clamp position				<0.01**
Infrarenal	19 (38.0)	17 (85.0)	2 (6.7)	
Inter-renal	5 (10.0)	2 (10.0)	3 (10.0)	
Suprarenal	20 (40.0)	1 (5.0)	19 (63.3)	
Supramesenteric	4 (8.0)	0 (0.0)	4 (13.3)	
Supraceliac	2 (4.0)	0 (0.0)	2 (6.7)	
Proximal reconstruction				<0.01**
End-end infrarenal aorta	20 (40.0)	14 (70.0)	6 (20.0)	
End-side infrarenal aorta	3 (6.0)	3 (15.0)	0 (0.0)	
End-end juxtarenal aorta	15 (30.0)	3 (15.0)	12 (40.0)	
End-end infrarenal aorta (primary aortic closure)	12 (24.0)	0 (0.0)	12 (40.0)	
Renal artery revascularization	8 (15.1)	1 (4.8)	7 (21.9)	0.13
Bypass	2 (3.8)	0 (0.0)	2 (6.2)	0.51
Endarterectomy	5 (9.4)	0 (0.0)	5 (15.6)	0.14
Reimplantation	1 (1.9)	1 (4.8)	0 (0.0)	0.99
Operative time (minutes)	348.5, 360.8 ± 104.4, 160-651	345, 357 ± 84.6, 255-600	350, 363 ± 115.4, 160-651	0.97
Renal or mesenteric ischemic time >0	26 (54.2)	3 (15.8)	23 (76.4)	<0.01**
Renal ischemic time[b]	22.5, 22.5 ± 10.2, 5-47	30, 29 ± 8.5, 20-37	22, 21.7 ± 10.2, 5-47	0.22
Mesentric ischemic time[b]	24, 23.7 ± 9.3, 10-36	10 (n = 1)	27, 26 ± 7.7, 14-36	0.13
Blood replace save (units)	1.0, 1.9 ± 2.0, 0-9	1.0, 1.6 ± 1.5, 0-5	1.0, 2.1 ± 2.3, 0-9	0.64
Intraoperative blood banked (units)	0, 1.0 ± 1.5, 0-8	0, 0.7 ± 1.0, 0-3	0.5, 1.2 ± 1.8, 0-8	0.32

IRAO, Infrarenal occlusion patients; *JRAO,* juxtarenal aortic occlusion.
[a]longitudinal pararenal aortototomy with primary aortic closure.
[b]Among patients with non-zero ischemic times.
*Significant at 5% level (0.01 < *P*-value < 0.05).
**Significant at 1% level (*P*-value <0.01).

Morbidity/Mortality. Mortality was defined as death in the hospital or within 30 days from operation. Cardiopulmonary and renal dysfunction were defined as followed:

- Cardiac morbidity was considered postoperative MI, defined by elevation of troponin values and electrocardiogram evidence of myocardial ischemia confirmed by a staff cardiologist, or cardiac arrhythmias requiring medical treatment. Pulmonary insufficiency after surgery was present in patients requiring prolonged mechanical ventilator support for more than 72 hours, requirement of reintubation for the diagnosis of pulmonary failure, or the development of pneumonia confirmed by clinical and radiologic data. These variables were combined as a single cardiopulmonary postoperative complication outcome.
- Postoperative renal insufficiency (RI) was defined by a serum creatinine rise of 0.5 mg/dL or greater after the procedure. Renal dysfunction was also assessed using The Modification of Diet in Renal Disease study equation to calculate changes in glomerular filtration rate (GFR; mL/min per 1.73 m^2).[19,20] Recovery of renal function was based on serum Cr in mg/dL values measured at discharge; renal function recovery was defined as "recovered" if the serum Cr levels returned to baseline or serum Cr <1.2 mg/dL.

Minor non-cardiopulmonary postoperative complications were collected and are summarized in Table III. Postoperative complications were collated in a single variable, excluding postoperative renal insufficiency, which was analyzed independently. Total postoperative complications were defined as all postoperative complications and or the development of postoperative renal insufficiency.

Follow up

Patients returned at 2 to 4 weeks postoperatively, followed by a 6-month clinic visit. Graft surveillance and longitudinal follow up was insured by an annual scheduled appointment in the university vascular clinic with an affili-

Table III. Postoperative outcomes and their significant associations[a] with demographic/operative variables

Outcome	*Number (%) or mean ± SD (range), median*	*Significant associations*	P *value*
Mortality	0 (0.0)		
Cardiac-pulmonary complications	4 (8.2)		
Pulmonary insufficiency	3 (6.1)		
Myocardia infarction	1 (2.0)		
Renal insufficiency	10 (18.9)		
Temporary dialysis[b]	2 (4.1)		
Permanent dialysis	0 (0.0)		
Minor postoperative complications	15 (30.0)	Ethnicity (African American)	.048
		Coronary artery disease	.048
Wound infection	4 (8.2)		
Deep venous thrombosis	1 (2.0)		
Ileus	4 (8.2)		
Anemia	1 (2.0)		
Colitis	3 (6.1)		
Total complications[c]	23 (43.4)	Age (55 ± 8.0 vs 49.5 ± 8.4 years)	.02
Length of hospital stay (days)	9.8 ± 9.5 (4-66), 7	Intraoperative blood replace	.001
Intensive care unit length of stay (days)	4.0 ± 3.1 (1-22), 3	Age	.03
		Aortic occlusion level	.003
		Operative procedure	.008
		Clamp placement	.006
		Proximal anastomosis	.05
		Aortic renal endarterectomy	.014
		Renal/mesenteric ischemic time >0	.02
		Intraoperative blood replace	.03
Change in right ABI	0.54 ± 0.25 (0.0-1.04), 0.58		
Change in left ABI	0.59 ± 0.22 (0.12-1.10), 0.58		
Graft patency (months) n = 49	39.1 ± 21.4 (2.5-100.2), 38.9		
1-year primary patency	98.0%		
6-year primary patency	73.5%		
Survival follow up (months) n = 52	42.9 ± 24.0 (2.5-116), 38.2		
3-year survival rate[d]	86.6%	History of myocardial infarction	.008
5-year survival rate[d]	76.3%	History of coronary artery disease	.005
7-year survival rate[d]	50.9%	History of coronary artery disease	<.01

[a]Calculated on non-missing values.
[b]Included in postoperative complication.
[c]Postoperative complications and/or postoperative renal insufficiency.
[d]Calculated by the Kaplan-Meier method.

ated accredited vascular laboratory (Intersocietal Commission for the Accreditation of Vascular Laboratories). Graft patency was determined by evidence of a palpable graft pulse at the femoral artery exposure sites in the groins and or palpable pedal pulses at each current visit. Objective evidence was obtained in 38 patients with non-invasive arterial studies and in three by aortic ultrasounds. Phone call interviews were performed at the end of the study to determine clinical status and survival information by a staff vascular surgeon. Only eight patients did not have current follow up. In these, the state health statistics bureau assisted in determining survival status.

Statistical analysis. All continuous variables are represented with the mean ± standard deviation or median (range). Categorical variables are listed as frequencies and percentages. The χ^2 or Fisher test was used to determine association between a categorical outcome and a categorical factor. The Wilcoxon rank sum test was used to determine association between a categorical outcome and a numeric factor, while the Spearman rank correlation coefficient was used to determine association between a numeric outcome and a numeric factor. Multiple logistic regression and general linear regression analyses were used to determine independent significant factors for categorical and numeric outcomes, respectively. The Kaplan-Meier method was used to calculate patient survival and graft patency rates. The log rank test of the proportional hazard model was used to determine factors significantly associated with patient survival or graft patency. A 5% level of significance was used for all statistical tests. SAS Version 9.2 (Cary, NC) was used for statistical computing.

RESULTS

Demographics/patient characteristics and preoperative comorbidities. The patients were classified into two CAAAO groups; 34 and 20 patients belong to the JRAO and IRAO groups, respectively (Table I). Only one patient was not treated surgically at the time of data collection and was excluded from final analysis. There were 35 men (64.8%) and 19 women (35.2%); median age was 51.9 years (range, 32-72 years). The IRAO and JRAO groups were compared on patient characteristics, preoperative comorbidities and hemodynamic measures listed in Table I. Major comorbidities include smoking (100%), CAD (51.8%), pulmonary insufficiency or chronic obstructive pulmonary disease (20.4%), renal dysfunction (serum Cr >1.5 mg/dL; 3.7%), and diabetes (15.1%). Severe disabling claudication was present in 36 patients (66%), 18 (33%) had evidence of advanced ischemia of lower extremities, and one patient in the pararenal occlusion group presented with ascending aortic thrombosis in acute renal failure. Critical limb ischemia was present in 44% (15/34) of JRAOs and 15% (3/20) of IRAOs (P = .04). Hemodynamic evaluations with preoperative non-invasive arterial studies revealed a median ABI of 0.40 and 0.45, respectively, between the right and left lower extremities for the two groups combined. There were no significant differences in pre- and postoperative ABIs between the IRAOs and JRAOs, as shown in Table I.

Surgical/operative data. Fifty-three patients were treated surgically; 50 underwent aortic reconstructions with ABF-I. Overall, ABF-I with pararenal thrombectomy was performed in 30 (56.6%) patients (Table II). Operative data are compared in Table II, between the 20 IRAO and 33 JRAO patients. Pararenal thrombectomy was performed in 29 (87.9%) of JRAOs and in only one patient (5.0%) in the IRAO group. In the JRAO group, one patient (3%) had ABF with IRC without evidence of thrombectomy. The JRAO and IRAO groups differed significantly on operative procedures performed (P < .01). AR-TEA was required in 26 (49.1%) patients, 25 of 30 (75.8%) among the JRAOs and 1 of 20 (5%) among the IRAOs (P < .01). The two occlusion groups also differed significantly on aortic clamping (P < .01) as outlined in Table II.

For the IRAOs, 17 of 20 (85%) had ABF only with IRC, two (10%) underwent ABF only with interrenal clamps, and one patient (5%) underwent ABF with suprarenal clamp. The JRAO group had mostly (19 or 63.3%) suprarenal clamps. Proximal reconstruction was likewise significantly different between the two occlusion groups (P < .01). For those requiring suprarenal clamping with non-zero ischemic intervals, median renal ischemic time was 22.5 minutes (range, 5-47 minutes), and the median mesenteric ischemic time was 24 minutes (range, 10-36 minutes). Renal artery revascularization was required in 15.1% (8/53); one (4.8%) IRAO and seven (21.9%) JRAO patients (P = .13). There were no observed significant differences between the IRAO and JRAO groups on proportion of patients requiring renal revascularization, or on average operative time and number of units of blood replaced. Median operative time and transfusion requirements (blood replacement) are summarized in Table II.

Surgical results. Postoperative outcomes and their observed significant associations (using separate univariate analyses) with demographic and operative variables are shown in Table III. Thirty-day and in-hospital mortality was zero. Complications included cardiopulmonary dysfunction in four (8.2%) patients, (one MI and three had pulmonary insufficiency), postoperative RI in 10 (18.9%), and minor postoperative complications in 15 (30%) patients listed in Table III. Total postoperative complications were present in 23 of 53 (43.4%) patients. Median length of hospital stay (LOS) was 7 days (range, 4-66 days), and median ICU length of stay was 3 days (range, 1-22 days).

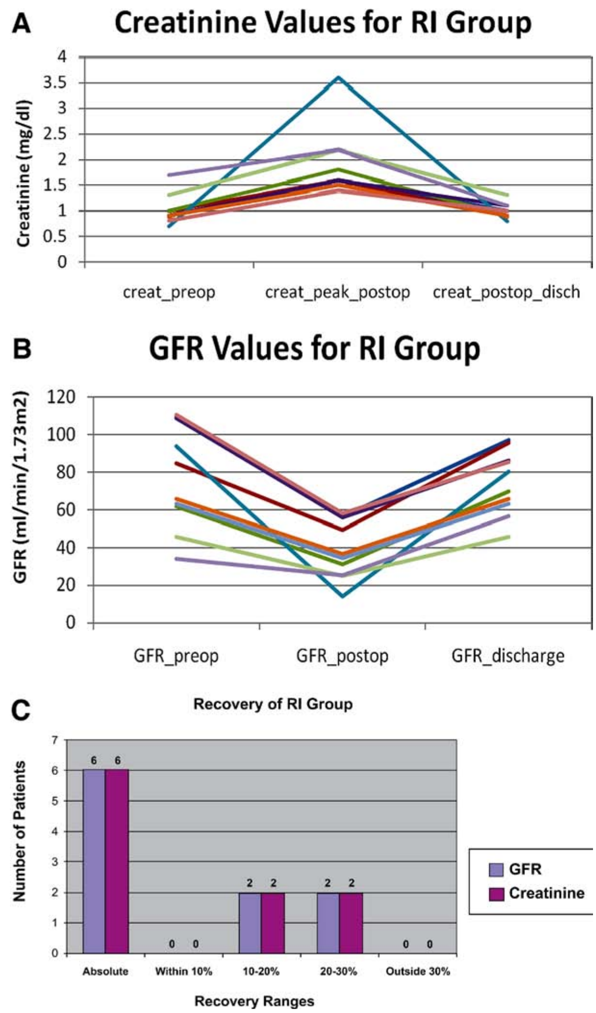

Fig 1. A, A graph of all patients experiencing renal postoperative renal insufficiency, defined as Cr ≥0.5 mg/dL. Three point trends of preoperative Cr values, peak postoperative values, and Cr values at discharge are represented. **B,** Graph of all patients experiencing postoperative renal insufficiency calculating glomerular filtration rate (*GFR*) using MDRD study equation (mL/min per 1.73 m^2). Three point trend of preoperative GFR values, GFR reductions postoperatively, and values at discharge are represented. **C,** GFR and Cr values for renal functional recovery expressed in percent from baseline values. *RI*, Renal insufficiency.

Renal insufficiency and functional recovery

Postoperative RI occurred in 18.9%, 3 of 20 (15%) were IRAOs and 7 of 34 (21.2%) were JRAOs (P = .73). All 10 with RI recovered renal function to baseline creatinine or a

Table IV. Associations[a] of complication outcomes with hospital and intensive care unit stays (univariate analyses)

Complication outcome	*Hospital stay (group median)*	P *value*	*Intensive care unit stay (group median)*	P *value*
Cardiac-pulmonary complication	Yes (n = 4); 24 No (n = 45); 6.5	.006	Yes (n = 4); 75 No (n = 45); 3	.001
Postoperative complication	Yes (n = 15); 10 No (n = 35); 6	.02	Yes (n = 15); 5 No (n = 35); 3	.03
Postoperative renal insufficiency	Yes (n = 10); 10 No (n = 44); 6	.03	Yes (n = 10); 4.5 No (n = 44); 3	.02
Total postoperative complication[b]	Yes (n = 23); 10 No (n = 31); 6	.003	Yes (n = 23); 4 No (n = 31); 3	.003

[a]Calculated on non-missing values.
[b]Postoperative complication and/or postoperative renal insufficiency.

Table V. Independent significant prognostic factors for lengths of hospital and intensive care unit stay (multivariate analysis)

Length (days) of	*Median, mean ± SD, range*	*Significant factors*	*Adjusted* P *value*
Hospital stay	7, 9.8 ± 9.5, 4-66 days	Intraoperative blood replace	.003
		Postoperative complications	<.01
		Postoperative renal insufficiency	<.01
		Total complication	<.01
Intensive care unit stay	3, 4.0 ± 3.1, 1-22 days	JRAO	.04
		Postoperative complication	.02
		Postoperative renal insufficiency	.013
		Total complication	.04

Cr value ≤1.1 mg/dL (Fig 1A). Calculated changes in GFR are illustrated in Fig 1B. GFR was restored to a level within 30% of baseline prior to dismissal in all patients (Fig 1C).

Of two patients (4.1%) requiring temporary dialysis, only one actually developed acute renal failure after repair, and one patient presented in renal failure secondary to ascending aortic thrombosis. Renal function was rescued from dialysis several months later in both. There were no factors that were significantly associated with RI.

Complications and LOS

Minor postoperative complication(s) were significantly associated with ethnicity and CAD. The proportion of patients developing postoperative complications was significantly higher among African Americans and among those with CAD, compared with Caucasians and patients without CAD ($P < .05$). The mean age of patients with total postoperative complication proportion was significantly higher than that for patients without total postoperative complication ($P = .02$). LOS was significantly associated with number of units for intraoperative blood replaced ($P < .01$). Complications observed to be significantly associated with prolonged hospital and ICU stay are summarized in Table IV. Both LOS and ICU stay were associated with all four complication variables listed in Table IV. Using multivariate analysis with the general regression model, the independent significant variables predictive of prolonged hospitalization and ICU stay are shown in Table V.

Graft patency/hemodynamics, amputations, and survival

Forty-nine patients were sufficiently evaluated by the end of the study for graft patency. In these, primary graft patency at 1 and 6 years was 98% and 73.5%, respectively. One axillofemoral graft occluded less than 5 months after surgery, and a single limb of an aortic reconstruction failed 6 years postoperatively but was recanalized with thrombolytic therapy. Table III shows the mean change in ABIs between right and left lower extremities. There were no major amputations after surgery when the follow up was completed. In the 52 patients, the overall 5-year survival was 76.3% (Fig 2). A history of MI and CAD were associated with reduced survival ($P = .008$ and $P = .005$, respectively) and is detailed in Table III.

DISCUSSION

CAAAO is an uncommon vascular condition occurring with a frequency of 0.15% from necropsy studies.[1] Prior to recent advances in endovascular therapy for complex aortoiliac atherosclerosis, open surgical treatment of chronic aortic occlusion accounted for only 4% to 10% of those undergoing aortic reconstruction for obstructive disease.[21-24] Currently, CAAAO remains one of the few well accepted indications for aorto-femoral bypass grafting. Our data are consistent with other reports, which indicate that over 50% of those with CAO have proximal occlusions that are pararenal or juxtarenal.[11,16,25] In CAAAO, atherothrombotic disease adjacent to or circumferentially encom-

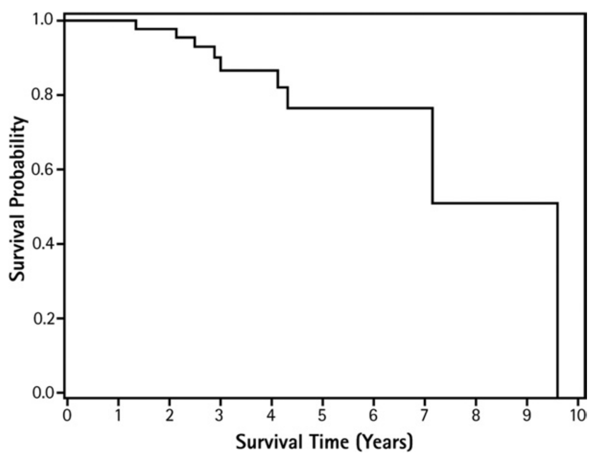

Fig 2. Ten-year survival among 52 chronic atherosclerotic abdominal aortic occlusion (CAAAO) patients (Product-limit method of Kaplan-Meier). The 3-, 5-, and 7-year survival are 86.6%, 76.5%, and 50.9%, respectively.

passing the renal artery origins requires extensive aortic exposure, and, in most cases, obligatory suprarenal or supravisceral clamping. Frequently, there is a need for detailed aortic thrombendarterectomy, which carries the associated risks of atheroembolic complications.[11,12] These factors account for an increased level of complexity involved in the surgical management of CAO.

In reports of CAO, the most common indication for surgical treatment is debilitating claudication.[11,22-25] The presentation of advanced ischemia occurs less frequently, and occasionally CAAAO may be asymptomatic.[6] In evaluating demographic variables between the two groups of chronic aortic occlusion, JRAOs were found to have an increased frequency of critical limb ischemia (44% compared with 15%) than the IRAO group ($P = .04$). A slight increase in the incidence of femoral-popliteal disease in those with JRAOs (11 [34.4%] JRAOs and 5 [25%] IRAOs; $P = .48$), and also loss of iliolumbar and inferior mesenteric collaterals may explain the increased frequency of advanced ischemia in those with juxtarenal occlusion.

It is well accepted that renal and or mesenteric occlusive disease may predispose patients with CAO to the risk of ascending aortic thrombosis and potentially fatal viscerorenal complications.[9,16,26] In our study, CTA evidence of either isolated renal artery stenosis or chronic thrombus impinging on the outflow tract of the renal arteries was not uncommon; however, only one patient of the 54 presented in acute renal failure with associated ascending thrombosis and concomitant bilateral renal artery stenosis resulting from primary renal ostial atherosclerotic plaques. It is conceivable that pararenal thrombus as an in situ lesion may also produce flow-limiting hemodynamics and increase atheroembolic risk, but this is unproven. The risk of ascending aortic thrombosis may be considered small, but we believe, as others do, that coexistent renal artery occlusive disease and CAO is a dangerous combination.[16,26]

Chronic thrombotic material that adheres and incorporates into the aortic wall at the renal artery level represents an important technical challenge. Although techniques for thrombectomy have been described to eradicate the thrombotic plug, it has been our experience that performing thrombectomy with manual finger maneuvers only partially removes thrombotic material adherent to the aorta and the renal orifices and precludes treatment of associated renal artery disease.[6-8,13]

When treating patients with CAAAO, a mandatory assessment of the central aorta for pararenal disease with CTA is critical in determining the extent of operative procedure required to completely remove thrombus from this aortic segment. We have found it essential to completely mobilize the pararenal aorta and place a vertical suprarenal or surpamesenteric clamp to perform a complete AR-TEA in those with evidence of pararenal thrombus. Routine findings during dissection included dense inflammatory tissue involving the aortic wall, transmural aortic calcifications, and adherent chronic pararenal thrombus; however, in no case did these factors or the need for redo aortic procedures become a deterrent to proceed with open abdominal reconstruction.

Over the last decade, operative mortality outcomes after aortic surgery have been reported primarily from studies on infrarenal aneurysm repairs ranging from 2.7% to 5.8%.[27-30]

Reported mortality rates from surgical series of CAAAO over the last three decades have ranged from 0% to 9%.[6-8,22-24] In the two most current studies of predominately juxtarenal aortic occlusions, mortality rates were reported at 5% and 5.6%, respectively.[16,25] Evaluating results from large retrospective series of aorto-femoral reconstructions for occlusive disease in the modern era reveals reported mortality rates ranging between 2.5% and 4.5%.[31-34] In the current report, there were no early deaths. Low mortality may be related to the reduced mean age in our study or a contemporary trend towards improved results with open aortic surgery.

In our cohort, postoperative renal insufficiency occurred in 10 patients (18.9%). Similarly, in two contemporary reviews of juxtarenal and pararenal aortic aneurysm repairs, RI was found to occur in 18% and 22%, respectively.[35,36] From these series, factors associated with postoperative renal insufficiency were supravisceral clamping, renal vein division, requirement of renal artery bypass, prolonged operative times (>351 minutes), and renal ischemic intervals over 23 minutes. In a 25 year survey in one of the largest series of aortofemoral reconstructions, RI occurred in 17.5% (defined as serum Cr >1.5 mg/dL) of those requiring renal artery procedures verses 0.7% of those without.[33] In our study, no particular factor could be identified that increased the risk of developing postoperative renal dysfunction. The presence of JRAO did not confer a significant risk for developing postoperative renal dysfunction; however, a trend towards this complication was apparent.

An important limitation of our study is its retrospective nature. While we observed some factors (patient characteristics and operative variables) to be significantly associated with some outcomes, we are unable to conclude causation between a factor and an outcome.

Endovascular treatment options for chronic aortic occlusion at this juncture have been proven possible but may have limitations in cases of proximal occlusion. Advances in endovascular therapy for CAAAO will include overcoming technical challenges and must prove durable over time before being considered as the treatment of choice.

CONCLUSION

Abdominal aortic reconstruction is safe and effective in treating CAAAO and is associated with low mortality and acceptable morbidity. Suprarenal aortic clamping followed by AR-TEA and aortic replacement is effective in many instances of CAO and can be performed without significant renal impairment. In our series, we have found no anatomic variant or pathologic conditions that contraindicate such an approach. These results may be used to compare future attempts to broaden endolumenal indications to treat CAO.

AUTHOR CONTRIBUTIONS

Conception and design: CW
Analysis and interpretation: CW, GC, LJ, TS
Data collection: CW, LD, RS, SC
Writing the article: CW, LJ, GC
Critical revision of the article: CW, LJ, GC, LD
Final approval of the article: CW, LJ
Statistical analysis: GC, TS
Obtained funding: CW
Overall responsibility: CW

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