Renal artery reconstruction for the preservation of renal function

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Purpose: We reviewed a 13-year experience with an emphasis on long-term survival and renal function response when renal artery reconstruction (RAR) was performed primarily for the preservation or restoration of renal function in patients who had atherosclerotic renovascular disease.
Methods: From January 1, 1980, to June 30, 1993, 139 patients underwent RAR for renal function salvage and were retrospectively reviewed. Inclusion criteria were either preoperative serum creatinine level >2.0 mg/dl (67% of patients) or RAR to the entire functioning renal mass irrespective of baseline renal function. Patient survival was calculated by life-table methods. Cox regression analysis was used to determine relative risk (RR) estimates for the late outcomes of continued deterioration of renal function and late survival after RAR. A logistic regression model was used to evaluate variables associated with perioperative complications.
Results: Clinical characteristics of the cohort were notable for advanced cardiac (history of congestive heart failure, 27%; angina, 22%; previous myocardial infarction, 19%) and renal disease (serum creatinine level <2.0 mg/dl, 33%; 2.0 mg/dl to 3.0 mg/dl, 40%, >3.0 mg/dl, 27%). Cardiac disease was the principle cause of early (6 of 11 operative deaths) and late death. Operative management consisted of aortorenal bypass in 47%, extraanatomic bypass in 45%, and endarterectomy in 8%; 45% of patients required combined aortic and RAR. The operative mortality rate was 8%; significant perioperative renal dysfunction occurred in 10%. Major operative morbidity was associated with increasing azotemia (RR = 2.1; $p = 0.001$; 95% confidence interval [CI], 1.3 to 4.7 for each 1.0 mg/dl increase in baseline creatinine level). Of those patients who had a baseline creatinine level ≥2.0 mg/dl, 54% had ≥20% reduction in creatinine level after RAR. Late follow-up data were available for 87% of operative survivors at a mean duration of 4 years (range, 6 weeks to 12.6 years). Actuarial survival at 5 years was 52% ± 5%. Continued deterioration in renal function occurred in 24% of patients who survived operation, and eventual dialysis was required in 15%. Deterioration of renal function after RAR was associated with increasing levels of preoperative creatinine (RR = 1.6; 95% CI, 1.2 to 1.8; $p = 0.001$ for each 1.0 mg/dl increment in baseline creatinine level), and inversely related to early postoperative improvement in creatinine level (RR = 0.41; 95% CI, 0.2 to 0.9; $p = 0.04$).
Conclusions: Intervention before major deterioration in renal function and an aggressive posture toward the frequently associated coronary artery disease are necessary to improve long-term results when RAR is performed for renal function salvage. (J Vasc Surg 1996;24:371-82.)

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Impairment of glomerular excretory function in association with hemodynamically significant renal artery stenosis has been referred to as "ischemic nephropathy," a term that describes a clinical circumstance rather than a specific pathologic entity.[1] Although it has been recognized for more than 30 years that renal artery reconstruction (RAR) can potentially reverse renal dysfunction,[2] even to the dramatic extent of discontinuing dialysis therapy,[3] optimal patient selection for renovascular reconstruction to salvage or reverse renal dysfunction remains ill-defined. A recent clinical review that considered more than 500 patients who were treated with surgery or angioplasty during the past decade indicated that although these interventions improved renal function in some 50% of patients another 25% had a deterioration in renal function or died as a complication of their treatment.[4] It is generally acknowledged that diffuse atherosclerosis, and coronary artery disease in particular, is prevalent[5] and constitutes the principle limitations on longevity in patients who are treated for atherosclerotic renovascular disease (RVD).[6-9] Furthermore, the immediate renal function response to revascularization is often limited or, in fact, prevented by the almost universally present renal parenchymal disease.[10] Renal parenchymal disease may be unrelated to the large-vessel RVD per se, as in the circumstance of nephrosclerosis from longstanding hypertension, diabetic nephropathy, or in the case of renal atheroembolism, the renal and juxtarenal aortic atherosclerosis may be directly responsible for renal parenchymal damage.[11]

Assessment of the functional result of renovascular reconstruction may be problematic. With the notable exception of the carefully and prospectively studied patients of Dean's groups,[1,3,8,10] the outcome parameters of renal function response generally are limited to the sequential determination of serum creatinine levels; the clinically important endpoints of death and the institution of dialysis are perhaps the best parameters of the clinical value of RAR when performed for the salvage of renal function.[12] This statement, of course, implies that adequate follow-up data are available to formulate meaningful conclusions. In this report, we emphasize late functional outcome and survival data in a consecutive 13-year experience wherein RAR procedures for atherosclerotic disease were performed for the preservation or restoration of renal function.

PATIENTS AND METHODS

From January 1, 1980, to June 30, 1993 (chosen to ensure a minimum 2-year follow-up), 139 consecutive patients who had atherosclerotic disease underwent RAR for the preservation or restoration of renal function. This group represented 44% of the patients who underwent RAR for atherosclerotic disease during this period. The inclusion criterium was an RAR procedure performed primarily for renal function salvage, defined either by a baseline serum creatinine level >2.0 mg/dl (67% of patients) or by a serum creatinine <2.0 mg/dl in a patient in whom RAR was performed to the entire functioning renal mass (bilateral RAR/unilateral RAR with contralateral nephrectomy, unilateral RAR to a single functioning kidney; see below). Thirty-two percent of the cohort met both parts of the inclusion criterium. Patients in whom an RAR procedure was performed for fibromuscular disease, trauma, and reimplantation of nonstenotic renal arteries during the course of aortic surgery were excluded. Clinical, demographic, and follow-up data were obtained by a review of original hospital and physician's or surgeon's records. Current follow-up data were obtained at a return visit either to our clinic or with local physicians. Follow-up information was available for 85% of patients.

Definitions. For the purposes of recording preoperative clinical information, perioperative results and complications, late renal function response, and survival, the following definitions were used. A history of congestive heart failure was defined as current or previous hospitalization for that condition. Hypertension was considered "poorly controlled" if the diastolic blood pressure was ≥100 mm Hg on multiple determinations in the hospital before surgery, and recent acceleration of hypertension was noted if the number of medications doubled or if the diastolic blood pressure became "poorly controlled" in the 6 months before surgery. The response of the hypertensive condition to the RAR procedure was defined by previously published criteria[13] (cured patients were normotensive [diastolic blood pressure <90 mm Hg] without medications; improved patients were normotensive with therapy, had a diastolic blood pressure ≥15% below baseline, or had elimination of two or more antihypertensive medications). The baseline serum creatinine level was the level that was recorded closest to the date the patient underwent surgery. Recent deterioration in renal function was recorded when the serum creatinine level had doubled in the 12 months before surgery. Patients were considered to have a "single functioning kidney" if any of the following criteria (regarding the contralateral kidney) were met: (1) surgically or congenitally absent kidney; (2) no visible nephrogram on contrast arteriogram; or (3) <10% of total renal function in a kidney, as assessed by Technicium 99 renal scintigraphy.

A history of cerebrovascular disease was considered as any previous stroke, transient ischemic attack, or carotid endarterectomy. Leg occlusive disease was considered present in patients who had either claudication, rest pain, or gangrene, or had undergone a previous leg bypass procedure or amputation. All patients underwent contrast arteriography. Death within 30 days of surgery was considered operative death; major cardiac complications were any myocardial infarctions documented by sequential cardiac enzymes, any cardiac event that resulted in transfer to an intensive care unit, or any cardiac event that was considered to have prolonged hospitalization. Major pulmonary complications included the requirement for >48 hrs of postoperative ventilation, pneumonia verified by a chest roentgenogram, and any respiratory event that resulted in transfer to an intensive care unit. Renal-related complications were considered major if dialysis was required after surgery unless such therapy had been present before operation, or if a patient's preoperative creatinine level had doubled. For the purposes of assessing the early and late renal function response to revascularization, the following definitions were used: improvement in renal function required a ≥20% reduction in the creatinine level; renal function was considered as having worsened if a ≥20% increase in the creatinine level occurred. Patients who had lesser degrees of change in creatinine level after RAR was performed were considered to have "stable" renal function. Late outcomes with respect to renal function response were classified as "continued deterioration" for patients who went on to dialysis, died of renal-related causes during follow-up, or had late creatinine levels two times the baseline value or more.

Statistical methods. All statistical computations were performed on a DEC VAX 11780 computer (Digital Equipment Corp., Maynard, Mass.) with the use of the following statistical modules: BMDP4F (frequency tables), BMDP1L (survival analysis), BMDP2L (Cox proportional hazards regression) and BMDPLR (logistic regression). Frequency tables were analyzed for statistical significance with χ^2 or Fisher exact tests, and the Mantel-Cox test was used to compare survival curves. Life tables were constructed for the determination of late survival rates. A Cox proportional hazards regression model was developed to derive relative risk (RR) estimates for late outcomes. A logistic regression model was created to evaluate variables associated with perioperative complications.

RESULTS

Preoperative clinical profile. Clinical and demographic features of the study group are displayed in Table I. They are representative of a patient cohort with diffuse atherosclerosis. Hypertension was universal, and more than 50% of patients were taking more than three antihypertensive medications. As displayed in Table I, significant (creatinine level ≥2.0 mg/dl) baseline renal insufficiency was present in two thirds of patients, and only 22% had a preoperative serum creatinine level in the normal range (≤1.5 mg/dl). Recent deterioration in renal function was noted in 25%, but only three patients were undergoing dialysis therapy before the RAR procedure. Extrarenal atherosclerotic disease was commonplace, as displayed in Table II. Clinically manifest coronary artery disease (previous myocardial infarction, history of angina, history of congestive heart failure, or previous coronary artery bypass grafting procedure) was common, yet few patients underwent specific preoperative cardiac testing with dipyridamole thallium scintigraphy (19%) or coronary angiography (7%). Five patients underwent a coronary artery bypass grafting procedure in the 3 months before RAR. Surgery was restricted to patients who had high-grade (≥75% diameter stenosis) lesions or occlusions, and 13% of treated arteries were totally occluded before RAR was performed.

Table I. Demographic and clinical features

Variable	*n (%)*
Age (mean, range)	67 yr (40 to 90)
age ≥70 yr	54 (39)
Male	74 (53)
History of smoking	70 (50)
Diabetes	21 (15)
Hypertension	137 (99)
Poorly controlled	48 (34)
Recent acceleration	50 (36)
Renal insufficiency (creatinine ≥1.5 mg/dl)	109 (78)
Serum creatinine level <2.0 mg/dl	47 (33)
Serum creatinine level 2.0-3.0 mg/dl	55 (40)
Serum creatinine level >3.0 mg/dl	37 (27)
Single functioning kidney	63 (45)

Surgical management and perioperative results. As displayed in Fig. 1, a spectrum of surgical techniques was used. Combined aortic and renal artery grafting procedures were performed in 45% of patients, with equivalent (45%) use of extraanatomic bypass procedures. Unilateral RAR procedures were performed in 87% of patients and bilateral reconstruction in 13% (eight of 18 with staged bilateral repair). Contralateral nephrectomy was performed in 11%. Recognized perioperative graft thrombosis was identified in five patients (4%), three of whom underwent immediate and successful revision. The operative mortality rate was 8% (11 of 139); the causes of perioperative deaths and significant complications are detailed in Table III. Cardiac-related events accounted for the majority of the complications and

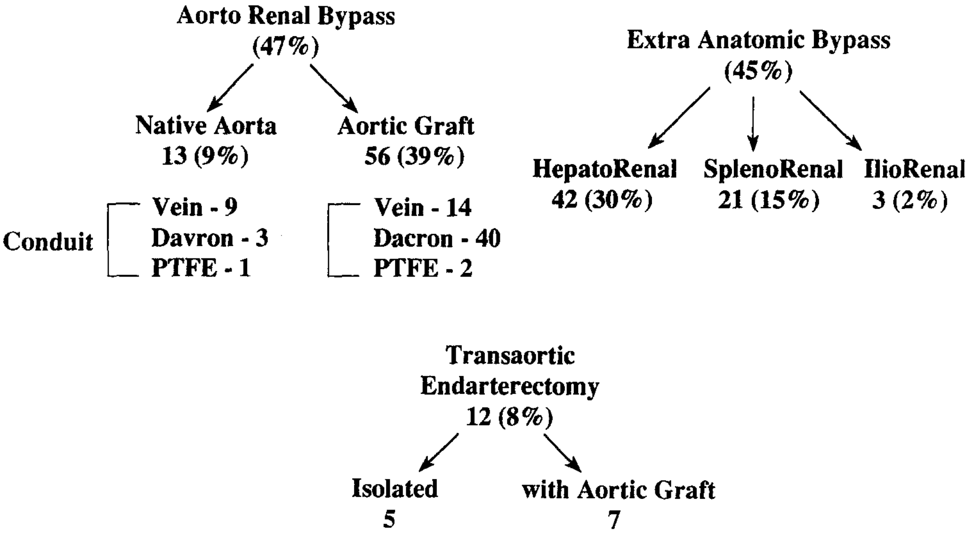

Fig. 1. Operative management of RVD. A total of 147 procedures were performed in 139 patients. Eight patients underwent staged bilateral RAR procedures.

deaths. In considering the 21 patients who either died in the perioperative period or had major cardiopulmonary complications, only increasing azotemia (RR = 2.1; $p = 0.001$; 95% confidence interval [CI], 1.3 to 4.7 for each 1.0 mg/dl increase in preoperative creatinine) was associated with such complications and deaths..

Other variables that were assessed but that were found not to be associated with major perioperative complications included age, diabetes, clinical evidence of coronary artery disease, history of cerebrovascular or peripheral vascular disease, and combined aortic reconstruction and RAR. Dialysis was instituted after surgery in six patients (4%; excluding three patients on dialysis before surgery), and half of them needed permanent dialysis. All but one of these patients had a preoperative creatinine level ≥3.0 mg/dl. Dialysis was being used before surgery in only three patients, and RAR was successful in eliminating this need in one patient; the other two died in the perioperative period. The immediate impact of RAR on renal function was assessed with serum creatinine determinations at hospital discharge or 1 month after surgery. By the stringent criteria of a ≥20% reduction in the creatinine level at the time of hospital discharge, 54% of patients who had an initial creatinine level ≥2.0 mg/dl demonstrated improvement in renal function. Seventy-three percent of patients had either stable or improved renal function within 1 month of RAR, and of a variety of clinical variables examined only revascularization to a single functioning kidney ($p \cong 0.04$) and a significant diminution in postoperative antihypertensive medication requirement ($p = 0.04$) were associated with immediate improvement or stability in renal function.

Late functional outcomes and survival. Follow-up data, at a mean duration of 48 months (range, 6 weeks to 12.6 years), were available for 87% of the patients who survived operation. The response to RAR in terms of hypertension control was favorable. Although cure of hypertension was rare (8% of patients), an additional 71% of patients demonstrated improvement in hypertension control at the time of the last follow-up. Long-term improvement or stability in renal function was noted in 76% of late surviving patients (n = 51) at a mean duration of 4.8 years (range, 4 months to 12.5 years). Dialysis was instituted during the follow-up period in 17 patients (15% operative survivors) at a mean interval of 38 months after operation (range, 2 to 96 months). Patients who eventually required dialysis, those who died of renal failure without institution of dialysis, and those whose serum creatinine levels at least doubled over baseline values could be broadly considered as the group with continued deterioration in renal function. Late occlusion of the RAR could be identified as having contributed to this deterioration in only four patients. Late renal function deterioration occurred in 24% of 107 patients for whom adequate follow-up information was available. Cox analysis revealed a strong association of late functional deterioration with increasing preoperative serum creatinine levels. The relative risk for the continued deterioration of renal function was 1.6 ($p = 0.001$; 95% CI, 1.2 to 1.8) for

Table II. Associated vascular diseases

Disease site	*n (%)*
Documented coronary artery disease	76 (55)
History of congestive heart failure	37 (27)
History of angina	31 (22)
History of myocardial infarct	27 (19)
Prior CABG*	13 (9)
Cerebrovascular	43 (31)
Lower extremity occlusive	70 (50)
Aortic aneurysm	68 (49)

CABG, coronary artery bypass grafting procedure.
See text for inclusion criteria.
*Excludes five patients who underwent CABG ≤3 months before surgery.

Table III. Perioperative complications

Factor	*n (%)*
Death within 30 days of surgery	11 (8)
Myocardial infarction	6
Perioperative hemorrhage	2
Stroke	2
Ruptured AAA	1
Nonfatal cardiac complications*	21 (15)
Major	13
Minor	8
Pulmonary complications*	20 (15)
Major	13
Minor	7
Major renal complications*	14 (10)
Early thrombosis reconstruction	5 (4)

AAA, abdominal aortic aneurysm.
*See text for definition.

each 1.0 mg/dl increment in basement creatinine level. As displayed in Fig. 2, *A* and *B*, the probability of continued deterioration in renal function after RAR was significantly increased when patients were divided according to different threshold levels of preoperative azotemia. The probability of continued deterioration in renal function was striking ($p = 0.0007$) for those patients who had baseline creatinine levels ≥3.0 mg/dl. Other variables that were *inversely* associated with continued renal function deterioration were the notation of early postoperative improvement in renal function (RR = 0.41; 95% CI, 0.2 to 0.9; $p = 0.04$) and a significant reduction in the number of early postoperative antihypertension medications required (RR = 0.03; 95% CI, 0.0 to 0.5; $p = 0.02$).

Cumulative survival data for the study group (operative deaths included) are displayed in Table IV. The median length of survival after operation was 5.6 years, but the survival rate at 5 years was only 52% ± 5%. Univariate predictors of late death included diabetes ($p < 0.06$), treatment for associated abdominal aortic aneurysm ($p < 0.02$), and a history of preoperative congestive heart failure ($p < 0.03$). The survival rate among patients who eventually required dialysis after operation was poor, with 11 of 17 such patients dying (65%), seven within 1 year of the institution of dialysis. The impact of baseline renal insufficiency on late death was significant. The relative risk of late death was 1.5 ($p = 0.001$; 95% CI, 1.3 to 1.7) for each 1 mg/dl increment in preoperative creatinine level, and late survival could be differentiated significantly ($p = 0.008$) by a threshold of preoperative creatinine level greater than or less than 2.0 mg/dl (Fig. 3). An even greater negative impact on late survival was noted for those patients who had a history of congestive heart failure (RR = 1.9; $p = 0.01$; 95% CI, 1.1 to 3.1). Causes of late death are displayed in Table V.

DISCUSSION

Available natural history data have demonstrated that atherosclerotic RVD is progressive and is often accompanied by a deterioration in overall renal function.[14-19] Despite the lack of controlled trials, a general consensus exists that performing RAR for renal function salvage can provide favorable results, occasionally to the extent of reversing the need for dialysis in selected patients.[3,4] It also has been emphasized that the patients' profile is one of advanced age and systemic atherosclerosis and that the indications for intervention have shifted from control of hypertension alone to RAR for renal function salvage.[6-9,20] The clinical characteristics in our patients (Tables I and II) are consistent with multiple other contemporary reports and continue to emphasize that long-term results in these patients are often limited by extrarenal atherosclerosis—in particular, associated coronary artery disease. Our series emphasizes the importance of cardiac disease, both with respect to surgical complications and with respect to limitations on longevity (Table V). We and others have emphasized that the detection and treatment of associated coronary disease is commonplace and is an important factor in the current safety of RAR.[8,21] In contemporary practice, approximately 60% of our patients have undergone specific cardiac evaluations, and fully 40% of patients who are treated with combined aortic reconstruction and RAR have undergone surgery with antecedent mechanical correction of their coronary artery disease.[21] The corresponding figures in this report (preoperative dipridamole thallium study, 19%; previous CABG, 9%) reflect earlier practice patterns.

Inclusion criteria as to which patients, which variations of RVD anatomy, and which procedures

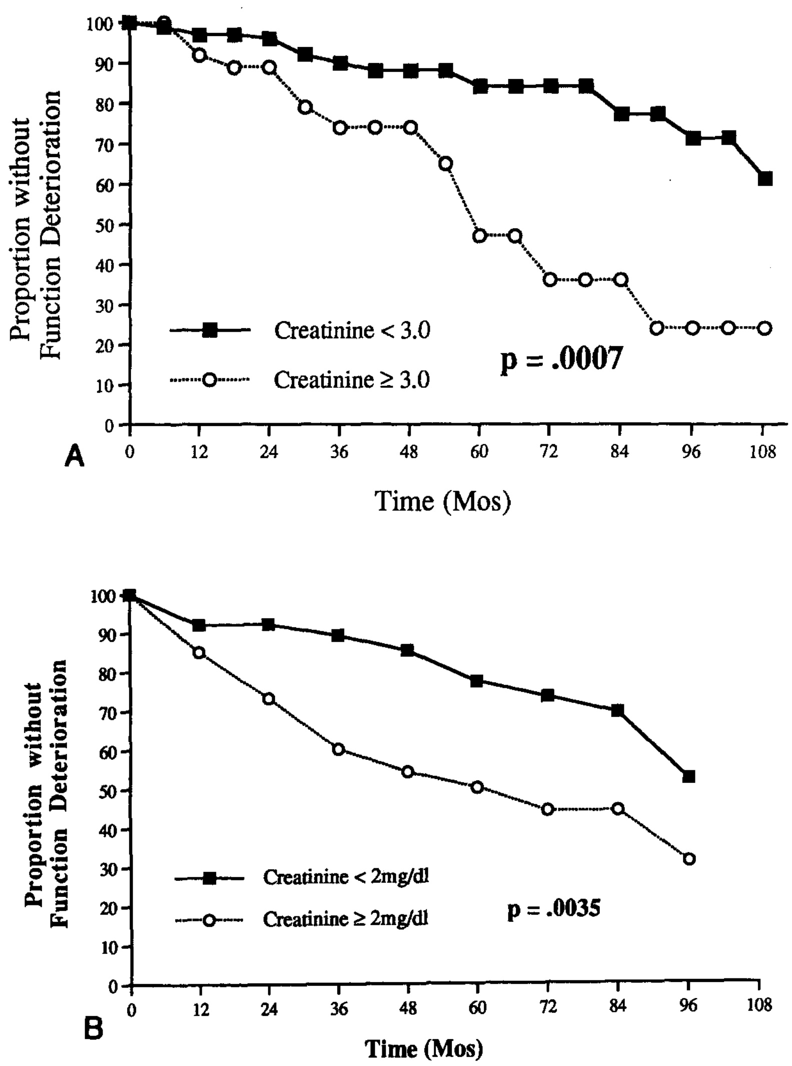

Fig. 2. Life-table analysis of likelihood of continued deterioration in renal function after RAR, stratified by preoperative baseline serum creatinine levels less than or greater than 3.0 mg/dl (**A**) and less than or greater than 2.0 mg/dl (**B**).

constitute renovascular surgery for function salvage vary widely. On the basis of the original reports of Dean et al.,[10] which suggested that revascularization to the entire functioning or potentially functioning renal mass was an important variable correlated with successful RAR, we included in this review those patients whose RAR encompassed all potentially functioning renal mass, irrespective of preoperative global renal insufficiency. Similar criteria for patient inclusion in the spectrum of RAR for function salvage have been reported by Libertino et al.[22] and Novick et al.[20] Others have chosen some arbitrary level of renal insufficiency (typically a serum creatine level ≥1.8 to 2.0 mg/dl) as the inclusion criteria.[7,12] Perhaps more important is the percentage of patients who have extreme (serum creatinine level ≥ 3.0 mg/dl) baseline renal insufficiency.

One-third of the patients reported in our study had such extreme renal insufficiency before operation, a proportion that is consistent with other contemporary reports.[6-8,12,22] It can be anticipated that the reported results for RAR, particularly late outcome parameters, will vary in accordance with the clinical characteristics in a particular series. Hansen et al.[8] noted the poor outcome (nearly 50% mortality rate) at 4 years in patients who had "extreme" disease (creatinine level ≥3.0 mg/dl with diffuse atherosclerotic cardiovascular disease or evidence of left ventricular

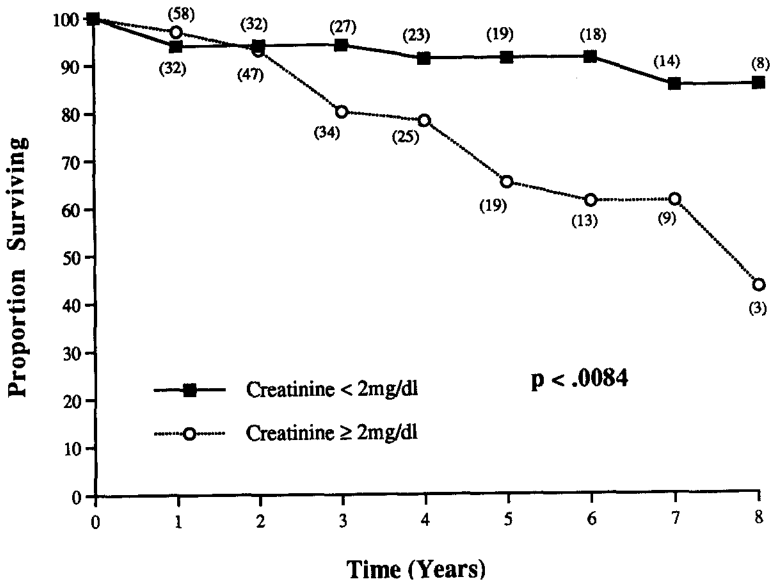

Fig. 3. Life-table survival curves for patients treated who had baseline serum creatinine levels greater than or less than 2.0 mg/dl. Numbers in parentheses indicate number of patients who entered each interval.

dysfunction). Our data detailing the negative impact of increasing azotemia and previous congestive heart failure on late survival are quite similar. Furthermore, late survival in our series is significantly worse than we previously reported when all patients who underwent RAR for RVD at our institution are considered (Fig. 4). In comparing these groups of patients, the severity of the RVD and renal dysfunction is the principle difference. Because cardiac disease is the principle source of late death, this suggests a quantitative relationship between the RVD and cardiac disease, as noted by others.[5]

Criteria for assessing renal function response and what constitutes improved, stable, or worsened renal function have varied. Some authors have designated a ≥20% change from baseline serum creatinine level as constituting a significant change in either direction[20]; Hallett et al.[6] consider an absolute 1.0 mg/dl of serum creatinine change as significant; others have used lesser changes from baseline creatinine values to define the response to RAR.[22-24] In our report, we have emphasized late outcome endpoints and acknowledge the imprecision of serum creatinine levels in assessing the early response to RAR, as emphasized by others.[12] Dean et al.[10] demonstrated that in patients who had modest preoperative azotemia (creatinine level ≤2.0 mg/dl), early improvements in serum creatinine level were not evident despite the fact that most of these patients had measurable improvement in glomerular filtration rate.[10] The term "stable" renal function, which is more properly stated "unchanged" in considering short-term outcomes, only has meaning with adequate follow-up duration. The clinically relevant endpoints of patient survival and eventual dependence on dialysis therapy can only be assessed from reports that contain adequate follow-up data. Our series, with a mean follow-up duration of 4 years, compares favorably with the bulk of the available literature in this regard. The series that are summarized by Rimmer and Grennari[4] and reports that appeared subsequent to that review either report short-term results or follow-up intervals that average approximately 2 years.[6,24] It seems logical to conclude that the rates of survival and progression to dialysis will vary in accordance with follow-up duration. Alternatively, the eventual need for dialysis in our patients (15% of late survivors) does not differ significantly from the 7%-to-18% range that was reported in four recent reports from centers with acknowledged expertise whose mean follow-up interval ranged from less than 2 years to 4 years.[6,8,12,23] The majority of our patients began dialysis within 2 years of RAR, which is consistent with the hypothesis of Dean et al.[1] that ischemic nephropathy is a rapidly progressive disease. The implication is that many patients are treated with RAR when their vascular and renal parenchymal disease is at a relatively advanced stage, and RAR represented a desperate and often failed attempt to alter the clinical course of the disease.

The significant impact of what others have termed

Table IV. Long-term survival data for 139 patients after renal artery reconstruction

Interval (yr)	*No. of patients*	*Patients withdrawn*	*Patients dead*	*Proportion dead*	*Proportion surviving*	*Cumulative proportion surviving at beginning of interval*
0-1	139	20	29	0.2533	0.7752	1.0000
1-2	90	3	8	0.0904	0.9096	0.7752
2-3	79	9	9	0.1208	0.8792	0.7051
3-4	61	9	4	0.0708	0.9292	0.6194
4-5	48	6	4	0.0889	0.9111	0.5760
5-6	38	4	3	0.0833	0.9167	0.5248
6-7	31	7	1	0.0364	0.9636	0.4811
7-8	23	7	5	0.2564	0.7436	0.4636
8-9	11	2	3	0.3000	0.7000	0.3447

Table V. Causes of late death

Factor	*No. of late deaths (%)*
Cardiac	21 (37)
Renal	6 (11)
Malignant disease	9 (16)
Stroke	6 (11)
Miscellaneous	10 (18)
Gastrointestinal-perforated viscus	3
Multisystem organ failure	4
Ruptured AAA	1
Mesenteric ischemia	2
Unknown	4 (7)
Total	56

AAA, abdominal aortic aneurysm.

"extreme" baseline renal insufficiency (serum creatinine level ≥3.0 mg/dl) in predicting the continued deterioration of renal function in our patients is a finding that is noted in most reports that detail late outcomes. Hallett et al.[6] reported that 35% of patients who had a baseline creatinine level ≥3.0 mg/dl who were treated with RAR began undergoing dialysis less than 2 years after operation. Chaikoff et al.[12] noted nearly identical findings, with an estimated probability of requiring dialysis of at least 30% at 2 years for patients who had poor preoperative functional reserve (creatinine level ≥3.0 mg/dl). In the recent report of Hansen et al.,[8] dialysis was eventually required in 7% of 157 patients who underwent RAR for atherosclerotic disease, but only half of these patients had initial creatinine levels >2.0 mg/dl. Virtually all patients who underwent dialysis had extreme (creatinine level ≥3.0 mg/dl) baseline renal insufficiency or were already dialysis-dependent before operation. Novick et al.[25] suggested that performing RAR procedures is not worthwhile when serum creatinine levels exceed 4.0 mg/dl because irreversible renal parenchymal damage already will have occurred. Yet a subgroup of patients (25% in our series) who had even extreme preoperative renal insufficiency will benefit from RAR. The report of Hansen et al.,[3] which focused on dialysis-dependent patients, is notable in that dialysis had been instituted a mean of 3 weeks before surgery, and rapid preoperative decline in renal function characterized this group. Many of their patients had acute clinical deterioration similar to those reported by Messina et al.[26] who had recurrent pulmonary edema. This suggests that the clinical context of patients' presentation when extreme levels of renal dysfunction are present may be an important variable in predicting the response to RAR.

The surgical approach when RAR is performed for function salvage has evolved, both related to comorbidity considerations and with accumulating evidence that a comprehensive bilateral reconstruction affords the best opportunity for function restoration.[3,6,10] Bilateral RAR or RAR with contralateral nephrectomy was performed in only 23% of our patients, and the high percentage of patients (45%) who had a single functioning kidney partially accounts for this number. It is possible, even likely, that some of our patients could have benefitted from bilateral, more comprehensive revascularization. This possibility, of course, relates to the lower limits of function restoration by RAR performed in small, compromised kidneys, most of which harbor total chronic occlusions. We believe that distal arterial reconstitution on the late phase of arteriography remains the best single predictor of the value of RAR in this setting.[10] However, limiting characteristics imposed by fixed renal disease and clinical factors such as diabetes remain undefined and are worthy of further study. Our preference for performing extraanatomic bypass procedures when unilateral RAR is indicated, and the favorable results with this approach, have been previously described.[9] The percentage of patients who were treated with combined aortic reconstruction

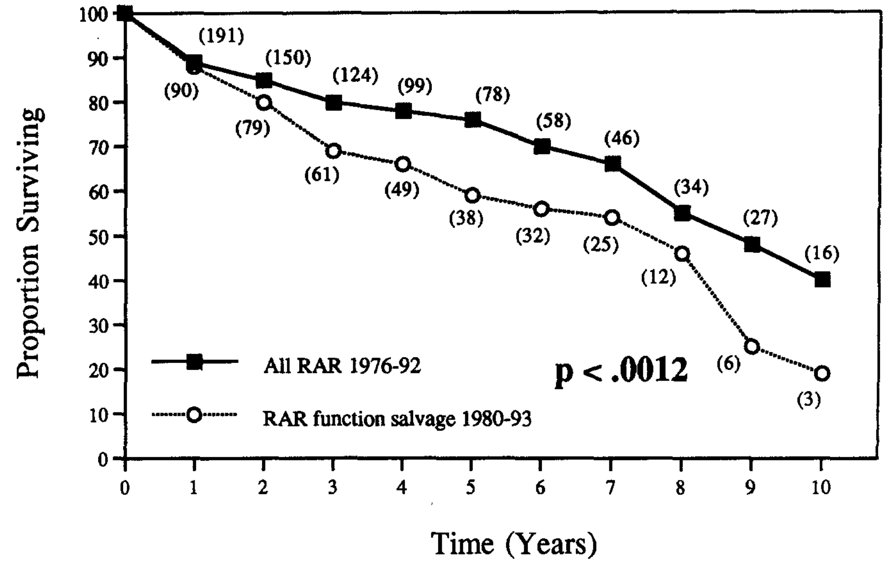

Fig. 4. Comparative life-table survival curves for the present series and a consecutive series[9] of all patients who underwent RAR for atherosclerotic disease at our institution. There is a significant ($p < 0.0012$) decrease in late survival in the present series, i.e. the subgroup undergoing RAR for renal function salvage.

and RAR (45% in this series) is typical of contemporary reports that consider RAR for atherosclerotic disease.[3,6,23] In our practice, the combined operation now accounts for 50% of all RAR procedures, and there has been a corresponding 10% decrease in the use of extraanatomic bypass procedures during the past 5 years. Although performed infrequently in our series, transaortic endarterectomy is commonly applied in current practice in circumstances of bilateral simultaneous RAR or combined aortic reconstruction and RAR.[6,21] The operative mortality rate in our series is consistent with that of other studies that encompass the same time interval.[7,27,28] Operative complications generally have been concentrated in those patients who had multiple comorbid conditions and their association with severe levels of azotemia demonstrated in this report and others.[6,8] The morbidity rate of RAR is cited in the rationale for treating RVD with catheter-based interventions. The surgery and angioplasty series summarized by Rimmer and Grennari,[4] however, demonstrated equivalent procedure-related mortality rates for surgery and angioplasty. Furthermore, even recent reports relative to the use of angioplasty or stents for RVD continue to detail inferior anatomic and clinical results[29-31] when compared with the durability of surgical RAR.[9] Largely related to the anatomic fact that most RVD is an extension of aortic atherosclerosis, we believe that surgical RAR is the preferred approach for the majority of these patients.

On the basis of this experience, we conclude that intervention before major deterioration in renal function and an aggressive posture toward the detection and treatment of the frequently associated coronary artery disease will be necessary to improve late results when RAR is performed for renal function salvage. Although the survival data reported herein are sobering, they do compare favorably with the expected clinical course of patients with atherosclerotic disease who come to dialysis.[32] Detection of patients who have RVD at an earlier stage of clinical deterioration by screening of high-risk patient groups holds promise.[33,34] Further prospective study of the clinical and renal pathologic variables that might predict the response to RAR is warranted.

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DISCUSSION

Dr. Steven J. Burnham (Chapel Hill, N.C.). I congratulate the authors on this commendable presentation. The material complements your publication in the June issue of the *Journal of Vascular Surgery* that dealt with simultaneous aortic reconstruction and RAR.[21]

This report covers 139 patients during a 13-year period. It represents 44% of the RAR procedures that were performed during that period of time. I would ask about the larger cohort of RAR procedures performed in patients who did not meet your inclusion criteria. Were the reconstructions performed for hypertension in patients who had normal creatinine levels?

In the one third of the patients who had preoperative serum creatinine levels <2 mg/dl, I would assume that the reason for referral to a vascular surgeon was not progressive deterioration in renal function. Were these patients seen because of leg occlusive disease and found to have renal artery stenosis at the time of aortography? If so, could you please share with us your indications for performing RARs in lesions found incidentally on aortograms?

The 45% of patients who had extraanatomic reconstructions might deserve further comment. Was there a difference in preoperative serum creatinine levels compared with patients who underwent aortorenal bypass or endarterectomy?

Finally, the endpoints of this review were changes in serum creatinine level, death, and the institution of dialysis. I think the life-table data are similar to those for major leg vascular reconstructive procedures and probably reflect the continuation of the primary disease process rather than the technical excellence of the reconstructive procedure. I suspect that there are no differences in the life tables if you compare the aortorenal reconstructions with the visceral artery with renal reconstructions. Is this true?

You certainly have data for the life-table analysis to describe the preservation of renal function with the criteria that you define. I think this is very interesting and can teach us about the impact of operation on prevention of the need for dialysis. I think it is interesting to look at this and compare the two major types of renal reconstructions, and this might guide our aggressiveness in approaching these patients. I also think that this will be benchmark for our colleagues in interventional radiology.

Dr. Richard P. Cambria. You asked about the larger cohort of patients who underwent a surgical RAR procedure for atherosclerotic disease during the same time interval; I did show that data, although they are not contained in the manuscript. The principle difference in the clinical factors was referable to the morbid sequelae of RVD, that is, the incidence of patients who had renal insufficiency and a single functioning kidney. Other clinical and demographic data, including age, incidence of coronary disease, and so forth, were no different between the two cohorts.

With respect to the mode of referral of these patients, that data was not specifically included in the manuscript. Approximately 80% of these patients were referred either with the knowledge or the suspicion of RVD or combined aortic and renovascular disease. As the vascular surgeons in the audience are likely aware, it is not uncommon to have a patient referred for "aneurysm resection" only to find out that the patient has a serum creatinine level of 2 mg/dl, one shriveled kidney, and a stenosis in the artery to the remaining kidney. We certainly believe that these patients fit into the general category in which RAR is performed for the salvage of function, despite the fact that their initial mode of referral may not have included this procedure. We found in a review of all of these patients that roughly half of them will come with antecedent knowledge or the suspicion of RVD and half of them will be referred for manifestations of their aortic disease, and it is not uncommon then for the vascular surgeon to discover both anatomic and functionally severe RVD.

With respect to our criteria for intervention after finding RVD during aortography for associated aortic disease, this runs the spectrum. Many of these patients will have functionally significant RVD. The controversial point, of course, relates to those who do not, who have undergone so-called "prophylactic" RAR, as will be discussed in a later presentation. In our report in the June 1995 issue of *Journal of Vascular Surgery,* we have advocated an aggressive posture towards the so-called "incidentally" discovered renal artery stenosis on the basis of the available natural history of that disease process.[21] I certainly admit that that is a controversial stance, and of our combined aortic and renal graft operations only 5% of the RARs were considered "prophylactic."

With respect to the extraanatomic versus the combined aortic and renovascular operations, there was no difference in the clinical or demographic features between these two groups, and we have used the extraanatomic bypass grafting procedures for unilateral reconstruction for more than 20 years at our institution, and we believe they are worthwhile procedures. I will add, however, with respect to the mode and technique of revascularization, that endarterectomy is now our preferred technique for the patient who requires bilateral simultaneous operation. Only 20% of the patients in our series underwent bilateral reconstruction, and our report in the June 1995 issue of *Journal of Vascular Surgery* verifies that in contemporary practice that percentage has greatly increased.[21]

With respect to the life-table survival rate, we showed that for all patients in our unit who have undergone RAR procedures the 5-year actuarial survival rate is distinctly better than that reported for our present cohort, and we think that survival rate this reflects both more severe renal insufficiency and a quantitative relationship between the severity of the RVD and the coronary disease, as has been reported by Dr. Valentine of this Society.

Dr. Ronald J. Stoney (San Francisco, Calif.). I would like to ask you about the 25% of your patients whose renal function continued to decline after the operation. This event was unanticipated and certainly was not the objective of the operation. These patients could have had progressive impairment of renal flow through their reconstruction. I am wondering what surveillance methods you used, what you did when you detected this problem, if you did, and what your current methods are for surveillance, be it arteriography, magnetic resonance angiography, or duplex.

Dr. Cambria. This was a retrospective review, and certainly no routine method of late surveillance of the reconstruction was used. We do have data for the patients who went on to have continued renal function deterioration, because they were looked at closely. In only four of those patients could we discover a technical or anatomic problem with the RAR procedure as a possible contributing factor to their late deterioration in renal function. Our data with respect to the durability of all the different modes of

RAR has been published previously, and we believe it is fair to say that the majority of technical failures occur early on. Currently, I like to observe these patients with renal scans and clinical variables. For many of the patients who have undergone reconstruction to a single functioning kidney, it is quite obvious on the basis of clinical and laboratory grounds whether or not the reconstruction is at least patent, although up until recently with the magnetic resonance angiography there has been no good noninvasive way to observe these patients.

Dr. Jose Alvarez, Jr. (Miami, Fla.). How many of these patients underwent failed percutaneous treatment of the renal artery disease, how many patients had stents placed, and how do you deal with the 80-year-old patient who has diffuse atherosclerotic disease, renovascular hypertension, and coronary disease—which is the usual type of patient we see here in Florida?

Dr. Cambria. None of the patients had stents placed because the inclusive period was only up to 1993, and there were only a few patients in the series who underwent a failed previous angioplasty procedure. At our institution, surgical reconstruction remains the preferred method for intervention for RVD, although we certainly haven't gone about in any prospective fashion to look at the results of performing angioplasty procedures.