ONLINE FIRST

Influence of Chronic Renal Insufficiency on Outcomes Following Carotid Revascularization

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Objectives: To examine the perioperative and long-term outcomes of patients undergoing carotid revascularization and to determine the influence moderate or severe renal insufficiency may have on these outcomes.

Design: Retrospective database review.

Setting: Academic tertiary hospital.

Patients: Patients undergoing carotid endarterectomy and carotid angioplasty and stenting from 1996 to 2006.

Intervention: Carotid revascularization.

Main Outcome Measure: Glomerular filtration rate (GFR) was calculated based on the Modification of Diet in Renal Disease equation. Groups were analyzed by stages 0 to 2 (GFR ≥60 mL/min/1.73m^2) vs stage 3 (GFR <60 and ≥30 mL/min/1.73m^2) vs stages 4 and 5 (GFR <30 mL/min/1.73m^2).

Results: Nine hundred twenty-one carotid interventions were performed (750 carotid endarterectomy, 171 carotid angioplasty and stenting). The overall 30-day mortality and morbidity rates were 1.1% and 16.9%, respectively. Sixty-six percent of patients had normal renal function (stages 0-2). Twenty-eight percent of patients had moderate renal insufficiency (stage 3) and 6% of patients had severe renal insufficiency (stages 4-5). The 30-day stroke rates for groups were 2.98% (normal renal function), 2.67% (moderate renal insufficiency), and 5.45% (severe renal insufficiency) (P=.54). Thirty-day mortality rates between groups were 0.66% (normal renal function), 1.15% (moderate renal insufficiency), and 5.45% (severe renal insufficiency) (P=.005). For carotid endarterectomy, no difference in freedom from stroke existed based on level of renal function. For carotid angioplasty and stenting, patients with severe renal insufficiency exhibited significantly lower rates of freedom from stroke.

Conclusions: Chronic kidney disease is prevalent among patients undergoing carotid revascularization. Overall, patients with moderate renal function have similar outcomes. However, those with severe renal insufficiency have significantly higher 30-day mortality when undergoing carotid revascularization.

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STROKE IS THE THIRD LEADING cause of mortality in the United States.[1] Both carotid endarterectomy (CEA) and carotid angioplasty and stenting (CAS) are performed for the prevention of stroke.

Carotid endarterectomy with the addition of optimal medical therapy has been shown to provide superior protection from future stroke compared with optimal medical therapy alone.[2,3] The large randomized trials evaluating CEA excluded patients with specific comorbidities. The absence of these subgroups of patients from large randomized trials has been interpreted as defining these subgroups as high surgical risk for CEA. Carotid angioplasty and stenting is an alternative treatment modality for carotid stenosis and often chosen for patients deemed as high surgical risk for CEA owing to physiological or anatomic reasons.

Renal insufficiency has been shown to be a negative predictor for freedom from myocardial infarction (MI) and survival in atherosclerotic patients.[4-6] Multiple prospective and retrospective studies have reported the outcomes of patients undergoing CEA with renal insuffiency,[7-17] while fewer studies have reported the outcomes of CAS for this group of patients.[18]

See Invited Critique at end of article

As part of the National Surgical Quality Improvement Program, Sidawy et al[10] examined the effects of chronic renal insufficiency during CEA in the largest series published and found higher rates of cardiac and pulmonary complications in patients with a glomerular filtration rate (GFR) from 30 to 59 mL/min/1.73m^2 and

greater mortality for those patients with a GFR less than 30 mL/min/1.73m^2.

The primary objectives of this study were to examine the perioperative and long-term outcomes of patients undergoing carotid revascularization, both CEA and CAS, and to determine the influence moderate or severe renal insufficiency may have on these outcomes.

METHODS

STUDY DESIGN

A database of patients undergoing carotid revascularization from 1996 to 2006 was queried. Patients undergoing CEA and CAS for significant primary atherosclerotic occlusive disease were analyzed. Vessels treated for intimal hyperplasia, in-stent restenosis, irradiation-induced arteritis, repeated CEA, and trauma were excluded. Data use fell under the category of secondary use of preexisting data.

PROCEDURES

Patients underwent CEA or CAS where carotid stenosis was 80% or more for asymptomatic and 50% or more for symptomatic patients and was detected on duplex scan imaging and was confirmed in most cases on computed tomographic angiography or magnetic resonance angiography. Routine preprocedural and postprocedural neurology consultations were not requested, unless the patient was symptomatic. For CEA, patients took aspirin as maintenance therapy and the majority underwent endarterectomy under regional block, with the remainder undergoing general anesthesia with electroencephalography monitoring. Both polyethylene terephthalate fiber patch angioplasty and eversion endarterectomy were performed. For carotid stenting, the patient was given clopidogrel bisulfate (75 mg/dL) and aspirin (81 mg) beginning 3 days before the intervention. After the stenting procedure, clopidogrel was continued for 1 month, and aspirin was continued for life. All patients undergoing carotid stenting received an intravenous heparin bolus (100 U/kg) to achieve systemic anticoagulation during the carotid intervention (activated coagulation time >250 seconds). All carotid stenting procedures were performed in fixed imaging procedure rooms under conscious sedation. The technique of stenting with an embolic protection device has been described previously.[19] Self-expanding monorail carotid stents (Wallstent; Boston Scientific, Natick, Massachusetts; Precise; Cordis, Warren, New Jersey; or Acculink; Guidant, Santa Clara, California) were deployed across the internal carotid stenosis. Poststenting balloon angioplasty was performed with either a 5- or 6-mm-diameter angioplasty balloon, depending on the appearance of the completion angiogram. Procedures were performed with local institutional review board approval and/or as part of an approved multicenter clinical trial and followed Centers for Medicare & Medicaid Services guidelines. Patients, after both CEA and CAS, were routinely kept in the hospital overnight and discharged home on the following day. In general, patients were followed up by duplex ultrasonography scan every 6 months for 2 to 3 years and then yearly thereafter if there was no contralateral disease. If there was 50% or more disease present, 6-monthly follow-ups were the norm. We intervened if lesions were 80% or more during follow-up. All duplex ultrasonography scans were performed at approved vascular laboratories accredited by the Intersociety Commission for the Accreditation of Vascular Laboratories using the University of Washington criteria.

DEFINITIONS

Renal function was evaluated by means of the Modification of Diet in Renal Disease formula for GFR.[20] Normal renal function was defined as a GFR of 60 mL/min/1.73m^2 or more. Moderate renal function was defined as a GFR of less than 60 but 30 mL/min/1.73m^2 or more. Severe renal function was defined as a GFR of less than 30 mL/min/1.73m^2. Coronary artery disease was defined as a history of angina pectoris, MI, congestive heart disease, or prior coronary artery revascularizations. Cerebrovascular disease included a history of stroke, transient ischemic attack, or carotid artery revascularization. Diabetes mellitus was defined as a fasting plasma glucose level of 110 mg/dL or more (to convert to millimoles per liter, multiply by 0.0555) or a hemoglobin A_{1c} level of 7% or more (to convert to proportion of total hemoglobin, multiply by 0.01). Diabetic patients were characterized as having insulin-dependent diabetes mellitus or non–insulin-dependent diabetes mellitus. Hypertension was defined as a systolic blood pressure greater than 140 mm Hg or diastolic blood pressure greater than 90 mm Hg on 3 occasions during a 6-month period. Restenosis was defined as the development of 50% or more stenosis. For in-stent restenosis, duplex ultrasonography velocities more than 225 cm/s were defined as stenosis more than 50%. Technical failure was defined as an inability to perform the intended procedure or if a reintervention occurred within 30 days of the initial procedure. A major adverse event (MAE) was defined as an ipsilateral stroke, MI, or death during follow-up. The time to MAE was determined as the first occurrence of any of the 3 MAE factors (stroke, MI, or death). Unlike the Stenting With Angioplasty and Protection in Patients at High Risk for Endarterectomy trial, patients did not have a troponin series performed or formal neurological consultations postprocedure.

A death within 30 days of the procedure was considered procedure related. Perioperative was defined as a stroke occurring during the hospital admission and less than 30 days postprocedure. A major complication was defined as any event, regardless of how minimal, not routinely observed after therapy that required treatment with a therapeutic intervention or rehospitalization within 30 days of the procedure.

STATISTICAL ANALYSIS

Measured values are reported as percentages or means and standard deviations. Rates for comorbidities, complications, and 30-day outcomes were compared between patients with normal renal function, moderate renal insufficiency, and severe renal insufficiency by χ^2 test. Survival, patency, stroke-free, MI-free, and MAE-free rates were calculated using Kaplan-Meier analysis and are reported using current Society for Vascular Surgery criteria. Standard errors are reported in Kaplan-Meier analyses. The log-rank test was used to determine survival differences between patients with normal, moderate, or severe renal insufficiency. Statistical significance is defined as a 2-tailed *P* value of less than .05 for all tests.

RESULTS

PATIENT POPULATION

Nine hundred twenty-one carotid revascularization procedures were performed. Sixty-four percent of the patients were male. The mean (SD) age was 71 (10) years. The proportion of patients older than 80 years was 19%. Forty-eight percent of the patients were asymptomatic. Of those presenting with symptoms, the most common was

Table 1. Patient Comorbidities

	%					%		
	Total (N=921)	Normal RF (n=604)	Moderate RI (n=262)	Severe RI (n=55)	*P* Value	CEA (n=750)	CAS (n=171)	*P* Value
Myocardial infarction	27	23	29	55	<.001[a]	23	46	<.001[a]
Congestive heart failure	12	8	15	33	<.001[a]	7	30	<.001[a]
Hypertension	87	85	90	96	.03[a]	87	88	.66
Non–insulin-dependent DM	28	25	33	42	.01[a]	3	5	.19
Insulin-dependent DM	4	2	5	9	.007[a]	29	27	.67
Hypothyroidism	11	10	16	9	.04[a]	11	14	.21

Abbreviations: CAS; carotid angioplasty and stenting; CEA, carotid endarterectomy; DM, diabetes mellitus; Moderate RI, moderate renal insufficiency; Normal RF, normal renal function; Severe RI, severe renal insufficiency.
[a]Significant.

ipsilateral transient ischemic attack (30%), followed by ipsilateral stroke (19%) and vertebrobasilar symptoms (2%). All of the patients with vertebrobasilar symptoms had 80% or more carotid stenosis at presentation.

RENAL FUNCTION STATUS

Using the Modification of Diet in Renal Disease formula for evaluation of renal function, the mean estimate of GFR was 69.5 mL/min/1.73m^2. Renal function by staging system was as follows: stage 0 or 1 (18%), stage 2 (48%), stage 3 (29%), stage 4 (5%), and stage 5 (1%). By group, there were 604 patients (66%) classified as having normal renal function, 262 patients (28%) as having moderate renal insufficiency, and 55 patients (6%) with severe renal insufficiency. Seven patients were currently undergoing hemodialysis at the time of intervention.

COMORBIDITIES

For cardiac comorbidities, 27% had a prior MI, 12% carried a diagnosis of congestive heart failure, 87% presented with hypertension, and 9% were known to have atrial fibrillation. Ten percent of the patients had chronic obstructive pulmonary disease. Thirty-two percent of the patients were diabetic (28% with non–insulin-dependent diabetes mellitus and 4% with insulin-dependent diabetes mellitus). Eleven percent had hypothyroidism. Seventy-three percent of the patients had a tobacco use history. See **Table 1** for a breakdown of comorbidities by group and procedure.

PROCEDURES

Nine hundred twenty-one carotid revascularizations were performed, 750 (81%) were CEA and 171 (19%) were CAS. Patients with normal renal function underwent 506 CEAs (84%) and 98 CAS (16%). Of those with moderate renal insufficiency, 202 CEAs (77%) were performed and 60 CAS (23%) were performed. Patients with severe renal insufficiency underwent 42 CEAs (76%) and 13 CAS (24%). When compared with those patients with normal renal function, patients with moderate renal function underwent CEA at a statistically significant lower rate (84% vs 77%; $P=.02$), whereas there was no statistical difference between those with normal renal function and severe renal insufficiency (84% vs 76%; $P=.16$). For patients undergoing CEA, 49% received a cervical block, and 51% underwent general endotracheal anesthesia. The choice of anesthesia was not found as a predictor for perioperative events. For those undergoing CAS, 137 (80%) had a successful deployment of an embolic protection device, 10 (6%) had a failed attempt at embolic protection device deployment, and 24 interventions (14%) did not attempt deployment. Of the 10 failed embolic protection device deployments, one of the failures was associated with an intraprocedure stroke.

THIRTY-DAY OUTCOMES

The 30-day overall mortality rate was 1.1%. The overall 30-day stroke and MI rates were 3.04% and 1.30%, respectively. The overall 30-day combined stroke/death rate was 3.58%. The 30-day and 90-day MAE rates were 4.3% and 5.9%, respectively, for all patients. The 30-day morbidity rate for all patients was 16.9%. Systemic complications were infrequent: 16 (1.7%) cardiac, 9 (1.0%) pulmonary, and 2 (0.2%) renal. For regional complications, bradycardia (2.9%) and hypotension (2.5%) were the most common. The most frequent local complication was hematoma (7.1%) and vasospasm (1.1%). The patient's renal function status was not associated with overall morbidity occurrence.

Between the 3 groups of patients based on renal function, no difference was seen between the groups with regard to 30-day outcomes for stroke, MI, reintervention, or combined stroke/death. The severe renal insufficiency group exhibited a higher 30-day mortality rate compared with those with normal renal function (5.45% vs 0.66%; $P=.001$).

Isolating the groups of patients by procedure type, no difference was found in 30-day outcomes for those undergoing CEA. However, a significant difference was noted in 30-day outcomes for patients based on renal function status for those undergoing CAS. Patients with severe renal insufficiency when undergoing CAS had statistically higher rates of 30-day mortality (15.39%), 30-day stroke (23.08%), and 30-day combined stroke and death (23.08%) (**Table 2**).

Examining all patients regardless of renal status, differences were observed between CEA and CAS for 30-day outcomes. Patients undergoing CAS experienced higher rates of 30-day MI (3.5% vs 0.8%; $P=.005$) and 30-day mortality (2.9% vs 0.7%; $P=.01$) with respect to patients undergoing CEA. The 30-day stroke rate for patients undergoing CAS was increased (5.3% vs 2.5%) when compared with patients undergoing CEA but insignificant ($P=.07$).

Table 2. Thirty-Day Outcomes

	Total, %			
	Normal RF	Moderate RI	Severe RI	*P* Value
Overall				
Mortality	0.66	1.15	5.45	.005[a]
Stroke	2.98	2.67	5.45	.54
Myocardial infarction	0.99	1.91	1.82	.52
Combined stroke and death	3.64	2.67	7.27	.25
Major adverse event	4.30	3.82	7.27	.52
Morbidity	18	16	13	.64
CEA				
Mortality	0.59	0.50	2.38	.37
Stroke	2.77	2.48	0	.55
Myocardial infarction	0.59	1.49	0	.41
Combined stroke and death	3.36	2.48	2.38	.80
Major adverse event	3.75	3.47	2.38	.89
Morbidity	15	11	10	.39
CAS				
Mortality	1.02	3.33	15.39	.02[a]
Stroke	4.08	3.33	23.08	.01[a]
Myocardial infarction	3.06	3.33	7.69	.69
Combined stroke and death	5.10	3.33	23.08	.02[a]
Major adverse event	7.14	5.00	23.08	.08
Morbidity	33	33	23	.76

Abbreviations: CAS, carotid angioplasty and stenting; CEA, carotid endarterectomy; Moderate RI, moderate renal insufficiency; Normal RF, normal renal function; Severe RI, severe renal insufficiency.
[a]Significant.

LONG-TERM OUTCOMES

The mean duration of follow-up was 4.5 years. During this period, 33 (4%) required reintervention, 50 (5%) experienced an ipsilateral stroke, 89 (10%) had an MI, and 259 (28%) died. Three hundred twenty-one (35%) experienced an MAE during follow-up.

For all patients, no difference in 5-year stroke rates was identified by Kaplan-Meier analysis between the 3 groups of patients based on level of renal function. However, a difference was observed for MI, survival, and MAE by Kaplan-Meier analysis for all patients based on renal function status. Isolating only those patients undergoing CEA, no statistical difference was identified in the 5-year stroke rate based on Kaplan-Meier analysis, but there were differences in 5-year rates of freedom from MI, survival, and freedom from MAE. For the patients who underwent CAS only, no difference was identified for 5-year freedom from MI or MAE. However, a significant difference was observed for the patients who underwent CAS only for 5-year freedom from stroke and survival (**Table 3**).

The 5-year outcomes were similar for patients with normal renal function when compared with moderate renal insufficiency. No significant difference was observed for 5-year rates of freedom from stroke, MI, or MAE for these 2 groups whether undergoing CEA or CAS. However, 5-year survival rates did differ for those patients with normal vs moderate renal function when undergoing CEA. A survival difference was identified for patients undergoing CAS between patients with normal renal function and moderate renal insufficiency (**Table 4**).

Patients with severe renal insufficiency overwhelmingly had poor outcomes compared with those with normal renal function. For those undergoing CEA only, patients with severe renal insufficiency had lower rates for freedom from MI, survival, and freedom from MAE at 5 years. For those undergoing CAS only, patients with severe renal insufficiency had significantly lower rates of freedom from stroke, survival, and freedom from MAE at 5 years (Table 4).

COMMENT

In this study, we examined the outcomes of carotid revascularization by means of CEA or CAS for 921 patients. A substantial proportion of our patient population exhibited renal insufficiency, moderate (28%) or severe (6%). As reported earlier, the outcomes for these 3 groups differed significantly.

Multiple prospective and retrospective studies have evaluated the perioperative outcomes of patients with renal insufficiency undergoing CEA,[7-17] and fewer have studied those undergoing CAS.[18] All of the CEA studies examining the outcomes for patients with severe renal insufficiency (creatinine level >3.0 mg/dL [to convert to micromoles per liter, multiply by 88.4] or GFR <30 mL/min/1.73m^2) have shown significantly higher rates of 30-day mortality when compared with patients with normal renal function. The 30-day outcomes for stroke and MI are not consistent among all of the prior studies between patients with normal renal function and severe renal insufficiency when undergoing CEA. A single-center study by Saw et al[18] evaluated CAS outcomes for patients with chronic kidney disease and reported a significantly higher rate of 6-month death, stroke, or MI.

Table 3. Five-Year Freedom From Event Rates

	Total, %			
	Normal RF	Moderate RI	Severe RI	*P* Value
Overall				
Mortality	80.3	69.7	37.0	<.001[a]
Stroke	94.5	94.4	89.4	.10
Myocardial infarction	91.4	89.7	68.3	<.001[a]
Major adverse event	72.0	64.6	32.3	<.001[a]
CEA				
Mortality	80.3	71.7	33.6	<.001[a]
Stroke	94.7	94.1	93.1	.69
Myocardial infarction	92.3	90.6	65.9	<.001[a]
Major adverse event	72.5	66.6	28.8	<.001[a]
CAS				
Mortality	86.7	54.2	58.6	.04[a]
Stroke	94.9	96.7	76.9	.01[a]
Myocardial infarction	88.2	89.4	73.3	.86
Major adverse event	75.4	48.3	47.5	.11

Abbreviations: CAS, carotid angioplasty and stenting; CEA, Carotid Endarterectomy; Moderate RI, moderate renal insufficiency; Normal RF, normal renal function; Severe RI, severe renal insufficiency.
[a]Significant.

Table 4. Five-Year Freedom From Event Rates: Normal vs Moderate Renal Insufficiency and Normal vs Severe Renal Insufficiency

	%				
	Normal RF	Moderate RI	*P* Value	Severe RI, %	*P* Value
CEA					
Mortality	80.3	71.7	.02[a]	33.6	<.001[a]
Stroke	94.7	94.1	.77	93.1	.39
Myocardial infarction	92.3	90.6	.83	65.9	<.001[a]
Major adverse event	72.5	66.6	.18	28.8	<.001[a]
CAS					
Mortality	86.7	54.2	.058	58.6	.003[a]
Stroke	94.9	96.7	.60	76.9	.01[a]
Myocardial infarction	88.2	89.4	.70	73.3	.54
Major adverse event	75.4	48.3	.45	47.5	.03[a]

Abbreviations: CAS, carotid angioplasty and stenting; CEA, carotid endarterectomy; Moderate RI, moderate renal insufficiency; Normal RF, normal renal function; Severe RI, severe renal insufficiency.
[a]Significant.

Only 2 prior studies have examined the outcomes of patients undergoing CEA and used the Modification of Diet in Renal Disease formula for estimation of renal function, the earlier-mentioned report by Kretz et al[13] and a multicenter Veterans Affairs study examining 20 899 patients using National Surgical Quality Improvement Program data by Sidawy et al.[10] Kretz et al found similar outcomes for patients with normal renal function and moderate renal insufficiency when undergoing CEA. Meanwhile, patients with severe renal insufficiency had statistically significant higher rates of 30-day mortality, 30-day neurological events, and combined 30-day stroke/death rates when undergoing CEA. From the National Surgical Quality Improvement Program data of 20 899 patients examined by Sidawy et al, patients with moderate renal insufficiency exhibited higher rates of cardiac and pulmonary events but no difference in 30-day mortality or 30-day stroke when undergoing CEA. The patients with severe renal insufficiency only exhibited higher rates of mortality when compared with those with normal renal function, and thus, no difference was found for 30-day stroke or 30-day cardiac events.

OVERALL OUTCOMES

In this study, we reported the outcomes for all patients undergoing carotid revascularization and examined based on degree of renal function, as well as for the individual carotid revascularization procedure, CEA or CAS. This is a retrospective study, and the patients were not randomized to undergo CEA or CAS. At the time of intervention, the vascular surgeon and patient deemed one procedure over the other as the more appropriate intervention. The patients undergoing CAS had statistically significant higher rates of prior MI and congestive heart failure, both negative predictors for postoperative cardiac complications. Patients with moderate renal insufficiency were more likely to undergo CEA over CAS, whereas there was no significant difference for patients with severe renal insufficiency undergoing CEA vs CAS. The separate analysis of

outcomes for patients based on renal status for the individual procedures is to highlight the influence of renal insufficiency on perioperative and postoperative outcomes for that individual intervention rather than to defend one procedure as superior to another for patients with renal insufficiency.

CEA OUTCOMES

Our study reports similar outcomes to those stated by Kretz et al[13] and Sidawy et al[10] with respect to patients with moderate renal insufficiency (GFR 30-59 mL/min/1.73m^2). We did not identify higher rates of 30-day mortality, 30-day stroke, 30-day MI, or 30-day MAE for patients with moderate renal insufficiency undergoing CEA when compared with those with normal renal function. Our findings of patients with severe renal insufficiency (GFR <30 mL/min/1.73m^2) were the same, with no statistically significant difference of 30-day event rates when undergoing CEA. We did not identify a higher 30-day cardiac events rate for patients with severe renal insufficiency, as Sidawy et al found, but we did not include 30-day pulmonary event rates in our outcomes analysis. Likewise, our results differed from Kretz et al with respect to patients with severe renal insufficiency undergoing CEA and did not identify higher rates of 30-day mortality, 30-day stroke, or 30-day stroke/death.

However, our study did examine outcomes between these groups of patients beyond 30 days. By extending our evaluation of outcomes to 5 years by Kaplan-Meier analysis, we did find significant differences between groups undergoing CEA based on level of renal function. For those with moderate renal insufficiency, the only outcome significantly different at 5 years was survival when compared with those with normal renal function undergoing CEA. Patients with severe renal insufficiency had significantly lower rates at 5 years for freedom from MI, survival, and freedom from MAE when compared with patients with normal renal function undergoing CEA. We did not identify differences in 5-year rates of freedom from stroke when undergoing CEA, regardless of level of renal function.

CAS OUTCOMES

The single-center study by Saw et al,[18] which evaluated 6-month outcomes for patients with chronic kidney disease undergoing CAS, separated patients into 1 of 2 groups based on a GFR more or less than 60 mL/min/1.73m^2 and did not divide patients into normal, moderate, or severe renal insufficiency groups. Our short-term perioperative outcomes (30 day and 90 day) for MAE were similar to Saw et al and found patients with severe renal insufficiency undergoing CAS to have significantly higher MAE rates. These patients with severe renal insufficiency undergoing CAS exhibited higher 30-day stroke, 30-day death, and 30-day MAE rates when compared with those with normal renal function undergoing CAS. We did not identify a difference in 30-day outcomes between patients with normal renal function and moderate renal insufficiency when undergoing CAS. Among long-term outcome, only a 5-year survival advantage was observed for patients with normal renal function undergoing CAS compared with those patients with moderate renal insufficiency. Long-term analysis revealed no difference in 5-year rate for freedom from stroke, MI, and MAE between patients with normal renal function and moderate renal insufficiency. However, patients with severe renal insufficiency had significantly lower rates at 5 years for freedom from stroke, death, and MAE compared with those with normal renal function.

STUDY LIMITATIONS

This study is a retrospective study and thus has the all problems related to such a study. There were no formal neurological or cardiac evaluations postprocedure, which may have resulted in an underestimation of these complications. Finally, there were a number of patients who underwent hemodialysis in the 2 cohorts. A further limitation of this study, when comparing CEA vs CAS, is a potential unequal distribution of patients toward one modality based on the preconceived notion that one modality was safer for high-risk patients. During our study period, 1996 to 2006, CAS was often seen as the "less invasive" and therefore safer operation for patients deemed as medically high risk. We used the Vascular Study Group of New England Cardiac Risk Index to evaluate the cardiac risk of patient and treatment groups.[21] The mean Vascular Study Group of New England Cardiac Risk Index score for the 3 groups based on renal function was significantly different: normal renal function, 4.4; moderate renal insufficiency, 5.6; and severe renal insufficiency, 7.7; $P<.001$. However, between treatment modalities, no difference was seen; patients undergoing CAS and CEA had a mean score of 5.2 and 4.9, respectively ($P=.14$). As mentioned in the "Results" section, patients with moderate renal insufficiency (GFR 30-59 mL/min/1.73m^2) did undergo CAS at a statistically significant higher rate; however, no difference was identified for patients with severe renal insufficiency (GFR <30 mL/min/1.73m^2) being selected for one modality vs the other.

CONCLUSIONS

Renal impairment is prevalent among patients undergoing CEA or CAS for carotid revascularization. Overall, patients with moderate renal function have similar outcomes during the perioperative period. However, those with severe renal insufficiency have significantly higher 30-day mortality when undergoing carotid revascularization. When undergoing CEA, both the short-term and long-term outcomes for freedom from stroke are similar among patients, regardless of degree of renal function. However, when undergoing CAS, patients with severe renal insufficiency exhibit higher rates of stroke during both the perioperative period as well as during long-term analysis.

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INVITED CRITIQUE

Should Patients With Chronic Renal Insufficiency Undergo Carotid Intervention?

When analyzing the findings of this study,[1] the following facts must be kept in mind. Chronic renal insufficiency (CRI) is associated with advanced multiple vascular pathologies affecting various systems, eg, coronary artery disease, cerebrovascular disease, and peripheral arterial disease, which may affect the operative outcome. Several studies have called into question the best treatment for patients with carotid stenosis concomitant with chronic renal failure, showing increased morbidity and mortality after carotid endarterectomy. Several other studies have only shown differences when patients are separated into mild (creatinine level of 1.6-2.9 mg/dL [to convert to micromoles per liter, multiply by 88.4]) vs severe (creatinine level of ≥3 mg/dL) CRI, with increased stroke or death in patients with severe CRI after carotid endarterectomy. A few studies have shown that carotid angioplasty and stenting was associated with unacceptable risks in patients with CRI and questioned its effectiveness.

The variations in the results of these publications can be explained by the definitions of renal insufficiency that were used. Some authorities use a plasma level of creatinine to define CRI, while others believe creatinine clearance is better; meanwhile, others combine both functions. Furthermore, different levels of serum creatinine have been used to define the degree of CRI. The methods used to calculate creatinine clearance may also differ. In most studies, either the Cockcroft-Gault or the Modification of Diet in Renal Disease method was used.[2] This makes it difficult to compare the results of these studies and to determine the stage of CRI that may impact the results of carotid intervention. It is generally believed that creatinine is a late and insensitive marker, which can remain lower than 2.0 mg/dL, despite a significant reduction of the glomerular filtration rate to as low as 15 mL/min/1.73 m^2. Because of these inaccuracies, the National Kidney Foundation Kidney Disease Outcomes Quality Initiative guidelines recommended the use of glomerular filtration rate as a better early indicator of chronic kidney disease.

A recent study by van Lammeren et al[3] concluded that patients with an estimated glomerular filtration rate of