

Renal angioplasty and stenting with distal protection of the main renal artery in ischemic nephropathy: Early experience¹

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Purpose: We present a retrospective review of a single tertiary hospital experience in renal artery stent revascularization with distal protection in patients with ischemic nephropathy. The objectives of the study included preliminary assessment of the effect of distal protection on procedure-related acute deterioration in renal function and on renal salvage.

Material and methods: All patients had significant atherosclerotic main renal artery stenosis, documented at preprocedural imaging, and a degree of chronic renal impairment before revascularization. Forty-six renal arteries were treated in 37 patients with preprocedural renal impairment, which was mild in 10 patients, moderate in 19 patients, and severe in 8 patients. Median patient age was 72 years (range, 59-85 years). All patients underwent primary stenting of renal artery ostial stenoses with adjuvant use of a filter device (Angioguard guide wire system; Cordis Corp, Division of Johnson & Johnson, Miami, Fla) in the distal main renal artery. The filter baskets were recaptured for pathologic analysis.

Results: Overall, in 95% of patients, including all patients with preprocedural mild or moderate renal impairment, renal function was stabilized or improved after revascularization. In 5% of patients decline in renal function was unchanged. No patients had acute postprocedural deterioration. Mean follow-up was 12.5 months (range, 2-28 months). These results are better than in most reports in the literature and also better than in a historical group of similar patients with ischemic nephropathy who underwent stent revascularization without distal protection at the same institution. The improved results are thought to be due to prevention of cholesterol atheroembolization during the procedure by the distal filter baskets. Sixty-five percent of the distal protection baskets contained embolic material, including fresh thrombus, chronic thrombus, atheromatous fragments, and cholesterol clefts.

Conclusion: A distal protection device may significantly improve results during stent revascularization. There are a number of unique demands on a renal protection device, and the ideal device has not yet been developed. (J Vasc Surg 2003;38:962-8.)

Atherosclerotic renal artery stenosis is a significant cause of chronic renal failure,¹ particularly in elderly patients.² Moreover, at least 50% of significant renal artery stenoses will progress.^{3,4} The results of renal artery angioplasty in patients with ischemic nephropathy have been mixed, but generally disappointing.⁵ We postulated that procedure-related atheroembolization contributes to the unfavorable outcome with this procedure. Early experience with renal angioplasty and stenting, with distal protection of the main renal artery, is reported in a patient group with ischemic nephropathy.

MATERIAL AND METHODS

Retrospective data were analyzed for consecutive patients with ischemic nephropathy and atherosclerotic renal artery stenosis. The diagnosis of ischemic nephropathy was made on the basis of chronic renal impairment and demonstrable significant main renal artery stenosis. No patients had significant proteinuria, which would suggest other causes of nephropathy.

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Competition of interest: none.

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Patients were referred by hospital-based specialist referral services, including renal medicine, cardiology, and vascular surgery. All patients had demonstrated a decline in renal function over the previous 6 to 12 months. Patients with hypertension (65%) were referred for possible improvement in control of blood pressure and maintenance of renal function; the remainder were referred for preservation of renal function (renal salvage). No patients were primarily referred for treatment of cardiac complications such as flash pulmonary edema.

Forty-six renal arteries in 37 patients with ischemic nephropathy underwent renal artery angioplasty and stenting, with distal main renal artery protection, at Auckland Hospital between June 2000 and October 2002 (28 months). The patient group included 27 men (73%) and 10 women (27%), with median age 72 years (range, 59-85 years). Serum creatinine concentration (SCr) measured immediately before renal artery revascularization was used to indirectly calculate creatinine clearance with the Cockcroft-Gault equation. On the basis of this indirect creatinine clearance calculation, patients were divided into three groups, that is, with mild, moderate, or severe renal impairment. Ten patients had mild renal impairment (creatinine clearance, >40 mL/min), 19 patients had moderate renal impairment (creatinine clearance 15-40 mL/min), and 8 patients had severe renal impairment (creatinine clearance <15 mL/min). The preintervention diagnosis of renal artery stenosis was made with magnetic

resonance angiography in 26 patients (70%), digital subtraction angiography in 10 patients (27%), and renovascular Doppler scanning in 1 patient (3%). All stenoses involved the main renal artery ostium, defined as stenosis without a non-diseased renal arterial segment between the lesion and the aortic lumen. In 9 patients bilateral high-grade renal artery stenosis was treated during a single procedure; in the remaining 28 patients single renal arteries were treated. Of these, 12 patients had complete occlusion of the contralateral main renal artery, and 2 patients had previously undergone nephrectomy. In 4 patients the contralateral main renal artery was of normal caliber, but abnormal renal function and hypertension were present. In the remaining 10 patients contralateral renal artery stenosis was not treated, because of small kidney (<7 cm) on ultrasound scans or magnetic resonance images (n = 6) or a diffusely small-caliber main renal artery (n = 4).

Treated main renal artery stenosis was assessed as greater than 80% diameter loss compared with the closest downstream arterial segment (beyond any poststenotic dilatation) at preprocedural digital subtraction angiography or contrast enhanced magnetic resonance angiography in 36 patients. The severity of stenosis was confirmed at the interventional procedure, although intra-arterial pressure measurements were not routinely obtained. In one patient a renovascular Doppler scan suggested the presence of critical stenosis, which was confirmed on the procedural angiogram.

Patients were admitted to hospital the day before the procedure for overnight intravenous hydration, which was continued for approximately 24 hours after the procedure. In 12 patients (32%) an intra-arterial gadolinium chelate was used as the procedural contrast medium, up to a dose limit of 0.3 mmol/kg. The chelates used included gadodiamide (Omniscan; Amersham Health, Oslo, Norway) and gadopentate (Magnevist; Schering AG, Berlin, Germany), both in concentrations of 0.5 mmol/mL. In the remaining patients only iodinated contrast medium was used. In the last five of these patients oral acetylcysteine was administered (600 mg twice daily) the day before and the day of the procedure. All patients received intra-arterial bolus doses of heparin (5000 IU) and glyceryl trinitrate (mean, 175 μ g per patient) during the procedure.

A common femoral artery approach was used in all patients. After 0.018-inch guide wire traversal of the stenosis, an 8F guide catheter with central dilator was introduced through the stenosis, effectively producing "Dotter dilation" of the stenosis up to the outer diameter of the 8F guide catheter (2.7 mm). This enabled safe delivery of the distal protection device and subsequent primary stenting of the stenosis (Fig 1). No stenosis required predilatation to deliver the guide catheter. The distal protection device used in all patients was the Angioguard emboli capture guide wire system (Cordis Corp, Division of Johnson & Johnson, Miami, Fla), deployed in the distal main renal artery. This device consists of a 0.014-inch guide wire with a polyurethane basket at the distal end. The basket has 100- μ m pores and is supported by eight nitinol struts. A balloon-expand-

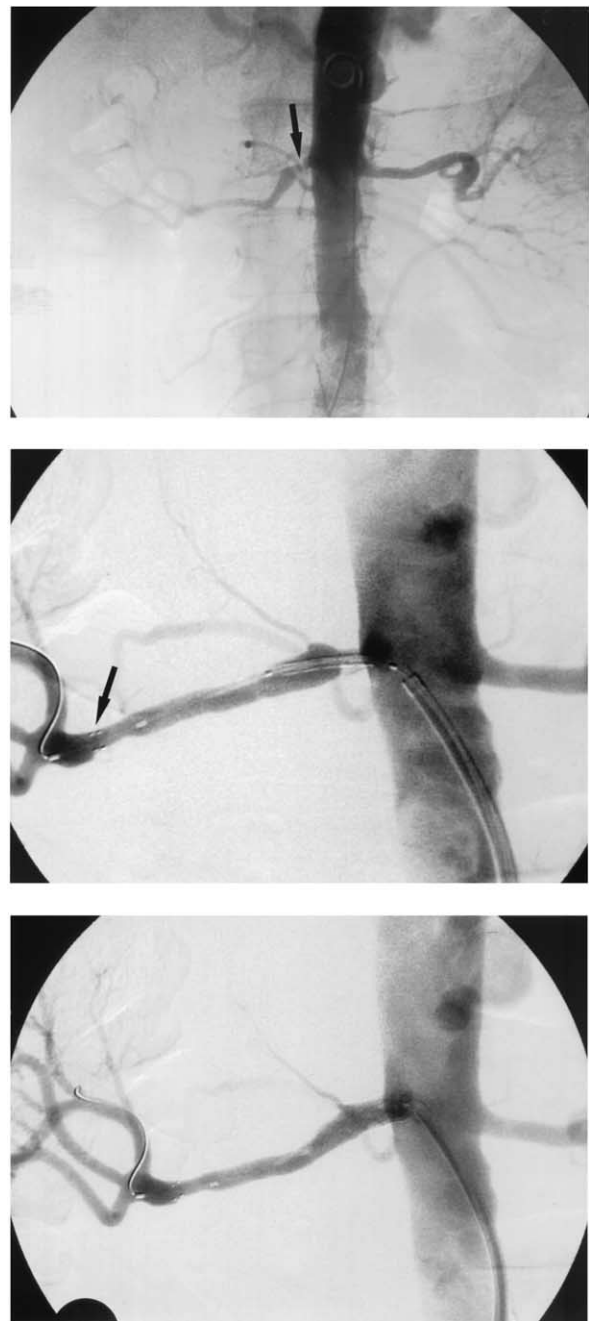


Fig 1. Right renal artery angioplasty and stenting with distal renal artery protection. **A**, Abdominal aortogram with gadolinium chelate as intra-arterial contrast medium. Stenosis involving ostium of right main renal artery is confirmed (arrow). **B**, Angiogram obtained in left anterior oblique position via guide catheter enables accurate position of stent relative to renal artery ostium. Filter lies in distal main renal artery (arrow). **C**, Completion angiogram obtained before removal of distal filter.

able stent was then primarily deployed after withdrawal of the guide catheter. Angiography via the guide catheter in anteroposterior and oblique planes was performed before

Overall results of renal artery stent revascularization

Outcome	No. of procedures			
	Without distal protection		With distal protection	
	n	%	n	%
Improved renal function		0	14	38
Stabilized renal function	15	75	21	57
Unchanged decline	4	20	2	5
Acute deterioration	1	5	0	0

stent deployment, to assist in accurate localization of the renal artery ostium. Most stents (87%) were inflated to a diameter of 6 mm, with the remainder (13%) inflated to 7 mm. After completion angiography, the distal basket was recaptured and sent for pathologic analysis.

Renal function alterations after renal artery revascularization were determined with measurement of SCr. In all patients SCr was measured within 24 hours after the procedure (day 1 SCr). The most recent SCr measurement was also recorded (renal follow-up SCr). Creatinine clearance was again indirectly calculated with the Cockcroft-Gault equation. Changes in renal function after the procedure were classified as renal function improved (follow-up SCr >20% below pretreatment SCr), renal function stabilized (follow-up SCr <20% above or below pretreatment SCr), or unchanged decline in renal function (follow-up SCr >20% above pretreatment SCr, with decline occurring at a rate similar to pretreatment decline). Day 1 SCr more than 20% below pretreatment SCr indicated procedure-related acute deterioration.

Baseline renovascular Doppler scanning was performed at 6 weeks in 30 patients (81%). These studies included direct interrogation of the treated main renal artery plus indirect assessment of the stenosis by obtaining spectral waveforms from intrarenal segmental arteries, with measurement of acceleration times and resistive indices. In the patient group with hypertension, review of clinical records and patient telephone contact was performed to assess alterations in blood pressure control after renal artery revascularization.

A retrospective analysis of 22 arteries in 20 patients with ischemic nephropathy was performed. These patients underwent renal artery stent revascularization without distal renal artery protection at the same institution in the 2 years before the current study (October 1998-May 2002). These patients were a little younger (median age, 69 years), again with a male predominance (60%). Compared with patients who underwent revascularization with distal renal artery protection, these 20 patients had better renal function before revascularization, that is, mild renal impairment (creatinine clearance >40 mL/min) in 25% of patients and moderate renal impairment (creatinine clearance 15-40 mL/min) in 75% of patients. No patients had severe renal impairment, and none received intra-arterial gadolinium or acetylcysteine.

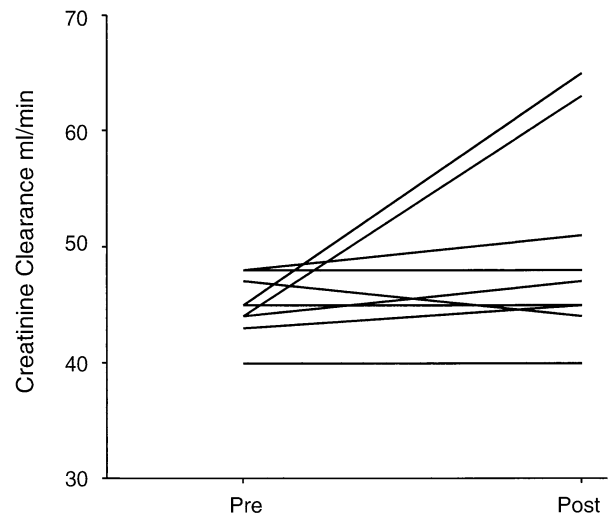


Fig 2. Changes in creatinine clearance after renal angioplasty and stenting with distal renal artery protection in patients with mild chronic renal impairment (creatinine clearance >40 mL/min).

RESULTS

Changes in renal function after stent revascularization with distal renal artery protection are summarized in the Table. In 95% of patients renal function was stabilized or improved. Mean follow-up was 12.5 months (range, 2-28 months). In all patients with mild or moderate renal impairment before revascularization, renal function improved or was stabilized after the procedure (Figs 2, 3). In the group with severe renal impairment, 2 patients (5%) had unchanged decline in renal function (Fig 4). One of these patients also had longstanding, poorly controlled diabetes and diabetic nephropathy, and was receiving dialysis therapy 5 months after revascularization. In the remaining patients in this group renal function improved or was stabilized after revascularization. In no patient was there acute decline in renal function after the procedure.

One patient experienced short-term improvement in renal function after bilateral renal artery stenting with distal renal artery protection. However, endoluminal repair of an infrarenal abdominal aortic aneurysm was performed 1 month later with the stented renal arteries unprotected during the procedure. Severe renal and peripheral atheroembolization developed immediately after the procedure. This patient's aorta was severely atheromatous, which was likely the source of atheroembolization due to stiff guide wire irritation during the endoluminal procedure.

The distal protection baskets contained macroscopic or microscopic contents in 30 of 46 cases (65%). These included fresh thrombus, chronic thrombus, atheromatous fragments, and cholesterol clefts. The remainder of the baskets were either empty or contained insufficient material to survive processing.

Changes in renal function after stent revascularization in the control group without distal renal artery protection

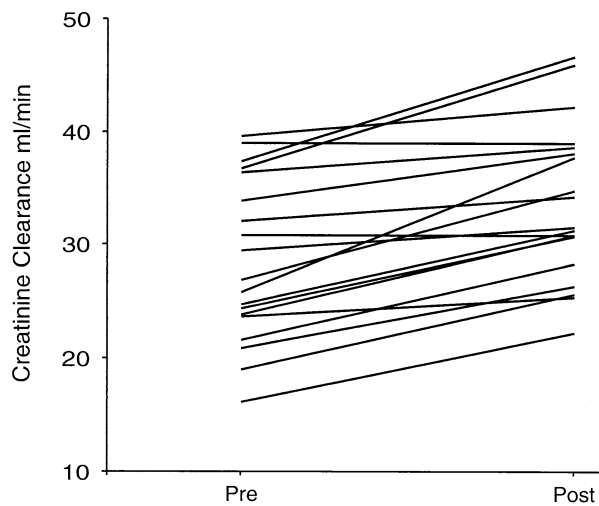


Fig 3. Changes in creatinine clearance after renal angioplasty and stenting with distal renal artery protection in patients with moderate chronic renal impairment (creatinine clearance 15-40 mL/min).

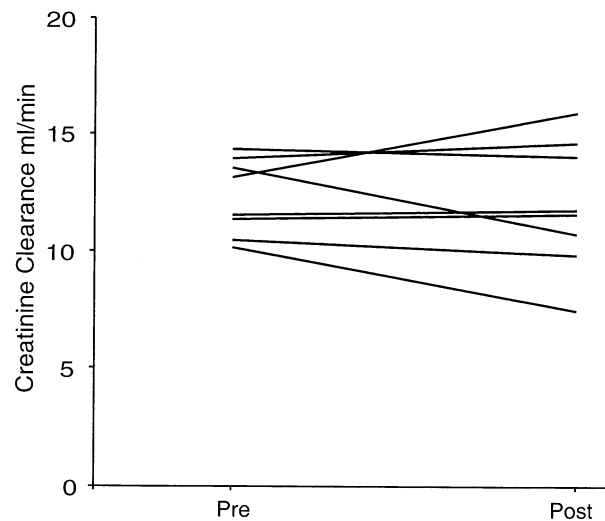


Fig 4. Changes in creatinine clearance after renal angioplasty and stenting with distal renal artery protection in patients with severe chronic renal impairment (creatinine clearance <15 mL/min).

are summarized in the Table. Although this patient group had better pretreatment renal function, 25% of patients experienced either unchanged decline or acute deterioration in renal function after the procedure.

In the 81% of patients who underwent 6-week post-treatment renovascular Doppler scanning, all treated renal arteries (100%) were patent, with no evidence of residual stenosis. A smaller group of patients (21%) also underwent 6-month renovascular Doppler scanning. In one of these patients significant in-stent recurrent stenosis was demonstrated, and was confirmed at angiography. Management was with redilatation.

Before revascularization, patients with hypertension were receiving, on average, 2.5 antihypertensive medications. After renal artery revascularization, hypertension was not "cured," but the number of medications was reduced in 14 patients (57%), with the overall average number of medications reduced to 1.9 per patient. In a further 8 patients (33%), blood pressure was less labile, even though the number of medications was not changed.

DISCUSSION

Common indications for endovascular revascularization in renal artery stenosis are renovascular hypertension and ischemic nephropathy. Many studies report satisfactory symptomatic improvement with renal artery revascularization in patients with renovascular hypertension.^{6,7} Meta-analysis by Palmaz of eight studies, with 349 patients with renovascular hypertension, demonstrated improved blood pressure control in 56% of patients with endovascular stent revascularization, and resolution of hypertension in 10% of patients.⁵ However, several randomized prospective trials have shown little advantage of renal angioplasty over optimum medical management in patients with normal renal

function and blood pressure well-controlled with medication.^{8,9} These studies may not represent best endovascular practice, often including angioplasty alone rather than stent placement. Primary angioplasty with stenting significantly improves renal artery patency in ostial atherosclerotic disease.¹⁰⁻¹² Patients with hypertension that is resistant to medical therapy and with progressive renal insufficiency respond better to endovascular revascularization.

A number of investigations have enabled more accurate identification of patients with hypertension who will respond to endovascular treatment. Clinical predictors include flash pulmonary edema,¹³⁻¹⁵ hypertension resistant to medical therapy,¹⁶ rapid decline in renal function,¹⁶ and middle age rather than old age.¹⁷ Patients with decline in renal function after commencing angiotensin converting enzyme (ACE) inhibitor therapy also have a high incidence of renal artery stenosis.¹⁸ The most sensitive noninvasive investigations are captopril scintigraphy and Doppler scanning of intrarenal resistive index.^{17,19,20} Selective measurement of renal vein renin concentration is more invasive and appears to lack sensitivity as a reliable screening method for renovascular hypertension.²¹ Renal vein renin concentration measurement may have a role in identifying patients with hypertension who will benefit from nephrectomy.²²

Ischemic nephropathy is defined as excretory dysfunction resulting from impaired renal perfusion.²³ The role of renal artery revascularization in ischemic nephropathy is less clear than in renovascular hypertension. Many retrospective studies contain small patient numbers, with brief follow-up. Meta-analysis by Palmaz of 8 studies, with 349 patients, reported stabilized renal function in 38% of patients, and unchanged decline in 62% of patients.⁵ Other studies report similar or slightly better results.^{6,24-27} These studies report a low incidence (15%-25%) of improved renal



Fig 6. Completion angiogram after stenting of right main renal artery. Artery is patent to distal filter, but not beyond it, because of macroscopic emboli within filter. Flow was restored after filter recapture.

function after renal artery revascularization. In contrast, meta-analysis by Leertouwer et al²⁸ of 24 studies described renal function improvement in 30% of patients after renal artery angioplasty or stenting. An older meta-analysis reviewed studies that assessed surgical renal artery revascularization,²⁹ with reported improved renal function in 55% of patients. Of interest, one study was excluded from this meta-analysis because the results were considerably worse than in the remaining studies. Surgical manipulation of the atheromatous aorta was associated with a significantly poorer outcome, presumably due to atheroembolization.

Unlike renovascular hypertension, there are no reliable predictors of favorable response to revascularization in ischemic nephropathy. Noninvasive investigations for hyper-renin states, such as captopril-induced scintigraphy, do not necessarily predict a favorable response for renal salvage, especially in patients with normotension. There is evidence that pre-interventional assessment of intrarenal resistive indices may have some predictive value.¹⁹ There is no medical alternative that achieves improved renal perfusion in this patient group.

Most studies of endovascular revascularization in ischemic nephropathy report procedure-related acute decline in renal function of 10% to 20%.^{6,24-27} A possible reason for this decline is cholesterol atheroembolization. Cholesterol atheroembolization is embolization of atheromatous plaque fragments and cholesterol crystals. This is usually associated with catheter or surgical manipulation of a severely atheromatous aorta.^{30,31} The condition may present with acute renal failure, but more commonly with progressive loss of renal function over weeks.³¹ Cutaneous, gastrointestinal, and central nervous system manifestations are also noted. The reported incidence of cholesterol athero-

embolization as an acute complication of renal artery angioplasty and stenting is low (1%-2%).⁵ However, the true incidence is likely much higher, because reported cases are biopsy-proved and associated with systemic manifestations. The carotid angioplasty and stenting literature shows that guide wire and catheter manipulation, and especially angioplasty, is associated with distal embolization, as recognized on transcranial Doppler scans or from clinical symptoms.³² Cerebral protection devices reduce the number of emboli that reach the target organ (brain) and reduce target organ damage.³³ Endovascular manipulation of the atheromatous renal artery ostium is also a likely source of cholesterol atheroembolization.

SCr is frequently used as a convenient measure of functional renal reserve, because creatinine is almost exclusively excreted into the urine by glomerular filtration. However, SCr is altered by a number of factors, including muscle mass. Consequently, elderly patients, with reduced muscle mass, tend to have lower SCr, even if renal function is impaired. In these patients creatinine clearance is a better measure of glomerular filtration rate. Because of the large functional renal reserve, as much as 50% of total glomerular filtration can be lost before SCr becomes abnormal (Fig 5, online only).³⁴ However, once the SCr becomes abnormal, the curve relating GFR to SCr becomes much steeper. Small reductions in residual functional renal mass are then associated with exponential elevation in SCr. Thus, if endovascular revascularization is performed in a patient with renal impairment and is complicated by cholesterol atheroembolization, a dramatic post-procedural elevation in SCr is seen. This serious complication has stimulated interest in use of renal artery protection during endovascular revascularization in patients with ischemic nephropathy.

This study reports initial experience of renal artery stent revascularization with distal renal artery protection in patients with ischemic nephropathy. In most patients (95%) renal function was stabilized or improved. These results are considerably better than most reported in the literature. They are also better than for a historical group of renal revascularization procedures performed at the same institution but without renal artery protection, even though that group had better baseline renal function. It is likely that use of distal renal artery protection contributed to these results. The pathologic yield from the distal baskets supports this conclusion (Fig 6). In an unfortunate, but instructive, case, the patient successfully underwent stent revascularization of both renal arteries with distal renal artery protection, but cholesterol atheroembolization subsequently developed during endoluminal aneurysm repair without protected renal arteries.

In this study the best results were achieved in patients with moderate renal impairment (creatinine clearance 15-40 mL/min) before revascularization. These patients have significant arterial insufficiency, but with a reasonable amount of functional renal parenchyma, and therefore are an attractive treatment group.

There is little literature describing use of distal renal artery protection in revascularization, although safety and

feasibility with a temporary occlusive balloon has been demonstrated.³⁵ Our study confirms safety with an alternative distal protection device, a distal filter. The technical demands on a renal protection device are different from those on a cerebral protection device. Cerebral devices that occlude the relevant artery rely on the excellent collateral circulation of the circle of Willis to maintain end organ perfusion. These are not appropriate in renal arteries, which lack adequate collateral circulation. Experience from the surgical literature confirms that suprarenal aortic cross-clamping, even for short periods, is associated with deterioration in renal function in a significant number of patients.³⁶ A distal filter device that maintains perfusion throughout the procedure is ideal for renal protection.

Anatomic differences between carotid and renal arteries place different demands on the stent-protection system. In carotid bifurcation disease, the access artery (common carotid artery) and target artery (internal carotid artery) are essentially parallel. In addition, the external carotid artery may be used as a guide wire anchor vessel to achieve stable access. For renal artery ostial disease, the access artery (abdominal aorta) and target artery are essentially perpendicular, and there is no guide wire anchor vessel. This renal anatomy places extra demand on the profile of the protection device and strength of the guide wire to support angioplasty balloons and stents as they traverse angulated vessels. Before beginning this study, primary passage of distal filter systems through renal artery ostial stenoses was attempted in a number of patients. Guide wire passage was unsuccessful in most, because of the profile of the distal filter system, and poor torque control and relative fragility of the leading guide wire. For these reasons, we decided to perform Dotter dilation of the stenosis, with a guide catheter and central dilator, up to the outer diameter of the 8F catheter (2.7 mm). This procedure enables rapid and accurate deployment of the distal filter and placement of the stent. Although Dotter dilation itself may produce distal embolization, the absence of any deterioration in creatinine clearance on day 1 post-procedural measurements suggests that distal embolization is minimal. The guide catheter often briefly occludes the renal artery at the level of the stenosis (Fig 7, online only). This occlusion may prevent propagation of embolic material into peripheral arterial branches until the guide catheter is withdrawn. At this stage, the distal filter is in place. Angioplasty with stenting is thought to be the most embologenic procedure,³² and the kidney is also protected at this stage. As the profile of distal protection devices decrease, primary passage of the protection device through the renal artery ostium is likely to become routine.

A number of adjuvant techniques are used to preserve renal function during endovascular treatment of renal artery stenosis in ischemic nephropathy. Adequate periprocedural hydration appears most important. There is evidence that acetylcysteine may also be nephroprotective.³⁷ Intra-arterial gadolinium chelates appear to be less nephrotoxic than iodinated contrast medium,³⁸ at least at the dosage used.³⁹ Although they are less radiopaque than iodinated

contrast medium,⁴⁰ gadolinium chelates can be used to significantly reduce iodinated contrast requirements. The effect of intra-arterial gadolinium and acetylcysteine cannot be accurately assessed in this study, because of the small number of patients and lack of control subjects.

The ideal renal stent-protection system is not yet available. Future developments include reduction in protection device profile, modifications of the angioplasty balloon-stent design, and use of short guide wires and rapid exchange systems. Use of buddy wires may also improve support during the procedure. The total length of the renal stent-protection system should be 35 mm or less if most main renal arteries are to be adequately protected. Use of magnetic resonance imaging-compatible stents⁴¹ would enable magnetic resonance surveillance after stent revascularization.

CONCLUSIONS

Use of a distal filter device during stent revascularization of renal artery stenosis can significantly improve results in ischemic nephropathy, with either improved or stabilized renal function in most patients. The filter device prevents the acute procedure-related decline in renal function that is seen in 10% to 20% of patients, which appears to be due to cholesterol atheroembolization. There are specific demands on a protection device in renal arteries, and the ideal device has not yet been developed.

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