Experience of stenting for atherosclerotic renal artery stenosis in a cardiac catheterization laboratory: Technical considerations and complications

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BACKGROUND: Atherosclerotic renal artery (RA) stenosis contributes to hypertension, renal insufficiency and end stage renal disease, and is independently associated with adverse cardiovascular events. Percutaneous renal intervention is efficacious in treating renovascular hypertension and may be effective in stabilizing or improving renal function, thereby reducing cardiovascular risk. However, high rates of procedural complications have been reported.

OBJECTIVES: To determine the nature and frequency of complications of percutaneous renal intervention using contemporary techniques and equipment in a high-volume cardiac catheterization laboratory.

METHODS: Consecutive patients undergoing attempted RA stenting for atherosclerotic RA stenosis in the cardiac catheterization laboratory at the Vancouver General Hospital (Vancouver, British Columbia) between June 2000 and March 2007 were enrolled in a prospective registry. Baseline clinical characteristics, procedural and technical information, and complications were recorded.

RESULTS: A total of 132 RAs were stented in 106 patients during 108 procedures. The procedural success rate was 100%, with no related death, myocardial infarction, nephrectomy or dialysis. Major complications included three pseudoaneurysms (2.8%) and acute deterioration in renal function in six patients (5.5%), although renal function returned to baseline in one patient at 12 months.

CONCLUSIONS: RA stenting can be successfully and safely performed using contemporary techniques, and the low complication rates described should be the minimum standard for contemporary trials evaluating RA stenting.

Key Words: Complications; Percutaneous renal intervention; Renal artery stenting; Renal dysfunction

Atherosclerotic renal artery (RA) stenosis (ARAS) is a progressive disease leading to hypertension, renal insufficiency and dialysis-dependent renal failure. It is also independently associated with a high rate of cardiovascular and neurological events such as unstable angina, congestive heart failure, stroke and death (1-4). Percutaneous renal intervention (PRI) has been shown to be modestly effective in treating hypertension (3). The results of observational studies (5-7) have also suggested that renal intervention with routine stenting may be effective in stabilizing or improving renal function and reducing cardiovascular events such as unstable angina or congestive heart failure. However, in the absence of

Pose d'endoprothèse pour sténose athéroscléreuse de l'artère rénale en laboratoire de cathétérisme cardiaque : Considérations techniques et complications

HISTORIQUE : La sténose athéroscléreuse de l'artère rénale (AR) contribue à l'hypertension, à l'insuffisance rénale et à la maladie rénale terminale et elle est liée de manière indépendante à des complications cardiovasculaires. L'intervention rénale percutanée est efficace pour le traitement de l'hypertension rénovasculaire et pourrait contribuer à stabiliser ou à améliorer la fonction rénale, ce qui réduirait le risque cardiovasculaire, mais des taux élevés de complications ont été signalés lors des interventions.

OBJECTIFS : Déterminer la nature et la fréquence des complications de l'intervention rénale percutanée effectuée au moyen de techniques et d'équipements modernes dans un laboratoire de cathétérisme cardiaque achalandé.

MÉTHODES : Des patients consécutifs candidats à une pose d'endoprothèse pour sténose athéroscléreuse de l'artère rénale en laboratoire de cathétérisme cardiaque ont été inscrits à un registre prospectif à l'Hôpital Général de Vancouver (Vancouver, Colombie-Britannique) entre juin 2000 et mars 2007. Les auteurs ont recensé les caractéristiques cliniques de base, les données sur l'intervention et la technique, de même que les complications.

RÉSULTATS : En tout, 132 endoprothèses d'AR ont été posées chez 106 patients lors de 108 interventions. Le taux de réussite des interventions a été de 100 %. On n'a signalé aucun décès ni infarctus du myocarde et aucune néphrectomie ni dialyse. Les principales complications ont été trois pseudo-anévrismes (2,8 %) et une détérioration aiguë de la fonction rénale chez six patients (5,5 %), bien que la fonction rénale soit revenue à ce qu'elle était au départ chez un patient à 12 mois.

CONCLUSION : L'endoprothèse de l'artère rénale peut être effectuée avec succès et sans danger à l'aide des techniques modernes et le faible taux de complications décrit devrait être la norme minimum pour les études actuelles sur les endoprothèses de l'artère rénale.

adequately powered, randomized clinical trials, considerable controversy remains as to whether the potential risks of renal revascularization outweigh the benefits (8,9). These risks include procedure-related death, deterioration in renal function or dialysis, peripheral atheroembolization and vascular access site complications. Complication rates ranging from 15% to 20% have been reported in some studies (10,11).

The prevalence of significant ARAS is likely to be more common than previously appreciated, particularly in individuals with advanced coronary artery or lower extremity atherosclerotic vascular disease, where it may reach 30% or more (3). Our group previously published

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a detailed profile of cardiac patients with coexistent ARAS (12), which was intended to focus the application of coincident renal angiography on those at highest risk at the time of coronary angiography. We now report procedural safety and complications of PRI in a consecutive series of 106 patients referred for this procedure by a nephrologist. All patients were preidentified as having ARAS using a previously described algorithm employed at diagnostic cardiac catheterization.

METHODS

Patient identification and selection

The presence of RA stenosis in patients already undergoing nonemergent diagnostic cardiac catheterization at Vancouver General Hospital (Vancouver, British Columbia) was identified using a previously described algorithm (12). Briefly, individuals with resistant or severe hypertension, unexplained renal dysfunction (or induced by angiotensin-converting enzyme [ACE] inhibitors or angiotensin receptor blockers [ARBs]), pulmonary edema with preserved systolic function; or the presence of clinically evident atherosclerosis in two vascular territories, were evaluated for ARAS using coincident selective renal angiography or abdominal aortography. Patients with severe ARAS (70% or greater) were referred to a renovascular clinic directed by nephrologists who determined indications for revascularization, addressed other causes of renal dysfunction where present and referred patients back for renal stenting if believed to be appropriate. Between June 2000 and March 2007, 132 consecutive RA interventions for de novo ARAS were prospectively registered in 106 patients, during 108 procedures. All of the procedures resulted in stent implantation.

Preprocedural preparation

A preprocedural serum creatinine concentration was obtained within seven days before the procedure and an estimated glomerular filtration rate (eGFR) was calculated using the Modification of Diet in Renal Disease (MDRD) formula (13). The profile and number of antihypertensive drugs used was recorded. Office cuff blood pressures were measured on usual therapy. All patients were prehydrated for a minimum of 6 h at a minimum of 1 mL/kg/h intravenous saline. N-acetyl cysteine was used at the discretion of the responsible physician. ACE inhibitor or ARB therapy was discontinued on the day of the procedure and for at least 24 h following the procedure. All patients were loaded with acetylsalicylic acid (ASA) 325 mg and clopidogrel (300 mg more than 6 h or 600 mg more than 2 h before the procedure).

Procedural aspects

Procedures were performed by one of five operators via the femoral artery using predominantly 6 Fr or 7 Fr guiding catheters with direct RA engagement. In 14 cases, a 'minimal touch' technique that employed a 4 Fr Judkins right-4 diagnostic catheter telescoped within a short guide to preselect the RA was used. The stenosis was wired before removing the 4 Fr diagnostic catheter and engaging with the guide catheter.

Baseline angiography was performed as previously described (12) in the anteroposterior view with the image intensifier angled to optimally demonstrate the plane of the ostium. Ioversol (Optiray; Mallinckrodt Inc, USA) or iodixanol (Visipaque; GE Healthcare, USA) contrast diluted with saline to a ratio of 1:1 was generally used for selective renal angiography before, during and after completion of the procedure. Patients received unfractionated heparin at a dose of 70 U/kg to 100 U/kg at the start of the procedure. Activated clotting time measurements were not routinely performed.

Extra-support 0.014-inch coronary guide wires were used exclusively. Distal embolic protection using the FilterWire EZ (Boston Scientific Corporation, USA) or AngioGuard (Cordis Corporation, USA) was used in five cases (3.8%). According to operator preference

and lesion characteristics, predilation was performed with coronary rapid exchange balloons. The balloon diameter was undersized for the artery to minimize the risk of dissection.

Stenting: Bare metal stents were used exclusively, including Express Biliary (Boston Scientific; 14.3%), Genesis (Cordis Corporation; 2.9%), Herculink (Guidant, USA; 20%), Racer (Medtronic, USA; 4.3%), Ross (evYsio Medical Devices, Canada [investigational stent used in the unpublished ROSSE study]; 32.9%), Tetra (Guidant Corporation, USA; 1.4%), Ultra (Abbott Laboratories, USA; 7.1%) or Liberte (Boston Scientific Corporation; 17.1%). Coronary stents were used when the estimated reference vessel diameter was less than 5 mm. Because the majority of lesions involved the ostium, operators endeavoured to deploy the stent with the proximal 1 mm to 2 mm protruding into the aorta. High-pressure postdilation was performed at the operator's discretion, with the balloon retracted a few millimetres further into the aorta, or with a shorter, noncompliant balloon to optimize stent expansion and minimize the risk of distal stent edge dissection. Procedural success was defined as successful stent delivery with residual stenosis of less than 20% and no immediate procedural complications.

Postprocedural care, follow-up and complications

Vascular hemostasis was generally achieved by clamp compression 4 h after heparin administration, although closure devices such as Angio-Seal (St Jude Medical Inc, USA) and Perclose (Abbott Laboratories) were used at the operator's discretion in seven cases (6.5%). Intravenous hydration was continued for at least 6 h following the procedure. Blood pressure was closely monitored during the in-hospital stay and renal function was checked at 24 h, one week and one month, and by the referring physician subsequently thereafter. Periprocedural complications were contemporaneously documented and the patients were examined immediately following the procedure and after 24 h. One-month follow-up data were obtained from direct telephone interviews, clinic visits, and primary physician and hospital records. Further follow-up was with the referring physician. All patients were discharged on ASA 325 mg/day and clopidogrel 75 mg/day for at least one month, before reduction to ASA 81 mg/day monotherapy indefinitely.

Complications were recorded as major or minor as per American Heart Association guidelines for reporting of RA revascularization (14). Prespecified major clinical adverse events were death within 30 days; predischARGE cardiovascular complications including myocardial infarction, stroke, pulmonary edema, aortic dissection, peripheral embolism, femoral pseudoaneurysm, bleeding or hematoma requiring transfusion or prolonged hospitalization; and renal complications including renal perforation or hemorrhage, nephrectomy, dialysis and an acute persistent (beyond 30 days) rise in serum creatinine (more than 120 $\mu\text{mol/L}$) by more than 20% or a fall in eGFR by more than 25%.

RESULTS

A total of 106 patients underwent stenting for 132 ARAS during 108 independent procedures between June 2000 and March 2007. A total of 34 patients (32.1%) had significant bilateral ARAS and 24 (22.6%) underwent bilateral RA stenting, of which 22 (20.8%) were performed during a single procedure. Baseline characteristics and indications for intervention are shown in Tables 1 and 2. The mean ($\pm$ SD) age of the patients was 72.1 ± 8.8 years (range 38 to 91 years). The majority of patients (92.5%) had coexistent coronary artery disease and 39 (36.8%) had peripheral arterial or aortic disease. Approximately one-third of the patients were diabetic and more than two-thirds had poorly controlled hypertension. The mean serum creatinine at baseline was 140.5 ± 62.0 $\mu\text{mol/L}$. Sixty-five patients (61%) had a baseline eGFR of less than 60 mL/min. Lesion and procedural characteristics are shown in Table 3.

Kidney size, as assessed by magnetic resonance imaging or ultrasound, was available for 49 patients with unilateral RA stenosis. The

TABLE 1**Baseline characteristics of study patients (n=106)**

Characteristic	
Age, years mean $\pm$ SD (range)	72.1 $\pm$ 8.8 (38 to 91)
Women, n (%)	41 (38.7)
Ethnicity, n (%)	
Caucasian	86 (81.1)
South Asian	9 (8.5)
Chinese	11 (10.4)
Body mass index, kg/m ² , mean $\pm$ SD	27 $\pm$ 4.6
Hypertension, n (%)	102 (96)
Diabetes, n (%)	34 (32.1)
History of smoking, n (%)	43 (40)
Hyperlipidemia, n (%)	87 (82.1)
Peripheral vascular/aortic disease, n (%)	39 (36.8)
Coronary artery disease, n (%)	98 (92.5)
Bilateral renal artery stenosis ($\geq$ 50%), n (%)	34 (32.1)
Contralateral renal artery occlusion, n (%)	2 (1.8)
Stroke, n (%)	26 (24.5)
Chronic obstructive pulmonary disease, n (%)	9 (8.5)
Malignancy, n (%)	13 (12.4)
Other significant disease, n (%)	22 (20.8)
Creatinine, μ mol/L, mean $\pm$ SD	139.6 $\pm$ 62.0
Estimated glomerular filtration rate, mL/min, mean $\pm$ SD	47.4 $\pm$ 19.3
Urea, mmol/L, mean $\pm$ SD	11.8 $\pm$ 7.3
Systolic blood pressure, mmHg, mean $\pm$ SD	165.8 $\pm$ 28.2
Diastolic blood pressure, mmHg, mean $\pm$ SD	74.09 $\pm$ 13.5
White blood cells, $\times 10^9$ /L, mean $\pm$ SD	8.2 $\pm$ 3.5
Hemoglobin, g/dL, mean $\pm$ SD	124 $\pm$ 16

TABLE 2**Clinical indications for renal artery stenting (n=106)**

Indication (not mutually exclusive)	n (%)
Uncontrolled hypertension	73 (69)
Renal insufficiency	65 (61)
Pre-CABG or valve surgery	21 (20)
Flash pulmonary edema	13 (12)
Uncontrolled congestive heart failure	10 (9)
ACE/ARB intolerance	2 (2)

ACE Angiotensin-converting enzyme; ARB Angiotensin receptor blocker; CABG Coronary artery bypass graft

mean kidney size on the intervention side was 10.33 $\pm$ 1.2 cm compared with 10.46 $\pm$ 1.2 cm in the contralateral kidney (nonsignificant difference). No differences in demographics or outcomes existed between those with known and unknown kidney size.

Stent implantation was successful in 132 cases (100%) with a residual diameter stenosis of 20% or less. The mean stent diameter was 5.6 $\pm$ 0.7 mm with a mean stent length of 17.6 $\pm$ 2.8 mm. In seven lesions (5.3%), a second stent was required because of inadequate lesion coverage (six cases) or stent edge dissection (one case). For unilateral RA stenting, the mean procedural time was 34.2 $\pm$ 17.4 min, with a fluoroscopy time of 12.7 $\pm$ 8.2 min. The mean volume of contrast used was 117 $\pm$ 61.2 mL.

Complications

Procedural complications: No patient had a procedure-related death, myocardial infarction, stroke or pulmonary edema. There were no mechanical kidney or renovascular complications such as occlusive dissection, side-branch occlusion, perforation, embolization, renal infarction, subcapsular hematoma or requirement for nephrectomy.

TABLE 3**Procedural characteristics of study participants (n=106)**

Procedural characteristic	
Bilateral renal artery stenting, n (%)	
Same procedure	22 (20.8)
Staged procedure	2 (1.8)
Procedures (n=108)	
Coincidental cardiac procedure, n (%)	
Angiogram	10 (9.2)
Percutaneous coronary intervention	20 (18.5)
N-acetyl cysteine used, n (%)	29 (26.8)
Fluoroscopy time, min, mean $\pm$ SD*	12.78 $\pm$ 8.2
Procedure time, min, mean $\pm$ SD*	34.2 $\pm$ 17.4
Contrast volume, mL, mean $\pm$ SD*	117 $\pm$ 61.2
Renal artery lesions treated (n=132)	
Ostial renal artery lesion, n (%)	102 (77.2)
Lesion severity, %, mean $\pm$ SD	82 $\pm$ 8.8
Predilation performed, n (%)	63 (47.7)
Stent diameter, mm, mean $\pm$ SD	5.6 $\pm$ 0.7
Stent length, mm, mean $\pm$ SD	17.6 $\pm$ 2.8
Two stents required, n (%)	7 (5.3)
Postdilation performed, n (%)	44 (33.3)

*Single renal artery stent procedures only

TABLE 4**Long-term renal function of patients with elevated serum creatinine one month following the procedure**

Patient	Contrast volume, mL	Preprocedure		Postprocedure				
		1 year	6 months	Baseline	24 h	1 month	6 months	1 year
1	175	90	—	87	120	153	—	157
2*	90	—	—	246	270	300	321	—
3†	100	108	—	96	86	184	193	116
4	185	171	221	177	180	240	388	303
5†‡	280	—	—	133	137	163	—	—
6§	125	124	153	126	106	150	256	220

Data presented as μ mol/L of creatinine unless otherwise specified.

*Cardiovascular death 10 months postintervention; †Concomitant percutaneous coronary intervention and renal stenting; ‡Cardiovascular death 1.5 months postintervention; §Bilateral renal artery stenting

Three subjects (2.8%) developed a false femoral aneurysm at the puncture site, which was treated by ultrasound-guided thrombin injection or compression, and one (0.9%) had a significant (larger than 5 cm) femoral access site hematoma but did not require transfusion or delayed discharge.

Renal dysfunction: At one month, six patients (5.5%) had a rise in serum creatinine of more than 20% or a decline in GFR by more than 25%. Three of these patients underwent compound procedures, including two with coincident percutaneous coronary intervention (PCI) and one with bilateral renal stenting. None of these cases was attributable to new therapy with an ACE inhibitor, ARB or diuretic following the procedure, although patients already on such treatment may have had dose adjustments. Longer-term creatinine measurements in these six patients are shown in Table 4. Of the six patients with postprocedural deterioration of renal function, one died at six weeks and a second at 10 months, both from cardiac causes. Of the remaining four patients, three had persistent elevation of creatinine at 12 months, but in one, the creatinine returned to baseline. None of these patients required dialysis during the first month of follow-up, although another patient with pre-existing chronic renal failure (baseline creatinine 497 μ mol/L) started dialysis

electively on the day of renal intervention and subsequently remained on dialysis. The overall mean ($\pm$ SEM) serum creatinine was significantly lower 24 h postprocedure (129.6 ± 5.6 mmol/L) and at one month (126.9 ± 5.2 mmol/L) than at baseline (140.5 ± 6.0 mmol/L; $P < 0.001$). Overall, nine patients (8.3%) had a decrease in serum creatinine of more than 20%.

Clinical events at 30 days: No deaths, myocardial infarctions or strokes occurred within 30 days of the procedure. Although not classified as procedural complications, two patients who underwent RA stenting following admission due to congestive heart failure (8.7% of patients with initial symptoms of heart failure or flash pulmonary edema and 1.9% overall) required rehospitalization for heart failure within 30 days. One patient (0.9%) was rehospitalized with unstable angina, three (2.8%) underwent scheduled PCI and nine (8.3%) underwent scheduled coronary artery bypass graft surgery within one month, but there were no unplanned revascularizations during this period.

Therefore, the major complication rate of 8.3% (5.5% plus 2.8%) consisted entirely of femoral pseudoaneurysms ($n=3$ [2.8%]), which were easily dealt with, and deterioration in renal function ($n=6$ [5.5%]). Of these six patients, three had combined coronary or bilateral renal intervention and in one case, renal function returned to baseline at 12 months.

DISCUSSION

Our results show that RA stenting using contemporaneous techniques and equipment can be performed with reliable technical success in a cardiac catheterization laboratory with a low complication rate, despite the advanced age and vascular disease that is typical in patients with ARAS. Feared mechanical complications such as occlusive RA dissection, thrombosis or rupture, perirenal hematoma or perforation, renal infarction and retroperitoneal hemorrhage were absent, as were major cardiovascular events in the immediate periprocedural period.

Previous studies and definitions of complications

Previous studies evaluating RA stenting have shown high adverse event rates but used nonstandardized definitions of major and minor complications. In an early systematic assessment of complications following RA stent placement (10), the rate of 'serious' complications was 10%, although the authors did not include a renal perforation resulting in a retroperitoneal hemorrhage, perirenal hematoma, embolized stents, a femoral artery bleed requiring blood transfusion and femoral artery pseudoaneurysms, all of which were categorized as "minor clinical consequences". In the multicentre Erasme study (15), stents were placed in 120 RA lesions in 106 patients. The major complication rate was reported to be 6.6%, but other complications, including a retroperitoneal hemorrhage, a groin bleed requiring transfusion, a psoas hematoma and three femoral artery pseudoaneurysms, occurred in 11.3% of cases. The incidence of acute deterioration in renal function at one month was not systematically documented in either of these reports. Zeller et al (16) reported an overall complication rate of 10% from 320 procedures in 268 patients from 1997 to 2001, including RA rupture, aortic dissection and four patients in whom permanent hemodialysis was required. A large meta-analysis of 14 studies between 1991 and 1998, with stent treatment of 799 lesions in 678 patients, documented a major complication rate of 11%, with a mortality rate of 1% (17). More recent studies (11,18-21) also report overall complication rates as high as 18%, with major complications occurring in 2.9% to 8.4% of patients. Again however, definitions of 'major complication' were not uniform, nor were the criteria for determining postprocedural deterioration of renal function.

To address these inconsistencies, guidelines for reporting RA revascularization in clinical trials have been published by the American Heart Association, with clearer definitions of major and minor adverse events (14). Although a transient rise in serum creatinine of less than 20% from baseline is classified as a minor

complication, the threshold for acute decline in renal function to qualify as a major complication is not clearly specified. The use of a binary outcome measure such as a threshold value for a rise in serum creatinine or a fall in GFR is potentially problematic because this may not take into account a slower decline in previously deteriorating renal function. A widely accepted definition for contrast-induced nephropathy, for example, is a fixed ($44 \mu\text{mol/L}$ [0.5 mg/dL]) or proportionate (25%) rise in serum creatinine levels after exposure to the contrast medium (22).

We applied a stringent definition that required an increase in serum creatinine of more than 20% or a fall in GFR by 25% at 30 days. Patients meeting these criteria were further classified as having a major complication. Whereas the mean and median serum creatinine in our cohort was unchanged at 30 days, six patients (5.5%) met the criteria for procedure-associated renal deterioration.

Mechanisms for renal dysfunction following PRI

A number of mechanisms exist for renal dysfunction following PRI and contrast-induced nephropathy is a likely contributing factor. In our series, the mean procedural contrast volume was 117 mL for single RA stent procedures. Three of the six patients whose kidney function deteriorated by 30 days had significantly higher contrast loads and of these three, one underwent concomitant PCI (Table 4). Of 22 bilateral RA stent procedures however, only one resulted in a possible deterioration of renal function and the majority improved. Nevertheless, reduction of radiographic contrast volume by avoidance of additional procedures, preprocedural hydration and dilution of contrast for selective renal imaging are all likely to be important in minimizing nephrotoxicity.

It is widely accepted that the bulky nature of atherosclerotic RA plaque and adjacent aortic disease predisposes to atheroembolization during renal intervention. Minimally traumatic guide catheter manipulation, coupled with rapid exchange, low-profile balloons and stents may have contributed to the reduction in complication rates for PRI over time (19,23). Nevertheless, the use of distal embolic protection has also been advocated as an additional measure used by some authors. Although distal protection has proven effective in other vascular territories, the results in branching vessels have been disappointing (24). No controlled studies of distal protection during RA stenting have been performed. However, in one study, the GuardWire (Medtronic Inc, USA) occlusion balloon or a distal filter device was used during stenting of 65 renal arteries in 56 patients (25). Visible debris were aspirated in all cases with the GuardWire and found in 80% of filter baskets. In this small series, renal function did not deteriorate in any patient at six months. Holden and Hill (26) evaluated the AngioGuard distal filter system during stenting of 46 RAs in 37 patients. Sixty-five per cent of filter baskets contained embolic material, although a decline in renal function (rise in serum creatinine of more than 20%) was still seen in 5% of patients, a rate similar to that observed in our study. The efficacy of embolic protection during renal stenting merits further assessment because passage of the undeployed filter or occlusion balloon may itself precipitate embolism. Moreover, in cases in which the RA is short or bifurcates early, this poses significant technical challenges for current distal protection technologies.

Although not seen in our study, renovascular complications such as branch vessel occlusion, dissection or thrombosis with renal infarction can all result in reduced kidney function. Concomitant initiation or dose adjustment of drugs such as ACE inhibitors, ARBs or diuretics may also be implicated, although this also did not appear to be the case in our patients.

Imprecise or unstable baseline estimation of kidney function (eg, due to preprocedural hydration) with subsequent regression to the mean might also account for our findings. As shown in Table 4, creatinine measurements from six months or one year before the procedure were available for four of the six patients whose renal function worsened at 30 days. In three cases, these were very

similar to baseline preprocedural creatinine levels. In one patient however, the creatinine level six months preprocedure was similar to the one-month postprocedure level, suggesting a degree of 'noise' in baseline biochemical measurements, and arguing against a significant deleterious effect as a result of the stent procedure.

True baseline renal function may, however, predict the response to renal stenting. While patients with significant impairment of GFR have less renal reserve and are thus more susceptible to further deterioration from the mechanisms described above (27), it has also been shown that as a group, these patients derive more benefit, with greater improvements in renal function, than patients with normal or only mildly depressed GFR (20,28). In our study, the mean baseline creatinine was 140.5 $\mu\text{mol/L}$ (eGFR 47.4 mL/min), indicating mild-to-moderate renal impairment. Overall, this improved to 126.9 $\mu\text{mol/L}$ (eGFR 53.5 mL/min) at one month following the procedure.

Finally, these patients also had a high prevalence of cardiac comorbidity and two of the six patients with persistent deterioration in renal function at one month died from cardiac causes within one year. One patient was known to have severe three-vessel coronary disease and it is possible that a low-output cardiac state may have contributed to the decline in renal function.

CONCLUSION

Previous studies have demonstrated a reduction in mechanical complications over time and with operator experience (16). No serious mechanical complications occurred in the present study and, of the six cases in which acute deterioration of renal function occurred, these were distributed over a six-year period with no clustering to indicate this was related to a learning curve. However, even in these patients, the range of dysfunction attributable to the renal stent procedure was relatively modest and no patients required renal replacement therapy. The role of stenting for ARAS in the treatment of hypertension, ischemic nephropathy and recurrent cardiovascular events remains unclear and may be clarified by ongoing large-scale randomized controlled trials such as STAR (the benefit of STent placement and blood pressure and lipid-lowering for the prevention of progression of renal dysfunction caused by Atherosclerotic ostial stenosis of the Renal artery) (29), CORAL (Cardiovascular Outcomes in Renal Atherosclerotic Lesions) (30), and ASTRAL (Angioplasty and Stent for Renal Artery Lesions) (31). Nevertheless, it is clear that concern over possible complications has reduced enthusiasm for this procedure. We have shown that renal stenting can be performed with high technical success and without serious mechanical complications. This should be considered the minimal standard for current or future trials evaluating RA stenting.

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