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Fifteen Years' Experience of Treating Atherosclerotic Renal Artery Stenosis by Interventional Nephrologists in India

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ABSTRACT

Atherosclerotic renal artery stenosis (ARAS) is an important cause of kidney disease, accelerated hypertension (HTN), and its treatment is controversial. Our aim was to evaluate the outcomes, safety, and efficacy of percutaneous transluminal angioplasty (PTA) for ARAS. Retrospective analysis of ARAS was performed among 470 angiographies during 1995–2010. Patients with nonatherosclerotic RAS and renal transplant were excluded. We assessed preintervention and postintervention mean arterial pressure (MAP), antihypertensive medications, and renal function to classify as deteriorated (>10% increase in MAP/increase in drugs/>20% reduced GFR), improved (>10% reduced MAP/reduced drugs/>20% increased eGFR), or stabilized (<10% change in MAP/same antihypertensive drugs/<20% change in eGFR) at last follow-up. A total of 220 subjects with mean age of 57.6 ± 10.4 years underwent PTA and/or stenting. The average follow-up was 23.07 ± 21.2 months. Accelerated HTN, HTN onset >50 years, unexplained renal failure, and unilateral small kidney were the most common presentations. In all, 255 significant stenotic lesions in 220 patients (119 unilateral, 66 single functioning kidney, and 35 bilateral) were observed. In total, 255 PTA were performed, including 177 stenting. Technical success was seen in 220/243 (90.5%) subjects. Combined MAP and antihypertensive drugs improved in 154/220 (70%) patients. Renal function improved/stabilized in 175/220 (79.5%). Angioplasty and stenting are relatively safe and feasible tools for control of blood pressure (BP) in ARAS. Angioplasty produced improvement/stabilization of BP in 70%, and the renal function in 79.5% subjects.

Renal artery stenosis (RAS) is an important cause of hypertension (HTN) and kidney failure. Flow-obstructing lesions of the renal arteries may be caused by atherosclerosis, fibromuscular dysplasia, vasculitis, neurofibromatosis, congenital bands, extrinsic compression, emboli, aortic dissection, and radiation (1). Atherosclerotic RAS (ARAS) will account for approximately 90% of cases of RAS (2).

The progressive nature of ARAS is now well recognized (3–11). Observational data suggest that untreated RAS can lead to progressive HTN, renal insufficiency, and increased mortality (9,12–14). The incidence of progressive ischemic nephropathy resulting from ARAS has been underestimated in the past. The prevalence of ARAS increases with age, particularly in patients with diabetes, hyperlipidemia, other atherosclerotic disease, and HTN. ARAS is present in 1–5% of the nearly 60 million Americans with HTN (15–17), in 30% of patients with coronary artery disease (18), in 7% of those over the age of 65 (19), in up to 20% of new patients >50 years old requiring hemodialysis (1), and in up to 50% of elderly patients with diffuse atherosclerotic disease.

Medical management of RAS is mainly through control of HTN, dyslipidemia, antiplatelet agents, and management of associated comorbidities. The two primary indications for renal artery revascularization are (i) preservation of renal function and (ii) relief of renovascular (rennin-dependent) HTN. Although surgical revascularization can improve blood pressure (BP) and delay the progression of renal failure (2,14–21), it has been reserved for those who are not amenable to percutaneous intervention. Surgical treatment, mainly aorto-renal bypass, carries with it high morbidity and mortality (rates up to 6–8%) (17,22–26). Percutaneous revascularization with angioplasty and stenting has offered the benefit of revascularization with significantly reduced morbidity, mortality, and in-hospital stay, in high-risk patients for surgery.

Observational studies have reported improvement in BP in a large proportion of the patients following renal

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artery stenting. However, literature regarding the effect of renal artery stenting on renal function reveals conflicting results. Some authors reported improved renal function in 40–100% of patients (27–39), whereas others found no significant impact of revascularization on renal function (5,40–48). Others have even reported worsening of renal function following renal angiography or percutaneous revascularization in 10–40% of patients, some of them subsequently requiring hemodialysis (34,46,48–50). The purpose of this retrospective study was to evaluate the clinical outcomes, safety, and efficacy of percutaneous transluminal angioplasty (PTA) on HTN and renal function in patients with ARAS (> 70% diameter stenosis).

Methods

Patient Group and Study Design

This was a single-center, retrospective, longitudinal, follow-up study of all subjects who underwent renal angioplasty/and stenting for treatment of RAS at Muljibhai Patel Urological Hospital between January 1995 and December 2010. The study was approved by the Institutional Ethics Committee. Patients who had main or large segmental RAS secondary to ARAS and underwent PTA were included in this study. Patients with nonsignificant/nonpassable stenosis, nonatherosclerotic RAS, and stenosis of transplant arteries were excluded. The patients' demographic details, mode of presentation, BP, antihypertensive drugs, and renal function were recorded. All subjects underwent diagnostic angiography either in the same sitting or before any interventional procedure. Decisions regarding treatment were based on several factors, such as percentage of stenosis, kidney size and extent of disease, natural history of the lesions, technical difficulty, and ease of medical treatment. Stenting of the renal arteries was started since 2000 and only angioplasty was performed prior to 2000.

All interventions were performed by the nephrologists taking care of the patients. Patients were subjected to angiography only if they were willing to consider further revascularization, if needed. All patients had definite clinical, noninvasive imaging, and biochemical reason to suspect physiologically significant RAS. Study details are shown in Fig. 1.

Angioplasty Technique

Angiographies were performed by the nephrologists. All procedures were performed under local anesthesia through femoral arterial access (preferably) or through the left brachial approach, whichever is convenient. After the femoral cannulation, aortogogram was performed using 6F pigtail catheter (Cordis, Miami Lakes, FL, USA) using iodinated contrast. Selective cannulation of one or both the renal vessels was performed using 5F RDC catheter (Cordis) to confirm, or

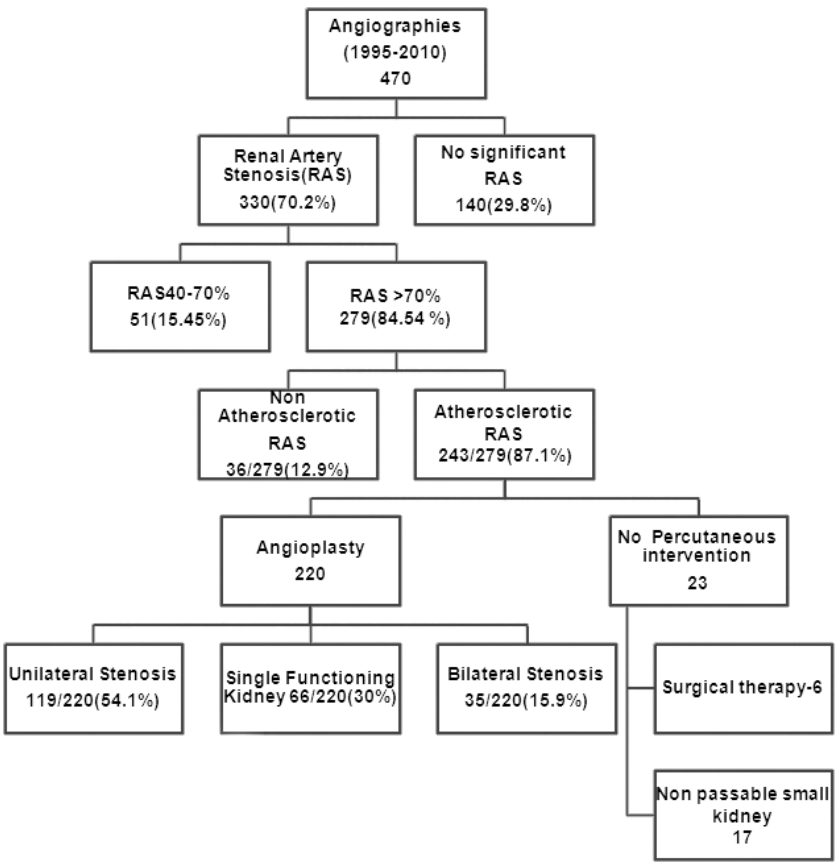

FIG. 1. Study plan.

to rule out, significant RAS. If there was significant stenosis, the RAS was crossed with a guide wire and angioplasty catheter. The balloon/stent diameter (5–6 mm) was decided based on the estimated normal diameter of the stenotic segment and not that of the poststenotic segment. Heparin was administered intravenously (40–50 U/kg) before the balloon was inflated. Premounted balloon-expandable stents were used whenever stenting was performed. After the RAS/stenting, sustained increase in blood vessel diameter and residual stenosis was confirmed using repeat contrast study as shown in Fig. 2. A technically successful procedure was defined as $<20\%$ residual diameter stenosis with brisk distal flow in the target vessel. Technical failure was defined as being unable to pass guide wire/catheter or unable to dilate vessel with balloon. All patients received antiplatelet medication 24 hours prior to the procedure.

Follow-up Monitoring and Assessment of Outcomes

All patients were monitored for renal function using serum creatinine and BP. eGFR was estimated using Cockroft Gault Formula. Antihypertensives were adjusted to control the BP. Mean arterial pressure (MAP) was defined as improved, if it reduced by $>10\%$ compared with the baseline, and stabilized, if it varied $<10\%$, and worse, if increased by $>10\%$. BP assessment (combined MAP and antihypertensive drugs) of outcomes was defined as: (i) "cured," with normal BP (<95th percentile for age, gender, and height) with no antihypertensive treatment; (ii) "improvement" with improved BP after reduced antihypertensive treatment; (iii) "stabilized" with improved BP after reduced treatment; (iv) "worse" with BP either increased or needed increased dose of antihypertensive medications despite angiographic success. Patency of the treated artery was assessed by duplex Doppler ultrasound.

Renal function was defined as "abnormal," if baseline eGFR was <60 ml/minute. "Improvement" in renal function was defined as increase in eGFR by $\geq 20\%$ compared with baseline. Renal function was considered "unchanged," if eGFR varied by $\leq 20\%$ and "worse," if eGFR reduced by $\geq 20\%$ compared with baseline. Serum creatinine levels were followed up on an outpatient basis at 48 hours, 1 week after the procedure, and at the clinician's discretion during the subsequent follow-up. Serum creatinine was evaluated at approximately 6 months, 1, 2, and 3 years postrenal artery stenting.

Statistical Analyses

Results were presented as mean $\pm$ SD and range, whenever necessary. The results of balloon dilation at baseline versus last follow-up were compared with results of paired *t*-test. A *p*-value < 0.05 was considered statistically significant. Data were analyzed using SPSS version 15 (SPSS, Chicago, IL, USA).

Results

Four hundred and seventy angiographies were performed for diagnostic purpose. Three hundred and thirty subjects showed RAS of $>40\%$. Two hundred and seventy-nine subjects showed significant stenosis

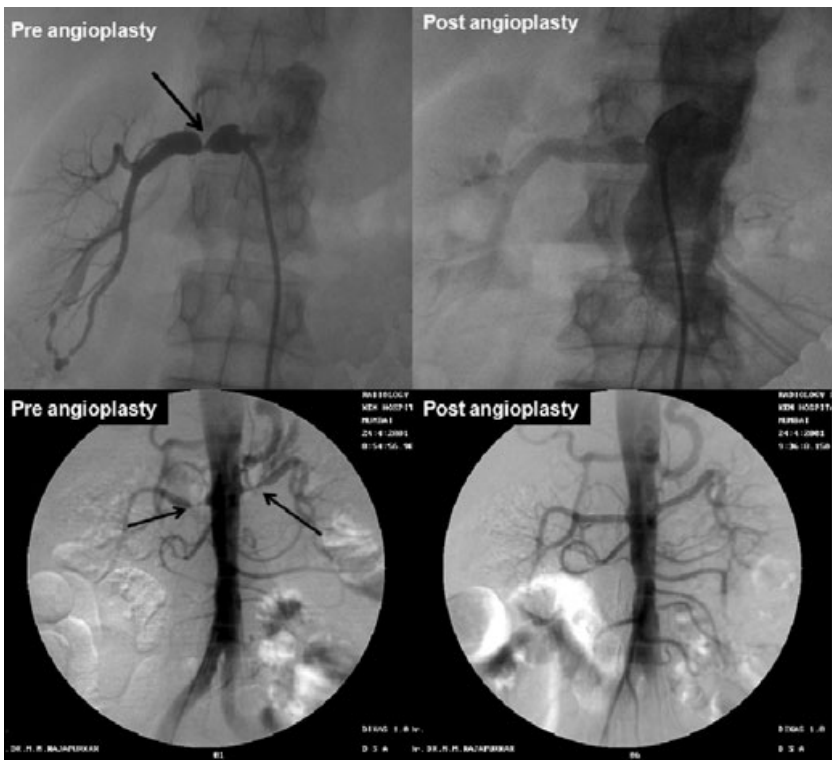

FIG. 2. Images showing pre and post angioplasty and stenting in RAS in single functioning kidney and in bilateral RAS.

defined by >70% luminal narrowing. Of 279 subjects, in 243 (87.09%), RAS was due to atherosclerosis, and in 36 (12.9%), it was due to nonatherosclerotic RAS. Of the 220 subjects of ARAS, 78 patients underwent angioplasty only. Angioplasty and stenting were performed in the remaining 142 patients in 177 renal arteries.

The average age before the intervention was 57.6 ± 10.4 years and men constituted 70.5%. The details are shown in Table 1. Unilateral RAS was seen in 119/220 (54.1%), and 35/220 (15.9%) had bilateral stenosis. Single functioning kidney stenosis was observed in 66/220 (30%) subjects. Technical success was obtained in 220/243 (90.5%) subjects. Coronary artery disease was associated in 55/220 (25%) subjects, and diabetes was seen in 60/220 (27.3%).

Clinical Indicators and Noninvasive Tests for RAS

The angiographies were performed by the nephrologists whenever there was a strong clinical, radiological, and biochemical indicator of physiologically significant RAS, such as unilateral small kidney—105/220 (47.7%); CKD of undetermined etiology having atherosclerotic disease—103/220 (46.8%); HTN onset >50 years—98/220 (44.5%); severe HTN at presentation—89/220 (40.5%); and vascular disease in other territories—89/220 (40.5%); or acute deterioration on renal function with angiotensin-converting enzyme inhibitors or angiotensin receptor blockers—24/220 (10.9%) as shown in Table 2. In addition to these, at least one of the noninvasive tests for RAS, such as renal Doppler, CT angiography, or MR angiography, was performed before the conventional renal angiography/digital subtraction angiography.

Effect of Angioplasty on BP

Overall BP (MAP) improved form 114.79 ± 12.9 to 109.67 ± 11.0 ($p < 0.0001$) and antihypertensive drug requirement reduced from 2.4 to 2.1 ($p < 0.0001$). BP (MAP) and antihypertensive drug requirement stabilized or improved in 188 (85.5%) and 182 (82.7%), respectively, as shown in Fig. 3. The combined BP and antihypertensive need stabilized or improved in 163 (74.1%). Both antihypertensive requirement and MAP improved significantly in single functioning kidney; only MAP improved significantly in unilateral kidney RAS as shown in Table 3.

TABLE 1. Demographics

Parameters	Results
Age (years)	57.6 ± 10.4
Gender (M/F)	155/65
HT duration (months)	63.66 ± 5.31
No. of anti-HT drugs	2.4 ± 1.05
Diabetes mellitus (%)	60/220 (27.3)
Ischemic heart disease (%)	55/220 (25)
Peripheral vascular disease (%)	16/220 (7.3)
Follow-up (months)	23.1 ± 1.3
Unilateral stenosis (%)	119/220 (54.1)
Single functioning kidney (%)	66 (30)
Bilateral stenosis (%)	35 (15.9)

HT, hypertensive.

TABLE 2. Indicators and noninvasive tests for renal artery stenosis (RAS)

S. no.	Indicators for RAS	Number	Percentage
1	Hypertension <30 years and vascular disease	42	19.1
2	Hypertension >50 years	98	44.5
3	Severe hypertension	89	40.5
4	Unilateral small kidney	105	47.7
5	Accidental deterioration after ACEI/ARB	24	10.9
6	Evidence of vascular disease (PVD/CVD)	89	40.5
7	Abdominal bruit	75	34.1
8	CKD of undetermined etiology	103	46.8
9	Flash pulmonary edema	15	6.8
Noninvasive tests			
1	Doppler evaluation	104	47.3
2	CT angiography	17	7.7
3	MR angiography	9	4.1

ACEI, angiotensin-converting enzyme inhibitors; ARB, angiotensin receptor blockers.

Effect of Angioplasty on Renal Function

Overall, eGFR improved by 2.5 ml (from 39.0 ml/minute to 41.6 ml/minute; $p = 0.007$) over 23 months of mean follow-up. eGFR stabilized or improved in 186 (84.5%) subjects as shown in Fig. 3. Nondiabetic subjects had improvement in the eGFR by 3.7 ml/minute as compared with 0.2 ml/minute deterioration in diabetics. Thirty-five bilateral RAS subjects who underwent angioplasty had significant improvement in eGFR (37.6 ml/minute to 44.7 ml/minute; $p = 0.029$) at last follow-up. There was no significant renal function (average eGFR) improvement in the unilateral or single functioning kidney subjects (details are shown in Table 3).

Patients with Baseline eGFR > 60 ml/minute (n = 56)

Fifty-six (56/220 = 25.5%) subjects had eGFR > 60 ml/minute at baseline with an average of eGFR 85.2 ± 20.1 ml/minute. The eGFR remained unchanged in 53/56 (94.6%) at the last follow-up, and in 3/57 (5.4%) subjects, eGFR became worse at the last follow-up. Combined BP (MAP and drugs) worsened in 13/56 (23.2%) subjects.

Patients with Baseline eGFR < 60 ml/minute (n = 164)

Abnormal renal function, that is, eGFR < 60 ml, was observed in 164/220 (74.5%) subjects with average eGFR of 26.13 ± 14.7 ml/minute. The renal function "improved" in 47/164 (28.7%) patients, remained "unchanged" (stabilized) in 74/164 (45.1%) patients, and worsened in 42/164 (25.6%) subjects. Combined BP (MAP and drugs) worsened in 53/164 (32.3%) subjects;

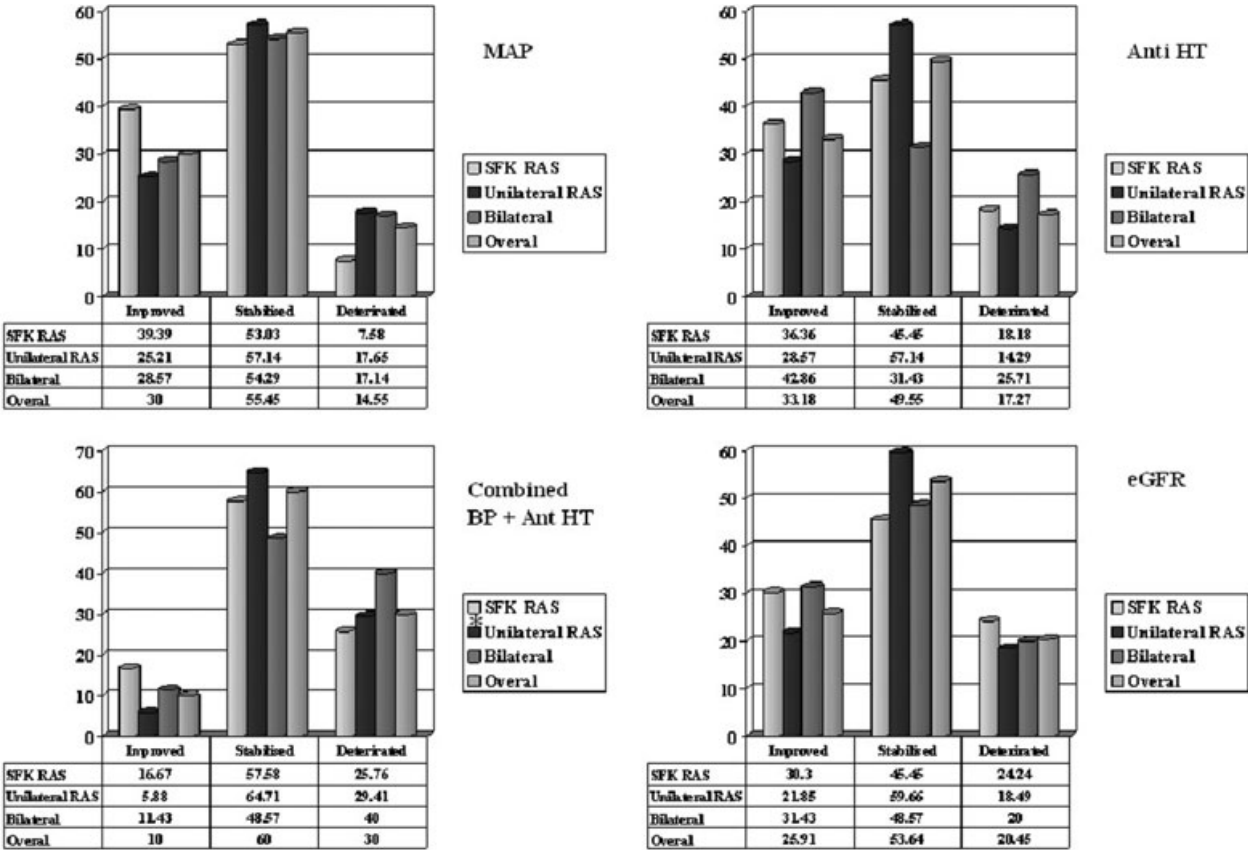

FIG. 3. Outcome of Blood pressure and renal function after Angioplasty.

TABLE 3. Effect of angioplasty

	Total	eGFR ≤ 60	eGFR > 60	Diabetes	No diabetes
Mean blood pressure (mmHg)					
Pre	114.79 ± 12.9	114.7 ± 12.4	115.1 ± 14.3	112.1 ± 10.5	115.8 ± 13.6
Post	109.67 ± 11.0	110.7 ± 11.3	106.6 ± 9.6	109.5 ± 10.1	109.7 ± 11.4
p-value	0.0001	0.001	< 0.0001	0.167	< 0.0001
No. of antihypertensive drugs					
Pre	2.4 ± 1.1	2.42 ± 1.08	2.35 ± 0.99	2.25 ± 1.1	2.46 ± 1.03
Post	2.12 ± 0.9	2.18 ± 0.97	1.95 ± 0.85	2.03 ± 0.96	2.16 ± 0.95
p-value	0.0001	0.006	0.002	0.129	0.001
Serum creatinine (mg%)					
Pre	3.2 ± 2.7	3.91 ± 2.7	0.95 ± 0.24	3.21 ± 2.31	3.13 ± 2.83
Post	3.1 ± 2.7	3.90 ± 2.8	0.93 ± 0.31	3.51 ± 2.53	3.00 ± 2.81
p-value	0.95	0.966	0.689	0.115	0.442
eGFR (ml/minute)					
Pre	39.01 ± 27.86	25.1 ± 14.7	78.7 ± 16.7	29.7 ± 18.3	42.5 ± 30.0
Post	41.62 ± 30.51	27.8 ± 18.9	81.9 ± 19.5	29.5 ± 20.5	46.2 ± 32.4
p-value	0.007	0.020	0.134	0.846	0.03

21/164 subjects needed dialysis prior to the angioplasty for uremia or volume overload. One-third (7/21) of the subjects became dialysis-free after the angioplasty and stenting. One subject worsened to ESRD after 14 months of intervention following acute kidney injury secondary to sepsis.

Patients with Unilateral RAS (*n* = 119)

Unilateral RAS was observed on angiography in 119/220 (54.1%) subjects. The average eGFR was 41.4 ± 29.2 ml/minute. The average MAP improved significantly after the angioplasty/stenting ($p = 0.016$). Combined BP and eGFR improvement was seen in 84% and 81.5% at the last follow-up as shown in Table 4.

Patients with Single Functioning Kidney RAS (*n* = 66)

RAS in a single functioning kidney was observed on angiography in 66/220 (30%) subjects. The average eGFR was 35.4 ± 24.4 ml/minute. The average MAP ($p = 0.0001$) and the need for antihypertensive

TABLE 4. Effect of angioplasty in single functioning kidney, unilateral renal artery stenosis (RAS), and bilateral RAS

	Single functioning kidney	Unilateral RAS	Bilateral RAS
Mean blood pressure			
Before	118.8 ± 12.2	113.4 ± 13.6	111.9 ± 10.3
After	109.6 ± 9.3	109.9 ± 11.6	108.9 ± 12.4
p-value	0.0001	0.016	0.272
Mean antihypertensive drugs			
Before	2.59 ± 1.0	2.34 ± 1.1	2.23 ± 0.8
After	2.23 ± 0.9	2.13 ± 1.0	1.91 ± 0.9
p-value	0.007	0.102	0.102
Mean serum creatinine			
Before	3.14 ± 2.7	2.9 ± 2.7	3.7 ± 3.5
After	3.28 ± 2.7	3.0 ± 2.6	3.3 ± 3.2
p-value	0.527	0.825	0.233
Mean eGFR			
Before	35.4 ± 24.4	41.4 ± 29.2	37.6 ± 29.4
After	37.5 ± 26.1	42.9 ± 31.3	44.7 ± 35.2
p-value	0.262	0.150	0.029

medications ($p = 0.007$) improved significantly after the angioplasty/stenting. Combined BP and eGFR improvement was seen in 92.4% and 75.8% at the last follow-up.

Patients with Bilateral RAS (*n* = 35)

Bilateral RAS was observed on angiography in 35/220 (15.9%) subjects. The average eGFR was 37.6 ± 29.4 ml/minute. The average eGFR improved significantly after the angioplasty/stenting ($p = 0.029$). Combined BP and eGFR improvement was seen in 82.9% and 80% at the last follow-up.

Complications

Twenty-three complications were encountered in 19 of a total of 220 patients (8.6%). The most serious complications were renal arterial injury in two subjects, which needed emergency nephrectomy, contrast-induced nephropathy in eight, stent displacement in three, renal artery dissection in two, and brachial artery thrombosis in one. Local hematoma was observed in four, and one developed femoral aneurysm at the puncture site, which needed repair. Two subjects developed acute left ventricular failure after the angioplasty and one developed hypotension, as they had serious cardiovascular disease also. One subject developed stent thrombosis after 2 days of angioplasty. The two subjects, who underwent emergency nephrectomy, died within 10 days of the procedure (procedure-related mortality) due to myocardial infarction and pulmonary embolism.

Discussion

This is the largest series of renal angioplasty and stenting from India where the renal artery interventions are performed by the nephrologists. This is a noncomparative study of percutaneous transluminal renal angioplasty (PTRA), with or without stent placement for RAS, over 15 years. The 90.5% technical success rate we have demonstrated is comparable to the rates between 88% and 100% reported in other large series (17–21).

One goal of PTRA is to achieve a more effective control of BP with fewer antihypertensive drugs. We found that renal angioplasty and stenting resulted in a decrease in the BP with the same or reduced dose of antihypertensives in 74.1% subjects with mean MAP reduction by 5.1 mmHg. Ramsay and Waller (51) showed that balloon angioplasty led to a cure from HTN in 24%, and to improved BP control (as measured by a reduction in the dosage of antihypertensive drugs by at least half a tablet a day) in 43% of people. The dose of antihypertensives was reduced from 2.4 to 2.1 after the angioplasty and stenting in our series. Essai Multicentrique Medicaments vs. Angioplastie (EMMA) trial (45) also showed that there was a significant decrease in median daily drug dosage (baseline was 1.33 in both groups and decreased to 1.0) in the balloon angioplasty group. Dutch Renal Artery Stenosis Intervention Cooperative (DRASTIC) trial (47) that consisted of 106 patients showed no significant advantage of angioplasty over medical therapy. In our study, MAP reduced by 9.1, 3.5, and 3 mmHg, and BP (MAP and antihypertensive medications) improved or stabilized in 77.3%, 74.8%, and 68.6% in single functioning kidney, in unilateral RAS and in bilateral RAS, respectively. Canzanello et al. (48) showed that unilateral RAS revascularization is easier, safer, and more likely to result in a favorable BP outcome than in cases with bilateral RAS or RAS affecting a solitary kidney.

Renal function improved in 10% and stabilized in 60% of the subjects overall. eGFR improved significantly in bilateral RAS, and eGFR improved or stabilized in 75.5–81% of subjects in single functioning kidney, unilateral, or bilateral RAS. Zierler et al. (52) showed that in a number of patients, PTRA may improve or stabilize renal function. In a series of 23 patients, Weibull et al. (43) showed that renal-impaired patients treated with PTRA showed improved serum creatinine in 16 (49%) patients. In 13 patients (39%), renal function was stabilized, whereas it deteriorated in 4 (12%) after 12 months. In another report by Pattison et al. (53), the benefits of PTRA in 60 patients with baseline serum creatinine > 150 μmol/l showed renal function improvement (20% reduction in serum creatinine) in 24 (40%) patients, whereas 6 (10%) showed deterioration at 1 month. Yevzlin et al. (54) performed four unilateral angioplasties in nine subjects referred for angiography as they had significant RAS. This is the first report of RAS managed by the nephrologists. The technical success was 100% and the serum creatinine improved from 2.4 mg/dl to 1.8 mg/dl over 3–7 days postintervention (54).

In the Stent Placement in Patients with Atherosclerotic Renal Artery Stenosis and Impaired Renal Function (STAR) trial (55), 140 patients with eGFR < 80 ml showed no clear effect on progression of impaired renal function. In this study, clinically significant stenosis was defined as > 50%, which may not always be hemodynamically significant. Of the 64 subjects randomized to stenting, only 46 received stenting

(12 had stenosis < 50% and 6 were not stented for other reasons). In our study, all subjects had >70% stenosis. In the STAR study, there was a question about the skill of the operator, as only one stenting was performed per year in a center. We performed angioplasty in 220 subjects over 15 years, that is, >14 per year. In the Angioplasty and Stenting for Renal Artery Lesions (ASTRAL) trial (56), the change in renal function over time that was assessed by the mean slope of the reciprocal of the serum creatinine showed no evidence of a worthwhile clinical benefit from revascularization. In the ASTRAL trial, patient selection was poor. Patients were excluded from the study, if the physician thought that they would benefit from intervention. In our study, we considered intervention when there were strong indicators clinically, biochemically, and radiologically, and the person was ready to undergo angioplasty with stenting in the same sitting. Percentage of RAS was measured visually and not by using computer program. Of the subjects, 41% were having insignificant stenosis (<70%) in the ASTRAL trial, which is one of the reasons for nonsuperiority of intervention. In our study, intervention was considered only if the stenosis was >70%. Three hundred and eight (76.4%) subjects assigned to intervention arm underwent angioplasty and stenting. In both studies, pressure gradient was not measured. The technical success was 90.5% in our study as compared with 82% in the ASTRAL trial. We did not perform the stenosis if the kidney size was <6.5–7 cm. Only 50–60 ml of iodinated contrast was used, which possibly reduced the contrast-induced nephropathy. The BP improved or stabilized in 74.1% subjects, and renal function improved or stabilized in 70% subjects over 23 months of mean follow-up. The major studies gave no significant benefit of angioplasty in controlling BP or in reducing the deterioration of renal function. In the DRASTIC trial (47), RAS > 50% was considered significant, which may not be physiologically significant. In all, 44% in the medical group underwent angioplasty for uncontrolled BP or progression of RAS after 3 months of enrollment. Although the BP remained the same, the number of antihypertensive medications were reduced in the intervention arm (2.1 ± 1.3 vs. 3.5 ± 1.5: $p < 0.001$). In our study, BP medicines were reduced from 2.4 to 2.1, and overall MAP reduced by 5 mmHg from baseline to last follow-up. Both DRASTIC and STAR trials were underpowered to reflect the benefit of intervention.

Study Limitations

This is a retrospective study of intervention in >70% RAS with a mean follow-up of approximately 23 months. As it was not randomized, we could not compare the benefit of intervention with only medical therapy. A randomized prospective evaluation with longer follow-up is desirable. The percentage of stenosis was assessed visually and computer program was not used. Visual assessment may overestimate the stenosis. Serum creatinine and eGFR were used as the markers of renal function. Serum creatinine may not detect the small change in the renal function accurately. More accurate ways of quantifying renal function like GFR by nuclear renal scans were not used. We did not measure the pressure gradient across the stenosis or intravascular ultrasound in any of the patients. Peak systolic pressure gradient >20 mmHg or mean pressure gradient >10 mmHg in a symptomatic RAS demarcates subjects who could benefit from interventions. Embolic protection devices were not used to prevent atheroembolism. Use of these devices could have improved the results more than the present state by preventing renal failure due to atheroembolism.

The complication rate in our center was 8.6%, which is almost similar to that in the ASTRAL trial (7%). Among 8.6% of complications, 1.8% were minor. Two of 220 (0.9%) patients had dissection of the renal artery, which is less than that in the ASTRAL (1.1% [4/359]) and STAR trials (4.3% [2/46]). Procedure-related mortality (<30 days) was 0.9% in our study, which was more than that in the ASTRAL trial (0.55%), but less than that in the STAR trial (4.3%).

ARAS is a progressive disease and leads to complete occlusion if untreated. All renal arteries with stenosis do not need to be (and should not be) stented. There must be a good clinical indication, and hemodynamically significant stenosis should be treated with angioplasty and stenting to get better results. Incidentally detected stenosis during the coronary angiogram in an asymptomatic patient may not be physiologically significant. Hence, interventions in these stenosis patients may not give improvement in BP or renal function. We hope that adequately powered, prospective randomized control trials in the future may give us a clear answer to the question whether the renal artery stenting is beneficial in the patients with RAS.

Conclusion

In our study of 220 patients, we observed improvement/stabilization of BP in 70% and the renal function in 79.5% subjects. Careful selection of patients with good clinical indicators of physiologically significant stenosis is a must prior to angioplasty. Angioplasty and stenting are safe and feasible options to preserve the renal function in addition to medical management in RAS.

References

1. Executive Summary: United States Renal Data System 1999 Annual Data Report. *Am J Kidney Dis* 34:S9–S19, 1999
2. Novick AC, Pohl MA, Schreiber M, Gifford RW Jr, Vidt DG: Revascularization for preservation of renal function in patient with atherosclerotic renovascular disease. *J Urol* 129:907–912, 1983
3. Meaney TF, Dustan HP, McCormack LJ: Natural history of renal arterial disease. *Radiology* 91:881–887, 1968
4. Wollenweber J, Sheps SG, Davis GD: Clinical course of atherosclerotic renovascular disease. *Am J Cardiol* 21:60–71, 1968
5. Pohl MA, Novick AC: Natural history of atheroscl and fibrous renal artery disease: clinical implications. *Am J Kidney Dis* 5:A120–A130, 1985
6. Strandness DE Jr: Natural history of renal artery stenosis. *Am J Kidney Dis* 24:630–635, 1994
7. Chrysochou C, Kalra PA: Epidemiology and natural history of atherosclerotic renovascular disease. *Prog Cardiovasc Dis* 52:184–195, 2009

8. Caps MT, Perissinotto C, Zierler RE, Polissar NL, Bergelin RO, Tullis MJ, Cantwell-Gab K, Davidson RC, Strandness Jr DE: Prospective study of atherosclerotic disease progression in the renal artery. *Circulation* 98:2866–2872, 1998
9. Cheung CM, Wright JR, Shurrab AE, Mamtora H, Foley RN, O'Donoghue DJ, Waldek S, Kalra PA: Epidemiology of renal dysfunction and patient outcome in atherosclerotic renal artery occlusion. *J Am Soc Nephrol* 13:149–157, 2002
10. Rimmer JM, Gennari FJ: Atherosclerotic renovascular disease and progressive renal failure. *Ann Intern Med* 118:712–719, 1993
11. Pillay WR, Kan YM, Crinnion JN, Wolfe JH: Prospective multicentre study of the natural history of atherosclerotic renal artery stenosis in patients with peripheral vascular disease. *Br J Surg* 89:737–740, 2002
12. Textor SC: Progressive hypertension in a patient with "incidental" renal artery stenosis. *Hypertension* 40:595–600, 2002
13. Novick AC, Textor SC, Bodie B, Khauli RB: Revascularization to preserve renal function in patients with atherosclerotic renovascular disease. *Urol Clin North Am* 11:477–490, 1984
14. Dean RH, Kieffer RW, Smith BM, Oates JA, Nadeau JH, Hollifield JW, DuPont WD: Renovascular hypertension: anatomic and renal function changes during drug therapy. *Arch Surg* 116:1408–1415, 1981
15. Hansen KJ, Cherr GS, Craven TE, Motew SJ, Travis JA, Wong JM, Levy PJ, Freedman BI, Ligush Jr J, Dean RH: Management of ischemic nephropathy: dialysis-free survival after surgical repair. *J Vasc Surg* 32:472–481; discussion: 481–482, 2000
16. Cambria RP, Brewster DC, L'Italien GJ, Gertler JP, Abbott WM, LaMuraglia GM, Moncure AC, Vignati J, Bazari H, Fang LT, Atamian S: Renal artery reconstruction for the preservation of renal function. *J Vasc Surg* 24:371–380; discussion: 380–382, 1996
17. Hansen KJ, Starr SM, Sands RE, Burkart JM, Plonk GW Jr, Dean RH: Contemporary surgical management of renovascular disease. *J Vasc Surg* 16:319–330; discussion: 330–331, 1992
18. Morris GC Jr, De Bakey ME, Crawford ES, Cooley DA, Zanger LC: Late results of surgical treatment for renovascular hypertension. *Surg Gynecol Obstet* 122:1255–1261, 1966
19. Ascer E, Gennaro M, Rogers D: Unilateral renal artery revascularization can salvage renal function and terminate dialysis in selected patients with uremia. *J Vasc Surg* 18:1012–1018, 1993
20. Dean RH, Tribble RW, Hansen KJ, O'Neil E, Craven TE, Redding JF 2nd: Evolution of renal insufficiency in ischemic nephropathy. *Ann Surg* 213:446–455; discussion: 455–456, 1991
21. Libertino JA, Bosco PJ, Ying CY, Breslin DJ, Woods BO, Tsapatsaris NP, Swinton Jr NW: Renal revascularization to preserve and restore renal function. *J Urol* 147:1485–1487, 1992
22. Novick AC: Current concepts in the management of renovascular hypertension and ischemic renal failure. *Am J Kidney Dis* 13:33–37, 1989
23. Aurell M, Jensen G: Treatment of renovascular hypertension. *Nephron* 75:373–383, 1997
24. Textor SC: Revascularization in atherosclerotic renal artery disease. *Kidney Int* 53:799–811, 1998
25. Cambria RP, Brewster DC, L'Italien GJ, Moncure A, Darling Jr RC, Gertler JP, La Muraglia GM, Atamian S, Abbott WM: The durability of different reconstructive techniques for atherosclerotic renal artery disease. *J Vasc Surg* 20:76–85; discussion: 86–87, 1994
26. Novick AC, Ziegelbaum M, Vidt DG, Gifford RW Jr, Pohl MA, Goormastic M: Trends in surgical revascularization for renal artery disease. Ten years' experience. *J Am Med Assoc* 257:498–501, 1987
27. Connolly JO, Higgins RM, Walters HL, Mackie AD, Drury PL, Hendry BM, Scoble JE: Presentation, clinical features and outcome in different patterns of atherosclerotic renovascular disease. *Q J Med* 87:413–421, 1994
28. Dorros G, Jaff M, Mathiak L, Dorros II, Lowe A, Murphy K, He T: Four-year follow-up of Palmaz–Schatz stent revascularization as treatment for atherosclerotic renal artery stenosis. *Circulation* 98:642–647, 1998
29. Dorros G, Jaff M, Mathiak L, He T: Multicenter Palmaz stent renal artery stenosis revascularization registry report: four-year follow-up of 1,058 successful patients. *Cathet Cardiovasc Intervent* 55:182–188, 2002
30. Rees CR, Palmaz JC, Becker GJ, Ehrman KO, Richter GM, Noeldge G, Katzen BT, Dake MD, Schwarten DE: Palmaz stent in atherosclerotic stenoses involving the ostia of the renal arteries: preliminary report of a multicenter study. *Radiology* 181:507–514, 1991
31. van de Ven PJ, Beutler JJ, Kaatee R, Beek FJ, Mali WP, Geyskes GG, Koomans HA: Transluminal vascular stent for ostial atherosclerotic renal artery stenosis. *Lancet* 346:672–674, 1995
32. Burket MW, Cooper CJ, Kennedy DJ, Brewster PS, Ansel GM, Moore JA, Venkatesan J, Henrich WL: Renal artery angioplasty and stent placement: predictors of a favorable outcome. *Am Heart J* 139:64–71, 2000
33. Watson PS, Hadjipetrou P, Cox SV, Piemonte TC, Eisenhauer AC: Effect of renal artery stenting on renal function and size in patients with atherosclerotic renovascular disease. *Circulation* 102:1671–1677, 2000
34. Rundback JH, Jacobs JM: Percutaneous renal artery stent placement for hypertension and azotemia: pilot study. *Am J Kidney Dis* 28(2):214–219, 1996
35. Boyer L, Bouchet F, Boissier A, Alexandre M, Baguet JC, Viallet JF: Pattern of blood creatinine levels in 140 hypertensive patients after successful percutaneous transluminal angioplasty for renal artery stenosis. *J Radiol* 74:609–613, 1993
36. Perkovic V, Thomson KR, Mitchell PJ, Gibson RN, Atkinson N, Field PL, Becker GJ: Treatment of renovascular disease with percutaneous stent insertion: long-term outcomes. *Australas Radiol* 45:438–443, 2001
37. Rocha-Singh KJ, Ahuja RK, Sung CH, Rutherford J: Long-term renal function preservation after renal artery stenting in patients with progressive ischemic nephropathy. *Catheter Cardiovasc Intervent* 57:135–141, 2002
38. Taylor A, Sheppard D, Macleod MJ, Harden P, Baxter GM, Edwards RD, Moss JG: Renal artery stent placement in renal artery stenosis: technical and early clinical results. *Clin Radiol* 52:451–457, 1997
39. Harden PN, MacLeod MJ, Rodger RS, Baxter GM, Connell JM, Dominiczak AF, Junor BJ, Briggs JD, Moss JG: Effect of renal-artery stenting on progression of renovascular renal failure. *Lancet* 349:1133–1136, 1997
40. Jiang X, Ming G, Wu H, Wang L, Wang J, Zheng D, Liu G, Liu L: Preliminary results of stenting revascularization as treatment for renal artery stenosis. *Zhonghua Nei Ke Za Zhi* 41:82–85, 2002
41. Bonelli FS, McKusick MA, Textor SC, Kos PB, Stanson AW, Johnson CM, Sheedy 2nd PF, Welch TJ, Schirger A: Renal artery angioplasty: technical results and clinical outcome in 320 patients. *Mayo Clin Proc* 70: 1041–1052, 1995
42. Hoffman O, Carreres T, Sapoval MR, Auguste MC, Beyssen BM, Raynaud AC, Gaux JC: Ostial renal artery stenosis angioplasty: immediate and mid-term angiographic and clinical results. *J Vasc Interv Radiol* 9:65–73, 1998
43. Weibull H, Bergqvist D, Bergentz SE, Jonsson K, Hulthén L, Manhem P: Percutaneous transluminal renal angioplasty versus surgical reconstruction of atherosclerotic renal artery stenosis: a prospective randomized study. *J Vasc Surg* 18:841–850; discussion: 850–852, 1993
44. Webster J, Marshall F, Abdalla M, Dominiczak A, Edwards R, Isles CG, Loose H, Main J, Padfield P, Russell IT, Walker B, Watson M, Wilkinson R: Randomized comparison of percutaneous angioplasty vs continued medical therapy for hypertensive patients with atheromatous renal artery stenosis. Scottish and Newcastle Renal Artery Stenosis Collaborative Group. *J Hum Hypertens* 12:329–335, 1998
45. Plouin PF, Chatellier G, Darne B, Raynaud A: Blood pressure outcome of angioplasty in atherosclerotic renal artery stenosis: a randomized trial. Essai Multicentrique Medicaments vs. Angioplastie (EMMA) Study Group. *Hypertension* 31:823–829, 1998
46. van de Ven PJ, Kaatee R, Beutler JJ, Beek FJ, Woittiez AJ, Buskens E, Koomans HA, Mali WP: Arterial stenting and balloon angioplasty in ostial atherosclerotic renovascular disease: a randomized trial. *Lancet* 353:282–286, 1999
47. van Jaarsveld BC, Krijnen P, Pieterman H, Derkx FH, Deinum J, Postma CT, Dees A, Woittiez AJ, Bartelink AK, Man in 't Veld AJ, Schalekamp MA: The effect of balloon angioplasty on hypertension in atherosclerotic renal-artery stenosis. Dutch Renal Artery Stenosis Intervention Cooperative Study Group. *N Engl J Med* 342:1007–1014, 2000
48. Canzanello VJ, Millan VG, Spiegel JE, Ponce PS, Kopelman RI, Madias NE: Percutaneous transluminal renal angioplasty in management of atherosclerotic renovascular hypertension: results in 100 patients. *Hypertension* 13:163–172, 1989
49. Sabeti S, Schillinger M, Mlekusch W, Ahmadi R, Minar E: Reduction in renal function after renal arteriography and after renal artery angioplasty. *Eur J Vasc Endovasc Surg* 24:156–160, 2002
50. Pattynama PM, Becker GJ, Brown J, Zemel G, Benenati JF, Katzen BT: Percutaneous angioplasty for atherosclerotic renal artery disease: effect on renal function in azotemic patients. *Cardiovasc Intervent Radiol* 17:143–146, 1994
51. Ramsay LE, Waller PC: Blood pressure response to percutaneous transluminal angioplasty for renovascular hypertension: an overview of published series. *Br Med J* 300:569–572, 1990
52. Laird JR, Rundback J, Zierler RE, Becker GJ, O'Shaughnessy C, Shuck JW, Allie D, Olin JW, Cantwell-Gab K, Thomas J; SOAR Investigators: Safety and efficacy of renal artery stenting following suboptimal renal angioplasty for de novo and restenotic ostial lesions: results from a nonrandomized, prospective multicenter registry. *J Vasc Interv Radiol* 21:627–637, 2010
53. Pattison JM, Reidy JF, Rafferty MJ, Ogg CS, Cameron JS, Sacks SH, Williams DG: Percutaneous transluminal renal angioplasty in patients with renal failure. *Q J Med* 85:883–888, 1992
54. Yevzlin AS, Vikram C, Chan M, Gupta K: Comprehensive renal artery stenosis management by interventional nephrologists. Presented at 7th Annual Scientific Meeting ASDIN 2011 [Abstract]. *Semin Dial* 24:249–253, 2011
55. Bax L, Woittiez AJ, Kouwenberg HJ, Mali WP, Buskens E, Beek FJ, Braam B, Huysmans FT, Schultze Kool LJ, Rutten MJ, Doorenbos CJ, Aarts JC, Rabelink TJ, Plouin PF, Raynaud A, van Montfrans GA, Reekers JA, van den Meiracker AH, Pattynama PM, van de Ven PJ, Vroegindeweij D, Kroon AA, de Haan MW, Postma CT, Beutler JJ: Stent placement in patients with atherosclerotic renal artery stenosis and impaired renal function: a randomized trial. *Ann Intern Med* 150:840–841, 2009
56. Wheatley K, Ives N, Gray R, Kalra PA, Moss JG, Baigent C, Carr S, Chalmers N, Eadington D, Hamilton G, Lipkin G, Nicholson A, Scoble J: Revascularization versus medical therapy for renal-artery stenosis. *N Engl J Med* 361:1953–1962, 2009