Percutaneous Transluminal Renal Angioplasty in Management of Atherosclerotic Renovascular Hypertension: Results in 100 Patients


The long-term effect of percutaneous transluminal renal angioplasty (PTRA) on blood pressure and renal function was assessed in 100 consecutive patients with atherosclerotic renovascular hypertension. Technical success rates (complete plus partial) of a first PTRA averaged 76.2%, 74.1%, and 67.7% for the unilateral (n=42), bilateral (n=27), and solitary (n=31) groups, respectively. Of the technical successes, 59% (43/73) experienced sustained blood pressure benefit (mostly amelioration) during a mean follow-up period of 29 months. Rates of blood pressure benefit were similar in the three groups. Ostial lesions comprised the majority of blood pressure benefit failures. Repeat angioplasty in 14 patients resulted in a 71% technical success rate and a 50% blood pressure benefit rate during a mean follow-up period of 22 months. Long-term stability of mean serum creatinine level was observed after technically successful angioplasty in all three groups. Acute renal insufficiency, which was reversible in all but one patient, complicated 26% of the procedures. Mechanical complications occurred in 14% (20/145) of the arteries acted on; surgical intervention was required in five patients. The mortality rate was 2%. These results suggest that angioplasty is effective in both the long-term management of renovascular hypertension and the preservation of renal function in a large fraction of patients with atherosclerotic renovascular hypertension. (Hypertension 1989;13:163-172)

Renovascular disease is responsible for the hypertension present in approximately 4% of the general hypertensive population. Among patients with accelerated or malignant hypertension, the prevalence of renovascular hypertension is about 30%. Moreover, it is estimated that up to 45% of patients with accelerated hypertension and renal insufficiency suffer from renovascular hypertension. The development of potent and tolerable antihypertensive medications has greatly improved the medical management of hypertension associated with renovascular disease. Unfortunately, however, a progressive loss of renal mass is commonly observed despite adequate blood pressure control by medical means. Well-founded concerns have been raised concerning the potential of medical therapy to precipitate or exacerbate renal dysfunction.

Surgical revascularization has been demonstrated effective both in terms of improved blood pressure control and retrieval or stabilization of renal function. Yet, the morbidity and mortality associated with renovascular surgery continue to be substantial, especially in patients with extensive atherosclerotic vascular disease. In such patients, the lowest surgical risks have been reported in association with repair of coexisting carotid or coronary artery disease before renal revascularization. In addition nephrectomy, either as primary treatment or secondary to complications or technical failure, is a relatively common outcome of surgical intervention.
Percutaneous transluminal renal angioplasty (PTRA) has recently emerged as a promising alternate method of renal revascularization. In patients with hypertension associated with fibromuscular disease or extent of atherosclerotic vascular disease. The vast majority of patients in each group suffered from diffuse atherosclerotic vascular disease. In most patients, hypertension had been difficult to control or had remained uncontrolled despite intensive antihypertensive regimens. All patients with long-standing hypertension had experienced a recent exacerbation of their hypertension. Significant differences in baseline renal function were evident among the groups: mean serum creatinine values were 1.5±0.1 mg/dl for the unilateral group, 2.1±0.2 mg/dl for the bilateral group (p<0.05 vs. solitary group), and 4.2±0.4 mg/dl for the solitary group (p<0.05 vs. either unilateral or bilateral group). All data on blood pressure measurements, antihypertensive medications, and serum creatinine values before and after PTRA were obtained from the records of the Hypertension and Nephrology Clinics of this institution or by direct communication with each patient's primary physician. The short-term outcome of PTRA has been reported previously in 25 of the 100 patients.

Patients and Methods

Patient Selection

The first 100 consecutive patients with atherosclerotic renovascular disease who underwent PTRA at the New England Medical Center from February 1978 to May 1985 form the basis of this report. All patients had angiographic documentation of an atherosclerotic lesion producing a 75% or greater reduction in the cross-sectional area of one or more renal arteries. Based on the initial angiographic characteristics, patients were classified into one of three groups: unilateral (n=42), bilateral (n=27), or solitary (i.e., stenosis of a renal artery supplying a solitary functioning kidney) (n=31). Each lesion was categorized as nonostial or ostial. Of a total of 125 arterial lesions, 75 were classified as nonostial and 50 as ostial. Three of the nonostial lesions had resulted in occluded vessels. All patients were previously diagnosed to have hypertension and required one or more medications for blood pressure control. Indications for PTRA included: the presence of hypertension in all patients and, additionally, the presence of renal insufficiency (as defined by a serum creatinine level ≥1.5 mg/dl) in 66 patients. Patient characteristics before PTRA are shown in Table I. The presence of diffuse atherosclerosis was established by evidence for one or more of the following: 1) previous atherosclerotic complications such as myocardial infarction, cerebrovascular disease, or intermittent claudication; 2) the presence of carotid or femoral bruits or pulse deficits on physical examination; 3) angiographic findings of diffuse atherosclerosis that usually involved the abdominal aorta, mesenteric vessels, or lower extremity vasculature. There were no significant differences between the three patient groups in terms of age, sex, duration of hypertension, average level of blood pressure, number of antihypertensive medications, or extent of atherosclerotic vascular disease. The vast majority of

Protocol and Technique of Percutaneous Transluminal Renal Angioplasty

The PTRA protocol and technique have been previously reported. The balloons of the angioplasty catheters used (Medi-Tech Division of Cooper Scientific Corporation, Watertown, Massachusetts or Cook Inc., Bloomington, Indiana) had maximal outer diameters ranging from 3.7 to 6.0 mm.

Criteria for Outcome of Percutaneous Transluminal Renal Angioplasty

The technical outcome of PTRA was judged from the immediate postprocedural arteriogram according to criteria previously employed by us and others. For unilateral or solitary stenoses, complete success was defined as residual stenosis of 50% or less; partial success, as residual stenosis more than 50%, but less than or equal to 70%; and failure, as residual stenosis more than 70% or inability to cross the lesion with the angioplasty catheter. For bilateral stenoses, complete success was defined as residual stenosis of all lesions 50% or less; partial success, as residual stenosis 70% or less on at least one side; and failure, as bilateral residual stenoses more than 70%, or inability to cross the lesions with the angioplasty catheter. Criteria for blood pressure outcome have also been described previously. Blood pressure measurements at latest follow-up were used to determine outcome. Cure was defined as a diastolic pressure of 90 mm Hg or less while the patient was not receiving antihypertensive medication. Classification as improvement required a 15% or greater decrease in the diastolic pressure while the patient received the same or fewer antihypertensive medications as before the procedure. All other blood pressure responses were considered failures.
FIGURE 1. Bar graph showing technical success of percutaneous transluminal renal angioplasty in patients with atherosclerotic renovascular disease. Overall technical success rate was 73% (73/100). Technical success rates were not significantly different among groups.

Statistical Analysis

Student's t test or analysis of variance was applied to continuous data as appropriate. Discontinuous data was analyzed by \( \chi^2 \) analysis. Unless otherwise specified, the term significant is used to describe a difference that has a \( p \) value of <0.05. Data are presented as mean±1 SEM.

Results

Technical Outcome of First Percutaneous Transluminal Renal Angioplasty

One hundred patients underwent a first PTRA of lesions in a total of 125 renal arteries. The procedure was judged technically successful in 73 patients. The technical outcome of PTRA according to patient group is shown in Figure 1. The technical success rates (complete plus partial success) were 76.2% (32/42), 74.1% (20/27), and 67.7% (21/31) for the unilateral, bilateral, and solitary groups, respectively. These rates were not significantly different. The apportioning of the technical success rates to complete or partial success categories was 30.9% and 45.2%, respectively, in the unilateral group; 7.4% and 66.7% in the bilateral group; and 41.9% and 25.8% in the solitary group.

The influence of the location of the renovascular lesion on technical outcome is shown in Figure 2. For nonostial lesions (\( n=75 \)), complete or partial technical success was obtained in 29.3% (22/75) and 42.7% (32/75), respectively, for an overall technical success rate of 72% (54/75). For ostial lesions (\( n=50 \)), complete or partial success was obtained in 24% (12/50) and 38% (19/50), respectively, for an overall technical success rate of 62% (31/50). These rates in overall technical success were not significantly different.

Blood Pressure Outcome After a Technically Successful First Percutaneous Transluminal Renal Angioplasty

Blood pressure response at latest follow-up in patients with a technically successful first PTRA is shown in Figure 3. Mean time of follow-up (range) in months, was 35±4 (6-72), 23±5 (6-72), and 24±3 (6-54) in the unilateral, bilateral, and solitary groups, respectively. Considering all three groups together, 40 of the 73 patients who had undergone a technically successful first PTRA were followed for at least 24 months, and 29 patients for at least 36 months. As can be seen in Figure 3, the overall benefit rates (cured plus improved) were 71.9% (23/32), 45% (9/20), and 52.3% (11/21) for the unilateral, bilateral, and solitary groups, respectively. These differences were not significant. In the unilateral group, 9% (3/32) were cured and 62.5% (20/32) were improved. In the bilateral group, 5% (1/20) were cured and 40% (8/20) were improved. In the solitary group, no patients were cured and 52.3% (11/21) were improved. Overall, 59% (43/73) of patients having a technically successful first PTRA derived
benefit in blood pressure control during a mean follow-up of 29±2 months.

Blood pressure response at latest follow-up, analyzed according to the degree of technical success of PTRA for each group, is shown in Figure 4. Blood pressure benefit tended to be higher for complete, as opposed to partial, technical success in all three patient groups; although these differences were not significant.

Blood pressure response at latest follow-up was also analyzed according to whether the lesion was nonostial or ostial in location. The results are shown in Figure 5. In the unilateral group, blood pressure benefit rate was 85.7% (18/21) for patients with nonostial lesions compared with 45.5% (5/11) for patients with ostial lesions (p<0.05). Significant differences in blood pressure benefit between patients with nonostial or ostial lesions were not observed in the bilateral and solitary groups.

The influence of location of the stenosis and degree of technical success of PTRA on blood pressure response analyzed for the entire group of patients who had undergone a technically successful first PTRA is shown in Figure 6. Patients with ostial
lesions comprised a significantly \((p<0.01)\) greater proportion of the blood pressure failures compared with those who benefited, 64.5\% (20/31) versus 32.5\% (14/43), respectively. On the other hand, despite an apparent trend, the degree of technical success did not influence the blood pressure outcome.

Long-term blood pressure outcome was further analyzed according to the baseline patient characteristics described in Table 1. Discontinuous and continuous data were analyzed by \(\chi^2\) analyses and unpaired \(t\) tests, respectively. Comparisons between the group with blood pressure benefit and that with blood pressure failure demonstrated no significant differences in terms of age, sex, duration of hypertension, average level of blood pressure, number of antihypertensive medications, extent of atherosclerotic vascular disease, or baseline renal function.

**Renal Function Outcome After a First Percutaneous Transluminal Renal Angioplasty**

Renal function outcome in patients with a technically successful first PTRA is shown in Table 2. Renal function, as reflected by mean serum creatinine \((S_{Cr})\), was well maintained in all three groups during the time of follow-up. The fraction of patients in each group that demonstrated a lowered or stable \(S_{Cr}\) at latest follow-up was 53\% (17/32) in the unilateral group; 61\% (11/18) in the bilateral group; and 80\% (22/28) in the solitary group.
TABLE 1. Patient Characteristics Before Percutaneous Transluminal Renal Angioplasty

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (yr)</th>
<th>Sex (% male)</th>
<th>Duration of hypertension (mo)</th>
<th>Blood pressure (mm Hg)</th>
<th>Antihypertensive medications (n)</th>
<th>Diffuse ASVD (%)</th>
<th>Serum creatinine (mg/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral (n=42)</td>
<td>56±1</td>
<td>62</td>
<td>82±16 (1-456)</td>
<td>183±4/105±2</td>
<td>2.8±0.1</td>
<td>88</td>
<td>1.5±0.1 (0.8-4.2)</td>
</tr>
<tr>
<td>Bilateral  (n=27)</td>
<td>61±2</td>
<td>52</td>
<td>108±17 (1-300)</td>
<td>184±4/101±2</td>
<td>2.5±0.2</td>
<td>96</td>
<td>2.1±0.2 (0.8-5.3)</td>
</tr>
<tr>
<td>Solitary   (n=31)</td>
<td>60±2</td>
<td>48</td>
<td>109±19 (1-480)</td>
<td>185±4/100±2</td>
<td>3.0±0.2</td>
<td>90</td>
<td>4.2±0.4*† (1.2-11.1)</td>
</tr>
</tbody>
</table>

Data are presented as mean±SEM. Range is indicated in parentheses. ASVD, atherosclerotic vascular disease.

42% (8/19) in the solitary group. The SCr increased in the remaining patients of each group.

Analysis of Blood Pressure Failures

Of the initial 73 patients who underwent a technically successful first PTRA, 30 (41.0%) were eventually classified as blood pressure failures after a mean follow-up of 17±3 months. Additional features of this group are shown in Table 3. With the exception of a larger proportion of ostial lesions (Figure 6), the group of blood pressure failures did not differ significantly in any of these features from the group of blood pressure benefit. Of a total of 30 classified as blood pressure failures, 18 (60%) patients consented to repeat renal angiography. In 14 of these patients (78%) restenosis of the originally dilated lesions had occurred. In the remaining four patients (22%), the originally dilated lesions were patent, but new stenosing lesions had developed in two of these patients.

Patients Undergoing a Repeat Percutaneous Transluminal Renal Angioplasty

The 14 patients with restenosis of the originally dilated lesions underwent a repeat PTRA at a mean time from the first PTRA of 8±2 months. The overall technical success in this group was 71% (10/14) with a blood pressure benefit rate of 50% (5/10) at a mean follow-up time of 22±5 months. In the 10 patients who underwent a technically successful repeat PTRA, SCr averaged 2.5±0.7 mg/dl at baseline and 3.4±1.0 mg/dl (difference was not significant) after a mean follow-up of 22±5 months.

Complications

Acute renal insufficiency. Acute renal insufficiency that occurred as a complication of the PTRA procedure was defined according to the following changes in the SCr during the immediate postprocedural interval: 1) an increase of 0.5 mg/dl or more if baseline SCr was 1.9 mg/dl or less, 2) an increase of 1.0 mg/dl or more if baseline SCr was 2.0–4.9 mg/dl, and 3) an increase of 1.5 mg/dl or more if baseline SCr was 5.0 mg/dl or more. These criteria are identical to those employed in a recent study of hospital-acquired renal insufficiency.26

Of a total of 114 PTRA procedures (100 primary and 14 repeat), 30 (26.2%) were complicated by acute renal insufficiency. Each of these episodes was experienced by a separate patient; of the 30 affected patients, nine belonged to the unilateral group, 12 to the bilateral group, and nine to the solitary group. Mean SCr for these patients (n=30) at baseline, peak elevation, and post-PTRA were 2.7±0.3, 5.3±0.6, and 3.4±0.5 mg/dl, respectively. The mean increase in SCr from baseline to peak was 2.6±0.4 mg/dl. Four of these 30 patients with acute renal insufficiency required dialysis. The mean SCr for this subgroup was 4.2±1.5 mg/dl before PTRA and increased to a peak value of 10.1±1.7 mg/dl. In three of these patients, the SCr returned to pre-PTRA levels whereas one patient (pre-PTRA SCr 8.0 mg/dl) required chronic dialytic therapy.

Mechanical complications. In all, 145 renovascular lesions were acted on during the 114 PTRA procedures. The resulting mechanical complications are shown in Table 4. The overall incidence of mechanical complications was 13.8% (20/145). There were seven episodes of segmental or subsegmental renal parenchymal defects, presumably reflecting

TABLE 2. Renal Function Outcome in Patients With a Technically Successful First Percutaneous Transluminal Renal Angioplasty

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline SCr (mg/dl)</th>
<th>Latest SCr (mg/dl)</th>
<th>p*</th>
<th>Follow-up (mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral (n=32)</td>
<td>1.4±0.1</td>
<td>1.6±0.2</td>
<td>NS</td>
<td>29±3 (1-63)</td>
</tr>
<tr>
<td>Bilateral  (n=18)</td>
<td>2.1±0.3</td>
<td>2.4±0.5</td>
<td>NS</td>
<td>16±4 (1-60)</td>
</tr>
<tr>
<td>Solitary   (n=19)</td>
<td>4.5±0.6</td>
<td>4.9±1.0</td>
<td>NS</td>
<td>21±4 (1-52)</td>
</tr>
</tbody>
</table>

Data presented as mean±SEM. Range is indicated in parentheses. NS, not significant.

*p paired t test.
Table 3. Characteristics of Patients Classified As Blood Pressure Failures (n=30)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Failure n=20</th>
<th>No Failure n=50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean time at BP failure (months)</td>
<td>17±3</td>
<td>14±2</td>
</tr>
<tr>
<td>Sex</td>
<td>20 M, 10 F</td>
<td>34 M, 16 F</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>58±2</td>
<td>53±3</td>
</tr>
<tr>
<td>Duration of HBP (mo)</td>
<td>88±16</td>
<td>108±20</td>
</tr>
<tr>
<td>Blood pressure at baseline (mm Hg)</td>
<td>189±5/103±2</td>
<td>150±10/90±2</td>
</tr>
<tr>
<td>Antihypertensive medications at baseline (n)</td>
<td>2.8±0.2</td>
<td>2.0±0.1</td>
</tr>
<tr>
<td>Unilateral</td>
<td>9 (30)</td>
<td>15 (30)</td>
</tr>
<tr>
<td>Bilateral</td>
<td>11 (37)</td>
<td>18 (36)</td>
</tr>
<tr>
<td>Solitary</td>
<td>10 (33)</td>
<td>12 (24)</td>
</tr>
<tr>
<td>Ostial lesions</td>
<td>20 (67)</td>
<td>35 (70)</td>
</tr>
<tr>
<td>Partial technical successes</td>
<td>22 (73)</td>
<td>35 (100)</td>
</tr>
</tbody>
</table>

Percentage is indicated in parentheses.
BP, blood pressure; M, male; F, female; HBP, high blood pressure.

Discussion

In 100 consecutive patients with severe hypertension associated with atherosclerotic renovascular disease, the overall technical success rate of a first PTRA was 73%. Moreover, 59% of patients undergoing a technically successful first PTRA experienced sustained blood pressure benefit, as judged during a mean follow-up period of 29 months. Accordingly, the results of the present study indicate that PTRA is an effective modality in the management of atherosclerotic renovascular hypertension.

The technical outcome of angioplasty in the present study is comparable with that obtained at other centers. For example, in the report on 51 patients with atherosclerotic renovascular hypertension by Sos et al, which also provided an analysis of the technical result of PTRA according to the anatomy of the lesion, the combined rates of complete plus partial success averaged 67% for the unilateral as well as the bilateral groups. As shown in Figure 1, our technical success rates averaged 76%, 74%, and 68% for the unilateral, bilateral, and solitary groups, respectively. Although displaying a trend toward lower values, overall technical success rate for ostial lesions in our study was not significantly different from that for nonostial lesions and similar apportioning to complete or partial success rates in the two types of lesions was observed (Figure 2). Sos and colleagues also attained similar cumulative technical success rates for ostial and nonostial lesions in unilateral stenosis (such analysis was not presented for the bilateral group); in contrast to our experience, however, technical successes were exclusively complete in nonostial lesions, but largely partial in ostial lesions.

This difference notwithstanding, Sos et al did not discern a statistical difference in the reduction of mean peak systolic pressure gradient across the stenosis between ostial and nonostial lesions.

As noted, 59% (43/73) of patients who underwent a technically successful first PTRA in our series derived a substantial and lasting benefit in blood pressure control. This result confirms and extends the observations made by other investigators in smaller groups of patients that were followed up for a shorter mean time period. The extent of the benefit obtained by the patients in our study may be better appreciated when considering that the large majority suffered from diffuse atherosclerotic vascular disease and had hypertension of long-lasting duration, which had been difficult to control or had remained uncontrolled despite intensive antihypertensive regimens (Table 1). Amelioration, rather than cure, of hypertension was the typical benefit. Such response is not unexpected in this population of patients that usually features long-standing hypertension, advanced atherosclerotic renovascular hypertension.
nephrosclerosis, and, often, kidneys with ischemic atrophy. Furthermore, in a considerable fraction of these patients atherosclerotic renovascular hypertension was probably but one component of the hypertensive state that was superimposed on pre-existing primary hypertension.

Patients with unilateral disease tended to have a greater blood pressure benefit rate as compared with those in the bilateral or solitary groups (Figure 3). We were unable to identify any baseline patient characteristic as an important predictor of blood pressure response to a technically successful angioplasty. Although not studied by formal protocol, baseline renal vein renin data were available in 26 patients in the unilateral group. Blood pressure benefit was achieved in 68% (15/22) of patients with a renal vein renin ratio (affected kidney/unaffected kidney) of 1.5 or more; yet, benefit also occurred in 100% (4/4) of patients whose ratio was less than 1.5. The limitations of the renal vein renin ratio as a prognosticator of blood pressure benefit after PTRA have been reported by others and reviewed by us. Although a trend toward greater blood pressure benefit for complete, as opposed to partial, technical success was apparent, the observed differences were not significant (Figures 4 and 6). This finding suggests that even partial dilatation was frequently sufficient to render the stenosis hemodynamically not significant. In this regard, our experience stands in contrast to that of Sos and colleagues, who reported a uniformly unfavorable blood pressure response to partial technical success.

Although the technical outcome of PTRA apparently was not influenced by the location of the underlying stenosis (i.e., nonostial vs. ostial, Figure 2), successful PTRA conferred greater long-term blood pressure benefit in patients with nonostial as compared with ostial lesions (Table 3 and Figures 5 and 6). Insight into this seeming paradox may be gleaned from the fact that 78% of the 18 patients classified as blood pressure failures who consented to repeat arteriography (14 patients) displayed restenosis of the originally dilated lesions. It should be recalled that the technical outcome of PTRA was judged from the immediate postprocedural arteriogram, whereas the blood pressure outcome was determined from measurement at latest follow-up. Accordingly, the data are consistent with the interpretation that initially dilated ostial lesions are prone to restenosis that results in loss of the acquired blood pressure benefit. Nonetheless, a substantial number of successfully dilated ostial lesions derived lasting blood pressure benefit (Figures 5 and 6). Moreover, when the hypertensive state reoccurred after a technically successful PTRA and an initially favorable blood pressure outcome, it was only after a mean interval of 17±3 months from the intervention. Most importantly, repeat PTRA offered a technical success rate of 71% and a long-term blood pressure benefit rate of 50%, results similar to those of the initial procedure. We conclude, therefore, that an ostial lesion, although associated with a less favorable outcome, is not a contraindication to performing PTRA.

Among the 18 patients classified as blood pressure failures who were investigated by means of repeat renal arteriography, four (22%) displayed patency of the originally dilated lesions. In two of these patients, new stenosing lesions had developed, a finding consistent with the known progressive nature of atherosclerotic renovascular disease. This knowledge mandates an aggressive approach toward all present risk factors for atherogenesis in addition to controlling hypertension. The fact that the remaining two patients classified as blood pressure failures featured fully patent renal arteries on repeat arteriography disqualifies them from the diagnosis of renovascular hypertension. These patients, and additional patients reported by other investigators and reviewed by us, re-emphasize the fact that currently definitive diagnosis of renovascular hypertension can only be made retrospectively by demonstrating that hypertension has been eradicated or substantially ameliorated after technically successful renovascular intervention (or nephrectomy).

In addition to blood pressure control, the impact of PTRA on subsequent renal function appeared to be substantial. Two thirds of our patients had been investigated for renovascular disease because difficult-to-control or refractory hypertension had been present in the company of renal insufficiency. In many patients, attempts at achieving control of severe hypertension with a medical regimen had been frustrated by progressive renal insufficiency. Technically successful PTRA was associated with stabilization or retrieval of renal function in a substantial fraction of each of the three groups of patients. Available data, however, do not provide insights into the factors that determined whether stabilization or retrieval as opposed to progressive loss of renal function would obtain after a technically successful outcome. Renal function tended to deteriorate more among blood pressure failures as compared with blood pressure successes, but this difference was not statistically significant. Despite notable exceptions, patients with advanced renal insufficiency at baseline progressed regardless of the blood pressure outcome. Unfortunately, in the absence of a follow-up arteriogram in all patients, no rigorous interpretation of the impact of PTRA on subsequent renal function can be made.

The complication rate associated with PTRA in our series was substantial. Acute renal insufficiency complicated 26% of the procedures; four of the 30 affected patients required dialytic support, of which one was committed to chronic dialysis (baseline S<sub>cr</sub> of 8.0 mg/dl). Mechanical complications occurred in 14% (20/145) of the arteries acted on; surgical intervention was required on five occasions. Finally, the mortality rate in our series was 2%. For several reasons, it is difficult to compare our complication rate with that of other PTRA series. Patients with fibromuscular disease (typically young women in oth-
otherwise good health and with normal renal function) are often included in the denominator of reported complication rates; the extent of the prevailing atherosclerotic vascular disease is rarely defined; and a rigorous definition of acute renal insufficiency generally has not been employed. Given these considerations, reported rates of major complications have ranged from 7% to 14%. Mortality rates associated with PTRA have ranged from 0% to 3%, as recently reviewed by Mahler et al.31

How do the results of our study compare with those of other modalities in the management of atherosclerotic renovascular hypertension? Turning first to renovascular surgery, direct comparison is often hindered by several limitations of the available surgical reports. Inclusion of patients with fibromuscular renovascular disease in reporting outcomes, incomplete description of baseline patient characteristics, failure to provide an explicit account on the number, location, and severity of the stenoses, varying definitions of blood pressure outcome, and uncertainty on the length of the follow-up are but some of these limitations. Miller and coworkers22 have compared the results of PTRA with those of renovascular surgery at the same institution. After 6 months of follow-up, blood pressure benefit rates were 59% (20/34) (of which 25% were cured and 75% were improved) in the PTRA group and 50% (12/24) (of which 4% were cured and 96% were improved) in the surgical group. Major complications of PTRA occurred in 3% of patients versus 20% for surgery, whereas the incidence of minor complications was 10% and 13% for PTRA and surgery, respectively. These results, although suggesting comparability of the two procedures, must be interpreted cautiously in view of the retrospective uncontrolled nature of the report and the fact that patients with technically unsuccessful PTRAs were included in the surgical group.

Expert contemporary renovascular surgery offers a benefit rate in the range of 90% for unilateral, focal atherosclerotic disease and 70–80% for bilateral lesions in patients with diffuse atherosclerosis.1,34,35 Of the patients who benefit, some two thirds realize improvement in blood pressure control and the remainder are cured. In addition, improvement in renal function has been obtained in about 60% of patients with advanced atherosclerosis and baseline renal dysfunction, whereas an additional 30% experiences stabilization of renal function.11,12 Undoubtedly, these results are superior to those obtainable by PTRA. By the same token, the physical and emotional stress of renovascular surgery are decisively greater. Although operative mortality in focal atherosclerotic disease currently is on the order of less than 1%, mortality rates of 2–17% are still observed in patients with diffuse atherosclerosis.1,11,13,31,34,36 In one center reporting an overall operative mortality rate of 2.1% after surgery for atherosclerotic renovascular disease, patients were first subjected to an exhaustive evaluation and underwent surgical management of coexisting coronary artery disease or cerebrovascular disease before the renovascular intervention.11 Finally, although nephrectomy is now reserved for limited indications,1 the incidence of primary or secondary (i.e., after a failed bypass procedure) nephrectomy was 9% and 4%, respectively, in a recent single-center series of 113 operations in 90 patients with atherosclerotic renovascular disease.14

On the other hand, the results of medical management of renovascular hypertension have not, in general, been satisfactory. Although modern pharmacotherapy enables adequate blood pressure control in the large majority of patients,34 several studies have documented the progressive nature of renovascular disease and the progressive deterioration of renal function in medically treated patients.1,5,6,10 Such deterioration in renal function has been attributed to ischemia and nephrosclerosis, but a disturbing concern has been raised over the potential of effective pharmacotherapy to promote renal dysfunction by decreasing perfusion pressure and, therefore, by aggravating renal ischemia.7–9

In conclusion, we suggest that revascularization by PTRA is effective in both the long-term management of hypertension and the preservation of renal function in a large fraction of patients with atherosclerotic renovascular disease. Although possibly less effective than renovascular surgery, angioplasty might be considered the procedure of first choice because it is less invasive and less risky and has a much lower incidence of eventual nephrectomy. In fact, the lower effectiveness of PTRA compared with renovascular surgery, might be more apparent than real because the differences in patient characteristics, follow-up methods, and response criteria alluded to earlier hinder a direct comparison of the two procedures. Angioplasty is most effective in patients with unilateral nonostial lesions. Ostial lesions comprise the majority of restenoses and, therefore, are associated with frequent failure to achieve long-term blood pressure control. Identification of an ostial lesion, however, should not preclude PTRA, since a substantial fraction of patients with such lesions appear to derive long-term blood pressure benefit and preserved renal function. Repeat angioplasty is suitable treatment for restenosed lesions. Technical failure of PTRA or documentation of recurrent restenosis are appropriate indications for surgical revascularization. Renovascular, usually ostial, lesions in the company of a markedly diseased aorta (including the presence of an aortic aneurysm) should best be treated directly by surgery. Our own experience and that of others suggests that patients with such pathology suffer the most and the gravest complications from PTRA. Finally, poor surgical-risk patients with diffuse atherosclerosis, compromised renal function, and attendant cardiac, cerebrovascular, or pulmonary disease should be treated medically. Although a cautious attempt at angioplasty may be justified if pharmacotherapy of hypertension proves ineffective
or intolerable and progressive renal dysfunction ensues, in general great restraint is recommended when considering invasive approaches in such patients. These considerations notwithstanding, it is obvious that a true judgment on the merits of PTRA and a definition of its role in the management of atherosclerotic renovascular hypertension can only be achieved through appropriate randomized trials.

Acknowledgment
The authors acknowledge the valuable statistical assistance of Mr. Nick Papathanasopoulos.

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6. Dean RH, Kieffer RW, Smith BM, Oates JA, Nadeau JH: Nephritis, in general great restraint is recommended when considering invasive approaches in such patients. These considerations notwithstanding, it is obvious that a true judgment on the merits of PTRA and a definition of its role in the management of atherosclerotic renovascular hypertension can only be achieved through appropriate randomized trials.

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