Are Patients With Renal Failure Good Candidates for Percutaneous Coronary Revascularization in the New Device Era?

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Background—Patients with end-stage renal disease undergoing conventional balloon angioplasty have reduced procedural success and increased complication rates. This study was designed to determine the immediate and long-term outcomes of patients with varying degrees of renal failure undergoing percutaneous coronary intervention in the current device era.

Methods and Results—We compared the immediate and long-term outcomes of 362 renal failure patients (creatinine >1.5 mg/dL) with those of 2972 patients with normal renal function who underwent percutaneous coronary intervention between 1994 and 1997. Patients with renal failure were older and had more associated comorbidities. They had reduced procedural success (89.5% versus 92.9%, P=0.007) and greater in-hospital combined major event (death, Q-wave myocardial infarction, emergent CABG; 10.8% versus 1.8%; P<0.0001) rates. Renal failure was an independent predictor of major adverse cardiac events (MACEs) (OR, 3.41; 95% CI, 1.84 to 6.22; P<0.00001). Logistic regression analysis identified shock, peripheral vascular disease, balloon angioplasty strategy, and unstable angina as independent predictors of in-hospital MACEs in the renal group. Compared with 362 age- and sex-matched patients selected from the control group, patients with renal failure had a lower survival rate (27.7% versus 6.1%, P<0.0001) and a greater MACE rate (51% versus 33%, P<0.001) at long-term follow-up. Cox regression analysis identified age and PTCA strategy as independent predictors of long-term MACEs in the renal group. Finally, within the renal failure population, the dialysis and nondialysis patients experienced remarkably similar immediate and long-term outcomes.

Conclusions—Although patients with renal failure can be treated with a high procedural success rate in the new device era, they have an increased rate of major events both in hospital and at long-term follow-up. Nevertheless, utilization of stenting and debulking techniques improves immediate and long-term outcomes. (Circulation. 2000;102:2966-2972.)

Key Words: renal failure □ angioplasty □ stents □ coronary devices

Patients with varying degrees of renal failure make up an increasing percentage of the population undergoing percutaneous coronary intervention (PCI). This trend is largely due to the prolonged lifespan of renal failure patients combined with a predisposition to accelerated atherosclerosis. Patients with renal failure at the time of admission were older and had more associated comorbidities. They had reduced procedural success and greater in-hospital combined major event rates. Renal failure was an independent predictor of major adverse cardiac events (MACEs). Logistic regression analysis identified shock, peripheral vascular disease, balloon angioplasty strategy, and unstable angina as independent predictors of in-hospital MACEs in the renal group. Compared with age- and sex-matched patients selected from the control group, patients with renal failure had a lower survival rate and a greater MACE rate at long-term follow-up. Cox regression analysis identified age and PTCA strategy as independent predictors of long-term MACEs in the renal group. Finally, within the renal failure population, the dialysis and nondialysis patients experienced remarkably similar immediate and long-term outcomes.

Methods

Patient Population
From a total of 3334 patients who underwent percutaneous coronary revascularization between October 1994 and January 1997, we identified 362 patients with renal failure at the time of admission. These patients comprised the study population (renal group). Renal failure was defined as a preprocedural creatinine >1.5 mg/dL. Of these 362 patients, 27 (7.5%) were on chronic dialysis.
failure (control group). In the second phase, long-term outcome of the patients in the renal group was compared with that of 362 patients matched by age and sex selected randomly from the control group (matched group). Finally, outcomes of the dialysis patients were compared with those of the remaining nondialysis patients within the renal group.

Clinical and Periprocedural Variables

Demographic, clinical, and preprocedural data were determined as part of the routine evaluation before attempted coronary intervention and entered prospectively in the InterCard database. Patient demographics, coronary risk factors, preprocedural associated major comorbidities, and clinical admission syndrome, including chronic stable angina, unstable angina, post–myocardial infarction angina, cardiogenic shock, evolving myocardial infarction, and congestive heart failure, were prospectively collected as part of the routine evaluation before attempted coronary intervention.

Coronary intervention was considered to be complicated by a major adverse event when death (cardiac and noncardiac) or Q-wave myocardial infarction occurred during the hospital stay, regardless of the time that elapsed between the procedure and the event. Coronary bypass surgery was considered to be a major adverse event when performed within the first 24 hours after the procedure. A >2-fold increase in creatine kinase-MB above the upper limit of normal (10 ng/mL), regardless of total creatine kinase, in the absence of new Q waves in the ECG, was considered to indicate a non–Q-wave myocardial infarction. Patient charts were reviewed daily for adverse events until hospital discharge or death.

Procedural Variables and Quantitative Coronary Angiography

Lesion morphology was classified according to the American Heart Association/American College of Cardiology (AHA/ACC) Classification Task Force, with the exception that type B lesions were further stratified into B1 and B2 lesions according to Ellis and coworkers. Device strategy and utilization, intraprocedural adverse events, and procedural outcome were recorded. A lesion treatment was considered to be successful when there was a >20% gain in luminal diameter and ≤50% residual diameter stenosis in the absence of major complications (death, Q-wave myocardial infarction, or emergency bypass surgery).

Reference and minimal luminal diameter and percent degree of stenosis were determined by use of a computer-assisted, automated edge detection algorithm (MEDIS, Computer Measurements System).

Follow-Up

Follow-up information was obtained by trained medical personnel using direct telephone interviews with the patients. When necessary, local physicians were contacted for further information, and medical records were reviewed. This information included mortality and major adverse cardiac events (MACEs). MACE at long-term follow-up was defined as death, myocardial infarction, CABG, or repeated PCI.

Statistical Analysis

Continuous variables are expressed as mean±SD; categorical variables, as percent. Student’s t test and χ² analysis were carried out for comparison of continuous and categorical variables, respectively. A value of P<0.05 was considered significant. All analyses were performed with SAS software version 6.10 (SAS Institute). Demographic, clinical, procedural, angiographic, and periprocedural variables were tested to determine significant univariate correlates of both procedural success and combined major adverse events. Univariate correlates with values of P<0.05 were considered significant.

Multiple stepwise logistic regression analysis of all significant univariate factors was performed to determine both independent predictors of procedural success and correlates of combined in-hospital major events. Cox regression analysis was performed to determine independent predictors of combined major events in the renal group.

Long-term outcomes of the renal and matched groups were determined by Kaplan-Meier curves and compared by the log-rank test. Similar analyses were performed to compare the dialysis and nondialysis renal groups. Finally, Cox regression analysis was used to identify independent predictors of both MACEs and mortality at follow-up in the renal group.

Results

Patients Characteristics

The 362 patients with renal failure represent 11% of the entire population. The baseline clinical characteristics, associated comorbidities, admission syndromes, and median creatinine values of the 3 groups of patients are shown in Table 1. Compared with the control group, patients with renal failure were older and presented more frequently with clinical syndromes known to be associated with periprocedural complications, ie, diabetes, hypertension, lower left ventricular ejection fraction, chronic obstructive pulmonary disease, vascular disease, congestive heart failure, cardiogenic shock, multivessel disease, history of prior CABG, and history of previous myocardial infarction. Compared with the matched group, patients with renal failure demonstrated the same statistically significant differences that were noted with the control group with the exception of age (because they were age matched), chronic obstructive pulmonary disease, and family history of coronary artery disease. History of PCI was similar in all groups. Importantly, the renal failure patients were more likely to present with myocardial infarction, cardiogenic shock, and congestive heart failure and less likely to present with stable or unstable angina.

Angiographic Characteristics

The angiographic characteristics of the 3 groups of patients are shown in Table 2. Compared with the control and matched groups, the renal patients were more likely to have interventions performed on saphenous vein bypass grafts and on type C lesions. There were no statistically significant differences in AHA/ACC lesion types A, B1, and B2 or in the preprocedure and postprocedure quantitative coronary angiographic analysis characteristics among the 3 groups of patients. There was no statistically significant difference in the incidence of native target arteries with reference diameter ≥2.5 mm among the 3 groups of patients.

Interventional Strategy

The interventional strategies utilized in the 3 groups of patients are shown in Table 3. There was no statistically significant difference in interventional strategy used in the 3 groups. Importantly, the use of stenting dramatically increased in the overall population from a utilization rate of 12.8% in the first half of 1994 to a 65% (P=0.0001) utilization rate by the end of the study period. This was associated with a concomitant increase in lesion success rate from 90.6% to 94.6% (P<0.0001) over the same time period. Similarly, in the renal group, stent utilization increased from 9% to 56% (P<0.0001), and the procedural success rate increased from 84% to 95% (P<0.05). Importantly, the improvement in procedural success was more marked in the
renal group than in the control population (relative risk [RR], 2.4; \( P < 0.0001 \)), suggesting that renal failure patients derive a greater benefit from stenting.

**In-Hospital Results**

Procedural success and in-hospital outcomes are shown in Table 4. Procedural success was lower in the renal group than in the control and the matched groups. MACE rate was greater in the renal group than in the control and the matched groups. This difference was entirely attributable to an increased death rate in the renal group. There was no statistically significant difference in emergent CABG or Q-wave myocardial infarction among the 3 groups of patients. When patients in cardiogenic shock were excluded from the analysis, the MACE rate decreased to 6.0% but was still significantly higher than for either the control or matched group (6.0%, 1.4%, and 1.7% for the renal, control, and matched groups, respectively; \( P < 0.001 \)). In addition, renal patients had a higher incidence of blood transfusion and vascular repair. Median postprocedure length of hospital stay was greater in the renal group than in the control and the matched groups. Finally, there were no statistically significant differences in in-hospital outcomes between the dialysis patients and the remainder of the renal group (Table 5). Again, in-hospital MACE rate was almost entirely a function of mortality, with a negligible contribution from emergent CABG and Q-wave myocardial infarction.

**Predictors of In-Hospital MACE in Overall Population**

In the overall population, multiple stepwise regression analysis identified the presence of renal failure as an independent predictor of in-hospital MACE (OR, 3.41; 95% CI, 1.84 to 6.22; \( P < 0.00001 \)). Other independent predictors of in-hospital MACE included cardiogenic shock (OR, 19.94; 95% CI, 10.0 to 39.6; \( P < 0.00001 \)), increased age (OR, 7.60; 95% CI, 1.43 to 43.52; \( P < 0.02 \)), type C lesions (OR, 2.60; 95% CI, 1.37 to 4.66; \( P < 0.002 \)), and the presence of congestive heart failure (OR, 1.98; 95% CI, 1.01 to 3.77; \( P = 0.04 \)). Patients with unstable angina (OR, 0.41; 95% CI, 0.20 to 0.80; \( P = 0.01 \)) and those who received stents (OR, 0.23; 95% CI, 0.05 to 0.63; \( P = 0.04 \)) were significantly less likely to experience an adverse outcome.

**Predictors of In-Hospital MACE in the Renal Group**

Cardiogenic shock (OR, 17.7; 95% CI, 6.1 to 56.9; \( P < 0.00001 \)), conventional balloon angioplasty strategy (OR, 4.38; 95% CI, 1.4 to 19.4; \( P = 0.02 \)), presence of vascular disease (OR, 2.89; 95% CI, 1.1 to 8.0; \( P = 0.03 \)), and unstable angina (OR, 0.11; 95% CI: 0.02 to 0.4; \( P = 0.004 \)) were
identified as independent predictors of in-hospital MACE rates in the renal failure group. Of note, diabetes mellitus was not an independent predictor of in-hospital MACE in patients with renal failure.

Long-Term Follow-Up Results
Long-term follow-up outcomes are shown in Table 6. Follow-up information was successfully obtained in 78.7% of the renal group patients and in 77.8% of the matched group patients (P < NS). Follow-up MACE rate was significantly greater in the renal group than in the control group. This difference was due to an increased rate of mortality and myocardial infarction in the renal group. Kaplan-Meier analysis showed that both survival (Figure 1) and event-free survival (Figure 2) were significantly worse in the renal failure group. One-year actuarial survival was lower for the renal than the matched group (75% [95% CI, 70 to 80] versus 97% [95% CI, 93 to 99], P < 0.00001). One-year actuarial event-free survival was also lower for the renal than the matched group (55% [95% CI, 49 to 61] versus 78% [95% CI, 71 to 84], P < 0.00001). The curves separated very early after the index procedure and continued to diverge over the course of follow-up, with a steeper slope noted in the initial 6 to 10 months. The incidence rate of survival was 0.16% and 1.97% for the renal and the matched groups, respectively (P < 0.00001). The incidence rate of event-free survival was 1.07% and 4.53% for the renal and the matched groups, respectively (P < 0.00001).

Cox regression analysis identified age, &lt;74 years (RR, 1.8; 95% CI, 1.3 to 2.5; P = 0.001), PTCA strategy (RR, 1.7; 95% CI, 1.1 to 2.5; P = 0.01), and female sex (RR, 1.4; 95% CI, 1.0 to 2.0; P = 0.07) as independent predictors of MACE at long-term follow-up in the renal group. Finally, long-term outcomes were similar in the dialysis patients compared with the remainder of the renal population. Follow-up information was obtained in 74% of the dialysis patients compared with 78% in the nondialysis renal population (P = NS). Kaplan-Meier analyses showed no statistically significant difference in survival or event-free survival between the dialysis and nondialysis renal failure patients (Figure 3).

**TABLE 2. Angiographic Data**

<table>
<thead>
<tr>
<th></th>
<th>Renal</th>
<th>Control</th>
<th>Matched</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients, n</td>
<td>362</td>
<td>2,972</td>
<td>362</td>
<td>...</td>
</tr>
<tr>
<td>Lesions, n</td>
<td>543</td>
<td>4,366</td>
<td>541</td>
<td>...</td>
</tr>
<tr>
<td>Vessel treated, %</td>
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<td></td>
<td></td>
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<tr>
<td>LAD</td>
<td>33.5</td>
<td>36.8</td>
<td>41.4</td>
<td>NS</td>
</tr>
<tr>
<td>Right coronary</td>
<td>27.4</td>
<td>33.4</td>
<td>29.8</td>
<td>NS</td>
</tr>
<tr>
<td>Circumflex</td>
<td>24.5</td>
<td>22.2</td>
<td>19.6</td>
<td>NS</td>
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<tr>
<td>Left main</td>
<td>1.5</td>
<td>0.9</td>
<td>0.6</td>
<td>NS</td>
</tr>
<tr>
<td>Graft</td>
<td>13.1</td>
<td>6.9</td>
<td>8.7</td>
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<td>AHA/ACC lesion, %</td>
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<tr>
<td>Type A</td>
<td>9.6</td>
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<td>11.7</td>
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<td>Type B1</td>
<td>27.6</td>
<td>33.8</td>
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<tr>
<td>Type B2</td>
<td>44.0</td>
<td>43.0</td>
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<tr>
<td>Type C</td>
<td>17.3</td>
<td>10.2</td>
<td>10.0</td>
<td>&lt;0.001†</td>
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<tr>
<td>Quantitative coronary analysis</td>
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<td>Reference diameter, mm</td>
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<td>2.8±0.7</td>
<td>2.8±0.6</td>
<td>NS</td>
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<td>MLD Pre, mm</td>
<td>0.8±0.4</td>
<td>0.8±0.5</td>
<td>0.8±0.5</td>
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<tr>
<td>MLD Post, mm</td>
<td>2.2±0.8</td>
<td>2.2±0.8</td>
<td>2.1±1.0</td>
<td>NS</td>
</tr>
<tr>
<td>Stenosis Pre, %</td>
<td>76±16</td>
<td>75±16</td>
<td>76±16</td>
<td>NS</td>
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<tr>
<td>Stenosis Post, %</td>
<td>26±19</td>
<td>25±17</td>
<td>27±17</td>
<td>NS</td>
</tr>
<tr>
<td>Lesion length, mm</td>
<td>10.3±5.7</td>
<td>10.1±5.3</td>
<td>9.2±4.8</td>
<td>0.003†</td>
</tr>
<tr>
<td>Reference diameter ≤2.5 mm, %</td>
<td>41.9</td>
<td>43.1</td>
<td>46.5</td>
<td>NS</td>
</tr>
</tbody>
</table>

LAD indicates left anterior descending; MLD, minimal luminal diameter; Pre, pre coronary intervention; and Post, post coronary intervention.

*Renal vs control; †renal vs matched.

**TABLE 3. Interventional Strategy**

<table>
<thead>
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<td>Lesions, n</td>
<td>543</td>
<td>4,366</td>
<td>541</td>
<td>...</td>
</tr>
<tr>
<td>Conventional PTCA, %</td>
<td>58.9</td>
<td>58.3</td>
<td>68.0</td>
<td>0.002‡</td>
</tr>
<tr>
<td>Primary stenting, %</td>
<td>22.3</td>
<td>24.1</td>
<td>12.0</td>
<td>0.0001†</td>
</tr>
<tr>
<td>Total stenting,* %</td>
<td>31.5</td>
<td>36.4</td>
<td>22.7</td>
<td>0.02†</td>
</tr>
<tr>
<td>Debulking, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCA</td>
<td>5.5</td>
<td>6.6</td>
<td>6.5</td>
<td>NS</td>
</tr>
<tr>
<td>Rotablator</td>
<td>11.0</td>
<td>10.0</td>
<td>11.8</td>
<td>NS</td>
</tr>
<tr>
<td>TEC</td>
<td>1.8</td>
<td>1.0</td>
<td>1.7</td>
<td>NS</td>
</tr>
</tbody>
</table>

DCA indicates directional coronary atherectomy; TEC, extraction coronary atherectomy.

*Includes primary and provisional stenting.
†Renal vs control; ‡renal vs matched.
Discussion

The present study demonstrates that patients with varying degrees of renal failure can be treated with a high procedural success rate in the current era of percutaneous coronary revascularization. However, despite this high procedural success rate, these patients continue to suffer significant in-hospital and long-term morbidity and mortality. Importantly, utilization of stenting and debulking techniques improves immediate and long-term outcomes in this complicated patient population.

Although coronary revascularization in end-stage renal disease patients has been studied extensively in the past decade, little is known about the impact of coronary intervention on the complex and diverse population of patients with varying degrees of renal failure. In our study, 92.5% of the patients with renal failure were not on chronic dialysis. Additionally, the renal failure cohort constitutes 11% of the entire population undergoing PCI at our institution during the study period. A thorough assessment of the characteristics, outcomes, and predictors of failure or success in this growing population is long overdue.

The renal failure population was a high-risk group. They were older and presented more frequently with clinical syndromes associated with increased periprocedural complications, such as diabetes, hypertension, chronic obstructive pulmonary disease, congestive heart failure, cardiogenic shock, multivessel coronary artery disease, history of previous myocardial infarction, and history of previous CABG, and a higher incidence of saphenous vein graft and AHA/ACC type C lesion interventions.

Consequently, compared with patients with normal renal function, renal failure patients exhibit inferior immediate and long-term outcomes. They have a lower procedural success rate, increased in-hospital MACE rates, and increased noncardiac postprocedural complications. Interestingly, these inferior results are present within both the dialysis cohort and the nondialysis cohort, with no statistically significant differences. These poor outcomes in the overall renal failure population are largely the result of complex lesion morphology and the multitude of comorbid conditions previously identified as factors associated with an increased risk during PCI. Thus, renal failure is a marker for clinical and morphological characteristics associated with lower chances of successful percutaneous intervention and a higher incidence of in-hospital and follow-up adverse events.

Nevertheless, complex lesion morphology and comorbidities do not solely account for the poor outcomes in patients with renal failure. We identified renal disease itself as an independent predictor of in-hospital MACE. In fact, renal disease was the strongest predictor after cardiogenic shock and increased age. Furthermore, this finding was independent of the increased incidence of diabetes mellitus in the renal failure population.

Over the last decade, new lesion-specific coronary devices have resulted in improved angiographic outcomes for complex lesions. Because patients with renal failure have a higher incidence of complex coronary lesion morphology, which is less amenable to conventional balloon angioplasty, these new devices may offer hope to this population. In our study, percuta-
neous interventional methods changed considerably during the period of observation. In particular, over the 3 years analyzed in the present study, we witnessed the evolution of stent utilization from its limited initial role to its current widespread use. In our population, stent placement in our overall population increased from 12.9% in 1994 to 70% by the beginning of 1997, thus overtaking conventional balloon angioplasty as the principal coronary interventional strategy. Regression analysis showed that those patients who received stents were significantly less likely to experience an adverse outcome.

A similar trend was observed in the renal group during this time period, as stent utilization increased from 9% in 1994 to 56% by the beginning of 1997. This increase in stent utilization in the renal group was associated with a concurrent increase in procedural success from 84% to 95%. Regression analysis identified the use of conventional balloon angioplasty strategy as an independent predictor of in-hospital MACE rates in the renal failure group. In fact, it was the second strongest predictor of a poor outcome after cardiogenic shock. Thus, the use of new devices (ie, stenting and debulking techniques) improves outcomes in the renal failure population.

The long-term results of our patients with renal failure were also inferior compared with a matched group of patients with normal renal function. Despite a high initial procedural success rate, the renal group experienced a significantly lower survival and event-free survival compared with the matched group. These inferior long-term outcomes were experienced by both the dialysis and nondialysis patients within the renal failure population, as evidenced by their almost superimposable Kaplan-Meier curves. Increased rates of mortality and myocardial infarction in the renal population accounted for the disparity between the 2 groups. This difference was evident very early after the index procedure and continued to increase over the course of follow-up. Again, in the renal group, regression analysis identified PTCA strategy as the second strongest predictor of long-term follow-up MACE after age >74 years. Thus, new devices not only affect procedural success and in-hospital outcomes but also improve long-term outcomes. With the advent

![Figure 1. Kaplan-Meier survival curves of patients with renal failure vs matched control subjects.](image1)

![Figure 2. Kaplan-Meier event-free survival curves of patients with renal failure vs matched control subjects.](image2)
of advanced stent technology, greater experience with combined debulking-stenting techniques, ongoing and exciting development of coronary brachytherapy, and the use of adjunctive pharmacological therapy, we expect that the outcomes of renal failure patients undergoing PCI will continue to improve.

**Study Limitations**

The present study is a retrospective analysis based on data from our registry. The matched group was a computer-generated match of the renal failure patients by age and sex. We obtained follow-up information from telephone interviews with patients and their family members for 78% of patients in both the renal and matched groups. Because it is possible that patients may have been lost to follow-up as a result of an adverse event, we may have underestimated the long-term follow-up rates. However, a similar percentage of patients was lost to follow-up in both groups. Furthermore, we compared baseline characteristics of the patients lost to follow-up with those of the entire group and found no appreciable differences.

**Conclusions**

Patients with renal failure can be treated with a high procedural success rate in the new device era. Despite this increase in success rate, they have an increased rate of major events, both in hospital and at long-term follow-up. Nevertheless, utilization of stenting and debulking techniques improves immediate and long-term outcomes.

**References**

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