Best Threshold for Diagnosis of Stenosis or Thrombosis within Six Months of Access Flow Measurement in Arteriovenous Fistulae

MARCELLO TONELLI,*†‡ GIAN S. JHANGRI,§ DAVID J. HIRSCH,¶ JOANNE MARRYATT,¶ PAULA MOSSOP,‖ COLLEEN WILE,¶ and KAILASH K. JINDAL*

*Department of Medicine, University of Alberta, Edmonton, Canada; †Department of Critical Care, University of Alberta, Edmonton, Canada; ‡Institute of Health Economics, Edmonton, Canada; §Department of Public Health Sciences, University of Alberta, Edmonton, Canada; ‖Department of Medicine, Dalhousie University, Halifax, Canada; and ¶ Queen Elizabeth II Health Sciences Centre, Halifax, Canada

Abstract. Canadian clinical practice guidelines recommend performing angiography when access blood flow (Qa) is <500 ml/min in native vessel arteriovenous fistulae (AVF), but data on the value of Qa that best predicts stenosis are sparse. Because correction of stenosis in AVF improves patency rates, this issue seems worthy of investigation. Receiver-operating characteristic curves were constructed to examine the relationship between different threshold values of Qa and stenosis in 340 patients with AVF. Stenosis was defined by the composite outcome of access failure or angiographic stenosis occurring within 6 mo of the first Qa measurement. The Qa value was then classified as true negative, true positive, false negative, or false positive for stenosis. An additional analysis was performed in which Qa was corrected for systolic BP before assigning it to one of the four diagnostic categories. The area under the curve for the composite definition of stenosis was 0.86. Graphically, Qa thresholds of <500 and <600 ml/min had similar efficacy for detecting stenosis or access failure within 6 mo, and both seemed superior to <400 ml/min. However, the frequency of the composite definition of stenosis among AVF with Qa between 500 and 600 ml/min was only 6 (25%) of 24, as compared with 58 (76%) of 76 when Qa was <500 ml/min. This suggests that most lesions that would be found using a threshold of <600 ml/min occurred in AVF with Qa <500 ml/min and that the small gain in sensitivity associated with the <600-ml/min threshold would be outweighed by the reduced specificity compared with <500 ml/min. Correcting Qa for BP did not improve diagnostic performance or change these results, which were consistent in several sensitivity analyses. Qa measurements seemed to predict stenosis or incipient access failure equally well in groups defined by diabetic status, gender, and AVF location. In conclusion, it was found that Qa <500 ml/min seems to be the most appropriate threshold for performing angiography in patients with native vessel AVF. It is recommended that clinicians arrange angiography when Qa is <500 ml/min in AVF.

Measurements of access blood flow (Qa) have been shown to identify first and recurrent episodes of stenosis in patients with native vessel arteriovenous fistulae (AVF) (1,2). Canadian clinical practice guidelines recommend performing angiography in AVF when Qa is <500 ml/min (3), which is associated with a positive predictive value for stenosis of approximately 70%.

Because AVF seem to remain patent at Qa that would be associated with thrombosis in polytetrafluoroethylene (PTFE) grafts (4,5), reserving angiography for lower levels of Qa might reduce the false-positive rate associated with screening. Conversely, such a strategy might result in increased rates of AVF loss, because thrombosis already occurs in patients who have positive screening studies and are awaiting fistulography (1). However, because no large-scale comparison of different threshold values for angiography has been performed, the potential value of using thresholds other than 500 ml/min is uncertain. Because correction of stenosis in AVF improves access patency and reduces access-related morbidity (6), determining the optimal Qa threshold for performing angiography may be particularly important.

We used receiver-operating characteristic (ROC) curves to examine the relationship between different levels of Qa and stenosis in a large group of patients with AVF. We hypothesized that performing angiography only when Qa was <400 ml/min would improve the predictive accuracy of Qa measurements. In addition, because BP is known to influence Qa (7), we assessed the diagnostic performance of Qa that had been adjusted for BP.

Materials and Methods

Study Design

We began routinely screening patients with functioning AVF using Qa measurements in October 1999 as per published guidelines (3,4).
No other access screening was performed. All incident and prevalent chronic hemodialysis patients with a functioning AVF at the Queen Elizabeth Health Sciences Centre were eligible for inclusion in the current study. Patients were followed from the time of their first screening study until access failure, transplantation, transfer to another hemodialysis unit, or death. AVF were considered to have failed when they could not deliver sufficient blood flow to permit a hemodialysis treatment.

**Dialysis Technique**

Patients were dialyzed according to their usual prescription. No patients received antiplatelet or anticoagulant agents specifically to maintain access patency. Blood pump speeds were set as high as venous pressures would allow, and fistulae were cannulated with 15-gauge needles whenever possible.

**Procedure for Access Screening**

Screening studies were performed bimonthly with a Transonic HD01 Monitor (Transonic Systems Inc., Ithaca, NY), using indicator dilution technology, where the ultrasound velocity through blood is the indicator and dilution is provided by the bolus of normal saline. The validation of this device has been described elsewhere (8,9).

Each patient had Qa measured twice in succession during the same dialysis treatment, and the mean value was recorded. BP was measured using an automated device within 5 min of the Qa measurements. Studies were not performed during the last hour of hemodialysis or during periods of clinically significant hypotension (at the discretion of the dialysis unit nurses). To ensure independence of observations, we considered only the first screening measurement made per patient.

**Gold Standard for Stenosis**

As per published guidelines, patients underwent angiography only when Qa was <500 ml/min, when Qa had declined by >20% from baseline values (regardless of the Qa value itself), or in cases of clinical access dysfunction (defined by persistent difficulty in needleling, poor Qb, low urea reduction ratio, or physical findings suggesting stenosis) (3). As in our previous work, we referred for angiography all patients in whom Qa could not be measured (1). Because no Qa values were available for these patients, they could not be included in the current analysis; however, many had stenosis as previously reported (1). Significant stenosis was defined as >50% luminal diameter on biplanar angiography. Small-caliber vessels were not considered to represent stenosis, but patients in whom this abnormality was found were referred for creation of a new access when clinically indicated. Radiologists were asked to ensure that the arteriovenous anastomosis was visualized in all AVF undergoing angiography. They were not aware of Qa results when interpreting angiograms.

Because not all patients underwent angiography, radiologic evidence could not be used as the sole gold standard for stenosis. However, because the function of screening is to prevent access failure, it could be argued that failing to detect lesions that do not result in thrombosis or clinically evident access dysfunction is of no clinical consequence.

We approached this problem by constructing a data set in which the gold standard for stenosis was defined by the composite outcome of access failure or angiographic stenosis occurring within 6 mo of the Qa measurement. The 6-mo period was selected arbitrarily to balance the competing risks of overestimating the false-negative rate and true-negative rate of stenosis with longer and shorter intervals, respectively. The length of this period was then varied in sensitivity analyses (3 mo and 9 mo after the Qa measurement, respectively).

**Statistical Analyses**

Each Qa measurement was classified as true negative, true positive, false negative, or false positive for stenosis. Additional analyses were performed in which Qa was corrected for BP before assigning it to one of the four diagnostic categories. For all of these analyses, Qa values were categorized into 100-ml/min intervals (<100, 100 to 199.9, 200 to 299.9 etc.). ROC curves were then constructed using standard techniques, and sensitivity, specificity, the likelihood ratio of stenosis associated with a positive test, and the likelihood ratio of stenosis associated with a negative test were calculated. To evaluate for the presence of spectrum effect (10), we repeated analyses in groups defined by diabetic status, gender, and access location.

Predictive power of the various ROC curves was compared using the method of Delong et al. (11). A two-sided P value of <0.05 was considered significant. Statistical analysis was performed using Intercooled Stata (College Station, TX) and SAS 8.2 (Cary, NC).

**Results**

**Clinical Characteristics and Outcomes**

A total of 340 patients were eligible for the study (Table 1). To calculate diagnostic properties of the various Qa thresholds, we used data from all patients, regardless of whether they underwent angiography or developed clinical evidence of stenosis. Overall, mean Qa was 989 ml/min (range, 30 to 3887 ml/min), and the median within-patient coefficient of variation for Qa was 5.0%. In 96 of 340 patients, angiography was performed within 6 mo of the Qa measurement. Angiography was indicated only because of abnormal screening values in 62, only because of clinical suspicion of stenosis in 14, and for both reasons in 20. Among the patients with clinical evidence of dysfunction, mean Qa was 545 ml/min (range, 110 to 1410 ml/min), and 19 (55.9%) of 34 had Qa <500 ml/min. Stenosis was found in 81 (84.4%) of 96 patients undergoing angiography.

**Diagnostic Properties of Qa Measurements**

The area under the ROC curve (AUC) for the composite definition of stenosis was 0.86. Graphically, Qa thresholds of

**Table 1. Clinical characteristics of patients**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>64.9 ± 16.4 yr</td>
</tr>
<tr>
<td>Male gender</td>
<td>60.2%</td>
</tr>
<tr>
<td>Diabetes</td>
<td>36.4%</td>
</tr>
<tr>
<td>Systolic BP</td>
<td>136.7 ± 24.4 mmHg</td>
</tr>
<tr>
<td>Diastolic BP</td>
<td>74.5 ± 41.2 mmHg</td>
</tr>
<tr>
<td>Previous myocardial infarction</td>
<td>17.2%</td>
</tr>
<tr>
<td>Location of AVF</td>
<td></td>
</tr>
<tr>
<td>forearm</td>
<td>59.1%</td>
</tr>
<tr>
<td>upper arm</td>
<td>40.9%</td>
</tr>
<tr>
<td>Erythropoietin use</td>
<td>74.3%</td>
</tr>
</tbody>
</table>

*AVF, arteriovenous fistulae. Data are mean ± SD where appropriate. BP measurements were obtained within 5 min of the access blood flow (Qa) measurement.*
<500 and <600 ml/min seemed to have similar efficacy for detecting stenosis, but a threshold of <400 ml/min was associated with considerable loss of sensitivity without significant improvement in specificity. Table 2 shows the diagnostic properties of the different Qa thresholds.

Although the specificity of the <600 ml/min threshold (86%) seems similar to that of the <500 ml/min threshold (93%), these categories are not mutually exclusive. Our impression was that most of the predictive power associated with the <600 ml/min threshold was derived from AVF with Qa <500 ml/min. To confirm this, we examined the subgroup of patients with Qa between 500 and 600 ml/min and found that only 6 (25%) of 24 had stenosis by our definition (Table 3). Overall, 58 (76.3%) of 76 patients with Qa <500 ml/min had stenosis, as compared with 64 (64%) of 100 of those with Qa <600 ml/min. Conversely, 16 (76%) of 21 AVF with Qa between 400 and 500 ml/min and 42 (76.4%) of 55 of those with Qa <400 ml/min had stenosis.

Because Qa is measured bimonthly, analysis of only the first Qa measurement per patient might overestimate the false-negative rate of a given screening strategy, because subsequent Qa values might decline to below the threshold before thrombosis occurred—allowing angioplasty to be arranged. To address this possibility, we examined follow-up Qa measurements among the 14 patients in whom thrombosis occurred within 6 mo of the initial Qa measurement (mean Qa, 432 ml/min).

In 10 of these, the initial Qa measurement was <500 ml/min (seven with Qa <400 ml/min, three with Qa 400 to 499.9 ml/min, three with Qa 500 to 599.9 ml/min, and one with Qa >1000 ml/min). In all three cases of thrombosis observed in patients with initial Qa values of 500 to 599.9 ml/min, a second screening measurement of Qa was performed before access failure was found to be <300 ml/min, triggering angiography. In two of these, no correctable lesion was found (one had progression of severe subclavian stenosis that had failed previous attempts at angioplasty, and one had a completely normal angiogram). The third had a severe proximal lesion that did not improve despite multiple attempts at angioplasty and was referred for creation of a new access. Although we cannot exclude the possibility that earlier intervention would have prevented thrombosis in this last patient, we believe that it is unlikely, and we do not believe that the other two episodes of access failure were preventable. Thus, routinely performing angiography when Qa was <600 ml/min would have necessitated 28 additional angiograms while preventing (at most) one episode of thrombosis (Table 3).

One of three AVF with Qa between 400 and 500 ml/min failed while awaiting angioplasty, and one thrombosed but was successfully thrombolysed and angioplastied. Angioplasty was not feasible in the other such AVF. In the remaining patient with AVF thrombosis, the initial Qa was >1000 ml/min. Routine follow-up screening showed a decline of >20% in Qa (to 900 ml/min) and angiography was arranged, but angioplasty was unsuccessful and the access failed shortly afterward. Table 3 shows the additional number of angiograms that would be required for different Qa thresholds and the apparent clinical benefit that could be expected.

**Adjustment of Qa for BP**

Because BP influences Qa, we examined the impact of adjusting Qa measurements for BP on their predictive power for the composite outcome of stenosis or access failure within 6 mo. Preliminary analyses demonstrated that systolic BP (SBP) is more highly correlated with Qa than diastolic BP or mean arterial pressure. Figure 1 presents the ROC curve evaluating the ability of Qa adjusted for SBP to predict stenosis. Comparison of AUC for curves in Figures 1 and 2 suggested that adjustment for SBP did not improve the predictive power of Qa measurements ($P = 0.58$). Similarly, adjusting Qa for diastolic BP ($P = 0.21$) or mean arterial pressure ($P = 0.59$) also did not improve predictive ability.

**Sensitivity Analyses**

We repeated analyses that varied the composite definition of stenosis by considering shorter and longer periods from the Qa measurement. Performing angiography when Qa was <400 ml/min continued to be associated with less favorable

**Table 2.** Diagnostic properties of different Qa thresholds for predicting stenosis as defined by confirmed stenosis or access failure within 6 mo

<table>
<thead>
<tr>
<th>Qa (ml/min)</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Correctly Classified</th>
<th>LR+</th>
<th>LR−</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1000</td>
<td>90.4%</td>
<td>48.6%</td>
<td>58.8%</td>
<td>1.76</td>
<td>0.20</td>
</tr>
<tr>
<td>&lt;900</td>
<td>89.2%</td>
<td>57.6%</td>
<td>65.3%</td>
<td>2.10</td>
<td>0.19</td>
</tr>
<tr>
<td>&lt;800</td>
<td>85.5%</td>
<td>67.3%</td>
<td>71.8%</td>
<td>2.62</td>
<td>0.22</td>
</tr>
<tr>
<td>&lt;700</td>
<td>81.9%</td>
<td>75.9%</td>
<td>77.4%</td>
<td>3.40</td>
<td>0.24</td>
</tr>
<tr>
<td>&lt;600</td>
<td>77.1%</td>
<td>86.0%</td>
<td>83.8%</td>
<td>5.50</td>
<td>0.27</td>
</tr>
<tr>
<td>&lt;500</td>
<td>69.9%</td>
<td>93.0%</td>
<td>87.4%</td>
<td>9.98</td>
<td>0.32</td>
</tr>
<tr>
<td>&lt;400</td>
<td>50.6%</td>
<td>94.9%</td>
<td>84.1%</td>
<td>10.0</td>
<td>0.52</td>
</tr>
<tr>
<td>&lt;300</td>
<td>34.9%</td>
<td>96.9%</td>
<td>81.8%</td>
<td>11.2</td>
<td>0.67</td>
</tr>
<tr>
<td>&lt;200</td>
<td>20.5%</td>
<td>97.7%</td>
<td>78.8%</td>
<td>8.77</td>
<td>0.81</td>
</tr>
<tr>
<td>&lt;100</td>
<td>3.6%</td>
<td>99.6%</td>
<td>76.2%</td>
<td>9.29</td>
<td>0.97</td>
</tr>
</tbody>
</table>

*LR+, likelihood ratio of stenosis associated with a positive test; LR−, likelihood ratio of stenosis associated with a negative test.*
diagnostic properties than thresholds of <500 or <600 ml/min when this period was decreased to 3 mo or increased to 9 mo.

Qa measurements seemed to predict the composite outcome of stenosis or access failure equally well in patients with and without diabetes (AUC = 0.94 and 0.86, respectively; \( P = 0.11 \)), forearm and upper arm fistulae (AUC = 0.86 and 0.92, respectively; \( P = 0.29 \)), and in female patients compared with male patients (AUC = 0.94 and 0.88, respectively; \( P = 0.14 \)). There was no evidence that reserving angiography for AVF with Qa <400 ml/min would have improved diagnostic performance for any of these groups.

### Table 3. Clinical consequences of different Qa thresholds for angiography

| Qa Threshold (ml/min) | Total No. of Angiograms Required to Implement This Threshold* | No. with Stenosis by Our Definition† | No. With an Indication for Angiography at Time of Initial Qa Measurement‡ | No. Developing Another Indication for Angiography Within 6 Mo§ | No. of Additional Preventable Episodes of Thrombosis|| No. of Additional Angiograms Required||
|-----------------------|---------------------------------------------------------------|------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|----------------------|
| <1000 ml/min          | 218                                                           | 75                                 | 62                                                             | 34                                                             | 1                                                             | 122                                                            | 1000 ml/min          |
| <800 ml/min           | 170                                                           | 71                                 | 62                                                             | 34                                                             | 1                                                             | 74                                                             | 800 ml/min           |
| <600 ml/min           | 124                                                           | 64                                 | 62                                                             | 34                                                             | 1                                                             | 28                                                             | 600 ml/min           |

* Number of patients in whom the first Qa was below this threshold or who developed another indication for angiography within 6 mo of the first measurement (fall of >20% from baseline or clinical evidence of stenosis).
† Stenosis was defined by the occurrence of confirmed stenosis on angiography or access failure within 6 mo of the initial Qa measurement (see text).
‡ Number of patients who met one of these criteria at the time of the first Qa measurement; § Number of additional patients who subsequently met one of these criteria and thus underwent angiography within 6 mo of the initial Qa measurement.
∥ Implied by using the Qa threshold in the table, compared with performing angiography only when Qa was <500 ml/min, when Qa declined by >20% from baseline, or in the presence of clinical evidence of stenosis.

### Discussion

We found that reserving angiography for AVF with Qa <400 ml/min would have resulted in substantially reduced sensitivity for clinically relevant stenosis within 6 mo, with little gain in specificity. Conversely, the increased sensitivity for stenosis associated with increasing the threshold from <500 to <600 ml/min does not seem to justify the reduced specificity that would result. The findings were unchanged in several sensitivity analyses, suggesting that our conclusions are robust. These data support current clinical practice guidelines that recommend angiography for AVF with Qa <500 ml/min (3). Our data do not allow us to determine the optimal frequency of screening. However, it is important to note that our
findings depend on follow-up Qa measurements being made bimonthly and that the optimal threshold value for angiography might be higher if screening were performed less frequently.

Recent data suggest that detecting stenosis in AVF is beneficial, because angioplasty of such lesions is associated with increased patency and with reduced access-related morbidity (6). Consequently, one might argue that screening strategies should focus on sensitivity rather than specificity. However, we found a relatively low frequency of stenosis among those with Qa between 500 and 600 ml/min (25%), suggesting that any improvement in sensitivity associated with thresholds >500 ml/min would be modest. In addition, unexpected failure did not occur in such AVF during the current study, because all such accesses underwent angiography before thrombosis occurred. Although we cannot exclude the possibility that earlier detection might have prevented access failure in one of three such cases, we believe that this is unlikely, and the remaining two patients had no correctable lesions identified. In any case, our data suggest that increasing the threshold for angiography from 500 to 600 ml/min would have resulted in a substantial number of additional angiograms (n = 28) while preventing no more than one episode of thrombosis. Presumably, routine performance of angiography at even higher Qa values would result in a higher ratio of angiograms to the number of lesions detected.

Because Qa is influenced by BP (7,12), adjusting Qa measurements for this parameter might theoretically improve the diagnostic accuracy of screening. However, adjusted and unadjusted ROC curves were almost identical for both definitions of stenosis, suggesting that this is not the case provided that care is taken to standardize the timing of Qa measurements. Similarly, although it has been hypothesized that the diagnostic properties of Qa measurements might vary by AVF location, we found no evidence of this (13).

We studied a large unselected group of patients with AVF at a single institution, ensuring that an appropriate spectrum of diseased and nondiseased patients was considered (14). Both incident and prevalent patients were included because this is the clinical situation in which access screening is performed. Because Qa measurements were not provided to radiologists, it is unlikely that screening results influenced the interpretation of angiograms (15).

Current Canadian clinical practice guidelines were published in 1999 and recommend a threshold for angiography of <500 ml/min in AVF, based on the findings of two small observational studies that included a total of 115 fistulae (16,17). Although there are surprisingly few data to support these recommendations, our findings suggest that they do not require modification. In contrast, K/DOQI guidelines recommend angiography when Qa is <600 ml/min for both AVF and PTFE grafts, despite recognizing that AVF can remain patent at Qa that would cause thrombosis in grafts (4). In our opinion, the findings of the current study justify reassessment of this recommendation.

Our study has several limitations that should be considered. First, because we did not perform angiography in all patients, a surrogate gold standard had to be used—aimed at capturing clinically relevant lesions. In the primary analysis, we considered stenosis or access failure occurring within 6 mo of the Qa measurement to be reflective of an underlying lesion at the time that screening was performed. Because the purpose of screening is to detect abnormalities that will lead to thrombosis or access-related morbidity, we believe that this surrogate outcome is appropriate. A similar approach was used in a landmark study evaluating the diagnostic properties of ventilation/perfusion scans in the diagnosis of pulmonary embolism, also to avoid the universal use of an invasive gold standard (18).

Although we believe that they are unlikely to have affected our conclusions, we acknowledge that our estimates of both false-negative and false-positive rates may have been affected by this assumption. For example, if lesions developed after the Qa measurement was made, resulting in thrombosis, then this would favor the use of a higher Qa threshold, because a higher baseline Qa value would have been spuriously associated with access failure. This bias could have resulted in an underestimation of the benefits of lowering the Qa threshold for angiography to 400 ml/min. However, the current data show that AVF failure within 6 mo is most likely when Qa is <400 ml/min, and because angiography and angioplasty require time to arrange, we believe that adoption of this threshold would be unwise.

Conversely, although it is probable that some AVF with Qa >500 ml/min at baseline had clinically silent stenoses that were not detected during follow-up, the significance of such lesions is unclear. Although a previously conducted randomized trial showed that correcting stenosis in AVF is beneficial, the 95% confidence interval for overall pre-angioplasty Qa in this article seems to exclude 600 ml/min, and the median value was approximately 300 ml/min (6). Thus, the benefits of correcting stenosis are unknown at higher levels of Qa. If additional undetected asymptomatic lesions were present in the current study, then our findings suggest that they do not require intervention in the context of preserved (>500 ml/min) and stable Qa and bimonthly follow-up screening measurements. However, a randomized trial would be necessary to confirm this hypothesis.

Our results are also potentially vulnerable to verification bias, because the Qa measurement affected the decision to perform the gold standard test. This form of bias may decrease the detection rate of milder forms of disease (14,19). We attempted to address this issue with analyses considering only stenosis (which might be less likely to result from less severe lesions) and by including clinical episodes occurring up to 9 mo from the index Qa measurement (to increase the chance that milder lesions would declare themselves). Finally, verification bias would not affect differences in diagnostic accuracy between thresholds of <500 and <400 ml/min, because all AVF with Qa <500 ml/min underwent angiography.

Third, because of statistical considerations related to performing multiple correlated measures per patient, we did not address the diagnostic accuracy of another recommended criterion for performing angiography—a decrease in Qa of >20% from baseline. However, this parameter has been shown to
predict stenosis in both PTFE grafts and AVF, suggesting that it should continue to be used (1,20). Fourth, this was an observational study rather than a randomized trial. Although the latter design would be required to identify conclusively the optimal threshold for angiography, we believe that there is little basis for conducting such a trial, given the robust nature of our findings. Finally, although the number of patients within any given category of Qa was relatively small, to our knowledge, this is the largest study to date to evaluate the diagnostic properties of Qa in AVF.

In conclusion, performing angiography when Qa is <500 ml/min in patients with native vessel AVF leads to identification of stenosis in the majority of instances (81 of 96 patients [84%]). Our results suggest that altering the Qa threshold for angiography to <400 or <600 ml/min would not improve the diagnostic performance of screening. Diagnostic accuracy of Qa measurements was not affected by access location or gender, and was not improved by adjustment for BP. Given recent data indicating that correction of stenosis in AVF results in improved patency compared with no intervention, we recommend that clinicians arrange angiography when Qa is <500 ml/min in AVF. However, randomized trials would be required to show that early correction of stenosis leads to better access survival than reserving intervention for thrombosed fistulae and to confirm that Qa of <500 ml/min is the optimal threshold for arranging angiography in AVF.

Acknowledgment

Dr. Tonelli was supported by a grant from the Alberta Heritage Foundation for Medical Research.

References


Access to UpToDate on-line is available for additional clinical information at http://www.jasn.org/