Permanent hemodialysis vascular access survival in children and adolescents with end-stage renal disease

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Background. Transplantation is the optimal therapy for pediatric end-stage renal disease (ESRD) patients, but in a subset of patients with peritoneal membrane failure, failed transplants or poor social situations, chronic hemodialysis (HD) remains the only option. Long-term survival of arteriovenous fistulas (AVFs) and arteriovenous grafts (AVGs) in pediatric patients has not been well described.

Methods. We studied the survival of permanent vascular access in 34 pediatric ESRD patients treated with chronic HD at our institution between 1/1/89 and 12/1/95 and followed to 12/31/2000.

Results. Twenty-four AVFs and 28 AVGs were created in 19 and 23 patients, respectively. Mean age and weight at insertion were 15.1 years (range 7.1 to 20.9) and 46 kg (18 to 81) for AVFs and 13.3 years (3.8 to 21.1) and 41.5 kg (10.5 to 145) for AVGs. Fifteen patients weighed <35 kg at the time of access creation (7 AVFs in 5 patients, 14 AVGs in 13 patients). Excluding primary failures, one-year, three-year and five-year patency rates for AVFs (74%, 59%, 59%) and AVGs (96%, 69%, 40%) were not significantly different. Patency did not correlate with patient weight or age at access creation. Primary access failure occurred more often (P < 0.01) in AVFs (8/24) compared to AVGs (1/28). Access thrombosis, stenosis and infection occurred more frequently in AVG (P = 0.02).

Conclusions. Both AVF and AVG function well even in small pediatric patients and have survival rates equivalent to adult series and longer than cuffed venous catheters in pediatric patients. Both AVFs and AVGs are preferable for long-term HD access in pediatrics.

Insertion and maintenance of vascular access for hemodialysis (HD) is a critical aspect of taking care of end-stage renal disease (ESRD) patients on HD. Pediatric literature relating to permanent HD access is sparse due to the small number of patients with arteriovenous fistula (AVF)/arteriovenous graft (AVG) treated with long-term chronic HD. AVF or AVG placement in pediatric ESRD patients may be limited for a number of reasons including the common use of peritoneal dialysis (PD) as a dialysis modality, early transplantation, and the perception that small patient size increases the complication rate for this access. As pediatric dialysis patients survive longer, develop peritoneal membrane failure or return to dialysis after a failed renal transplant, a significant number of children may need chronic HD for extended periods of time. Creation and preservation of permanent HD access becomes a critical issue in these children with ESRD.

While cuffed venous catheters (CVCs) serve well in small children, whose small vessel caliber is not amenable to placement of a permanent access, venous catheters are often problematic because of frequent infection, thrombosis, interrupted flow, poor position, or occurrence of central venous stenosis. In addition, median survival of CVCs has been reported to be in the range 4.0 to 10.6 months [1–4]. Data for long-term actuarial survival and complication rates of AVFs and AVGs in pediatric and adolescent patients are lacking. The aims of the present study were to analyze the five-year patency rates for AVFs and AVGs to determine complication rates for each access type, and to compare the suitability of AVFs and AVGs for long-term HD access in pediatric patients receiving chronic HD.

METHODS

The charts of all pediatric patients with ESRD treated with chronic HD for a minimum of one month at Texas Children’s Hospital, Houston, Texas between January 1, 1989 and December 1, 1995 were reviewed. Age, gender, ethnicity, original disease leading to ESRD, use of steroids and age at onset of ESRD were noted as well as

Key words: dialysis vascular access survival, A-V fistula, A-V grafts, pediatric hemodialysis, stenosis, graft failure, end-stage renal disease, kidney and children.
details regarding the type of access used, date of creation, duration of function, complications and interventions during this six-year period. Data regarding patency of the AVFs/AVGs were obtained for the ten-year period from January 1, 1989 through December 31, 1999. All permanent access was placed either by a pediatric surgeon or by an adult vascular surgeon at our hospital. The respective surgeons performed all surgical revisions. Pre-access placement screening included a careful history and physical examination. All patients with a past history of prior catheter use or multiple access placements underwent formal venography to delineate vascular anatomy.

In order to avoid rethromboses, either after new access creation or after surgical thrombectomy, careful attention was paid to maintenance of systolic blood pressures and avoidance of dehydration and/or a high hematocrit in the immediate post operative period. Routine anticoagulation after access thrombectomy in the post-operative period was not used. An antiplatelet agent in the form of aspirin was used in patients with recurrent access thromboses.

Venograms and angioplasties were performed in an outpatient setting by interventional radiologists experienced with both adult and pediatric vascular access. Surveillance venograms were performed at three-month intervals in patients with recurrent thromboses and at six-month intervals in patients with no clinical problems. Other indications for venograms included clinical parameters such as an abnormal physical exam of the access, high dialyzer venous pressure or prolonged bleeding after needle removal at the end of dialysis as well as a measured increase in access recirculation.

Definitions

Primary access patency was defined as the time from access creation to the first intervention. Secondary access patency was the cumulative time from access creation to failure (not salvaged). Primary access failure was defined as non-patent access at six weeks, while intervention was surgical revision, thrombectomy or balloon angioplasty performed to maintain access patency.

Statistical methods

Statistically significant differences between demographics or complications of AVFs versus AVGs were determined by Fisher’s exact test or Chi square analysis. Factors associated with primary access failure as well as subsequent complications were analyzed using Fisher’s exact test or Chi square tests for statistical difference between groups. The unpaired t test was used to determine differences in mean insert ages and weights for each access type. Kaplan-Meier survival curves were generated to assess access survival. Primary access failures were excluded in the analysis in order to determine the actuarial survival of functioning access. Log-rank analysis was used to determine differences between survival curves of functional AVFs and AVGs. Accesses that were still patent at the end of the study period, at the time of change in modality, or in patients who were transplanted or transferred from the unit were considered as censored for survival analysis purposes. Linear regression was used to determine correlation of patient age and weight at access insertion with access patency.

RESULTS

Demographics

Records of all 47 patients (32 male, 15 female) who received chronic HD at our institution during the study period were reviewed. Eleven patients (23.4%) were Caucasian, 15 (31.9%) were African American, 19 (40.4%) were Hispanic, and 2 (4.3%) were Asian. The median patient age at the start of chronic HD was 13.1 years (range 0.9 to 21.3). Median time for treatment with chronic HD for these 47 patients was 16.9 months (range 1.9 to 99.3). Twenty of 47 patients (42.6%) had both CVC and permanent access creation at different times during the length of the study, 13 patients (27.7%) had CVC access only, and 14 patients (29.7%) had permanent access only. Permanent access was created preemptively weeks to months before starting chronic HD in those patients who had permanent access only.

A total of 34 of 47 (72.3%) patients, of which 23 were male and 11 female, had the creation of one or more permanent access at some time during their HD course. Of these, eight had both AVF and AVG placed at different times. A total of 52 permanent accesses (24 AVFs in 19 patients and 28 AVGs in 23 patients) were created during the study period. Twenty-three patients required only a single access creation, while the other 11 patients had two to four permanent access creations per patient. Fifteen patients were small, weighing between 10 and 35 kg at the time of permanent access creation (7 AVFs in 5 patients, 14 AVGs in 13 patients; both an AVF and AVG in 3/15 patients). No significant difference was noted in the demographics between patients with AVFs and AVGs (Table 1).

Sites

The most common site (22/24) for an AVF was the wrist (Brescia-Cimino fistula). The other two AVFs were placed in the upper arm and in the thigh. The most common sites for AVG placement were in the thigh (14/28) and forearm (12/28). Two AVGs were placed in the upper arm. Five of the 14 thigh AVGs were placed as a first access due to small patient size (mean age 6.0 years, mean weight 15.5 kg). Two of the 14 thigh AVGs were placed at that site to avoid pain from needle sticks, since the patients had spina bifida with decreased lower...
limb sensation. The other seven thigh AVGs were placed in five patients (mean age 15.2 years, mean weight 32 kg) after failure of one or more upper arm permanent accesses. Venogram evaluation of these patients showed either subclavian vein stenosis (4/5 patients) or inadequate upper extremity vasculature (1/5 patients).

### Survival

During the 10-year study period, primary access failure occurred in eight AVFs (33.3%) and one AVG (3.7%; Table 2). One year actuarial primary patency rate excluding primary access failure was 50% for AVF and 41% for AVG (P = NS). After excluding primary access failures, the one-year actuarial secondary patency rates were 74% for AVFs and 96% for AVGs, much higher than the 30 to 60% secondary patency rates reported for CVCs in pediatric patients [1–4]. Actuarial cumulative survival over five years was not significantly different for AVFs or AVGs (Fig. 1). Overall, secondary patency rates at one, three and five years for AVFs were 74%, 59% and 59%, respectively. One, three and five year secondary patency rates for AVGs were 96%, 69% and 40%, respectively. No correlation was noted between the insert age or weight and secondary patency of the vascular access. Cumulative AVF and AVG survival did not differ significantly after stratification for patient weight at insertion (≤ or >35 kg) or access site.

### Complications

**Primary failure.** Primary access failure occurred significantly more often with AVFs (8/24, 33.3%) than with AVGs (1/28, 3.6%; P < 0.01; Table 2). Creation of AVFs in patients of smaller size and younger age did not explain the rate of primary AVF failure. Rates for primary AVG failure were not significantly different for patients weighing 10-35 kg (3/7, 42.8%) compared to patients weighing >35 kg (5/17, 29.4%). When patients with primary AVF failure were compared to those with a functional AVF at six weeks, no significant difference was noted for age at insertion [median age 14.1 years (range 11.3 to 20.9 years) vs. 15.9 years (range 7.1 to 19.8 years), respectively] or weight at insertion [median 48 kg (range 30 to 71 kg) vs. 41.0 kg (range 18 to 81 kg), respectively]. Primary AVF failure did not correlate with gender, ethnicity, history of FSGS or steroid use.

**Other complications.** Thirty-six separate complication episodes occurred in 13 of 16 (81.3%) AVFs over 322 access-months, resulting in a complication rate of 1.3 per 12 access-months. This rate was significantly lower (P = 0.02) compared to the AVG complication rate of 2.9 per 12 access-months (158 complications in 21/27 AVGs over 648 access-months). Access stenosis and infection episodes were significantly lower for AVFs, but the rate of thrombotic episodes was not significantly different for AVFs compared to AVGs. Stenosis and thrombosis rates were not significantly affected by gender, ethnicity or history of FSGS or steroid use.

### Interventions

Thirty-seven interventions for thromboses or venous stenosis were performed in 10 of 16 (62.5%) AVFs over 322 months (1.38 interventions per 12 access-months), which was significantly less than 149 interventions in 16 of 27 (59.2%) AVGs over 648 access-months (2.76 interventions per 12 access-months; Table 3). The total number of interventions was significantly higher in AVGs (P = 0.05); however, the percentage of accesses in each group requiring intervention was not significantly different (P = 0.16).

### DISCUSSION

The literature contains very little data regarding the success of permanent vascular access in pediatric patients [1, 5, 6]. Few studies report rates of primary vascular access failure [5, 6] or patency [1, 5, 6], and no studies report long-term actuarial survival analysis for pediatric vascular access. To our knowledge, this study is the first to confirm that primary failure of AVFs and AVGs and long-term patency rates are comparable to results for adults [7–15]. Primary failure rates for AVFs in adults are reported in the 8 to 40% range [7, 13, 14], which is similar to the 33.3% failure rate found in our study. Primary AVF failure did not correlate with smaller patient size or younger age in our pediatric patients, suggesting that early AVF function is probably more dependent on surgical expertise and vessel integrity than vessel caliber.

Reported one-year primary patency rates for AVFs and AVGs in adults are in the range of 40 to 60% [7–10].

### Table 1. Demographics of patients with AVG and AVF

<table>
<thead>
<tr>
<th></th>
<th>AVF (N patients)</th>
<th>AVG (N patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N access</td>
<td>24 (19)</td>
<td>28 (23)</td>
</tr>
<tr>
<td>% Male</td>
<td>63</td>
<td>73.9</td>
</tr>
<tr>
<td>% African American</td>
<td>42.1</td>
<td>43.5</td>
</tr>
<tr>
<td>% Hispanic</td>
<td>42.1</td>
<td>47.8</td>
</tr>
<tr>
<td>% GN (% FSGS)</td>
<td>54 (25)</td>
<td>29 (14)</td>
</tr>
<tr>
<td>% With history of steroid use</td>
<td>58</td>
<td>43</td>
</tr>
<tr>
<td>Mean (median) age in years at access insertion [range]</td>
<td>15.1 (15.6)</td>
<td>13.3 (13.6)</td>
</tr>
<tr>
<td>Mean (median) weight in kg at access insertion [range]</td>
<td>46.0 (43)</td>
<td>41.5 (35)</td>
</tr>
<tr>
<td>N patients &lt;35 kg at access insertion</td>
<td>5</td>
<td>33</td>
</tr>
<tr>
<td>N (%) with previous TX</td>
<td>3 (15.8)</td>
<td>8 (34.8)</td>
</tr>
<tr>
<td>N (%) with history of PD</td>
<td>5 (26.3)</td>
<td>1 (11)</td>
</tr>
<tr>
<td>Mean N (range) accesses per patient prior to functioning AVF/AVG</td>
<td>2.7 (0–10)</td>
<td>3.3 (0–12)</td>
</tr>
<tr>
<td>N (%) placed 4 weeks prior to HD start</td>
<td>9 (37.5)</td>
<td>7 (25.0)</td>
</tr>
</tbody>
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*P = 0.05

Six AVG had failed AVF
Table 2. Complications in AVFs and AVGs in pediatric ESRD patients on maintenance HD (1989–1999)

<table>
<thead>
<tr>
<th>Complication</th>
<th>AVF</th>
<th>AVG</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary failure %</td>
<td>8 (33.3%)</td>
<td>1 (3.6%)</td>
<td>0.009</td>
</tr>
<tr>
<td>% without complications</td>
<td>23.5%*</td>
<td>22.2%*</td>
<td>NS</td>
</tr>
<tr>
<td>N access-months*</td>
<td>322</td>
<td>648</td>
<td></td>
</tr>
<tr>
<td>Total N of complications (total N accesses)</td>
<td>36 (13)</td>
<td>158 (21)</td>
<td>0.03b</td>
</tr>
<tr>
<td>Incidence of complications per 12 access-months</td>
<td>1.3</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>N stenosis episodes (N accesses)</td>
<td>9 (3)</td>
<td>57 (14)</td>
<td>NSb</td>
</tr>
<tr>
<td>Incidence of stenosis per 12 access-months</td>
<td>0.33</td>
<td>1.06</td>
<td></td>
</tr>
<tr>
<td>N thrombosis episodes (N accesses)</td>
<td>21 (8)</td>
<td>71 (15)</td>
<td>NSb</td>
</tr>
<tr>
<td>Incidence of thrombosis per 12 access-months</td>
<td>0.78</td>
<td>1.31</td>
<td></td>
</tr>
<tr>
<td>N pseudoaneurysms (N accesses)</td>
<td>3 (2)</td>
<td>5 (3)</td>
<td>NSb</td>
</tr>
<tr>
<td>Incidence of pseudoaneurysms per 12 access-months</td>
<td>0.11</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>N infections (N accesses)</td>
<td>3 (3)†</td>
<td>26 (14)†</td>
<td>0.03b</td>
</tr>
<tr>
<td>Incidence of infections per 12 access-months</td>
<td>0.11</td>
<td>0.48</td>
<td></td>
</tr>
</tbody>
</table>

*Excluding accesses with primary failure
†Comparison made between the number of affected accesses in both groups
‡Four were AVG infections with bacteremia, one required excision; the remaining were superficial infections of the overlying skin; no deep AVF infections or AVF infections associated with bacteremia occurred

Similar to the primary patency rates for pediatric patients in our study. The one-year secondary patency rates for adults are reported to be in the range of 52 to 80% for AVFs and 54 to 83% for AVGs, respectively [7–15]. Recent K-DOQI guidelines for vascular access in adults suggest aiming for one- and three-year patency rates of 70% and 50% for AVGs, respectively [16]. Patency rates at one and three years in our study were 74% and 59% for AVFs and 96% and 69% for AVGs, respectively, which are similar to the rates reported for adults and the suggested K-DOQI guidelines for AVGs. Few data are available to allow formulation of evidence-based pediatric vascular access guidelines. Our study demonstrates that the K-DOQI guidelines recommended for adults also can be achieved in pediatric patients. In addition, our study did not demonstrate a decrease in one-, three- or five-year permanent vascular access patency rates for patients of smaller size or younger age, suggesting that permanent vascular access can be successful in most pediatric patients, even those as small as 10 to 35 kg.

As expected, complications occurred more frequently with AVGs compared to AVFs in our study. Episodes of stenosis and infection were more common for AVGs than AVFs, but the frequency of episodes of thrombosis were similar. During most of the 10 years of this study,
we had an active AVG venogram surveillance program designed to detect and monitor progression of stenosis with early appropriate intervention to prevent actual thrombosis. Interventions were more frequent for AVGs compared to AVFs (2.76 vs. 1.38 interventions per 12 access-months), which may have led to reduced thrombosis rates and increased patency rates for AVGs, and account for the similarity of actual thrombotic episodes between the AVF and AVG groups. Our AVG intervention rate is similar to the three interventions per graft-year for adults reported recently by Dixon, Novak and Fangman [7].

Focal segmental glomerulosclerosis is a common disease leading to ESRD in children. FSGS and steroid therapy are associated with hypercholesterolemia, hypercoagulability and systemic hypertension, all of which predispose to atherosclerotic vascular disease. Lower AVG patency and thrombus-free graft survival has been reported in a subgroup of African American hemodialysis patients with FSGS [17]. We surmised that a history of FSGS or steroid use might increase the primary failure rate, increase the occurrence of thrombosis and stenosis, and/or reduce the long-term patency rate of vascular access in our pediatric patients. Our study failed to demonstrate any correlation of these factors with success of permanent vascular access.

Renal transplantation remains the therapy of choice for pediatric ESRD patients. High transplantation rates limit the need for long-term dialysis in many pediatric patients. However, in a subset of pediatric and adolescent patients chronic HD may be the only treatment option. Patients not eligible for early transplantation due to their social situation or high risk of recurrent disease as well as patients with a failed renal transplant who are highly sensitized often require maintenance dialysis for extended periods of time. Peritoneal membrane failure, non-adherence to the medical regimen and difficult social situations may make long-term HD the only viable dialysis option. In these patients, creating and maintaining adequate HD access for prolonged periods of time through their lifetime is critical.

Tunneled cuffed catheters (CVCs) remain the most commonly used vascular access for chronic HD in the pediatric age group, with usage as high as 77% compared to 11% AVFs and 12% AVGs reported for 682 children in North America (NAPRTCS database) [1]. One-year survival time for CVCs in children ranges from 27 to 62% [1, 2, 4], which is similar to the survival time of CVCs at our center [3] and much lower than the one-year actuarial survival rates of 74% for AVFs and 96% for AVGs demonstrated in our study. AVF and AVG survival rates at three and five years decrease (59% and 59% for AVF; 69% and 40% for AVG, respectively), but are comparable to AVG rates at those times for adults. Actuarial survival over five years is not different for patients weighing 10 to 35 kg compared to >35 kg. The data of this study strongly suggest that if long-term HD is anticipated in pediatric ESRD patients >10 kg, permanent vascular access should be the vascular access of choice. Early creation of an AVF with ample maturation time is desirable for the best outcome. Vigilant surveillance and early intervention for access complications may continue to improve AVF and AVG survival. Peculiar use of permanent HD access in pediatrics will preserve vascular sites for use later in life and improve the long-term outcome in pediatric and adolescent ESRD patients.

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