Clinical Course Associated with Vascular Access Type in a National Cohort of Adolescents Who Receive Hemodialysis: Findings from the Clinical Performance Measures and US Renal Data System Projects

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Limited research has described clinical outcomes that are associated with the type of vascular access in pediatric patients who receive maintenance hemodialysis. This retrospective cohort study examined prevalent pediatric patients who were aged 12 to <18 yr and identified in the 2000 ESRD Clinical Performance Measures Project as receiving in-center hemodialysis. Vascular access type as of December 31, 1999, was identified. These patients were linked with 1 yr of data (January 1, 2000, through December 31, 2000) from US Renal Data System standard analytic files that allow for the comparison of rates of hospitalizations and access complications by access type. Of the 418 patients who met inclusion criteria, the mean age was 15.6 yr, 53% were male, 49% were white, the mean time on dialysis was 22 mo, and 42% had a structural/urologic cause of ESRD; 42% of patients had an arteriovenous graft or fistula, and 58% had a vascular catheter. Patients with a vascular catheter as compared with those with a graft or fistula had the following adjusted relative risks (95% confidence interval): 1.84 (1.38 to 2.44) for hospitalization for any cause, 4.74 (2.02 to 11.14) for hospitalization as a result of infection, and 2.72 (2.00 to 3.69) for a complication of vascular access. Vascular catheters are the predominant access type in adolescent patients who receive maintenance hemodialysis and are associated with significantly more hospitalizations and complications.


Clinical outcomes that are associated with the various types of vascular access in adults who have ESRD and receive maintenance hemodialysis have been well described. Studies have demonstrated repeatedly that arteriovenous fistulas (AVF) have increased longevity and decreased complication rates in adults as compared with arteriovenous grafts (AVG) and vascular catheters (1–14). This evidence has contributed to AVF’s being the preferred hemodialysis access type in adults. This has been emphasized by the National Kidney Foundation Kidney Disease Outcomes Quality Initiative (NKF-K/DOQI) Clinical Practice Guidelines for vascular access and the Centers for Medicare & Medicaid Services (CMS) Fistula First, the National Vascular Access Improvement Initiative (15,16).

A significant number of pediatric patients receive hemodialysis as renal replacement therapy. Of the 2271 prevalent dialysis patients aged 0 to 19 yr in the US Renal Data System (USRDS) reported in 2003, approximately 60% received hemodialysis. In the 15- to 19-yr age group, >70% received hemodialysis. Among incident pediatric patients who were aged 0 to 19 yr and initiated dialysis from 1993 to 2003, the percentage of patients who were on hemodialysis increased from 54% in 1993 to 59% in 1998 and 62% in 2003 (17).

Vascular catheters are the predominant form of vascular access in the pediatric hemodialysis population. The 2004 ESRD Clinical Performance Measures (CPM) Project reported vascular access type in a national cohort of 678 pediatric patients who were receiving in-center hemodialysis as of December 31, 2003. Twenty-seven percent were dialyzed with an AVF, 12% with an AVG, and 60% with a catheter. Examination of vascular type in adolescent patients during the past 5 yr of ESRD CPM Projects reveals a steady increase in the use of vascular catheters (18,19).

Limited research has examined clinical outcomes that are associated with the various access types in children. The majority of the studies published are retrospective and center or region specific (20–27). Limited data and pediatric-specific challenges regarding vascular access complicate the determination of the applicability and the relevance of the adult-based
Materials and Methods
Design, Setting, and Participants
This is a retrospective cohort study using merged data from two national databases in the United States: CMS’s ESRD CPM Project and the USRDS, which collect clinical and demographic information, as well as data regarding hospitalization and survival of patients who receive hemodialysis. CMS began routinely assessing the quality of care that is provided to adult ESRD patients in 1994, and this data collection now is known as the ESRD CPM Project. Details of the methods of data collection for the ESRD CPM Project have been reported elsewhere (15,28). The USRDS maintains data on all incident and prevalent ESRD patients in the United States, including demographic, laboratory, insurance, and medical data. The USRDS collects additional data on dialysis claims and information on treatment history and hospitalization events (17).

A limited data set was created by linking the USRDS patient identification number in the USRDS standard analytic file with ESRD CPM data collected in 2000 (for October through December 1999). At the time of this analysis, the USRDS standard analytic file was updated through January 2001. These data were examined to describe clinical outcomes, including hospitalizations, procedures, and mortality associated with the various types of vascular access in the pediatric age group. The 2000 ESRD CPM Project year was the first year that data collection was expanded to include all adolescents (>12 to <18 yr of age) patients who were receiving in-center hemodialysis in the United States as of December 31, 1999 (corresponding with ESRD CPM Project Year 2000). From this cohort, patients were included in this study when their vascular access type was indicated in the ESRD CPM Project and they were identified in the USRDS.

Variables of Interest and Methods
The independent variable of interest was type of vascular access. These data were obtained from the ESRD CPM patient data file, which described the type of vascular access in use on or between October 1, 1999, and December 31, 1999, the period of data collection for the 2000 ESRD CPM Project year. Access type choices that were included on the 2000 ESRD CPM data collection form were AVF, synthetic AVG, bovine graft, vascular catheter, other, or unknown.

For patients who met inclusion criteria, 12 mo of USRDS inpatient hospitalization and outpatient records were available for examination. A timeline was created for the year of follow-up, to account for possible switches in access type and facilitate a time-at-risk analysis. The beginning of the observation period was January 1, 2000, and the end was December 31, 2000. Patients were censored for kidney transplant and death. Patients were reassigned to a new access type according to the following rules: (1) When AVF creation was listed in the procedure codes, the patient was reassigned to AVF 12 wk after the procedure; (2) when AVG creation was listed in the procedure codes, the patient was reassigned to AVG 3 wk after the procedure; and (3) when a vascular catheter was listed in the procedure codes, the patient was reassigned to a vascular catheter on the day of the procedure.

To assess the validity of reported access type in the ESRD CPM Project, we compared the access type indicated for patients who were present in both the 2000 and the 2001 ESRD CPM study, and this also was correlated with hospitalization and procedure claims in the USRDS. Approximately 10% of patients who were categorized as having an AVF or an AVG in the ESRD CPM 2000 Project year subsequently were categorized in the opposite category in the ESRD CPM 2001 Project year, with no procedure codes to support such a switch. For example, a patient with an AVF in the ESRD CPM 2000 Project year was listed as having an AVG in the ESRD CPM 2001 Project year, with no supporting or confirming evidence in the USRDS data file for this switch. For access types in question (graft versus fistula), USRDS procedure records for the year before January 2000 were examined in an attempt for clarification but with little success. Given that the ESRD CPM data collection forms and the administrative data that are used by the USRDS to create the standard analytic data files commonly are completed by administrative and dialysis staff (nurses or social workers) who likely are not assessing the patient’s access regularly, potential for significant misclassification of subcutaneous access types (AVG versus AVF) existed, and our exploratory analyses supported this. Therefore, we chose to collapse the categories of AVF and AVG into a single category, graft/fistula (hereafter referred to as “permanent access”).

The patient data file from the ESRD CPM Project provided relevant demographic and clinical variables, including age, gender, body size, race, ethnicity, assigned cause of ESRD, date of first dialysis treatment, serum albumin, hemoglobin, and single-pool Kt/V (spKt/V; Daugirdas II method). Underlying causes of ESRD were stratified into the following categories: Congenital/urologic, glomerulonephritis, focal segmental glomerulosclerosis, systemic lupus erythematosus, and other. For serum albumin, hemoglobin, and spKt/V, up to three values were available from data collection during the study period of October, November, and December 1999; an average was taken of these values. For the purpose of regression analyses, covariates were dichotomized as follows: Race, black versus nonblack; dialysis vintage, <6 mo versus greater >6 mo; mean hemoglobin, <11 versus >11 g/dl; mean serum albumin, <3.5 versus 3.5/3.2 versus >3.5/3.2 g/dl (brom cresol green/brom cresol purple laboratory methods).

Dependent variables included all-cause hospitalization, infection-related hospitalization, and access-related complications. Hospitalizations were assigned as infection related when the International Classification of Diseases, Ninth Revision code 038.xx (septicemia) or 790.7 (bacteremia) was listed as either the principal or the secondary diagnosis in the USRDS inpatient claims file.

The following inpatient or hospital outpatient procedures were identified within the USRDS standard analytic files to aid in the classification of vascular access, censoring, and determination of an access-related complication: Transplant of kidney, revision of vascular procedure, revision/removal of arteriovenous shunt for renal dialysis, other revision of vascular procedure, arteriovenousostomy for renal dialysis, insertion/replacement of vessel to vessel cannula, venous catheterization for renal dialysis, and thrombectomy/embolectomy.

Complications of vascular access were determined as follows: (1) Thrombectomy/embolectomy of any access type and (2) vascular catheter placed in a patient with a permanent access and considered as a complication of a permanent access. In addition, single procedures that were >7 d apart were considered as separate complications, multiple procedures within the same 7-d period were considered one complication, and vascular catheters that were placed at the time of a kidney transplant were not considered a complication of vascular access or included in the analysis.

Statistical Analyses
The crude incidence rates of all-cause hospitalization, infection-related hospitalization, and access complications were calculated by...
Results

A total of 433 prevalent adolescent patients who were receiving hemodialysis were identified in the 2000 ESRD CPM Project Year. Of this cohort, 418 patients had the type of vascular access identified in the ESRD CPM Project and were identified in the USRDS and therefore were included in subsequent analyses. As of December 31, 1999, 175 (42%) patients had a vascular catheter and 243 (58%) had a permanent access. Patient characteristics are presented in Table 1. Patients had a mean age of 15.6 yr (SD 1.6); 53% were male, 49% were white, 22% were of Hispanic ethnicity, and 42% had a congenital/urologic cause for their ESRD. The mean dialysis vintage was 22 mo (SD 30). The mean hemoglobin was 11.0 g/dl (1.6), the mean serum albumin was 3.85 g/dl (0.53)/3.61 g/dl (0.52; bromcresol green/bromcresol purple methods), and the mean spKt/V was 1.49 (0.46). When patients were stratified by their type of vascular access, patients with a vascular catheter, as compared with those with a permanent access, were significantly more likely to be younger, to be female, and to have been receiving hemodialysis for a shorter period of time. Patients with a vascular catheter also had a significantly lower hemoglobin and serum albumin as compared with those with a permanent access and were significantly more likely to have a spKt/V <1.2. There was no significant difference in body mass index z score categories, race, ethnicity, cause of ESRD, or occurrence of kidney transplantation by vascular access type.

Table 1. Patient characteristics, 2000 ESRD CPM Project Yeara

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total Population (n = 418)</th>
<th>Stratified Population</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Catheter (n = 175)</td>
</tr>
<tr>
<td>Mean age (yr [SD])</td>
<td>15.6 (1.6)</td>
<td>15.4 (1.6)</td>
</tr>
<tr>
<td>Male (%)</td>
<td>53</td>
<td>45</td>
</tr>
<tr>
<td>White (%)</td>
<td>49</td>
<td>51</td>
</tr>
<tr>
<td>Hispanic ethnicity (%)</td>
<td>22</td>
<td>19</td>
</tr>
<tr>
<td>Congenital/urologic disease as cause of ESRD (%)</td>
<td>42</td>
<td>45</td>
</tr>
<tr>
<td>Dialysis vintage (mo [SD])</td>
<td>22 (30)</td>
<td>14.7 (26)</td>
</tr>
<tr>
<td>Mean hemoglobin (g/dl [SD])</td>
<td>11.0 (1.6)</td>
<td>10.6 (1.6)</td>
</tr>
<tr>
<td>Mean hemoglobin &lt;11.0 g/dl (%)</td>
<td>44.5</td>
<td>58.1</td>
</tr>
<tr>
<td>Mean serum albumin &lt;3.5/3.2 g/dl (%)b</td>
<td>17.5</td>
<td>24.4</td>
</tr>
<tr>
<td>Mean spKt/V (SD)</td>
<td>1.5 (0.5)</td>
<td>1.4 (0.5)</td>
</tr>
<tr>
<td>Mean spKt/V &lt;1.2 (%)</td>
<td>23.7</td>
<td>30.8</td>
</tr>
<tr>
<td>BMI z score categories (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;−2</td>
<td>11.9</td>
<td>11.4</td>
</tr>
<tr>
<td>−2 to 2</td>
<td>79.2</td>
<td>76.7</td>
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<tr>
<td>&gt;2</td>
<td>8.9</td>
<td>12.0</td>
</tr>
<tr>
<td>Received transplant during year of follow-up (%)</td>
<td>13</td>
<td>16</td>
</tr>
</tbody>
</table>

aBMI, body mass index; CPM, Clinical Performance Measures; spKt/V, single-pool Kt/V.
bBromcresol green/bromcresol purple laboratory method.
rate of a vascular catheter, 1.23 per person-year, was more than double that for a permanent access, 0.54 per person-year. Adjustment for age, gender, race, dialysis vintage, hemoglobin, and albumin (Table 3) provided relative risk estimates that were similar to the crude rate ratios.

Sensitivity analyses that were based on the algorithm described did not significantly change the point estimates or CI. For example, the population designated as having complete Medicare coverage during the follow-up period (n = 366) had the following relative risks (95% CI), comparing vascular catheters with a permanent access: All-cause hospitalization 1.88 (1.39 to 2.56), infection-related hospitalization 5.50 (2.21 to 13.72), and; complication of access 2.94 (2.13 to 4.05).

Discussion
Caregivers of pediatric patients who receive hemodialysis likely concur that “providing dialysis access to the pediatric population is a time-consuming and frustrating challenge” (22). The complication and hospitalization rates that are associated with vascular access and that were observed in this analysis support this statement. This challenge is compounded by the fact that decisions related to the placement and management of vascular access in children carry a lifelong impact. The high rate of renal transplantation in children supports the modus operandi that dialysis is “a bridge to transplantation.” However, with current management, the vast majority of these children ultimately will return to dialysis at least once in their lifetime. Analysis of United Network for Organ Sharing data from 1987 to 1996 projected graft half-lives of 7yr for the adolescent age group (13 to 21yr of age), 11yr for children (3 to 12yr of age), and 18yr in those who are younger than 2yr (29,30).

Data regarding outcomes in the pediatric population exist but have been sparse. Regarding access longevity, Lumsden et al. (22) retrospectively examined hemodialysis access in 24 children. Of 15 AVF, one third failed to mature, and the mean functional patency was 6.2 ± 10.2 mo. Of 21 AVG (polytetrafluoroethylene), the mean functional patency was 11 ± 11.1 mo; thrombectomy was performed in 25 cases; and eight graft infections occurred, seven of which resulted in graft loss. Gradman et al. (21) examined 47 consecutive children (mean age 14.6 yr) in whom AVF were constructed. Primary patency at 1 and 2yr was 100 and 96%, respectively. Three accesses had thromboses, and of these, two were salvaged. No infections were reported. Brittinger et al. (20) reported 20 yr of experience with various types of AVF and AVG in all age groups. Complication-free functioning of AVF after 12mo ranged from 57 to 100% for the various age groups and fistula types and from 50 to 100% for AVG. Sheth et al. (24) examined the survival of permanent vascular access in 34 pediatric patients with ESRD. Of 24 AVF, eight (33%) had primary failure. Of the functioning AVG, the 1- and 3-yr patency rates were 74 and 59%, respectively. Of 28 AVG, the 1- and 3-yr patency rates were 96 and 69%, respectively. Thrombosis, stenosis, and infection occurred significantly more frequently in AVG. A 20-yr retrospective study was performed by Ramage et al. (23) A total of 304 access procedures were performed on 114 pediatric patients. Primary failure occurred in 25 of 107 AVG placed. Considering only first-access procedures, the median survival of AVF was 3.1yr. Of the 182 vascular catheters, the median survival was 0.6yr. Of possible complications, infections led to access loss in 30% of those with a catheter and 3% of those with an AVF, and thrombosis led to access loss in 54% of those with catheter and 71% of those with AVG. Microsurgical techniques for the placement of AVG and AVF have resulted in improved long-term access survival. Patent and functional AVF in >60% of pediatric patients have been reported at 4yr of follow-up (31–34). Goldstein et al. (26) examined the survival of 22 cuffed catheters. The 1yr survival was 27%, with infection and kinking being the most common reasons for removal. Finally, to examine the clinical outcomes of urea clearance, anemia, and serum albumin concentration, Chand et al. (25) prospectively followed 140 pediatric patients during a 2-yr period. A trend toward better urea clearance, higher hemoglobin, and higher albumin was observed in patients with a permanent access compared with those with a catheter.

In this study, having a vascular catheter for hemodialysis access was independently associated with an almost two-fold increase in hospitalization, an almost five-fold increase in hospitalization as a result of infection, and an almost three-fold increase in complications of access. Patients with vascular catheters also were more likely to have lower hemoglobin, serum albumin, and spKt/V values. Although this study examines the largest cohort of pediatric hemodialysis patients assembled, it has limitations. USRDS data are generated from administrative billing data; therefore, the possibility of misclassification exists for hospitalizations and procedures by access type. This misclassification bias, however, likely would bias toward a lower estimate of risk than reported. The collapse of the AVF and AVG access categories into the single permanent access category limits comparison of these two groups. However, preliminary analysis of these data found that as compared with AVF, there was not an increased risk for infection-related hospitalization in patients with an AVG (odds ratio 1.2; 95% CI 0.3 to 3.9). In the same analysis, patients with a vascular catheter were 4.5 times more likely to have an infection-related hospitalization as compared with those with an AVF.

Pediatric-specific issues related to vascular access must be acknowledged. Patient body size and the availability of vascular surgeons who are skilled and willing to create such accesses in the pediatric population limit options in particular cases.
However, as has been proved in the adult population with ESRD, AVF are associated with less morbidity in the pediatric population. It is likely that most pediatric nephrologists have already extrapolated evidence regarding improved clinical outcomes that are associated with AVF in the adult ESRD population to the pediatric population, yet vascular catheters continue to be the predominant form of vascular access, and there is no evidence that catheter use has decreased during at least the past 5 yr. Future study needs to place emphasis on the barriers to the creation and maintenance of AVF in the pediatric hemodialysis population. With this information, pediatric-specific vascular access guidelines can be formulated so that pediatric nephrologists will be well informed about their current vascular access choices, and their patients will be well positioned for a lifetime of managing chronic kidney disease.

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