Low Infection Rates and Prolonged Survival Times of Hemodialysis Catheters in Infants and Children

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Background and objectives: Hemodialysis (HD) catheter-related complications are regarded as the main cause of HD failure in infants and children with ESRD. In this study, we determined HD catheter infection rates and survival times in children.

Design, setting, participants, & measurements: We analyzed demographic, clinical, laboratory, and microbiologic data on all infants and children with ESRD who received HD therapy through a tunneled central venous catheter (CVC) in our Pediatric Dialysis Unit between January 2001 and December 2009. Our strict care of HD-CVCs makes no use of any kind of prophylactic antibiotic therapy.

Results: Twenty-nine children with ESRD (median age, 10 years) received HD through a CVC, for a total of 22,892 days during the study period. Eleven (38%) children were infants (<1 year of age) who received HD for a cumulative 3779 days (16% of total). Fifty-nine CVCs were inserted, of which 13 (22%) were in infants. There were 12 episodes of CVC infection—a rate of 0.52/1000 CVC days. Four (33%) episodes occurred in infants—a rate of 1.06/1000 CVC days. Only three (5%) of the CVCs were removed because of infection. Median catheter survival time for all children was 310 days and for infants was 211 days.

Conclusions: Very low CVC infection rates (one infection per 5 CVC years) and prolonged CVC survival times (around 1 year) are achievable in infants and children with ESRD receiving HD therapy by adhering to a strict catheter management protocol and without using prophylactic antibiotic therapy.


H emodialysis (HD) is a widely used mode of renal replacement therapy in infants and children with ESRD (1–3). The US Renal Data System for 2008 reports that, at the initiation of renal replacement therapy, 43.9% of pediatric patients with ESRD (age, 0 to 19 years) were receiving HD compared with 30.5 and 25.6% who were receiving peritoneal dialysis or preemptive renal transplantation, respectively (3). The main advantages of HD over peritoneal dialysis include its fast and very efficient correction of fluid and metabolic abnormalities, improved oral intake of food and drugs, and no need for active participation of patient or family in the dialysis procedure. Long-term HD in the pediatric age group is performed mainly through tunneled cuffed central venous catheters (CVCs) inserted angiographically or surgically, most often into the superior vena cava (4–6). Arteriovenous fistulas (AVFs) or grafts (AVGs), which are used commonly in adults, are used less often in children because of technical difficulties in creating them in small children and because the waiting time for transplantation (during which the AFV/AVG is used) is much shorter in children than in adults (3,7–9).

The main complication of CVCs in HD is blood stream infections. CVC-related infections are very common, often necessitate catheter removal, and are the leading cause of morbidity and mortality in infants and children receiving HD therapy (7,9–11). Nevertheless, data on CVC infection rates and survival times in children on HD therapy are scarce. Several studies (4,7–12) (Table 1) have reported a rate of bacterial infection in CVCs used for HD in children with ESRD in the range of 1.5 to 4.8 episodes/1000 catheter days. Reported CVC survival times have varied between 84 and 290 days (4,7–10). The few studies that address potential measures to improve these unfavorable data focus on prophylactic (topical, catheter lock, or systemic) antibiotics (13,14).

The purpose of this study was to retrospectively determine CVC infection rates and survival times in a pediatric dialysis unit in northern Israel and to analyze the factors influencing these parameters. We show that very low CVC infection rates (one infection per 5 catheter years) and prolonged CVC survival times (around 1 year) are achievable in infants and children with ESRD receiving HD therapy by strictly adhering to practices designed to prevent infections without the need for prophylactic antibiotics.

Materials and Methods

We analyzed the data of all infants and children with ESRD who received HD therapy through a CVC in the Pediatric Dialysis Unit at Meyer Children’s Hospital in Haifa between January 2001 and December 2009. This tertiary care hospital serves a population of approxi-
mately half a million children of various ethnic groups in northern Israel. Demographic, clinical, laboratory, and microbiologic data on patients and their HD-CVCs were obtained and analyzed. Analysis was done on all patients grouped together and on infants and children separately. Instances of CVC removal were subdivided by the cause of removal: infection, malfunction (obstruction, self expulsion, tear), success-ful kidney transplantation, or patient death.

The diagnosis of HD-CVC infection was made in any child with a fever >38.5°C of >24-hour duration, with or without chills, leucocyto-sis with a shift to the left, and no clinical, laboratory, or radiologic evidence of another source of infection. Blood cultures for aerobic and anaerobic bacteria were drawn from both lumens of the catheters. The episodes of HD-CVC infections were subdivided into culture positive and culture negative. If CVC infection was suspected, empiric, broad-spectrum antibiotic therapy was administrated intravenously. Between the years 2001 and 2006, empiric therapy in all suspected cases was composed of vancomycin and amikacin. In the last 3 years of the study (2007 to 2009), milder cases (good general condition, fever <39°C, and no chills) were empirically treated intravenously with ceftazidime as opposed to sicker children who received empiric therapy with vanco-myacin and amikacin. Subsequent therapy was dependent on results of blood cultures; culture-positive CVC infections were treated according to pathogen sensitivity and culture-negative cases continued to receive the empiric therapy indicated above for 14 days.

Our routine management of HD-CVC includes a strictly sterile use and care of catheters performed on a daily basis in the hospital on dialysis days by the nursing staff and at home by all appropriately trained parents. On dialysis days, before catheter handling and opening, the patient has a whole body shower and rinses the CVC with warm water and Septal Scrub (chlorhexidine gluconate 4%) solution. The patient, parent, and nurse rinse their hands with Septol (0.5% chlorhexidine gluconate in 70% ethanol) emollient and wear masks; the nurse handling the catheter puts on sterile gloves as well. Before connecting the CVC to the dialysis tubing, the CVC head is soaked in alcohol chlorhexidine (0.5% chlorhexidine gluconate in 70% isopropanol) solution for 2 to 4 minutes. Once the catheter lumens are open, a syringe is immediately attached to drain the heparin (see later), and dialysis tubing is attached. At the end of each dialysis session, both CVC lumens are filled with a concentrated (5000 U/ml) heparin solution at catheter size-appropriate volumes. As stated above, this heparin is removed immediately on opening the catheter lumens for the next dialysis. CVC care at home on nondialysis days by parents includes careful showering of the child and rinsing of the CVC as above, as well as dressing of the CVC head with two Hypodress BWT sterile adhesive island dressings (composed of a thin polyurethane film).

Our meticulous care of HD-CVCs makes no use of prophylactic (topical, catheter lock, or systemic) antibiotic therapy. Our approach to the care of HD-CVCs includes a strict limitation on its use and handling. Under no circumstances (including hospitalization for any reason) is the catheter used for any purpose other than HD or HD-related procedures, and no hospital staff member other than a pediatric dialysis nurse of our team is allowed to open and/or use the catheter at any time.

Results

Patients

During the 9-year study period, 33 patients with ESRD received long-term HD therapy. Four patients were excluded from the study: two residents of neighboring countries who received HD through a CVC and were lost to follow-up and two who received this therapy using an AVF. Of the 29 patients in the study, 18 (62.1%) were children (>1 year of age) and 11 (37.9%) were infants (<1 year of age). The median age of patients at insertion of the first CVC was 10 years (range: 3 months to 17 years). Fifteen patients were girls and 14 were boys. The group included 21 Arabs and 8 Jews. The etiologies of ESRD in the study population included congenital urinary tract abnormalities in eight children (28%), chronic glomerulo-nephritides in five children (17%), primary hyperoxaluria in five children (17%), Bartter syndrome in two children (7%), hemolytic uremic syndrome in two children (7%), acute kidney injury in two children (7%), congenital nephrotic syndrome in two children (7%), and other causes (diabetic nephropathy and unknown etiology) in three children (10%).

Table 1. Clinical data on long-term (cuffed) HD-CVCs in children reported in the literature

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of children</th>
<th>Duration of study (years)</th>
<th>Median age (years)</th>
<th>Age range (years)</th>
<th>No. of CVCs inserted</th>
<th>Total catheter days</th>
<th>CVC infection rate (per 1000 CVC days)</th>
<th>No. of CVCs removed because of infection</th>
<th>Median CVC survival time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref. 4</td>
<td>23</td>
<td>3.25</td>
<td>11.2 a</td>
<td>1 to 16</td>
<td>40</td>
<td>NR</td>
<td>1.5</td>
<td>4 (10%)</td>
<td>84 a</td>
</tr>
<tr>
<td>Ref. 7</td>
<td>9</td>
<td>5</td>
<td>13.8</td>
<td>0.9 to 21.6</td>
<td>22</td>
<td>NR</td>
<td>1.94</td>
<td>8 (36.3%)</td>
<td>123</td>
</tr>
<tr>
<td>Ref. 8</td>
<td>89</td>
<td>20</td>
<td>8.9 a</td>
<td>0.07 to 20.2</td>
<td>182</td>
<td>NR</td>
<td>3.3</td>
<td>30 (16.5%)</td>
<td>220</td>
</tr>
<tr>
<td>Refs. 9 and 10</td>
<td>59</td>
<td>5</td>
<td>13.9 a</td>
<td>NR</td>
<td>175</td>
<td>NR</td>
<td>4.8</td>
<td>74 (42%)</td>
<td>290 a</td>
</tr>
<tr>
<td>Ref. 12 (1990 to 1995)</td>
<td>36</td>
<td>5</td>
<td>15.9 a</td>
<td>NR</td>
<td>82</td>
<td>NR</td>
<td>2.1</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Ref. 12 (2000 to 2005)</td>
<td>32</td>
<td>5</td>
<td>13.7 a</td>
<td>NR</td>
<td>61</td>
<td>NR</td>
<td>2.2</td>
<td>NR</td>
<td>310</td>
</tr>
<tr>
<td>Our Study</td>
<td>29</td>
<td>9</td>
<td>10</td>
<td>NR</td>
<td>59</td>
<td>NR</td>
<td>0.52</td>
<td>3 (5%)</td>
<td></td>
</tr>
</tbody>
</table>

NR, not reported.

aReported as a mean value.
**HD Catheters**

Table 2 outlines the clinical data on patients and their HD catheters. Fifty-nine CVCs were inserted in the 29 children during the 9-year study period. Sixteen (27%) of the catheters were inserted surgically (all of them before January 2005), whereas 43 (73%) catheters were inserted angiographically. All CVCs were double-cuffed catheters. Seventeen (29%) CVCs were Medcomp brand catheters (Medical Components, Harleysville, PA) generally used in children weighing <15 kg, whereas 42 (71%) were Permcat brand catheters (Quinton Instrument Company, Seattle, WA), which were inserted in older children. Of the 59 catheters, 13 (22%) were inserted in infants younger than 1 year of age, the youngest being 3 months old and weighing 2.9 kg. The cumulative survival for all 59 catheters was 22,892 days; 3779 days (16.5%) for CVCs inserted in infants and 19,113 days (83.5%) for catheters in older children. All but 1 of the 43 catheters inserted angiographically were inserted into the internal jugular vein. All 16 catheters inserted surgically were placed into the subclavian vein.

During the study period, there were 12 episodes of catheter infections, of which 9 (4 in infants and 5 in children) were culture positive. Pathogens isolated in these episodes included the following: in infants, Acinetobacter sp. (2), Rhizobium radiobacter (1), and Clostridium tertium (1); in children, Staphylococcus aureus (2), Acinetobacter sp. (2), and Klebsiella sp. (1). The clinical picture of the three culture-negative episodes was compatible with a CVC infection (see Materials and Methods). It is noteworthy that all 12 infection episodes occurred in only 5 of the 29 patients. Also, two of these five patients had two HD-CVC infection episodes each, occurring within 1 month of each other and caused by the same pathogen. This clinical scenario likely represents one extended infection episode for each one of the two patients. Nevertheless, each of these “four” episodes was listed here as a separate HD-CVC infection.

CVC infection rate for all 59 catheters was 0.52/1000 CVC days or one infection per 62 CVC months. The infection rates for infants and children were 1.06/1000 CVC days (one infection per 31 CVC months) and 0.42/1000 CVC days (one infection per 78 CVC months), respectively.

Figure 1 depicts the numbers of catheter days, HD treatments, and CVC infections by year of study. The presented data show clearly that, despite a very significant increase in both catheter days (311%) and HD treatments (375%) from 2001 to 2009, the number of infection episodes has remained very low, between zero and three per year. It should be noted that the high numbers of HD treatments that are close to the numbers of CVC days throughout the study period reflect the relatively high proportion of infants requiring almost daily HD in our patient population.

The outcome of the HD-CVC during the study period is outlined in Table 3. Of the 59 catheters inserted, 31 (52.6%) were removed because of malfunction. Of these catheters, only three (5% of all catheters inserted) were removed because of infection. In 28 (47.5%) of the catheters, the cause of removal was obstruction, self-expulsion, or catheter tear. In 17 (28.8%) of the CVCs, a properly functioning catheter was removed because of successful transplantation (13) or patient death (4). None of the patient deaths were related to CVC infection. Eleven (18.6%) of the catheters inserted were in place at the end of the study. The total median CVC survival time for the whole group of patients during the study period was 310 days (range, 27 to 1578 days; Table 2). The median CVC survival time for the infants was 211 days (range, 27 to 619 days) and for children was 361 days (range, 27 to 1578 days).

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**Table 2. Clinical data on patients and HD-CVCs during the 9-year study period**

<table>
<thead>
<tr>
<th></th>
<th>Infants (n = 11)</th>
<th>Children (n = 18)</th>
<th>Total (n = 29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of catheters inserted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>surgically</td>
<td>4</td>
<td>12</td>
<td>16 (27.1%)</td>
</tr>
<tr>
<td>angiographically</td>
<td>9</td>
<td>34</td>
<td>43 (72.9%)</td>
</tr>
<tr>
<td>total</td>
<td>13 (22%)</td>
<td>46 (78%)</td>
<td>59 (100%)</td>
</tr>
<tr>
<td>Cumulative catheter days</td>
<td>3779 (16.5%)</td>
<td>19,113 (83.5%)</td>
<td>22,892 (100%)</td>
</tr>
<tr>
<td>No. of catheter infection episodes</td>
<td>4</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>No. of culture positive infection episodes</td>
<td>4</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>CVC infection rates (per 1000 catheter days)</td>
<td>1.06</td>
<td>0.42</td>
<td>0.52</td>
</tr>
<tr>
<td>CVC survival times (days)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>median</td>
<td>211</td>
<td>361</td>
<td>310</td>
</tr>
<tr>
<td>range</td>
<td>27 to 619</td>
<td>27 to 1578</td>
<td>27 to 1578</td>
</tr>
</tbody>
</table>
Table 3. Outcome of HD-CVCs during the 9-year study period

<table>
<thead>
<tr>
<th></th>
<th>CVCs in Infants (n = 13; 22%)</th>
<th>CVCs in Children (n = 46; 78%)</th>
<th>Total CVCs (n = 59; 100%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malfunctioning CVCs removed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>infection</td>
<td>1</td>
<td>2</td>
<td>3 (5.1%)(^a)</td>
</tr>
<tr>
<td>obstruction, catheter tear, clot, self-expulsion,</td>
<td>8</td>
<td>20</td>
<td>28 (47.5%)(^a)</td>
</tr>
<tr>
<td>Properly functioning CVCs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>removed because of successful kidney transplantation</td>
<td>0</td>
<td>13</td>
<td>13 (22%)(^a)</td>
</tr>
<tr>
<td>removed because of patient’s death</td>
<td>1</td>
<td>3</td>
<td>4 (6.8%)(^a)</td>
</tr>
<tr>
<td>in place as of 12/31/09</td>
<td>3</td>
<td>8</td>
<td>11 (18.6%)(^a)</td>
</tr>
</tbody>
</table>

\(^a\)Percent of total catheters.

Discussion

An increasing number of children with ESRD worldwide receive long-term dialysis therapy while awaiting kidney transplantation, which is the “light at the end of the tunnel” for these children and their families. The majority of these children receive HD therapy (1,3,12,13). Major improvements in HD equipment and techniques and the accumulating experience in HD therapy of the young have led to a growing number of infants receiving this mode of extracorporeal therapy (4,5,9,15).

The key factor for successful, efficient, and long-term dialysis is well-functioning vascular access. Because AVFs/AVGs are used in a small minority of older children (3,6,9), the double-cuffed, dual lumen CVCs are the leading type of long-term vascular access in infants and children with ESRD (3–9). Nevertheless, whereas HD-CVCs are very efficient in delivering adequate dialysis in children, accumulating data have shown a high rate of catheter-related blood stream infections and short survival times for these catheters (4,8–12,14,16). Table 1 summarizes studies 4,7–10,12 that have examined the complications and outcome of HD-CVCs in children with ESRD. These studies have shown CVC-related infection rates that have varied between 1.5 and 4.8/1000 catheter days in children. In contrast to these data, our findings (Tables 1 and 2) showed markedly low CVC infection rates (0.52/1000 catheter days) and prolonged catheter survival times (a median of 310 days) in the population of infants and children included in our study.

Catheter-related infections and other complications are known to be age-related and especially high in infants and young children. In a study by Kovalski et al. (5) on 11 small children (weighing <15 kg) receiving HD therapy, the mean HD catheter infection rate (for both acute and cuffed catheters) and survival time (for cuffed catheters) were 1.3/1000 patient days and 64.2 days, respectively. Another study by Shroff et al. (15) in children younger than 2 years of age found the median HD catheter survival to be 21 days and the median infection rate to be 2.7/patient-years, which is equivalent to an infection rate of 7.4/1000 CVC days.

It is remarkable, therefore, that our very favorable results of low infection rates (0.52/1000 CVC days) and prolonged survival times (median of 310 days) of HD catheters have been achieved despite the low median age (10 years) of our study population and, more importantly, despite an exceptionally high proportion of infants (38%). The CVC infection rates and median survival times of 1.06/1000 and 211 days, respectively, observed in our group of infants when analyzed separately (Table 2) further underscores the significance of our findings.

It is noteworthy that our small and condensed pediatric dialysis facility, which is often overcrowded with patients, families, and personnel, as well as the relatively high rate of nosocomial infections in our very active, tertiary care hospital, should have resulted in a much higher rate of catheter-related complications and worse outcome of HD-CVCs rather than lead to our favorable findings.

How do we explain these very favorable catheter outcome data achieved by us? It is possible that factors such as angiographic catheter insertions by a very proficient and experienced invasive radiology team (which has become our routine for CVC insertion, including in infants), our preferential placement of catheters in the internal jugular vein rather than the subclavian vein (the latter associated with an increased risk of stenosis) (7,17,18), and the preferential use of specific CVC brands suited to patient’s age and size could have contributed to our favorable findings. The relative role of each of these factors in CVC outcome remains to be determined.

Nevertheless, we strongly believe that it is our routine, meticulous, and very strict care of HD catheters that results in our remarkably low catheter infection rates and prolonged catheter survival times. A “back to basics” approach to catheter handling and prevention of infections seems to be the key factor in our success to substantially improve catheter outcome results.

As outlined in Materials and Methods, the three mainstays of our approach include a very strict aseptic handling of catheters by staff/parents, the strict limitation on the opening/use of the catheters to be performed only by a small group of highly trained nursing staff, and the absolute avoidance of use of HD catheters for any purpose other than HD (despite occasional objections from the hospital staff to the latter two measures).

Several studies have investigated the potential role of prophylactic antibiotics in preventing HD-CVC infections in adults (19–21) and children (22). Onder et al. (22) evaluated the effectiveness of antibiotic catheter lock in reducing CVC infection rates in a group of children receiving HD with a history of recurrent CVC infections. This therapy reduced CVC infection rate but still resulted in a very high rate of CVC infections.
(6.2/1000 catheter days) in the group of treated children. Two additional studies by the same group showed that tissue plasminogen activator–antibiotic lock effectively cleared CVC-related bacteremia, but prophylaxis of infections was not addressed in these studies (14,23).

Our data, however, clearly show that our approach achieves very favorable results without the need for prophylactic (topical, catheter lock, or systemic) antibiotics, which we have not used in the management of CVCs.

The efficacy of our CVC management protocol in minimizing catheter-related complications is further underscored by our observation (Figure 1) that the number of CVC infections in our patients has remained stable and very low throughout the 9-year period of the study despite a marked increase in number of HD treatments and catheter days over the years. This, in fact, has resulted in a longitudinal decrease in rate of CVC infections.

Of particular note is our finding (Table 3) that only 3 (5%) of the 59 inserted catheters were removed because of uncontrolled infection. This is in sharp contrast to recent studies (7–9,11,15) showing that infection is the leading cause for CVC removal in children on long-term HD, with up to 42% of CVCs lost because of infection (Table 1). Our finding of a very low rate of infection-related catheter loss further shows the efficacy of our catheter management protocols.

In conclusion, very low CVC infection rates (one infection per 5 catheter years) and prolonged CVC survival times (around 1 year) are achievable in infants and children with ESRD receiving this therapy. With appropriate management of HD catheters, CVC infection can become a minor cause of catheter removal. These very favorable CVC-related outcomes can be achieved without using any prophylactic (topical, catheter lock, or systemic) antibiotics by strictly adhering to practices designed to prevent infection.

Acknowledgments

We gratefully acknowledge the dedication and assistance of our Pediatric Dialysis Unit staff and the medical and nursing staff of Meyer Children’s Hospital throughout the years of the study.

Disclosures

None.

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