Initial results of a new access device for hemodialysis

Technical Note

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Initial results of a new access device for hemodialysis.

Background. A new subcutaneous device (DIALOCK™) provides vascular access to patients who currently require hemodialysis (HD). The device consists of a port-like valve, implanted subcutaneously below the clavicle, which provides a linear flow passage to two catheters placed in the right atrium via the internal or external jugular vein. The valve is accessed percutaneously with needle-cannulas that functionally convert the device to twin catheters for connecting the patient to the HD lines.

Methods. The device was implanted in 10 outpatients under local anesthesia. Patients used the device during dialysis 3 times/week, and data were collected on blood flow, pressures, adverse events and patient and nurse satisfaction.

Results. The device was used for HD almost immediately (median 3 days after implantation) and functioned successfully for more than nine months (mean ± SD 7.3 ± 1.5) in all but one patient who died of unrelated causes after one month; there were >800 dialysis sessions total. Blood flows over 300 ml/min were consistently achieved (average 326 ± 40) with venous and arterial pressures of 200 ± 44 and −246 ± 29 mm Hg, respectively. After 66 patient-months, condition of the needle puncture sites remained satisfactory. Five systemic infections occurred in four patients, producing 2.3 bacteremic episodes per 1000 patient-days. All resolved without the need for device removal. There were no infections at the puncture sites. Two patients required fibrin sheath stripping of their catheters, one whose heparin lock was not changed for 23 days (for reasons unrelated to the device). Patient and nurse acceptance was excellent.

Conclusion. The device represents a positive improvement in the area of HD access.

A large number of patients are dependent on externalized catheters for their access to hemodialysis (HD). These include those awaiting the maturation of a newly created arterio-venous fistula or the sufficient healing of a freshly implanted polytetrafluoroethylene (PTFE) graft, and patients who have no other access sites available due to prior use, poor vascular anatomy, or compromised cardiac function. While a number of catheter choices are available for these patients, none offers a favorable prognosis for more than 12 months, on average, because of the high incidence of early failure due to thrombosis and infection [1]. The silicone catheter, for example, is used widely as both a bridge device for fistula and graft patients (65% to 80% of total HD patients) [2] and as a permanent access in 10 to 20% of patients [2, 3] when other modes of access are either physically impossible or medically contraindicated. Even in patients with a fistula or graft, 1.6 catheters are used per HD patient per year on average [4].

The substantial use of catheters, despite their high failure rate, reflects a major problem in HD access. No new access devices or methods have been clinically adopted in almost two decades despite ample descriptions of the failures, complications and the costly nature of present blood accesses. Access dysfunction is the most frequent cause of hospitalization for the ESRD patient [1], comprising one sixth of all hospitalizations in this population and 2.5 times the number of hospitalizations for renal failure [2]. The total cost to the nation’s health care system for diagnosis of access malfunction, access repair and the treatment of complication due to access failure is approximately $1.25 billion for 1995 and is growing at a rate of 9% a year. Frequent access dysfunction and consequent medical intervention, even when successful, adversely affects patient quality of life.

To address the difficulties with current HD access devices, a new device (Dialock™) based on the concept of the Vascular Access Port has been developed. The original Vascular Access Port is a totally implanted subcutaneous device, which is accessed by percutaneous puncture and has
an outlet catheter that communicates with the vascular system [5]. It has been associated with a reduced incidence of thrombosis and infection (compared to external catheters) and excellent patient acceptance [6]. It is easy and convenient to use across medical specialties, and it is cost-effective [6].

Several devices that comprise ports for hemodialysis access have been developed previously. Two such ports were investigated in the U.S. and Europe. They ultimately failed due to inadequate blood flow, but patients reported them to be more acceptable than PTFE grafts [7]. Neither, however, addressed the two major obstacles in using ports in this capacity, namely: (1) the need for high blood flow within the device without damage to red cells or activation of platelets, and (2) the ability to function over many years without degradation of the sealing mechanism. Modifications contained in the Dialock™ should permit higher blood flow rates, as required for HD treatment and an increased product life, compared to the Vascular Access Port [8]. This new design and the subcutaneous placement of the port should obviate many conditions and factors that produce the major failures of current access (that is, clotting and infection).

We describe the first clinical evaluation of the Dialock™ as a chronic hemodialysis access device. Results of an ongoing pilot study in 10 patients are presented after nine months of experience with the oldest implant.

METHODS

Dialock™ hemodialysis access device

The access port dimensions are approximately 5.1 × 2.9 × 1.3 cm (Fig. 1). The port housing is constructed of titanium and has two needle-accessible passages. The housing entrance incorporates a trough-like design intended to guide the user in accessing the individual needle passages. A septum-valve assembly within the passage is opened by the force of the needle insertion, prevents the needle from inadvertently slipping out of the port and automatically closes when the needle is withdrawn, thus preventing blood backflow through the port. A slight narrowing of the inside wall of the passage stops the access needle from advancing, preventing damage to catheters or tissue, and cues the user that the needle is properly “docked” within the passage. Each passage ends in a nipple connection (outlet tube) that allows a secure force fit of a customized dialysis catheter. When the needle is inserted, the entire length of the passage to the catheter remains one smooth channel with no sharp edges, gullies, or intrusions. This design feature is intended to minimize turbulence, hemolysis and platelet activation during blood flow through the device.

Fig. 1. The Dialock™ hemodialysis access device.
The Dialock™ is implanted in a subcutaneous pocket below the clavicle. Its two catheters are inserted into the internal or external jugular vein, with their tips placed at different levels in the right atrium and are then tunneled from the base of the neck to the subcutaneous pocket. A plate with suture holes, riveted to the underside of the port housing, secures the device to fascia within the subcutaneous pocket. The riveted connection allows the port housing to pivot slightly on the suture plate, within the subcutaneous pocket and relative to the skin surface, thus allowing for a wider area of needle puncture sites on the skin surface.

The dialysis catheters are constructed from medical grade silicone blended with barium sulfate to render them radiopaque. They are 40 cm long with an 11 Fr OD and 2.2 mm ID and include a spiral hole pattern at their distal end typical of many dialysis catheters. Catheters are cut to the proper length at the time of implantation depending on individual patient requirements. Centimeter markings on the catheters assist in determining their final lengths.

At the time of dialysis, the port is accessed by means of novel needle-cannulas, which pass through the skin and enable the clinician to functionally use the Dialock™ as if it were a standard twin-luminal catheter (Fig. 2) [9, 10]. Each single-use cannula consists of a square-tipped 15-gauge tube attached to silicone rubber tubing fitted with a standard Luer-lock connector, which provides linkage between the patient and HD machine. Each cannula is temporarily converted to a non-coring needle by inserting a mating stylet, and in combination they sequentially penetrate the skin with minimum trauma and push open the septum-valve assembly of the access port. When properly docked within the port, the cannula hubs external to the skin interlock to increase the stiffness of the accessed system, making it less likely that an accidental needle pullout might occur. Besides providing for access, the needle set allows for the instillation of a heparin lock within the Dialock™ catheters, preventing clotting between dialysis sessions.

*In vitro* tests to determine if flow through the Dialock™ causes damage to the blood were performed using a mock dialysis flow loop and standard measures of lactate dehydrogenase (LDH) and potassium release [11]. Results demonstrated acceptably low levels of hemolysis, that is, changes in soluble LDH and potassium corresponding to <4% hemolysis after simulating HD for up to eight hours. Parallel tests with a standard 16 gauge fistula needle instead of the Dialock™ system yielded up to 7% hemolysis. Mechanical tests of the Dialock™ valve mechanism’s ability to survive the equivalent of more than five years of access punctures demonstrated no degradation in its ability to withstand backflow and pressure. This suggests that a product life of more than five years without a hardware failure may be expected, which is substantially longer than the longevity of current vascular accesses other than the native fistula. If confirmed for the entire Dialock™ system in vivo, this means that most Dialock™ patients might avoid access emergencies in their lifetime, contrasted with current HD patients who average an access complication every nine months. Animal tests (1 month) confirmed the biocompatibility of the device and its repeated accessibility after subcutaneous implantation.
Clinical study

In a pilot study, the Dialock™ was implanted and utilized at two sites in the United States, with appropriate Institutional Review Board approval and the patients’ informed consent. All patients had been prescribed a catheter for permanent access due to the absence of a viable fistula (native or prosthetic), and all were in imminent or immediate need of dialysis. All implants were performed during outpatient procedures under local anesthesia. Patient characteristics and implant dates are listed in Table 1.

After using EMLA® (lidocaine and prilocaine) topical anesthetic cream for a minimum of 30 minutes [12], percutaneous access to the Dialock™ was achieved using aseptic technique, with both patient and nurse wearing masks and caps. With the fluid connections established, 5 ml blood was aspirated into each cannula tubing and discarded, usually with 3 to 5 cm segments of spaghetti-like clot having the exact form of the catheter tips. The cannulas were flushed with saline and then connected to the dialyzer via standard HD tubing, and dialysis was carried out in the standard fashion.

Measurements were routinely made of maximum blood flow, arterial and venous pressures and the times required to obtain access prior to dialysis and to secure hemostasis when the Dialock™ needles were removed from the skin after dialysis. At each session, the condition of the skin at the puncture sites was assessed, and patients were asked to record their response to the Dialock™ by responding (on a visual analog scale) to questions regarding their level of comfort and pain during daily activities and sleep, as well as their level of satisfaction. Each week, nurses were also asked to evaluate the device, particularly the degree of difficulty of obtaining access, and to compare it to other methods for providing hemodialysis access.

RESULTS

Ten patients received Dialock™ implants between May and August 1997. One patient died, within the first month, of a cardiac event unrelated to her implanted device. After nine months, the average implant time in the surviving patients was 7.3 ± 1.5 months (mean ± sd), with 94 ± 18 dialysis sessions (range 71 to 113) using the device.

Surgery was uneventful in all cases, and healing of the implant site occurred without major incident. In most cases the Dialock™ was used within a few days (Table 1), with a median interval of three days. In several patients, the presence of a hematoma at the implant site for up to the first week led to a delay in the Dialock’s™ use, in deference to the patient’s comfort and ability to forego immediate dialysis. In all cases, the medical staff indicated that the device could have been used if immediate dialysis had been necessary and in no case was a catheter used at an alternative site (such as, femoral vein) to provide temporary access. In one patient, the Dialock™ was implanted when his creatinine clearance was still around 14 ml/min, and the use of his implant was delayed for 23 days since dialysis was not needed during that period. The delay was not for reasons related to the Dialock™ implant, and dialytic therapy through the device was begun following a further decline in renal function.

Successful access for hemodialysis was achieved in 818 of 824 total sessions (99.3%) during the nine months following implantation of the first Dialock™. After an initial training period of several dialysis sessions, access was typically accomplished within a minute. Two failures to access occurred in the first patient to receive a Dialock™. The first failure occurred during his second session with the Dialock™ due to the staff’s inexperience in performing the access procedure. The second failure to access was due to a contact dermatitis that occurred at the needle puncture site, after one month of Dialock™ use, related to the patient’s overuse of the EMLA anesthetic cream. Avoidance of EMLA use for 10 days and its more judicious use thereafter prevented a repeat of this incident. A third access failure occurred when another patient experienced unusual swelling following weight lifting exercises. The remaining failures were related to the presence of “fibrotic tissue” between the skin and Dialock™ needle passage, in one patient. This tissue impeded passage of the needle.

Table 1. Patient characteristics and Dialock™ use

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age</th>
<th>Underlying disease</th>
<th>Reason for enrollment in study</th>
<th>Date of implant</th>
<th>First access</th>
<th>Days*</th>
<th>Dialysis sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>47</td>
<td>Diabetes</td>
<td>Inadequate vasculature for access</td>
<td>5-6-97</td>
<td>5-9-97</td>
<td>274</td>
<td>113</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>49</td>
<td>Hypertension</td>
<td>Fistula not yet available</td>
<td>5-6-97</td>
<td>5-9-97</td>
<td>274</td>
<td>113</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>67</td>
<td>Diabetes; hypertension</td>
<td>Inadequate vasculature for access</td>
<td>5-29-97</td>
<td>6-5-97</td>
<td>252</td>
<td>106</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>64</td>
<td>Polycystic kidney disease; hypertension</td>
<td>Inadequate vasculature for access</td>
<td>6-27-97</td>
<td>7-10-97</td>
<td>223</td>
<td>90</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>53</td>
<td>Diabetes; hypertension</td>
<td>Inadequate vasculature for access</td>
<td>7-22-97</td>
<td>7-23-97</td>
<td>29b</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>65</td>
<td>Diabetes; hypertension</td>
<td>Inadequate vasculature for access</td>
<td>8-11-97</td>
<td>8-12-97</td>
<td>177</td>
<td>76</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>45</td>
<td>Hypertension; urate nephropathy</td>
<td>Inadequate vasculature for access</td>
<td>8-20-97</td>
<td>8-21-97</td>
<td>169</td>
<td>71</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>53</td>
<td>Chronic glomerulonephritis</td>
<td>Fistula not yet available</td>
<td>5-19-97</td>
<td>5-27-97</td>
<td>261</td>
<td>106</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>68</td>
<td>Diabetes</td>
<td>Fistula not yet available</td>
<td>7-14-97</td>
<td>8-6-97</td>
<td>200</td>
<td>73</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>39</td>
<td>Glomerulosclerosis</td>
<td>Fistula not yet available</td>
<td>8-18-97</td>
<td>8-22-97</td>
<td>170</td>
<td>66</td>
</tr>
</tbody>
</table>

* Up to 2-05-98
b Patient died 8-13-97
when the access was attempted, but with additional experience, nurses were able to avoid the fibrotic area and this difficulty was no longer a problem. In most cases, the condition of the skin at the puncture sites was remarkably good, as judged by the nursing staff. This satisfactory result may have been helped by the patients’ routine use of aloe vera cream between dialysis sessions.

Flows measured at each dialysis session for all patients and averaged on a monthly basis are shown in Figure 3 and Table 2. The only patient whose flows were below 300 ml/min during his first four months of dialysis had experienced the 23 day delay between implantation and hemodialysis. A fibrin sheath was found to have formed around his catheter tips, presumably as a result of the failure to replenish his catheter’s heparin lock. This fibrin sheath was treated by stripping, using a snare, via a femoral access [3, 13]; this procedure had to be performed three times. The use of high doses of urokinase within the catheter and systemically [14] at the time of the third stripping procedure appears to have corrected the problem; this patient’s blood flow is now consistently over 350 ml/min. One other patient underwent a single fibrin sheath stripping without subsequent urokinase treatment. There were no catheter occlusions.

The dose of dialysis given (Kt/V) has been consistently over 1.2 (Table 2). Values of hematocrit remain well within the normal guidelines (Table 2).

Patients were asked to indicate on a visual analog scale the level of pain and discomfort that they experienced with the Dialock [103x78]y. With the exception of some discomfort during the first week after implantation, in 1 patient, the average score was <0.1, that is, negligible, on a scale of 0 to 10. Similar scores were obtained for the Dialock’s interference with activities of daily life and during sleep. Regarding their level of satisfaction with the device, 73% and 27% of all responses indicated that they were either “very satisfied” or “satisfied,” respectively; none indicated neutrality or dissatisfaction. The nurses’ evaluation was similarly positive, with 72% and 27% responding “very satisfied” and “satisfied,” respectively, to questions regarding the ease of access.

Initially, a prolonged time to achieve hemostasis after removal of the Dialock [412x582]y cannulas (3 to 6 hr on 4 occasions) reflected inaccuracies in the manufacturer’s initial recommendation for volumes of heparin to be used in establishing a heparin lock. However, at no time was the amount of bleeding more than a slow “ooze” that required moderate compression; patients were not in danger of serious blood loss. Downward adjustment of this heparin volume was helpful, but the spilling of heparin into the systemic circulation may continue to occur as a result of mechanical stimulation of the catheter tips in the right atrium. Further reductions in the concentration of heparin reduced the average time of bleeding after cannula removal to just over five minutes (range of averages for all patients was 2.2 to 6.4 min).

Five infections occurred in four patients (Table 3). Normalizing the number of bacteremic episodes to the length of implant time (dividing by the cumulative number of days of Dialock [390x378]y implant) yielded an infection rate of 2.3 bacteremias per 1000 patient-days (Fig. 4). This compares favorably with the recently reported values of 3.9 to 5.1 obtained with standard permanent catheters [15–17]. In each case, the use of a catheter lock consisting of heparin combined with antibiotics [18, 19] during the interval between dialysis sessions, together with systemic antibiotic therapy resolved the infection. All previously infected devices were infection-free for 2 to 30 weeks at the end of the study period (Table 3).

One patient died while on dialysis three weeks after implantation of the Dialock [442x242]y, due to an apparent cardiac event. This 55-year-old patient had a previous history of diabetes and of myocardial infarction. Blood gas analysis showed a pO2 of 391 mm Hg and a pCO2 of 9 mm Hg (during mechanical ventilation), which were consistent with the absence of pulmonary embolism, and a stable EKG rhythm made it unlikely that a fatal arrhythmia had occurred. Death was considered to be the result of an electro-mechanical dissociation, with no relationship between the patient’s death and use of the access device. No autopsy was performed.

**DISCUSSION**

The problems of dialysis access survival are too well known to be dwelled upon in detail here. The Dialock [em] represents a modification of the Vascular Access Port, a
well-proved device for access to the circulation with numerous advantages. Application of hemodynamic principles to this device permits blood flows suitable for high efficiency dialysis without damage to red cells. The Dialock® has the potential for very low thrombosis rates, and its subcutaneous position should reduce the potential for infection compared to catheters. The latter property may also provide for an improved patient self-image and a better quality of life due to its cosmetic advantage. The use of the right atrium for blood source and return makes it impossible for cardiopulmonary recirculation to occur [20].

During the first nine months of the clinical study reported herein, the device was well accepted by patients and staff. Access was relatively easier after experience had been gained, and the problems that occurred did not relate to the port aspect of device. Post-dialysis bleeding occurred due to overheparinization, and fibrin sheath formation occurred in two patients and was treated by stripping using a snare, with follow-up urokinase therapy in one of them. Infection in four patients was effectively treated without the need for the device to be removed. In fact, after nine months all surviving patients continued to receive chronic hemodialysis, three times a week, through their initial implant. The cumulative infection rate was lower than what has been reported for permanent catheters, especially when taking longevity of the device into account. While not totally free of complications, these early results suggest that the few problems encountered in using the Dialock® are manageable and are easily offset by its consistent ability to support blood flows of over 300 ml/min.

The place of this device in the field of vascular access will depend on further trials. At present, the experience gained suggests advantages over internal jugular vein catheters; a long-term study will be necessary before a relevant comparison can be made with synthetic arterio-venous grafts. A potential application for the device, if current results persist, would be to safely permit the more complete maturation of primary arterio-venous fistulas, which often

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**Table 2.** Results for most recent month

<table>
<thead>
<tr>
<th>Patient</th>
<th>Blood flow ml/min</th>
<th>Venous arterial pressure mm Hg</th>
<th>Pre-pump pressure</th>
<th>Time to hemostasis min</th>
<th>Kt/V</th>
<th>Hematocrit %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>309 ± 24</td>
<td>256 ± 30</td>
<td>−242 ± 9</td>
<td>4.1 ± 1.4</td>
<td>1.5</td>
<td>36.0 (30.0)</td>
</tr>
<tr>
<td>2</td>
<td>337 ± 35</td>
<td>185 ± 35</td>
<td>−240 ± 13</td>
<td>5.3 ± 0.5</td>
<td>1.8</td>
<td>35.0 (25.3)</td>
</tr>
<tr>
<td>3</td>
<td>338 ± 37</td>
<td>165 ± 26</td>
<td>−228 ± 17</td>
<td>6.1 ± 4.6</td>
<td>2.2</td>
<td>25.9 (18.4)</td>
</tr>
<tr>
<td>4</td>
<td>332 ± 18</td>
<td>197 ± 25</td>
<td>−243 ± 7</td>
<td>5.4 ± 0.5</td>
<td>2.1</td>
<td>35.1 (28.7)</td>
</tr>
<tr>
<td>5</td>
<td>328 ± 20</td>
<td>192 ± 32</td>
<td>−224 ± 17</td>
<td>25.5 ± 12.8c</td>
<td>—</td>
<td>(34.0)</td>
</tr>
<tr>
<td>6</td>
<td>348 ± 4</td>
<td>181 ± 24</td>
<td>−244 ± 8</td>
<td>5.4 ± 0.9</td>
<td>1.4</td>
<td>34.1 (32.5)</td>
</tr>
<tr>
<td>7</td>
<td>346 ± 4</td>
<td>183 ± 19</td>
<td>−235 ± 9</td>
<td>6.8 ± 1.5</td>
<td>1.6</td>
<td>23.8 (25.9)</td>
</tr>
<tr>
<td>8</td>
<td>304 ± 14</td>
<td>260 ± 50</td>
<td>−290 ± 34</td>
<td>3.6 ± 0.9</td>
<td>1.3</td>
<td>40.8 (32.4)</td>
</tr>
<tr>
<td>9</td>
<td>299 ± 55</td>
<td>265 ± 59</td>
<td>−280 ± 51</td>
<td>2.2 ± 0.8</td>
<td>1.3</td>
<td>39.7 (33.6)</td>
</tr>
<tr>
<td>10</td>
<td>389 ± 24</td>
<td>261 ± 20</td>
<td>−270 ± 28</td>
<td>4.2 ± 2.0</td>
<td>1.4</td>
<td>38.4 (36.0)</td>
</tr>
</tbody>
</table>

*a Extracorporeal circuit  
b Parentheses indicate value at time of entry into study  
c First month only (patient died early in study)

**Table 3.** Treatment of systemic infections

<table>
<thead>
<tr>
<th>Patient</th>
<th>Date diagnosed</th>
<th>Organism</th>
<th>Probable source</th>
<th>Treatment</th>
<th>Culture negative</th>
<th>Follow-up time weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>6-21-97</td>
<td><em>E. coli</em></td>
<td>Urinary tract</td>
<td>i.v. cefazolin and gentamicin for &gt; 1 week, then 40 mg gentamicin combined with a heparin lock of 5000 U/ml.</td>
<td>7-8-97</td>
<td>30</td>
</tr>
<tr>
<td>8</td>
<td>6-25-97</td>
<td><em>Staph. epidermidis</em></td>
<td>Puncture site</td>
<td>i.v. cefazolin and vancomycin for 4 weeks, then 25 μg vancomycin/ml combined with a heparin lock of 100 U/ml.</td>
<td>7-28-97</td>
<td>27</td>
</tr>
<tr>
<td>9</td>
<td>8-20-97</td>
<td><em>Propionibacterium acnes</em></td>
<td>Puncture site</td>
<td>i.v. vancomycin, then 100,000 U/ml penicillin G combined with a heparin lock of 5000 U/ml.</td>
<td>8-28-97</td>
<td>23</td>
</tr>
<tr>
<td>8</td>
<td>10-15-97</td>
<td><em>Staph. epidermidis</em></td>
<td>Puncture site</td>
<td>i.v. vancomycin for 2 weeks, then 1 mg/ml vancomycin combined with a heparin lock of 100 U/ml.</td>
<td>10-31-97</td>
<td>14</td>
</tr>
<tr>
<td>1</td>
<td>12-3-97</td>
<td><em>Staph. capitus</em></td>
<td>Puncture site</td>
<td>i.v. vancomycin for 7 weeks, plus 1 mg/ml vancomycin combined with a heparin lock of 100 U/ml. One dose of 80 mg gentamicin was given at the start of treatment.</td>
<td>1-21-98</td>
<td>2</td>
</tr>
</tbody>
</table>

*a All devices functioning and infection free at the time of this report
fail when used too early [21]. This could more easily enable clinicians to fulfill the DOQI guideline of having at least 50% of new dialysis patients obtain their HD access via this modality [21]. In summary, the new device represents a major improvement in vascular access for hemodialysis, at least for those patients who currently depend on externalized catheters for temporary access. Evaluation of its long-term benefits awaits further study.

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REFERENCES


Fig. 4. Cumulative rate of bacteremic episodes, referenced to “1000 patient-days”.