Hemodialysis Vascular Access Morbidity

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ABSTRACT

Complications associated with hemodialysis vascular access represent one of the most important sources of morbidity among ESRD patients in the United States today. In this study, new data on the magnitude and growth of vascular access-related hospitalization in the United States is presented, demonstrating that the costs of this morbidity will soon exceed $1 billion per yr. This study also reviews published literature on the morbidity associated specifically with native arteriovenous fistulae, polytetrafluoroethylene bridge grafts, and permanent central venous catheters. Next, new information on the changing patterns of vascular access type in the United States is presented, demonstrating the continuing evolution of medical practice away from the use of arteriovenous fistulae in favor of more reliance on synthetic bridge grafts. Based on these data, a discussion is provided of the tradeoffs among the most commonly available modalities of vascular access today. Although radial arteriovenous fistulae continue to represent the optimal access modality, the appropriate roles for brachial arteriovenous fistulae, synthetic bridge grafts, and central venous catheters are less certain because of inadequate data on the long-term function of the first and the high rates of complications associated with the latter two. To reduce vascular access-related morbidity, strategies must be developed not only to prevent and detect appropriately early synthetic vascular access dysfunction, but to better identify the patients

In whom radial arteriovenous fistula is a viable clinical option.

Key Words: Arteriovenous fistula, polytetrafluoroethylene bridge graft, permanent central venous catheter, hospitalization, ESRD

Chronic hemodialysis for patients with ESRD first became technically feasible in 1960 with the introduction of the Quinton-Scribner shunt (1). Although this external arteriovenous (AV) shunt provided, for the first time, direct access to the circulation so that hemodialysis could be performed in the outpatient setting, patient care was complicated by frequent thrombosis and infection (1-3). Autologous arteriovenous fistulae (AVF), introduced by Brescia and Cimino in 1966, overcame many of the problems of external dialysis shunts (4). Subsequent to this advance in dialysis vascular access surgery, AVF became the primary mode of achieving vascular access for chronic hemodialysis. Once an AVF has matured and been used for dialysis, the subsequent or secondary failure rate is low, with most patients enjoying long-term fistula function lasting for many years (3-5).

Since the early 1970s, the rapid growth of the U.S. ESRD Program has been accompanied by a diminution in the use of AVF in favor of alternative types of AV bridge grafts and, more recently, permanent indwelling central venous catheters. This evolution has been attributed to the growing primary failure rate of AVF, often attributed to the increasing age and comorbidity of the dialysis population, as well as the more rapid usability of alternative vascular accesses as compared with AVF (6-11). Supporting this formulation is the extensive change in the demographics of the U.S. ESRD population over the past two decades. Although only 6.6% of ESRD patients had diabetes in 1972 and fewer than 20% of ESRD patients were older than 65 yr of age, 36% of the ESRD population in 1991 had diabetes and nearly 1 in 2 (45%) was 65 yr of age or older (12). It has been estimated that fewer than 25% of incident ESRD patients successfully undergo the construction of a native AV fistula, an estimate recently borne out by special studies conducted by the U.S. Renal Data System (10,13,14).

Early alternative surgical techniques utilizing autologous saphenous vein grafts and implanted bovine carotid heterografts to form bridge AV anastomoses had unacceptably high rates of thrombosis and pseudoaneurysm (2,3,6,15-17). In an attempt to achieve better long-term success for dialysis vascular accesses, the same synthetic materials used for artery to
artery vascular bypass procedures were implanted into dialysis patients as bridging AV anastomoses. Dacron® (E.I. duPont de Nemours and Co., Wilmington, DE) was used initially chosen for these access devices but was rapidly replaced by polytetrafluoroethylene (PTFE) (GoreTex®, W.L. Gore and Assoc., Flagstaff, AZ; Impra®, Impra, Inc., Tempe, AZ) after early experience suggested better short-term patency rates with this newer synthetic material (10,18). As will be discussed below, the substitution of synthetic access grafts for AVF has been accompanied by enormous growth in the rate of secondary vascular access failure, along with its attendant costs.

Below, we provide new data from Medicare’s ESRD Program and summarize published research describing the morbidity associated with hemodialysis vascular accesses in current use today in the United States, including AVF, PTFE bridge grafts, and indwelling central venous catheters. We also provide recent data from the U.S. Renal Data System on the continuing transition from AVF to alternative synthetic access devices. Finally, we present a discussion of the tradeoffs involved in choosing a type of vascular access in the clinical setting, and the data needed to establish appropriate guidelines for making this choice.

VASCULAR ACCESS COMPLICATIONS IN THE UNITED STATES

We have previously reported on the magnitude of vascular access morbidity in the United States by using hospitalization claims data from Medicare’s End-Stage Renal Disease database, the ESRD Program’s Medical Management Information System (ESRD PMMIS) (19). Vascular access complications were tabulated by counting the number of hospital stays for one of three ICD-9 diagnosis codes recorded as the first diagnosis in the hospitalization record of PMMIS.*

Prevalent Medicare-entitled U.S. ESRD patients in 1984, 1985, and 1986 were studied (see Table 1). Complications of vascular accesses alone accounted for one of the most important causes of hospitalization in the ESRD population. Between 1984 and 1986, the number of hospitalizations for revision of dialysis vascular accesses rose by 25.0% and represented 14.1% of all ESRD hospitalizations that year.

Table 1. Hospitalization for vascular access morbidity, 1984 to 1986

<table>
<thead>
<tr>
<th>Diagnosis/Hospital Stay</th>
<th>1984</th>
<th>1985</th>
<th>1986</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of ESRD hospital stays for any diagnosis</td>
<td>150,775</td>
<td>158,634</td>
<td>170,572</td>
</tr>
<tr>
<td>Frequency of hospital stays with ICD-9 996.1b</td>
<td>6,079</td>
<td>5,755</td>
<td>5,953</td>
</tr>
<tr>
<td>Frequency of hospital stays with ICD-9 996.6c</td>
<td>5,831</td>
<td>6,837</td>
<td>7,889</td>
</tr>
<tr>
<td>Frequency of hospital stays with ICD-9 996.7d</td>
<td>11,791</td>
<td>13,452</td>
<td>15,899</td>
</tr>
<tr>
<td>Total number of stays with 996.1, 996.6, or 996.7 listed as any diagnosis</td>
<td>23,701</td>
<td>26,044</td>
<td>29,741</td>
</tr>
<tr>
<td>Total number of stays with 996.1, 996.6, or 996.7 listed as first diagnosis</td>
<td>9,170</td>
<td>21,016</td>
<td>24,025</td>
</tr>
<tr>
<td>Access-related stays as percentage of Total</td>
<td>15.7</td>
<td>16.4</td>
<td>17.4</td>
</tr>
<tr>
<td>Mean length of access-related stays</td>
<td>7.6</td>
<td>7.3</td>
<td>7.4</td>
</tr>
</tbody>
</table>


b Mechanical complication of vascular device, implant, and graft.

c Infection and inflammatory reaction as a result of internal prosthetic device, implant, and graft.

d Other complications of internal prosthetic device, implant, and graft.

* The three ICD-9 codes searched for included: 996.1, Mechanical complication of vascular device, implant and graft; 996.6, Infection and inflammatory reaction due to internal prosthetic device, implant, and graft; and 996.7, Other complications of internal prosthetic device, implant, and graft.
than 20% in 1991. These estimates of hospitalization because of vascular access complications are most likely underestimates of access complications in the ESRD population, as they do not consider access-related morbidity diagnosed and treated in the outpatient setting, outpatient procedures performed in a hospital, or hospitalization paid for by insurers other than Medicare. Although the disproportionate increase in morbidity may be a result of increasing severity of illness among U.S. ESRD patients, the increasing demand for accesses that can accommodate higher blood-flow rates as well as the use of new diagnostic technologies such as color-flow Doppler ultrasonography may also have increased the detection of heretofore occult vascular access problems. Unfortunately, no single data source exists that provides information on outpatient access-related morbidity or morbidity paid for by insurers other than Medicare. Medicare does maintain data files that record bills for outpatient procedures such as fistulography and color-flow Doppler ultrasonography studies, but to our knowledge, these data have not been exploited to estimate outpatient vascular access morbidity.

Costs of Vascular Access Dysfunction in the United States

Approximately one-half of Medicare’s ESRD budget (over $6 billion in 1991) is spent on the procedural costs of delivering dialysis to ESRD patients (21,22). The remainder of ESRD expenses arise primarily from the costs of morbidity and associated hospitalizations, of which greater than 14% have been estimated to result from complications of vascular access (19). Assuming a similar rate of growth in vascular access-related hospitalization as observed between 1986 and 1991, we project that Medicare will pay for more than 90,000 hospitalizations for vascular access-related problems in 1995. If vascular access repair procedures are increasingly performed in the outpatient setting, the number of hospitalizations may not rise as quickly as it has in the past. Nonetheless, based on a conservative estimated cost of $7500 per hospital stay, the projected costs to Medicare for these hospitalizations alone will rise above $675 million annually, representing nearly 10% of its ESRD budget. This analysis represents a gross underestimate of the total cost for vascular access-related morbidity in the United States for at least two important reasons. First, the hospitalization data cited do not include hospitalization paid for by insurers other than Medicare. Second, the costs of diagnostic screening procedures (e.g., fistulography, Doppler ultrasonography, etc.) and outpatient therapies (e.g., thrombolysis, angioplasty, etc.) are also not included. Thus, the annual cost of vascular access-related morbidity in the United States will rapidly approach and exceed $1 billion per yr.
**ARTERIOVENOUS FISTULAE**

**Arteriovenous Fistula Function**

Numerous investigators have studied the likelihood of successful maturation of AVF into functional hemodialysis vascular accesses (5,8,17,23-32). Primary failure of AVF is defined as insufficient dilation and arterIALIZATION needed for function as a dialysis vascular access. The observed risk of primary failure of these accesses has ranged from 9% (24) to 30% (17) in surgical experience accumulated since the late 1960s. Once AVF mature, numerous investigators have documented their excellent long-term function. Winslett and Wolma reported the complication rates for 273 AVF after successful maturation into functional vascular accesses (17). After 2 yr of dialysis, 90% of these accesses continued to function, with 80% still in use after 3 yr. They observed a complication rate of five events per 1000 patient-months of follow-up for AVF, which was considerably and statistically smaller than the 37 events per 1000 patient-months observed in recipients of PTFE synthetic dialysis grafts. Similar fistula survival rates were also cited by Reilly and colleagues in their report of 148 AVF created in England between 1976 and 1981 (25) and more recently by Kherlakian and colleagues (8). Bonalumi and coworkers have reported the longest follow-up of AVF, observing that 52% of end-to-end radial artery fistulae continued to be useful after 6.5 yr of hemodialysis (5).

More recently, native AVF constructed using the brachial artery have been evaluated as an alternative access procedure when a radiocephalic fistula was not able to be constructed (33-35). Although uncontrolled studies have documented primary patency rates as high as 86% at 2 yr of follow-up (33), the long-term function of these accesses has not yet been evaluated.

**Risk Factors for AVF Dysfunction**

Despite the excellent long-term function of fistulae after successful maturation, little consensus has been achieved regarding the predictors of the primary failure of AVF. A number of potential risk factors, including gender, vessel size, surgical technique, surgical skill, and primary diagnosis have been postulated as having an important impact on the likelihood of successful AVF maturation. Several studies in the early 1970’s reported that women had a higher risk of primary failure than men (24,26). Several other reports (5,27-30) have looked for but failed to identify specific risk factors of primary AVF failure. Many of these studies were small in size and carried out limited analyses to control for potential confounding factors.

Reilly and coworkers presented one of the best documented and one of the few prospective risk-factor studies of dialysis fistula function published to date (25). They studied 157 consecutive patients between 1976 and 1981. Intraoperative data, including size and type of anastomosis, size of vessels, suture material, and adequacy of flow were recorded. Univariate and multivariate analysis demonstrated that vein size was an important predictor of long-term access complications. The power of this study, however, was limited because of its sample size, and no specific analysis of the predictors of inadequate fistula maturation was performed.

Few recent data are available regarding the risk factors for inadequate maturation of AVF. Pourchez et al. reported that 41 of 47 French dialysis patients older than 75 yr of age underwent successful construction of an AVF (36). Kobrin et al. evaluated 48 AVF constructed between 1989 and 1991 at the University of Pennsylvania (37). Overall, 44% of AVF had successfully matured at 3 months, whereas primary failure occurred in 56%. Although age, gender, location of the AVF, and the presence of diabetes mellitus did not affect AVF maturation, the small size of the study limited statistical power to detect clinically relevant differences in access function. Few investigators have analyzed the impact of the use of recombinant erythropoietin (EPO) on AVF function (38,39) but the few data available seem to suggest that AVF thrombosis is not a very common complication. Neither Be-sarab et al. (39) nor Tang et al. (40) found thrombosis of AVF to be more common with EPO use.

Thus, extensive published experience with AVF demonstrate their long-term utility and low rate of complications among patients in whom primary fistula function is achieved. However, despite a large risk of primary fistula failure, little is known about the specific surgical, comorbidity, or demographic factors predictive of primary fistula function. Although it is probably true that an older and sicker ESRD population may less commonly undergo successful AVF construction, the subgroup of patients in whom fistulae should be created is poorly defined. Several recent reports (23,33-37) suggest that despite the older age and worse comorbidity of U.S. ESRD patients as compared with two decades ago, a substantial number of patients remain viable candidates for placement of AVF. This is especially true if upper-arm fistulas such as brachial artery-basilic vein fistulae are considered. A review of alternatives to AVF readily demonstrates that unnecessary substitution of synthetic grafts for autologous AVF greatly enhances both the morbidity of and costs for the U.S. ESRD population.

**POLYTERAFLUOROOETHYLENE DIALYSIS ACCESS**

**Patency and Complications of Polytetrafluoroethylene Dialysis Access**

PTFE was introduced as a material for vascular bypass grafts in 1976 (10). Since that time, this material has become the mainstay for dialysis vascular accesses when an autologous AVF is either believed to be technically impossible or has failed to mature, or commonly when there is insufficient time for an AVF to mature before the need for hemodialysis because of the late presentation of a patient’s symp-
tomatic advanced renal failure. PTFE dialysis grafts are currently the most common type of dialysis access, accounting for as many as 83% of access placements among prevalent ESRD patients (38). A great majority of hemodialysis patients undergo only PTFE graft placement despite the high probability that a significant proportion of them would have been able to undergo successful AVF construction. However, few data exist documenting the proportion of accesses that are constructed of PTFE but that could have been successfully created as a native AVF. Nonetheless, the potential excess use of PTFE vascular accesses and the protean complications possible after their placement, including stenosis, occlusion, infection, aneurysm and pseudoaneurysm formation, cardiovascular instability, and nerve injury, are all potentially responsible for a large component of the high morbidity in the U.S. ESRD population.

Numerous investigators have reported 1-and 3-yr patency rates for PTFE grafts. Between 63 and 90% of grafts still function after 1 yr, whereas only 42 to 60% remain patent after 3 yr (9,13–15,17,41–47). Most of these reports defined patency as persistent graft function, regardless of treatment for access complications such as thrombectomy or percutaneous angioplasty. Complication-free graft survival has been reported by a number of investigators (17,41,45). Sabanayagam and colleagues (45) reported the complication-free survival of PTFE grafts to be 77.1% at 1 yr; Palder and colleagues reported complication-free PTFE graft survival to be 51% at 2 yr (41); and Winsett and Wolma reported complication-free PTFE graft survival to be 39% at 3 yr (17). Outflow obstruction and thrombosis accounted for the vast majority of the complications observed. Unfortunately, none of these studies reported the influence of patient comorbidity on access dysfunction. By prospectively studying a subgroup of 52 healthier patients who lived longer than 3 yr on dialysis, Schuman and colleagues grossly controlled for comorbidity and observed one access complication for every 515 patient-days of follow-up (14).

In recent years, increasing attention has been given to the detection and repair of stenosis of PTFE grafts. Color-flow Doppler ultrasonography and contrast fistulography are widely utilized. Repair by transluminal angioplasty or surgical vein-patch angioplasty may promote delivery of adequate dialysis and prevent graft thrombosis. Whether repair before thrombosis extends the useful life of PTFE grafts has yet to be proven. A large, but not precisely determined, cost is incurred by these diagnostic tests and interventional procedures, which are performed for the most part on an outpatient basis. A detailed discussion of the diagnosis and therapy of stenosis of PTFE grafts is beyond the scope of this paper, but the reader is referred elsewhere for recent discussions of these issues (48–51).

Risk Factors for Complications from PTFE Dialysis Access

Thromboses of PTFE access grafts have been thought to result from a number of causes, including venous outflow obstruction and inadequate arterial inflow. Outflow obstruction has usually been attributed to neointimal hyperplasia (52–54) or central venous stenosis/thrombosis from prior central venous access (55). Inadequate arterial inflow has resulted from a small or diseased arterial source as well as from recurrent bouts of intradialytic hypotension (56–59). Postdialysis dehydration with increased blood viscosity; low serum albumin; inadequate anticoagulation; external compression either from perigraft hematomas, overly vigorous pressure at needle sites, occlusive bandages, or inopportune arm positioning during sleep; the presence of anticardiolipin antibodies, diabetes mellitus, and high hematocrit with EPO therapy have all been claimed, with varying justification, to contribute to PTFE graft thromboses (39,40,52,57,59–64).

Despite these numerous hypothetical risk factors, few studies have examined specific risk factors in a controlled fashion. Aman et al. reported on 91 PTFE grafts followed for 24 months and observed a significantly increased graft patency rate with the use of double-lumen dialysis needles (54). They were unable to find a relationship between graft survival or complication-free graft survival and sex, race, degree of hypertension, heparin dosing, or intradialytic hypotension, although the statistical power of their study was limited. Munda and colleagues followed 67 PTFE grafts for 2 yr and found that a forearm loop configuration had greater than twice the rate of secondary patency of forearm straight grafts (57).

Although controversial, several reports have suggested an association between diabetes mellitus and PTFE graft thrombosis (19,65,66). Windus and colleagues observed a rate of PTFE graft thrombosis at 1 yr of 72% among patients with diabetes, compared with a rate of 49% among patients without diabetes (65). Data from Medicare and the U.S. Renal Data System (19,66) have been consistent, demonstrating higher rates of hospitalization for vascular access problems among the subset of ESRD patients with diabetes.

Several investigators have evaluated the impact of therapy with recombinant EPO on synthetic vascular access function and reported conflicting results (39,40,62). Besarab and colleagues compared the rate of thrombotic events in 164 patients receiving EPO for at least 2 months with that among 142 patients treated earlier, before the availability of EPO. They were unable to detect any differences in the rate of thrombosis either for synthetic grafts or AVF (39). Consistent with these findings have been a number of other studies (67–70), each failing to note an increase in access thrombosis with EPO.

In contrast to these findings, Dy and colleagues
performed a nonconcurrent cohort study of 46 dialysis patients before and after treatment with EPO (62). They reported a greater incidence of graft thrombosis in the EPO period. Similar findings were reported by the Canadian Erythropoietin Study, a randomized comparison between treatment with placebo (N = 40) and treatment with EPO targeting either a hemoglobin concentration of 9.5 to 11.0 g/dL (N = 40) or 11.5 to 13.0 g/dL (N = 38). A 2.5% rate of access thrombosis at 6 months was observed in the placebo group with a mean hemoglobin of 7.4 g/dL. In contrast, the two groups treated with EPO achieved mean hemoglobin concentrations of 10.2 g/dL and 11.7 g/dL with 6-month thrombosis rates of 10% and 18%, respectively (71). The low rate of thrombosis in the placebo group was considerably lower than that published by Eschbach and colleagues (67), making this study’s findings difficult to interpret. Although several investigations reporting substantial thrombosis rates in patients with PTFE grafts on EPO have recently been reviewed (68), none of these studies have included control groups off EPO.

Thus, several investigators have independently confirmed the impression derived from the hospitalization data in Medicare’s ESRD database: the rate of complications, especially stenosis and thrombosis, arising from synthetic dialysis vascular accesses is very large. The mean duration of the complication-free access survival appears to be between 9 and 16 months, with a great majority of patients experiencing a complication by the end of the 3rd yr after graft placement. This extraordinarily high complication rate, with its attendant suffering and high utilization of U.S. Dialysis Program resources, makes the search for better strategies to improve outcomes among recipients of synthetic vascular accesses urgent. Formulation of such strategies will require, in part, better delineation of the risk factors for failure of PTFE access grafts.

INDWELLING CENTRAL VENOUS DIALYSIS CATHETERS

Intended originally as a temporary measure, the silicone double-lumen catheter with Dacron® cuff has inevitably come into long-term use in patients in whom peripheral vascular access (fistula or graft) is unsuitable. The Dacron® cuff decreases infection and makes long-term use possible. When catheters are intended for use for less than 1 month, a polyurethane, non-cuffed central venous access is normally used. However, if catheter use is expected to exceed 1 month, the cuffed SILASTIC® (Dow Corning, Midland, MI) catheter is preferred (73). The proportion of hemodialysis patients in the United States in whom cuffed SILASTIC® catheters provide long-term vascular access is unknown. Based on data from the 1991 U.S. Renal Data System (USRDS) Special Study of Case Mix, it can be estimated that 4% of U.S. ESRD patients begin dialysis with a permanent catheter. These data underestimate the actual prevalence of catheter use, as they do not account for usage after failure of more traditional vascular accesses, AVF, or PTFE grafts. In a survey of 17 dialysis units in the Chicago area, the proportion of patients using permanent double-lumen catheters ranged between 3.3 and 45%; of 1372 patients, 210 (15%) received or already had such catheters (74). Increasing long-term survival of the end-stage renal population has enhanced the incidence of depletion of potential sites for AV vascular access, and the use of central venous catheters for permanent access is likely to be increasing.

A jugular vein has become the preferred site for permanent central venous catheter insertion. Percutaneous jugular venous insertion is safer than in the subclavian location. Subclavian catheters have caused subclavian thrombosis and stenosis (75), which can preclude creation of AV vascular access in the ipsilateral arm, and there may be less mechanical malfunction in catheters placed in the jugular rather than subclavian location (76), particularly the right jugular veins (77). Blood-flow rates of 200 to 300 mL/min are routinely achieved (78–80); flows up to 400 mL/min can be achieved in some patients, but sometimes not consistently. Recirculation in various studies has ranged from 5.5 to 8.6% (79–82). Unlike AV fistulas and grafts, dialysis through central venous catheters is not affected by cardiopulmonary recirculation.

Actuarial catheter survival at 12 months has ranged from 30 to 65% (76,79,80,83). Catheter failure has been the result primarily of malfunction (thrombosis or poor blood flow) or infection, in roughly equal proportions. Catheter malfunction can be reduced by proper placement of the catheter tip in the right atrium and by the use of chronic anticoagulation, beginning with aspirin and using warfarin if necessary (74). Urokinase and streptokinase and mechanical means have been used to open thrombosed catheters and those with poor flow (74,76–80,84–86). Infection with septicemia occurs with a frequency between 0.25 and 1.0 infections per patient-year (76–79). Although Gram-positive infections have been successfully treated with antibiotics alone, many infections, especially those resulting from Gram-negative organisms, have required catheter removal.

Use of permanent central venous catheters has important morbidity. Insertion can be complicated by arterial puncture, pneumothorax, hemothorax, arrhythmia, and perforation or laceration of the brachial plexus, trachea, superior vena cava, or myocardium. Jugular venous cannulation is generally safer than subclavian cannulation and the incidence of these complications is low in experienced hands (73). Late complications include catheter malfunction because of thrombosis or malposition, infection, and subclavian or superior vena cava thrombosis or stricture (73,87,88). The latter complications, which occur with internal jugular as well as subclavian catheters, may prevent subsequent use of the ipsilateral arm or of both arms for AV access. Superior vena cava throm-
bosis may be more common than has been reported (88), but the actual rates of occurrence of these mor-
bidities are unknown.

Permanent dual-lumen central venous catheters have some advantages over AV access, including ease
of insertion, removal, and replacement, immediacy of use, absence of hemodynamic stress or steal syn-
drome, absence of cardiopulmonary recirculation, and avoidance of venipuncture. Indications for such
catheters include loss of other vascular access sites, prolonged period of maturation of other accesses
(usually AVF), cardiovascular instability or steal syn-
drome, and short expected duration of dialysis (e.g.,
malignancy, impending renal transplantation). If rates of poor flow and thrombosis and infection are as
low as in some series, permanent catheters may even be considered an acceptable alternative to PTFE grafts
in the general population of patients in whom creation of an AVF is not feasible (80).

PATTERNS OF VASCULAR ACCESS UTILIZATION IN
THE UNITED STATES

The only national data permitting study of specific
types of vascular access were collected as part of the
special studies of Case Mix conducted by the USRDS,
first for patients in 1986 and 1987, and subsequently
for patients in 1991. Although these data are older,
they provide us with an opportunity to examine the
evolution of the patterns of vascular access utilization
in the United States that have not been previously
published.

By using data from the USRDS 1986 to 1987 Special
Study of Case Mix, we are able to estimate the distrib-
ution of vascular access type in the United States.
This study examined the initial medical records for a
nearly random sample of 4964 U.S. dialysis patients
initiating dialysis in 1986 and 1987. Among them,
1518 were identified as beginning hemodialysis with
an AVF, 1498 with a PTFE graft, and 77 with a central
venous catheter. The remainder of the patients either
initiated peritoneal dialysis or could not be catego-
ized into one specific vascular access group. As is
demonstrated in Figures 2 and 3, older age and female
gender were associated with lower utilization of AVF in
1986 and 1987. A similar analysis failed to demon-
strate an association between AVF utilization and
either race or the presence of diabetes mellitus.

The 1991 USRDS Special Study of Case Mix demon-
strated that the pattern of AVF utilization had
substantially changed over the span of 4 to 5 yr. This
study, which analyzed the initial vascular access
among 1673 randomly selected hemodialysis pa-
ients, demonstrated that AVF utilization among dia-
betics had fallen substantially from over 40% to about
25% (see Figure 4). Similarly, but to a lesser extent,
AVF utilization had also fallen among ESRD patients
without diabetes (see Figure 4). Although these
changes may be a reflection of further increases in the
morbidity of the ESRD population, leading to less

![Graph](image-url)

Figure 2. Vascular access type by age: data from USRDS Special Study of Case Mix: 1986 to 1987.
successful efforts to place AVF, these trends may also reflect changes in patterns of practice that favor placement of synthetic vascular accesses available for use almost immediately after insertion. Finally, the estimates of AVF utilization defined here among incident ESRD patients probably overstate the prevalence of AVF use among all hemodialysis patients. Windus has recently estimated that approximately 11% of American hemodialysis patients in 1990 used AVF for angioaccess (38).

**CLINICAL SELECTION OF VASCULAR ACCESS MODALITY: WHAT ARE THE TRADEOFFS?**

Numerous options currently exist for achieving vascular access for ESRD patients today. Selection among these options requires evaluation of the potential toxicities and benefits of each of the access choices, so as to understand the tradeoffs inherent in choosing a particular access method (see Figure 5). Data currently available strongly suggest that when technically feasible, radial AVF represent the optimal solution for vascular access. Identification of patients in whom a radial AVF would mature, however, is difficult with currently available information. Attempting to place radial AVF before the need for dialytic therapy would minimize the morbidity and costs associated with use of central venous catheters while awaiting AVF maturation. Even when a radial AVF fails to mature adequately, a PTFE graft or a brachial AVF can usually be placed in the ipsilateral arm. Success of these accesses may even be enhanced by venous dilatation that may have arisen as a result of the initial radial AVF. Selection of the patients in whom a radial AVF should be attempted, however, often presents a more difficult decision when patients require immediate or imminent dialysis. Under these circumstances, both the high probability of unsuccessful maturation especially among older and sicker patients, and the morbidity associated with central venous catheters necessary for dialysis while waiting for AVF maturation, lead many clinicians directly to an alternative access choice. Usually their choice is a PTFE graft, which permits dialysis very soon after placement. Better delineation of both the profile of patients likely to experience successful maturation of a radial AVF as well as quantification of the morbidity associated with temporary central venous catheters necessary for expanded utilization of AVF are needed to determine the appropriate clinical thresholds for AVF use.

Currently, three distinct alternatives exist to radial artery AVF; brachial AVF, PTFE bridge grafts, and permanent indwelling catheters. Although available data demonstrate that radial AVF are superior to PTFE grafts and catheters, the appropriate role of brachial artery AVF is still not entirely defined. Although these accesses are likely to enjoy some of the benefits of radial AVF (e.g., only one anastomosis is required and many infections are treatable without access removal), their long-term patency is uncertain.
Although several small studies suggest that patency of brachial artery AVF at least rivals PTFE graft patency, more research is needed. Whether problems such as steal syndrome and heart failure secondary to the high rates of blood flow through these accesses will limit their use is still unknown. Despite these unknowns, we currently believe that the preponderance of evidence supports attempting to place a brachial AVF before a PTFE graft in patients in whom a radial AVF is either not possible or has failed.

In the tradeoff between use of a PTFE graft and a permanent central venous catheter for angioaccess, several considerations must be weighed. Permanent dual-lumen central venous catheters have some advantages over PTFE grafts, including ease of insertion, removal, and replacement, immediacy of use, absence of hemodynamic stress or steal syndrome, absence of cardiopulmonary recirculation, and avoidance of venipuncture. However, the permanent venous catheter may not support blood flow at rates adequate to ensure optimum dialysis; this problem, together with loss of time because of the need for clotting with urokinase, could lead to underdialysis. Episodic poor flow often makes use of these catheters frustrating for technical staff. However, despite high rates of poor flow, thrombosis, and infection in some series, permanent catheters have even been considered an alternative to PTFE grafts in the general population of ESRD patients in whom creation of a native AVF is not feasible (80). Like central venous catheters, PTFE grafts similarly are complicated by thromboses and high recirculation from stenoses, leading to possible underdialysis and necessitating anatomical correction (e.g., angioplasty, surgical revision). Both PTFE grafts and catheters may require anticoagulation, adding a risk of hemorrhage, including subdural hematoma. Although infection of a central venous catheter may be treated with antibiotics without catheter loss and catheter replacement is relatively easy, infection of a PTFE graft almost always requires graft removal, which can entail significant morbidity.

Despite the problems associated with PTFE grafts, one final distinction between them and central venous catheters weighs most heavily in our opinion that catheters not be used as a primary permanent access when either an AVF or PTFE graft can be placed. Central venous stricture or thrombosis subsequent to placement of a central venous catheter may eliminate all potential access sites in one or both arms. Given the often catastrophic impact of this loss of upper-extremity access sites, the PTFE graft, despite its complications, is preferable to the central vein catheter used as a permanent access.

**SUMMARY**

Vascular morbidity in the United States is substantial and is growing faster than is attributable to the
growth of the ESRD population or growth in other morbidity among ESRD patients. Morbidity from access dysfunction continues to grow faster than suggested by available data on hospitalization for vascular access dysfunction, in part because of the shift to outpatient therapies such as thrombolysis and angioplasty. The growth in vascular access morbidity may be a result of the rising age of the ESRD population, its worsening severity of illness, increasing demands on vascular accesses to tolerate greater blood-flow rates, and increasing diagnostic activities focused on detecting occult access dysfunction.

In addition to the growing age and comorbidity of patients independent of surgical technique, an evolving pattern of surgical practice away from the creation of autologous AVF to the construction of synthetic PTFE dialysis vascular access grafts is also responsible for the increase in vascular access-related morbidity. The substitution of PTFE grafts for AVF contributes to the extensive access-related morbidity currently confronting dialysis patients and providers. Although these synthetic accesses typically function immediately after their construction, their rate of later secondary failure is much higher than that for radial AVF. A great challenge before the dialysis community is the identification of patients in whom an AVF is a viable vascular option so that shorter-lived synthetic (PTFE) vascular access grafts can be reserved for patients in whom an AVF is unlikely to mature successfully. To accomplish this, the identification of risk factors for inadequate maturation of AVF into long-lasting hemodialysis vascular accesses must be a high priority. In addition, it is essential that prospective recipients of AVF be identified early and that every effort be made to avoid venipuncture in the arm intended for the vascular access.

PTFE AV bridge grafts are accompanied by a high rate of complications primarily from stenosis and occlusion, and to a lesser extent, infection. Risk factors for early PTFE access complications, too, are incompletely defined. Such data are needed to prevent not only the morbidity of vascular access dysfunction per se, but potential underdialysis from access dysfunction that represents a most important, but often hidden and insidious, cost of vascular access morbidity.

Permanent central venous catheters may not only represent an access of last resort when other access sites have been exhausted, but may offer an alternative to PTFE grafts. The population in whom perma-
m demonstrate central venous catheters may be a superior alternative to PTFE grafts, even when sites for grafts have not been exhausted, needs to be better defined in controlled studies.

Clinical strategies to optimize the diagnosis and therapy of vascular access dysfunction also need to be identified. These strategies must define the appropriate threshold of abnormal morphology and function that justifies radiologic and/or surgical intervention. Clearly, early intervention may preserve the secondary patency of synthetic vascular access grafts. However, aggressive diagnostic activities plausibly may lead to a higher rate of radiologic and surgical interventions for detectable but not yet clinically important stenoses. These interventions (e.g., angioplasty or surgical repair) themselves may reduce the feasibility of later interventions and may damage the vascular access directly, thereby shortening its long-term function.

Finally, identification of the fundamental mechanisms of vascular access dysfunction should also be the focus of investigation so that specific therapies and preventive strategies can be developed and implemented.

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