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A Prospective Study of Vascular Access Infections At Seven Outpatient Hemodialysis Centers

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Running head: Vascular access infections in hemodialysis

INTRODUCTION

Infections are a major cause of morbidity and mortality in chronic hemodialysis patients. Infections accounted for 14.2% of deaths in these patients during 1995-1997, second only to cardiovascular disease as a cause of death.¹ Most of the infectious deaths were caused by septicemia or pneumonia, which accounted for 10.3% and 2.4% of total deaths, respectively. End stage renal disease (ESRD) patients have a number of immune deficits,^{2,3} vascular access provides a portal for entry of infecting organisms. Currently available data indicate that vascular access infections account for one-third of the bacterial infections and more than one-half of the bacteremias in hemodialysis patients.^{4,5}

The frequent use of antimicrobials is a major contributor to selection for, and spread of, antimicrobial-resistant bacteria.⁶ ESRD patients have been at high risk of vancomycin-resistant enterococci infection and colonization,^{7,8} and the majority of U.S. patients infected with strains of *Staphylococcus aureus* with reduced susceptibility to vancomycin have been on acute or chronic dialysis.^{9,10} Therefore, preventing vascular access infections in this population is important both for patient welfare and to control the spread of antimicrobial resistance.

Preventing infections depends, in part, on understanding and modifying risk factors for their occurrence. Patient-based risk factors for access infections or bacteremia suggested in previous studies include older age, nonwhite race, diabetes, human immunodeficiency virus (HIV) infection, poor hygiene, low serum albumin, immunosuppressive therapy, or a history of previous infection.^{4,5,11,12} In addition, the degree of risk varies with the type of vascular access, with risk highest for catheters, intermediate for polytetrafluoroethylene grafts, and lowest for native fistulas.¹³⁻¹⁵ Many of these risk factors were identified in small, single-center studies or in

analyses of large national databases, which may have limitations on the level of detail available. Further, some studies included bacteremia of unspecified source^{1,13} or focused on hospitalization for bacteremia.¹² To date, the effect of dialysis center as a risk factor has not been examined.

We report the results of a prospective study of the incidence of, and risk factors for, vascular access infection among hemodialysis patients at seven outpatient hemodialysis units conducted during December 1997-June 1998.

METHODS

Study Centers and Patients

Seven dialysis centers, three in Baltimore, Maryland, and four in Richmond, Virginia, participated in this study. Centers were selected to represent both urban and suburban outpatient settings. All chronic dialysis patients ≥ 18 years of age at the participating centers were studied. The study protocol was approved by the Institutional Review Board (IRB) at the Centers for Disease Control and Prevention (CDC) and at all study sites.

Design and Data Collection

A prospective cohort study was conducted during December 1997-June 1998 at the centers in Richmond and January-July 1998 at the centers in Baltimore (i.e., study period). Study personnel used standardized forms to abstract data from clinical and administrative records. A baseline form was completed on all patients at initiation of the study, and an incident form was completed at each outpatient initiation of a course of intravenous (IV) antimicrobials or at an inpatient hospital admission.

The baseline form contained data on demographics; underlying diseases (i.e., diabetes, HIV infection, or IV drug use); smoking; vascular access type (catheter, graft, or fistula; patients

having both a catheter and graft or fistula were categorized as having a catheter); albumin level (the mean of two determinations); urea reduction ratio (the mean of two determinations); whether skin/clothing was clean vs visibly soiled; and functional status. The functional status scale, similar to the Kamofsky performance scale,¹⁶ was scored as 1, normal function; 2, minor signs and symptoms, full activity; 3, usual activities with effort; 4, independent, most out-of-home activities; 5, independent, limited to home; 6, needs assistance with errands; 7, needs assistance with meal preparation; 8, needs assistance with bathing/dressing; 9, home attendant, not totally disabled; 10, disabled, living at home; or 11, nursing home for chronic care.

The incident form included the presence or absence of fever; the presence or absence of pus or redness at the vascular access site; whether a blood culture was obtained at the time of hospital admission or before the start of an IV antimicrobial; the results of blood and any other cultures obtained; and a description of the reason for hospitalization or antimicrobial therapy.

The following procedure was used to determine the duration of follow-up for each patient. For all patients, the start date for computing patient-months at risk began with the first day of our study and not the first day of access use (most patients had a prevalent access in place at the beginning of the study period). For a patient with no infectious event, the stop date was the end of the study period. If a patient had a vascular access infection, the stop date was the date of onset of the infection, and the patient was excluded from analysis for the next 30 days. Multiple episodes in a single patient were treated separately with the new start time at risk beginning 30 days after a previous event and continuing until the end of the observation period or a subsequent infectious event. Because the mean duration of hospitalization for U.S. dialysis patients is 7.6 days,' if a patient was admitted to a hospital during the study period, 8 days were subtracted from

his or her duration followed.

Definitions

The primary outcome variable, vascular access infection, was defined as local signs (pus or redness) at the vascular access site or a positive blood culture with no known source other than the vascular access; and hospitalization or receipt of an IV antimicrobial. The secondary outcome variable, access-related bacteremia, was defined as a positive blood culture with no known source other than the vascular access; and hospitalization or receipt of an IV antimicrobial. The determination as to whether the vascular access site was the only likely cause of bacteremia was based on clinical and microbiologic information recorded on the incident forms. Vascular access infection included events both with and without a positive blood culture, whereas access-related bacteremia included only events with a positive blood culture.

Statistical analysis

For a given patient, some variables (i.e., vascular access type, number of hospitalizations in the previous 90 days) could change during the study and were treated as time-dependent covariates, i.e., allowed to change values during the follow-up period.

Overall infection rates were calculated using all episodes of infection that met the definitions. However, risk factor analyses were performed on a dataset including only the first episode of infection for each patient, to avoid the problem of lack of independence of events. For determining risk factors for vascular access infections, albumin level and urea reduction ratio were categorized into quartiles, with each quartile representing one fourth of the total patient-months of follow-up. However, for access-related bacteremias, the number of infections was too small to divide the data into quartiles; therefore albumin and urea reduction ratio were analyzed

as continuous variables.

For univariate analyses, infection rates per 100 patient-months were calculated by dividing the number of infections by the number of patient-months of follow-up, and multiplying the result by 100; rate ratios were calculated; and exact p-values were determined using the binomial theorem. Multivariate analyses were performed using Cox regression with time-dependent covariates to control for time at risk. Using a forward stepwise algorithm, all variables that were statistically significant in univariate analysis were considered for inclusion in the models, and variables that were statistically significant were retained in the models. All p-values were two-tailed. P-values of $\leq .05$ were considered statistically significant.

RESULTS

Characteristics of dialysis centers and patients

Of the seven participating centers, five were freestanding and two were hospital-affiliated (Table 1). The 796 patients were followed for a total of 4,134 patient-months (mean 5.2, median 6.0 months per patient). The patients' median age varied from 51.7 to 66.8 years among the centers, albumin level from 3.7 to 4.1 grams per deciliter (g/dL), and urea reduction ratio from 66.0% to 73.5% (Table 1). The proportion dialyzed with a catheter was 19.7% overall and varied from 5.5% to 32.0% among the centers. Median albumin levels were lower in patients with catheters (3.65 g/dL) than in patients with fistulas (3.90 g/dL) or grafts (3.85 g/dL); median urea reduction ratios showed a similar pattern, catheters (62.5%), fistulas (70.0%), and grafts (72.0%).

Vascular access infections

There were 145 vascular access infections, and the rate of occurrence was 3.5 per 100 patient-months (145 episodes during 4,134 patient-months). Ninety-seven patients had one

vascular access infection, 21 patients had two, and 2 patients had three. Among the 145 infections, bacteremia was present in 57 (39%) and fever was reported in 41 (28%). The patient was admitted to a hospital in 53 (37%) episodes and treated with IV antimicrobials as an outpatient in 92 (63%).

Restricting the analysis to the first vascular access infection for each patient, there were 119 vascular access infections during 3,896 patient-months. The vascular access infection rate varied from 1.2 to 5.5 per 100 patient-months among the seven centers (Table 2). In univariate analyses, significant factors included the treating dialysis center, patient hygiene, HIV infection, IV drug use, access type, albumin level, urea reduction ratio, and number of hospitalizations during the previous 90 days (Table 2). In the multivariate model, independent risk factors included the specific dialysis center (relative hazards varying from 1.0 [reference] to 4.10), use of a catheter for access (relative hazard 2.07 compared with implanted accesses), albumin level (relative hazard 2.37 for the lowest compared with the highest quartile), urea reduction ratio (relative hazard 2.22 for the lowest compared with the highest quartile), and hospitalizations within the prior 90 days (relative hazard 4.91 for ≥ 5 compared with no hospitalizations) (Table 3).

Access-related bacteremia

There were a total of 57 access-related bacteremias; the rate of access-related bacteremia was 1.38 per 100 patient-months (57 events during 4,134 patient-months). Forty-seven patients had one episode, and five patients had two episodes. Sixty-five organisms were isolated from blood cultures (one organism was isolated from each of 50 episodes of bacteremia, two organisms were isolated from each of six episodes, and three organisms were isolated from one

episode). These organisms included 18 (27.7%) *S. aureus*, 16 (24.6%) coagulase-negative staphylococci, 6 (9.2%) *Enterococcus* spp., 7 (10.8%) other gram-positive bacteria, 14 (21.5%) gram-negative rods (3 *Acinetobacter* spp., 2 *Eschevichia coli*, 2 *Enterobacter* spp., 2 *Klebsiella* spp., 2 *Serratia* spp., and 3 others), and 4 (6.2%) fungi. *S. aureus* comprised a larger proportion of the isolates in patients with implanted access (14 [36.8%] of 38 isolates) than patients with catheters (4 [14.8%] of 27 isolates; $p = .05$).

Restricting analysis to first access-related bacteremia for each patient, there were 52 vascular access infections during 3,923 patient-months. Univariate analyses are not presented, but are similar to the following multivariate analysis. In the multivariate model, independent risk factors included three of the seven dialysis units, female gender, HIV infection, albumin level, urea reduction ratio, and hospitalizations during the previous 90 days (Table 4).

Center-Specific Infection and Blood Culturing Rates

When all episodes (i.e., not just the first episode for a given patient) were included, the rate of vascular access infection varied from 1.15 to 6.25 among the seven centers, and the rate of access-related bacteremias varied from 0.28 to 3.25 (Figure 1). The percent of outpatient IV antimicrobial starts before which a blood culture was obtained was 32.3% overall (63 cultures before 195 antimicrobial starts) and varied from 3.0% to 72.0% among the centers. Two centers (D and B) had rates of vascular access infection above the mean, but rates of access related bacteremia below the mean. The low rate of blood culturing at these two centers (3.0% and 5.9%) may have contributed to this discrepancy.

DISCUSSION

We studied vascular access infections at seven outpatient hemodialysis centers and found

an overall rate of 3.5 infections per 100 patient-months, i.e., 3.5% of patients had a vascular access infection each month. Independent risk factors for vascular access infections included the specific dialysis center where the patient was treated, use of a catheter for access, albumin level, urea reduction ratio, and the number of hospitalizations during the previous 90 days. These data confirm that vascular access infections are common in these patients and help to identify risk factors, some of which may be modifiable.

The rate of drawing blood cultures before starting antimicrobials varied widely (from 3% to 72%) among the seven centers; this variation may have contributed to differences among centers in reported rates of bacteremia. Two of the seven centers (centers B and D) had low rates of performing blood cultures and low rates of access-related bacteremia, but high rates of vascular access infection (the latter includes both bacteremic and nonbacteremic episodes). Variability among facilities in rates of performing cultures, and a higher infection rate when more cultures were performed, was found in the 1970s among the 338 hospitals participating in the Study of the Efficacy of Nosocomial Infection Control.(SENIC) ¹⁷ A similar relationship between culturing frequency and infection rates was found in a recent study at long-term care facilities.” If the definition of an outcome variable requires a positive test result, then the frequency of use of the test must be considered when assessing the rate of the outcome.

The rate of vascular access infection that we found, 3.5 per 100 patient-months, is in the range reported in other studies (1.3-7.2 per 100 patient-months).^{4,15,19,20} Our reported rate of access-related bacteremia, 1.38 per 100 patient-months, also is similar to rates found in other studies (0.63-1 .53 per 100 patient-months).^{4,5,13,15,19,21,22} These results also are similar to preliminary results from national surveillance in 68 U.S. dialysis centers, which show rates of

vascular access infection of 3.3 per 100 patient-months and access-related bacteremia of 1.8 per 100 patient-months²³(CDC, unpublished data).

This study is the first to highlight a dialysis center effect as a significant independent risk factor for vascular access infection. Previous studies of infection either did not include the center as a dependent variable or analyzed data from a single center only. Centers may differ in their risk of infection due to unmeasured intrinsic patient risk factors, differences in vascular access care, or differences in adherence to infection control practices.

Among other risk factors we identified, catheter use is a well-recognized determinant of access infection.^{13,15} Low serum albumin has been found to be associated with increased mortality²⁴ and both access and nonaccess infections.^{11,12,25} Previous hospitalization is a plausible risk factor for infection, since patients with more hospitalizations are likely to have more comorbid conditions, to have had previous infections or vascular access complications, or to have become colonized with antimicrobial-resistant pathogens during their hospitalizations.

We found that the risk of vascular access infection was increased among patients with a urea reduction ratio $\leq 66\%$, the lowest quartile among our study patients. Interestingly, the Dialysis Outcomes Quality Initiative (DOQI) guidelines suggest that all dialysis patients should be treated to achieve a urea reduction ratio of $\geq 65\%$.²⁶ To our knowledge, dialysis adequacy has been examined in only one study and was not found to be a risk factor for infection.¹³ In our study, catheter use may have confounded the association between infection and both albumin level and urea reduction ratio, as both these parameters were lower in patients who received dialysis through catheters; however, when we adjusted for catheter use in our multivariate model, the associations remained.

Risk factors for access-related bacteremia included four (specific center, albumin level, urea reduction ratio, and hospitalizations) that were also associated with vascular access infection and have been discussed above. Additionally, female gender and HIV infection were associated with access-related bacteremia. The association with gender is unexplained and has not been previously reported.¹¹ HIV infection is associated with higher rates of hospital-acquired catheter-associated bloodstream infection²⁷ but has not been reported as a risk factor for hemodialysis-associated infections. In part, this may be due to low numbers of HIV-infected patients at most centers. Although the number of such patients in our study was also low, HIV infection was reported in 5.2% of our study patients, much higher than the 1.3% prevalence reported nationally.²⁸

Although vascular access infections were associated with catheter use, access-related bacteremia was not. Many bacteremias occurred among patients without catheters at two centers in Baltimore (E and F), and these data strongly influenced the results. At these inner-city centers, poor vascular access care by either the staff or patients, a high severity of illness not captured in our data collection form, or IV drug use unknown to the staff may have contributed to an increased risk for bacteremia in patients without catheters. Also, the number of events studied was relatively small and some random error may have been present.

Patient hygiene has been reported to be a risk factor in one study;⁴ although we found an association in univariate analysis, hygiene was not significant in the multivariate model. Prior bacteremia is a reported risk factor for subsequent events.¹³ We also found higher rates of infections in patients after an initial episode (data not shown); however, for statistical reasons, we excluded repeat infections from our formal risk factor analyses. Some previous studies found an

association between vascular access infections or bacteremia and race, age, or diabetes;¹² however, in agreement with other studies,” we did not find these associations. Another recent analysis showed no association between diabetes and septicemia.²⁵ These differences in results among studies may be due to differences in definitions, study methods, types of vascular access, or patient populations. For example, the prevalent patients in our study had a mean age 10 years higher than that of the incident patients included in some earlier studies.^{12,25}

With the exception of *S. aureus*, we found that the distribution of organisms causing bacteremia was similar to that reported previously. We found that *S. aureus* comprised 28%, coagulase-negative staphylococci 25%, and gram-negative rods 22% of blood isolates; corresponding figures from a recent study in France were 40%, 30%, and 26%.¹³ These differences may be due to the fact that fewer patients with catheters were followed in the French study and the authors excluded single blood cultures positive for low-virulence organisms such as coagulase-negative staphylococci. We did not make similar exclusions because often only one blood culture was drawn and thus it is unknown whether a second culture would have been positive. However, clinicians treating patients with blood cultures positive for these organisms should carefully evaluate the clinical situation and avoid antimicrobial therapy when culture contamination appears likely.

Our study is limited in that we collected data at only seven dialysis centers, which may not have been representative of others in the United States. It often was difficult to find necessary data, especially the results of cultures performed after hospital admission. Additionally, the number of bacteremic events studied was small, limiting the power of the study.

If our reported rate of vascular access infection (3.5 per 100 patient-months) were

representative of other U.S. centers, we estimate that there would be over 92,000 episodes per year of vascular access infection among 220,000 prevalent hemodialysis patients; about one-third of these infections would be treated by hospitalization and the remainder by outpatient IV antimicrobials. These results raise concerns regarding both treatment and prevention. Regarding treatment, the surprisingly infrequent use of blood cultures before antimicrobial use at some centers is disturbing. Blood cultures should be obtained before most courses of IV antimicrobials in hemodialysis patients, especially if the site of infection is unknown or is suspected to be the vascular access. The results of such cultures could help optimize antimicrobial use and the duration of treatment so that infections could be eradicated while minimizing selection for antimicrobial resistance.

The most important way to prevent vascular access infections is to reduce the use of catheters for hemodialysis. Clearly, additional preventive strategies would be welcome. Our results suggest that improving values for two core indicators, serum albumin and urea reduction ratio, might improve immune function and overall patient welfare, and thereby reduce the risk of vascular access infection. Also, the marked differences in infection rates among the seven centers suggest that it may be fruitful to study high vs low rates to identify practices associated with fewer infections. In the interim, dialysis center personnel should follow the DOQI guidelines²⁶ for preventing vascular access infections and CDC guidelines for preventing catheter-associated infections.²⁹

Based on the findings of this study, and because of the importance of vascular access and other bacterial infections in hemodialysis patients, CDC began a national voluntary dialysis surveillance network in fall of 1999.²³ Information about this project may be obtained from

<http://www.cdc.gov/ncidod/hip/Dialysis/procedure.htm> or by calling 404-639-6422.

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Table 1. Characteristics of Dialysis Centers and Patients, Seven Dialysis Centers, Baltimore, MD and Richmond, VA, December 1997-June 1998

<u>Center</u>	<u>City</u>	<u>Location</u>	<u>Hospital Unit</u>	<u>No. of Patients</u>	<u>Age, years</u>	<u>Albumin, g/dL</u>	<u>URR, %</u>	<u>HIV Positive</u>	<u>White Race</u>	<u>Vascular Access Type</u>		
										<u>Fistula</u>	<u>Graft</u>	<u>Catheter</u>
					<u>median</u>			<u>percent of patients</u>				
A	R	Suburb	No	110	53.0	4.0	72.0	0.9	2.7	17.3	68.2	14.6
B	R	Suburb	No	106	66.8	3.7	72.8	0	48.1	5.7	73.6	20.8
C	R	City	Yes	94	66.7	3.8	73.0	3.2	18.1	10.6	81.9	7.4
D	R	Suburb	No	73	55.3	4.1	73.5	1.4	9.9	21.9	72.6	5.5
E	B	City	No	169	51.7	3.8	68.5	16.6	5.3	20.7	47.3	32.0
F	B	City	Yes	166	61.5	3.7	66.0	4.8	27.9	21.7	59.6	18.7
G	B	Suburb	No	78	66.8	3.8	73.4	0	68.0	10.3	60.3	29.5
All	--	--		796	59.9	3.8	71.0	5.2	23.4	16.3	63.9	19.7

URR denotes urea reduction ratio; R denotes Richmond, VA; B denotes Baltimore, MD.

Table 2. Potential Risk Factors for First Vascular Access Infection, Seven Dialysis Centers, Baltimore, MD and Richmond, VA, December 1997-July 1998

<u>Factor</u>	<u>Patient- Months</u>	<u>No. of Infections (Rate/100 Patient- Months)</u>	<u>Rate Ratio</u>	<u>P-Value</u>
All	3,896	119 (3.1)	--	--
Center				
A	598	12 (2.0)	1.68	<.0001
B	495	27 (5.5)	4.55	
C	501	6 (1.2)	Ref	
D	334	11 (3.3)	2.75	
E	732	37 (5.1)	4.22	
F	834	20 (2.4)	2.00	
G	403	6 (1.5)	1.24	
Age				
≤59.6	1,929	65 (3.4)	Ref	.27
>59.6	1,935	53 (2.7)	0.81	
Gender				
F	1,766	59 (3.3)	1.18	.41
M	2,119	60 (2.8)	Ref	
Race				
Black	2,962	86 (2.9)	1.23	.6
Other	42	1 (2.4)	Ref	
White	866	31 (3.6)	1.51	
Hygiene				
Clean	3,846	113 (2.9)	Ref	.0047
Soiled	50	6 (11.9)	4.05	
Functional Status				
≤3	2,536	78 (3.1)	Ref	1.0
>3	1,301	40 (3.1)	1.00	
Diabetes				
No	2,240	63 (2.8)	Ref	.26
Yes	1,603	56 (3.5)	1.24	
HIV				
No	3,739	104 (2.8)	Ref	.0001
Yes	158	15 (9.5)	3.42	
IV drug use				
No	3,563	99 (2.8)	Ref	.0044
Yes	333	20 (6.0)	2.16	
Access				
Catheter	553	39 (7.0)	3.90	<.0001
Fistula	720	13 (1.8)	Ref	
Graft	2,623	67 (2.6)	1.42	
Albumin quartile, g/dL				
1: ≤3.6	1,123	55 (4.9)	2.84	.0002
2: 3.61-3.8	823	18 (2.2)	1.27	
3: 3.81-4.05	1,018	29 (2.8)	1.65	
4: ≥4.06	926	16 (1.7)	Ref	

Urea reduction ratio quartile, %				
1: ≤ 66	967	53 (5.5)	2.61	.0001
2: 66.1-71.0	963	26 (2.7)	1.29	
3: 71.1-75.5	984	20 (2.0)	0.97	
4: ≥ 75.6	954	20 (2.1)	Ref	
Hospitalizations during previous 90 days				
0	3,550	99 (2.8)	Ref	.0009
1-2	251	10 (4.0)	1.43	
3-5	57	6 (10.5)	3.78	
26	39	4 (10.3)	3.69	

IV denotes intravenous.

Table 3. Cox Regression Model, Risk Factors for First Vascular Access Infection, Seven Dialysis Centers, Baltimore, MD, and Richmond, VA, December 1997-July 1998.

<u>Variable</u>	<u>Relative Hazard</u>	<u>P-value</u>
Center		
A	1.92	<.0001
B	4.10	
C	Ref	
D	3.50	
E	3.61	
F	1.36	
G	1.32	
Access		
Fistula, graft	Ref	.0006
Catheter	2.07	
Albumin level, g/dL		
1: ≤ 3.6	2.37	.013
2: 3.61-3.8	1.27	
3: 3.81-4.05	1.67	
4: ≥ 4.06	Ref	
Urea reduction ratio level, %		
1: ≤ 66	2.22	.0042
2: 66.1-71.0	1.16	
3: 71.1-75.5	1.00	
4: ≥ 75.6	Ref	
Hospitalizations during previous 90 days		
0	Ref	.0038
1-2	1.79	
3-4	4.13	
≥ 6	4.91	

Table 4. Cox Regression Model, Risk Factors for First Access-Related Bacteremia, Seven Dialysis Centers, Baltimore, MD, and Richmond, VA, December 1997-July 1998.

<u>Variable</u>	<u>Relative Hazard</u>	<u>P-value</u>
Center		
A	3.14	.001
E	5.55	
F	2.42	
B, C, D, and G	Ref	
Gender		
Male	Ref	.01
Female	2.27	
Known HIV infection		
No	Ref	.001
Yes	3.40	
Albumin level, g/dL	0.48*	.03
Urea reduction ratio level, %	0.50†	.0001
Hospitalizations during previous 90 days		
0-3	Ref	0.01
24	3.62	

* per 1.0 g/dL increase

† per 10% increase

Figure 1. Access-related bacteremia and vascular access infection rates per 100 patient months at participating centers. Note that access-related bacteremias include only episodes with a positive blood culture, whereas vascular access infections include episodes with and without a positive blood culture. The numbers above the bars denote the percent of outpatient intravenous antimicrobial starts before which a blood culture was obtained.