EMBEDDED CATHETERS: MINIMIZING EXCESSIVE EMBEDMENT TIME AND FUTILE PLACEMENT WHILE MAINTAINING PROCEDURE BENEFITS

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◆ **Background:** Embedding peritoneal catheters far in advance of anticipated need may successfully commit patients to their modality choice and reduce central venous catheter use but can be complicated by excessive embedment periods and futile catheter placement.

◆ **Objective:** Embedded catheter outcomes were studied to identify factors that minimize inordinate embedment time and futile placement while maintaining procedure benefits.

◆ **Methods:** Clinical and laboratory data were examined in 107 patients with embedded catheters that were either externalized, remained embedded, or were futilely placed.

◆ **Results:** Externalization of 84 catheters was performed after a median embedment period of 9.4 months. Flow dysfunction occurred in 14.3% of externalized catheters. Overall function rate was 98.8% after laparoscopic revision. One patient changed their mind about modality choice. Except for 1 patient hospitalized acutely in a facility unfamiliar with embedded catheters, none remaining on a peritoneal dialysis pathway initiated dialysis with a central venous catheter. Including catheters with extremely long embedment periods, the incidence of futile placement was 13.1%. Multiple regression analysis identified estimated glomerular filtration rate (eGFR) and serum albumin as the 2 variables best associated with catheter embedment duration ($r^2 = 0.44$, $p < 0.0001$). Diabetic nephropathy was statistically more likely to be associated with lower serum albumin values ($p < 0.0001$); however, no association was noted between diabetic status and embedment duration ($p = 0.62$).

◆ **Conclusions:** Timing of the embedment procedure should include appraisal of both eGFR and serum albumin. Appropriate consideration of these values together may help

minimize excessive embedment periods and decrease futile placements while preserving procedure benefits.

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Commonly referred to as the Moncrief-Popovich technique, catheter embedding consists of implanting a peritoneal dialysis (PD) catheter far in advance of anticipated need (1). Instead of bringing the external limb of the catheter out to the surface, it is embedded under the skin in the subcutaneous space. When renal function declines to the point of needing to initiate dialysis, the external limb is brought to the outside through a small skin incision. Because the catheter has been afforded extended healing time within the abdominal wall, the patient is able to proceed straight to full-volume PD without the necessity of a break-in period that ordinarily accompanies a newly placed catheter (2,3).

The benefits of creating peritoneal access in advance of expected need include reduced likelihood that patients will initiate dialysis with a central venous catheter and relief of stress on operating room access by permitting surgical scheduling as an elective non-urgent procedure (2,4,5). With the external catheter limb temporarily embedded under the skin, there is better patient acceptance for earlier commitment to PD because catheter maintenance is deferred until such time that it is actually needed. Once an embedded catheter is in place, patients tend to remain committed to their dialysis modality choice (2).

While the catheter embedment strategy appears to reduce central venous catheter use and may improve

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patient fidelity to original modality choice, exceptionally long embedment periods might adversely affect catheter functionality or result in a number of futile placements in which the catheter was never used because of death, onset of medical conditions preventing self-care, transplantation, or removal during unrelated surgery (6). Optimal use of the catheter embedding approach requires appropriate timing of the catheter placement procedure in order to reach an acceptable balance among these competing concerns. The aim of the present study was to examine our embedded catheter outcomes and to evaluate clinical and laboratory parameters that best indicated expected embedment duration, thus assisting in more precise scheduling of the procedure.

MATERIALS AND METHODS

The study population was comprised of all patients undergoing catheter implantation with embedment beginning January 2004 and followed through July 2012. Patients who selected PD as renal replacement therapy during predialysis education and who were expected to initiate dialysis within a 1.5- to 5-month window were offered advanced catheter placement with embedment (6). Timing of catheter embedment was generally based upon the same principles commonly employed for vascular access referral, therefore, estimated glomerular filtration rate (eGFR) values of 15 – 20 mL/min/1.73m² (7).

Our methodology for catheter implantation with embedment, perioperative management, and clinical outcomes has been previously described in detail (8). Externalization of the embedded catheter was performed with the appearance of uremic symptoms or when the eGFR approached 10 mL/min/1.73m². Catheter flow dysfunction was defined as one- or two-way obstruction that was not remedied by nonsurgical interventions.

Peritoneal dialysis catheter access procedures, complications, and patient outcomes were recorded prospectively in an Institutional Review Board-approved database. Laboratory values for serum creatinine, blood urea nitrogen, serum albumin, neutrophil to lymphocyte ratio, and urine albumin to creatinine ratio were retrieved retrospectively from the electronic medical record. The eGFR was calculated using both the 4-variable and 6-variable Modification of Diet in Renal Disease (MDRD) formulas and identified as eGFR-4 and eGFR-6, respectively (9).

Fisher's exact test was used to compare nominal data. Chi-square test was used as an overall test to compare nominal data when more than 2 groups were examined. When the overall test was statistically significant, chi-square pairwise comparisons were performed with

Bonferroni's correction of the significance level. Mann-Whitney test was used to compare continuous data. Kruskal-Wallis test was used to compare continuous data when more than 2 groups were examined followed with Dunn's multiple comparison test when it was significant. Univariate associations of laboratory and demographic variables with duration of embedment were made by Pearson correlation and univariate linear regression. Multiple linear regressions with both backward elimination and stepwise forward selection were used to assess laboratory and demographic variables that best predicted duration of embedment. These variables included those used in the univariate analysis and the dichotomous variables, gender, black race, and diagnosis of diabetes, which were assigned numeric values of 0 or 1. To avoid problems with multicollinearity, eGFR-4 and eGFR-6 were not included in the same model. The criterion for retention or selection of variables in the multiple regression model was a coefficient *p* value < 0.15.

Analyses were performed with SAS software version 9.2 (SAS Institute, Cary, NC, USA), GraphPad Prism version 6.02, and GraphPad InStat version 3.10 (GraphPad Software, San Diego, CA, USA). All results were considered significant at *p* < 0.05.

RESULTS

A total of 107 catheters were embedded during the study period. All were first catheters for patients reaching advanced stages of chronic kidney disease. Study population demographics for the group as a whole and according to catheters externalized, remaining embedded, and futilely placed by the end of the study period are summarized in Table 1.

EXTERNALIZED CATHETERS

Eighty-four catheters were exteriorized during the study period. The median duration of embedment was 9.4 months (mean = 13.9 ± 12.9; interval 0.5 – 68.5). At the time of exteriorization, 72 of 84 (85.7%) catheters exhibited immediate good performance. The median period of embedment for catheters displaying good function was 9.1 months (mean = 12.7 ± 10.9; interval 0.5 – 56.2). The 12 externalized catheters displaying poor flow were buried for a median duration of 11.6 months (mean = 21.3 ± 20.4; interval 5.2 – 68.5). Poor flow function occurred exclusively in 2-piece extended catheters used for upper abdominal and presternal exit-site configurations.

Only 1 patient underwent insertion of a central venous catheter prior to externalization of the embedded peritoneal catheter. The patient was hospitalized at a

TABLE 1
Study Population Demographics

	Whole group	Externalized	Remaining embedded	Futile
Patient and laboratory data				
Number of subjects (%)	107 (100)	84 (78.5)	14 (13.1)	9 (8.4)
Age (mean±SD) (years)	57.0±13.2	57.1±13.2	56.9±15.6	55.7±11.7
Male gender (%)	64 (59.8)	48 (57)	9 (64.3)	7 (77.8)
Black race (%)	16 (15)	11 (13.1)	3 (21.4)	2 (22.2)
Body mass index (mean±SD) (kg/m ²)	31.0±5.9	31.1±5.9	29.3±6.2	33.1±5.6
Serum creatinine at embedment (mean±SD) (mg/dL)	4.1±1.2	4.1±1.1	3.6±0.8	5.3±2 ^a
Blood urea nitrogen at embedment (mean±SD) (g/dL)	60±20	60.3±19.8	48.4±16.3	75±17.7 ^b
Serum albumin at embedment (mean±SD) (g/dL) ^c	3.6±0.4	3.6±0.5	3.8±0.2	3.5±0.4
Urine albumin to creatinine ratio at embedment (mean±SD) (µg/mg)	1872±2472	2115±2714	928±1313	1406±1218
Neutrophil to lymphocyte ratio at embedment (mean±SD)	3.98±2.35	4.00±2.32	3.22±1.54	4.67±3.36
eGFR-4 at embedment (mean±SD) (mL/min/1.73m ²)	14.9±3.7	14.8±3.6	17.3±3.9	12.2±3 ^d
eGFR-6 at embedment (mean±SD) (mL/min/1.73m ²) ^c	14.1±3.5	13.9±3.1	16.8±4	10.6±3 ^d
Duration of embedment, median (interval) (months)	10.5 (0.5, 82.9)	9.4 (0.5, 68.5)	25.1 (5.5, 82.9) ^e	13.4 (4.7, 53.7)
Cause of chronic kidney disease (%)				
Diabetes mellitus	51 (47.7)	44 (52.4)	2 (14.3) ^f	5 (55.6)
Hypertension	31 (29)	24 (28.6)	6 (42.9)	1 (11.1)
Polycystic kidney disease	7 (6.5)	7 (8.3)	0 (0)	0 (0)
Chronic glomerulonephritis	7 (6.5)	3 (3.6)	3 (21.4)	1 (11.1)
Other	11 (10.3)	6 (7.1)	3 (21.4)	2 (22.2)

SD = standard deviation; eGFR-4 = estimated glomerular filtration rate from 4-variable formula = $175 \times \text{serum creatinine}^{-1.154} \times \text{age}^{-0.203} \times (1.212 \text{ if black race}) \times (0.742 \text{ if female})$; eGFR-6 = estimated glomerular filtration rate from 6-variable formula = $161.5 \times \text{serum creatinine}^{-0.999} \times \text{age}^{-0.176} \times \text{blood urea nitrogen}^{-0.17} \times \text{serum albumin}^{0.318} \times (1.18 \text{ if black race}) \times (0.762 \text{ if female})$.

^a Serum creatinine significantly different from Remaining embedded, $p < 0.01$.

^b Blood urea nitrogen significantly different from Externalized ($p < 0.05$) and Remaining embedded ($p < 0.01$).

^c Serum albumin and eGFR-6 values were absent in 8 and 2 subjects in Externalized and Futile groups, respectively; eGFR-6 formula includes the value of serum albumin.

^d eGFR significantly different from Remaining embedded, $p < 0.05$.

^e Duration of embedment significantly different from Externalized, $p < 0.01$.

^f Proportion of chronic kidney disease from diabetes mellitus, significantly different from Externalized, $p < 0.05$.

facility where the healthcare providers were unfamiliar with embedded catheters. A central venous catheter was placed for acute hemodialysis. Following the hospitalization, the patient underwent uneventful externalization of the peritoneal catheter in the clinic. Eleven of the 12 patients with catheter flow dysfunction underwent successful salvage by laparoscopic interventions. Overall, 83 out of 84 (98.8%) embedded catheters were successfully used for PD.

Limited by 8 patients with absent serum albumin measurements prior to embedment, 76 patients (90.5%) had sufficient data for Pearson correlation and regression analyses. Correlations between laboratory and demographic variables and duration of catheter embedment are listed in Table 2.

Multiple linear regression was used to predict duration of embedment from the interaction of multiple independent variables. Non-significant contributors to the multiple regression model included body mass index, age, neutrophil to lymphocyte ratio, blood urea nitrogen, urine albumin to creatinine ratio, creatinine, gender, black race, and diagnosis of diabetes. Multiple linear regression analysis identified serum albumin ($p = 0.0003$) and eGFR-6 ($p = 0.0002$) as the 2 variables best associated with embedment duration ($r^2 = 0.44$, $p < 0.0001$). The strength of the multiple regression model was insufficient to serve as an accurate prognosticator of embedment duration. The prediction error was a median of -1.5 months (interquartile interval [IQI] -6.6, 4; interval -24.2, 31). In a separate

regression model, serum albumin ($p < 0.0001$) and eGFR-4 ($p = 0.0004$) were best associated with embedment duration but the strength of the association was less than when eGFR-6 was included in the model ($r^2 = 0.37$, $p < 0.0001$).

Catheter embedment duration of the externalized group relative to median values for serum albumin and eGFR-6 at the time of embedment is shown in Table 3, demonstrating that serum albumin and eGFR-6 are directly associated with the duration of embedment. In addition, the stratification of embedment duration in Table 3 by including serum albumin as a covariate with eGFR provides better resolution than duration of embedment based upon median eGFR values alone (below median = 9.2 months [IQI 4.8, 12.3], above median = 17.8 months [IQI 10.5, 31.4], $p = 0.0004$).

TABLE 2
Pearson Correlation Coefficients Between Laboratory and Demographic Variables and Duration of Catheter Embedment

Laboratory and demographic variables	r	p value
Serum albumin	0.457	<0.0001
Serum creatinine	-0.333	0.003
Blood urea nitrogen	-0.189	0.102
Neutrophil to leukocyte ratio ^a	0.128	0.338
Urine albumin to creatinine ratio ^a	-0.282	0.021
eGFR-4	0.333	0.003
eGFR-6	0.457	<0.0001
Age	0.033	0.777
BMI	-0.025	0.828

eGFR-4 = estimated glomerular filtration rate from the 4-variable Modification of Diet in Renal Disease (MDRD) formula; eGFR-6 = estimated glomerular filtration rate from the 6-variable MDRD formula; BMI = body mass index.

^a Natural logarithm transformed values.

TABLE 3
Catheter Embedment Duration of the Externalized Group Relative to Median Values at the Time of Catheter Embedment for Serum Albumin and Estimated Glomerular Filtration Rate

Median serum albumin = 3.5 g/dL Median eGFR-6 = 14.6 mL/min/1.73m ²	Albumin Below, eGFR-6 Below	Albumin Below, eGFR-6 Above	Albumin Above, eGFR-6 Below	Albumin Above, eGFR-6 Above
Subject number	20	18	17	21
Median duration of embedment (months)	8.5	11.2	11.1	24.8
Interquartile interval (months)	2.7, 11	6.5, 17.6	7.3, 24.1	15.7, 40.7

Kruskal-Wallis test: $p < 0.0001$; Kruskal-Wallis statistic 24.09.

eGFR-6 = Estimated glomerular filtration rate from the 6-variable Modification of Diet in Renal Disease formula.

Diabetes as a cause of kidney disease was statistically more likely to be associated with lower serum albumin measurements (Table 4). No significant association between diabetic status and embedment duration was demonstrated in the multiple regression model ($p = 0.62$).

REMAINING EMBEDDED

By the end of the study period, 14 catheters remained embedded for a median period of 25.1 months (mean = 35.0 ± 26.3 ; interval 5.5, 82.9). This duration of embedment was significantly longer than the group of catheters that underwent externalization ($p < 0.01$). On average, the catheters remaining embedded had higher eGFR and serum albumin levels at the time of implantation (Table 1). In addition, there was a significantly lower prevalence of diabetes as a cause of kidney disease in these patients compared to those having undergone externalization ($p < 0.05$). Five of these 14 catheters (35.7%) were embedded for more than 5 years (1 nearly 7 years).

FUTILE PLACEMENT

The reasons for the 9 patients ending up with futile embedding procedures are summarized in Table 5. The median period of futile embedment was 13.4 months (mean = 18.5 ± 14.9 ; interval 4.7 – 53.7). Four of these patients initiated dialysis with a central venous catheter: 2 developed inability to provide self-care, 1 underwent bladder augmentation surgery in preparation for kidney transplantation, and 1 changed their mind about initiating PD prior to undergoing open heart surgery in preparation for kidney transplantation.

DISCUSSION

Much of the early literature following the introduction of the embedded catheter technique by Moncrief *et al.*

TABLE 4

Serum Albumin Measurements at the Time of Catheter Embedment Relative to Diabetic Status among Patients in the Externalized Group*

Median serum albumin = 3.5 g/dL	Diabetic	Non diabetic
Above median albumin	14	26
Below median albumin	30	6

* Fisher's exact test: $p < 0.0001$.

TABLE 5

Reasons for Futile Catheter Embedment

Kidney transplant recipient	2
Moved out of service area	2
Developed inability for self-care	2
Changed modality choice	1
Died	1
Bladder reconstruction in preparation for transplant	1

in 1993 was focused upon the potential reduction of dialysis-related infections by allowing the buried catheter to heal in the subcutaneous space without exposure to contamination from the presence of an exit wound (1,10–14). In these studies, the duration of embedment was often fixed at 1 to 1.5 months (10,11,14), occasionally using temporary hemodialysis with a central venous catheter until the prescribed healing period had elapsed (11). While efficacy in reduction of dialysis infections has not been validated (15), other benefits to patients and dialysis programs provided by the buried catheter approach have become more important, particularly, greater patient acceptance for earlier commitment to PD, avoidance of urgent hemodialysis with a central venous catheter, and more efficient surgical scheduling as a non-urgent elective procedure (2,16,17).

Our experience with embedded catheters affirms the benefits of this approach. With an embedded catheter in place, all but 1 patient in our series remained committed to their modality choice. Except for an unusual circumstance in which 1 of our patients was hospitalized acutely in a facility unfamiliar with embedded catheters, none of the patients remaining on a PD pathway initiated dialysis with a central venous catheter. Upon externalization, 85.7% of catheters displayed immediate good flow and all but 1 of the dysfunctional catheters were recovered with laparoscopic interventions to achieve an overall function rate of 98.8%. In a previous report from our institution, no significant association between flow malfunction and embedment duration was demonstrated (8).

The major drawback of prolonged catheter embedment duration is futile placement. For a variety of reasons, 8.4% of embedded catheters in our series were never used for PD. This is similar to the 8.7% incidence of futile catheter embedment procedures observed by Brown *et al.* (6). No predominant reason for these nonproductive efforts was identified in either series. In the present report, catheters that were futilely placed tended to be embedded for longer periods than those that were externalized and used. The proportion of catheters that remain buried in our series and the Brown report are 13.1% and 11.5%, respectively. By the end of our study, more than one-third were embedded for more than 5 years, potentially bringing the total incidence of futile placement as high as 13.1%.

It is unlikely that futile catheter placement can be completely avoided. The highest average values for serum creatinine and blood urea nitrogen were in the futile group indicating that some of these patients had an impending need for dialysis. However, when the time came, instead of utilizing the embedded catheter, one third of the patients in this group initiated dialysis with a central venous catheter due to acquired medical conditions rendering them unable to pursue PD. In addition, the competing risk of death prior to commencement of dialysis will always be a contributing factor to futile placement.

The benefits of the embedded peritoneal catheter strategy only accrue if dialysis initiation occurs. Therefore, one of the challenging aspects of the buried catheter approach is predicting if and when patients will need dialysis. Ideally, patients should undergo catheter embedment only when the perceived benefits of advanced access placement exceed the potential downsides of the procedure. Few studies have evaluated the efficacy and outcomes of different approaches to timing of the embedment procedure. Recommendations for timing of placement tend to fall into 2 categories: those suggesting embedment within a prespecified time period before anticipated initiation of dialysis and those identifying a threshold level of eGFR (6,18). The first approach presumes that clinicians can reliably predict when a given patient will begin dialysis; however, such appraisals are exceedingly inaccurate. While appearing more objective, the second approach may be overly simplistic. Depending on each patient's rate of decline in renal function, any given threshold level of GFR may be associated with very different time periods before dialysis is needed.

In the present study, eGFR was calculated from the 4- and 6-variable MDRD formulas (9). It is recognized that the study populations used to develop the MDRD and other commonly employed formulas are not well

represented at the lower end of the GFR spectrum to provide sufficient weight to properly influence the equations (9,19,20). As a result, all of these formulas overestimate the GFR at the lower end of the scale (20). In this low-end range, patients often initiate dialysis at higher than anticipated eGFRs. This phenomenon may account in part for the effect of eGFR-6 in our multiple regression model where the prediction error (observed minus predicted embedment duration) had a median value of -1.5 months. Moreover, it has been demonstrated that the accuracy of these eGFR equations is worse in advanced stages of kidney disease for patients with higher age and diabetic nephropathy (20).

Inherent weaknesses of the eGFR equations at the low end of renal function may also explain why we found serum albumin ($p = 0.0003$) to have such a strong and independent effect in the presence of eGFR-6 ($p = 0.0002$) on embedment duration when albumin is included in the eGFR-6 equation.

While diabetic status was found to have a statistically significant association with lower albumin levels, any link between diabetes and duration of embedment could be accounted for by the effect of albumin—not by a direct effect of diabetes itself.

These results underscore the importance of not making decisions regarding the timing of the embedding procedure based upon eGFR alone. As shown by the embedment durations in Table 3, timing can be improved with additional consideration of the serum albumin level. Still, laboratory measures should not displace clinical judgment. Numbers and formulas do not account for comorbid conditions or treatments that influence the rate of decline in renal function or the consequences of patient noncompliance with diet and medications.

The concerns for excessive embedment periods and futile placement must be balanced with the advantages of performing the procedure far enough in advance to capture patients who choose PD as their renal replacement therapy and to enable it as an effective strategy to promote growth of home dialysis programs. Allowing sufficient lead time can avoid unplanned starts on dialysis with a central venous catheter due to abrupt final deterioration in renal function or delays in peritoneal catheter insertion caused by operating room access issues, surgical backlog, or patient indecision. Timing of the embedment procedure should include appraisal of both eGFR and serum albumin. Appropriate consideration of these values may help minimize excessive embedment periods and decrease futile placements while preserving the benefits of patient commitment to PD and reduced use of central venous catheters.

Lastly, it is interesting to contrast the futile and primary failure rates of anticipatory arteriovenous fistulas (AVFs) for hemodialysis to those of embedded catheters. Futile AVFs due to death, transplant, refusal of dialysis, and fistula failure have a reported occurrence rate varying between 20 and 60% compared to the <9% incidence of futilely placed embedded catheters described herein and by others (6,21,22). In the era of increased emphasis on AVFs as the preferred access, primary failure rates are now as high as 60% (23,24). The incidence of primary flow failure upon externalization of embedded catheters is much lower, varying between 7 and 15% (6,8,25). Weighed against anticipatory AVFs, the lower futile and primary failure rates associated with embedded catheters correspond to reduced use of central venous catheters and fewer interventions to salvage access failures, resulting in better health outcomes and lower health care costs.

DISCLOSURES

JHC is a consultant for MedComp, Inc., and Baxter Healthcare. He is a member of the speakers' bureau for Baxter Home Therapies Institute, DaVita Healthcare Partners, and Fresenius Medical Care Advanced Renal Education Program.

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