Percutaneous Fibrin Sheath Stripping versus Transcatheter Urokinase Infusion for Malfunctioning Well-positioned Tunneled Central Venous Dialysis Catheters: A Prospective, Randomized Trial[1]

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Abbreviation: UK = urokinase

PURPOSE: To compare central dialysis catheter patency rates after stripping procedures with those after urokinase (UK) infusion.

MATERIALS AND METHODS: Fifty-seven tunneled catheters with either (i) flow rates less than 250 mL/min and established baseline flow rates ≥300 mL/min or (ii) flow rates 50 mL/min less than higher established baseline flows were prospectively randomized to undergo stripping procedures (n = 28) or UK infusion (n = 29) at 30,000 U/h via each port concurrently, for a total 250,000 U. Success and patency were determined by dialysis at normal flow rates (≥300 mL/min) or at the previously established higher baseline rate. Flow rates were monitored weekly. Primary patency ended with catheter malfunction or removal. Kaplan-Meier survival analysis was used to construct survival curves.

RESULTS: In the stripping group, initial clinical success was 89% (25 of 28). The 15-, 30-, and 45-day primary patency rates were 75% (n = 20), 52% (n = 13), and 35% (n = 8), respectively. The median duration of additional function was 32 days (95% CI: 18–48 d). In the UK group, initial clinical success was 97% (28 of 29). The 15-, 30-, and 45-day primary patency rates were 86% (n = 21), 63% (n = 13), and 48% (n = 9), respectively. The median duration of additional patency was 42 days (95% CI: 22–153 d). The Wilcoxon test for equality detected no significant difference in the survival curves for the two treatment groups (P = .236).

CONCLUSION: There is no significant difference in time to primary patency between the two methods. Both allow temporary catheter salvage in most patients.

THE first-line therapy for dialysis catheters with suboptimal flow rates (<300 mL/min) (1) unresponsive to simple positional maneuvers and port reversal has usually been instillation of a small quantity of urokinase (UK) in the dialysis unit for periods as long as 20 minutes (2–4). This may be attempted several times. Patients whose catheters fail a thrombolytic instillation are typically referred for transcatheter venography to confirm satisfactory catheter position and to evaluate for the presence of pericatheter fibrin sheath or thrombus (1). Poorly positioned or kinked catheters are usually treated in a straightforward

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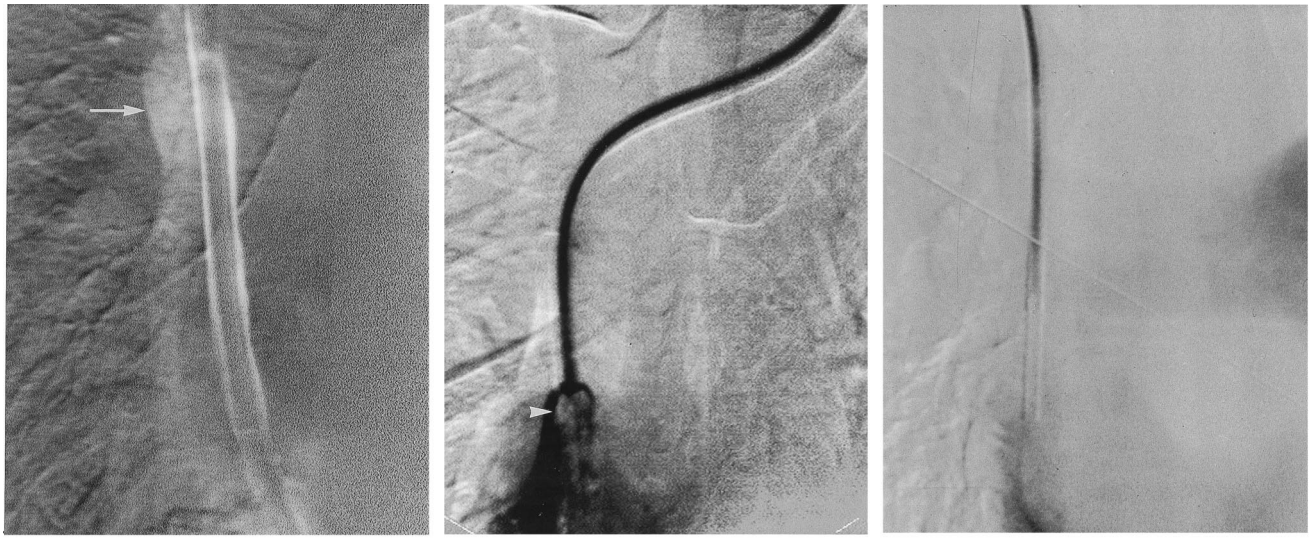
manner with standard interventional techniques (4,5). Pericatheter fibrin sheaths and/or thrombus have been treated with use of a variety of methods, including percutaneous fibrin sheath stripping (4,6–9) and thrombolysis through the dialysis catheter (2,10–12), with return of catheter function for at least one dialysis session in most patients. Nevertheless, the subsequent patency rates after thrombolysis are unknown and the results after percutaneous fibrin sheath stripping have varied widely. These issues led us to conduct a prospective, randomized trial of a 4-hour UK infusion compared to percutaneous fibrin sheath stripping. Herein we report the results of this trial and review the pertinent literature.

MATERIALS AND METHODS

Between April 30, 1996 and October 28, 1998, 57 patients who had 57 poorly functioning dialysis catheters were enrolled in the study under the auspices of the hospital's Institutional Review Board. There were 34 women and 23 men, with a median age of 60 years (range, 26–91 y). The study was explained to all patients and a protocol consent form was signed. Each patient was enrolled only once, even if a new catheter was later inserted at the same or a new puncture site. During the course of the study, 54 other patients were excluded from enrollment for the following reasons: refusal to undergo stripping procedure before ($n = 28$) or after ($n = 2$) randomization, refusal or inability to consent ($n = 17$), and contraindication to UK ($n = 7$). Risk factors for chronic renal failure included hypertension ($n = 23$), diabetes mellitus ($n = 18$), chronic glomerulonephritis ($n = 1$), systemic lupus erythematosus ($n = 1$), and multiple myeloma ($n = 1$). The cause of renal failure was uncertain in the other 15 patients. Ten patients had clinically apparent coronary artery disease, seven had a history of coronary artery disease and congestive heart failure, and two had a history of congestive heart failure. There were eight current smokers.

Forty-six catheters had been indwelling for a median of 59 days (range, 11–682 d) at the time of referral for catheter malfunction. Because we practice in a tertiary referral center, the exact indwell times were not known for the other 11 catheters. Either vascular access surgeons or interventional radiologists had originally inserted the catheters. Most had failed a trial of UK instillation (Opencath; Abbott Laboratories, North Chicago, IL) in the dialysis clinic. There were 45 Permcaths (Quinton Instrument Company, Bothel, WA), seven Tesio catheters (Medcomp, Harleysville, PA), and five Hickman catheters (Bard Access Systems, Salt Lake City, UT) inserted via the right internal jugular vein in 40 patients, right subclavian vein in three, left internal jugular vein in 12, and left subclavian vein in two. All catheters had established baseline flow rates greater than or equal to 300 mL/min (1) for at least three dialysis treatments after catheter insertion. Catheter malfunction was defined as a flow rate through one or both ports less than 250 mL/min or a decrease through one or both ports greater than 50 mL/min if the established baseline flow rate was greater than 300 mL/min. Indications for treatment included blood flow rates less than 250 mL/min through both ports (29 cases), blood flow rates less than 250 mL/min via the arterial (nine cases) or venous (one case) port, a decrease in flow rate greater than 50 mL/min below established baseline flow through both ports (three cases), decrease in flow rate greater than 50 mL/min below established baseline flow through the venous (three cases) or arterial (one case) port, and complete occlusion of the arterial (seven cases), venous (two cases), or both (four cases) ports.

All catheters were observed with transcatheter digital subtraction venography during very slow hand injections of 5–25 mL iodinated contrast material through each port consecutively. Contrast tracking retrogradely along the catheter or flowing sluggishly away from the catheter tip was considered diagnostic of a pericatheter fibrin sheath **(Fig 1a)**. Filling defects were considered diagnostic of pericatheter thrombus **(Fig 1b)**. The venographic study was considered normal if contrast material flowed immediately away from the catheter tip **(Fig 1c)**. With use of these criteria, 79% (45 of 57) of the transcatheter venograms before treatment were abnormal; 61% (35 of 57) revealed fibrin sheaths, 7.0% (4 of 57) fibrin sheath and thrombus and 11% (6 of 57) pericatheter thrombus. None showed large clots around the catheter. The studies were normal in 15.8% (9 of 57) of cases and nondiagnostic (because of respiratory motion) in 5.3% (3 of 57) of cases. Based on these contrast studies, the catheter tips were located in the right atrium of 22 patients, bridging the superior vena cava/right atrial junction in 24 patients, and in the superior vena cava just above the right atrium in 11 patients. The superior vena cava was considered normal in 23 patients, stenosed in one patient, and not evaluable in 34 patients. A computer-generated randomization schedule was used to assign patients to the UK infusion or stripping group after transcatheter venography showed satisfactory catheter position and no mechanical problems such as kinking. The median catheter indwell time at the time of treatment in the UK group (26 catheters) was 68 days (range, 14–682 d) and 35 days (range 11–306 d) in the stripping group (20 catheters); the exact indwell times for the other 11 catheters were not known. The median test did not indicate a significant difference in the known pretreatment indwell times between the groups ($P = .388$). The median test compares the proportions in each sample that are less than the combined median with use of a binomial test (ie, Fisher exact test). It is sensitive to difference in location. It is the most powerful test for comparing skewed, asymmetric distributions.



a. **b.** **c.**

Figure 1. **(a)** Transcatheter contrast injection shows the catheter tip in the right atrium. Contrast material passes retrogradely within a fibrin sheath, outlining the catheter before passing through a fenestration in the sheath to opacify the superior vena cava (arrow). **(b)** Transcatheter contrast study shows a globular filling defect indicative of pericatheter thrombus (arrowhead). **(c)** Image obtained during catheter contrast injection through the red port shows contrast material flowing rapidly away from the red port.

• Urokinase Infusion

A solution of 250,000 U of UK (Abbott Laboratories) dissolved in 250 mL 0.9 normal saline or 5% dextrose was administered at 30 mL/h concurrently via both ports (60,000 U/h total) over the course of 4 hours and 10 minutes. The 4-hour infusion was chosen to facilitate treatment for outpatients. Urokinase was administered to outpatients ($n = 21$) in either the Interventional Radiology Recovery Room or a 23-hour admission bed and to inpatients ($n = 8$) usually in their hospital beds. No other procedure medications were administered in this treatment group.

• Percutaneous Fibrin Sheath Stripping

Other investigators (4,6–8) have described the technique in detail. Briefly, all procedures were performed from a right (24 cases) or left (four cases) common femoral access with a 25-mm (11 cases) or 35-mm (17 cases) Amplatz Nitinol snare (Microvena, Vadnaise Heights, MN). The dialysis catheter was engaged with the snare, which was advanced over the catheter as far as possible, tightened, and pulled off the catheter tip **(Fig 2)**. For Tesio catheters (Medcomp), the two catheters were stripped independently. The dialysis catheter hub was aseptically prepared and a guide wire was passed through the catheter to facilitate readvancement of the snare over the dialysis catheter tip for additional stripping passes (6) **(Fig 3)**. The number of stripping passes was at the operator's discretion, which resulted in wide variation in the number of passes performed: 4–6 passes were made in two patients, 7–9 passes were made in five, 10–12 passes were made in nine, and more than 12 passes were made in nine. The number of passes was not recorded for three procedures. Midazolam was administered to 23 patients; 19 of these patients also received fentanyl. One patient was pretreated with intravenous cefoxitin. This patient also received diphenhydramine because of a history of hives caused by iodinated contrast material. Outpatients ($n = 25$) were observed for 2 hours and inpatients ($n = 3$) were transported to their rooms after hemostasis was achieved.

• Follow-Up

Posttreatment transcatheter contrast studies were performed at the operators' discretion, but the results were not used for patency determinations because clinical function was considered more important. Immediate clinical success was defined as at least one successful dialysis session with flow rates higher than the previously established baseline flow rate. Follow-up flow rates were obtained by routine weekly review of dialysis clinic records. Primary patency was defined as a flow rate greater than the established baseline flow rate without additional intervention. Secondary patency was defined as a flow rate greater than the established higher baseline flow rate assisted by repeat treatment with the same treatment modality, either stripping or UK infusion. Study endpoints included restoration of catheter function by another treatment modality (eg, crossover to UK or stripping or catheter exchange), catheter re-

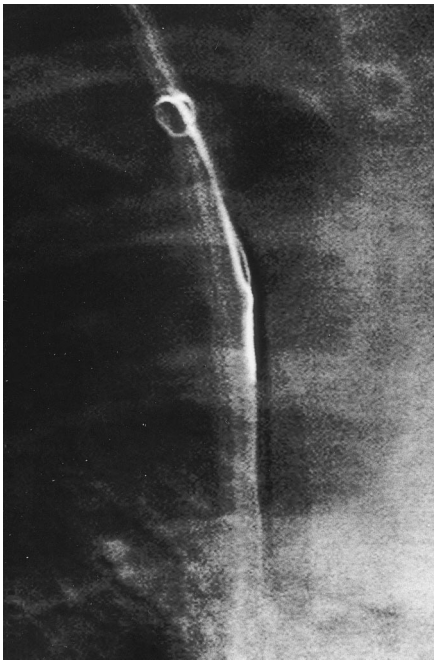


Figure 2. Amplatz snare wrapped around the catheter during a stripping pass.

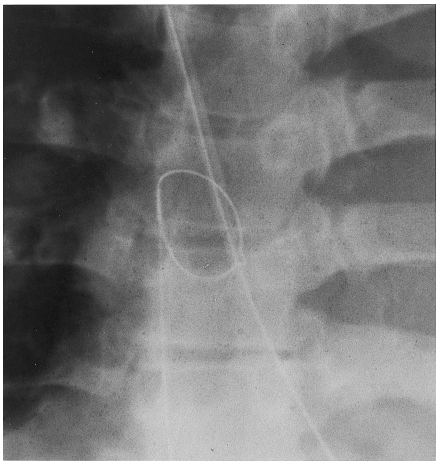


Figure 3. Amplatz snare positioned around the guide wire near dialysis catheter tip to facilitate another stripping pass.

moval for any reason (eg, catheter malfunction, permanent access available, accidental catheter removal), or patient death. All analyses were performed with the Statistical Analysis Software System (Stat Version 7.0; SAS, Cary, NC). The Kaplan-Meier nonparametric maximum likelihood estimator was used to estimate survivor functions. Data were right censored. The difference between survivor functions was tested with use of the Wilcoxon statistic.

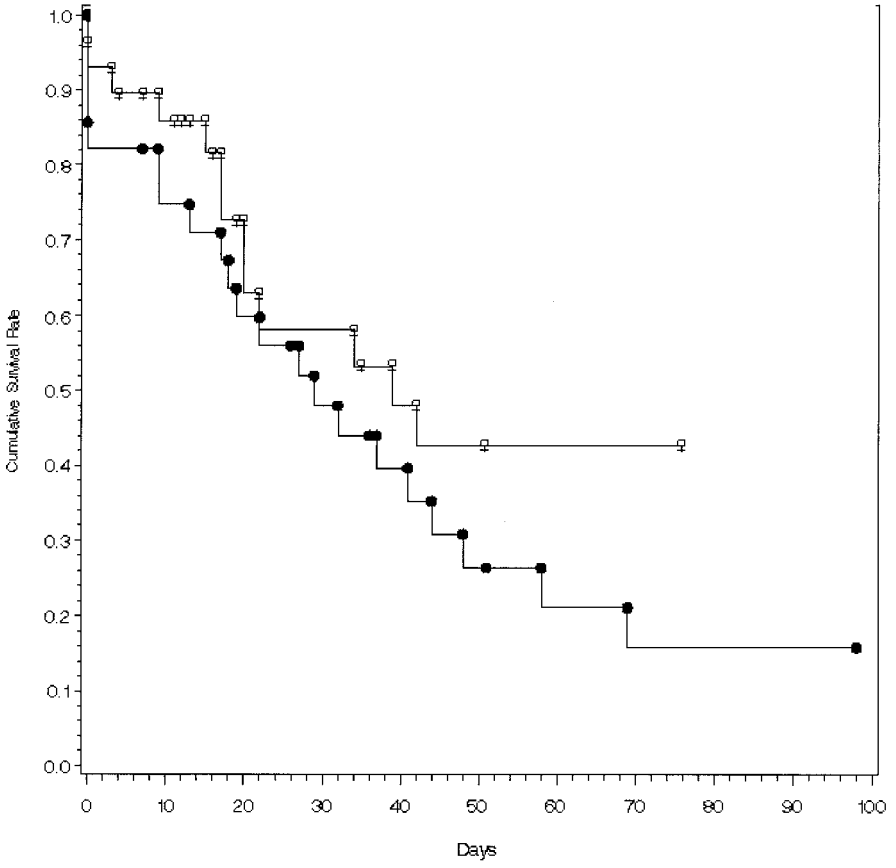


Figure 4. Stripping and UK survival curves. ■ = stripping; □ = urokinase.

RESULTS

According to the randomization schedule, 28 patients were treated with a stripping procedure and 29 patients were treated with UK infusion. Plots of the product-limit survival estimates and 95% confidence bands are presented in **Figure 4 and Table 1**.

• Urokinase Group

Seventy-six percent (13 of 17) transcatheter contrast studies after UK infusion were normal; three had fibrin sheaths and one had a peri-catheter clot. The other 12 patients were not evaluated angiographically after treatment because the pretreatment study was normal (n = 4) or the operator chose not to (n = 8).

The initial clinical success rate was 97% (28 of 29). The 15-, 30-, and 45-day primary patency rates were 86% (n = 21), 63% (n = 13), and 48% (n = 9), respectively. The median duration of additional satisfactory catheter function after infusion was 42 days (95% CI: 22–364 d). As of 28 weeks after treatment, one catheter is still being used without further treatment. Endpoints for primary patency included recurrent catheter malfunction treated by repeat UK infusion (n = 3), stripping (n = 2), or catheter exchange (n = 5). The other endpoints were catheter removal for recurrent malfunction (n = 6), matured permanent access (n = 7), or

Table 1
Values for Survival Curves (see Fig 4)

Time	Censor	Number at Risk	Survival Distribution Function Estimate	Lower Bound of CI	Upper Bound of CI
			Urokinase Group		
0	0	29	1.00000	1.00000	1.00000
0	0	28	0.96552	0.89911	1.00000
3	0	27	0.93103	0.83881	1.00000
4	0	26	0.89655	0.78571	1.00000
7	1	25	0.89655	–	–
9	1	24	0.89655	–	–
11	0	23	0.85920	0.73105	0.98734
12	1	22	0.85920	–	–
13	1	21	0.85920	–	–
15	1	20	0.85920	–	–
16	0	19	0.81624	0.66942	0.96305
17	1	18	0.81624	–	–
19	0	17	0.72554	0.54927	0.90182
20	1	15	0.72554	–	–
22	0	14	0.62880	0.43153	0.82608
34	0	12	0.58043	0.37682	0.78404
35	0	11	0.53206	0.32452	0.73961
39	1	10	0.53206	–	–
42	0	9	0.47886	0.26749	0.69023
51	0	8	0.42565	0.21360	0.63771
51	1	7	0.42565	–	–
76	1	6	0.42565	–	–
76	1	5	0.42565	–	–
112	0	4	0.34052	0.11458	0.56647
117	1	3	0.34052	–	–
195	1	2	0.34052	–	–
364	0	1	0.17026	0.00000	0.43187
465	1	0		–	–
			Stripping Group		
0	0	28	1.00000	1.00000	1.00000
0	0	24	0.85714	0.72753	0.98676
7	0	23	0.82143	0.67957	0.96329
9	1	22	0.82143	–	–
13	0	20	0.74675	0.58437	0.90914
17	0	19	0.70942	0.53946	0.87937
18	0	18	0.67208	0.49601	0.84814
19	0	17	0.63474	0.45389	0.81559
22	0	16	0.59740	0.41298	0.78183
26	0	15	0.56006	0.37321	0.74692
27	1	14	0.56006	–	–
29	0	13	0.52006	0.33081	0.70931
32	0	12	0.48006	0.28982	0.67029
36	0	11	0.44005	0.25019	0.62991
37	1	10	0.44005	–	–
41	0	9	0.39605	0.20659	0.58550
44	0	8	0.35204	0.16503	0.53905
48	0	7	0.30804	0.12560	0.49047
51	0	6	0.26403	0.08845	0.43961
58	1	5	0.26403	–	–
69	0	4	0.21122	0.04300	0.37945
98	0	3	0.15842	0.00365	0.31319
109	1	2	0.15842	–	–
129	1	1	0.15842	–	–
267	0	0	0.00000	0.00000	0.00000

terminal illness ($n = 1$). One patient demanded the catheter be removed and three patients died with functioning catheters. Because only three patients were retreated with UK when the catheter malfunctioned again (operator's discretion), the secondary patency curve would not be significantly different from the primary patency curve.

• Stripping Group

Eighty-seven percent (20 of 23) transcatheter contrast studies after stripping procedures were normal; one had a fibrin sheath and two had pericatheter clots. The other five patients were not evaluated angiographically after treatment because the pretreatment study was normal ($n = 2$) or the operator chose not to ($n = 3$).

The initial clinical success rate was 89% (25 of 28). The 15-, 30-, and 45-day primary patency rates were 75% ($n = 20$), 52% ($n = 13$), and 35% ($n = 8$), respectively. The median duration of additional satisfactory catheter function after stripping was 32 days (95% CI: 18–48 d). As of 18 weeks after treatment, one catheter is still being used without further treatment. Endpoints of primary patency included restoration of catheter function by repeat stripping ($n = 3$), UK infusion ($n = 4$), or catheter exchange ($n = 6$). Other endpoints included catheter removal for recurrent malfunction ($n = 5$) or positive blood cultures ($n = 1$), permanent access ($n = 5$), transplant ($n = 2$), and accidental catheter removal ($n = 1$). Because only three patients were re-treated with a stripping procedure when the catheter malfunctioned again (operator's discretion), the secondary patency curve would not be significantly different from the primary patency curve.

• Sample Size Calculation

A sample of 70 patients (35 in each group) was initially chosen based on an expected difference in immediate success rates between

Table 2
Dialysis Catheter Removal

Study	Catheters	Malfunction* (%)	Infection (%)	CV Thrombosis (%)
McDowell (14)	172	5	5	0
Cappello (15)	107	5	5	0
Moss (2)	168	7	8	0
Gibson (16)	94	9	28	1.6
Schwartz (17)	118	17	19	0
Lund (11)	222	28	11	1.2
Trerotola (10)	250	19	7	0
Duszak (18)	77	—	13	0

Note.—CV = central vein.
* Variable definitions.

Table 3
Etiology of Catheter Malfunction*

Study	No. Catheters	Episodes	Mechanical	Sheath/Clot
Crain (6)	24	44	4	40
Suhocki (4)	—	42	4	38
Rockall (7)	29	31	7	24
Trerotola (10)	63	63	23	40

* UK instillation failed in most patients.

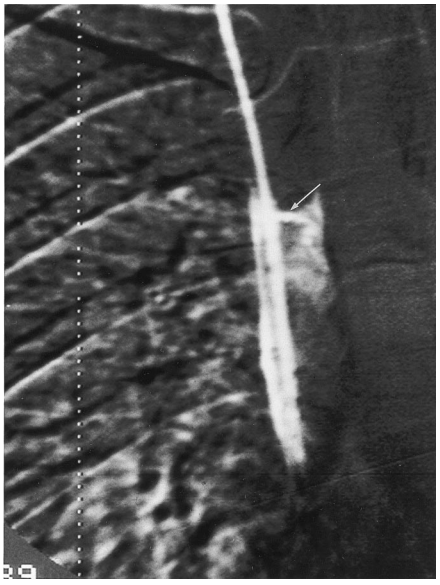


Figure 5. Slow contrast injection clearly shows the probable pathway that a subsequent transcatheter thrombolytic agent would take from the catheter tip to the nearest fenestration (arrow) in the fibrin sheath.

the treatment groups of 15%, type I error of 5%, and power of 80%. The initial clinical success and patency curves after 57 patients were enrolled were compared to the results obtained during an interim analysis after 44 patients were enrolled (13). Because there was no notable difference or change in the trends since the interim analysis and because the 95% confidence bands were broad, we concluded that enrollment of an additional 13 patients to reach the initial goal of 70 patients would not significantly change the final analysis. The study was therefore terminated after 57 patients were enrolled.

The Wilcoxon test indicated that the times to primary patency for the stripping and UK groups were not significantly different from each other ($\chi^2 = 1.41$; 1 degree of freedom; $P = 0.236$).

• Complications

There were two deaths in the UK group, one at 2 weeks and another at 1 month after the infusion. Both deaths were attributed to underlying disease and considered to be unrelated to the treatment. in the stripping group, one patient developed fever and positive blood cultures 5 weeks after treatment. Another patient presented with a symptomatic pericatheter innominate thrombosis necessitating catheter removal within days after the catheter had been unsuccessfully stripped.

DISCUSSION

Central venous dialysis catheter malfunction is a serious problem necessitating removal of as many as 28% of dialysis catheters simply because they do not work (2,10,11,14–17). Catheters are removed for malfunction approximately as often as for infection and far more frequently than for symptomatic pericatheter thrombus (2,10,11,14–17). **(Table 2)** Dialysis catheter malfunction not requiring removal is extremely common, affecting 3%–10% of all dialysis sessions (2,16), and 87% of all catheters at some time before removal (4). Until its removal from the market by the Food and Drug Administration, simple UK instillation at dialysis clinics restored immediate function to 74%–81% of dialysis catheters (2,4). Although this measure was performed blindly and the durability is unknown, it was effective enough to be the appropriate first-line therapy (1) because it was considered safe, inexpensive, and expediently allowed dialysis to resume after a minimal delay during the same scheduled dialysis session.

Catheters that fail postural maneuvers, port reversal, and UK instillation may be malpositioned or kinked, but mechanical problems are generally much less common than pericatheter fibrin sheath or clot formation (4,6,7,10) **(Table 3)** unless the catheter has been recently inserted. Catheter malfunction in well-positioned catheters is typically caused by the presence of a pericatheter fibrin sheath or a small amount of thrombus about the catheter tip (4,6,7,10). Pericatheter fibrin sheath formation has been shown in a human autopsy

Table 4
Thrombolytic Infusion

Study	No. of Catheters	Agent/Dose	Clinical Success	Additional Patency
Moss (2)	58	Streptokinase (12 h)	97%	–
Uldall (12)	103	UK (250,000 U bolus)	"nearly always"	–
Lund (11)	39	UK (250,000 U/6 h)	79.5%	–
Trerotola (10)	11	UK (250,000 U/6 h)	55%	31 d (mean)
Current Study	29	UK (250,000 U/4 h)	97%	48% at 45 d (primary)

Note.—No bleeding complications in 240 cases.

Table 5
Fibrin Sheath Stripping

Study	No. of Catheters	Clinical Success (%)*	Additional Patency
Crain (6)	40	98	45% at 3 months (primary)
Haskal (8)	24	92	8% (2/24) at 2 wks
Suhocki (4)	38	95	3 mo (mean)
Rockall (7)	31	61	4.25 mo (median)
Brady (9)	91	96	51% at 3 mo (primary)
Current Study	28	89	35% at 45 d (primary)

* At least one successful dialysis using variable criteria for success.

study (19) to occur as early as 24 hours after placement and is thought to occur in 80%–100% of central venous catheters 2–7 days after insertion (19–21). Fibrin sheaths propagate from the venous insertion site and from the tip toward the center of the catheter and can persist for weeks even after the catheter is removed (19). When the pericatheter sheath and/or associated thrombus infringe on the functional endhole(s) of the catheter, decreased dialysis flow rates result.

Fibrin sheaths can be demonstrated by intravascular ultrasound (22) but are usually diagnosed on transcatheter venographic studies with (21) or without (4,6,8,9) pulling the catheter back before injection of contrast material. Because the sensitivity of transcatheter venography for detection of fibrin sheaths is unknown, we included all malfunctioning well-positioned catheters in this study, whether or not a fibrin sheath was detected on transcatheter venography. Regarding venographic technique, we believe that it is very important to inject contrast material through the catheter slowly to avoid creating a hole in the fibrin sheath near the catheter tip. An iatrogenic fenestration from rapid contrast material (or saline) injection can hinder angiographic diagnosis of the fibrin sheath because contrast material can pass preferentially through the fenestration in the sheath rather than retrogradely around the catheter. In addition, a subsequently administered transcatheter thrombolytic agent will also run through the iatrogenic fenestration instead of bathing the catheter from the tip proximally to the nearest naturally occurring fenestration **(Fig 5)**. This will decrease the total surface area of the fibrin sheath that is exposed to the contrast agent.

The results of studies reporting thrombolysis (2,10–12), including ours, are presented in **Table 4.** The immediate success rates, defined as restoration of satisfactory function for at least one dialysis session, range from 55% to 97%. One investigator instilled a total of 250,000 U of concentrated UK into both ports and reported that it "nearly always" worked for restoring immediate catheter function (12). Our study confirms the previous studies' high rates of immediate functional restoration. These treatments appear to be very safe; there were no bleeding complications attributed to the thrombolytic agent in any of these studies. Trerotola et al (10) reported a 31-day mean period of additional function in their very small group of patients; otherwise, the durability of these treatments has not been previously studied. Our cumulative patency rates after transcatheter thrombolytic infusion indicate that approximately half (48%) of treated catheters will maintain function for an additional 45 days after treatment. Although modest, this additional period of function will allow permanent access creation and/or maturation in many patients.

The investigators (4,6–9) listed in **Table 5** have reported the results of pericatheter fibrin sheath stripping. The initial success rates in these series, including ours, are generally high, and the overall complication rate is 6% (16 of 253). We found a modest durability with 35% of catheters maintaining primary patency for 45 days. To the contrary, Crain et al (6) and Brady et al (9) reported primary patency rates of 45% and 65%, respectively, at 3 months; Crain also performed multiple stripping procedures and optimistically reported that 81% of the treated catheters functioned satisfactorily for at least 1 year after the initial catheter insertion. Similarly, Suhocki et al (4) emphasized that most treated catheters remained functional for their intended duration of use. Rockall and colleagues (7) were somewhat less optimistic, reporting a 61% (19 of 31) initial return of function; however, their experience illustrated the importance of evaluating for catheter malposition or kinks before percutaneous treatment. Contrary to the promising results in the above four studies, Haskal et al (8)

experienced dismal patency rates, finding that 92% (22 of 24) of catheters returned to the pretreatment blood-liter process rate by the fifth poststripping dialysis session. As a result, this group completely abandoned the stripping procedure.

Our results showed a significant difference between 4-hour UK infusion and fibrin sheath stripping for neither immediate restoration of catheter function nor maintenance of long-term patency. Although our results did not demonstrate a difference, a trend favoring UK is seen when looking at the Kaplan-Meyer-derived interval patency rates and the median time period of additional catheter function in both groups. Even if stripping and UK infusion have similar results, a thrombolytic infusion is our preferred therapy for several reasons. First, the patients prefer it. Our greatest difficulty enrolling an otherwise eligible patient for the study was patient refusal to undergo a stripping procedure after hearing about the lysis and stripping options. Second, transcatheter infusion is noninvasive; a stripping procedure requires a venous puncture. Third, stripping procedures have been associated with potentially disastrous complications, whereas transcatheter administration of thrombolytics has not (2,10–12): one group (6) reported asymptomatic common femoral puncture site thrombus and another (4) later published a case report of a septic pulmonary embolus caused by a stripping procedure (23). In addition, one of our patients presented with symptomatic pericatheter innominate vein thrombosis after an attempted stripping procedure. For all of these reasons, then, thrombolysis is our preferred treatment.

After poor results of stripping procedures (8) had been demonstrated at their institution, Duszak et al (18) began changing catheters through the same tract over a guide wire while making an attempt to position the catheter tip beyond or outside the confines of the fibrin sheath. This was done either by repositioning the tip more centrally or by manipulating a guide wire and the catheter tip through a fenestration in the fibrin sheath to a position outside of the sheath. They compared these catheter exchanges in a nonrandomized fashion with de novo catheter placement in the same patient population and found no significant differences in catheter patency or complication rates, including infections. Whether a catheter exchange or a thrombolytic infusion is preferable remains undetermined. As currently reimbursed by Medicare, a single catheter exchange is much less costly than an infusion. Catheter exchange over a guide wire spares vein (18) and usually allows a more expedient return to dialysis than an infusion does. Nevertheless, it is an invasive procedure that can be complicated by prolonged pericatheter tract oozing (18). In addition, patients would probably prefer a thrombolytic infusion because of its noninvasive nature.

Currently, the best method to minimize catheter malfunction is careful initial catheter insertion with good positioning of the catheter tip under fluoroscopy. Unfortunately, the optimal position and orientation of the catheter tip is unclear. In rats, a fibrin sheath does not envelop the catheter tip if it is in the right atrium (24). This is not the case for humans. Nevertheless, there is a growing consensus that the catheter tip should be at the superior vena cava/right atrial junction or in the right atrium (1). For dual-lumen catheters, Trerotola et al (10) emphasized the importance of orienting the arterial port tip toward the lumen and away from the vessel wall. For catheters positioned in the atrium, they recommended orienting the arterial port medially, toward the tricuspid valve. For catheter tips in the superior vena cava, they recommended that the arterial port be oriented laterally unless the tract is parasternal, in which case medial orientation of the arterial port was suggested. Oncay et al (25) examined the position and orientation of the catheter tip with respect to the need for subsequent intervention. They found no difference in malfunction rates between catheters with tips placed at the junction of the superior vena cava and the right atrium and those with tip placement in the atrium. Although the numbers were small, their preliminary results agreed with the DOQI Vascular Access Workgroup's opinion (1) by suggesting that catheter tips above the junction of the superior vena cava and the right atrium are more prone to malfunction. In addition, right internal jugular catheters with the arterial port oriented laterally at any level were more predisposed to malfunction; the numbers were again too small to draw firm conclusions, but are contradictory to the recommendations of Trerotola et al (10). Although central catheter tips have been shown to withdraw proximally in the upright position as opposed to the supine position (26,27), associated deleterious effects on dialysis catheter function have not been demonstrated.

Much remains to be learned about the prevention and treatment of dialysis catheter malfunction. New catheter designs, including subcutaneous implantable dialysis ports and nonthrombogenic catheter materials, are on the horizon. Low dose warfarin has been suggested in at least one study to decrease the incidence of catheter malfunction (12). Regarding therapy, we selected a 4-hour UK infusion to allow more expedient treatment than the previously reported 6-hour infusions (10,11). Nevertheless, if an even shorter thrombolytic infusion or bolus could provide similar results, (12) patients could be treated and return for dialysis on the same day. The gradual transformation of the pericatheter sheath from fibrin-containing material to organized fibrous connective tissue (24) suggests that thrombolytic instillation or infusion will lose effectiveness after longer catheter indwell times. As previously stated, the effectiveness of catheter exchange relative to a thrombolytic infusion remains to be elucidated; some have suggested balloon dilation (8,28) or mechanical disruption (8,10) of the fibrin sheath as an adjunct during catheter exchange; this has not

been studied in a systematic fashion either.

In conclusion, our study demonstrates that both UK infusion and sheath stripping allow a reasonable period of additional function for well-positioned central dialysis catheters with poor flow rates. Unfortunately, there is little reported experience with other thrombolytic agents for catheter clearance. We are beginning a catheter clearance feasibility study to determine the effectiveness and safety of tissue plasminogen activator. Conceptually, tissue plasminogen activator administered in dose-equivalent infusions to UK should be similar in effectiveness and safety and may be faster than UK infusions. Although we did not detect a significant difference in outcome between UK infusion and sheath stripping, we prefer a thrombolytic infusion because it is noninvasive, preferred by patients, and safer. We reserve stripping for rare cases in which thrombolytic infusion fails or is contraindicated and catheter exchange or replacement cannot be performed.

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