Initial Performance of Tesio Hemodialysis Catheters

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PURPOSE: This retrospective study was performed to investigate the authors' clinical observations that suggest that Tesio hemodialysis catheters may initially have suboptimal blood flow rates, which improve spontaneously after several hemodialysis treatment sessions.

MATERIALS AND METHODS: Sixty Tesio twin hemodialysis catheters were placed in 49 patients during a 2-year period. Thirty twin catheters were placed by radiologists, and 30 were placed by surgeons. The catheter blood flow rates and catheter line pressures, which were recorded during each of the first five hemodialysis treatment sessions, were reviewed and analyzed to determine the performance of each catheter during the first five hemodialysis treatments. In addition, the authors compared the site of catheter placement and responsible service (surgery or radiology) using this catheter performance data.

RESULTS: Twenty-six catheters (43%) provided adequate blood flow (250 mL/min) throughout the first five hemodialysis sessions. Twenty-six catheters (43%) had inadequate or variable blood flow rates, some of which improved without intervention. Eight catheters (13%) required an intervention before the first five hemodialysis sessions had been completed. Right-sided catheters performed better than left-sided catheters. There was no difference in performance between catheters placed by surgeons and those placed by radiologists.

CONCLUSION: This investigation supports the authors' suspicion that some Tesio catheters may have inadequate initial performance but the blood flows can improve, without intervention, during the first five hemodialysis sessions/2 weeks of use.

EFFICIENT hemodialysis is necessary to minimize a patient's time connected to a hemodialysis machine and to maximize the number of patients a hemodialysis unit can service. The amount of time that a patient is connected to a hemodialysis machine is related to several variables, including dialysis prescription, body weight, and the rate of extracorporeal blood flow that can be achieved through the patient's vascular access. The limiting factor for maximum blood flow is usually the vascular access. The search for convenient and durable sites for hemodialysis access continues. Arteriovenous fistulas or polytetrafluoroethylene grafts traditionally provide longer patency and better blood flow rates than tunneled catheters (1). However, patients must wait weeks to months after placement for these vascular access sites to mature before use. Grafts in particular have a limited lifespan, and once upper and lower extremity sites have been exhausted, alternative hemodialysis access is needed.

Tunneled central venous hemodialysis catheters fill such a need. They are used during the maturation of arteriovenous fistulas, as well as for permanent use when
grafts or fistula sites have been exhausted. Having the catheter tunneled through the subcutaneous tissues probably reduces the risk of catheter infection and prolongs catheter life (2). A variety of tunneled hemodialysis catheters are commercially available and several different types are utilized at our institution.

Anecdotal experience at our institution and others suggests that the Tesio hemodialysis catheters may initially experience suboptimal blood flow rates, with spontaneous improvement after several hemodialysis treatment sessions. This study was performed to investigate this suspected phenomenon.

**MATERIALS AND METHODS**

This retrospective study was approved by our institution’s Human Studies Committee. A search of the computer database of the outpatient hemodialysis unit based at our institution returned the names of all patients who had received a Tesio twin hemodialysis catheter through July 1, 1997. The radiology information system and hospital medical records were used to supplement this patient information regarding catheter insertion site, responsible service (surgery or radiology), and any interval interventions that were performed on the catheters. Patients who had multiple catheter insertions were studied separately for each catheter pair.

The Tesio twin catheter system (Medcomp, Harleysville, PA) consists of two separate silicone catheters, 10 F in diameter and 40 cm in length. Six multiple side holes, in a spiral configuration, are located along 3.5 cm of the distal catheter. In addition, the distal tip has a large end hole. A Dacron cuff is fixed 22 cm from the distal tip of each catheter, around a football-shaped focal widening of the catheter’s outer diameter. After insertion, the catheter is cut to appropriate length and color-coded removable Luer-lock hubs are attached.

Tesio catheters are placed by both the surgical and interventional radiology services at our institution.

During surgical placement, a standard surgical site preparation of the right side of the neck was performed. The right internal jugular vein, subclavian vein, or common femoral vein was accessed with an 18-gauge needle at two separate sites, at least 1 cm apart, with use of anatomic landmarks. Anatomic landmarks guided access; ultrasound guidance was not used. A small incision was made over the access site. The catheters, which were clamped to prevent air entry, were inserted into the vein through 11-F peel-away sheaths. Intraoperative fluoroscopy was used to confirm tip position. For jugular and subclavian placement, the arterial limb was positioned in the superior vena cava and the venous limb was positioned 4 cm distally, in the upper right atrium. Common femoral catheters were positioned with the tips in the infrarenal inferior vena cava. Each catheter was then separately tunneled from the incision site in the jugular vein to the right anterior chest wall or, in the case of femoral catheters, laterally. The catheters were cut to appropriate length and the Luer-lock hubs were attached. Both catheters were flushed with saline, then with 25,000 U of urokinase (5,000 U/mL), divided into two 2.5-mL boluses. The dermatotomy site was closed with 5-0 vicryl subcutaneous and 4-0 Maxon PDS (Ethicon, Somerville, NJ) subcuticular sutures.

Catheter placement in the interventional radiology suite was similar to placement in the surgical procedure. After standard surgical site preparation the right internal jugular vein was accessed at two sites, at least 1 cm apart, with use of ultrasound guidance. If both internal jugular veins were occluded, subclavian vein placement was performed under fluoroscopic guidance, with iodinated contrast material injected into a peripheral intravenous line to opacify the venous entry site. In the setting of bilateral internal jugular and subclavian vein occlusions, the right common femoral vein was accessed using anatomic landmarks.

The venotomy sites are dilated with 11-F peel-away sheaths, which allowed catheter placement into the vein. Fluoroscopy was used to verify position of the catheter tips, positioned 4 cm apart, in the superior vena cava and upper right atrium, or in the infrarenal inferior vena cava for femoral catheters. The two catheters were separately tunneled to the anterior right chest wall (or lateral for femoral catheters) using the “football” tunneling device included in the Tesio catheter set. The widened “football” portion of the tunnelling device was not used to dilate the inferior 3 cm of the subcutaneous tunnel to decrease the risk of the catheter pulling out. The catheters were cut to appropriate length and the Luer-lock hubs were attached. Catheters were flushed with saline, then with adequate heparin (1,000 U/mL) to fill each catheter. The dermatotomy was closed with a single 0 monocryl stitch and the catheters were sutured to the skin with a 0-silk stitch. The silk suture was scheduled for removal 2 weeks later, during dialysis.

After surgical or radiologic placement, the Tesio catheters were immediately ready for hemodialysis treatment.

Patients are routinely scheduled to undergo hemodialysis treatment three times each week. During each session, a hemodialysis blood flow sheet is filled out by the nursing staff. Catheter blood flow rate (Q), “arterial” aspiration limb pressure (AP), “venous” return limb pressure (VP), vital signs, dialysate flow, and other hemodialysis parameters were recorded during each hemodialysis session. Although the red limb is usually the aspiration catheter and the blue limb the blood return catheter, hemodialysis nurses were at liberty to reverse the flow as needed to maintain adequate blood flow rate, and these changes were incompletely documented on the dialysis sheets. Therefore, independent evaluation of the red and blue limb function could not be reliably performed retrospectively. Blood flow and pressure measurements were routinely recorded at 30-minute in-
clements. More frequent measurements were recorded if there was difficulty maintaining adequate flow. The blood flow rate was maximized at each session while keeping arterial and venous limb pressures below 300 mm Hg. The blood flow was not increased beyond 450 mL/min. At our institution, the hemodialysis center considers a flow rate of at least 250 mL/min to be adequate; this was the cutoff value used for this study. Dialysis Outcomes Quality Initiative (DOQI) guidelines, which were published after most of the data from the study had been collected, indicate that 300 mL/min should be the minimum.

The blood flow and catheter limb pressure information from the first five hemodialysis sessions after insertion of each Tesio catheter were reviewed. This length of time was selected based on our anecdotal experience that the catheters, which seemed to achieve spontaneous improvement, did so during the first few dialysis sessions. Those patients who were hospitalized during any of their first five hemodialysis sessions underwent dialysis in the acute inpatient hemodialysis unit at our institution. Hemodialysis data sheets from those sessions were available in the inpatient medical records and were also reviewed.

For statistical analysis, the blood flow rates and catheter limb pressures were averaged to a single blood flow rate, arterial limb pressure, and venous limb pressure value for each session. A mean of the recorded values from each hemodialysis session was used, without regard to the time interval between values during each hemodialysis treatment session. Measurements from poorly functioning catheters were more frequently recorded. Quartile plots of the blood flow and pressure values were created, graphically presenting the distribution of means at each of the first five hemodialysis sessions. Graphs of inter-session flow differences were also generated. Two-way analysis of variance (repeated measures ANOVA) compared the results for individual patients from session to session.

The original recorded blood flow data from each session were analyzed to evaluate catheter function. This avoided the limitation inherent in averaging recorded values in that a poorly functioning catheter with multiple frequent recorded measurements may average out to indicate the catheter is functioning even more poorly. Adequate function was defined as the ability to maintain extracorporeal blood flow rates of 250 mL/min or greater throughout the entire hemodialysis session. We compared catheter performance to the site of catheter placement, responsible service, and the number of previous catheters. We also evaluated the performance of catheters over the temporal course of the study period to evaluate for effects of a learning curve.

RESULTS

A total of 60 Tesio twin catheters were placed in 49 patients from the first insertion on August 14, 1995, through July 1, 1997. Six patients had two Tesio twin catheter placements during the study period, one patient had three, and one patient had four. Thirty of the Tesio twin catheters were placed by surgeons, and 30 were placed by interventional radiologists. The distribution of catheter site was right internal jugular vein (n = 23), left internal jugular vein (n = 20), left subclavian vein (n = 10), right subclavian vein (n = 4), and right common femoral vein (n = 3).

In the first attempted hemodialysis sessions, 22 of the 60 catheter pairs provided inadequate flow (not maintaining 250 mL/min or greater). Twenty-six of the 60 catheter pairs provided adequate flow throughout all of the first five dialysis sessions. Thirteen catheters achieved variable flow rates (ie, sometimes adequate and sometimes inadequate) during the first five hemodialysis sessions, without a definite pattern. Nine catheters had inadequate flows during both of the first two sessions, with adequate flow achieved in later sessions without intervention. Two Tesio catheters maintained adequate function during the first four sessions but were unable to maintain adequate flow during the fifth session. Two catheters could not maintain adequate flow rates through any of the five hemodialysis sessions.

Eight catheters required an intervention before five hemodialysis sessions had been completed. One limb of a surgically placed common femoral catheter was repositioned from an ascending lumbar vein into the inferior vena cava. The red limb of a radiologically placed left internal jugular pair was repositioned from the innominate vein to the superior vena cava. The blue limb of another radiologically placed left internal jugular pair developed a kink, which required further subcutaneous dissection near the venotomy. One surgically placed left internal jugular pair provided no flow and was completely replaced surgically 2 days later. Four catheters (radiologically placed left internal jugular, surgically placed left internal jugular, surgically placed left subclavian, and radiologically placed right common femoral) lost function due to thrombus and were restored to improved function after fluoroscopically guided passage of a biliary biopsy brush through the lumina to the end holes, clearing clot from the lumen and from the side holes.

The catheters were divided into four groups by performance over time as follows: A = adequate blood flows during the first five hemodialysis sessions; B = inadequate blood flow initially with spontaneous improvement; C = variable/late blood flow problems; and D = intervention needed before five hemodialysis sessions completed.

Quantile plots of Q, AP, and VP showed all three tended to be more variable in the first session than in later sessions. Two-way ANOVA confirmed the impression of a weak pattern in that the results approached statistical significance for the mean Q (P = .06), mean AP (P = .08), and mean VP (P = .10).

A graph of the distribution of the inter-session differences of the means showed what appeared to be a bimodal distribution for Q, sug-
surgical or radiologic placement of catheter function was assessed for its effect on catheter function. The site of placement had an evident impact on catheter function.

Two sessions were assessed to conform to a normal distribution centered at zero and had a substantially larger increase in flow between the first five hemodialysis sessions. However, even at the end of the study period, half of all catheters did not achieve consistently acceptable flow rates. All but one of the catheters requiring early intervention were placed during the first half of our study. The later catheter that required intervention was a common femoral vein catheter. The proportion of catheters that spontaneously improved did not significantly vary during the temporal course of the study.

Only eight patients had more than one catheter pair placed during the study period (Table 4). There is no clear trend of worse function in such situations, although the power of the study is insufficient to detect small to moderate differences.

**DISCUSSION**

Our experience with the Tesio twin catheter system confirms that there is a subset of catheters that demonstrates suboptimal initial performance, which spontaneously improves during the course of several hemodialysis treatment sessions. However, the exact etiology remains elusive.

The spontaneous improvement may reflect a learning curve as the patient and hemodialysis center determine how to optimize performance of a newly placed catheter.

It has been anecdotally suggested that thrombus may form within the catheter during the insertion procedure while the unflushed catheter resides within the vein. Some residual thrombus may persist during the first few dialysis sessions until cleared by the flow of blood through the catheter and the body's own thrombolytic system. At
our institution, the surgeons routinely instill urokinase into the catheters immediately after placement but the interventional radiologists flush the catheters with heparin solution alone. All catheters are routinely flushed with heparin after each hemodialysis session. The manufacturer recommends flushing with urokinase (5,000 U/mL) diluted with enough heparin (5,000 U/mL) to equal the priming volume of each lumen. The performance results are similar, which seems to discount the procedural thrombus theory. The long intravascular segment of the catheter contains multiple side holes, which when positioned in the bloodstream of the vena cava, probably results in the rapid wash-out of the instilled urokinase solution from the distal segment of the catheter. Because there is no evidence in our institution of a beneficial effect of the urokinase, we plan to continue the cost-saving measure of heparin flush alone.

Another hypothesis is that tunnel edema, due to the tissue trauma from the insertion procedure, causes compression of the catheter, which may be the origin of the suboptimal blood flow during the initial hemodialysis session. To our knowledge, narrowing of the catheter lumen, which would be expected if significant tunnel edema occurred, has not been demonstrated on postinsertion imaging studies. The tunnels themselves are usually oversized by the wide metallic device (“football”) used to create the tunnel. Any tunnel edema would have to be substantial to effectively narrow the oversized tunnel before beginning to compress the smaller catheter tubing within. The catheters are usually readily palpable in their subcutaneous tunnel. Our experience in physical examination of patients shortly after catheter placement does not support tense tissue edema of the sort that would be required to compress the tubing.

The silk suture placed around the catheter near the skin exit site could, if too tight, compromise the inner lumen of the catheter. We did not obtain a radiograph of the catheter at the suture site to evaluate. However, one would expect a disproportionate number of catheters placed radiologically to demonstrate this phenomenon because the surgeons placed no sutures to secure the catheter, relying on the wider “football” in the subcutaneous tunnel to prevent accidental removal.

The site of placement seems to be the most important predictor of catheter function. Overall, the right-sided catheters functioned better than left-sided catheters. Right-sided approaches result in a shorter course and fewer intravascular corners to reach the superior vena cava or right atrium than left-sided approaches. The more tortuous left-sided approach may lead to catheter kinks around intravascular curves. Autopsy studies have demonstrated reactive connective tissue growth along the intraluminal surface of Tesio catheters (2). The longer intravascular course of the left-sided catheters may result in a more extensive reaction to the foreign body, possibly accounting for the worse performance.

A disproportionate number of the catheters with initial poor blood flow, which showed spontaneous improvement, were internal jugular catheters. The etiology of this phenomenon remains elusive, and may be related to the relatively shorter intravascular course or the relatively longer subcutaneous tunnel length.

Our investigation demonstrated that the common femoral approach provided consistently suboptimal performance and should be avoided if alternate central access sites are available.

While our functional results were the best from the right subclavian approach, the right internal jugular approach was the next best and should be the preferred insertion site for tunneled cuffed hemodialysis catheters (3,4). This approach avoids acute and chronic injury to subclavian veins, which might compromise the longevity of a future ipsilateral upper extremity arteriovenous fistula or graft. The tunnel to the anterior chest wall is convenient to manage and keep clean.

There was no difference in short-term performance between catheters placed by surgeons and those placed by radiologists, despite some differences in technique. The improvement of catheter performance during the temporal course of the study period does suggest a learning curve in both the surgical and radiologic groups. As with other procedures, there is an efficiency that comes from experience. We have experimented with various tunnelling methods to provide more gradual curves of the catheter in the subcutaneous tunnel to avoid acute angulation that might decrease flow. A lateral approach to the internal jugular vein is also helpful to avoid acute angulation in the tunnel course.

Despite optimizing our placement procedure, we have achieved only mediocre overall performance using the Tesio twin catheter system. The blood flow rates achieved in this study did not meet minimally acceptable performance according to the DOQI guidelines, which state that the percentage of tunneled catheters that are unable to deliver adequate blood flow (>300 mL/min) during the first attempted dialysis treatment should be no more than 5% (5). Twenty-two of the 60 catheters (37%) in our study provided inadequate blood flow during the first attempted hemodialysis session; of these, blood flow improved in nine (41%). Our poor results are in distinction to other reports of acceptable results (6,7). Perhaps there is an especially long learning curve in our teaching institution with a large number of staff, fellows, residents, and nurses learning catheter insertion and care.

Our study did not examine catheter infection rate or durability. Further study may be warranted to examine the relationship of these factors to long-term performance. The study examined only the first five dialysis sessions; following the cathete-
CONCLUSION

Our experience supports our starting hypothesis, that a subset of Tesio hemodialysis catheters initially provides suboptimal blood flow with spontaneous improvement during the course of the first few hemodialysis sessions. Although this phenomenon is more often associated with an internal jugular approach, the exact mechanism remains unknown.

We recommend avoiding having patients return to the interventional radiology department for catheter checks or injections due to suboptimal flows during the first two hemodialysis sessions. Some of these catheters will spontaneously improve with time. If after three hemodialysis sessions the blood flow remains inadequate, intervention is warranted.

The early performance of the Tesio catheters in our experience did not meet DOQI guidelines, and further study may be helpful to evaluate long-term function and adequacy of this type of catheter for intermediate and long-term hemodialysis access.

References