9 Approach to a Nonfunctioning Catheter

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Introduction

Despite substantial efforts by nephrology community to reduce utilization of dialysis catheters, majority of end-stage kidney disease (ESKD) patients in the USA initiate hemodialysis (HD) with a tunneled dialysis catheter (TDC) with approximately one-quarter of them remaining catheter-dependent thereafter [1]. TDCs are associated with decreased patient survival [2], as well as multiple complications, such as central venous stenosis (CVS) [3, 4], infection [5, 6], and thrombosis [7]. In many cases, these lead to catheter dysfunction recently redefined as "failure to maintain the prescribed extracorporeal required for adequate hemodialysis" by 2019 KDOQI guidelines that eliminated specific target blood flow rates and circuit pressures [8]. Catheter dysfunction can increase arterial and/or venous pressures in the dialyzer circuit necessitating blood flow reduction and can result in significant recirculation leading to lower dialysis efficacy. Left untreated, such catheters require premature removal when they become nonfunctional (i.e., with one or both lumens that cannot be aspirated) [9]. Current KDOQI guidelines recommend routine assessment for TDC dysfunction based on history, physical examination, and inspection of the catheter.

TDC dysfunction is usually viewed as presenting early or late, which helps to determine etiology of the problem and to guide subsequent management. Dysfunction noted immediately after the catheter placement is likely due to the positioning of the catheter, preexisting vascular abnormalities (e.g., central venous stenosis) (Fig. 9.1), or mechanical damage to the catheter (e.g., tight suture or perforation). Dysfunction developing after successful initial use is usually due to thrombosis, fibrin sheath formation around the catheter, mural thrombus adhering to the catheter tip, or new CVS.

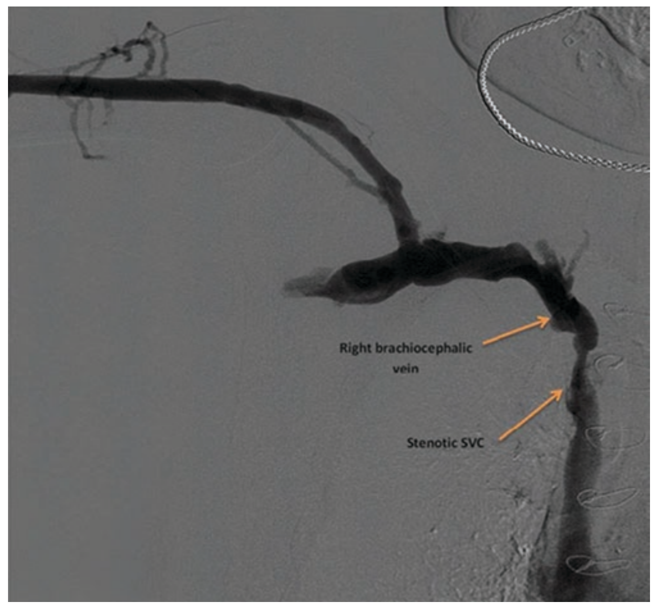

Fig. 9.1 Central vein stenosis

Initial Evaluation and Treatment

Catheter dysfunction is usually detected at a dialysis unit, where several steps can be taken to evaluate and resolve the problem. Improvement of blood flows after patient repositioning (e.g., in Trendelenburg position) is indicative of catheter tip malposition. Reversal of inlet and outlet lumens may overcome the ball valve effect of the fibrin sheath or a vessel wall in direct contact with one of the catheter tips. Dialysis equipment should be assessed for malfunction leading to activation of pressure alarms. Examples of equipment problems include line kinking, dialyzer pump failure, dialyzer

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clotting, etc. Instillation of a thrombolytic agent, such as alteplase, in TDC lumens for 1 h and up to 24 h is usually performed when intraluminal stenosis is suspected. Endoluminal fibrin analysis system (FAS) brush has been employed in attempt to maintain patency of various catheter types [10]; however only one small study sought to evaluate its effectiveness in TDC reporting positive results [11]. Figure 9.2 suggests a diagnostic and therapeutic algorithm for general nephrologists and dialysis unit staff to follow when catheter dysfunction is present.

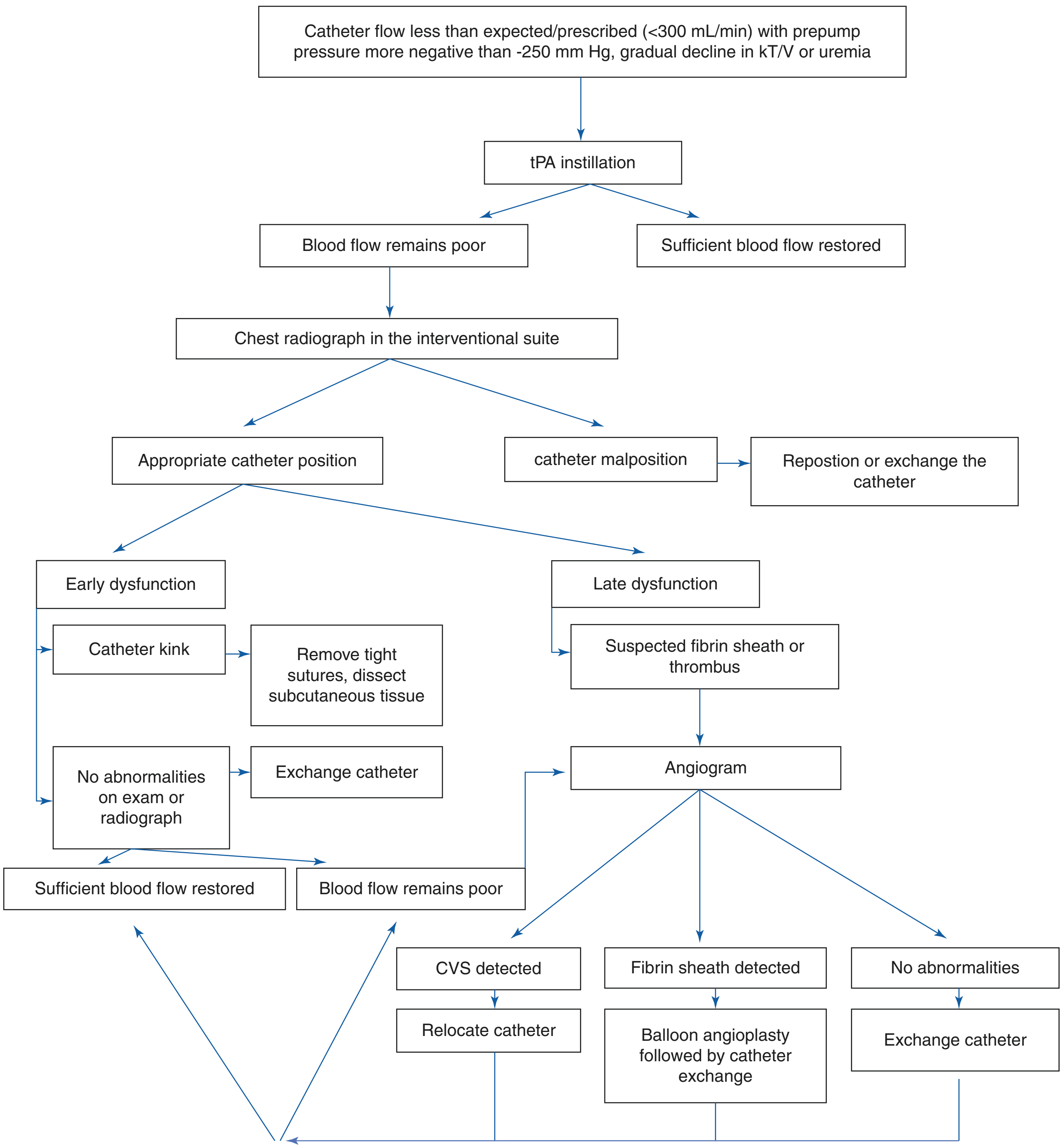

Fig. 9.2 Diagnostic and therapeutic algorithm for catheter dysfunction

Diagnostic Evaluation in an Interventional Suite

If adequate blood flows cannot be reestablished at the dialysis unit, referral to the interventional suite is indicated. There, a physical examination of the malfunctioning catheter should be performed as the first step in evaluation and should include aspiration of luminal contents, assessment for kinks, integrity, and tunnel infection of the TDC. A radiograph should be obtained to assess the catheter positioning. This may reveal a kink in the catheter, a catheter tip that migrated into the superior vena cava (SVC) or even into either of the brachiocephalic veins. The latter may happen in obese patients, whose cuff-to-vein catheter length may increase considerably with movement, thereby shortening the intravascular catheter length due to immovable subcutaneous cuff position. A curved caudal portion of the catheter or a doughnut ("down the barrel") appearance of the edge of the catheter's tip is indicative of azygous vein cannulation. Location of the distal portion of the catheter in the midsternal or left parasternal region should raise a suspicion of intraaortic placement of the catheter. A lateral radiograph showing the catheter projecting toward anterior mediastinum may further strengthen this suspicion [12, 13].

If there's a suspicion for a pericatheter thrombus or fibrin sheath, angiogram can be performed by slowly injecting 10–15 ml of contrast by hand through each catheter port. In presence of a fibrin sheath, the contrast will outline the sheath flowing retrograde from the catheter tip (Fig. 9.3). Antegrade contrast flow may also demonstrate a pericatheter filling defect consistent with a mural thrombus [14]. Alternatively, the catheter may be retracted over an Amplatz wire to position its tip in the internal jugular vein. In this case, the contrast flows antegrade clearly outlining the lumen of the fibrin sheath (Fig. 9.4) [15].

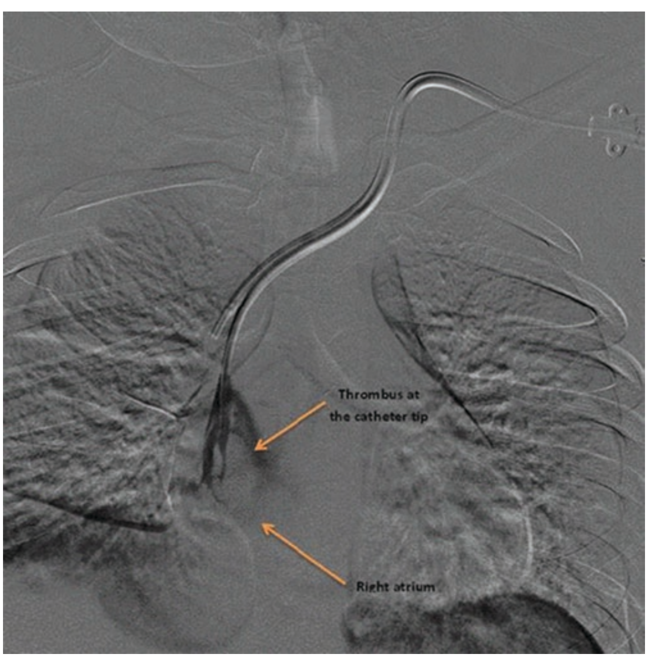

Fig. 9.3 Thrombus at the catheter tip

Fig. 9.4 Fibrin sheath

Interventions Directed at Specific Causes of Catheter Dysfunction

Catheter Damage

If a catheter wall integrity is compromised anywhere along its extravascular portion, either as a result of a manufacturing defect or an operator's mistake, the patient may present with either persistent bleeding from the tunnel or symptoms of air embolism [16, 17]. Diagnostic test of choice in this case is a catheterogram that can be performed by hand-injecting 10 cc of contrast into each catheter lumen. Extravasation of contrast confirms the diagnosis necessitating exchange of the malfunctioning catheter for a new one.

Catheter Kinking

The initial radiograph taken in the IR suite may immediately expose a problem such as a catheter kink. Kinking occurs either as a result of a "high stick," when the entry in the internal jugular vein was made high above the clavicle in the neck forcing the catheter to take a sharp turn from the tunnel and into the vein or when the catheter gets caught in the insufficiently dissected subcutaneous tissue at the neck incision site after it has been inserted in the vein through the splitsheath or over the wire. In the first scenario, the existing TDC has to be removed, and a new one has to be placed lower in the internal jugular vein after sufficient hemostasis has been achieved. In the second scenario, an Amplatz wire placed in the IVC through one of the lumens may be used to stabilize the catheter. Next, an incision in the skin overlying the kink is made with care taken not to nick the catheter, and a blunt-tip hemostat is used to dissect the tissue underneath the kink. Moving the catheter back and forth over the wire while applying pressure to the catheter bend usually allows the operator to eliminate the kink.

Tip Malposition

Due to complex anatomy of the thoracic veins, catheter malposition is common [18]. In the settings of SVC stenosis (itself common in HD patients) and resulting venous aberrations, such as dilatation of the azygous vein, the likelihood of incorrect catheter positioning is even higher [19]. Even if initially appropriately positioned, catheters have been described to migrate spontaneously, most commonly in the contralateral innominate vein generating an array of complications [12, 20]. TDC dysfunction in these cases is due to direct contact of the catheter tip or its side holes with the vessel wall causing obstruction of blood flow. A TDC placed through the left internal jugular vein may induce thrombus formation even if its tip only moves up into the upper portion of the SVC [21], because of the 90 degree turn the catheter has to take from the left brachiocephalic vein into the SVC. If the catheter is too short, its tip will be sticking against the right lateral wall of the SVC irritating endothelium.

If the TDC is found to be malpositioned within the first week of its placement, attempts can be made to advance it into the lower portion of the SVC over an Amplatz wire placed through one or both catheter lumens. Older TDCs will have fibrous tissue formed around the cuff necessitating subcutaneous dissection and subsequent exchange for a new TDC. An operator may choose to advance the new TDC further into the SVC to minimize the future catheter migration; however, observations from a small patient series reported by Haygood et al. [12] suggest this strategy does not necessarily changes the outcomes. Nevertheless, this option may still be appropriate for TDCs with split-tip design, as its tips are preformed to separate at an angle making it more likely for the shorter tip to end up in an inappropriate position. Because of that, some experts recommend placing the tips of a split-tip catheter in the right atrium [22]. This recommendation is somewhat controversial, as there are reports of higher incidence of atrial thrombi, vessel wall perforation leading to cardiac tamponade, and cardiac arrhythmias [23, 24], associated with atrial positioning of a catheter. Supporting evidence, however, is rather insufficient to advice against such practice. If the TDC is to be exchanged, an operator may also consider changing a split-tip catheter for a step-tip or symmetric-tip ones, which should theoretically lower the chances of tip migration.

Catheter Thrombosis

Intraluminal thrombosis remains the most common cause of TDC dysfunction despite routine use of anticoagulant locking solutions [25, 26]. After the initial evaluation ruling out a positional or mechanical problem, an instillation of a thrombolytic agent is recommended. Several drugs, such as urokinase and streptokinase, have been used in the past, but of drugs currently available on the market, only two – alteplase and reteplase – have been used for TDC thrombosis. Although reteplase has been purported to have superior clot penetration [27], it is rather cumbersome to use requiring frozen storage and aliquoting individual doses [28]. Thus, use of alteplase (t-PA) is more common in clinical practice. The dose of 2 mg per lumen is usually instilled for about an hour; however, if blood flow is not restored, the alteplase is aspirated from the lumens, and another dose is instilled for 10–24 h, although evidence exists that prolonged dwell time may not influence subsequent rates of TDC patency [29]. In general, treatment of intraluminal thrombosis with thrombolytics is associated with 70–88% immediate success rate of restoring adequate blood flow [29–33]. At 2 weeks following thrombolysis, only half of the TDCs remain patent [29]. These unsatisfactory patency rates are likely explained by the fact that catheter dysfunction in many patients included in these studies was due to thrombi extending outside of the catheter lumen or fibrin sheath that require a more intensive therapy than described above.

As previously mentioned, a FAS brush can be employed in the interventional suite in attempt to mechanically remove an intraluminal thrombus; however, the outcome and complication data are limited to a small trial reported by Tranter et al. [11]. The immediate success rate of 73% and 6-week patency of 50% are comparable to those of thrombolytic use, and it is unclear if this novel strategy can improve outcomes if used in combination with thrombolytic therapy.

Fibrin Sheath

Recurring use of thrombolytics should in itself raise suspicion for the presence of fibrin sheath around the catheter (Fig. 9.4) [34] – a problem affecting 40–100% of central venous catheters [35–37]. While thrombolytic therapy was demonstrated to have immediate success rate of 91%, 2-month patency was, expectedly, quite low at approximately 36% [38]. Subsequently, other strategies for restoration of catheter patency have been evaluated. Those included TDC exchange, percutaneous fibrin sheath stripping (PFSS), angioplasty disruption, and internal snare maneuver. In one study, patency rates were shown to be superior with catheter exchange compared to PFSS at 4 months [15], and in another one, PFSS did not improve catheter patency rates when compared to urokinase over 45 days following the procedure [14]. Yet another study showed no differences in immediate or long-term (6 months) outcomes following TDC exchange, PFSS, and angioplasty disruption [39]. In a pilot randomized controlled trial, Oliver et al. [35] demonstrated significantly improved median times to recurrent TDC dysfunction associated with angioplasty disruption followed by TDC exchange compared to TDC exchange alone (373 days versus 97.5 days, $p = 0.22$). Subsequently, two retrospective studies did not detect any difference in subsequent catheter-associated infection or TDC dysfunction. Based on these data, 2019 KDOQI guidelines leave the decision to disrupt the fibrin sheath and the choice of the procedure to the operator's discretion. Another technique of fibrin sheath removal by an "internal snare" has been described in 2007 and has not been compared head-to-head with other fibrin sheath disruption procedures. Authors, however, report 100% immediate success and 100% patency rate at a mean follow-up of 17 weeks [40]. Below is the brief description of these procedures.

TDC Exchange

One or two Amplatz wires are placed in the IVC under fluoroscopic guidance. Subcutaneous tissue around the cuff is dissected under local anesthesia with a hemostat, and the indwelling TDC is retracted over the wires that are then sterilized. A new TDC is then inserted through the existing tunnel over the wires into the appropriate position.

Percutaneous Fibrin Sheath Stripping

A standard 6-French sheath is placed in the femoral (usually right) vein, and a diagnostic angiographic catheter is advanced into the SVC over a guide wire. Next, the guide wire is exchanged for a 25-mm or 35-mm diameter nitinol loop snare, which is then engaged and advanced cranially to encircle the catheter. An Amplatz wire placed in the IVC though one of the TDC lumens may facilitate this maneuver. After the snare device reaches the catheter insertion site in the internal jugular vein, it should be tightened and retracted all the way out to manually clean it thereby minimizing the risk of distal embolization of fibrin. Contrast can be injected through the catheter to evaluate the outcome of this procedure.

Angioplasty Disruption

The indwelling TDC is retracted over two Amplatz wires as described in the "TDC Exchange" section above. A long (20 cm) 7-French sheath is then advanced over one of the Amplatz wires into the SVC, and a 12-mm balloon is inserted through the sheath and inflated several times along the fibrin sheath tract. To maximize the fibrin sheath disruption, the balloon may be moved back and forth in the SVC while inflated. Post-procedure angiography should be performed to ascertain success of the procedure.

Internal Snare

A 0.089-mm nitinol Terumo wire is folded in the middle to form a U-shaped loop and advanced through each TDC lumen under fluoroscopic guidance until the loop emerges from the catheter tip. Moving the loop back and forth around the tip of the catheter disrupts the fibrin sheath overlying the distal and proximal ports and restores the catheter flow.

Central Vein Stenosis

Stenosis of the brachiocephalic vein or SVC does not affect the TDC function as long as the catheter tip remains outside the stenotic segment and not in direct contact with the vessel wall (Fig. 9.5). If a patient develops SVC syndrome, however, the catheter has to be relocated. In the settings of SVC stenosis, the usual choice is a femoral vein. In many patients with long history of vascular access problems, internal jugular and femoral veins may become inaccessible, either due to

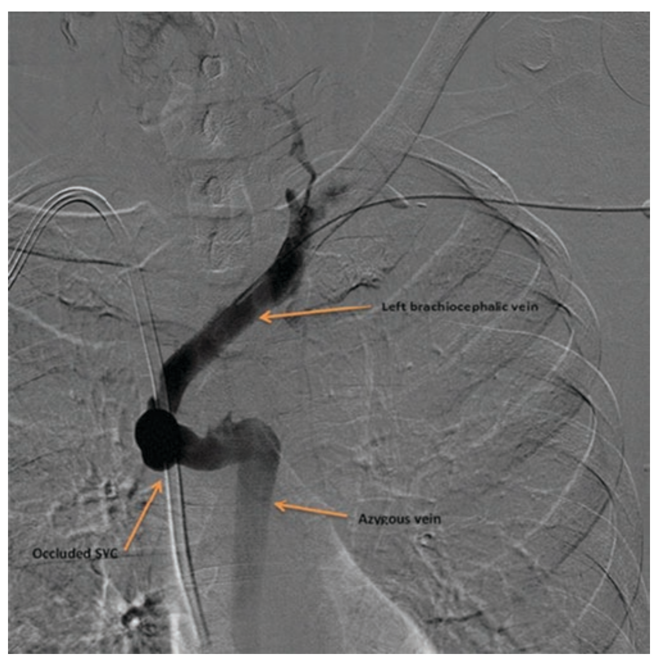

Fig. 9.5 SVC stenosis in the presence of catheter with blood draining via the azygos vein

Fig. 9.6 Right internal jugular vein stenosis

stenosis (Fig. 9.6) or venous stents placed in arteriovenous thigh grafts. Uncommon approaches to cannulation of these patients have been described, including translumbar approach [41, 42] or transhepatic approach [43, 44]. Decision to undertake one approach or the other should be based on an individual patient's anatomy and an operator experience with these procedures. Angioplasty with or without stenting of SVC stenosis should be deferred until after the catheter is removed and only if clinical signs and symptoms of the stenosis persist, because percutaneous intervention appears to accelerate stenosis progression and is associated with 20–30% 12-month patency rates [45, 46].

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