Side holes at the tip of chronic hemodialysis catheters are harmful

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ABSTRACT: Side holes at the inflow tip are necessary for acute hemodialysis catheters without inflow end-hole. Most catheters for chronic dialysis, both single and dual lumen, are also provided with side holes. There are no data in support of the notion that side holes improve blood flow or prolong the life of chronic catheters. The opposite may be true. Firstly, the side holes are created by drilling and have rough edges as can be seen in scanning electron microscopy. Secondly, many times, while removing chronic catheters, either electively or because of obstruction, a clot is found at the tip of the catheter and anchored in the side hole(s). Such a clot is difficult to strip by a snare *in situ*. Thirdly, a difficult to remove clot is formed on the outer surface of the catheter and extends to the inside lumen. If so, the holes have no role in extending the life of the catheter. Fourthly, the heparin or other anticoagulant, which is instilled to the catheter lumen at the end of dialysis, may not reach the catheter tip and/or be leached out in the period between dialyses, thus, predisposing to clot formation at the tip of the lumen. Finally, if the inflow bore is occluded and the blood flows through the side holes, it is likely that the vein intima is sucked into the holes, becomes damaged and causes formation of the mural thrombus. In such a case these holes would not be beneficial in prolonging catheter life, but may even preclude the possibility of inserting another catheter into the same vein at a later date. (The Journal of Vascular Access 2001; 2: 8-16)

KEY WORDS: *Hemodialysis catheters, Catheter tips, Side holes, Scanning electron microscopy*

All currently manufactured catheters for chronic hemodialysis are provided with side holes at the tip of the venous and/or arterial lumen. There are no data to support any benefit of the side holes and it is unclear why these side holes have become routinely made. Manufacturers claim that users demand side holes, believing in better blood flow (personal communication: E. David Fink, Kendall Healthcare Products Co., Mansfield, Massachusetts, June 2000). We suspect that the idea of providing chronic catheters with side holes came from the acute catheters. It seems that there is a widespread belief that the side holes would provide flow in case that a clot occludes the tip.

HISTORICAL BACKGROUND

Shaldon et al. introduced cannulation of femoral vessels for hemodialysis in 1961 (1). Shaldon used polytetrafluoroethylene (Teflon®) tubings for femoral artery and vein catheterization for repeated hemodialysis. Shaldon gradually improved his method and in 1964 used Teflon® tubing with silicone rubber extensions for veno-venous catheterization of femoral veins (2). These catheters were not provided with side holes.

Erben et al. first described subclavian vein cannulation for hemodialysis in 1969 (3). These authors used two single-lumen catheters inserted into both subclavian veins (59 cases), the same subclavian vein (14 cases), or one inserted in a subclavian vein and the other in a femoral vein (28 cases). All subclavian catheters were inserted through the infraclavicular route using the Seldinger method of insertion (4). The catheters did not have side holes.

By the end of the 1970's, soft, small-diameter catheters, used for parenteral nutrition, were modified to provide sufficient blood flow for plasmapheresis (5). These (Hickman) catheters were not

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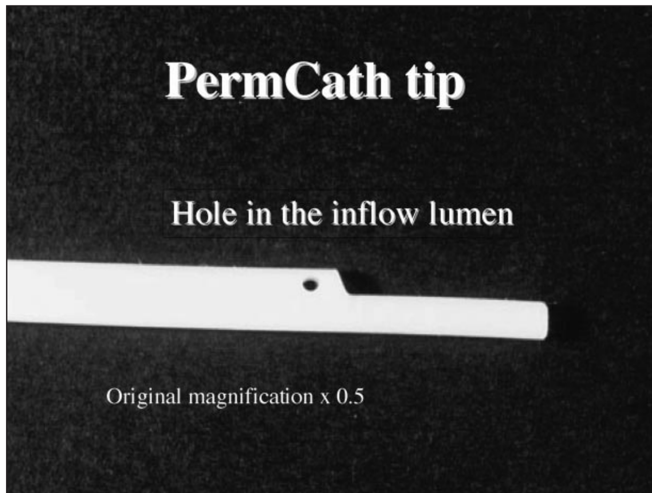

Fig. 1 - ***The tip of PermCath™ and Swan Neck PermCath™ dual lumen catheters (Kendall Healthcare Products Co. Mansfield, Massachusetts). The inflow lumen provided with two side holes.***

Fig. 2 - ***Higher magnification of the PermCath™ side hole and ground outflow tip. Both the holes and the outflow tip look smooth at this magnification.***

provided with the side holes. The Hickman catheters were used for single needle, long-term dialysis in children in the early 1980s (6). The authors reported experience with 26 catheters inserted through the left or right external or internal jugular veins into the right atrium or superior vena cava. A single-needle dialysis system was used and blood flows up to 70 ml/min were achieved.

In the early 1980s, dual or double lumen catheters were introduced to reduce the time of vessel cannulation. Initially, stiff, tetrafluoroethylene (7) or polyurethane (8) catheters were used. The first, double-lumen catheter, was developed by Vas-Cath of Canada and consisted of 17 cm long "arterial cannula" with six spirally placed side holes near the tip, and a 19 cm long inner, coaxially placed "venous cannula". The venous cannula was replaced for each dialysis. Quinton Instruments in Seattle, Washington, developed the second catheter consisting of a septate dual-lumen design. The venous lumen had a small end-hole for guidewire and blood outflow; the arterial lumen did not have the end hole. Therefore, acute catheters required side holes to provide blood inflow and sufficient blood outflow (9). It seems that the idea of providing arterial lumen tip with side holes started at that time.

In the late 1980s, a soft, silicone rubber, dual-lumen catheter (PermCath™) was used in adults as means of "prolonged" or short-term hemodialysis access or when other forms of access were not possible (10-12). The catheter was extruded with dual lumen, cut at the end, and then ground to stagger the tips by about 20 mm. Finally, two side holes were drilled at the arterial tip.

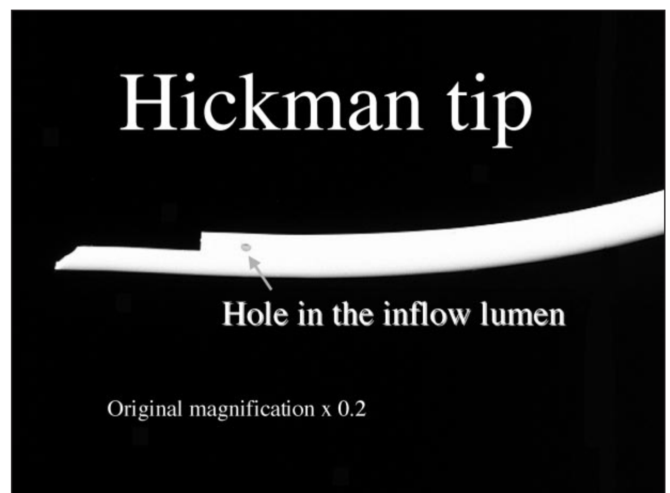

Fig. 3 - ***Hickman dual lumen catheter (BARD Access Systems, Salt Lake City, Utah). Side holes in the inflow lumen.***

As several groups were developing catheters with two lumens, Canaud et al. (13, 14) decided to continue the method of Erben et al. (3) using two single-lumen catheters, but changed the material from polyethylene to silicone rubber and used a jugular instead of a subclavian vein insertion site. The catheters with inner/outer diameters of 2.0/3.2 mm had 6 side holes on the 5 distal centimeters. The catheters were exteriorized by reverse tunneling (from the cervical incision to the skin exit), and extension-tubing adapters were attached to the catheters after their externalization. Canaud catheters were not provided with cuffs and infections were the most common complications of long-

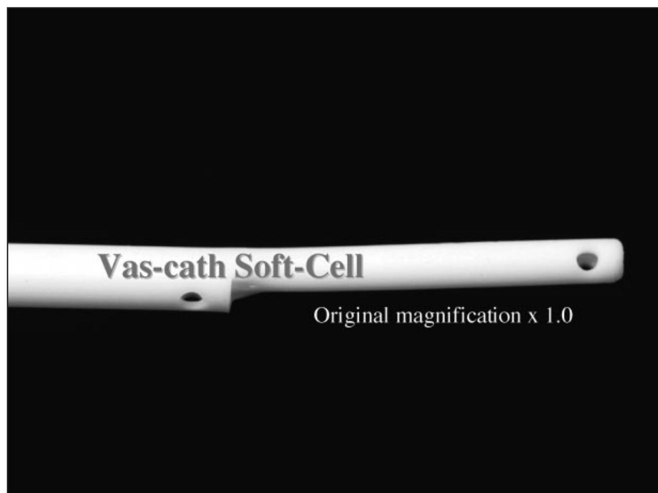

Fig. 4 - ***The tip of the Vas-Cath Soft Cell dual-lumen catheter (BARD, Salt Lake City, Utah, USA). Each lumen is provided with two holes at the end bore. The tip is not tapered.***

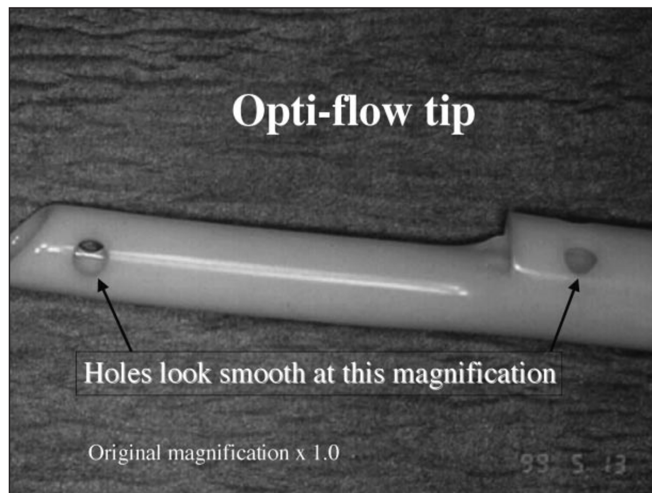

Fig. 5 - ***Opti-Flow dual-lumen catheter. Each lumen is provided with two holes at the end bore. The tip are not tapered. Holes look smooth at this magnification.***

Fig. 6 - ***Tips of the Tesio Catheter (Medcomp, Harleysville, Pennsylvania).***

term use of these catheters (15).

Single lumen catheters for single needle dialysis in adults were developed in the late 1980s. A regular, Tenckhoff peritoneal dialysis catheter was used by Liggett et al. (16). Tenckhoff catheter is provided with multiple side holes at the tip. Thrombotic complications with this catheter were frequent as the anticoagulant leached from the tip through the side holes. A single, silicone rubber catheter with fish-mouth tip to prevent creating vacuum by inflow holes at the vessel wall was developed by Bionic Company (Friedrichsdorf, Germany) and the results with this catheter were reported by Demers et al. (17). The catheter had a single polyester cuff as a barrier to periluminal bacterial penetration, and no side holes at the tip to avoid leaching out of anticoagulant and/or damage to the intima due to creation of the vacuum (17).

Most commonly used catheters

Currently most chronic catheters are provided with the side holes. Figures 1 – 5 show the tips of the most commonly used dual-lumen catheters. These catheters are made of silicone rubber or polyurethane. The most popular silicone rubber catheters include PermCath™ (Kendall Healthcare Products Co, Mansfield, Massachusetts) and a new Hickman catheter (BARD Access Systems, Salt Lake City, Utah). The PermCath™ catheters have a double O configuration and are oval upon cross section; the Hickman catheter has a double D configuration, and upon cross section is round. Recently Kendall Healthcare introduced a PermCath Swan Neck catheter, which has a permanent bend slightly distally to the cuff. This bend after implantation into the internal jugular vein is located in an arcuate tunnel over the clavicle. The most popular polyurethane catheters are the Vas-Cath and Opti-Flow (BARD Access Systems, Salt Lake City, Utah). Both have the double D configuration and the Opti-flow has a permanent bend, similar to that of PermCath Swan Neck catheter. Polyurethane is thermoplastic, while silicone rubber is thermoset and does not soften at body temperature. Silicone rubber is less thrombogenic than polyurethane.

Tesio et al. (18) used catheters very similar to those

Fig. 7 - ***Ash Split (Medcomp, Harleysville, Pennsylvania) catheter with tapered tip provided with drilled holes.***

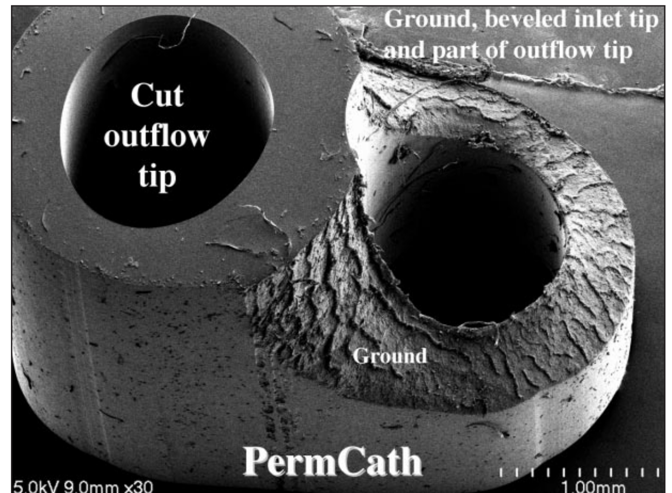

Fig. 8 - ***The view of PermCath™ from the tip on the ground surface of the inflow lumen (outflow tip cut off during preparation of the specimen). The surface cut with knife is much smoother than the ground surface.***

Fig. 9 - ***Ground outflow tip of the PermCath™. The remnant of the inflow lumen is smooth, whereas the ground surface is rough.***

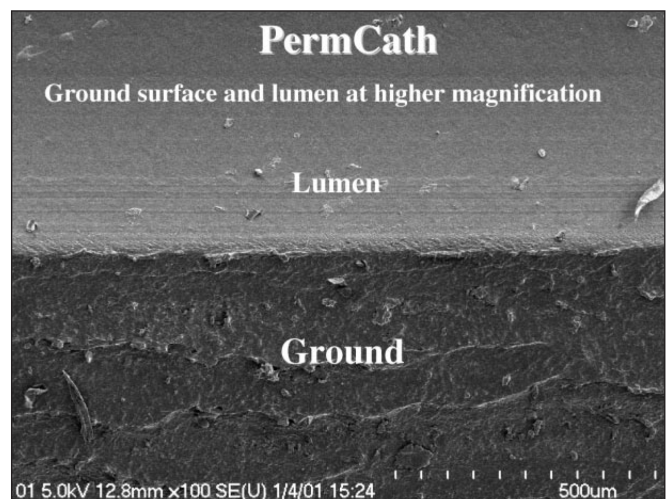

Fig. 10 - ***Higher magnification of the border between the ground and extruded surface of the PermCath's outflow tip.***

of Canaud. Unlike Canaud catheters, Tesio catheters were provided with a 1 cm olive-like device to better fix the cannula in the tunnel. A more recent model of the Tesio catheter is provided with a small cuff (2 mm wide) located on the olive-shape device. Tesio et al. (19) described lower infection rates than those reported by Canaud et al. (17). Tesio catheters have multiple side holes at the tips (Fig. 6).

A hybrid of single and dual lumen catheters, the Ash Split Cath was recently developed by Ash and his colleagues (20). The intravenous segment is composed of two separate D-shaped lumens, which have multiholed cylindrical, tapered tips (Fig. 7). The transcutaneous portion is a 14 French cylindrically shaped catheter with D-shaped lumens and a polyester cuff. The catheter is inserted with a single vein puncture. Because of tapered tips, side holes provide better pressure/flow relationships.

Another new device (Dialock™) was developed by Biolink Corporation (Middleboro, Massachusetts). The device consists of a port-like valve, implanted subcutaneously below the clavicle, which is connected to two single lumen catheters implanted into the right atrium and provided with multiple side holes (21). The tips are not tapered.

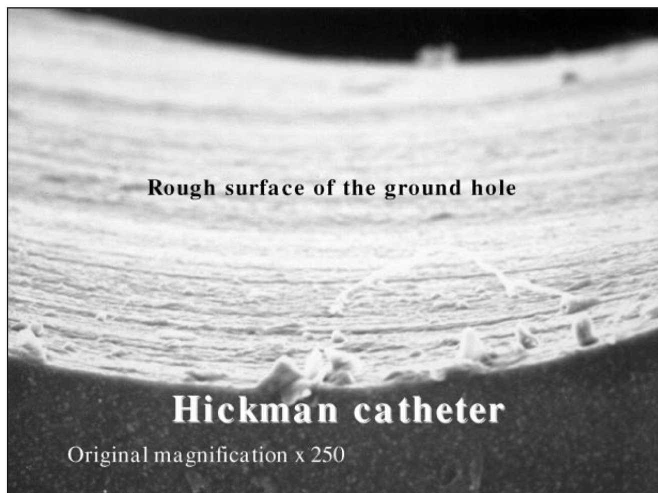

Fig. 11 - ***Rough surface of the drilled hole in the inflow lumen of the Hickman catheter.***

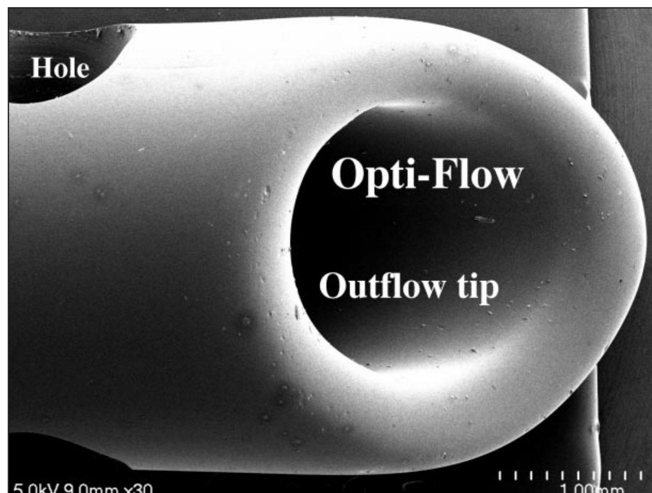

Fig. 12 - ***Smooth surface of the Opti-Flow catheter outflow tip.***

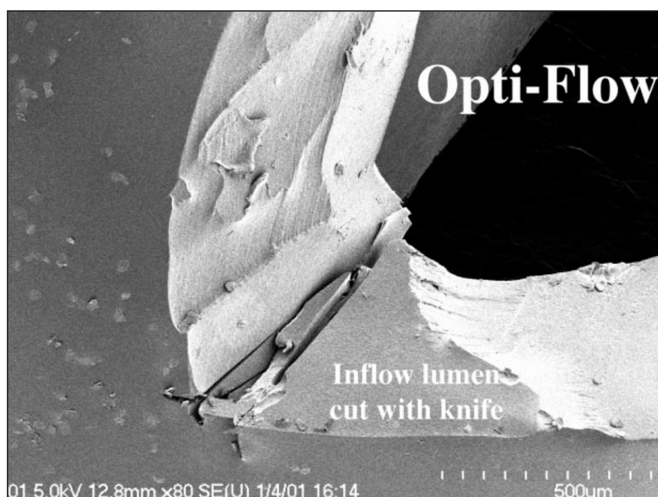

Fig. 13 - ***Inflow bore of the Opti-Flow catheter cut with knife during manufacturing process.***

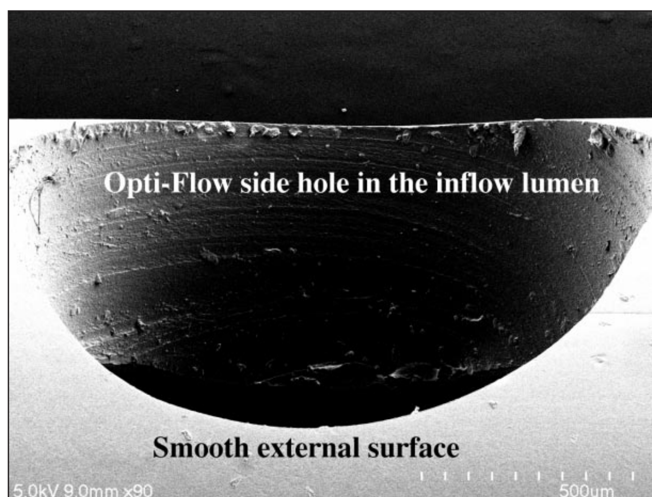

Fig. 14 - ***A drilled hole in the inflow lumen of the Opti-Flow catheter.***

Catheter surface in scanning electron microscopy

Electron microscopy images of the ground surface of the PermCath catheter tip are shown in Figures 8 – 11. Whereas the extruded part is smooth, the ground surface is rough. Rough surface is thrombogenic. To facilitate obtaining an image of the ground inflow bore, the outflow lumen was cut off. Figures 11 – 15 show electron microscopy images of the Opti-Flow catheter surface. Whereas the extruded surfaces are smooth, the surface of the drilled hole is rough. The inflow bore of the catheter shown in the Figure 13 was cut off during manufacturing process. Figure 16 shows the smooth surface of the Tesio catheter lumen. The ground tip of the Tesio catheter is shown in Figures 17 and 18. Figure 19 shows a drilled hole in the Tesio catheter. Figures 20 – 22 show electron microscopy images of the polyurethane Ash Split catheter. The rough surface of the drilled hole is clearly visible in Figure 22. Cracks, typical for polyurethane are also seen.

Pictures of clots anchored to the side holes

Figures 23 – 25 show photos of thrombi removed with the catheters. Usually the thrombi are stripped from the catheter during the removal process; however, thrombi, firmly anchored to

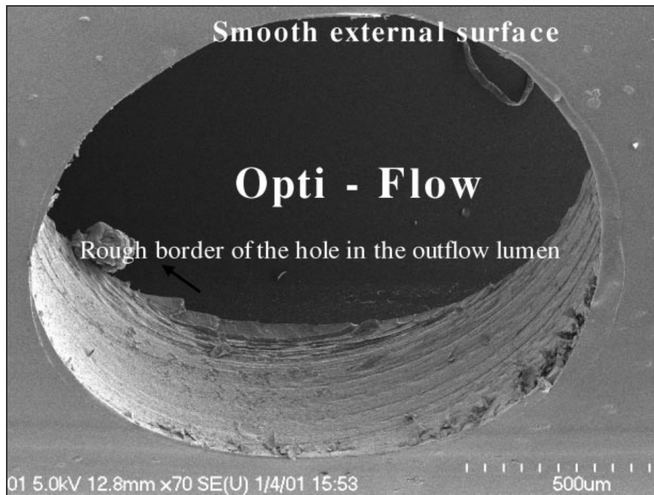

Fig. 15 - ***A drilled hole in the outflow lumen of the Opti-Flow catheter.***

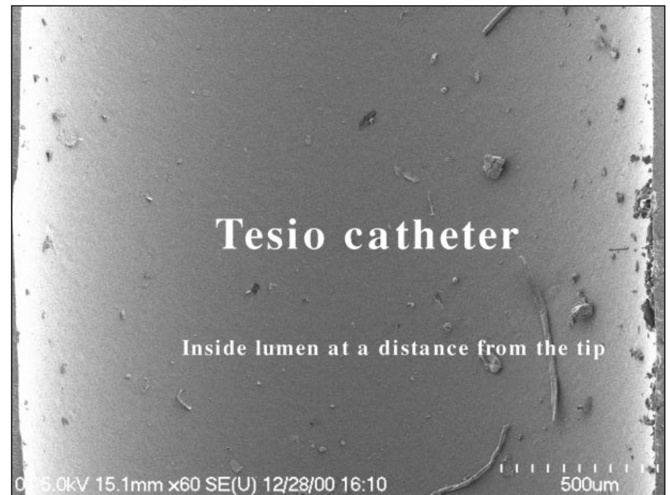

Fig. 16 - ***A smooth surface of the Tesio catheter.***

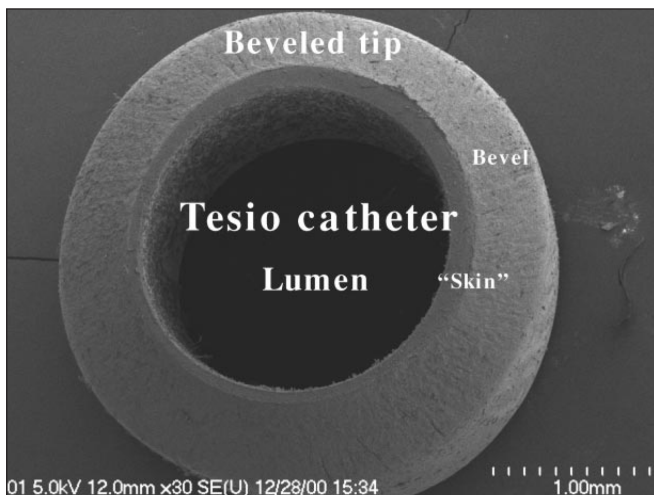

Fig. 17 - ***Ground, beveled tip of the Tesio catheter.***

Fig. 18 - ***Higher magnification of the Tesio catheter tip.***

the holes, resist stripping. Figure 26 shows an X-ray of the Tesio catheter after stripping. The clot, firmly anchored to the holes, could not be completely removed.

DISCUSSION

There are no data in support of the notion that side holes prolong the life or function of chronic catheters. The only exceptions are catheters with tapered tips (e.g., Ash Split catheter). In such catheters side holes may provide slightly better pressure/flow relationships, but at the expense of other previously mentioned disadvantages of side holes. In all other catheters the side holes are without any benefit and detrimental to their function.

Firstly, the side holes are created by drilling and have rough walls as can be seen with scanning electron microscopy (Figs. 11, 14, 15, 19, 22).

Secondly, many times, while removing chronic catheters, either electively or because of catheter obstruction, a clot is found attached to the tip of the catheter and anchored in the side holes of the inflow lumen (Figs. 23 – 25). Such a clot is difficult or impossible to remove or dissolve while *in situ*. Catheter stripping with a

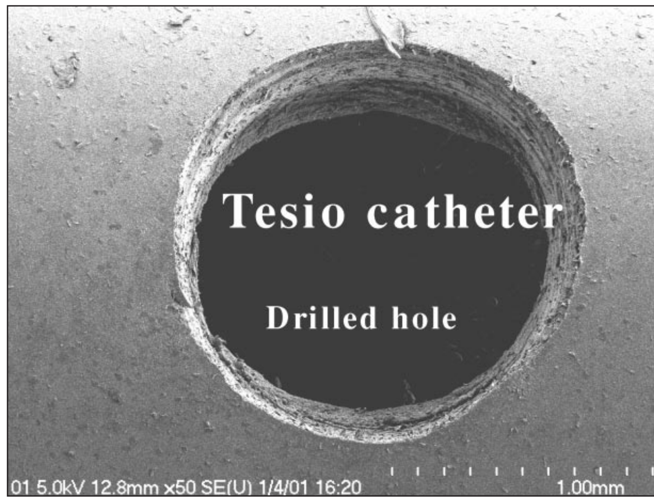

Fig. 19 - ***Rough surface of the drilled hole in the Tesio catheter.***

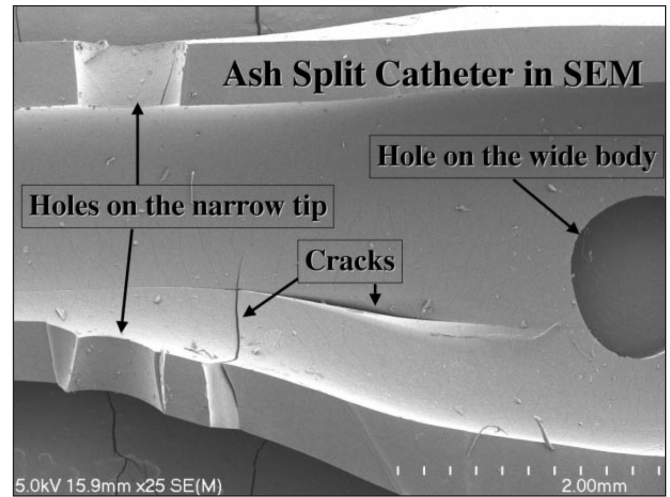

Fig. 20 - ***Ash Split catheter with visible drilled holes and cracks in scanning electron microscopy under low magnification.***

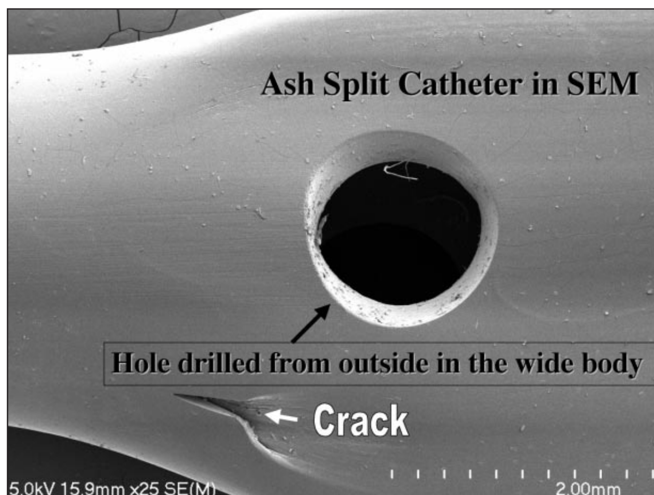

Fig. 21 - ***A drilled hole and crack in the wide body of the Ash Split catheter.***

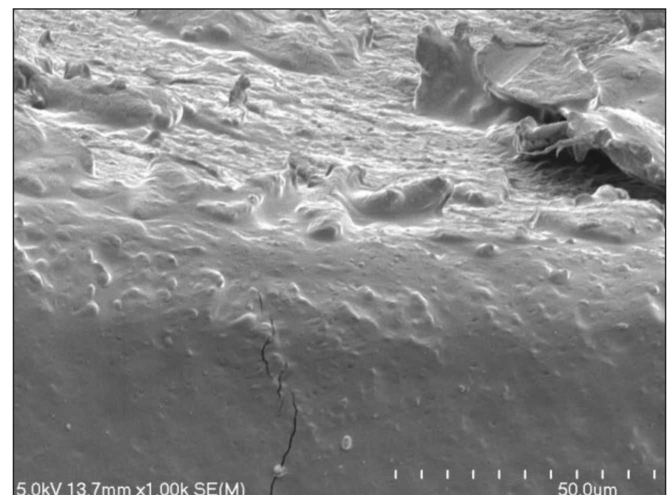

Fig. 22 - ***Rugged surface of the drilled hole in the wide body of the Ash Split catheter.***

snare also may not be successful (Fig. 26). Thirdly, a clot, which is difficult or impossible to remove is formed on the outer surface of the catheter and extends to the inside lumen. Under these conditions, the side holes have no role in extending the life of the catheter. Fourthly, heparin or other anticoagulant, which is instilled to the catheter lumen at the end of dialysis, may not reach the catheter tip and/or be leached out in the period between dialyses, thus, predisposing to clot formation at the tip of the inflow lumen. Finally, if the inflow bore is occluded and the blood flows through the side holes, it is likely that the vein intima will be sucked into the holes, become damaged and cause formation of a clot in the vessel lumen. In this case side holes would not be beneficial for the catheter life, but may be even precluding the possibility of inserting another catheter into the same vein at a later time.

Changing the shape of the tip by catheter grinding leaves rough surface (Figs. 8-10, 17, 18) predisposing to clotting and stronger adherence of the clot to the surface. Cutting catheter with knife leaves the surface smoother comparing to grinding (Figs. 8, 13).

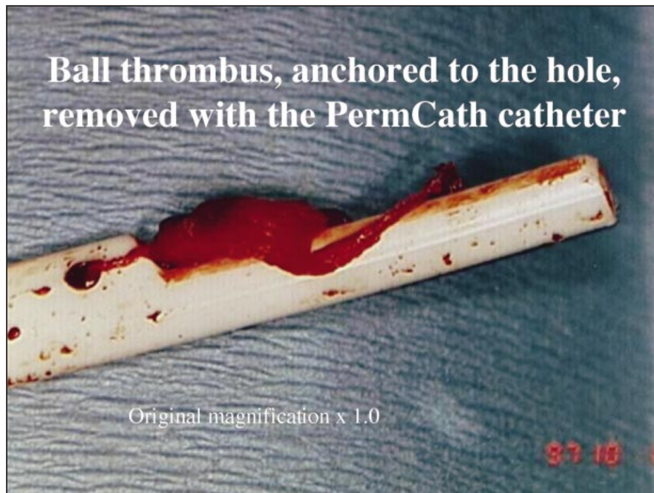

Fig. 23 - ***Ball thrombus, anchored to the hole, removed with the PermCath™ catheter.***

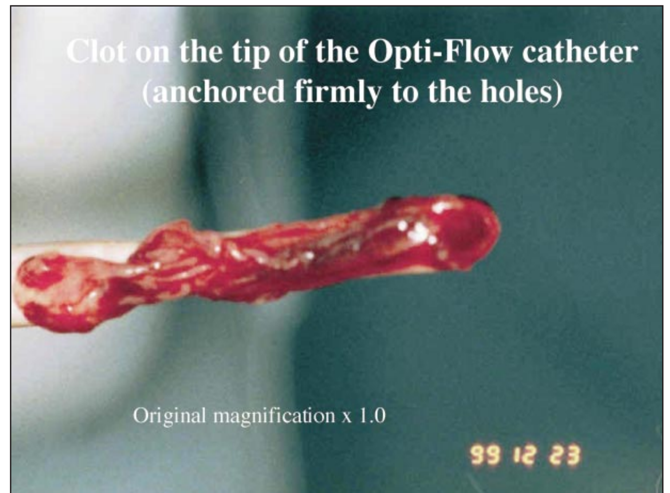

Fig. 24 - ***Clot adhered to inflow and outflow tips through the side holes on the Opti-flow catheter.***

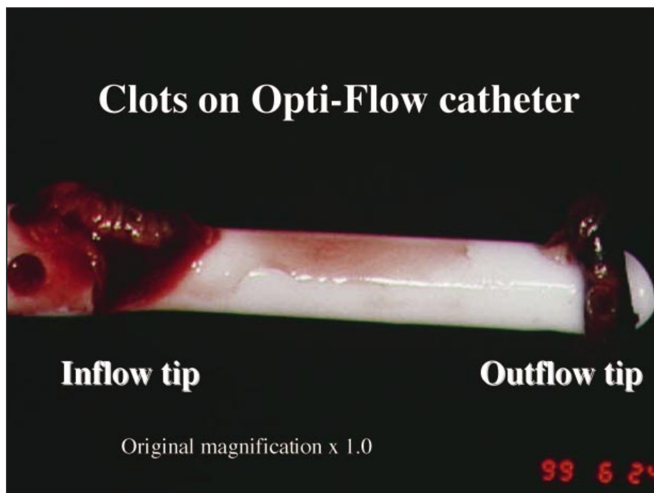

Fig. 25 - ***Two clots, firmly adhered to the holes, removed with the Opti-Flow catheter.***

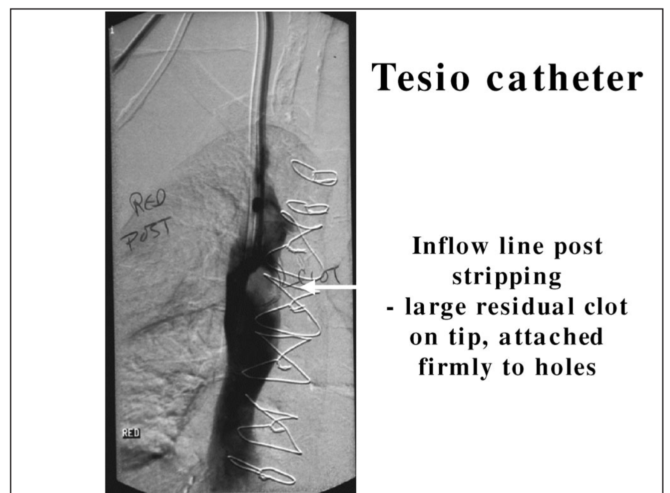

Fig. 26 - ***Tesio catheter after stripping. The clot, firmly anchored to the holes could not be removed.***

CONCLUSION

We believe that there are enough arguments and data to support the notion that the side holes in chronic hemodialysis catheters are not beneficial but detrimental to their function. A study comparing the function and survival of same catheters with and without holes is needed to confirm or refute our conclusion based on indirect evidence. Grinding of the catheter surface leaves the surface rough and should be avoided.

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