The Role of Surface Coatings on Central Venous and Hemodialysis Catheters

Antimicrobial and antithrombogenic coatings have been developed to combat catheter-related infection and thrombosis, but do they work?

BY ABIGAIL FALK, MD

It has been estimated that between 250,000 and 500,000 catheter-related infections occur each year in the US.[1] Each infection can increase health care costs between $4,000 and $56,000.[1] This means that at least $1 billion dollars is spent annually to treat just this one complication of catheters. This financial impact on hospitals and health care systems is quite significant, including the costs of antibiotics, new catheters, possible hospital stays, ICU care, and any follow-up procedures.

Of all catheters placed, between 42% and 100% develop fibrin sheaths,[2] and between 20% to 40% develop pericatheter thrombus.[3] The mutual cause-and-effect relationship of fibrin sheath and thrombosis and infection compounds the difficulty of treating patients who develop these conditions, as well as preventing them before onset. Once a pericatheter thrombus or fibrin sheath occurs, the patient is predisposed to infection; similarly, pericatheter infection increases the risk of thrombosis.[4-6]

The significant morbidity and mortality associated with infection and thrombosis limits the long-term use of catheters due to concerns of creating additional conditions in already sick patients. The effects of catheter-related infection vary widely, from rapid resolution in slightly symptomatic patients via antibiotic administration and catheter exchange, to death in some cases, particularly those involving immunocompromised patients. Depending on their severity, catheter-related thromboses can also compromise venous access sites for future procedures, which are often required in chronic disease care.

There are two primary routes of catheter infection: via the external and internal surfaces of the catheter. During the first 30 days after placement, most infections originate and spread from the external surface. Cuffed catheters, once incorporated into the subcutaneous tissue, decrease the spread of infection via this route. After 30 days, most infections are propagated through the internal surface, by contamination of the hub with hematogenous spread.[7]

ANTIMICROBIAL AND ANTITHROMBOGENIC COATINGS

New catheter technologies, particularly external and internal surface coatings, have been developed with the goal of improving the long-term use of catheters by reducing the incidence of catheter-related infection and thrombosis. From a clinical standpoint, the ideal surface coating should be resistant to fibrin disposition, biofilm, and infection; prevent thrombus formation; have proven long-term effectiveness; and be nontoxic. Both the internal and external surfaces should be treated. Two coating types, antimicrobial and antithrombogenic, have been developed to address infection and thrombosis, respectively, and perhaps concurrently.

Antimicrobial Coatings

During the past decade, catheters with antimicrobial coatings have been used in critical care patients with mixed results. The coatings on the first-generation devices were only effective for approximately 7 to 10 days, and non-preexisting conditions such as permanent hyperpigmentation from the catheter's silver coating were observed.[8] However, newer-generation antimicrobial coatings with increased bioactivity and application on both the internal and external surfaces have shown lower infection rates, low antibiotic resistance, and low allergic reactions in testing to date.[1]

(Images courtesy of respective manufacturers.)

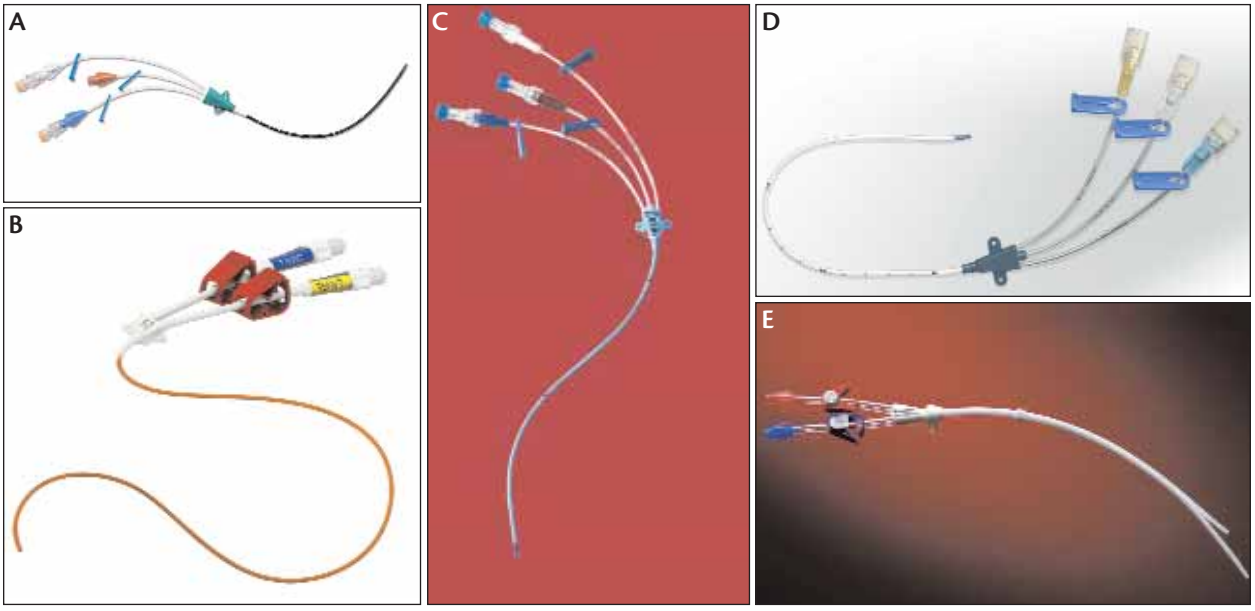

Figure 1. Catheters with antimicrobial coatings include the Edwards Vantex Catheter with Oligon (A), Cook Glide Spectrum (B), ArrowGard Blue and Blue Plus (C), and the Angiotech central venous catheter coated with 5-FU (D); the Medcomp SplitCath Core (E) is currently awaiting FDA approval.

In 2002, the US Centers for Disease Control and Prevention recommended selected use of microbial-coated catheters, stating that "Use of these catheters may be cost-effective in critical care patients, burn patients, neutropenic patients, and other patient populations in which the rate of catheter infections exceeds 3.3 per 1,000 catheter days."[9]

Current critical care central venous with antimicrobial coatings include the Vantex (Edwards Lifesciences, Irvine, CA) (Figure 1A), Glide Spectrum (Cook Medical, Bloomington, IN) (Figure 1B), ArrowGard Blue and Blue Plus (Arrow International, Reading, PA) (Figure 1C), and the 5-FU central venous catheter (Angiotech Pharmaceuticals, Inc., Vancouver, BC) (Figure 1D). These nontunneled, single or multilumen devices are not designed to stay in the patient for a prolonged or indefinite period of time. The Vantex catheter, coated with silver, carbon, and platinum, has a half-life of 7 days; however, Edwards is currently working on changes so that the catheter will have a 30-day half-life. The Glide Spectrum's minocycline/rifampin coating has a half-life of 25 days. The ArrowGard Blue only has chlorhexidine/silver sulfadiazine on the external surface, whereas the ArrowGard Blue Plus, which has an internal chlorhexidine/chloracetate coating and an external chlorhexidine/silver sulfadiazine coating, has a half-life of 30 days. Angiotech's 5-FU central venous catheter is coated in 5-fluorouracil on both the internal and external surfaces of the catheter.

Several hemodialysis catheters with antimicrobial coatings are available. Bard Access Systems (Salt Lake City, UT) offers its HemoSplit and HemoStar catheters with BioBloc (silver sulfadiazine) coatings on the external surfaces of the catheter that reside in the subcutaneous tunnels. The manufacturer states that this coating reduces bacterial adhesion for 21 days. Arrow International's ArrowGard Blue is a nontunneled catheter that is externally coated with chlorhexidine/silver sulfadiazine. The SplitCath Core (Medcomp, Harleysville, PA) (Figure 1E), which is currently awaiting FDA approval, has ciprofloxacin within the catheter material itself.

TABLE 1. ANTITHROMBOGENIC CATHETER COMPARISON

	Decathlon and Alta Gold (Spire)	**Palindrome Emerald (Covidien)**
Approved product claims	Reduced thrombus and fibrin sheath	Reduced platelet adhesion
Surface coverage	Internal/external	Internal/external
Coating durability	90 d	30 d (720 continuous hrs)
Coating activity	100%	60%–70%
In vitro tests	96%/91% reduction in thrombus	60% reduction in platelet adhesion
Catheter type	Split tip/fixed tip	Fixed tip

(Images courtesy of respective manufacturers.)

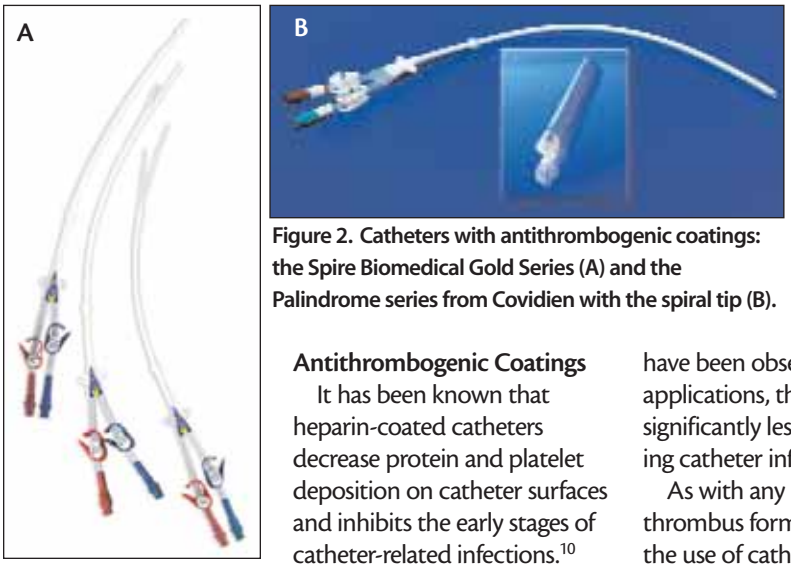

Figure 2. Catheters with antithrombogenic coatings: the Spire Biomedical Gold Series (A) and the Palindrome series from Covidien with the spiral tip (B).

Antithrombogenic Coatings

It has been known that heparin-coated catheters decrease protein and platelet deposition on catheter surfaces and inhibits the early stages of catheter-related infections.[10] This has lead to the application of antithrombogenic coatings on long-term hemodialysis catheters. Currently available antithrombogenic-coated hemodialysis catheters include the Decathlon Gold and Alta Gold from Spire Biomedical (Bedford, MA) (Figure 2A) and the Palindrome series from Covidien (Mansfield, MA) (Figure 2B). Table 1 depicts a comparison between these two antithrombogenic coatings.

The Carmeda Bioactive Surface on the 15.5-F Spire catheters is composed of endpoint-bonded heparin, applied to the internal and external catheter surfaces. Round and tapered split tips are available in the Decathlon Gold, and the Alta Gold has a fixed tip.

The Trillium Biosurface on the Covidien 14.4-F catheters consists of covalently bound heparin, also applied on the internal surface and on the external surface from the cuff to the tip—the Emerald model. The Ruby model comes with a silver polymer coating on the external surface from the hub to the cuff, designed to reduce microbial colonization within the tunnel. The Sapphire model is a combination of the two. The Palindrome catheter has a unique spiral z-tip fixed tip design.

CLINICAL DATA, ECONOMIC IMPACT, AND SUPER BUGS

Animal studies conducted on heparin-coated hemodialysis catheters have shown less thrombus formation on coated versus uncoated versions. However, hemodialysis catheters are often required to remain in the patient for several months—a critical factor when determining the efficacy of a coating. Human data on the actual duration of the efficacy of these coatings are needed in order to fully appreciate their role in dialysis care and determine their true effectiveness and value. Randomized, controlled trials are necessary to show the longevity of the coating protection, which should ideally approximate the length of their care or the intended length of a single catheter placement.

The cost associated with coated catheters is greater than their uncoated counterparts, at least in terms of the expense of the products themselves. If proven to be effective and free from any currently known and unknown side effects, such as the late thromboses that have been observed in some coronary drug-eluting stent applications, the front-end costs of these devices could be significantly less than the overall costs associated with treating catheter infections and thromboses.

As with any measure aimed at preventing infection and thrombus formation, there is a lingering concern regarding the use of catheter coatings contributing toward antibiotic resistance or drug and allergic reactions. For instance, antimicrobial devices contributing to the development of a "super bug" strain that is resistant to current medications could be a concern. Because these strains typically progress faster than the pace of medical device development and regulatory approval, their potential impact cannot be ignored and must be diligently monitored as these devices become available.

Catheter coatings may significantly decrease catheter complications and improve catheter survival, which would have a great impact on the field of venous access. This is an exciting area to follow. ■

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