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LifelineLetter
Living with home parenteral and/or enteral nutrition (HPEN)

# Central Venous Catheters, Biofilm, and Thrombosis

**Marcia Ryder, PhD, MS, RN**

*This article was adapted from a breakout session Dr. Ryder gave at the 2013 Oley Conference.*

Microorganisms (or bacteria) are everywhere. About one-hundredth the width of a human hair, they were the first living cells on Earth. They have had to adapt to survive over this vast time span. Ancient, invisible and powerful, bacteria cause catheter-related infections.

**Bacteria's Lifestyles**

In 1683, Van Leeuwenhoek developed the first microscope that was powerful enough to see bacteria. He didn't know what he was seeing, but he observed something alive and moving. Now we use a very sophisticated microscope called a "confocal laser," which takes real-time pictures. And while before we thought bacteria only existed as single cells, we now know there are two types of lifestyles for them.

Bacteria live as independent, single cells (which we call "planktonic") floating in liquids, but most often they live in a biofilm, as a community of microorganisms stuck to each other on a surface. The cells in a biofilm are physiologically distinct from planktonic cells.

**Biofilm**

Biofilm is all around us—on showerheads, toothbrushes, water systems, in our bodies….Some of the biofilms that live with us are good for us. We have over seven hundred species of bacteria in our mouth, and in the bowel, hundreds of thousands of bacteria help us digest food and absorb nutrients. All of these have jobs to do, and they help us be healthy. But biofilms on central venous access devices (we'll use the term catheters) shed cells into the circulatory system, and these can be harmful.

How do biofilms develop? When bacteria make contact with a surface—such as a catheter—the cells make a sticky substance that allows them to stick to the surface. They then release hormone-type substances that "talk to" other cells, triggering them to produce a material that envelopes them in a cluster. This is a survival technique: in biofilm, the cells are protected from enemies. For biofilm, your white blood cells are the enemies.



*Biofilm on the intraluminal surface of a catheter hub.*

Bacteria that switch into this biofilm mode—where they are cooperating and communicating with one another—change their DNA structure and how they live. For example, they down regulate, like a bear hibernating in a cave. Each cell becomes almost a completely different organism from when it started out. In this state, the bacteria are not hurting you. They are not doing anything except living in this little community.

When the biofilm reaches a mature state, however, it releases cells in order to colonize new surfaces. And if enough biofilm releases more cells than your white blood cells or antibodies can fight, you will get sick from infection.

**Resistance**

Bacteria in biofilm are profoundly resistant. They are resistant to host defenses (your white blood cells and antibodies) and to all antibiotics and antiseptics at the therapeutic doses we give. In order to kill biofilm cells, we would have to give ten to a thousand times the concentration of drug we use now.

Cells within biofilm can also rapidly develop antimicrobial resistance because they transfer a gene that makes them resistant to antibiotics. They also stick strongly to the surface. You have to use a lot of friction and mechanical scrubbing to get them off.

**Infection and Thrombosis**

When we place a catheter through the skin and into the body, we create a path for the entry of microorganisms. We also cause vessel injury (we put a hole in the vessel) and venous stasis (because the catheter will slow down the blood flow). So we now have two big potential problems: infection and thrombosis (or clotting). We'll discuss each individually, then address the connection between them.

Bacteria can attach to the inside (intraluminal) and outside (extraluminal) of a catheter, if either are

**Biofilm,** cont. pg. 2 ☛

**Biofilm**, from pg. 1

exposed to it. The most vulnerable time for bacterial attachment to the outside is during catheter insertion. Bacteria on the inside of the catheter come in through the catheter hub, from sources along your infusion set and the hub itself. Let's talk about the outside first.

When a catheter is placed, it passes through the skin and the tissue beneath the skin, then into the bloodstream. About 250 species of organisms exist on our skin; they help maintain it as a barrier. Before the catheter is inserted, the clinician scrubs the skin with an antiseptic to reduce the number of bacteria on the skin.

Bacteria that live in hair follicles and in deeper layers of the skin, however, can't be reached with antisepsis and may attach to the catheter surface. Within hours these deeper bacteria are going to come back up around the hair follicles and the sebaceous glands and recolonize the skin. This is why we need to use skin antiseptics and change the catheter dressing on a regular basis.

If bacteria are present, they will form a biofilm within the conditioning layer, fibrin clot, or thrombus.

Further, the open wound around the catheter will never completely heal shut; there will always be a space around it. With this open wound, there will be opportunities for the bacteria to get down in the subcutaneous tract, then into the bloodstream. This is why insertion site care is so important.

When do infections typically occur? Clinicians looked at all of the central-line–associated bloodstream infections (CLABSI) that were reported in the state of Pennsylvania in 2010. They mapped out each one of those to the day that the infection occurred.

They found that 54 of the 653 infections happened on the fifth day after the catheter was placed. They were early-onset, and the early-onset infections are due to insertion and mostly bacteria on the outside of the catheter.

What about the later infections? Those are primarily from bacteria inside of the catheter. Seventy-one percent of infections happened later, during routine use of the catheter. How do bacteria get inside the catheter? They can get in through a stopcock hub, an injection port, a needleless connector, or the catheter hub itself. This is why scrubbing these surfaces before infusing is crucial. That's where you fit in. [*Editor's note: prevention techniques discussed later.*]

**Thrombosis**

Let's go back to the catheter insertion. After the catheter goes through the skin, it enters the subcutaneous space. Your body will send fluids with white blood cells to the area to protect it and to begin to heal the wound. This is the inflammatory response.

Then the catheter enters the bloodstream, and proteins in the blood stick to the catheter surface. They touch the surface, turn into a solid, and begin to entrap some of the white blood cells and platelets, creating a protein or conditioning layer (see photo, page 3).

When the platelets activate, fibrin begins to build up around the protein layer, keeping the red and white blood cells together in a sheath or clot. This is the blood's normal reaction to the foreign object—the catheter—that's now in there. (We are working to discover catheter materials that won't allow this to happen. The fibrinous sheath can be very small or can become quite large, blocking the blood vessel.) A "thrombus" or "thrombosis" may form. A thrombus is a clot within a blood vessel (or vein). They can form on the vessel wall due to damage to the vein wall by the catheter.

**The Connection**

Infection and thrombosis are distinct problems, but they are also related. Here's how: If bacteria are present, they will form a biofilm within the conditioning layer, fibrin clot, or thrombus. These now provide added protection for the biofilm. The bacteria will say, "Yes! This is great for my community!" Bacteria have receptors and they particularly like sticking to fibrin.

We discussed how the catheter goes through the skin, then into a subcutaneous layer, and then into the blood vessel. Fibrin can develop in the subcutaneous space as well as in the bloodstream. It can create a tube of fibrin that goes along the catheter, through the tissue and into the vein. If bacteria get in that tube, they have the potential to spread through that tissue and into the blood.

You can have fibrin without having infection. If there's no bacteria, there won't be an infection, and bacteria don't just "appear"—they are transported there. You have to be very careful about doing your care so you don't let them get inside.

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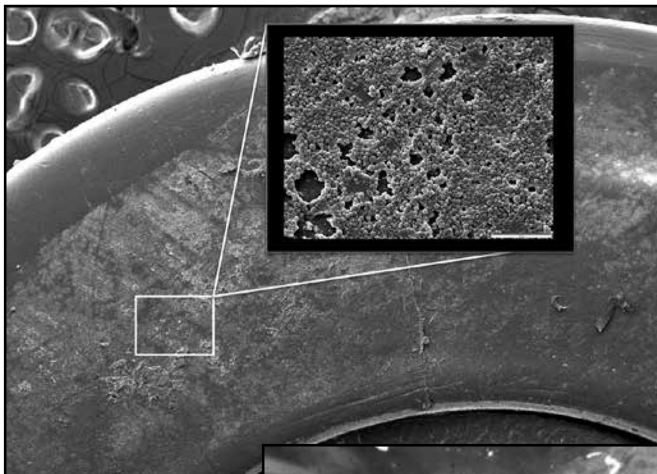
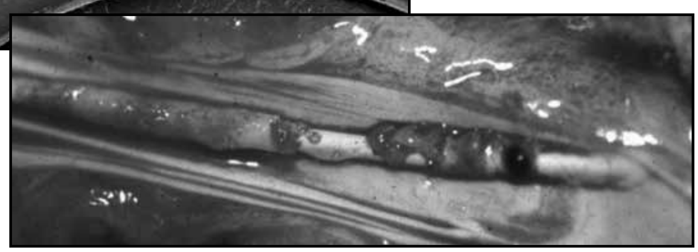
**Intraluminal Issues**

How does biofilm gets inside the catheter? I took some needleless connectors after they had been used by patients and put them under a scanning electron microscope. When I zoomed in, I saw staphylococcus in a very thick biofilm all over the top of the connector (see photo below). Biofilm will develop on anything; if you don't scrub the biofilm off before you inject, you're going to flush those cells right into the catheter. Once you put those cells in there, if they touch any part of the catheter or the inside of the connector, hub or catheter, they are going to stick to it and they're going to build more biofilm. The bacteria that don't stick go directly into the blood.

Later I took the connector apart and scanned the flow tube. It, too, was full of biofilm cells. Again, when you infuse, these cells can be released right into your bloodstream. This is very important in terms of your care.



*Left: Biofilm on the surface of the plastic rim of a needleless connector.*



*Right: Central venous catheter with fibrinous conditioning layer and thrombus formation.*

Photos: Marcia Ryder, all rights reserved.

**Blood Draws**

Although we try to minimize the times we pull blood through the catheter, sometimes we have to. But when blood comes in contact with the inside of the catheter, it's going to do the same thing it does on the outside: the plasma protein is going to stick to it and form a conditioning layer. That won't hurt you, but if there are bacteria there, they will become a part of it.

The other problem with pulling blood into catheters is clotting, especially if your catheter is not flushed correctly. Sometimes fibrin collects at the tip of the catheter, even though blood is flowing around it. A clot inside the catheter can mean that your catheter will become blocked.

**Interventions**

Here are some things you can do to prevent infection:

1. Wash your hands before you do anything to your catheter. Understand the proper techniques and proper types of antiseptics to use for washing and scrubbing.

2. Protect your catheter insertion site. First scrub the area with alcohol to remove all the oils, dead skin cells, and bacteria. Then apply 2% chlorhexidine with isopropyl alcohol for complete disinfection and to delay regrowth of bacteria on the skin.

From the moment of insertion and with each dressing change, apply a chlorhexidine patch to protect against regrowth of bacteria. (The Biopatch® is the most common, but there are new products coming out.) Bacteria can't regrow when they are exposed to the chlorhexidine. The patch will also protect against bacteria getting down around the catheter, and may help stabilize the catheter against migration.

Make sure the catheter is secure and cannot move in and out. Every time the catheter comes out a little, it picks up bacteria, and the back-and-forth motion drives bacteria down the catheter track.

3. When possible, select a connector with the lowest potential to allow bacteria to enter the connector if the bacteria have not been completely removed from the top of the connector. This is a topic I've been studying since 2006. The research is too detailed to summarize here, but when compared to other types of connectors, the Microclave® has consistently demonstrated the lowest risk for bacterial transfer.

4. Disinfect all connectors before you enter into them. You've got to disinfect anything you are going to put a syringe tip through, including the catheter hub. Bacteria are on the outside of everything, as well as on the threads of your catheter hub and inside the hub.

Also, remember we said biofilm is very sticky? You're going to need a strong antiseptic (either chlorhexidine or 70% alcohol) and you need to scrub (for how long depends on what you're using). This was a significant change in the last version of the CDC guidelines. They used to say just wipe, but they now get the biofilm picture and they changed "wipe" to "scrub." And you've got to do it every single time.

There is only one scrubbing device currently on the market. Called Site-Scrub™, it was designed for this purpose. When you put it over the needleless connector or catheter hub and twist it, it will scrub the outside, and the inside of the hub.*

5. It is better to use an intermittent push-pause method to flush your catheter. Push a little in, stop, push a little more in, stop, and keep using that method. This will not dislodge the plasma protein from the surface, but it will remove any other liquid in the catheter or any blood that has not been coagulated.

**Conclusion**

Vascular catheters can be life-saving and life-sustaining, but they also come with risks. It is important to know the risks and how they may occur. Understanding how to care for your catheter is an important part of your nutrition support plan. ¶

**Editor's note: passive alcohol caps are also available, including the SwabCap™ and the Curos® Port Protector. Also, to better protect your line when you are in hospital, consider bringing a poster for your chart from the Association for Vascular Access (AVA) I Save That Line campaign, available at www.avainfo.org.*