Blood is naturally compatible with vascular endothelium, not artificial surfaces

Blood is compatible with the healthy vascular endothelium, a single layer of cells that lines all blood vessels and the heart.

The endothelium plays an active biological role in maintaining homeostasis, or a balance, among the various body defense systems in a manner that simultaneously provides a state of readiness and avoids the trigger of adverse responses\(^1,2\).

The blood-contacting surfaces of endothelial cells are highly negatively charged, a characteristic that may repel the negatively charged platelets and be important in limiting the hemostatic reaction\(^3\).

**Why use biocompatible surfaces for extracorporeal circulation circuits?**

Blood recognizes the extracorporeal circuit surfaces as “foreign”, triggering coagulation and inflammatory events that may lead to adverse patient outcomes

Within seconds of blood exposure to artificial, non-endothelial surfaces, there is a rapid adsorption of proteins from the blood onto the surface of the foreign material\(^4\).

Adsorption onto a surface may result in protein denaturation, such as the denaturation of adsorbed fibrinogen, and ultimately lead to activation of the plasma proteolytic systems\(^5\). Subsequent events, including cell adhesion, are mediated by the adsorbed protein layer\(^1\).

The blood’s formed elements and other specific protein groups in the blood that are associated with the body’s defense systems may then interact with the material and its new protein layer\(^1,2\).

Ultimately, the biological reactions associated with the defense systems may affect the heart, lungs, brain and other organs, causing conditions that have been described as the “systemic inflammatory response syndrome”\(^5\).

**Biocompatible surfaces for Medtronic extracorporeal circulation technologies mimic critical characteristics of the vascular endothelium**

These biocompatible surfaces mitigate the foreign body response that occurs when blood comes in contact with non-endothelial surfaces.

Around the world, leading cardiovascular surgery teams adopt biocompatible surfaces offered by Medtronic as a critical component of comprehensive, multi-modal strategies to achieve the best possible outcomes for their patients undergoing extracorporeal circulation.
Trillium® Biosurface is a polymer coating with heparin applied to the blood contacting surfaces of cardiopulmonary bypass circuit devices. Its structure mimics critical characteristics of the vascular endothelium by providing a hydrophilic, negatively-charged surface that features heparin.

Peer-reviewed clinical and scientific evidence
With greater than a decade of extensive use for cardiopulmonary bypass procedures, Trillium® Biosurface clinical and scientific findings published in peer-reviewed cardiovascular surgery, perfusion and scientific literature include:

- Decreased likelihood to require blood products\(^*\)
- Less platelet activation\(^7\)
- Improved platelet count preservation\(^7,8,9,10\)
- Reduced thrombus formation\(^8,11\)
- Less granulocyte activation\(^7\)
- Less complement activation\(^12\)

Note: Citations with bold font represent clinical studies. Citations with standard font represent experimental in vitro and in vivo studies.

Warning: A strict anticoagulation protocol should be followed and anticoagulation should be routinely monitored during all procedures. The benefits of extracorporeal support must be weighed against the risk of systemic anticoagulation and must be assessed by the prescribing physician.

Caution: Federal law (USA) restricts devices coated with Trillium® Biosurface to sale by or on the order of a physician. For a listing of indications, contraindications, precautions and warnings, please refer to the Instructions for Use which accompanies each product.

1 Prime coat
A priming layer is strongly bonded to the artificial surface.

2 Functional layer
The hydrophilic ("water loving") functional layer with heparin is strongly bonded to the prime coat and provides the key endothelial-like benefits for the blood contacting surfaces of cardiopulmonary bypass circuits:

2a Heparin
Non-leaching heparin molecules are covalently bonded into the surface to provide beneficial effects as heparan sulfate does in the vascular endothelium.

2b Negative charge
Sulphate and sulfonate groups are incorporated into the Trillium Biosurface functional layer to mimic the negative charge of the vascular endothelium.

Research reports that negatively-charged sulphonated polymers:
- Repel platelets, which are negatively charged\(^13,14,15\)
- Inhibit thrombin by binding to antithrombin in a heparin-like manner\(^16,17,18\)
- May impair additional processes required for thrombus formation\(^16,19\)

2c Hydrophilicity
Polyethylene oxide (PEO) polymer is the third functional layer component. PEO is a hydrophilic molecule. In the primed circuit, PEO creates an "insulating" water layer structure between the blood and artificial surface to resist cell adhesion and protein deposition.

Schematic provided for illustrative purposes only and is not to scale.
Trillium®-Coated vs. Uncoated Oxygenators
Impact of Trillium Biosurface as compared to uncoated surfaces

Uncoated oxygenator fiber SEM (top) shows extensive platelet and cell deposition and activation on the fiber surface. In contrast, minimal deposition and activation is seen on the Trillium Biosurface SEM (bottom).

Ask your Medtronic Representative today about Medtronic perfusion technologies available with Trillium® Biosurface

Scanning electron micrographs (SEM) of oxygenator fiber surfaces after two hours of in-vitro circulation in a closed circuit using heparinized, human blood (200X magnification).

Uncoated oxygenator fiber SEM (top) shows extensive platelet and cell deposition and activation on the fiber surface. In contrast, minimal deposition and activation is seen on the Trillium Biosurface SEM (bottom).

Trillium® Biosurface is associated with a reduction in platelet activation as marked by reduced β-TG generation (6 p < 0.05, † p < 0.001).

Comparison between Trillium-coated and uncoated in vitro bench test circuits of percentage of platelets that are activated with adenosine diphosphosphate (ADP @ 20 μM) in circulating heparinized human blood over time.

Trillium® Biosurface is associated with a significantly greater percentage of functional platelets (6 p < 0.02 at 30, 60 and 120 minutes).

* Comparison between Trillium Biosurface-coated and uncoated in vitro bench test circuits circulating heparinized human blood over time at device maximum rated flow rate.
References


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For more information on other Medtronic technologies for extracorporeal circulation, blood processing and diagnostics, visit: www.perfusion.medtronic.com

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