SOARING Rx

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The Secret Life of **Arteries**

...blood, by the beat of the ventricles, flows through the lungs and heart and is pumped to the whole body. There it passes through pores in the flesh into the veins through which it returns from the periphery everywhere to the center.

...blood in the animal body moves around in a circle continuously, and... the action or function of the heart is to accomplish this by pumping.

This is the only reasonfor the motion and beat of the heart.

William Harvey *de Motu Cordis* 1628

Arteries are important to flight safety. If they pop or plug, we're always incapacitated. At best, for a bit. Or in the worst case, we croak. Either way, best not to have this happen on short final. More to the point, most people nowadays, and most pilots, die of arterial disease (*atherosclerosis).* This isn't completely necessary.

Many people don't have a need to know the difference between arteries and veins, which is a little bit like not knowing which is the hot wire and which is the ground wire – the need to know is temporary.

To be clear: arteries conduct blood away from the heart to our tissues. They are muscular and substantial. Veins collect blood from our tissue for return to the heart. They are thin-walled and delicate. In our extremities, we have two systems of veins.

Superficial veins, just under our skin, help keep our core temperature constant as they constrict and expand to conserve or release heat. Deep veins flank the arteries, exchanging heat to conserve central temperature.

Circulation: a modern idea

Humankind didn't know the functions of any body organ until recently. William Harvey 500 years ago proved the circulation of the blood, but he lacked a microscope, which was necessary to show that there actually are "pores in the flesh" through which blood passes from arteries to veins.

Marcello Malpighi, born the year *de Motu Cordis* was published, considered by some to be the father of microscopic anatomy, described these pores, microscopical vessels we call *capillaries*, first in the lung and then in other tissues, in the 1660s.

Before this, there were the usual silly ideas that always plague experts, who have the normal human proclivity to hold old assumptions in a tight embrace and scoff at crazy new ideas that don't make any sense in their world.

Harvey couldn't see capillaries because they are about 8 microns wide (1/125th millimeter). Malpighi could, because he owned one of the first microscopes. There weren't funding grants in those days. He had to buy it on his own. I expect it was dear, but can't find a price.

What are arteries like?

Arteries are pipes. They are active, dynamic, complex pipes that are continually adjusting to local and regional conditions. Like all complex systems, they are robust and resilient, but have many failure modes, and many mechanisms of damage.

The aorta is about an inch in diameter. The capillaries are microscopic, but are profuse, so don't provide any significant resistance to flow. Resistance is regulated by small arteries, "resistance vessels," that constrict or dilate depending on tissue flow needs.

These are *arterioles,* "resistance microvessels," encased in smooth muscle that modulates arteriolar caliber and thereby flow volume and upstream pressure. When arterioles contract, blood flow to capillaries is reduced, or may be shunted through "metarterioles" directly to the veins.

These resistance vessels are controlled by nerves that cover arteries like a net. Response to nerve signals is modified by regulatory proteins in the blood, by the acidity of arterial tissue, and most important, by a simple molecule, NO, *nitric oxide,* produced by the endothelial cells lining blood vessels. These factors cause perfusion to meet the metabolic needs of tissues.

Arteries are pipes of muscle interwoven with elastic, tiled on the inside with a single layer of cells, the active and complex *endothelial* cells, and covered on the outside with a net of nerves that regulate the tension in the muscle wall.

In Western society, we work hard to corrode these pipes through what we eat and inhale, and to destroy the intricate signaling systems of arteries.

Basics about blood

The most important function of arteries, of course, is to conduct blood. This puts special requirements on the pipe, because blood is not a simple fluid. It's sticky and thick. Blood contains the cells and proteins that cause it to gel if it stops flowing, touches raw tissue, or if certain initiating factors are activated.

Almost half of blood comprises cells, mostly red blood cells. The fluid part of blood is about 91% water and about 8% protein. A bit more than half of this is albumin, a protein whose main function is to maintain "osmotic pressure" that impels water to enter and remain in the blood vessels. About a third of the proteins in blood are immune globulins, and about 7% are blood-clotting proteins.

The work of arteries

When an artery is injured or cut, the muscle of the wall constricts to stanch flow, and both cell and protein contents of the blood are activated to rapidly create a plug.

Blood transports immune cells that must flow freely with the bloodstream until specific protein signals cause them to attach to the arterial wall and then slither through to enter the arterial wall or the surrounding tissues.

As we all know, what makes blood red are the *erythrocytes*, the Bismark-shaped packets of hemoglobin that transport oxygen from lungs to tissues. It just happens that capillaries are exactly big enough for red blood cells to slide through single-file. This creates the smallest possible distance for oxygen to traverse on its way to the interstitial fluid bathing our cells.

There is no arterial-style muscle around capillaries, for their sole function is exchange of nutrients and oxygen with carbon dioxide and metabolic byproducts, and migration of immune cells and proteins.

Capillary endothelial cells are only 1 micron thick (capillary diameter is about 8 microns), yet substantial enough to house the biochemical mechanisms that regulate chemical transport into and out of interstitial fluid.

Capillaries are sometimes called "exchange microvessels" to emphasize this role. Some small molecules (< 3 nm) are able to diffuse across the capillary endothelial-cell junctions, but all nutrients, immune proteins, and immune cells are specifically transported in each direction.

Immune cells, for example, latch onto "adhesion molecules" and migrate between endothelial cells through an active, regulated process.

One of the important functions of arteries is to accommodate to the pressure and flow needs of downstream organs. With exercise, a large flow increase is needed. Arterioles (resistance vessels) open, arteries relax, and the capillary matrix in muscle tissue is more fully perfused.

The muscle of the arterial wall relaxes when the interstitial fluid around it becomes acidotic (due to active work or metabolism) or through nerve signals via the enwrapping neural net.

The ability of arterial muscle to relax depends on the presence of NO, *nitric oxide*, secreted into the muscle by endothelial cells. Interestingly, if this is absent, arterial muscle contracts when told to relax. This was first seen when pieces of artery were stimulated with the endothelium intact and then with the endothelium stripped off.

Another function of endothelial cells is to regulate whether white blood cells "stick" to them. If they are injured, they express proteins that attract and grip these cells.

These two things are related.

The Curse of the Portly Packer-Backer.

I live in Wisconsin, OK? The relevant point is that high-fat food (cheese, fries, brats, burgers and other comfort foods) damages arterial endothelial cells. We Wisconsonites have no monopoly on this, but "Western Lifestyle Vascular Dysfunction," while more accurate, isn't as much fun to pronounce.

The other main thing that damages endothelium is smoke. As a society, most of our experience with chronic smoke inhalation involves burning tobacco, but other smoke is probably about as bad.

People inhale smoke, not because we like to cough, but because the leaves we burn recreationally contain tranquilizers such as nicotine and tetra-hydro-cannabinoids, THC. These happen to be rather addictive, which keeps the smoke coming.

The consequence of this is that the endothelium is damaged by fat or smoke. This damage is spotty.

In these spots, three things may happen:

- First, the local arterial wall tends to constrict when it should relax.
- Second, the damaged endothelial cells may attract clotting cells (platelets) and clotting proteins. Such a clot may plug the artery.
- Third, over time the damaged spots turn to scar, which may, over the years, build up and block the artery.

This is relevant to your risk of sudden in-flight incapacitation, and is what slew the beloved Richard Johnson.

Arterial flight-safety steps

I may leave the topic of what to do about this for another time, but the straightforward changes are

- Don't use tobacco or other smoke.
- Avoid cooked animal fat, and keep fat intake low
- Please don't eat quantities of refined carbohydrates.
- Do eat vegan delights, supplemented with modest amounts of lean protein.

If you do this, and exercise most days for up to a half hour, and feel loved, and are socially active, you will be a safer and, eventually, an older pilot than would otherwise happen.

Sources

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Vascular Biology Working Group. Carl J. Pepine, MD. University of Florida http://www.vbwg.org/

The best resource for physicians and educated laymen to learn about vascular biology and therapy.