Prosthetic HEART VALVES "The beat goes on"

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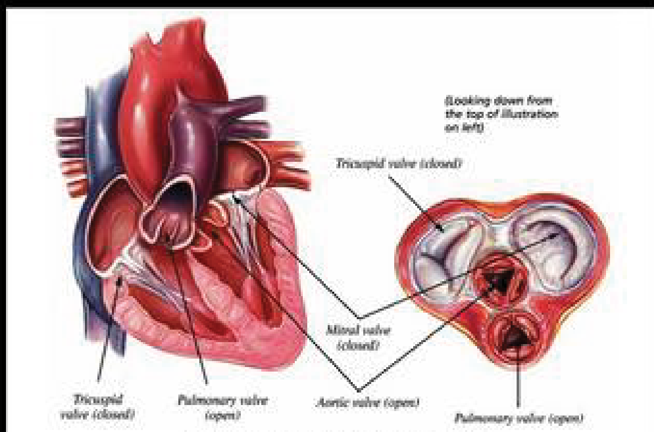
Any of the four heart valves naturally controls the blood circulation within the heart. Blood circulation is a cyclic process that repeats over a billion times during an average human lifespan. As a result, heart valves can develop certain inevitable defects. In Sri Lanka, thousands of people annually undergo surgeries to replace or repair their damaged heart valves.

Artificial heart valves (AHVs) have been designed to mimic the biological role of natural heart valves . Manufacturers use materials such as stainless steel, Titanium based metal alloys, polymers and other synthetic materials to design artificial heart valves. These materials must be biocompatible and mechanically robust to withstand lifelong repetitive cycles [1].

Prosthetic heart valves

The functions of these materials can be easily understood regarding the human heart valve. For instance, heart valves are made of strong, thin flaps of tissue called leaflets, facilitating unidirectional blood flow . These leaflets are in constant rapid motion due to the continuous blood flow through the valves. Thus, the materials used for the leaflet should have a meager resistance to motion in terms of elasticity and inertia. Another property is the load-bearing capacity. The material should to sustain loadings around 10 – 80 dynes/ cm^2 without any geometric distortion of the tissues [2]. The structural integrity over years of recurring stress cycles also should be considered.



Anatomy of human heart

Furthermore, geometric properties in terms of thickness, compliance and stress-strain relationships are considered. The following materials are being used for manufacturing prosthetic heart valves.

Titanium

Titanium is used in the coating of the valve. It has a high strength-to-density ratio, excellent corrosion-resistant properties and, most importantly, biocompatibility.The replaced valves will not elicit a rejection response from the body and will tolerate the mechanical stress effectively over time. Often it is alloyed with Aluminum or Vanadium to enhance its properties further. Since Titanium is non-ferromagnetic, patients can be safely examined with MRI scans even after the implants[1].

Pyrolitic Carbon

The inner orifice and the leaflets of bileaflet valves are composed of Pyrolitic carbon. The inner orifice is made out of 100% pyrolitic carbon. It is moulded onto the valve by depositing methane onto a heated graphite substrate near its decomposition temperatures above 1500 0C and allowing the substrate to crystallize. The material is structurally similar to graphite. But the additional biocompatible and durable properties have made it an essential component of AHVs. However, it is advised to use an additional coating of blood-contacting material over pyrolitic carbon to reduce any risks of thrombosis [3]

Polytetrafluoroethylene (Teflon)

In the case of open-heart surgery, suture rings are essential to hold sutures for suturing an artificial valve by inserting them into slits. These should be covered with biocompatible synthetic materials. Apart from the previously mentioned requirements, such selected material should not absorb blood and demonstrate a certain degree of water repellency. Polytetrafluoroethylene (Teflon) is a thermoplastic polymer composed of Fluorine and Chlorine. Since the high electronegativity of fluorine diminishes the London dispersion forces, it exhibits hydrophobic properties. Thereby, Teflon is an ideal candidate in this regard [3].

Polyethylene terephthalate (Dacron/PET)

Teflon is not suitable for the external regions of the suture ring. The surrounding tissue needs to colonize the outer surface, which is exposed to the sutured tissue. Therefore, the outer surface should be capable of blood absorption and colonization by some of the surrounding tissues. These necessities are satisfied by using a hygroscopic, porous material such as polyethylene terephthalate (Dacron or PET). The polymerization of ethylene glycol and terephthalic acid produces PET. Despite its simple nature, presence of repeating aromatic rings gives the polymer the stiffness and strength to tolerate frictional forces to which it is subjected after an implant [3].

Researchers work on adding further improvements to the design of AHVs. A major drawback in the modern mechanical valve design is that the patients will have to rely on lifelong anticoagulant medications for the optimal functioning of the implants. Dr. Geoff Moggridge, a chemical engineer attached to Cambridge University, has been working on a copolymer material that does not depend on anticoagulants for efficient functioning. According to him, the invention of such a material is "a matter of years rather than decades".

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