OVERVIEW OF
LEFT VENTRICULAR ASSIST DEVICES (LVAD’S)
AND THE TOTAL ARTIFICIAL HEART (TAH)

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Design of Implantable Medical Devices
ECEN 4011/5011
AXIAL PUMP DESIGNS

Rotary axial flow LVAD

This valve-less heart-assist pump is no bigger than a "C" battery. The turbine device pumps oxygenated blood throughout the body. The electrically powered pump does not beat or pulse like a real heart. In this case, the pump fits into the left ventricle. Other pumps are implanted in the chest or abdomen.

PROS: Smallest of the three; some models can be implanted within the ventricle ■ Low energy requirement ■ High output of blood

CONS: Bearings can wear out quickly unless properly lubricated or suspended ■ High speed of pump can destroy red blood cells unless impeller is carefully designed ■ Must be manufactured to strict tolerances for pump to be effective ■ No long-term experience in humans

Source: Texas Heart Institute

CAN BE MADE VERY SMALL FOR INFANTS:
Rotary centrifugal LVADs have two sealed chambers: a pump chamber that moves the blood; and a motor chamber which contains the mechanism that drives the pump. Power is transmitted between the chambers by magnetism.

Two tubes leaving the pump chamber carry the blood between the LVAD and the heart. Blood enters near the top center of the pump and leaves from the side.

The third tube to the motor chamber contains the wires to power the unit.

1. An electric motor turns a pair of magnets in the motor chamber.
2. The magnets turn magnets in the pump chamber.
3. The pump chamber magnets are attached to vanes that move the blood through the pump.

**PROS**
- Smaller than pulsatile, so more promise for use in women and children
- Less mechanical wear than the axial flow
- Low energy requirement
- Easier to manufacture

**CONS**
- No long-term experience in humans
- Larger than axial flow pumps
- Continuous flow is significantly different from natural heart action; physiologic effects not totally understood.

Source: Baylor College of Medicine
MAGNETICALLY LEVITATED BEARING: AXIAL DESIGN

This design eliminates the direct-contact mechanical bearing by replacing it with magnetically levitated bearings. This approach may help eliminate one source of clotting in such devices, i.e. at the mechanical bearing interface.
The Penn State total artificial heart

The Penn State total artificial heart (TAH) is driven by an electric motor. The motor turns a rollerscrew nut that pushes the rollerscrew sideways. The motor reverses polarity every four and one-half revolutions, and the rollerscrew is driven in the opposite direction. This back and forth motion within the artificial heart duplicates the pulsing of a real heart.

Source: Dr. Gerson Rosenberg, Penn State
The Abiomed total artificial heart

The Abiomed total artificial heart (TAH) uses a centrifugal pump to move silicone hydraulic fluid, which drives the device. A sleeved, rotating valve shuttles the fluid between the left and right blood pumps.

Front cross-section

Flexible double membrane

Hydraulic flow

Right blood pump

Left blood pump

Tri-leaflet valves made of polyetherurethane plastic prevent blood backflow.

Right-side cutaway

Woven polyester flexible tubing grafted to ascending aorta and pulmonary trunk.

Clear epoxy parts are easily cast into irregular shapes, and allow visual inspections for proper pump function and to ensure that no air is present before the artificial heart is turned on.

Pump impeller

Titanium-alloy case

Twist-lock quick connectors allow surgery without the artificial heart in the way.

Polyester cloth cuffs are sutured onto the remaining atria.

Sources: Steven Parnis, Texas Heart Institute, Abiomed, Inc.
CONNECTION OF THE ABIOMED TAH TO THE ATRIAL AND VESSEL STRUCTURES. NOTE THAT THE RIGHT AND LEFT ATRIA ARE RETAINED FOR CONNECTION TO THE TAH INLETS
Abiomed TAH ready for implant
Powering the heart pumps

Most totally implanted heart pumps will be powered by rechargeable, external batteries. A pair of coils, known as a transcutaneous energy transmission device, is used for power transfer across the intact skin, eliminating wires going through the skin and avoiding the risk of infection. One coil is implanted under the skin and a ringlike coil is strapped over it outside the body.

When showering, the battery packs and external coil can be removed and the pump works off an internal battery.

Heart pumps draw blood from the apex of the left ventricle with the opening directed toward the mitral valve. The blood is pumped into the ascending aorta and circulates throughout the body.

Sources: Novacor; Heart Failure, December 1994/January 1995, Clinical Experience With the HeartMate Left Ventricular Assist Device.
POWERING THE ABIOMED TAH VIA TRANSUCUTANEOUS ENERGY TRANSFER (TET)
SOME IMPLANTS IN PROGRESS
SynCardia CardioWest™
Total Artificial Heart System

Implantable TAH

External Console

Drivelines