

## Artificial hearts

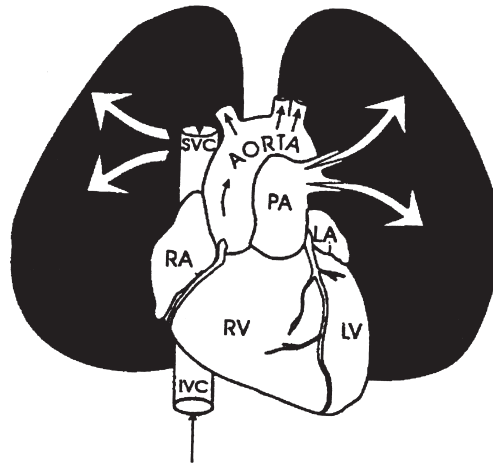
The heart is a muscular organ, which pumps blood around the body. It consists of four chambers:

- the left and right atria (blood receiving chambers)
- the left and right ventricles (the blood pumping chambers).

Blood within the left ventricle (left heart) is pumped into the aorta and on to the general body. Blood within the right ventricle (right heart) is pumped into the pulmonary artery and on to the lungs (figure 1).

Blood from the general body is received via the superior vena cava (SVC) and the inferior vena cava (IVC) into the right atrium (RA). It then passes from the right atrium into the right ventricle (RV) and is subsequently pumped via the pulmonary artery (PA) into the lungs.

Blood from the lungs is received by the left atrium (LA) and passes into the left ventricle (LV) from where it is pumped via the aorta into the general body.



### Who needs an artificial heart?

A person may require an artificial heart when his or her own heart fails and is unable to pump blood to meet the body's needs. These people may have symptoms such as persistent tiredness, lethargy, shortness of breath on exertion or at rest, poor appetite, and swelling of their ankles. Function of other body organs such as the lungs, liver and kidneys may also be impaired as a result of heart failure.

Reasons why the heart fails include:

- disease of the heart muscle itself (cardiomyopathy)
- disease of the arteries of the heart (coronary heart disease) and its complications (e.g. a heart attack)
- severe viral infections of the heart (myocarditis)
- other less common diseases.

People with a failing heart are first treated with drugs that take the load off the heart and help it function better. Sometimes the heart failure is so severe that the drugs are ineffective. The other treatment option for these severely ill people is heart transplantation.

Heart transplants are performed using hearts donated from people who suffer brain death; for example, as a result of a motor vehicle accident or a brain haemorrhage. These people's hearts are working well despite brain death. Unfortunately there are not enough heart donors in this country to help all those people who need a heart transplant. Therefore, some of these people will die from their heart failure before a transplant can be performed.

Artificial hearts may be used in these very ill people as a temporary measure until a donor heart becomes available, or to allow a person's damaged heart to rest or recover following damage. Occasionally, artificial hearts are implanted as a last resort in people who are unsuitable for heart transplantation.

Between twenty and thirty people receive artificial hearts in Australia each year. Most of these artificial hearts have been implanted as a bridge to heart transplantation. However, recently a small number have been implanted on a permanent basis as an alternative to heart transplantation.

### **What is an artificial heart?**

An artificial heart is an extra ventricle (pumping chamber) capable of pumping blood around the body of a person whose own heart is failing. The pump itself is made of a combination of metal and plastic and consists of a small pumping chamber lined by a special material that prevents blood clots from forming. The pumping chamber may be implanted within the body itself or may lie outside the body depending on the type of artificial heart being used.

An artificial heart may be connected to a person in various ways to support the left heart, the right heart or both sides of the heart (figure 2); that is, it may be:

- attached to the left atrium/ventricle and the aorta (called a "left ventricular assist device" or LVAD), or
- attached to the right atrium and pulmonary artery (called a "right ventricular assist device" or RVAD), or
- attached in both ways described above (called a "biventricular assist device" or BiVAD).

The device may bypass the weakened ventricle(s) either partially or totally.

Another type is the "total artificial heart" (TAH) which is a mechanical substitute for the entire heart. It is implanted after the person's heart has been removed. This type is rarely used at present.

### **How does an artificial heart work?**

Blood enters the artificial heart from the left or right atrium and is then pumped into the aorta or pulmonary artery, depending on which side of the heart is being supported.

The device is powered by either compressed air or electricity. A thin cable connects the pumping chamber to a control console from which the pump function is regulated. The control console may be a large box on wheels that stays beside the person and can move with the person when he or she walks around in the hospital. More recently, a much smaller controller with attachable batteries has been designed which can be worn by the person on a belt or vest. This allows the person much greater freedom and mobility compared with the large console.

## **History of the artificial heart**

Artificial heart technology dates back to the mid-1950s with the development of a total artificial heart (replacing the entire heart). Later, ventricular assist devices (to help either the left ventricle or right ventricle or both simultaneously) were developed. Most devices were implanted on a temporary basis, as significant complications occurred with long-term implants. The technology has gradually improved and smaller, more compact electrically-driven devices are currently being evaluated.

A major goal of research in this area is to develop a system that can be totally implanted, and not require a physical connection to an external power source. This is because the break in the skin currently required to link the device to its battery is a common source of infection. Such devices are currently being evaluated in a small number of people in international trials.

### **For how long does an artificial heart work?**

Once the artificial heart has been implanted it usually remains in place and functioning until the person receives a heart transplant. This time may range from a few weeks to more than one year. The person receives a transplant when his or her medical condition has improved enough to make it safe to perform the transplant and a suitable donor has been found. During the transplant operation, the artificial heart is removed.

In recent times, some artificial hearts have been implanted on a permanent basis for periods greater than one year in people who, for some reason, have not been able to have a heart transplant.

### **Care of a person with an artificial heart**

Before receiving an artificial heart, the person is very carefully examined to make sure that he or she is suitable for the procedure and, in most instances, for the heart transplantation that will follow. This includes a thorough evaluation of heart function and general health. People with other major medical problems, such as kidney, lung or liver disease, infection or cancer are usually not suitable for artificial heart implantation.

Once the artificial heart is implanted, the person is monitored closely in the Intensive Care Unit. The care is very similar to that given to patients having other cardiac surgery procedures. Particular attention is paid to artificial heart function, avoiding infection and the administration of blood thinners (aspirin and/or warfarin) to prevent blood clots forming as a result of the implantation.

### **Complications of artificial hearts**

Prior to the implantation of an artificial heart the person is usually extremely sick and most likely to die within a week or two. Once the device is implanted, the person's condition usually improves, but this may take several weeks. Eventually he or she may be able to walk around the hospital and be physically active while the device is in place. Such people are commonly allowed to go home or to a facility outside the hospital while they wait for their heart transplant.

Artificial hearts are very reliable and mechanical failure is extremely rare. Complications that may occur in people with an artificial heart include bleeding and infection. Failure of the major organs such as the kidneys, liver or lungs may occur; however, some of these organs may have been failing before the device was implanted. All people with an artificial heart must take blood thinners (anti-coagulants) to prevent clots from forming in the blood or on the surface of the device and potentially causing a stroke if a clot passes to the brain.

Not all people with an artificial heart recover sufficiently to have a transplant. Some will die of the complications mentioned above. Very rarely will a person recover sufficiently to have the artificial heart removed and not require a transplant. The vast majority of artificial hearts are removed at the time of transplantation.

### Unsolved problems with artificial hearts

The ideal artificial heart is small enough to be totally implantable within the body and is also able to function independently of any tubes or cables passing through the skin. This is because any break in the skin surface increases the risk of infection. All artificial hearts currently available in Australia have some component exterior to the body. Totally implantable artificial hearts are currently being evaluated in international trials, but are not yet generally available.

The absolute requirement for some form of 'blood thinning' drug in people with artificial hearts greatly increases the risk of bleeding complications. Researchers are attempting to modify the lining surfaces of these devices which come in contact with the blood so that there is minimal tendency to form clots, thereby hopefully reducing or eliminating the need for these drugs.

### Legends for figures

Figure 2A. A left ventricular assist device (LVAD). Blood is received into the device from the left ventricle (LV) and is pumped into the aorta.

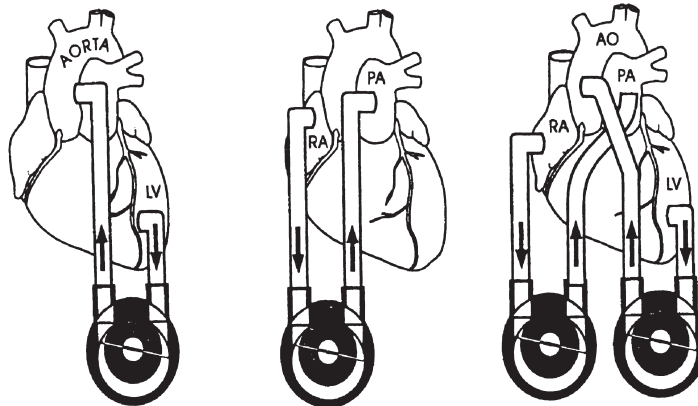


Figure 2A

Figure 2B

Figure 2C

Figure 2B. A right ventricular assist device (RVAD). Blood is received into the device from the right atrium (RA) and is pumped into the pulmonary artery (PA).

Figure C. A biventricular assist device (BiVAD). This is a combination of a left ventricular assist device (LVAD) and a right ventricular assist device (RVAD).

The Heart Foundation would like to thank Professor J Smith, MBBS, MS(Melb), FRACS, FACS, Cardiothoracic Surgery Unit, Monash Medical Centre, who assisted with the preparation of this information sheet.

Information on a range of heart health issues can be obtained by calling Heartline, the Heart Foundation's national telephone information service, on 1300 36 27 87 (local call cost).