Mechanical Heart Support

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Cardiopulmonary bypass (CPB):

- a technique that temporarily takes over the function of the heart and lungs during surgery, maintaining the circulation of blood and the oxygen content of the body.

- often referred to as a heart–lung machine or "the pump".

- CPB is a form of extracorporeal circulation.

Uses of cardiopulmonary bypass:

- commonly used in heart surgery because of the difficulty of operating on the beating heart.

- Operations requiring the opening of the chambers of the heart require the use of CPB to support the circulation during that period.

- used for the induction of total body hypothermia, a state in which the body can be maintained for up to 45 minutes without perfusion (blood flow).

If blood flow is stopped at normal body temperature, permanent brain damage normally occurs in three to four minutes — death may follow shortly afterward.

Similarly, CPB can be used to rewarm individuals suffering from hypothermia.

- Extracorporeal membrane oxygenation (ECMO) is a simplified form of CPB.

used as life-support for newborns with serious birth defects, or to oxygenate and maintain recipients for organ transplantation until new organs can be found.

- mechanically circulates and oxygenates blood for the body while bypassing the heart and lungs.

1. It uses a heart–lung machine to maintain perfusion to other body organs and tissues while the surgeon works in a bloodless surgical field.

2. The surgeon places a cannula in right atrium, vena cava, or femoral vein to withdraw blood from the body.

3. The cannula is connected to tubing filled with isotonic crystalloid solution.

4. Venous blood that is removed from the body by the cannula is filtered, cooled or warmed, oxygenated, and then returned to the body.

5. The cannula used to return oxygenated blood is usually inserted in the ascending aorta, but it may be inserted in the femoral artery.

6. The patient is administered heparin to prevent clotting, and protamine sulfate is given after to reverse effects of heparin.

7. During the procedure, hypothermia is maintained; body temperature is usually kept at 28oC to 32 oC (82.4–89.6 °F).

8. The blood is cooled during CPB and returned to the body.

9. The cooled blood slows the body’s basal metabolic rate, decreasing its demand for oxygen.

10. Cooled blood usually has a higher viscosity, but the crystalloid solution used to prime the bypass tubing dilutes the blood.

Surgical procedures in which cardiopulmonary bypass is used:

- Coronary artery bypass surgery

- Cardiac valve repair and/or replacement (aortic valve, mitral valve, tricuspid valve, pulmonic valve)

- Repair of large septal defects (atrial septal defect, ventricular septal defect, atrioventricular septal defect)

- Repair and/or palliation of congenital heart defects (Tetralogy of Fallot, transposition of the great vessels)

- Transplantation (heart transplantation, lung transplantation, heart–lung transplantation)

- Repair of some large aneurysms (aortic aneurysms, cerebral aneurysms)

- Pulmonary thromboendarterectomy

- Pulmonary thrombectomy

Components of cardiopulmonary bypass

- Cardiopulmonary bypass consists of two main functional units, the pump and the oxygenator which remove oxygen-deprived blood from a patient's body and replace it with oxygen-rich blood through a series of tubes (hoses).

- Tubing

The components of the CPB circuit are interconnected by a series of tubes made of silicone rubber or PVC.

- Pumps

i. Roller pump

The pump console usually comprises several rotating motor-driven pumps that peristaltically "massage" tubing. This action gently propels the blood through the tubing. This is commonly referred to as a roller pump, or peristaltic pump.

ii. Centrifugal pump

Many CPB circuits now employ a centrifugal pump for the maintenance and control of blood flow during CPB. By altering the speed of revolution (RPM) of the pump head, blood flow is produced by centrifugal force. This type of pumping action is considered to be superior to the action of the roller pump by many because it is thought to produce less blood damage (Hemolysis, etc.).

- Oxygenator

The oxygenator is designed to transfer oxygen to infused blood and remove carbon dioxide from the venous blood.

recently is the heparin-coated blood oxygenator which is believed to produce less systemic inflammation and decrease the propensity for blood to clot in the CPB circuit.

- Cannulae

Multiple cannulae are sewn into the patient's body in a variety of locations, depending on the type of surgery. A venous cannula removes oxygen deprived blood from a patient's body. An arterial cannula infuses oxygen-rich blood into the arterial system. A cardioplegia cannula delivers a cardioplegia solution to cause the heart to stop beating.

Some commonly used cannulation sites:

Venous	Arterial	Cardioplegia
Right atrium	Proximal aorta, distal to the cross-clamp	Proximal aorta
Vena cavae	Femoral artery	Coronarysinus(retrograde delivery)
Femoral vein	Axillary artery	Coronary ostia
	Distal aorta	Bypass grafts (during CABG)
	Apex of the heart	

Cardioplegia:

- A CPB circuit consists of a systemic circuit for oxygenating blood and reinfusing blood into a patient's body (bypassing the heart);

- and a separate circuit for infusing a solution into the heart itself to produce cardioplegia (i.e. to stop the heart from beating), and to provide myocardial protection (i.e. to prevent death of heart tissue).

Operation:

- A CPB circuit must be primed with fluid and all air expunged before connection to the patient.

- The circuit is primed with a crystalloid solution and sometimes blood products are also added.

- The patient must be fully anticoagulated with an anticoagulant such as heparin to prevent massive clotting of blood in the circuit.

Complications:

- Postperfusion syndrome (also known as Pumphead)

- Hemolysis

- Capillary leak syndrome

- Clotting of blood in the circuit – can block the circuit (particularly the oxygenator) or send a clot into the patient

- Air embolism

- Leakage – a patient can rapidly exsanguinate (lose blood perfusion of tissues) if a line becomes disconnected

- 1.5% of patients that undergo CPB are at risk of developing Acute Respiratory Distress Syndrome

- CPB may contribute to immediate cognitive decline. The heart-lung blood circulation system and the connection surgery itself release a variety of debris into the bloodstream, including bits of blood cells, tubing, and plaque. Other heart surgery factors related to mental damage may be events of hypoxia, high or low body temperature, abnormal blood pressure, irregular heart rhythms, and fever after surgery

Ventricular assist device (VAD):

- a mechanical circulatory device that is used to partially or completely replace the function of a failing heart. - Some VADs are intended for short term use, typically for patients recovering from heart attacks or heart surgery, while others are intended for long term use (months to years and in some cases for life), typically for patients suffering from congestive heart failure.

- VADs need to be clearly distinguished from artificial hearts, which are designed to completely take over cardiac function and generally require the removal of the patient's heart.

- VADs are designed to assist either the right (RVAD) or left (LVAD) ventricle, or both at once (BiVAD). Which of these types is used depends primarily on the underlying heart disease and the pulmonary arterial resistance that determines the load on the right ventricle.

- LVADs are most commonly used, but when pulmonary arterial resistance is high, right ventricular assistance becomes necessary.

- Long term VADs are normally used to keep patients alive with a good quality of life while they wait for a heart transplantation (known as a "bridge to transplantation").

- LVADs are sometimes used as destination therapy and sometimes as a bridge to recovery.

Design:

- Pumps

i. The pumps used in VADs can be divided into two main categories - pulsatile pumps, that mimic the natural pulsing action of the heart, and continuous flow pumps.

ii. Pulsatile VADs use positive displacement pumps.

iii. In some of these pumps, the volume occupied by blood varies during the pumping cycle, and if the pump is contained inside the body then a vent tube to the outside air is required.

iv. Continuous flow VADs normally use either centrifugal pumps or an axial flow pump.

Complications and side effects:

- VAD-related infection can be caused by a large number of different organisms:

i. Gram positive bacteria (Staphylococci especially Staph. aureus, Enterococci)

ii. Gram negative bacteria (Pseudomonas aeruginosa, Enterobacter species, Klebsiella species)

iii. Fungi especially Candida sp.

Initial treatment should be with broad spectrum antibiotics, with appropriate samples for culture and therapy must be based on the results of microbiological cultures.

- Immunosuppression

- clotting with resultant stroke

- bleeding secondary to anticoagulation