SNS COLLEGE OF ALLIED HEALTH SCIENCES

SNS Kalvi Nagar, Coimbatore - 35

Affiliated to Dr MGR Medical University, Chennai

DEPARTMENT OF CARDIO PULMONARY PERFUSION CARE TECHNOLOGY

COURSE NAME : PRINCIPLES OF PERFUSION TECHNOLOGY

II YEAR

TOPIC : BLOOD PUMPS

IDEAL CHARACTERISTICS OF BLOOD PUMP

- An ideal blood pump should be able to move large volumes of blood a flow rate of 7l/min at pressure 500mmhg
- The handling of blood by the pump should minimize the flow velocity so that damage to the blood is minimized.
- Pump components in contact with blood should not damage the blood cells and should not activate either the inflammatory or the coagulation cascades.
- Calibration- maintaining proper occlusion and revolution [for maintaining accurate flow]
- The pump should be automatically controlled and operated for routine use but it should be designed for possible manual operation in case of power failure.

Types of blood pumps

Pumps can be classified into two main categories

Displacement pumps

Rotary pumps

- Displacement pumps

  Roller pump

- Rotary pumps

  Radial (centrifugal) pumps

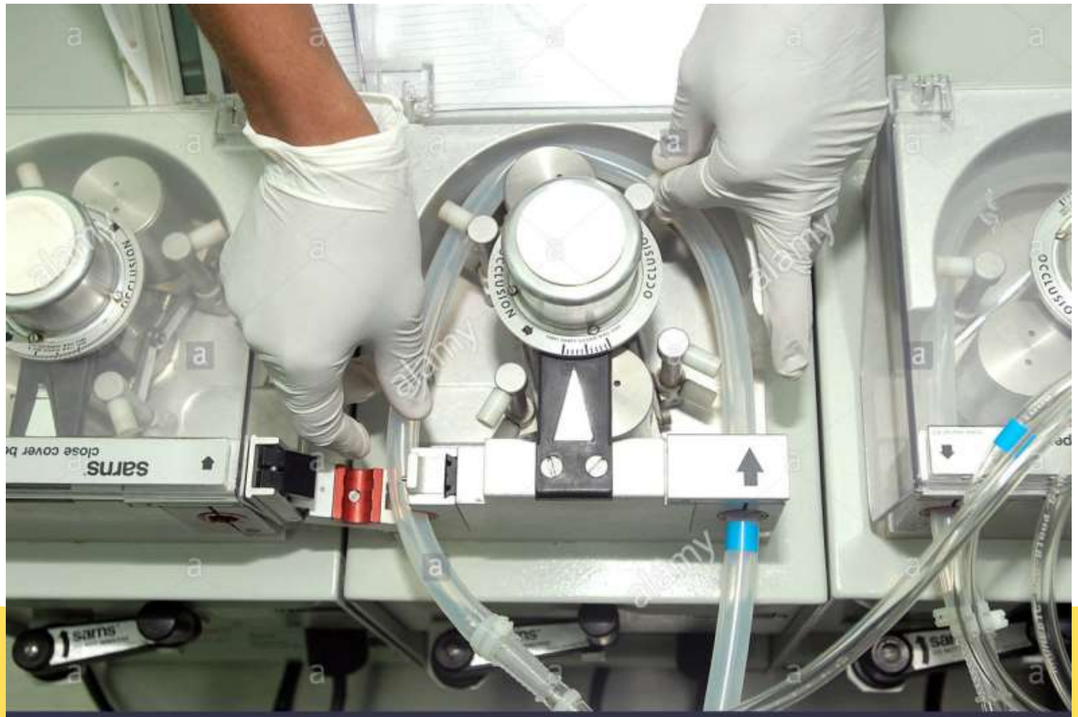
  Diagonal pump

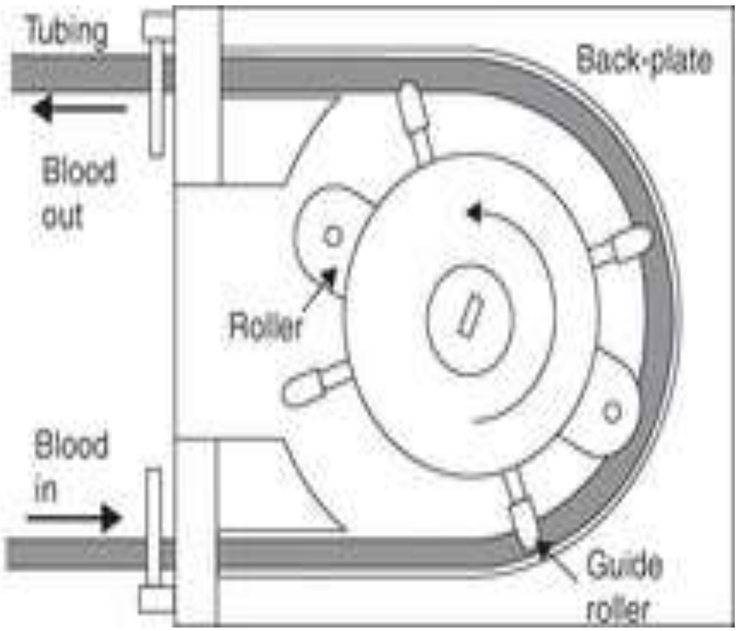
  Axial pump

Displacement pumps

Roller pump

- The roller pump was first patented in 1855.
- It is a type of positive displacement pump
- Most commonly used nowadays
- Invented by Debakey





Structure

- It contain of tubing located inside a curved raceway .The raceway is plated at travel perimeters of roller mounted on the ends of rotating arms
- Arranged in such a manner that one roller is compressing the tubing all the time
- The output of rotatory pump is determined by the revolution of the rollers and tubing size ; ½ ,3/4, ¼, 3/16
- Based on the number of rollers , the roller pump has divided into ;

  SINGLE ROLLER PUMP

  DOUBLE ROLLER PUMP

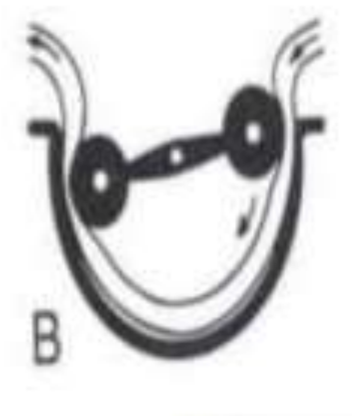
  MULTIPLE ROLLER PUMP

❖ SINGLE ROLLER PUMP

- Only one roller
- The roller rotate 360º to eject out the blood
- Used in 1950s & 1960s
- More pulsatile flow will be achieved
- The tubings are placed as 360º

❖DOUBLE ROLLER PUMP

- 2 rollers
- 180º rotation
- Back plate -210º , semi circular backplate
- The occlusion is done alternatively by the two rollers
- This is a non-pulsatile flow [continues flow]



MULTIPLE ROLLER PUMP

- More than 2 rollers
- Not used nowadays, because this cause more hemolysis

TUBINGS

- Silicon rubber
- Poly vinyl chloride [commonly used]
- Latex rubber

PVC is most because of its durability and acceptable hemolysis

Latex rubber –disadvantage-more hemolysis, also can cause reaction

SPALLATION

- When the rollers are crushing the tubings in hypothermic state during CPB there is a formation of microbubbles –in PVC tubing
- As compared to silicon and latex rubber the PVC is having less degree of spallation

Advantages of roller pump

- Reusable with inexpensive disposable part
- Easy to sterilize
- Simple flow rate determination
- Variable stroke volume for different sized particle
- The occlusion caused lowest hemolysis than non-occlusive pump

Disadvantages of roller pump

- Blood trauma
- Tubing spallation
- Possibility of circuit disruption and termination from excessive line pressure
- Particulate micro emboli from tubing spallation
- Possibility of massive air emboli
- Contra indicated for long term use because of tubing wear and blood trauma [in case of ECMO]

COMPLICATIONS

- Mal occlusion
- Fracture of tubing
- Run away of pumping
- Accident due to high pressure
- Cavitation –[stable air bubble formed in tube from a death space in that area]

Occlusion

- Refers to the occlusion as the roller presses the tubing against the raceway
- Occlusion is set by holding the tubing line vertically so the top of the fluid is about 30 cm above the pump and then gradually decreasing occlusiveness until the fluid level falls at a rate less than 1 cm/minute
- Occlusion should be set each roller separately.
- This compression appears to be more critical ,

  Excessive compression – hemolysis and tubing wear

  Very little compression –forward output impaired , rarely hemolysis

Occlusion setup

1. Load the unprimed tubing in the roller pump raceway
2. Introduce the appropriate amount of priming solution in the oxygenator
3. Close the sampling ports and recirculating lines.
4. Hold the distal arterial line vertically.
5. Advance a column of priming approximately 30cm above the level of the pump.
6. Deocclusion of the rollers by moving the rollers away from the backing plate to ensure there are no excessive occlusion.
7. Adjusting roller occlusion against the backing plate to allow slight drop of fluid at a rate less than 1cm/m.
8. The occlusion should be set to each roller separately (one by one),if one of the rollers in the pump head does not yield the same rate of fluiddrop(under occlusion),the occlusion should be set to the roller that is tightest.

Non occlusive pump

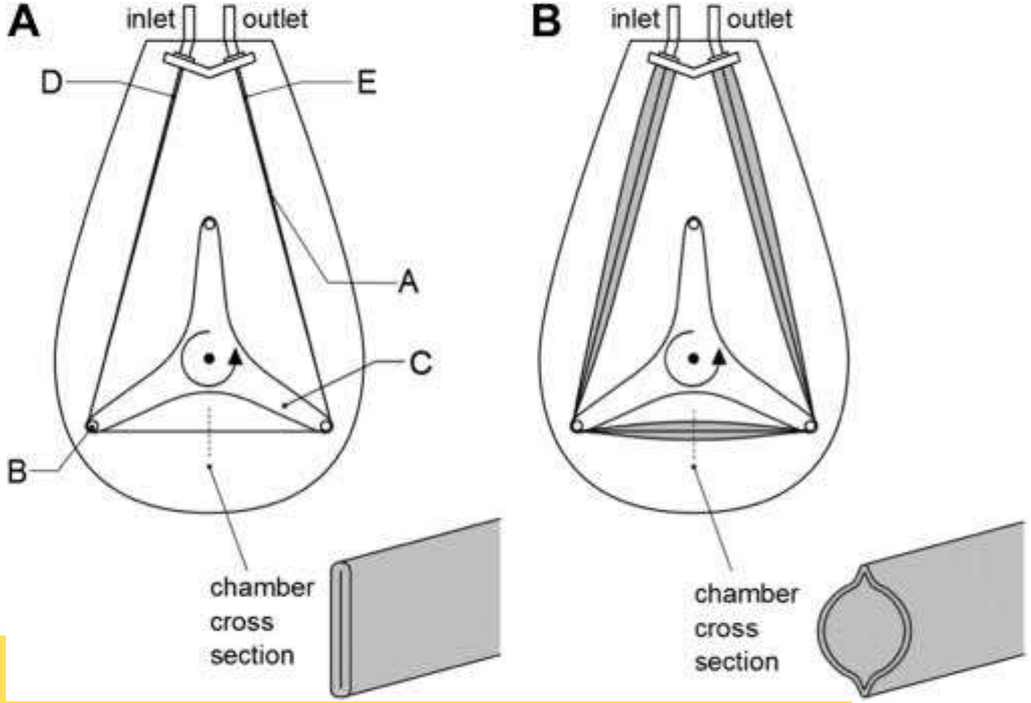
- Rhone-Poulec in France originally designed a non-occlusive roller pump for use in routine CPB procedures
- This pump became known world wide after its successful use in neonatal respiratory support
- The pump was further developed overtime for routine CPB and mechanical support
- The MC3 pump is a passive filling , peristaltic pump that combines many advantages of both the centrifugal and the roller pump.
- This pump is nonocclusive and should be used as for all nonocclusive pumps, in combination with a flow meter .
- It consists of a completely flat pump chamber that is wrapped under tension around rollers.
- The rollers are mounted on a rotor.
- Rotations of the rotor imparts a peristaltic motion to the blood within the pumping chamber
- When the inlet of the chamber is supplied with blood at a pressure above ambient , blood is moved toward the outlet .
- Because of its design, the pump chamber can only get filled when there is a positive hydrostatic pressure at the inlet .

- When there is no fluid in the chamber or when the pressure is below or equal to the ambient pressure , the pump chamber will be completely flat in the portion engaged by the rollers.

ADVANTAGES

- This pumping concept offers some unique safety benefits
- Air cannot be pumped because the pump needs a preload, which is only present with fluid in the reservoir .
- The natural flat shape of the pump chamber allows for a total collapse , thereby preventing retrograde flow when the pump is stopped.
- As the pump cannot generate negative pressure will minimize the blood damage and reduce microbubble generation

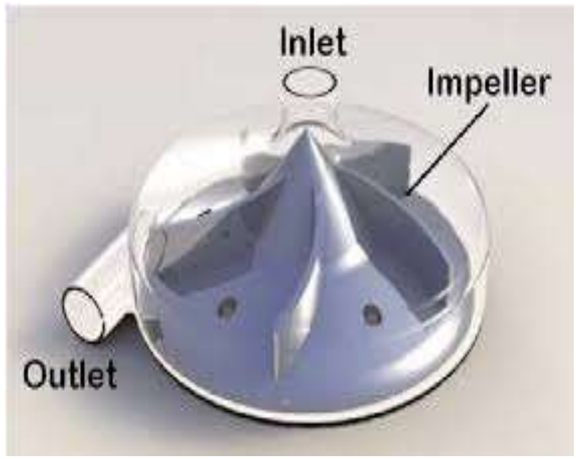
- The non-occlusive nature of the pump will prevent failure of tubing connections
- Although little research has been done, the MC3 seems to be least as hemocompatible as a centrifugal pump
- In vitro results showed a lesser activation of neutrophils and platelets as well as lower hemolysis level than in a centrifugal pump.
- Although this pump is available commercially , and appears to have major advantages, it has never become popular for clinical routine



Rotary pumps

CENTRIFUGAL PUMP

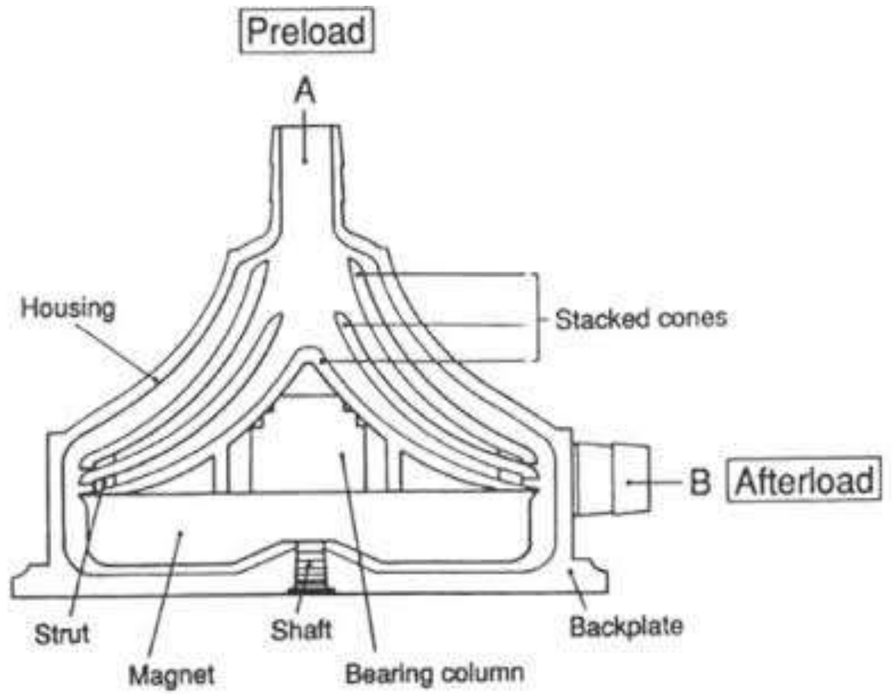
- Centrifugal pump produce flow by imparting kinetic energy to the fluid in rotating head
- In the early 1970s,research related to the development of an artificial heart was the basis of the development of centrifugal pumps for cpb.
- The biomedicus 600 became available in 1973.
- Together with the roller pump,the centrifugal pump is the most used pump for routine cpb.

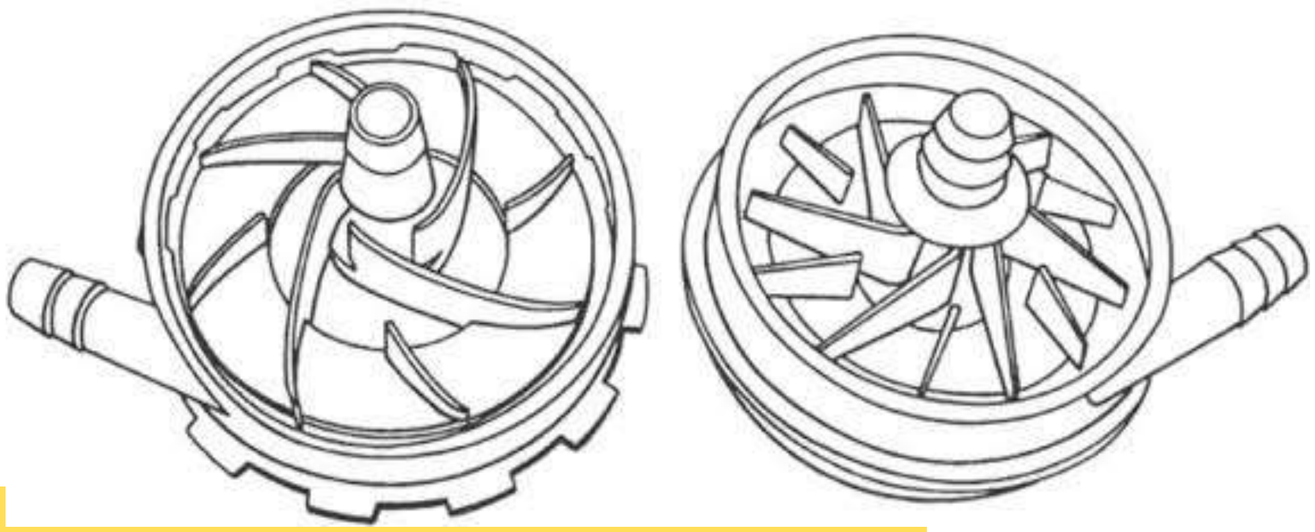


CHARACTERISTICS OF CENTRIFUGAL PUMP

- The basic design of centrifugal pump consist of an impeller arranged with either varies of smooth plastic cones inside a plastic housing .
- Blood enters at a point at the centre of the nested corners and exist in another point.
- The spinning cones create a negative pressure that pulls blood into the pump. Once the blood is inside the pump head, energy is imparted to blood by spinning cones, forming a vortex . The vortex is then constrained by the outside plastic housing , generating pressure to pump the blood at outlet

- The cone spin by means of an indirect magnetic connection to a drive shaft on the centrifugal pump console.
- Between inlet and outlet there is no occlusive device in the pump . If the corner were not spinning fluid could flow through the head in either direction
- During bypass flow is affected by preload and afterload
- PRELOAD- Pressure at the inlet point
- AFTERLOAD- Pressure at the outlet point
- The disposable pump head is placed in a permanent console


Preload
A
Housing
Stacked cones
B
Afterload
Strut
Shaft
Backplate
Magnet
Bearing column



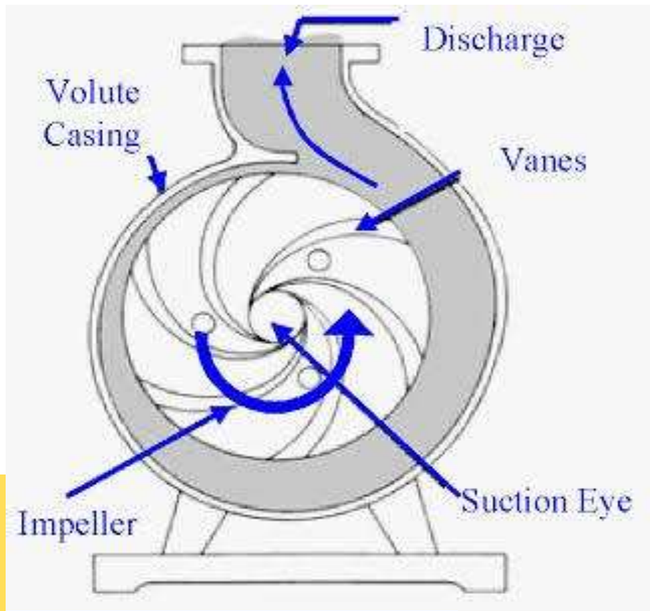
Two major types,

- The first type consists of a nest smooth plastic cones , contained within plastic housing.
- The second type consists of a vanes impeller , inside the conical plastic housing.
- The cones or impellers are rotating by coupled the base of the plastic housing (magnetic coupling) to an electric motor ,rapidly rotated lead to impart of kinetic energy to the blood , inducing forward flow.
- The centrifugal pump is non occlusive ,and flow is dependent on the pressure change created by the spinning cone within the pump.
- The flowrate is affected by the aortic cannula size , tubing length ,tubing diameter , restrictions in the tubing , and changes in the patient's systemic vascular resistance(svr).

- The blood is drive through the plastic housing by a pressure differential , Which results from the difference of the velocity of the narrow portion of the impeller cone (at the top) as compared with the wider portion of the cone(at the bottom) creates a pressure difference.
- When a centrifugal pump is used an electromagnetic flow meter probe must be placed to the arterial line to determine pump flow it is placed often between the arterial line filter and patient to accurately determine the flow rate.
- If the centrifugal pumps become filled with air ,it will not pump blood because they relies on centrifugal force to generate pressure
- But a small bubbles can be easily transmitted into the systemic circulation if they are present in the blood.

SMOOTH PLASTIC CONE

VANES IMPELLER



Advantages

- Because of centrifugal pumps are sensitive to afterload pressure there is no possibility of excessive line pressure build up in arterial line of the pump ,because flow decrease when pressure increases.
- Have tendency not to pump air that may be introduced into the circuit . Because of high pressure at periphery and low pressure at the centre of the pump head
- Decreased blood trauma
- Less cavitation
- Elimination of tubing wear or spallation

Disadvantages

- Different operation technique for initiation
- Flow meter is necessary
- Retrograde flow when pump slows or stops
- More expensive and non-reusable pump
- It is estimated that approximately 50% of all CBP procedure now use a disposable centrifugal pump head in the arterial position

SPECIFIC CLINICALLY AVAILABLE CENTRIFUGAL PUMP

1. Biomedicus pump
2. Delpin pump
3. Life stream pump
4. Capiox pump
5. Nikkiso pump

Comparison b/w roller pump & centrifugal pump

ROLLER PUMP	CENTRIFUGAL PUMP
• Positive displacement pump • Reusable pump with inexpensive disposable parts • Ease of sterilization • Simple flow rate determination • Variable stroke volume for differed sized patients • Preload and afterload independent • No chance of hypoperfusion • Spallation and blood trauma • High negative pressure hence risk of air embolism is high • Flow rate is determine by rpm× sv [stroke volume]	• Kinetic energy • More expensive and non- reusable pump • No possibility of disruption from excessive line pressure buildup • Decreased blood trauma • Less cavitation • Flow meter is necessary • Preload and afterload dependent • Cause hypoperfusion • No spallation occur • It will not generate high negative pressure and decreased risk of micro embolism

• Contraindicated for long term use because of tubing wear and blood trauma • Protein & platelet denaturation occurrence induces more compliment activation • Over pressurisation is one of the greatest hazard of using roller pump and causes circuit rupture when the outlet side is accidently kinked or clamped [350-500mmHg] • It is susceptible to emptying the reservoir and pumping air to patient • They are occlusive in nature • It does not cause retrograde flow	• It depends on the resistance of vascular system • It is indicated for long term procedure • It will not generate excessive pressure about 700-900mmHg • Non –occlusive • Causes retrograde flow

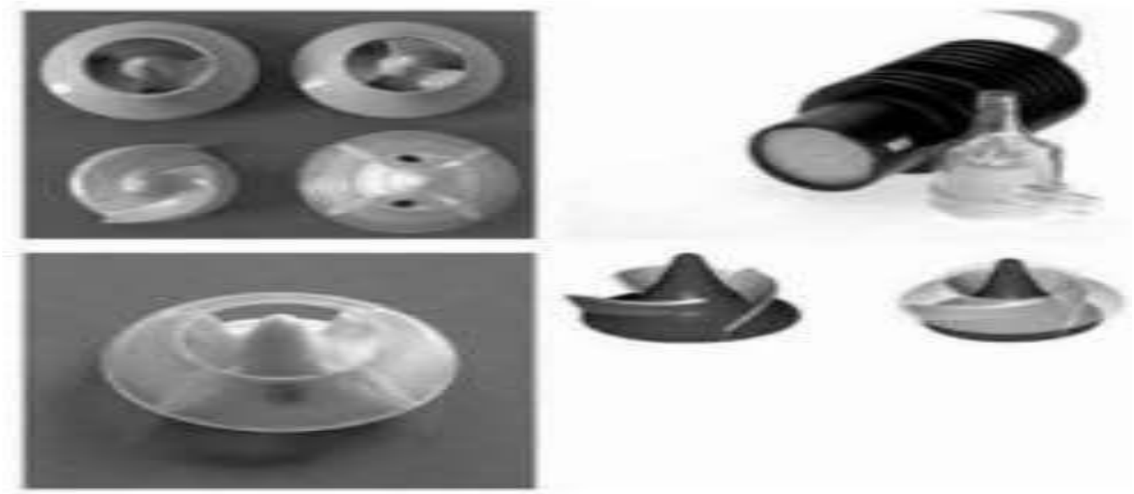
Diagonal pump

- There is currently only one diagonal pump available (the Delta Stream)
- This pump was developed by the Helmholtz Institute in Aachen to provide a **highly integrated blood pump** for use not only in cpb procedures but also for longer duration support , such as ECMO and ventricular assist.
- Two systems were developed , one with a built in electric motor for ventricular assist and ECMO procedures and the other with a disposable pump head and an external motor for short term procedures.
- Major advantages of this pump are its capability of **generating pulsatile flow**, small size , and simple design

Working principle

- The basic design has a hydraulic efficiency and a priming volume between that of an axial pump and centrifugal pump
- The pump consists of a cylindrical electric motor integrated into the pump and an annular blood flow path that surrounds the motor for cooling purposes.

- The impeller is positioned between the pump inlet and the motor.
- The motor cylinder and the impeller have a diameter of approximately 25mm.
- Colour Flow Doppler was used to optimize the blood path in the pump head.
- As could be expected from a diagonal design the RPM necessary to achieve a certain flow against a given resistance will be higher than that in impeller centrifugal pumps.

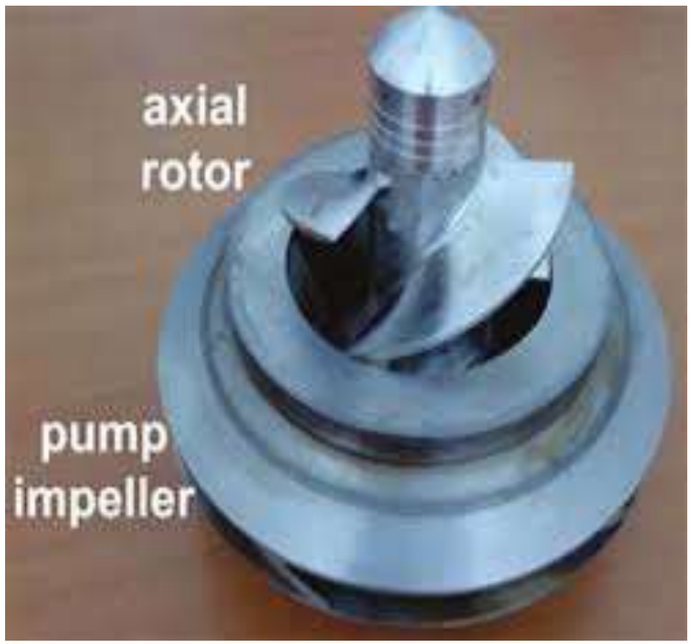


Axial pump

- The axial blood pump is a new generation of rotary pump , it consists of axial or diagonal impeller driven by an electric motor to generates an axial flow by rotating the blood internal impeller.
- Impeller is an important component in axial pump , and its structure mostly determines the heart pump performance , thus a marked improvements in impeller design ensures a high flow rate and little blood damage.
- Axial pump motivated by electric motor to provide high speed rotation.

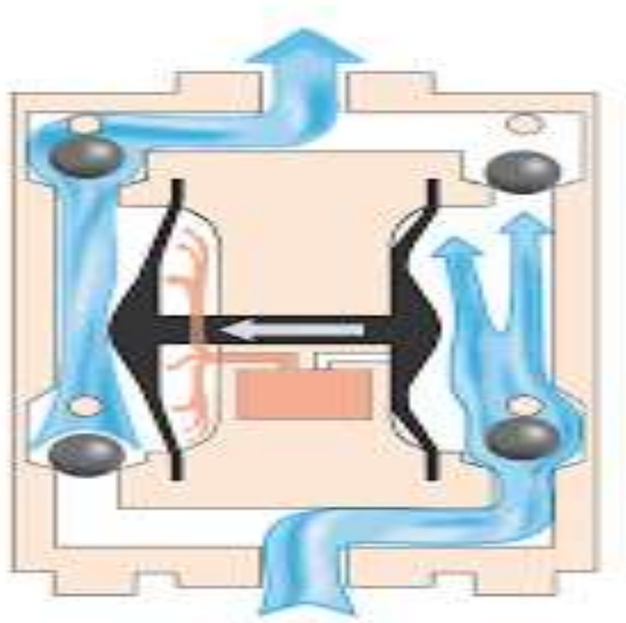
- In some generation both continuous flow and pulsatile operation are possible(eg.DP3 from medos)
- When comparing between centrifugal and axial pump design theory , centrifugal pumps are capable of producing higher pressures at lower flows ,where as axial pumps typically generate higher flows at lower pressure rises.
- The priming volume of axial pumps is smaller than that of centrifugal pumps, so it usually utilized in pediatrics ECMO and ventricular assist device.

- Axial flow pumps operate at much higher rotational speeds (up to 15000 rpm),than centrifugal pumps (up to 5500rpm) to produce the desired head pressure and flow.
- In addition axial flow pumps have a lower energy consumption , which allows lighter power supply components and eventually implantable batteries



DIAPHRAGM PUMP

- It is also known as membrane pump.
- It is a positive displacement pump that uses a combination of the reciprocating action of a rubber , thermoplastic or Teflon diaphragm and suitable valves on either side of the diaphragm to pump a fluid



Characteristics

- Have good suction lift
- Suitable for discharge pressure upto 1200 bar
- Have good dry running characteristics
- Can be upto 97% efficient
- Have good self priming capability

Pump composition

- Double diaphragm pumps consists of two diaphragm connected to a piston and contained within two separate displacement chambers , each with an inlet and discharge valve
- The diaphragms are made of **flexible material** compatible with the pumped media
- They are sealed in place b/w the side of the displacement chamber and an attached flange.
- The chambers volume is slightly greater than what the diaphragm can displace the valves are typically spring loaded ball valves or flapper valves and they function to admit the fluid in and out of the chamber

Advantages

- Seal less and oil free
- Almost steady flow
- Handless most media types-Particularly corrosive or abrasive chemicals

Disadvantages

- Low maximum speed

THANK YOU