Learning Objectives

- Explain the indications, function and complications for selected mechanical circulatory support devices.
- Describe examples of ventricular assist devices and total artificial hearts.

Noninvasive Mechanical Support Devices

Mechanical aids to external massage

- Automatic resuscitator - Michigan Instruments Thumper™
  - Advantages:
    - Consistent compression, without fatigue
    - Frees personnel for other actions
  - Problem - Patient tends to be moved out of correct position (Ouch!)

- Max Cart

Mechanical aids to external massage

- Michigan Instruments Thumper™ 1007

FYI - Click to see web page with ACDC Thumper™
http://www.cryonics.org/reports/ACDC_Thumpers.html

Courtesy Michigan Instruments
http://www.michiganinstruments.com/
**Mechanical aids to external massage**

- **Ambu Cardiopump™**
  - Suction cup attaches to chest, permitting upward traction
  - Delivers active compression & decompression of chest wall
  - Invented after woman resuscitated husband with toilet plunger
  
  Click to see Ambu Cardiopump™
  http://www.alcor.org/images/cardipump.jpg

  Click to see Ambu Cardiopump™ in use

**Advantages:**
- active decompression increases refill of ventricles and lungs
- may effectively ventilate
- small
- inexpensive
- research - improves short-term survival

**Difficulties with use:**
- body hair - maintaining a seal
- moisture - maintaining position
- initial trials - encouraging
- requires more study
- not available in U.S.A.

**Mechanical aids to external massage**

- **CPR vest (Zoll AutoPulse™)**
  - Vest surrounds body - intermittent inflation & deflation provides chest compression
  - Battery-powered - transport

  Click to see AutoPulse™ web page

**Advantages:**
- Less traumatic than manual
- No fatigue
- Frees personnel for other actions
- Can incorporate defibrillator
- Research - increased short-term survival
- May ventilate effectively

**Disadvantages:**
- Large; but replaces a person
- Expensive
- Requires more study
**Mechanical aids to external massage**

ResQPOD™ impedance threshold device

![ResQPOD](https://www.advancedcirculatory.com/)

**FYI - Click for Advanced Circulatory Systems, Inc. website**

http://www.advancedcirculatory.com/

- Connects between manual resuscitator and mask or artificial airway
- Improves hemodynamics during CPR
- Limits air entry to lung during chest compressions
  - increases negative intrathoracic pressure
  - increases ventricular preload

**Click for ResQPOD video (2.0)**


**Mechanical aids to external massage**

ResQPOD™ effects

- Doubles venous return
- Increases blood flow to the brain by 50%
- Doubles systolic blood pressure
- Increases survival

**Mechanical aids to external massage**

Tobacco enema (Dutch fumigation)

Invasive Circulatory Support
Open Chest Cardiac Massage
- Greater cardiac output than with closed-chest
- Requires surgeon to perform

Click to see picture of open chest cardiac massage
http://www.trauma.org/images/image_library/chest0052d.jpg

Intraaortic Balloon Pump (IABP)
- IABP is a left ventricular assist device
- Most commonly used circulatory support technique
- Balloon inserted into descending aorta and
  ◆ inflated during diastole (with Helium)
  ◆ deflated at end-diastole

Click to see balloon catheter in place
http://www.dkimages.com/discover/previews/936/65148525.JPG

IABP
- Effects
  ◆ increases coronary blood flow
  ◆ increases diastolic filling
  ◆ decreases left ventricular afterload and work
  ◆ increases cardiac output

Click to see video of balloon catheter effects (.6 min.)
http://www.youtube.com/watch?v=o1fhdVOYWA

IABP
- Indications
  ◆ cardiogenic shock
  ◆ acute myocardial infarction
  ◆ failure to wean from bypass
  ◆ bridge to transplant
  ◆ Permanent implantable pump is currently under study

IABP
- Limitation- provides only partial (1.5 L/min) cardiac output support
- Complications
  ◆ limb ischemia
  ◆ renal ischemia
  ◆ thrombocytopenia
  ◆ bleeding from insertion site
  ◆ balloon rupture
IABP

- Balloon insertion techniques
  - percutaneous via cutdown - least invasive
  - transthoracic - after cardiac surgery
- Position confirmed with fluoroscopy, chest radiograph

Console settings
- Trigger mode
  - ECG
  - arterial waveform
  - alternative modes - pacemakers
- Support ratio - inflations: heart rate
  - start with 1:1
  - wean as indicated, to removal

Timing
- early inflation - severe complications
  - impedes left ventricular emptying
  - increases myocardial O2 uptake
- early deflation - reduced effectiveness
  - ventricular afterload not decreased
  - coronary blood flow not increased

FYI - Click to see backup device
http://commons.wikimedia.org/wiki/Image:Bicycle_Pump_foot_operated.jpg
FYI - Link to Maquet™ IABP educational resource
http://www.datascope.com/clinician_information/educational_programs_material/e-learning_programs/

Click for image of transthoracic balloon insertion

Click to see a balloon pump
http://www.wemed1.com/images/CAR-AC-1PLUS.JPG

Click for illustration of IABP timing
http://crashingpatient.com/wp-content/images/part3/art-587246zacharowski.fig1_v2.jpg

Extracorporeal Membrane Oxygenation (ECMO)

- Definition - a modified form of heart lung bypass that supports patients with severe respiratory or cardiorespiratory failure.
- Description - Venous blood is drained via a cannula to a circuit containing an artificial membrane for gas exchange & returned to patient via artery or vein.

Rationale - ECMO assumes heart and/or lung function, allowing organs to rest and preventing:
- ventilator-induced lung injury
- oxygen toxicity
- damaging effects of prolonged use of inotropic agents
### Indications - Neonates
- Gestational Age $>34$ weeks
- Weight $>2$ kg
- Reversible disease
- No major ($>\text{grade 1}$) intracranial hemorrhage
- No lethal congenital abnormalities

### Specific Conditions - Neonates
- Meconium aspiration
- Congenital diaphragmatic hernia
- Persistent pulmonary hypertension
- RDS

### General Indications - Adults & Pediatric Patients
- Potentially reversible disease
- Failure to respond to maximal, less-invasive therapy

### Specific Conditions - Adults & Pediatrics
- Pneumonia, pneumonitis
- Bronchiolitis
- Septic shock
- ARDS
- Aspiration pneumonia
- Severe trauma
- Post cardiac surgery

### Contraindications
- Irreversible CNS injury
- Immunocompromise - high risk for lethal infection
- Coagulopathy - high risk for lethal hemorrhage

### System Circuit Components
- Venous line
- Blood pump
- Oxygenator
- Carbogen - CO2 must be added
- Heat exchanger
- Arterial line - for veno-arterial and/or ABG sampling
**ECMO Circuit**

**EXTRACORPOREAL LIFE SUPPORT**

- System controller unit - monitors and controls function
- Mechanical ventilator
  - maintain pulmonary expansion
  - minimal settings to avoid ventilator induced lung injury

Click to see photograph of ECMO with patient
http://www.mrtwee.nl/thumbnail/ECMO.jpg
Click to see video of ECMO function (1.0)
http://www.youtube.com/watch?v=J7FDpmlSJEU&feature=related

---

**ECMO**

- Complications
  - bleeding - including cerebral
  - risk from blood products
  - emboli
  - equipment malfunctions
  - infection through cannulation sites

FYI - Click to use ECMO simulator or bookmark for later
http://ecmojo.sourceforge.net/

---

**Ventricular assist device**

- Description
  - pump from ventricle(s) to aorta and/or pulmonary arteries, providing perfusion
  - native heart remains in place

Click to see ventricular assist device in place
http://media.web.britannica.com/eb-media/84/98484-004-A09346FF.jpg

---

**ECMO**

- Costs
  - equipment
  - medications
  - personnel (intensive)
    - respiratory therapist
    - registered nurse
    - perfusionist

FYI - Click for AARC position on respiratory therapists and ECMO
http://www.aarc.org/resources/position_statements/ecmo.html

---

**Ventricular assist device**

- Indication - ventricular failure
  - failure to wean from IABP
  - bridge to transplant or myocardial recovery
  - destination therapy - patients with contraindications to transplant

Click to see video of how VADs work (1.5)
http://www.youtube.com/watch?v=r6RyN0yf6Y&feature=related
Ventricular assist device

Complications
- Bleeding due to heparinization
- Clots
- Recurrent chest explorations
- Infection
- Hemolysis
- Device malfunction

Ventricular assist device

Thoratec™ VAD
- external placement
- univentricular, biventricular support
- supplanted by implantable devices

Click to see Thoratec™ VAD
FYI - Click for Thoratec web site with pictures and videos

Ventricular assist device

Thoratec Heartmate™ vented electric LVAD
- internal placement
- portable - patient can go home
- least thrombogenic
- pulsatile flow
- high cardiac output (>9 L/min)

Click to see Thoratec Heartmate™ vented electric LVAD
Click to see illustration of Thoratec™ VAD in place
http://my.clevelandclinic.org/PublishingImages/heart/thoratec.jpg
Click to see later generation- Thoratec Heartmate II™
http://www.texasheart.com/AboutUs/News/1st-hm2pt.cfm

Worldheart Novacor™ VAD
- internal placement
- portable - patient can go home
- high cardiac output
- mechanically reliable (multi-year life)
- thrombogenic
- one patient survived three years

Click to see thoratec heartmate ii™
Click to see illustration of Thoratec™ VAD in place
http://my.clevelandclinic.org/PublishingImages/heart/thoratec.jpg
Click to see later generation- Thoratec Heartmate II™
http://www.texasheart.com/AboutUs/News/1st-hm2pt.cfm

Ventricular assist device

Worldheart Novacor
- smaller patients
- women, adolescents
- destination device

Courtesy Worldheart™

Ventricular assist device

Worldheart Levacor
- smaller patients
- women, adolescents
- destination device

Courtesy Worldheart™

Click to see Worldheart™ investigational devices
http://www.worldheart.com/devices.cfm
**Ventricular assist device**
- **Abiomed BVS 5000**
  - external placement
  - non-portable
  - inpatients only - patient confined to bed
  - requires anticoagulation

[Link to picture of BVS 5000](http://www.scielo.cl/fbpe/img/rmc/v134n8/fig11-01.jpg)

**Jarvik 2000™**
- internal placement
- small
- portable
- easy to implant - DIY??

[Click to see article with Jarvik 2000 in place](http://emsstaff.buncombecounty.org/inhousetraining/jarvik/jarvik_overview.htm)
[Click to see child and infant Jarvik 2000 VADs](http://medschool.umaryland.edu/uploadedImages/Medschool/Departments/Surgery/Artificial_Organs_Link/Images/Jarvik.JPG)
[Click to see Jarvikheart™](http://www.jarvikheart.com/basic.asp?id=19)

**Berlin Heart- various models, sizes**
- Incor - internal placement
- Excor - external pediatric model is approved by FDA

[Click to see implantation of Berlin Heart Excor](http://www.youtube.com/watch?v=xsvc7o1cF04)
[Click to see Berlin heart VAD](http://cdn.medgadget.com/wp-content/uploads/2011/12/berlin-heart-excor.jpg)

**Total Artificial Heart**
- Description - replaces native heart, which is removed
- Purposes
  - failure to wean from IABP
  - bridge to transplant
  - destination therapy - patients with contraindications to transplant
  - commonly needed for dilational cardiomyopathy

**Abiomed Abiocor™ replacement heart**
- in the 2001 news media
- internal placement
- alternative to transplant
- portable

[Click for Abiocor™ website with information and video](http://www.abiomed.com/products/heart-replacement/)
Total Artificial Heart
- SynCardia - formerly Jarvik 7, Cardiowest
  - first implanted in 1982
  - effective bridge to transplant
  - adult and pediatric versions
  - replaces only the ventricles, valves

Click for illustration of SynCardia artificial heart
http://www.rcsiamj.com/wp-content/uploads/HeartTx-Fig3.png

Click to see animation of SynCardia heart (11 sec)
http://www.syncardia.com/educational/animation-syncardia-temporary-total-artificial-heart.html

Issues with MCS devices
- Goal for device - bridge or destination
- Removal of native heart
- Need for anticoagulants
- Response to increased demand
- Size
  - pediatric vs. adult
  - internal vs. external placement

Issues with MCS devices
- goal for device - bridge or destination
- removal of native heart
- need for anticoagulants
- response to increased demand
- size - for implantation
- portability
- reliability
- pulsatile flow - controversial
  - increased flow per unit of pressure
  - strengthens vascular wall muscles

Summary & Review
- Noninvasive devices
  - Thumper
  - Ambu Cardiopump
  - CPR vest
  - ResQPod
  - Dutch fumigation

Summary & Review
- Open-chest cardiac massage
- Intra-aortic counterpulsation
- ECMO
- Ventricular assist devices
- Total artificial heart

References
END