Mechanical Circulatory Support

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This Presentation is Approved for 1 CRCE Credit Hour

Learning Objectives

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

Noninvasive Mechanical Support Devices

Mechanical Aids to External Massage

Automatic resuscitator: Michigan Instruments Thumper™ * Pneumatically-powered compressor positioned over patient * Max Cart

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!)



Mechanical Aids to External Massage

➤ CardiopumpTM

- $\boldsymbol{\ast}$ Suction cup attaches to chest, permitting upward traction
- * Delivers active compression & decompression of chest wall
- $\ensuremath{\div}$ Invented after woman resuscitated husband with toilet plunger

See links below to view Cardiothump[™] & its usage

Mechanical Aids to External Massage

- Active decompression increases refill of ventricles &
- lungs
 May effectively ventilate
- Small
- Inexpensive
- Research improves short-term survival

Mechanical Aids to External Massage

- Body hair: maintaining a seal
- Moisture: maintaining position

Mechanical Aids to External Massage

CPR vest (Zoll AutoPulse[™])

- * Vest surrounds body: intermittent inflation & deflation provides chest compression
- * Battery-powered transport

See links below to view AutoPulse™ video

Mechanical Aids to External Massage

➤ Zoll AutoPulse™

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

Mechanical Aids to External Massage

* Requires more study

Mechanical Aids to External Massage



FYI see links below to view Zoll website

Mechanical Aids to External Massage

ResQPOD[™]

- * Connects between manual resuscitator & mask or artificial airway
- * Improves hemodynamics during CPR
- * Limits air entry to lung during chest compressions
 Increases negative intrathoracic pressure
 Terretered to the second second
 - Increases ventricular preload

See links below to view ResQPOD[™] video

Mechanical Aids to External Massage

- ResQPOD[™] effects
- Doubles venous return
 Increases blood flow to the brain by 50%
- * Doubles systolic blood pressure
- · Doubles systolic blood press
- * Increases survival

Mechanical Aids to External Massage

- ResQPOD[™] additional features
- * Timing assist lights (2) ventilation & compression rates * Atmospheric pressure sensor - regulates airflow
- impedance
- \star Safety valve to permit spontaneous inspiration @ -10 cm H_2O

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

Open Chest Cardiac Massage

> Indications

- Cardiac tamponade
 Penetrating chest injury
- * Hypothermia
- * Chest deformity, e.g. kyphoscoliosis

See links below to view open chest cardiac massage

Intra-aortic Balloon Pump (IABP)

> IABP is a left ventricular assist device

- > Most commonly used circulatory support technique
- Balloon inserted into descending aorta &
 Inflated during diastole (with helium)
 Deflated at end-diastole

See links below to view balloon catheter in place

IABP

Effects

- * Increases coronary blood flow
- Increases diastolic filling
 Decreases left ventricular afterload & work
- * Increases cardiac output

See links below to view balloon catheter effects

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

IABP

- Console settings
 Trigger mode
 - ECG
 - Arterial waveform
 - Alternative modes pacemakers
 - Support ratio inflations: heart rate
 Start with 1:1
 - Wean as indicated, to removal

See links below to view a balloon pump

IABP

> 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 see links below to view backup device

IABP

Timing

- Appropriate inflation: right after dicrotic notch of arterial wave form
- * Appropriate deflation: end-diastole on arterial wave form

See links below for illustration of IABP timing FYI see links below for Maquet[™] IABP educational resource

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

ECMO

- Rationale: ECMO assumes heart &/or lung function, allowing organs to rest & preventing
 - * Ventilator-induced lung injury
 - * Oxygen toxicity
 - * Damaging effects of prolonged use of inotropic agents

ECMO

- > Indications: neonates
 - * Gestational age > 34 weeks ♦ Weight > 2 kg
 - * Reversible disease
 - * No major (> grade 1) intracranial hemorrhage
 - * No lethal congenital abnormalities

ECMO

- Specific conditions
 - Meconium aspiration
 - * Congenital diaphragmatic hernia * Persistent pulmonary hypertension
 - * RDS

ECMO

- General indications: adults & pediatric patients * Potentially reversible disease
 - * Failure to respond to maximal, less-invasive therapy

ECMO

- Specific conditions: adults & pediatrics
 - * Pneumonia, pneumonitis
 - * Bronchiolitis * Septic shock
 - * ARDS
 - * Aspiration pneumonia
 - * Severe trauma
 - * Post cardiac surgery

ECMO

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

ECMO

- System circuit components
 - Venous line
 - * Blood pump
 - * Oxygenator
 - * Carbogen: CO₂ must be added
 - * Heat exchanger
 - * Arterial line for veno-arterial &/or ABG sampling



ECMO

- > System controller unit: monitors & controls function
- Mechanical ventilator
 - * Maintain pulmonary expansion
 - $\boldsymbol{\ast}$ Minimal settings to avoid ventilator induced lung injury

See links below to view ECMO with patient & video of ECMO function



* Infection through cannulation sites

FYI see links below to view ECMO simulator



Ventricular Assist Device

Description

- Pump from ventricle(s) to aorta &/or pulmonary arteries, providing perfusion
- * Native heart remains in place

Ventricular Assist Device

Indication: ventricular failure

- * Failure to wean from IABP
- * Bridge to transplant or myocardial recovery
- Destination therapy: patients with contraindications to transplant

See links below to view ventricular assist device in place

See links below to view how VADs work

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

See links below to view Thoratec[™] VAD FYI see links below for Thoratec[™] website with pictures & videos

Ventricular Assist Device

- - * Portable patient can go home
 - * Least thrombogenic
 - * Pulsatile flow
 - * High cardiac output (> 9 L/min)

See links below to view later generation Thoratec Heartmate II™

Ventricular Assist Device

➤ Worldheart NovacorTM VAD

- Internal placement
- * Portable patient can go home
- * High cardiac output
- Mechanically reliable (multi-year life)
- * Thrombogenic
- * One patient survived three years



Ventricular Assist Device

> Worldheart Levacor™

- * Smaller patients women, adolescents * Destination device



See links below to view HeartWare (formally Worldheart) website

Ventricular Assist Device

Abiomed BVS 5000™

* External placement

* Non-portable

- * Inpatients only: patient confined to bed
- * Requires anticoagulation

See links below to view BVS 5000™

Ventricular Assist Device

> Jarvik 2000®

- * Internal placement
- ♦ Small ♦ Portable
- * Easy to implant DIY?

See links below to view article with Jarvik 2000[©] in place & to view child & infant Jarvik 2000[®] VADs FYI see links below to Jarvik Heart

Ventricular Assist Device

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

Total Artificial Heart

See links below to view implantation of Berlin Heart® Excor & Berlin Heart® VAD

Complications

- * Same as VAD
- * Native heart is removed

Total Artificial Heart

SynCardia: formerly Jarvik 7, Cardiowest

- First implanted in 1982
- * Effective bridge to transplant
- * Adult & pediatric versions
- * Replaces only the ventricles, valves

See links below to view animation of SynCardia heart & illustration of SynCardia artificial heart

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
- ♦ ResQPodTM

* Dutch fumigation

Summary & Review

- > Open-chest cardiac massage
- > Intra-aortic counterpulsation
- > ECMO
- > Ventricular assist devices
- > Total artificial heart

References

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