Old School Technology - Bolts, Trephining, and the Stethoscope
New School Technology - Microprocessors and Nano-machines
Regarding Patient Devices

- Always listen to the local expert in the care of these complex patients.
  - Many times the patient and/or the family.
Technology Complex Patient
by Dr. Eric M. Rudnick, MD, FACEP

Sir William Osler
History and Physical Examination

- Sir William Osler – July 12, 1849 to December 29, 1919
- Father of Modern Medicine
- Out of the lecture hall to the bedside
- Bedside manner, empowering patients, and autonomy in clinical practice
- Renowned practical joker – Eagerton Y Davis

“Listen to your patient, he is telling you the diagnosis”
What is a Ventricular Assist Device (VAD)?

- Help failing hearts pump blood.
- Advanced or end stage heart failure patients.
- Heart failure effects 5 million Americans and each year an additional 550,000 are diagnosed.
- Heart muscle is too weak to adequately pump blood.
Bridge versus Destination Therapy

- Prolonged wait and limited donors
- 3,000 donor organs each year world-wide
- "buy time" for the patient or eliminate the need for a heart transplant
- Longer-term or ‘destination therapy’ in end-stage heart failure patients when heart transplantation is not an option.
REMATCH Study

• 48% decrease in the death rate from all causes with the LVAD over the first 2 years of use.
• One-year survival in the LVAD group was 52% compared with 25% in the group receiving optimal medical.
REMATCH Study

- 8% (1 out of 12) survived two years in the optimal medical management group.
- 23% were alive at 2 years in the LVAD group.
- 1-year survival for patients under 60 years was 74%.
- Quality of life improved in the LVAD group.
- Conducted on only the sickest patients, who had no alternative options.
LVAD or Pump Basics

- The LVAD (pump) has an inflow conduit that takes blood from the weakened ventricle and pumps it into the aorta via an outflow tract.
- The pump is placed in the upper part of the abdomen.
- The “driveline” is another line (tube) that leaves the body (percutaneously) through the abdominal wall.
  - This is connected to the device’s battery and control system.
First Generation Device
Pulsatile Blood flow
Second Generation Device - Non-Pulsatile Blood Flow

- Blood enters from the left ventricle
- Rotor spins at fixed speed
- Blood exits/returned to the aorta
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Slaughter et al
Percutaneous Driveline
Blood Pressure

- 1st Generation Pulsatile
- Traditional BP
- Pulse Oximetry reflects oxygen saturation
- Palpated pulse may appear irregular
  - LVAD pulse and native heart pulse not synchronized
  - LVAD rate reflects perfusion (displayed on controller unit)
  - Palpated pulse (LVAD +/- native heart) will be different from EKG heart rate (native heart only)
Blood Pressure

- 2nd Generation Non-pulsatile axial turbine
- The pump is continuous flow – the impellar may rotate at a rate of between 5,000 and 10,000 rpm
- No audible pump cycling
- Cuff BP will not be measurable
  - Low from poor native heart cardiac output
- Pulse oximetry will not see a capillary pulse wave and may not display a value
  - Unless native heart has sufficient cardiac output
- EKG shows native heart rate and rhythm
Blood Pressure / Basics 2nd Generation

- LVAD cardiac output displayed on controller unit
  - Alarms at less than 2 liters/min output
  - Doppler to obtain a Mean BP
- Goal Mean BP is 70-90
Blood Pressure Basics 2nd Generation

• Low BP
  ▫ Just because you can’t get a BP doesn’t mean it is low
  ▫ Is the patient perfusing? If yes, probably okay
    • Cap refill
    • Mentating properly
  ▫ If BP low – needs fluid
    • VAD patient is preload dependent – needs full tank
Special Considerations

- Non-Pulsatile flow LVAD patients will be on both ASA and Coumadin
  - Bleeding risk especially in trauma
- Pulsatile flow LVAD patients will be on ASA
Common Complications

- Arrhythmia – atrial and ventricular (more common)
- Bleeding
  - GI Bleeding
  - Hemorrhagic CVA
- Stroke
  - Ischemic
- Infection
  - Carefully inspect drive line site
  - Never tug or pull at it
Arrhythmia

- Heart failure patients are at increased risk for arrhythmias
- Many VAD patients will have an implanted cardioverter-defibrillator (ICD) or pacer-ICD
- Atrial dysrhythmias will not affect LVAD
- *Synchronized cardioversion and defibrillation OK using usual pad placement*
  - Move controller unit away from defibrillation pads
- Patient may still be conscious and perfusing
Arrhythmia

• Patients having arrhythmia problems may be functioning fairly normally
  ▫ Despite being in a lethal rhythm (VT), blood is still flowing to the body.
  ▫ They may have minimal symptoms, not be alert, or unconscious
Bleeding

- Most common in the GI tract and the brain
- Risk of bleeding is increased because LVAD patients need to be on anticoagulation
  - Warfarin and ASA (2nd Generation devices)
- GI bleeding is often from
  - Arterial-venous malformation (AVM)
  - Ulcer
- Bleeding in the brain is often from
  - AVM
  - Hypertension (HTN)
  - Stroke – ischemic (pump ?) or hemorrhagic
  - Trauma
Infection

- Driveline
  - Usually due to trauma
  - Excessive moisture
- Pump Pocket
  - Extensive driveline infection
- Systemic
  - Can be from an extensive driveline infection
  - From another source
  - May quickly develop septic shock
Acute MI Considerations

- May not have hemodynamic compromise with LVAD maintaining perfusion
- Right Ventricular MI can decrease filling of the LVAD and cause pulmonary edema and/or hypotension
- Ventricular paced rhythms should not be read as ***Acute MI*** by 12 lead ECG algorithm
Special Pump (LVAD) Considerations

• **“Red Heart Alarm”:** mechanical pump failure
  ▫ Symptoms: dyspnea, nausea, syncope, loss of consciousness

• LVAD pump filling depends upon right heart filling
  ▫ Hypervolemia, right heart failure (e.g. RV infarct) or cardiac tamponade reduces right heart cardiac output
  ▫ Treatment: IV saline bolus – at least 500 mls
Warning! Warning!

Code Situation

- **Hazard Alarm: Red Heart**
- **Tone: You will hear a CONTINUOUS alarm.**
  - Pump has stopped
  - Low flow <2.5 liters/minute
  - Driveline is disconnected
Code Situation

- Follow ACLS protocol for
  - Intubation
  - Medication administration
- Defibrillation
  - Most patients will have an AICD
- External Pacing and defibrillating is okay
  - Don’t place paddles over AICD or driveline of LVAD
CPR if Clinically Indicated

- What does this mean?
- Needs to be viewed cautiously because CPR may result in dislocation or damage of the cannulas or ventricle rupture, requiring emergency thoracotomy and heart surgery.
- But, if the patient is dead then can we really hurt them?
CPR or No CPR, That is the Question

- **Unconscious**
- **Apneic**
- **Unresponsive**
- **Pump is not running (Red Heart Alarm)**
  - CPR is indicated
    - If there is good perfusion and pump is still running, CPR is not indicated
- Find the other reason for unresponsiveness
- CPR as an absolute last resort
Reverse 911 Call for EMS

- These patients are leading normal lives
- Traveling, golfing, and riding motorcycles
- For example:
  - Patient shopping at mall
  - Battery alarm goes off and forgot spares
  - Called 911
  - Code 3 transport to patient’s home with lights and siren
  - Local hospital would not have proper equipment
Transport to Hospital

- Bring all the equipment to the hospital!
  - Back-up system controller and batteries
- Contact receiving hospital you are en route with a patient who has a LVAD
- Brownie points: contact the implanting hospital
- \textit{LVAD coordinator should have already been contacted even before 911 initiated}
Treatment Summary

• BLS and ALS treatment guidelines and procedures are applicable in LVAD patients.
• All ALS drugs are applicable in LVAD patients.
• There are No absolute contraindications for treatment guidelines or drugs.
• CPR: Unconscious, unresponsive, apneic, and with “Red Heart Alarm” audibly sounding on the controller unit.
Treatment Summary

• Take all LVAD equipment to hospital
  ▫ Power Base Unit
  ▫ All batteries
  ▫ Hand pump (displacement/pulsatile LVAD unit only)

• Keep patient’s trained companion with the patient (will manage LVAD)

• Anticipate expeditious (damn fast) interfacility transfer to LVAD program home hospital
Automatic Internal Cardioverter Defibrillator (AICD)

- Developed 1980’s
- Implantable – now inserted transvenous
- Treat cardiac tachydysrhythmias – especially ventricular
  - Sudden death survivors due to VF or VT (secondary prophylaxis)
  - Primary prophylaxis based upon guidelines
- Sensors can hopefully recognize supraventricular tachycardias – minimize shocks
- Magnet temporarily turns off defibrillator but not pacing
Automatic Internal Cardioverter Defibrillator

- Fixed rate (asynchronous) – R on T risk
- Demand (synchronous)
- Magnet inhibition – temporarily “reprograms” into asynchronous mode.
- If left on for 30 seconds, ICD turned off.
- To reactivate, remove the magnet and then replace the magnet.
- Listen for the tone(s)
Automatic Internal Cardioverter Defibrillator (AICD)

- Complications
  - Pain
  - Bleeding
  - Pneumothorax and/or hemothorax
  - Cardiac perforation
  - Infection
  - Lead dislodgment
  - Lead fracture
  - Inappropriate shocks
  - Erosion device through skin
- Resuscitation – defibrillation 10 cm away
External Defibrillator
What to do?
Temporary device
Pacemaker
Pacemaker

- Indications
  - Sick sinus
  - Symptomatic bradycardias
  - Tachycardia-bradycardia syndrome
  - Complete atrioventricular block (3rd degree)
  - Prolonged QT
- Generator and pacing leads, inserted transvenous
- Pulse generator placed subcutaneously or submuscularly
Pacemaker

- Complications
  - Failure to output
  - Failure to capture
  - Failure so sense
  - Pacemaker-mediated tachycardia
  - Runaway pacemaker
  - Pacemaker syndrome
Pacemaker

• Complications
  ▫ Twiddler’s syndrome
  ▫ Pain
  ▫ Bleeding
  ▫ Pneumothorax and/or hemothorax
  ▫ Cardiac perforation
  ▫ Infection
  ▫ Lead dislodgment
  ▫ Lead fracture
  ▫ Erosion device through skin
Home Infusions

- Insulin
- Pulmonary hypertension
- Antibiotic and other anti-infectives
- Vasopressors and inotropes - i.e. Dopamine for heart failure
- Hemophilia (factor therapy)
- Parenteral nutrition
- Intravenous gamma globulin (IVIG)
- Colony stimulating factors
- Chemotherapy
- Pain management
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Intratheal Pumps and Infusions

- Medications
  - Baclofen
  - Morphine

- Indications
  - Pain from severe spinal arthritis, spinal stenosis
  - Cerebral Palsy

- Access port to refill medications

- Programmable

- Battery changing is surgical procedure
Intratheal Pumps and Infusions

• Complications
  ▫ Pain
  ▫ Bleeding
  ▫ Infection
  ▫ Erosion
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Ventricular Peritoneal (VP) Shunt

• Placed for hydrocephalus
• Decrease intracranial pressure
• Drainage of CSF into abdomen
• Complications and issues
  ▫ Disconnection
  ▫ Fracture or dislocation
  ▫ Erosion of shunt into other organs
  ▫ Infection at the site and/or deep – needs emergent removal
Ventricular Peritoneal (VP) Shunt

- Signs and Symptoms caused by malfunction
  - Headache
  - Seizures – new or increased activity
  - Lethargy
  - Vomiting with little to no nausea
  - Altered personality
  - Altered intellectual ability
  - Visual disturbance
### Ventricular Peritoneal (VP) Shunt

- **Young child**
  - Impatient
  - Grouchy
  - Whiny
  - Anxious
  - Bulging fontanel and/or head enlargement
  - Mental and/or physical abilities (milestones) lost
  - Downward deviation eyes – diesel therapy
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Deep Brain Stimulator
Deep Brain Stimulator

- Indications
  - Parkinson’s Disease
  - Depression
- Parkinson’s Disease inserted into Thalamus or subthalamic region
- Eradication tremor and dystonia
- Programming issues
Deep Brain Stimulator

- Complications
  - Side effects of stimulation
    - Numbness
    - Weakness
    - Double vision
    - Imbalance
    - Problems thinking
  - Superficial bleeding
  - Bleeding into the brain (stroke) and/or death
  - Wound infection
  - Fracture of hardware
  - Erosion
Vagus Nerve Stimulator
Home Dialysis

- Hemodialysis
- Peritoneal
Dialysis

• Cardiovascular mortality is 10-20 times higher in dialysis patients than the normal population.
• All cause mortality in dialysis patients older than 65 years is more than 6 times the general population.
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Dialysis

• Arterial-Venous (AV) Shunt malfunction
  ▫ **Bleeding – can be severe** *Don’t use tourniquet*
  ▫ Infection
  ▫ Clotting

• Electrolyte abnormalities
  ▫ Hyperkalemia – sodium bicarbonate and Albuterol
    • Arrhythmias
    • Monitor abnormalities
    • Acidosis
  ▫ Hyponatremia
    • Mental Status changes
    • Seizures
    • Fluid overload
Dialysis

- Hypocalcemia or Hypermagnesemia
  - Weakness
  - Arrhythmias
- Hypocalcemia
  - Tetany
  - Parasthesia
- Hypermagnesemia
  - Neuromuscular depression
  - Loss of reflexes
Dialysis

- Sepsis – cautious fluid administration
- Cardiac arrest – standard ACLS with consideration of sodium bicarbonate (base hospital)
- Pericardial tamponade
- Fluid overload - nitrates
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Dialysis

• Peritoneal Dialysis
  ▫ Peritonitis – occurring once per year
  ▫ Abdominal pain – generalized versus localized
  ▫ Fever
  ▫ Cloudy effluent – ask the patient

• Site infection – local site redness
Halo Devices
External Fixators
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Exoskeletons
Robotic Limbs
What Does The Future Hold?