Swine-Based Teaching Labs
Center for Advanced Medical Simulation & Learning
University of South Florida
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The left ventricular assist device, or LVAD, is a kind of mechanical heart. It is placed inside a person's chest and helps the heart pump oxygen-rich blood throughout the body. Unlike an artificial heart, the LVAD doesn't replace the heart - it just helps it do its job. It allows a heart to rest after open-heart surgery and assists a heart that is too weak to effectively pump on its own. It buys time for someone waiting on a heart transplant.
Permanent LVADs are currently being used in some terminally ill patients whose condition makes them ineligible for heart transplantation “destination therapy”

Therapy with a permanent LVAD device has been documented to have doubled the one-year survival rate of patients with end-stage heart failure vs. drug treatment alone

- relieves symptoms such as being constantly tired or short of breath
- sometimes it lets the heart recover normal function by giving it a chance to rest
How Does an LVAD Work?

- One end of the device hooks up to the left ventricle, the other end hooks up to the aorta; the device then pumps oxygenated blood out of the lungs and out to the body.

- A tube passes from the device through the skin and attaches to a computer controller, a power pack, and a reserve power pack.

- Those parts of the system remain outside the body worn on a belt or harness.
Cardiopulmonary bypass (CPB)

- Cardiopulmonary bypass is commonly used 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 circulation during that period.
- The machine nourishes the blood cells and allows them to continue cellular respiration even through surgery.
- CPB mechanically circulates and oxygenates blood for the body while bypassing the heart and lungs.
- Often called a “heart–lung machine”, it maintains perfusion to other body organs and tissues while the surgeon works in a bloodless surgical field.
(CPB)

0 The surgeon places a cannula in right atrium to withdraw blood from the body
0 The cannula is connected to tubing filled with isotonic crystalloid solution
0 Venous blood that is removed from the body by the cannula is filtered, cooled or warmed, oxygenated, and then returned to the body usually via the ascending aorta
The patient is administered heparin to prevent clotting.

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

The blood is cooled during CPB and returned to the body. The cooled blood slows the body’s basal metabolic rate, decreasing its demand for oxygen.
0 Once stable CPB is established for at ~2min, lung ventilation is discontinued and the by-pass machine is hooked up to the vaporizer to provide O2 and Isoflurane

0 Regular Blood Gasses are pulled by the perfusionist
  0 We are not really running anesthesia at this time – they are
  0 We continue to monitor and record vitals every 15 min per SOP – changes are reported to the perfusionist & surgeon
  0 Monitor needs to moved so perfusionist can see the BP readings
Induction ("Pre-Prep")

**Ketamine/Diazepam**
- Diazepam (PO)
  - Crushed tablets given with simple syrup
  - Allow 30 min to effect prior to administration of ketamine
- Ketamine, Atropine (IM)
  - Usually administered in neck or hamhocks
  - Smooth induction, usually ready for intubation within 15 min

**Ketamine/Midazolam**
- Midazolam, Ketamine, Glycopyrolate (or Atropine) (IM)
  - Given as one mixed injection, usually in neck or hindquarters
  - Smooth very quick induction, usually ready for intubation within 10 minutes

Leave the room while drugs take effect (be very quiet if you must remain in the room)
Keep The Animal Calm

- Unhandled pigs can stress easily
  - Introduce them to Red Restraint Boards on arrival!
  - Train them to take Simple Syrup to improve their reception to the restraint boards and oral pre-meds

- Stress receptors compete for binding sites with some drugs and can cause an opposite reaction (excitement) and or prolonged induction

- A quiet undisturbed room after administration allows for a smoother induction – ALLOW TIME FOR DRUGS TO WORK before moving the animal!
  - Allow ~30min after oral Diazepam ...
  - Then give the Ketamine and allow 10min for both to work prior to shaving/hosing and then transporting from the room
IM injection locations

Dorsal Neck
- Preferred IM location, less stressful injection site
- Does not typically require restraint
- Be careful to not hit the fat pad – aim behind the ear

Hind Quarters
- Secondary IM pre-anesthetic location
- Ketamine is acidic, can sting, some restraint may be necessary – aka “the Board”
- Can accommodate larger volumes

IV butterfly catheters or needle/arterial extension line best bet to deliver bolus injections IM in swine
Handling The Anesthetized Pig

- Wash & shave in the animal room
  - Do not proceed until the animal is resting quietly
  - Use warm (not hot) water
  - Shave from shoulders to hips ~8-10” wide to accommodate Bovie pad & Water Circulation Pads
  - Shave from jowls to umbilicus to allow room for sternotomy access

- Pigs are prone to intestinal torsion
  - Transfer pig from cart to table by sliding pig sideways vs. “flipping”
  - Place pig with left side down
  - Place facemask and begin Isoflurane ~3.0% - 4.5%
Ensure a tight seal with nose cone:
- Avoid WAGs leaks
- Provides quicker induction
- Slide “grill” of wash table back to hold mask in place

Initially inducted pigs may still retain slight motor skills
- Rolling pigs may cause excitement and increase chances for torsion
- Apply eye lube and Cetacaine™ as soon as mask is in place
Prep Cart Set up:

- 22g IV catheters – “blue” for marginal ear veins
- 20g IV catheters – “pink” for auricular arteries
- Catheter plugs
- IV bag (heparinized NaCl)
- Ear support (optional)
- Tape or Tegaderm™ patches
- Cetacaine™ Spray
- Lidocaine gel
- Eye Ointment (Puralube)
- Laryngoscope
- Endotracheal tube (7.5, 8.0, 8.5)
- AmBu Check syringe or bulb
IV Catheters in Prep

Auricular Artery
- Deeper
- Need to quickly insert needle
- Smaller catheter size better (20g)

Marginal Vein
- Superficial
- Darker appearance
- More “forgiving”
- Catheter can be larger (22-18g)
IV Catheters in Prep

- 22g IV Catheter placed in each Marginal Ear Vein = 2 per pig (one per ear)
- Flush at initial placement and again when secured
0 20g IV Catheter placed in each Auricular Artery
   = 2 per pig
0 One each ear
0 Again flush on placement and then after secured in place
Secure IV Catheter

- Rolled up gauze or paper towels may be used to provide extra support
- Tape or Tegaderm secure the catheter(s) in place
- Always flush catheter to ensure patency
**Miller 4 (on top)**
- **Pro**: fiber optic – bright light for easy view
- **Con**: blade length can be short depending on pig, rendering more difficult intubation

**Wisconsin 11 (on bottom)**
- **Pro**: longer blade in larger pigs, easy to secure epiglottis under blade for easier intubation
- **Con**: older style light bulb, bulb can become warm to the touch, and dimmer than fiber optic styles
- **Con**: can be inserted too far and flatter tip can cause bleeding to epiglottis
Use an appropriate sized Endotracheal Tube for your pig (50-60kg = ~8)

Inflate cuff to ensure it holds pressure – note volume

FULLY deflate cuff
Make sure connector is firmly seated (“jam it on there”)

Coat ET tube in Lidocaine gel to aid intubation and lessen vasospasm

Length of roll gauze or umbilical tape to tie in position
Intubation in Left Lateral Recumbency

- Place pig in left lateral recumbency
  - Laryngoscope is designed for the right hand approach
  - Allows the left hand to guide ET tube easier
- Tongue is extended anteriorly, using dry gauze and secured below laryngoscope
• Gently tease epiglottis from soft pallet
• Secure epiglottis ventrally utilizing laryngoscope to visualize vocal cords
• Place laryngoscope at approximately a 30° angle
Placement of the ET Tube

- Advance ET tube to vocal cords
  - Listen for breath sounds & stop
  - When you hear inspiration
    - Advance tube through vocal cords (may require a slight twist)

- Ensure proper placement of ET tube
  - Look for fog in tube
  - Listen for breath sounds
    - May cough at this point
Ambu-Check Device

- Relies on the anatomical difference between the esophagus and trachea as its working principle:
  - If it “sticks” you are in the esophagus
  - If it “pops” you are in the trachea.
0 Hook up to Isoflurane (3.0-4.5%)
0 Slide the tube in the entire length
0 Inflate the cuff
  0 Do not attempt to push more than ~3/4 of the volume the cuff held during the pressure test!
0 Remember ET tube is NOT secure until tied in!
  0 Even then danger of extubation remains – take care when moving the pig
Secure ET Tube

- Secure tie around tube itself first with a square knot
- Secure ends around the ‘notched’ portion of the connector
- Secure the ends around the snout
  - Capture the inflation pillow
Check Shaved Areas

- Shaving and Bathing should have occurred during Pre-prep (aka: the animal room)
- Entire back and chest need to be shaved
Transport to OR

0 Take care when moving!!
  0 Extubation possibility
  0 Catheters could get pulled
  0 Rolling/dropping the patient is a danger
  0 Hurting yourself via improper bending/lifting
Transfer to Table

- Again – watch positioning!
  - Support head and stabilize airway
  - Position head so catheters don’t have positional flow problems
  - Secure feet all 4 corners
Transfer to Table

0 Hook up O2/Isoflurane & ventilator
0 Attach ECG leads (3)
0 Attach PulseOx sensor to lip, ear or vulva
0 Insert temperature probe rectally or vaginally
0 Take first set of readings in OR at this time!
  0 Adjust ventilator volume, isoflurane levels, etc. AFTER you’ve assessed the patient
Normal Values in Swine

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rectal Temperature</strong></td>
<td><strong>98.5 – 104.0 F°</strong></td>
</tr>
<tr>
<td>Heart Rate</td>
<td>70-120 bpm</td>
</tr>
<tr>
<td>Respiration Rate</td>
<td>8-20 bpm</td>
</tr>
<tr>
<td>SpO2</td>
<td>&gt;95%</td>
</tr>
<tr>
<td>ETCO2</td>
<td>30-40mmHg</td>
</tr>
<tr>
<td>Blood Pressure - systolic</td>
<td>80-120</td>
</tr>
<tr>
<td>Blood Pressure - diastolic</td>
<td>55-90</td>
</tr>
<tr>
<td>Mean Arterial Pressure</td>
<td>80-110mmHg</td>
</tr>
<tr>
<td>Tidal Volume</td>
<td>5-10 ml/kg</td>
</tr>
</tbody>
</table>

The mean arterial pressure has to be calculated using the following formula:
Mean BP = [((2 x diastolic) + systolic) / 3]
IV lines

- Use of IV Fluid Warmer
  - Turn it on (button on side)
  - Prime the IV line until fluid comes out where needle connects
  - Open the blue slide valve on the IV line to adjust drip rate

- Hook up IV lines to marginal ear veins (blue 22g cath)
  - Start saline drip ~4-8 drops/min
IV lines

0 Set pump to ~33ml/hour for Amioderone drip
  0 Hook IV line to bag and flush to fill line
  0 Set rate (33ml/hr) – “Start/OK”
  0 Set volume of bag (e.g.: 250ml) – “Start/OK”
  0 Press “run” (“Start/OK”)
  0 “Occlusion” alarm
    0 Check ear position
    0 Check line within unit (crimped)
Attach transducer to auricular ear artery (pink 20g cath)
To zero out:
- Toggle switch down
- Open/unscrew orange cap
- Press “zero IBP” on monitor
- Close/tighten orange cap when reading = 0 on monitor
- Toggle switch towards orange cap
- Flush line (squeeze blue valve – see orange arrows)
IV Lines

Common problems
- Air bubble at stop cock
- Lined up below heart
- Bag not inflated

This should roughly be even/slightly below the heart.

250mm or "some green showing"
Femoral Caths Placed

- We use a 5F catheter and Seldinger technique to percutaneously place the femoral artery catheters.
- Do NOT “pick up” by the legs when ANY femoral line is in place!
- Invasive blood pressure monitoring for during the by-pass and cross-clamping portion of the surgery.
- Will provide numeric readings during by-pass.
  - Monitor will “flat line”, watch trends/changes in systolic/dysstolic pressure.
Hook up Femorals

- Set the transducer to “off” by turning stop cock
- Remove from the auricular cath and attach to the femoral
- Open stopcock and take readings
- Note change on paperwork
Review Paperwork!

- Make sure all times for all drugs are recorded throughout
- Make sure times of events are recorded
  - Intubation
  - Femoral caths placed
  - Time of incision
- Ask floaters when to administer Amiodarone bolus
  - Confirm when subsequent drip will begin (~20-30min after bolus)
Monitoring the ECG - Normal waveform

Characteristics of normal sinus rhythm include:

- regular rhythm
- normal rate
- a P wave for every QRS complex; all P waves similar in size and shape

- all QRS complexes similar in size and shape
- normal PR and QT intervals
- normal (upright and round) T waves.
Monitoring the ECG - Sinus Arrhythmia

P wave normal
No Q wave
R&S ‘shortened’ & arrhythmic
T normal
Monitoring the ECG - Sinus Bradycardia

- P wave normal
- Q & S are both rounded
- Shortened R wave
- T wave normal

*HR below 60/min*
Monitoring the ECG - Sinus Tachycardia

- P wave normal
- QRS complex is short in time – but normal in appearance
- T wave normal

*Rhythm is regular but HR is above 120bpm*
# Most Common E-Drugs

<table>
<thead>
<tr>
<th>Drug name</th>
<th>Concentration</th>
<th>Dosage</th>
<th>Route</th>
<th>Drug Ranges</th>
<th>Indications/why we are dosing</th>
<th>Contraindications/other information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amiodarone</td>
<td>50mg/ml</td>
<td>10-12 mg/kg*</td>
<td>IV</td>
<td>30 0.0-3.0 0.6 6.0</td>
<td>cardiac antiarrhythmic</td>
<td>many drug interactions (do NOT use with Lidocaine)</td>
</tr>
<tr>
<td>Dexamethasone</td>
<td>2mg/ml</td>
<td>1-10 mg¹</td>
<td>IV or IM</td>
<td>30 0.05 5.0</td>
<td>used as an anti-inflammatory and immunosuppressant in emergency therapy. Enhances vasoconstriction and can increase blood pressure.</td>
<td>dexamethasone may decrease Diazepam effectiveness</td>
</tr>
<tr>
<td>Epinephrine</td>
<td>1:1000</td>
<td>0.5-1ml/45kg of 1:1000 dilution*</td>
<td>IM or SC</td>
<td>30 0.33 0.50 0.50 0.50 IV</td>
<td>counteracts asystole, decreases contractility. Pay close attention to dosages. Dilute 1:1000 Epinephrine to 1:1000 for IV administration.</td>
<td>to make 1:1000 dilution: add 1ml of 1:1000 Epinephrine to 9mls NaCl</td>
</tr>
<tr>
<td>Glycopyrrolate</td>
<td>0.2mg/ml</td>
<td>0.004-0.01 mg/kg*</td>
<td>IM or SC</td>
<td>30 0.60 1.50</td>
<td>IM - used as a preanesthetic to decrease salivations, reduce vagal/gag reflex IV - used to treat decreased heart rate. This drug has longer onset (&lt;15 min) and has increased duration</td>
<td>may decrease GI motility, decrease heart rate (at low doses), increased blood pressure (at higher doses), or cause cardiac arrhythmias</td>
</tr>
<tr>
<td>Heparin Sodium</td>
<td>1000u/ml</td>
<td>100-300units/kg initial*</td>
<td>IV</td>
<td>30 3.00</td>
<td>anticoagulant, dosages to left are listed on the low end of the range</td>
<td>Intense monitoring required, can cause severe bleeding</td>
</tr>
<tr>
<td>Lidocone HCl 12%</td>
<td>20mg/ml</td>
<td>1-4 mg/kg*</td>
<td>IV</td>
<td>30 1.50 6.00</td>
<td>antiarrhythmic, specifically ventricular tachycardia</td>
<td>do not use in conjunction with epinephrine or amiodarone</td>
</tr>
<tr>
<td>Phenylephrine</td>
<td>10mg/ml</td>
<td>0.5-1.0mg/kg*</td>
<td>IV</td>
<td>30 1.50 3.00</td>
<td>increases blood pressure through vasoconstriction</td>
<td>can cause severe hypertension, or ventricular tachycardia ensure there is an adequate blood volume (or fluid replacement) prior to dispensing</td>
</tr>
<tr>
<td>Sodium Bicarbonate</td>
<td>0.05-0.2meq/ml or 1.0 meq/ml</td>
<td>1-2 meq as directed by physician</td>
<td>IV</td>
<td>30 1.2 meq as directed by physician (usually follows blood gas)</td>
<td>treat metabolic and respiratory acidosis (will raise the pH of the blood). Use judiciously with blood gas monitoring (in cases where blood pH is &gt;7.0) or when directed by physician</td>
<td>keep tight control over your CO2 levels! adverse effects: metabolic alkalosis, heart failure, edema due to sodium overload</td>
</tr>
</tbody>
</table>
Work with the Ventilator

- Inspiratory Flow – changes inspiration volume
  - Clockwise = increase
  - Most pigs will range from 500-700mL. Watch pressure; do not exceed 30cm.H2O (red zone)

- Breaths/min – changes rate of respiration; numbers on dial are not accurate – take readings from monitor
  - Should range from 8-12.
  - Changing this setting will not affect IF

- Inspiratory Time – changes speed of respirations (time for each breath)
  - Attempt to replicate normal for the patient
  - Changing this setting will inversely affect volume! (i.e.: decreasing IT will increase IF)

- Clockwise = increase time of breath
All ventilators should be preset prior to patient arrival.

Begin with completely turned counter-clockwise, then back ¼ turn. Set breaths per minute at 15. Set on the red “*”.

Attach rebreather bag to hose.

Turn O2 to 1.5 LPM, and fill bellows with flush valve.

Turn Ventilator on and adjust IF to approx. 500mL

Now adjust IT to match, as close as possible, the speed of the patient’s breaths

IF will now need to be readjusted.

Adjust Breaths/min as needed

i.e.: ETCO2 high = ↑ rate or volume
ETCO2 low = ↓ rate or volume
Chest Cavity is Opened

What to expect

- Surgeon may ask to stop or ‘hold’ respirations
- Done during sawing thru the sternum to prevent cutting lungs
- Lasts ~20sec
  - Turn ventilator off
  - Ventilate manually via the “Transport Breath” button
  - Turn on when chest is open
By-Pass Procedure

0 Perfusionist will Heparinize the animal - NOTE THE TIME
0 10min post-heparin an ACT sample will be drawn from the Femoral line
  0 Turn stopcock “off” to transducer
  0 Draw 10cc blood sample
  0 Turn “off” to animal (or blood will leak all over)
  0 Discard 10cc sample and re-attach syringe
  0 Turn “off” to transducer and draw ½ cc for sampling
  0 Turn “off” to animal and attach flush and turn “off” to transducer
  0 Flush and turn stopcock “off” to syringe – BP readings will appear

This position allows BP reading

This position allows sampling
What to expect
- Perfusionist will ask for the O2 line
- Stop ventilator
- Set O2 flow per request (2.5-3.0 liters/minute)
- All drugs administered now will be by perfusionist
- We may need to draw up & or provide on request
  - Sodium Bicarb
  - Amiodarone
  - Epinephrine (mix 1cc in 10ml saline)
  - Phenylephrine (mix 1cc in 19cc saline)
By-Pass Procedure

What to expect

- Pulse Ox readings will stop
- ECG & HR readings will continue but become erratic
- Blood pressure numbers will need to be called out to perfusionist (especially if he can’t see monitor)
Blood Gas Results

- What to expect
  - Drawn on request only from femoral
  - Draw and discard 3cc
  - Draw 1/2cc for sample
  - Commonly asked for Sodium Bicarb administration post-draw

![Blood gas result](image)
LVAD Placement & Testing

What to expect

- May or may not unclamp to ‘test’ success of LVAD placement
- Have euthanasia solution ready
  - 30ml of KCL IV or IC
- Monitor until no heart beat present

Heart rate / electrical activity still evident in this screenshot – must wait until all values are “0” and no heart beat/lung sounds are heard w/stethoscope