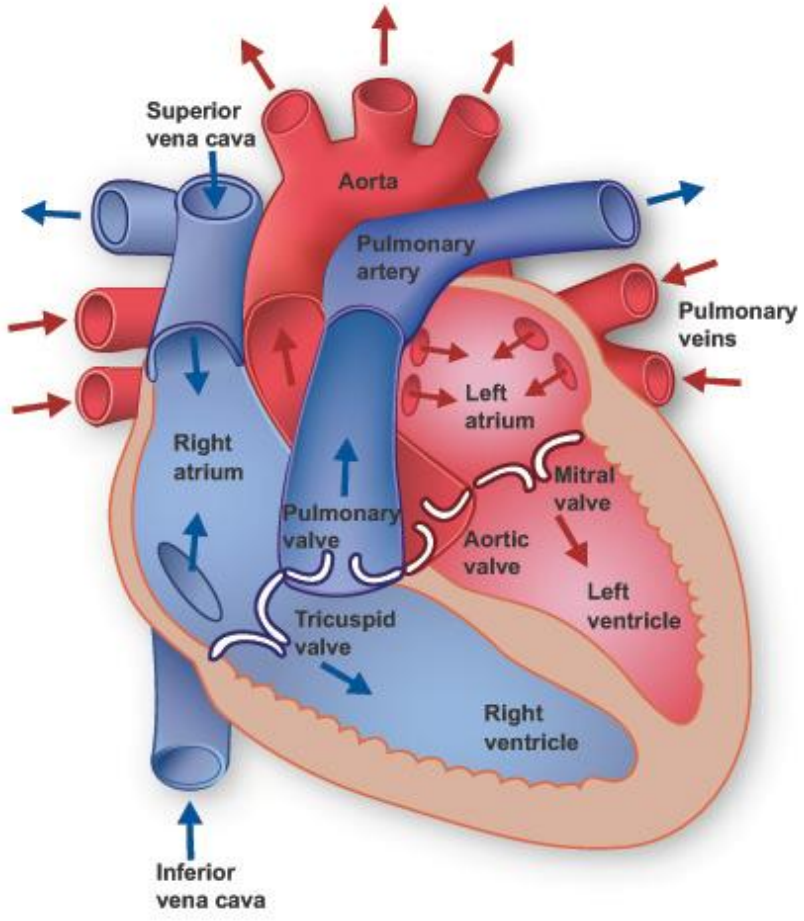
Invasive Hemodynamic Monitoring

- Brief cardiovascular anatomy refresher
- Define- Arterial line, Central venous catheter, Swan-Ganz, Flotrac
- Historical background – fun facts
- Insertion and setup, Contraindications, complications, ultrasound
- Monitoring – waveforms, normal pressure ranges
- Obstetric indication, Risks vs. Benefits, clinical scenarios

Cardiovascular Anatomy

- Heart
- Arterial system
- Venous system



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Arterial line

- Small catheter inserted into an artery which can be used to accurately monitor blood pressure in real time second by second. The catheter can also be used to draw arterial blood from the patient obtain laboratory results such as arterial blood gas and complete blood count.

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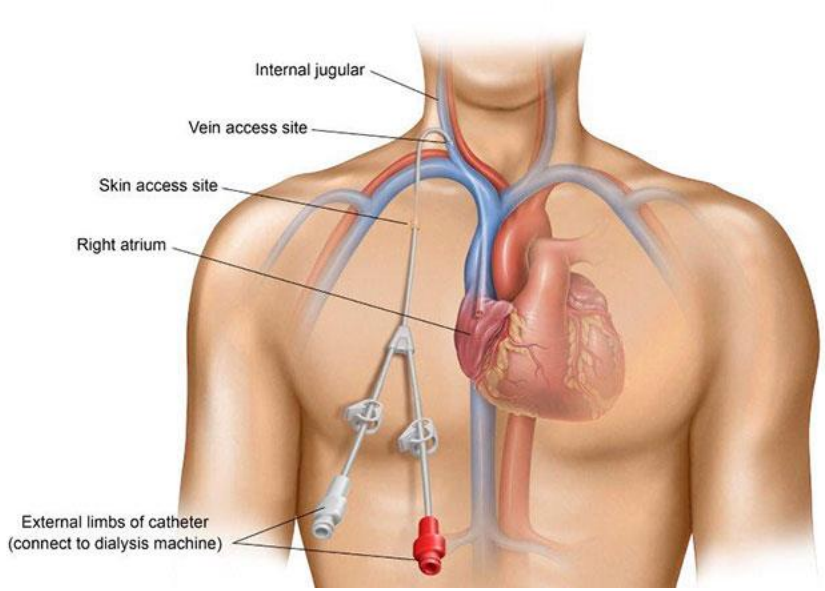
Central venous catheter (Central line)

- Long catheter inserted into a large vein and threaded so the tip is either in the superior vena cava or the inferior vena cava. Can be used to infuse vasoactive drugs or potentially caustic drugs. Can be used to draw venous blood from the patient in the case when serial lab results are necessary. Can be used to monitor central venous pressure (CVP) which is useful in determining the overall fluid status of the patient.



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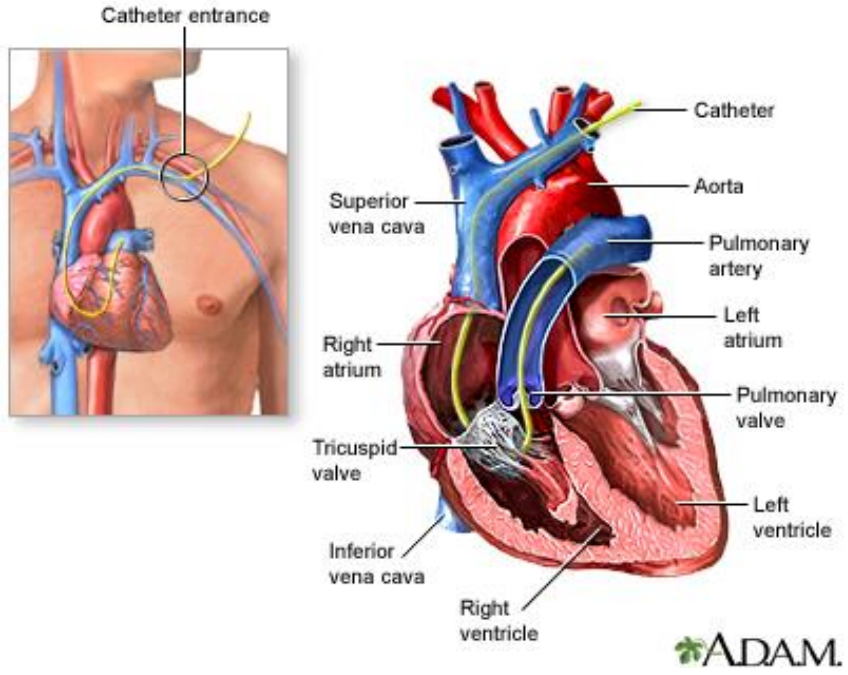
Swan-Ganz

(Pulmonary artery catheter)

- Long central venous catheter that passes through the right side of the heart and into the pulmonary artery. Can measure pulmonary artery pressures, pulmonary artery wedge pressures, cardiac index, systemic and pulmonary vascular resistance, core body temperature, and venous oxygen saturation.



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Flo Trac Sensor

- Sensor technology that used in conjunction with an arterial line can continuously monitor cardiac output/index, stroke volume/volume index, stroke volume variation (on a positive pressure ventilated patient). Uses algorithm to measure stroke volume which is directly related to the pulse pressure (the difference between systolic and diastolic pressure). This technological advancement is beneficial because clinicians can obtain measurements such as cardiac output without the potential complications from a Swan-Ganz catheter.

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History of invasive monitoring

- Arterial line: Detailed in the book Retrospectroscope: insights into medical discovery the first direct measurement of arterial blood pressure was accomplished by Stephen Hales in 1733 using a 9 foot glass tube connected using the trachea of a goose to the carotid artery of a horse.
- Was 1949 before an arterial catheter was described in use for a clinical setting.
- Now arterial lines are used every day in both the operating room and in intensive care settings.

- Central venous catheter: In 1929 Werner Forssman was the first person to introduce devices for central vein catheterization.
- 1953 Dr. Sven Ivar Seldinger introduce what is now referred to as the Seldinger technique which is essentially using a guide wire to safely insert a catheter.
- Today Central lines are used in multiple settings for invasive monitoring, administration of vasoactive drugs, parenteral nutrition, and chemotherapy.

History of invasive monitoring

- Swan-Ganz catheter: (pulmonary artery catheter) Named Swan-Ganz after the co inventors Jeremy Swan and William Ganz in the early 1970's.
- Difficulty getting the catheter to travel through the heart and enter the pulmonary artery Jeremy Swan came up with the current balloon tip of the catheter. We now "float" the Swan by inflating the balloon and watching the waveform to eventually stop inside the pulmonary artery.
- William Ganz added the thermistor to the catheter and using thermal dilution technique was able to measure cardiac output by quickly administering cool normal saline into the right atrium and measuring the temperature difference in the pulmonary artery.
- Modern catheters no longer require administration of cool saline which has increased the accuracy of the measurements.
- Common use of pulmonary artery catheters is controversial. Conflicting data regarding the benefits vs. risks of this invasive monitor.

Insertion, Contraindication, Complications

- Arterial line- can be placed in arteries including the radial, ulnar, brachial, axillary, posterior tibial, femoral, and dorsalis pedis.
- Radial artery is most often used because of accessibility, superficial position, and low rate of complication. Great collateral flow to hand via ulnar artery. Allen test can be used to ensure adequate perfusion through ulnar artery.
- Contraindications include absent pulse, thromboangitis obliterans, full thickness burns, and Raynaud syndrome.
- Use of ultrasound for real time placement should be considered gold standard.
- Complications include temporary artery occlusion and hematoma. More rarely infection, ischemic damage, nerve injury, artery dissection. Using ultrasound guidance may reduce potential complications.

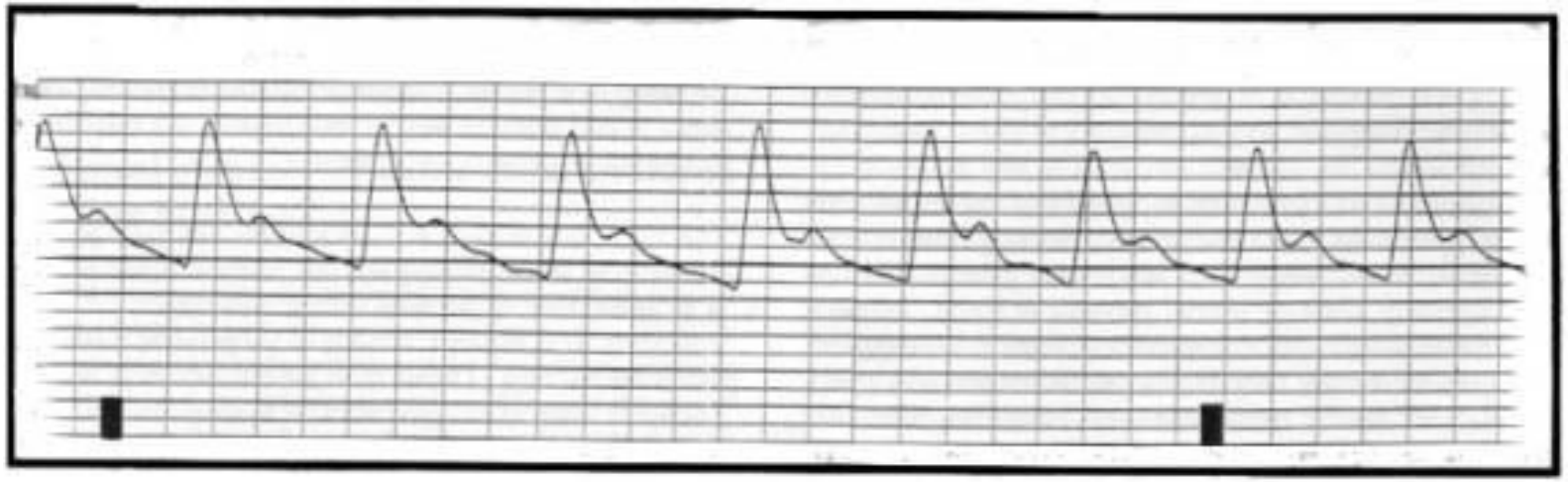
Insertion, Contraindication, Complications

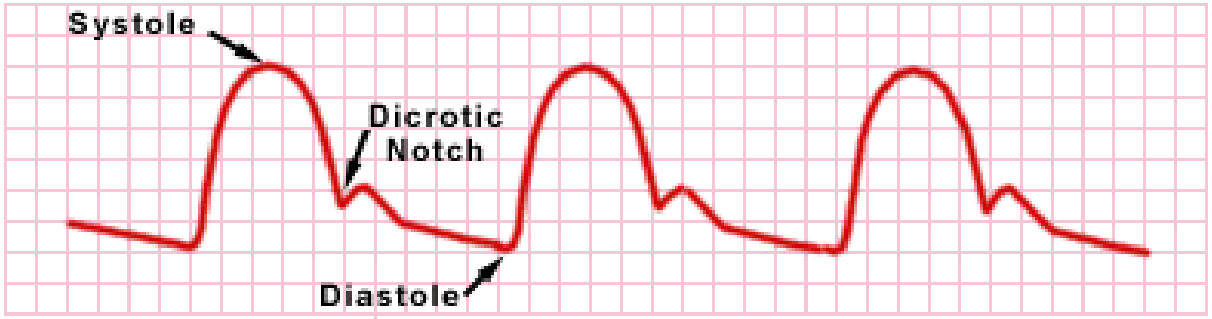
- Central venous catheter- Can be placed via internal jugular, subclavian, axillary, or femoral vein.
- PICC peripherally inserted central catheter- usually inserted through basilic vein in the upper arm and threaded to the superior vena cava.
- Internal jugular most common site, lowest potential complications, ability to use ultrasound for real time placement is important to avoid complications.
- Contraindications- severe coagulopathy, infection to area, obstructed vein, uncooperative patient when awake.
- Complications- pneumothorax, arterial puncture, arrhythmia, air embolism, thrombosis, vessel stenosis, infection.

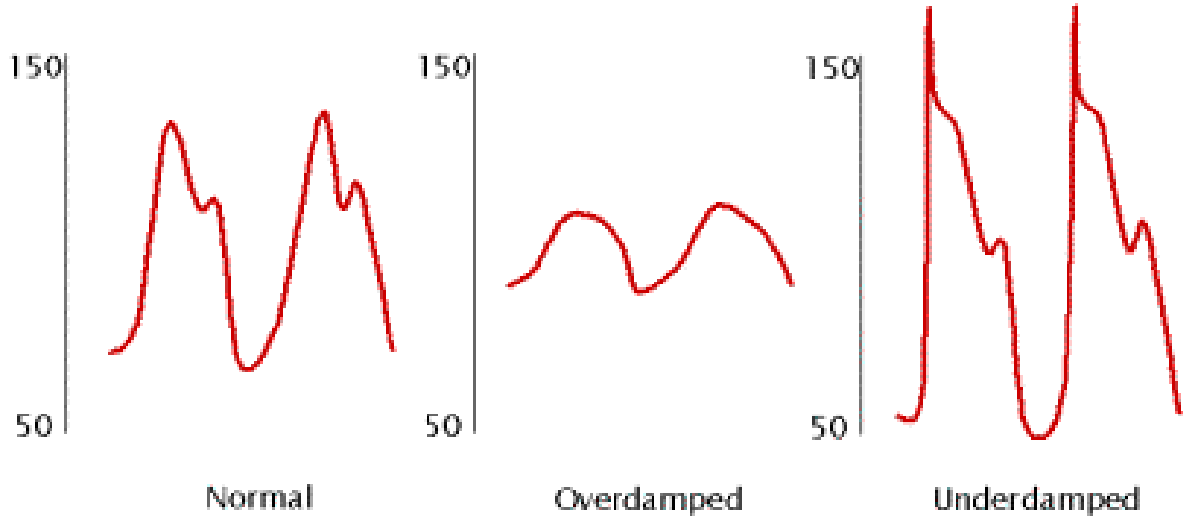
Insertion, Contraindication, Complications

- Swan-Ganz catheter- First access must be made to a large vein with a central vein cordis. Usually into the right internal jugular vein.
- Swan catheter is then passed through the cordis, balloon tip is then inflated and catheter is thread through the right heart and into the pulmonary artery identified by the change in PAC waveform. Continue to advance until a wedge waveform is detected.
- Contraindications- Tricuspid or pulmonary valve prosthesis or vegetations. Endocarditis and right heart tumor or blood clot.
- Complications- perforation of SVC, Hemothorax, pneumothorax, atrial fibrillation, ventricular arrhythmia, thromboembolic events, pulmonary infarction, endocarditis of pulmonary valve, air embolism from ruptured balloon.

Arterial line

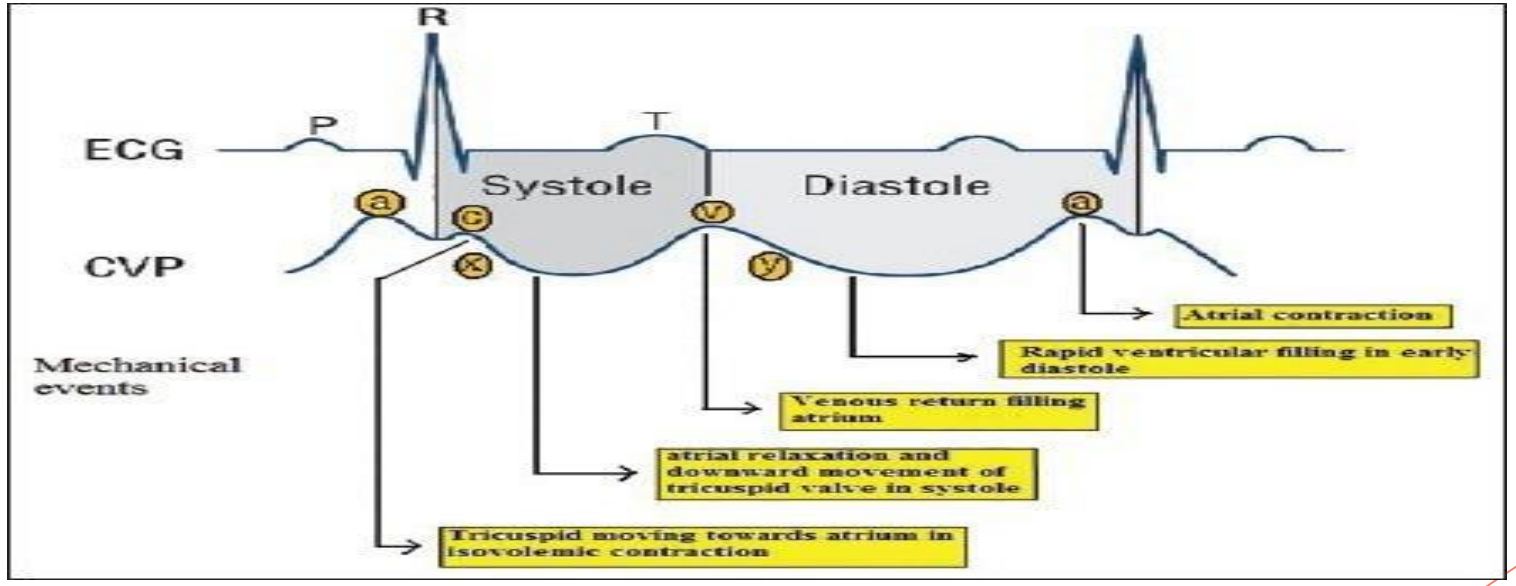






Central Venous Pressure

- CVP is essentially a good approximation of right atrial pressure and is a good indicator for preload. Normal range of CVP 0-10
- Low CVP- hypovolemia
- High CVP- right ventricular failure, tricuspid stenosis or regurgitation, fluid overload, high PEEP settings.



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Pulmonary artery catheter waveforms

https://www.youtube.com/watch?v=7putxZN7ij4&feature=share

Review of Normal Values

- RAP (CVP) 0-8 mmHg
- RVP 15-30/0-8 mmHg
- PAP 15-30/6-12 mmHg
- PAOP 8 - 12 mmHg

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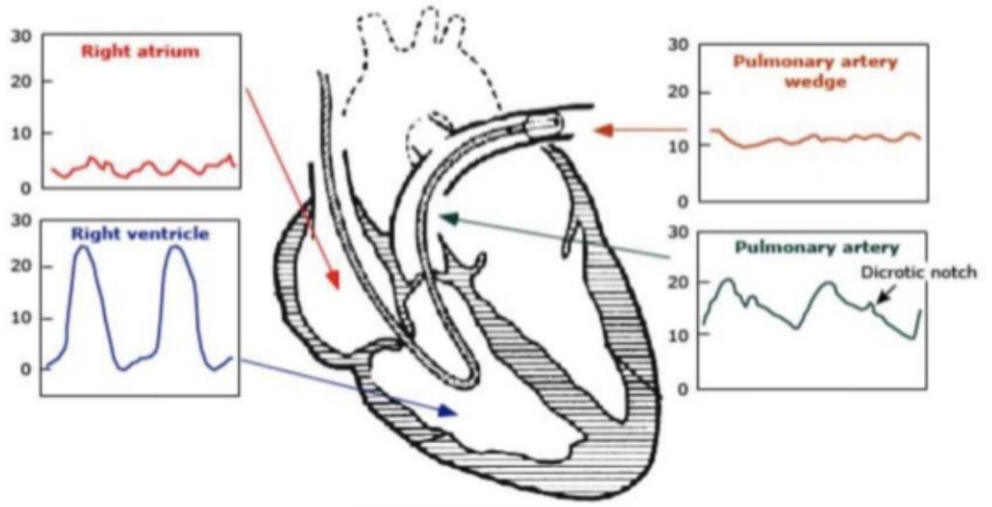
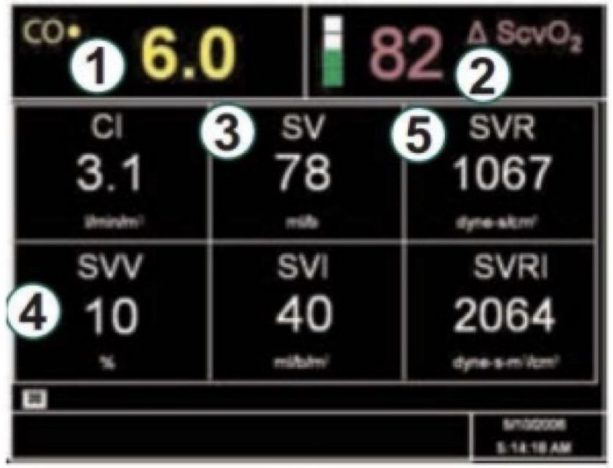
Waveforms by location of the pulmonary artery (PA) catheter tip



Tracings obtained in the right atrium or pulmonary capillary wedge position share similar morphology. The transition from the right ventricle to the pulmonary artery tracing can be identified by the increase in diastolic pressure and the presence of a dicrotic notch. The diastolic "step-up" results from the transducer crossing the pulmonic valve; the dicrotic notch reflects closing of the pulmonic valve.

Flotrac

- The Vigileo™/FloTrac™ system utilizes an existing radial or femoral arterial line that is attached to its monitoring unit.



PARAMETER	NORMAL RANGE
CO (Cardiac Output)	4.0 - 8.0 L/min
CI (Cardiac Index)	2.5 - 4.0 L/min/m²
SV (Stroke Volume)	60 - 100 mL/beat
SVI (Stroke Volume Index)	33 - 47 mL/beat/m²
SVR (Systemic Vascular Resistance)	800 - 1200 dynes - sec/cm⁻⁵
SVRI (Systemic Vascular Resistance Index)	1970-2390 dynes - sec/cm⁻⁵/m²
SVV (Stroke Volume Variation)	<13%

Stroke Volume Variation (on control-ventilated patients):

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Cardiovascular changes in pregnancy

Variable	Peak Change, %
Blood volume	+35
Plasma volume	+45
Heart rate	+20
Stroke volume	+30
Cardiac output	+40
Contractility	Variable
Central venous pressure	Unchanged
Pulmonary capillary wedge pressure	Unchanged
Systemic vascular resistance	−15
Systemic blood pressure	−5

Hemorrhage

- Uterus is a highly vascular organ especially during pregnancy. Maternal hemorrhage is one of the most common and potentially fatal conditions in the postpartum period.
- Arterial line- second to second blood pressure, direct access to blood sample for serial lab results, ability to utilize flotrac monitor to assess cardiac output/index/ and stroke volume. If the patient is intubated stroke volume variation can determine fluid status.
- Poiseuille's law- flow rate is dependent on diameter and the length of catheter. Fluid resuscitation- 2 large bore peripheral iv's are more effective than most central line catheters.
- Central line? Swan?

Cardiomyopathy with low EF

- Arterial line ✅
- Flotrac ✅
- Central line ✅ +/- Vasoactive drugs, electrolyte management and replacement, continuous gtt.

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Severe Pulmonary Hypertension

- Arterial line ✅
- Flotrac ✅
- Central venous catheter ✅
- Pulmonary artery catheter ✅

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To Place or not to Place that is the question

- Ultrasound guided radial arterial line- low risk, high benefit
- Flotrac- Why not?
- Ultrasound guided central line- moderate risk, good benefit for the right patient
- Pulmonary artery catheter- relatively high risk, controversial whether or not has good benefit for patient outcome.

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