Intraoperative Monitoring

Niels F. Jensen, MD

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Choose Your Weapons and Defend Yourself

Should transesophageal echocardiography be used routinely during coronary artery bypass surgery?

The Facts
1. Coronary artery disease is the most common cause of death in the adult population of the United States.
2. The ability of TEE to detect valvular dysfunction and regional wall motion abnormalities is undeniable. The significance of the later is controversial.
3. The cost to purchase a TEE is significant and maintenance is substantial.

The Arguments[1]:
Pro: With minimal risks and costs, TEE offers critical data about patients undergoing coronary bypass surgery. Specifically, it provides information about the presence or development of mitral regurgitation, causes of ventricular failure and hypotension, and potential cardiac sources of embolism. With respect to mitral regurgitation, incomplete preoperative evaluation as well as the dynamic nature of the condition make the use of TEE very important. Hypotension during weaning from cardiopulmonary bypass may be caused by hypovolemia, ischemia, hypocontractility, obstruction, tamponade, and valvular dysfunction. TEE can rapidly differentiate most of these. TEE can scan the transverse and descending aorta for plaque and this may modify the surgical approach and reduce the incidence of stroke. TEE should be used during cardiopulmonary bypass because it provides important information which is not otherwise available.

Con: No, TEE should not be routinely used during coronary artery bypass surgery. Certainly the monitor is useful in several specific situations but one must be very careful in arguing that this mandates its "routine" use. Outcome studies supporting this contention are simply not available. In terms of ischemia, there is no question that TEE can detect it but the question of whether it can improve outcome from it is unknown. This is a very promising device with much current and future potential, for example in possibly evaluating the adequacy of immediate revascularization. One must be careful, however, about making general statements about its "routine" need.

Note: The choice and discussion of monitors is clearly one of the most important aspects of the Oral examination. There are several reasons: First, it is an area that lends itself to the kind of organization that the examiners are testing. Second, it indicates medical concerns. Third, it provides ample opportunity to make both positive points as well as mistakes. Many have jeopardized their position by either having an inadequate basic knowledge of various monitors, failing to adequately monitor, or, perhaps most frequent, placing a monitor that is not needed. By knowing and clearly articulating the indications for the various monitors, you score. The appropriate use of arterial and pulmonary artery catheters is especially important.

I. Types of Monitors:
1a. Standard ASA
- a. EKG (V5, if necessary)
- b. BP cuff
- c. T-probe
- d. Oxygen monitor
- e. Pulse oximeter
- f. Capnograph
- g. Disconnect monitor
- h. Precordial stethoscope-esophageal stethoscope

[1]Konstadt, SN, Cooper, JR. Should transesophageal echocardiography routinely be used during coronary artery bypass surgery? Anesthesiology.

1b. Invasive

a. Foley catheter
b. Arterial catheter
c. CVP catheter
d. PA catheter

1c. Situation

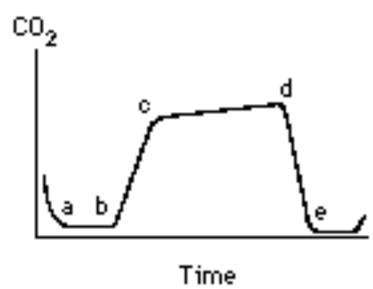
a. EEG, precordial doppler, intracranial pressure (see neuro)
b. SSEP (see neuro)
c. TEE
d. Fetal monitoring

II. Carbon dioxide[2,3]

1. CO2 Analysis-Capnography

a. CO_2 analysis evaluates the CO_2 waveform by infrared absorption.
b. Carbon dioxide contains two dissimilar atoms and absorbs infrared radiation in a spectral range that is convenient to measure.
c. Capnography is virtually infallible in detecting esophageal intubation and is better than a pulse oximeter in detecting esophageal intubation or disconnect.
d. It is important to consider several situations applicable to the capnograph:

THE NORMAL CAPNOGRAPH



Components of a normal waveform.

1) Segment AB represents the beginning of exhalation when tracheal dead space empties of its CO_2 free gas.
2) Segment BC represents the period of continued exhalation when increasing amounts of CO_2 rich respiratory gas mixes with dead space gas and results in increased CO_2 concentration.
3) Segment CD represents the near-end of exhalation, the so called "alveolar plateau" and it represents nearly constant CO_2 rich alveolar gas.
4) Point D is the highest value of CO_2 concentration at the end of normal exhalation and is the $PETCO_2$.

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[2]Swedlow, DB. ASA Refresher Course, Mass Spectrometers and Respiratory Gas Monitoring, Barash, PG, and Tinker, JH, (eds.), Lippincott.

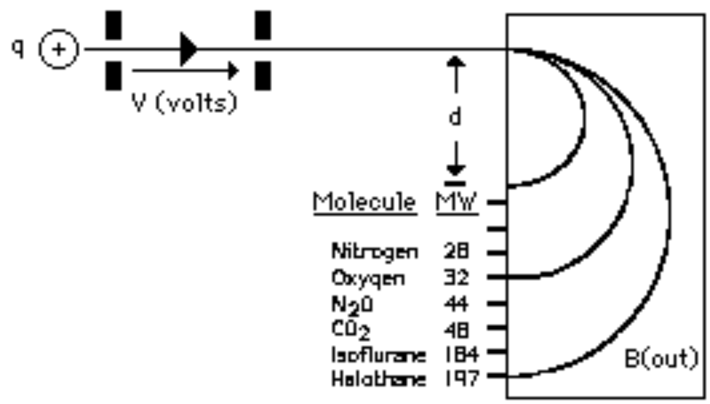
[3]Neustein, SM, Eisenkraft, JB. One-Lung Anesthesia. Clinical Cases in Anesthesia, Reed, AP (ed), Churchill Livingstone.

Causes of variation in the normal CO_2 waveform.

5) A Sudden drop to zero indicates a technical defect.
6) A Sudden drop but not to zero indicates leakage or partial obstruction.
7) An Exponential decrease should immediately raise suspicion about increased alveolar dead space such as occurs with a large pulmonary embolus.
8) A Sudden increase can be caused by the release of a tourniquet.
9) A Gradual increase may indicate one of several things, including decreased minute ventilation and prolapse of the expiratory valve.

III. Mass Spectrometer:[4]
1. The mass spectrometer performs an analysis of molecular mass to the charge. It is used to determine concentrations of oxygen, carbon dioxide, nitrogen, nitrous oxide, and volatile agents. Gases are ionized by an electric field and then accelerated into and separated by a magnetic field according to their molecular mass to charge. Lightest ions are deflected first.

MASS SPECTROMETRY



How the mass spectrometer works
The mass spectrometry works by an analysis of the molecular mass to the charge. After being ionized by a beam of electrons, a gas molecule is accelerated by an electric field and then shot into a magnetic field where the radius of the curvature depends on the mass of the molecule. The lightest ions are deflected first and this provides a way to identify compounds and to measure concentrations.

IV. Apnea Monitoring[5] (Little in Big Red is casual. This has been required. Know it!)
1. Apnea monitors detect apneic events. They sense respiration and trigger alarms if respiratory signals aren't detected. There are several methods to sense respiration:

a. The most common is impedance pneumography. Electrodes are placed on each side of the thoracic cavity and low intensity alternating current is passed between them. Small decreases in the impedance of the chest are sensed as a respiration.

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[4]Swedlow, DB. ASA Refresher Course, Mass Spectrometers and Respiratory Gas Monitoring, Barash, PG, and Tinker, JH, (eds.), Lippincott.

[5]Staewen, W. Apnea Monitoring Basics. Biomedical Instrumentation and Technology.

b. A second indirect method of monitoring respiration is a pressure sensitive pad. Transducers sense motion caused by breathing and convert the force to electrical signals.
c. The third major indirect monitor is the pneumatic abdominal sensor. Pressure changes caused by movement of the abdomen during respiration are detected as breaths.
d. Having reviewed the three major indirect monitors of respiration, there are three direct monitors as well: thermisters, proximal airway pressure sensors, and carbon dioxide sensors. The thermister, placed in front of the mouth or nose, detects the cool air passing by during inspiration and the warm air of expiration. These temperature changes vary electrical resistance and are detected as breaths. Proximal airway pressure sensors are also located at the mouth or nose. They contain pressure sensitive switches which are sensitive to the pressure changes during respiration. Carbon dioxide sensors measure carbon dioxide at exhalation. These are infrared sensors.
e. The worst case is when apnea monitors fail to alarm during apnea because they sense artifact and interpret it as respiration. Artifacts include vibration from equipment, heart beats, and patient movement. Impedance pneumographs and pressure sensitive pads are most common because they are the simplest to use. They are also the most prone to this type of error. The impedance pneumograph sometimes interprets heart rate as respiration or fails to detect upper airway obstruction because it senses continued chest wall activity as respiration. False negatives, failure to alarm when there is apnea, are obviously of concern.
f. A more common problem is alarming without apnea. Frequent causes include incorrect sensitivity settings, dry electrodes, or displaced electrodes or sensors.
g. Most new apnea monitors include heart rate monitoring. An alarm will sound with bradycardia, caused for example by hypoxemia induced by apnea.

V. Pulse oximetry[6]

1. Pulse oximetry involves transillumination of tissue with two frequencies of light. One frequency is at 940 nanometers and corresponds to 100% saturation of hemoglobin (and the absorption of less red light). The other frequency is at 660 nanometers and corresponds to 50% hemoglobin saturation which is also called the isobestic point (and corresponds to the absorption of more red light).

2. Oxygenated hemoglobin absorbs less red light than deoxyHb, accounting for its red color.

3. Basically, the pulse oximeter measures a difference between background absorption during diastole and peak absorption during systole.

4. It is difficult to obtain calibration data at a saturation less than about 30%. Therefore, the accuracy of the pulse oximeter tends to decrease during episodes of severe hypoxemia.

5. There must be a pulse to distinguish between light absorbed by arterial blood and background associated with venous blood. Therefore, vasoconstriction seen during hypovolemia, hypothermia, or shock leads to unreliable readings.

6. CarboxyHb is viewed by the pulse oximeter as oxygenated Hb. Therefore, COHb causes an overestimation of oxygenation. A co-oximeter must be used to distinguish COHb from oxyHb.

7. MetHb is seen by the pulse oximeter as having a saturation of approximately 85%.

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[6]Gilbert, HC, and Vender, JS. Monitoring the Anesthetized Patient. Clinical Anesthesia, Barash, PG, Cullen, BF, and Stoelting, RK, (eds.), Lippincott.

8. Methylene blue and indocyanine green lower the saturation reading for about 10 minutes.

9. Technical limitations of Pulse Oximetry:
- a. No pulse present: Low peripheral perfusion
  - 1) Hypotension
  - 2) Hypothermia
  - 3) Hypovolemia
- b. Hemoglobin variants present
  - 1) Carboxyhemoglobin is treated as oxygenated hemoglobin
  - 2) Met-Hb and indocyanine green are treated as having a saturation of 85%
- c. Severe anemia present
  - 1) If Hb is ≤ about 3-4 gm / dl thepulse oximeter doesn't function well
- d. Venous pulsations
  - 1) Right heart failure or tricuspid regurgitation disturb pulse oximetry

VI. Transcutaneous oxygen monitoring (TCOM)[7]

1. TCOM is a noninvasive way to measure tissue oxygenation.

2. TCOM is based upon the following concept: Capillary PO_2 may approximate arterial PO_2 in areas of skin where local blood flow exceeds the amount necessary for local tissue oxygen needs. This approximation may especially hold if the local area is warmed. Therefore, TCOM measures the PaO_2 in capillary blood noninvasively.

3. An electrode is attached to the skin, which is warmed to 40 ˚ C. This provides local vasodilatation. Oxygen from capillaries can then diffuse through the skin into a Clark type electrode, for direct measurement.

4. Limitations of TCOM:
- a. Errorenous measurement in the presence of peripheral vasoconstriction.
- b. Errorenous measurement in the presence of decreased cardiac output. Cutaneous hypoxia occurs and this creates an artifactual decrease in measured $PtcO_2$.
- c. Errorenous measurement in the presence of thick, adult skin. In infants, local blood flow to less cornified-keratininzed skin is high--making the technique more useful.
- d. Sudden decreases in PaO_2 are not detected because of the slow diffusion time of oxygen across skin. The time constant of measurement is minutes, limiting the ability for rapid therapeutic response. Conjunctival probes are available and partly lessen the problem of long diffusion time across skin.
- e. Skin burns can result from prolonged application. TCOM should not be left in place for longer than about 2-3 hours.

VII. Oxygen monitor: Two types

A. Paramagnetic analysis

1. Oxygen is paramagnetic, attracted to a magnetic field.

2. Most anesthetic gases are diamagnetic, repelled by a magnetic field.

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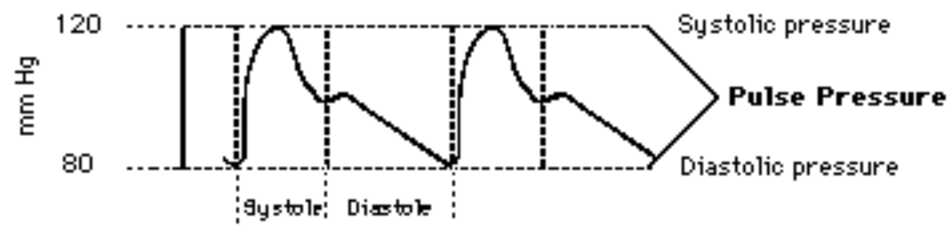
[7] Moon, RE, and Camporesi, EM. Respiratory Monitoring. Anesthesia, Miller, RD, (ed.), Chruchill Livingstone.

B. Electrochemical analysis

1. The diffusion of oxygen through an electrolyte solution creates an electric current which is proportional to concentration. This forms the basis of electrochemical analysis.

VIII. Arterial catheter:[8]

ARTERIAL CATHETER



1. Indications: An arterial catheter is indicated when there may be wide swings in blood pressure where such swings may be deleterious, such as in patients with cardiac or cerebrovascular disease. It is also indicated when frequent blood gas analysis will be necessary, for example in the setting of severe, chronic pulmonary disease.

    a. Blood pressure swings can be threatening in the presence of coronary artery disease or where there is a history of cardiac failure. Hypotension decreases coronary perfusion pressure and increases in afterload increase myocardial oxygen consumption.

2. MAP= 1/3 SBP + 2/3 DBP.

3. When a transducer is 10 cm below the right atrium, it generates a pressure that is 10 cmH2O or 7.5 mmHg higher than actual BP.

4. Systolic pressure in the aorta is far lower than in the radial artery. The further into the periphery one goes, the greater the systolic pressure and the lower the diastolic pressure. In other words, pulse pressure increases.

5. If the blood pressure cuff is too small or is loosely wrapped, the blood pressure reading will be too high. If the blood pressure cuff is too large, then falsely low recordings may result.

6. Manual blood pressure recordings: For many years, especially in children, blood pressure was measured by Doppler ultrasound. The Oscillometric method, embodied in the dinamap, is now the standard for automated blood pressure recording. How does this work?

    a. Initially the cuff is inflated above the systolic BP and there is no oscillation.
    b. As the cuff is deflated, oscillations begin and this is the mean BP.
    c. Values for the systolic and diastolic pressure are derived by using various formulas that examine the rate of change of pulsation. (The systolic point is generally chosen as the point at which pulsations are increasing and are 25-50% of maximum. Diastolic pressure is commonly placed at the point of 80% decline of pulse amplitude.)

7. The best first choices for cannulation are the radial, ulnar, and dorsalis pedis arteries. Brachial artery catheterization is associated with a higher incidence of thrombosis (about 10-

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[8]Gabrielson, GV. Abdominal Aortic Aneurysm. Clinical Cases in Anesthesia, Reed, AP (ed), Churchill Livingstone.

17%) but should be cannulated if an arterial catheter is needed and the other arteries cannot be cannulated. In this case, remove the catheter as soon as possible following surgery.

8. Contraindications to the radial arterial catheter:
   a. Local infection
   b. Pre-existing ischemia to the hand: An Allen test is not a reliable prognosticator of hand ischemia secondary to radial artery cannulation.
      1) The duration of the cannulation and the size of the cannula may not influence the incidence of hand ischemia.
      2) If the Allen's test is abnormal, place a pulse oximeter on one of the fingers distal to the cannula.
      3) Cannulation of the superficial temporal artery in a child may be associated with cerebral emboli via the carotid artery system.
      4) Spasm of an artery can cause ischemia and this is treatable with a sympathectomy (stellate ganglion block).
   c. Raynaud's phenomenon

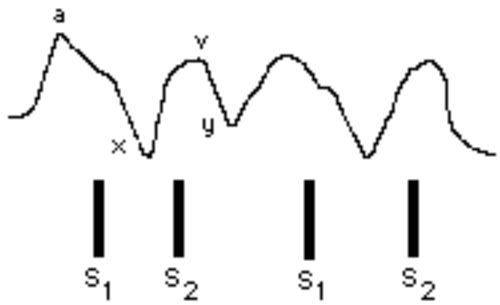
IX. CVP Monitoring:[9]

1. Central venous pressure monitoring is appropriate in cases of major surgery with major fluid shifts, either acutely or over several hours of surgery. It is also indicated for the following:
   a. Aspiration of air emboli
   b. Insertion of transvenous pacing wires
   c. Administration of vasoactive substances such as dopamine

2. Contraindications include local infection and placement of the line in the surgical field. Coagulopathies are not an absolute contraindication to the placement of central lines.

[9]Bodner, N. Intracranial Mass, ICP, Venous Air Embolism, Autoregulation. Clinical Cases in Anesthesia, Reed, AP (ed), Churchill Livingstone.

CVP WAVES



3. CVP Waves: To remember these four oscillations, think of the following sequence: atrial contraction, atrial relaxation, atrial filling, and atrial emptying.

a. The first elevation, the ***a wave***, reflects the slight rise in atrial pressure that accompanies atrial contraction. It occurs just before the first heart sound and before the carotid pulse.

b. The following trough, the ***x descent***, starts with atrial relaxation. It continues as the right ventricle, contracting during systole, pulls the floor of the atrium downward.

c. During ventricular systole, blood continues to flow into the right atrium from the venae cavae. The tricuspid valve is closed, the chamber begins to fill, and the right atrial pressure begins to rise again, creating the second elevation, the ***v wave***..

d. When the tricuspid valve opens early in diastole, blood in the right atrium flows passively into the right ventricle, and right atrial pressure falls again, creating the second trough or ***y descent*** .

e. Remember this: The a wave is absent in atrial fibrillation whereas cannon a waves are seen with junctional rhythms, tricuspid stenosis, right ventricular hypertrophy, pulmonary stenosis, and pulmonary hypertension

4. Most frequent causes of elevated CVP:

a. Volume overload and/or Right heart failure

b. Light anesthesia

5. The most frequently used veins are: brachial, cephalic, subclavian, internal and external jugular.

a. Long arm sites are associated with a higher incidence of failure to place centrally.

b. The subclavian vein approach is associated with a higher incidence of pneumothorax.

c. The right internal jugular site provides a straighter and shorter route to the SVC and is not associated with the risk of thoracic duct injury. In addition, the left pleural apex arises higher and the risk of pneumothorax is increased.

6. Subclavian lines: (tips for success)

a. Place the patient in a trendelenburg position with a roll between the shoulders.

b. Line up the bevel of the large needle with the numbers. Begin with the bevel straight up and when the vein is entered, turn the syringe about 90 degrees. This is a key point.

c. Error on the side of being too lateral to the sternal angle. Aim for the notch.

d. Go into the skin perpendicular and then place left thumb on the needle and guide it under the clavicle.

e. If possible, place the monitor with the patient awake and breathing spontaneously.

7. Mangano (1980) noted good correlation between the CVP and the PCWP in patients with good LV function, no wall motion abnormality, and a resting PCWP less than 18. If these conditions do not pertain, the correlation is not as good. In addition, the presence of COPD and/or pulmonary hypertension also makes the correlation less valid. **In fact, in these circumstances, the CVP and PCWP may have no correlation at all and the direction of change may be opposite.**

8. Why would a CVP ever be preferable to a PA cath? It is likely that some of the complications seen with the PA cath (see below) would not be seen as frequently.

"Let's Go For a Ranger Run!"

These tests are as close to a war as most of us are likely to come. The reality professionally is that passing is virtually mandatory in the current environment. The reality intellectually is that an academic career is incomplete without this certificate. The reality personally is that many aspects of private life are held hostage until this diploma arrives. If this isn't a "war" for an anesthesiologist, what exactly is it?

With the many demands upon us, rigorous discipline, training, and focus are required. Like Rangers, we must channel our worry into work, focus, train hard, and develop a "killing instinct". Onward Now to Victory!

A Ranger never quits.

A Ranger is disciplined.

A Ranger takes no hostages.

A Ranger doesn't ask, "Why" but yells, "I'll do or die!"

A Ranger volunteers for night fighting in heavy weather.

A Ranger loves the fight more than the ceremony following it.

X. PA catheters:[10,11,12]

1. Indications: The pulmonary artery catheter is indicated for patients who are undergoing major surgery with major fluid shifts who have severe LV dysfunction (and/or cardiac failure), pulmonary hypertension, or cor pulmonale. Thus, both the nature of the patient and the type of surgery to be performed are important. For example, if surgery is minimally invasive, the monitoring needs are very much different than if it is a major vascular, major abdominal, or thoracic case.

a. The PA catheter is primarily used to monitor both preload and afterload in order to reduce myocardial oxygen consumption.

b. Remember that the PA catheter is specifically useful in obtaining cardiac outputs, obtaining mixed venous gases, and calculating systemic vascular resistance.

c. If the aorta is to be crossclamped, a specific indication for the pulmonary artery catheter is to detect LV failure in response to cross-clamping, an event which is difficult to predict in the presence of mild to moderate left ventricular dysfunction.

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[10] Reich, DL, Joffe, D. Congestive Heart Failure. Clinical Cases in Anesthesia, Reed, AP (ed), Churchill Livingstone.

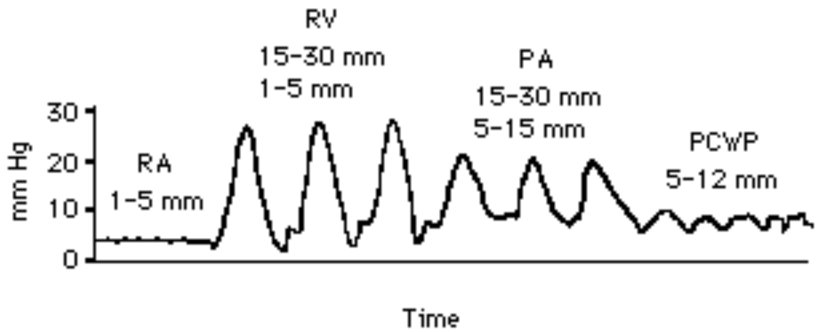
[11] Mihm, FG. ASA Refresher Course, Analysis of Information Pitfalls of Pulmonary Artery Catheter Monitoring, Barash PG, and Tinker, JH, (eds.), Lippincott.

[12] Gilbert, HC, and Vender, JS. Monitoring the Anesthetized Patient. Clinical Anesthesia, Barash, PG, Cullen, BF, and Stoelting, RK, (eds.), Lippincott.

NORMAL INTRACARDIAC PRESSURES

(This is their view: You wanted it, you better know about it)

a. RA 1-5 mm Hg
b. RV 15-30/1-5 mm Hg
c. PA 15-30/5-15 with mean of 10-20 mm Hg
d. PCWP 5-12 mm Hg



2. The PADP is usually 1-3 mmHg greater than the PCWP. At ≤ 15 mmHg, mean PCWP correlates well with LVEDP. Read pressures at end-expiration, since this is the closest to zero intrathoracic pressure.

3. Large A and V waves indicate mitral regurgitation, heart failure, or heart block.

4. An example of efficacy: The placement of a PA catheter in patients with mitral stenosis.
   a. Perform a history and physical examination and if there is a history of dyspnea, orthopnea, PND, or poor exercise tolerance with a physical examination suggesting failure (rales, edema, ascites, hepatosplenomegaly) then placement of a PA catheter should be done. In the presence of good exercise tolerance and no sign of cardiac failure, a PA catheter is not mandatory. Again, the type of surgery being performed and the anticipated blood loss associated with it should be assessed.
   b. Risks of a PA catheter:
      1) Risks of insertion
         a) Infection
         b) Pneumothorax
         c) Hematoma
         d) Injury to major vessels such as the carotid artery
         e) Air embolism
      2) Arrhythmias, Heart Block, and Heart perforation
         a) The PA catheter can produce right bundle branch block. If a left bundle branch block is already present, place a pacing Swan.
         b) Perforation of the heart can lead to cardiac tamponade.
      3) Valvular damage
      4) RA, RV, or PA perforation
         a) The incidence of pulmonary artery rupture is 0.2% and this risk is increased in the setting of pulmonary hypertension and anticoagulation. PA rupture is obviously a life-threatening emergency, associated with a very high mortality. Signs and symptoms include the emergence of blood from the endotracheal tube. Treatment entails thoracotomy with one lung anesthesia and CPB. Interim steps include:
            i) Leave the PA catheter in place.

ii) Get the patient into the operating room.
iii) Place a double lumen endotracheal tube
iv) Lower BP with nitroglycerin (unless the patient is already in profound, hypovolemic shock) to decrease blood loss.

b) Pulmonary infarction can occur if the balloon of the catheter is in a permanently wedged position.

5) <u>Thrombosis-thromboembolism / Air embolism</u>

c. Cephalic or basilar vein approaches have fewer complications but higher chance of failure.

5. Contraindications: PA catheter
   a. Mechanical heart valves
   b. Hypercoaguable states
   c. Recently inserted transvenous pacemaker, bifascicular heart block, coagulopathy, frequent dysrhythmias, history of pulmonary stenosis (all relative contraindications).

6. Thermodilution cardiac output is immeasurable or inaccurate in the following situations:
   T Tricuspid regurgitation
   I Intracardiac shunts
   A Atrial fibrillation

7. Cardiac output measurements should be made at end-expiration with 10 cc of room temp injectate. Cold (0-4• C.) injectate can be used to produce a better signal to noise ratio.

8. It is not always necessary to monitor PA pressure for coronary artery surgery. If LV function is very good and the patient does not have significant COPD, then the CVP correlates well with PCWP. <u>If LV function is not good or significant pulmonary hypertension exists, then the CVP does not correlate as well with the PCWP.</u>

9. Treating increased PCWP. Is it light anesthesia, fluid overload, vasoactive therapy, or heart failure? If the blood pressure is elevated, it may be light anesthesia. If the patient is hypotensive, it is probably fluid overload. Treatment of fluid overload:
   a. Restrict fluids
   b. Nitroglycerin, lasix, and an inotrope such as dopamine

10. PCWP=LAP=LVEDP=LVEDV

11. SVR= MAP - CVP / CO X 80 (Normal 900-1500)

12. Cardiac output: normal is 3.3-5.5 l / min
   a. Steps in treatment of low cardiac output:
      1) Optimize preload
      2) Optimize afterload
      3) Start an inotrope

13. If a PA catheter is placed for a patient having a thoracotomy:
   a. Obtain a postinsertion chest X-ray to rule-out pneumothorax
   b. Consider fluoroscopy to determine in which lung the balloon floats

14. How far should the catheter be inserted?
   a. The right atrium is usually encountered at 20 cm and the wedge position is encountered at about 50-55 cm.

b. Balloon inflation during catheter insertion is necessary to minimize damage to the endothelium.

15. Causes of elevated LVEDP:
   a. Hypervolemia, cardiac failure
   b. Vasoactive drugs (i.e. neosynephrine)
   c. Light anesthesia
   d. Aortic crossclamp

16. Causes of low LVEDP:
   a. Hypovolemia
   b. Vasodilator drugs (SNP and TNG)
   c. Deep anesthesia
   d. Unclamping of the aorta
   e. Hypoxia or hypercarbia (secondary to increased PVR and decreased filling)

17. Causes of pulmonary edema:[13]
   a. Increased capillary pressure
      1) MS
      2) Heart failure
      3) Retention of fluid by diseased kidney
   b. Increased capillary leak
      1) Aspiration
      2) ARDS
      3) Burns
      4) Neurogenic
   c. Decreased oncotic pressure caused by decreased albumin
      1) Albumin loss from burn or nutritional deficiency
   d. Lymphatic obstruction
      1) Tumor

18. If evidence of pulmonary edema appears, one must make the diagnosis between cardiogenic (increased capillary pressure) and noncardiogenic (increased capillary leak, oncotic, or lymphatic obstruction) processes. A PA catheter can be useful in this context.
   a. If cardiogenic pulmonary edema exists, the PCWP will be high (18 mmHg) and if aspiration has occurred it will generally be low. Cardiogenic pulmonary edema is also associated with bibasilar rales, patchy infiltrates, and pink, frothy sputum. It often requires fluid restriction, diuretics, and inotropes.
   b. Noncardiogenic pulmonary edema is associated with massive blood transfusion, smoke inhalation, sepsis, and DIC. There are bibasilar rales but the PCWP is not generally elevated. It often requires fluid restriction or cautious fluid administration.

19. Pulmonary Hypertension: The causes of pulmonary hypertension are from increased blood flow or increased pulmonary vasoconstriction. The PA systolic BP is above 30 mm Hg.
   a. PVR= mean PA - PCWP / CO X 80. (Normal $\leq$ 200)
   b. Causes:
      1) Increased pulmonary blood flow:
         a) Left to right intracardiac shunts
      2) Increased pulmonary resistance
         a) Hypoxia, hypercarbia, acidosis

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[13]Murray, TR, and Marshall, BE. ASA Refresher Course, Cause and Management of Perioperative Pulmonary Edema, Barash, PG, and Tinker, JH, (eds.), Lippincott.

b) Lung disease and destruction of pulmonary vascular beds
c) Embolism: fat, amniotic, and air

3) Increased backward pressure from mitral stenosis or mitral regurgitation

20. If a patient in cardiac failure develops the sudden onset of supraventricular tachycardia, how should this be treated? This is a common scenario. The treatment of SVT is adenosine, 6 followed by 12 mg. Esmolol and verapamil can worsen heart failure and exacerbate pulmonary hypertension. Hypotension should prompt cardioversion.

21. Is the PCWP a reliable monitor of intra-operative myocardial ischemia?

a. This is controversial. The PA cath is a valuable tool to monitor cardiac output and left ventricular preload. Furthermore, studies in which ischemia was provoked with atrial pacing or angioplasty reveal an increased PCWP.

b. Changes in the PCWP appear to be neither a sensitive nor reliable indicator of intraoperative myocardial ischemia. The 12 lead ECG appeared to be more sensitive in identifying ischemia detected by transesophageal echo than the wedge pressure.

XI. Doppler principle

1. Basics:

a. Frequency: Number of cycles / second
b. Wavelength: Distance travelled by sound during one cycle
c. Speed of sound (C)= Frequency (F) X Wavelength (λ); 1540 m / sec in water

2. The Doppler principle states that frequency and wavelength shifts will occur depending upon whether an object is moving toward or away from an observer. If an object is moving toward an observer reflected wavelength is shorter and frequency higher. If an object is moving away from an observer reflected wavelength is longer and frequency lower.

3. Example and application: When 2,000,000 Hz is reflected off from red blood cells moving toward an observer, they send back 2,006,000 Hz. The Doppler shift is +6,000 Hz.

XII. EKG monitoring[14]

1. When the patient is awake, angina is the best sign of myocardial ischemia. When the patient is asleep, a 1 mm ST depression in V5 is the best sign. 90% of ST segment information contained in a conventional 12 lead EKG is found in lead V5.

2. Many EKG machines do not have precordial leads. A modified V5 or CM5 may be used. Place the right arm electrode (negative) just to the right of the sternum. Place the left arm electrode at the V5 position (5th intercostal space at the anterior axillary line), and place place the left leg electrode at any convenient position. Now, monitor lead I.

3. CM5 might be just as good: Place the right arm (-) electrode over the middle part of the right scapula, the left arm electrode over the V5 position and monitor lead I.

4. What does the EKG tell us? You must be able to articulate what you know!

a. Rate, rhythm
b. Ischemia
d. Conduction abnormalities
e. Axis and hypertrophy

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[14]Stoelting, RK. Pharmacology and Physiology in Anesthetic Practice, Lippincott.

5. CAD and the myocardial ischemia are often regional disease processes. An inferior lead such as lead II may be normal while ST segment depression and T wave inversion can be evident in precordial leads. The following specific leads look at these specific regions:

a. II, III, aVF	RCA	Right atrium and right ventricle
b. V3-V5	LAD	Anterior lateral left ventricle
c. I, aVL	circumflex	Lateral LV

6. The usual 12 lead EKG can be broken down into the following:

a. Three standard limb leads: Record the potential difference between two points.

1) Einthoven's Law: I + III= II

b. Six precordial chest leads: The chest wall electrode is connected to the positive terminal while the negative terminal is connected to the right arm, left arm, or left leg. Nearness of the electrode to the heart means that small abnormalities of the ventricle can produce marked EKG changes. The V5 lead is so valuable because the ST segment is a very accurate predictor of ischemia.

1) V1-V2 are mainly negative because they are at the base.
2) V2-V6 are mainly positive because they are near the apex.

c. Augmented unipolar leads: Two limbs are connected to negative electrodes while the third is connected to the positive electrode.

1) aVR: positive electrode is on the right arm
2) aVL: positive electrode is on the left arm
3) aVF: positive electrode is on the left leg

7. Axis: Normally about 60 degrees. I and aVF should be positive.

a. LBBB or LVH causes left axis deviation (less than 0 degrees)
b. RBBB or RVH causes right axis deviation (greater than 100 degrees)

8. Decreased voltage is caused by:

a. Pericardial fluid

9. Q wave occurs because there is no electrical activity in the infarcted area. Must be more than 1 mm and greater than 0.04 seconds in duration (one box in depth and one box in duration).

10. T wave inversion: see below

11. Atrial and ventricular hypertrophy:

a. Ventricular hypertrophy: Look at S in V1 and R in V5. If they add up to greater than 35 mm (each box is 1 mm) there is probably LVH.
b. Atrial hypertrophy: Look at V1. If the p wave is more than 3 small squares wide and/or is biphasic one should suspect atrial hypertrophy

12. Evaluation of preoperative or intraoperative PVC's:

A. Begin by asking several questions--Are they present on the old EKG? What is the frequency? Are they unifocal or multifocal? Do they occur such that there is an R wave on the T wave? What should one do? If more than 6 per minute treat with lidocaine. While doing so review the causes and investigate. The causes are several and include the following: Investigations that are often appropriate are to check the vital signs, order an ABG, EKG, and serum electrolytes.

B. Consider the possible etiologies and treat accordingly:

a. Hypoxia, hypercarbia, pain
b. Hypotension- anemia

c. Myocardial disease: myocardial infarction, myocardial ischemia, CHF, cardiomyopathy- myocarditis, valvular heart disease, conduction system abnormality

d. pH abnormalities

e. Blood pressure abnormalities, either hypo or hypertension

f. Electrolyte abnormalities (K+, Ca+, and Mg+ are the most common offenders) and/or endocrine problems (hyperthyroidism, pheochromocytoma)

g. Temperature abnormalities

C. Is treatment necessary?

a. If they are ≤ 6/minute and are unifocal, no treatment is necessary.

b. If they are ≥ 6/minute, administer lidocaine 1 mg/kg loading with 0.5 mg/kg administered in 5 minutes. If they persist, a 1-4 mg/min drip should be started.

c. Vital sign check, ABG, EKG, and electrolytes. (VAE)

13. ST segment elevation or depression---T wave inversion/Q wave abnormality---"nonspecific" changes: Treat associated factors such as hypo or hypertension, anemia, and tachycardia and while preparing nitroglycerin consider other etiologies.

1) ST segment elevation:

While preparing to treat myocardial ischemia, a number of other etiologies for ST elevation should be considered:

Coronary artery disease
- Acute myocardial infarction

Epicardial injury
- Pericarditis
- Myocarditis
- Blunt Trauma
- Post-cardioversion

Agents/Drugs
- Hyperkalemia
- Digitalis
- Hypothermia
- Carbon Monoxide-Cyanide

2) ST segment depression or T wave inversion

Myocardial ischemia and subendocardial infarction

A. Digitalis-Quinidine
Injury to the CNS
Acute cor pulmonale (pulmonary embolus)
Athletic heart syndrome
Left Bundle Branch Block

B. Filters:

a. Filters cut-out electrocautery interference.

b. They lessen the fidelity of the monitor and sometimes if there is a prominent R wave the deflection makes it appear as if there is ST depression.

c. Therefore, if there is ST depression turn-off the filter.

3) Abnormal Q waves

Hallmark of transmural myocardial infarction
Left and right ventricular hypertrophy
Left and right bundle branch block
Cor pulmonale (pulmonary embolism)
Cardiomyopathy
IHSS
Pneumothorax, emphysema

4) Nonspecific ST or T wave changes on a preoperative EKG are not associated with increased perioperative risk.

XII. Foley catheter

1. Urine output is a very sensitive indicator of renal perfusion and intravascular volume. If the surgery involves significant fluid shifts, is going to be prolonged, or is to be performed in the setting of poor renal function, a foley catheter is indicated.

a. Morbidity from renal failure is high. Anesthesiologists must protect the kidneys by ensuring perfusion.
b. Urine output should be maintained at a level of at least 0.5 cc / kg / hr.
c. See renal section for treatment of intraoperative oliguria.

XIII. Peripheral Nerve Stimulator

1. See neuromuscular section

XIV. Transesophageal echocardiography[15]

1. Two dimentional transesophageal echocardiography provides remarkably revealing images of cardiovascular anatomy and physiology.

a. It not surprising that information derived from TEE can dramatically alter anesthetic and surgical management.
b. The fact that no adverse effects of ultrasound have been demonstrated in humans obviously adds to its risk-benefit ratio.

2. Pizoelectric crystals are the transducers and receivers of sound used in echocardiography.

a. These quartz crystals vibrate when electrically stimulated to produce ultrasound.
b. Two basics: First, when ultrasound strikes the interface of tissues of different densities a portion is reflected. The greater the difference in tissue density, the greater the portion reflected. Second, sound is assumed to travel at 1540 m / sec in all tissues of the body at 37 degrees centigrade and therefore the longer the sound wave takes to bounce back to the transducer, the greater its distance from the transducer.

3. The first echocardiograms were motion or M-mode echocardiograms but they revealed only a small part of the heart at once. By using multiple crystals, multiple views could be obtained and were collated into a 2 dimentional image.

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[15] Cahalan, MK. ASA Refresher Course, Transesophageal Echocardiography: Should I Be Using It?, Barash, PG, and Tinker, JH, (eds.), Lippincott.

4. While the current technology cannot reveal meaningful data on coronary blood flow, the monitor does provide other important data as to the presence of ischemic heart disease.

a. Specifically, segmental wall motion abnormalites have been recorded within seconds of the onset of regional ischemia and akinesia and dyskinesia clearly reveal regions of old infarction.

b. Besides providing an earlier and more reliable monitor for myocardial ischemia than ST segment changes, echocardiography is clearly a premier tool for the assessment of ventricular function, providing accurate assessments of ventricular filling and ejection, wall thickness, and mass. End diastolic volume, ejection fraction, wall stress, and correlates of contractility can be calculated from these.

5. Advances in West Germany in 1982 made it possible to position a phased transducer in the esophagus, making intraoperative 2D echo practical for the anesthesiologist.

a. A typical esophageal transducer is 42 mm long and is mounted upon a gastroscope.

b. Once the transducer has been inserted through the mouth, advanced 30-35 cm, retroflexed with the controls of the gastroscope to angle the beam about 10-30 degrees caudad, a view of the LA, LV, and LV outflow tract is clearly visible.

c. LV and RV size and fuction are demonstrable with small position changes.

d. These images can be recorded at the start and conclusion of surgery as well as at strategic intervals such as cross-clamping. <u>Therefore, TEE provides a direct and quantitative method to assess LV preload and ejection.</u>

e. Will the transesophageal echocardiography take the place of the PA catheter in many situations in the future? Probably, by virtue of both costs and benefits.

6. Other uses include diagnosis of atrial septal defects, evaluation of especially the mitral valve, and detection of air embolism and paradoxical air embolism. The TEE is more sensitive than a precordial doppler in detection of air.

7. Should you be using the TEE?

a. If one cares for patients at high risk for perioperative cardiovascular instability, the use of TEE is increasingly important.

b. The fact is that many of us have never used this device. Don't bluff! The basic information presented here is important but make it very clear that you have never used this device, if that is the case.

c. Please remember that the TEE is especially useful in viewing the mitral valve, an important fact when there is a failure to wean from CPB.

XV. EEG Monitoring

1. The EEG represents the summation of cortical electrical activity generated by post-synaptic potentials, in other words <u>electrical activity from the cerebral cortex, voltage against time</u>.

a. It permits evaluation of the CNS where it is not possible to perform a clinical exam, such as during general anesthesia.

2. The EEG is classified on the basis of both rhythm and frequency: Delta, Theta, Alpha, and Beta --each associated with different physiologic states.

a. Delta (0-4 Hz): Deep sleep, deep anesthesia, hypoxia, tumors.

b. Theta (4-8 Hz): Sleep, anesthesia, hyperventilation.

c. Alpha (8-13 Hz): Resting, alert adult. Dominant frequency in the awake state.

d. Beta (13-30 Hz): Mental concentration.

3. In general, patterns are used as opposed to frequency analysis and these patterns can be activated, depressed, or isoelectric.

4. Frequency is still important and many factors can alter it. (Know this in some detail.)

<u>Increased EEG frequency</u>
Hyperoxia
Hypercarbia: mild
Hypoxia: initial
Seizure
Barbiturates: Small dose
Diazepam:
N_2O: 30-70%
Inhalation agents < 1 MAC
Ketamine

<u>Decreased EEG frequency, Increased Amplitude</u>
Hypoxia: mild
Hypocarbia: moderate to extreme
Hypothermia
Barbiturates: moderate dose
Etomidate
Narcotics
Inhalation agent > 1 MAC

<u>Decreased EEG frequency, Decreased amplitude</u>
Hypoxia: marked
Hypercarbia: severe
Hypothermia
Hypotension
Barbiturates: large dose

<u>Electrical EEG Silence</u>
Brain Death
Hypoxia: severe
Hypothermia: profound
Barbiturates: coma dose
Isoflurane: 2 MAC

5. For anesthesiologists, the most important thing to know is that changes, especially decreased amplitude or slowing may represent CNS hypoxia.

a. Decreased amplitude or slowing of the EEG should be treated by optimizing (usually raising) blood pressure and ruling-out hypoxia and hypothermia.

6. Anesthetic effects: What do we need to have on the tip of our tongue?

a. In general, as the depth of anesthesia increases, EEG frequency decreases until a delta or theta level is reached.

Dr. Jensen's Presentation Points

Winston Churchill:
Comments to the Cabinet upon becoming Prime Minister, some of whom were known to favor the compromise that had marked the previous five years: "I am convinced that every man of you would rise up and tear me down from my place if I were for one moment to contemplate parley or surrender. If this long Island story of ours is to end at last, let it end only when each one of us lies choking in his own blood upon the ground."