Non invasive cardiac output measurements

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Are we monitoring patients the right way?

NO! Our current practices are not evidenced based and are dangerous to our patients.

What should we do?

What Should We Monitor?

- Current Practice
  - Respiration
    - Respiratory rate
    - Pulse oximetry
  - Cardiac function
    - Blood pressure
    - Urine output
    - LOC
    - Heart rate
- What should we be doing
  - Respiration
    - Capnography
  - Cardiac function/blood volume
    - Stroke volume
    - Peak velocity/flow time
    - StO2/ScvO2/lactate

Can't I look at my patient and tell if they are OK?

NO! Physical Assessment is often inaccurate, slow to change and difficult to interpret

Are Physical Signs Early or Late Indicators of Clinical Status

- When will blood pressure change? level of consciousness? Urine output?
- Signs of hypoperfusion
  - LV dysfunction
  - Hypovolemia
  - Sepsis
- Which signs are similar with all three?
  - BP
  - HR
  - LOC
  - Urine output

References – Inaccuracies of Physical Assessment

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Which Hemodynamic Device Would you Use in a Patient Assessment

- Device 1 –
  - Cheap (<$5/pt)
  - Research shows that is frequently inaccurate and slow to reflect patient changes
  - No evidence it changes patient outcome
  - Easy to use
- Device 2
  - $175/pt – physician reimbursed >$100-$400/pt
  - Accurate
  - 10 RCT's showing use can reduce LOS (save hospital 4X cost of the device)
  - Used on sedated patients only
    - OR, ICU, PAR
  - Gives continuous readings
  - Easy to use
- Device 3
  - $10/pt (initial cost is capital purchase)
  - Accurate
  - Can be used on almost anyone
    - OR, ICU, ED, floors, RRT, paramedics, MD office
  - Uses same principle as the above RCT's showing
  - No MD reimbursement
  - Gives intermittent readings

Devices

- Device 1 is blood pressure
- Device 2 is Esophageal Doppler
- Device 3 is External Doppler

Use of Stroke Volume as End Point

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IX. CMS Conclusion – May 2007

- CMS was asked to reconsider our current national coverage determination (NCD) on ultrasound diagnostic procedures. CMS has determined that there is sufficient evidence to conclude that esophageal Doppler monitoring of cardiac output for ventilated patients in the ICU and operative patients with a need for intra-operative fluid optimization is reasonable and necessary under Section 1862(a)(1)(A) of the Social Security Act and therefore, we are removing the past non-coverage of cardiac output Doppler monitoring.
- CMS will amend the NCD Ultrasound Diagnostic Procedures at section 220.5 of the NCD manual by adding "Monitoring of cardiac output (Esophageal Doppler) for ventilated patients in the ICU and operative patients with a need for intra-operative fluid optimization" to Category I, and deleting "Monitoring of cardiac output (Doppler)" from Category

Oxygenation as a Hemodynamic End Point

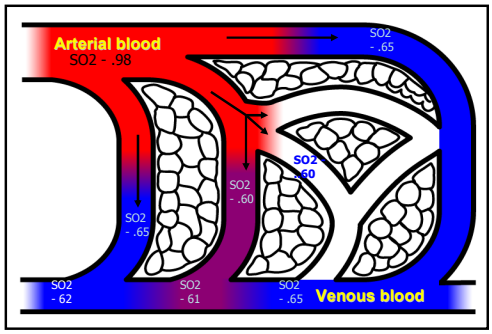
Background Physiology

What would you do?

No Ventilation CPR

ABC's or CAB's

In a cardiopulmonary arrest, which type of blood gas is most useful to assess the resuscitation effort- arterial or venous?



Triple Lumen Oximetry

- Triple lumen oximetry expands ability to assess tissue oxygenation
- Values obtained from distal tip
  - RA reading
  - Similar to PA values
- Used as end point in therapy
  - Potential to improve patient outcomes

Measures of Tissue Oxygenation

- Lactate/pH
  - Normal lactate – 1-2 mmol
  - pH – normal 7.35-7.45
  - If lactate > 4 mmol and pH is less than 7.30, consider tissue hypoxia
    - Lactate/pyruvate
      - Lactate normally 10 x pyruvate
      - If lactate rising proportionately faster than pyruvate, consider tissue hypoxia (Type A lactic acidosis)
- StO2
  - Reflects tissue perfusion
  - Should not be the same as ScvO2
  - Potentially earliest indicator of a threat to tissue oxygenation

Lactate as indicator of Hypoxia

Lactate Levels and SBP

Lactate N= 529	< 2 (N=219)	2-4 (N=177)	> 4 (N = 104)
SBP > 90	158/219 (72%)	116/177 (65%)	64/104 (62%)
SBP < 90	61/219 (28%)	61/177 (34%)	40/104 (38%)

StO2 Monitoring

Near Infra red spectrophotometry

Relationship between hemodynamics and StO2

- Normal
  - If flow is adequate to periphery, StO2 is normal (87% +/- 5%)
  - If flow decreases, increased extraction of oxygen causes StO2 to decrease
    - The severity of the decrease is proportional to the severity of the loss of blood flow
  - Re-establishing blood flow would cause StO2 to increase

Does CVP and PAOP tell us about blood volume and flow?

- CVP and PAOP should never be used in isolation
  - Inconsistent in revealing information about volume and flow
- Flow and pressure do not always correlate
  - *Marik et al. Based on the results of our systematic review, we believe that CVP should no longer be routinely measured in the ICU, operating room, or emergency department.*

Marik P, Baram M, Vahid B. Does central venous pressure predict fluid responsiveness? A Systematic Review ofthe Literature and the Tale of Seven Mares. Chest 2008;134;172-178

BP Measurement - Useful or Misleading?

- *Is BP is measured because it* can *be measured*
- *If BP increases, does blood flow increase?*
  - think of use of levophed

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Blood Pressure and Blood Flow

Do they equal each other?

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BP = CO x SVR

- CO = Stroke volume x heart rate
  - decrease in SV causes increase in heart rate
  - decrease in CO causes increase in SVR
- Compensatory changes keep the BP close to normal initially in shock states
- BP does not change until late due to these compensatory responses

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What is the Purpose of Blood Pressure?

The role of the biventricular cardiovascular system

Systemic	Values	*Pulmonic*	Values
LV	110/10	*RV*	25/0-5
Aorta	120/80	*PA*	25/10
Capillaries	30-50	*Capillaries*	12-17
RA	0-5	*LA*	8-12

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Easy Interpretation of Hemodynamics from any technology

Assessing the 3 Threats to Tissue Oxygenation (shock states)

Normal Hemodynamic Values

SvO2 (ScvO2)	**.60-75 (>7% higher)**
Stroke Index	**25-45 ml/m2**
Stroke Volume	50-100 ml
Cardiac Index/Output	2.5-4 L/m2 4-8 L/min
Lactate	1-2 mmol

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Normal Hemodynamic Information regarding Cardiac state

- Contractility
  - EF - >60%
  - Peak velocity >50 -120 cm/sec
- Preload
  - Flow time – 330-360 msec
  - PAOP – 8-12 mm Hg
  - CVP – 2-6 mm Hg

Common Forms of Threats to Tissue Oxygenation

- LV systolic dysfunction
  - MI
  - CHF
  - Cardiomyopathy
- Hypovolemia
  - trauma
  - postoperative blood loss
  - GI bleed
- Low SVR
  - sepsis/SIRS

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LV Dysfunction (systolic)

BP	100/58
P	110
SI	16 ↓
CI	1.8
Flow time	356
Peak velocity	48 ↓
CVP/PAOP	9/18 ↑
ScvO2/StO2	.41 ↓

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Hypovolemic Shock

BP	82/50
P	118
SI	14 ↓
CI	1.8
Flow time	315
Peak velocity	70
CVP/PAOP	3/7 ↓
ScvO2/StO2	.39 ↓

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Septic Shock

BP	82/50
P	110
SI	50 ↑
CI	5.5
Flow time	315 ↓
Peak velocity	58 ↔
CVP/PAOP	3/7 ↓
ScvO2/StO2	.89 ↑

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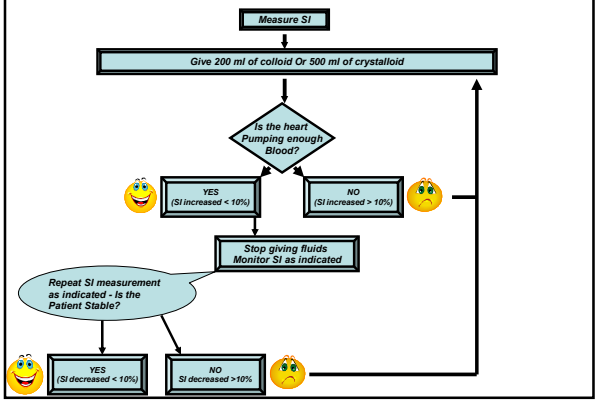
Moving toward Blood Flow Measurement

Stroke Volume as an End point

Stroke volume normal values
Stroke volume variation

McKendry M, McGloin H, Saberi D, Libby C, Brady A, Singer M. Randomised controlled trial assessing the impact of a nurse delivered, flow monitored protocol for optimisation of circulatory status after cardiac surgery BMJ 2004;

Sample Stroke Volume Optimization Protocol



Patients Indicated for Stroke Volume Measurement

- Intra op patients requiring fluid
- Post op patients requiring fluid
- Patients on Mechanical Ventilation
- Patients requiring vasopressors to Insure adequate volume resuscitation

Beyond the PA Catheter

New and current methods of measuring blood flow

Chapter 3
Which Technologies for Cardiac Output Measurement are Best?

Method	Accurate	Non-invasive	Use beyond ICU	Inexpensive	Easy to Use
Non invasive Doppler	✓	✓	✓	✓	✓
Bioimpedance	✓	✓	✓	✓	✓
Esophageal Doppler	✓	✓	✓	✓	✓
NICO (Mod Fick)	✓			✓	
LidCo (LiCl dil)	✓			✓	
PiCCO (Mod Tx)	✓			✓	
Flotrac (Art wave)	✓			✓	
Thermodilution (PAC)	✓			✓	

Use of Blood Flow Techniques

- All methods have strengths and limitations
- Many acute and critical care patients can have these techniques used
- All can be used within limitations
- Use oxygenation end points to validate information regarding blood flow

Non Invasive Cardiac Output Measurements

Doppler Techniques

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Physicians, APN's and bedside nurses can do Doppler monitoring

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Technology is Only As Good AS You

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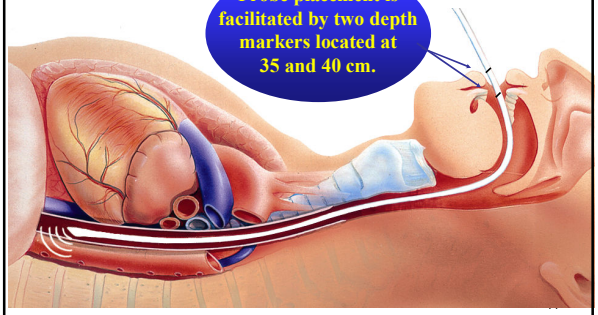
Probe Placement

Probe placement is facilitated by two depth markers located at 35 and 40 cm.



Esophageal Doppler Variables

Normal Ranges

FTc: Flow Time corrected
The time of systolic flow corrected to heart rate.
330 - 360 milliseconds

PV: Peak Velocity
The velocity of the blood measured at the peak of systole.
20 yrs: 90 - 120 cm/sec
50 yrs: 60 - 90 cm/sec
70 yrs: 50 - 80 cm/sec

NOTE: Normal Ranges should not be confused with a Physiological Target.

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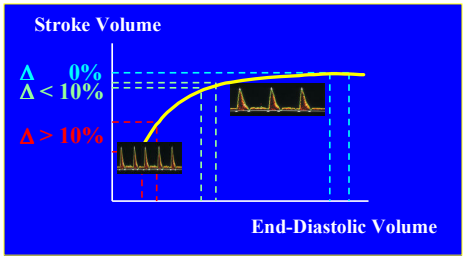
Treatment Guidelines

Determine success of fluid or inotropic therapy by
The response in stroke volume/index and SvO2



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Non Invasive Doppler Measurement of Blood Flow

Allows Both Left & Right Heart Measurement

AORTIC ACCESS

PULMONARY ACCESS

Any Change in Blood Flow (CO) Should be Compared against an Oxygenation End Point

ScvO2 or StO2

End Point Application Combining Blood flow and tissue oxygenation

- SI (by any method)
  - 26 to 22
  - StO2 .64 to .65
    - If heart rate unchanged, Suspect measurement error
  - 28 to 20
  - StO2 .61 to .43
    - Suspect clinical deterioration
- Lactate can be used in place of StO2 but is slower to change

Acceptance of Non Invasive Technology

Who is being harmed by our current practices?

We must have a sense of urgency

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