Assessing Preload Responsiveness: Incorporating Stroke Volume Variation into the Hemodynamic Profile

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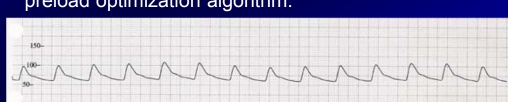
Disclosures

- Edwards Lifesciences:
  - Education Consultant

Objectives

- Discuss limitations of pressure-based parameters for preload assessment
- Describe how arterial pressure-based systems measure SV and CO
- Describe the physiologic principles of preload responsiveness
- Describe SVV and how it is used clinically
- Incorporate dynamic fluid assessment parameters into a preload optimization algorithm.

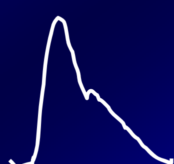


Static Measures of Preload

- Static measurements of preload / volume status:
  - CVP, PAOP and others
- When giving volume, how often have you accurately predicted how the patient will respond?
- Recent studies have confirmed these filling pressures have little correlation with fluid responsiveness

Ahrens T. Crit Care Nurse 2010;30(2):71-73; Enomoto TM, Harder L. Crit Care Clin 2010;26:307-321; Jain RK, et al. Shock 2010;33(3):253-257; Kumar A. Crit Care Med 2004;32:601-609; Kupchik N. AJN 2012;112(1):58-61; Osman D, et al. Crit Care Med 2007;35(1):64-68

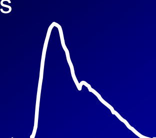
Arterial Blood Pressure Physiology



What do we know about the blood pressure?

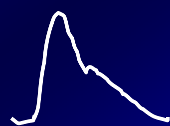
Systolic pressure determinants:

- Stroke volume
- Velocity of blood ejection from LV
- Systemic arterial resistance
- Distensability of arterial walls
- Viscosity of the blood
- LV preload



McGhee BH, Bridges EJ, Monitoring arterial blood pressure: What you may not know. *Critical Care Nurse*, 2002;22(2):60-79.

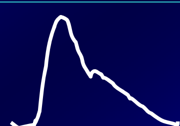
Diastolic Blood Pressure Determinants:



- Blood viscosity
- Arterial distensability
- Systemic resistance
- Length of the cardiac cycle

McGhee BH, Bridges EJ, Monitoring arterial blood pressure: What you may not know. *Critical Care Nurse*, 2002;22(2):60-79.

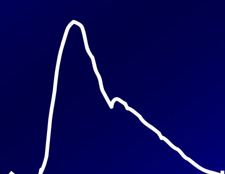
Pulse Pressure (PP)



- Definition:
- Increased:
  - Increased SV
  - Increased ejection velocity
- Decreased
  - Increased vascular resistance
  - Decreased SV
  - Decreased intravascular volume

McGhee BH, Bridges EJ, Monitoring arterial blood pressure: What you may not know. *Critical Care Nurse*, 2002;22(2):60-79.

Mean Arterial Pressure



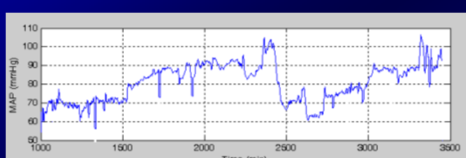
- Definition:
- Significance:
- Product of the SVR and CO

McGhee BH, Bridges EJ, Monitoring arterial blood pressure: What you may not know. *Critical Care Nurse*, 2002;22(2):60-79.

Does Pressure Indicate Flow?

- Blood flow is determined by a pressure gradient across the vascular bed = "Perfusion Pressure"
- Changes in flow are usually a result of changes in resistance

Does Pressure = Flow?



Basic Premises of Arterial Pressure-Based Technology

- Pulse pressure is proportional to stroke volume.
  - "In general, _the greater the stroke volume output_, the greater is the amount of blood that must be accommodated in the arterial tree with each heartbeat and, therefore, *the greater the pressure rise and fall during systole and diastole,* _causing a greater pulse pressure._"

  - *Guyton AC, Textbook of medical physiology, WB Saunders, 1981; 221-233.*

- "Aortic _pulse pressure is proportional to SV_ and is inversely related to aortic compliance."
  - *Boulain (CHEST 2002; 121:1245-1252)*

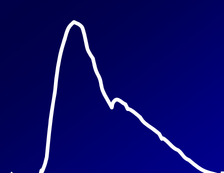
Basic Premises

- Arterial pulsations reflect heart rate:
  HR x SV = CO
- Assessment and compensation for:
  - Aortic Compliance:
    - input age, gender, height & weight
  - Peripheral Vascular Resistance:
    - waveform assessment

Arterial Pulse Technologies for Cardiac Output Monitoring

Different Methods: Comparisons

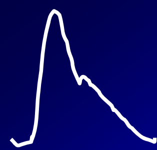
- Pulse Contour (PICCO®)
- Pulse Power (LIDCO®)
- Pulse Pressure / Flow (APCO / FloTrac®)



Bridges EJ. Crit Care Nurse 2008;23(2):105-112; Economoto TM, Harder L. Crit Care Clnins 2010;26:307-321; Marik PE, et al. Ann Intensive Care 2011;1(1):

Pulse Contour: PICCO®

- Uses the arterial waveform between the onset of systole to the dicrotic notch.
- Calculates the area under the systolic portion of the waveform, which divided by aortic impedance, allows for the estimation of stroke volume.
- Requires transthoracic thermodilution calibration
- Does not include the reflective wave



Reuter DA, Goetz AE. Arterial Pulse Contour Analysis: Applicability to Clinical Routine in Functional Hemodynamic Monitoring: eds MR Pinsky and D. Payen. *Update in Intensive Care and Emergency Medicine 42*. Springer- Verlag. New York. 2005: 175-181.

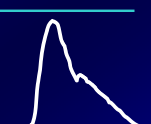
Pulse Power: LIDCO®

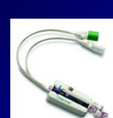
- Centered around theory that fluctuations in BP around a mean value are caused by the SV forced into the arterial conduit with each systole
- Uses transpulmonary indicator dilution technique
- Requires lithium calibration at frequent intervals (every time there is a change in resistance)

Rhodes A, Sunderland R. Arterial Pulse Power Analysis: The LiDCO TM plus System. in Functional Hemodynamic Monitoring Eds. Pinsky MR, Payne D. *Update in Intensive Care and Emergency Medicine 42*. Springer-Verlag. New York. 2005; 183-192.

Arterial Pulse Pressure: APCO / FloTrac®

- Utilizes the entire arterial waveform including the reflective wave
- Uses standard deviation of full arterial pressure and waveform analysis
- Does not require calibration





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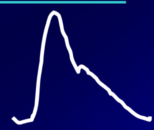
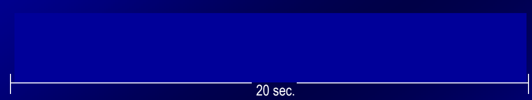
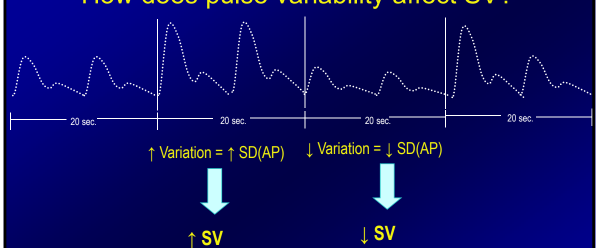


Turning Arterial Pressure Variation into SV



- Arterial pressure is sampled 100 times/second (100 Hz).
- Every 20 seconds, 2000 data points are compiled, variation analyzed, and a standard deviation (SD) of the sample is calculated.
- Calculated SD(AP) of the full waveform is proportional to SV.

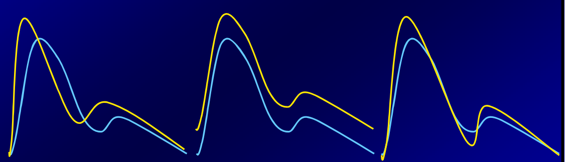
How does pulse variability affect SV?



- An increase in SD implies a proportional increase in SV, and vice versa.

Effect of peripheral resistance

- The algorithm looks for characteristic changes in arterial pressure that affect flow
- Those changes are included in the calculation of SV



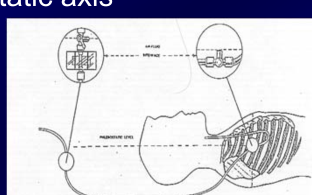
Concerns and Potential Limitations

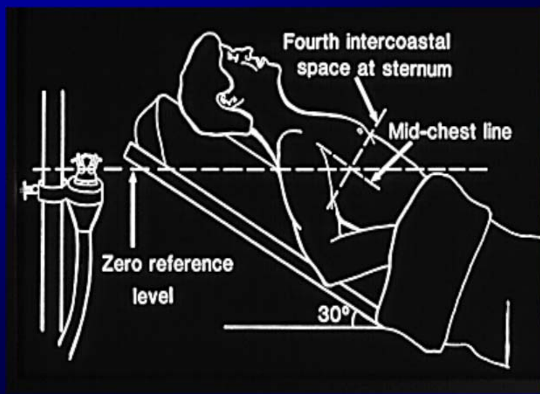
- Factors affecting arterial pressure monitoring
  - Proper leveling
  - Proper zeroing
  - Waveform integrity
  - HOB position

- Concerns with additional calibration

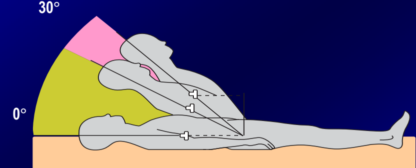
Appropriate Transducer Location

- Phlebostatic axis





A clinical question:
Can the head of bed be raised?



- YES, BUT... must ensure that the transducer air fluid interface is raised as well!

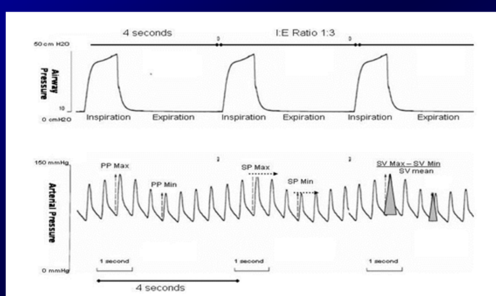
Arterial Pressure / Stroke Volume Variation Parameters

Definitions: All compare the difference between the maximum and the minimum value over a full respiratory cycle.

Arterial Based Parameters

- Systolic Pressure Variation (SPV):
  - difference between the maximum and minimum values of SBP over a single respiratory cycle
  - Normal < 10mmHg to 15mmHg
- Pulse Pressure Variation (PPV%):
  - maximal PP less the minimal pulse pressure divided by the average of these two pressures.
  - Normal approximately < 13%
- Stroke Volume Variation (SVV%):
  - maximal SV less the minimal SV divided by the average of these two stroke volumes.
  - Normal range: ≤13%

Relationship of Intra-thoracic Pressures to Arterial Pressures

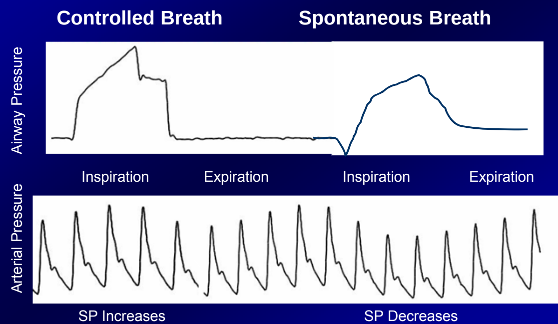


Physiology of Stroke Volume Variation

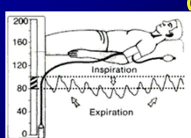
- Relationship of Intra-thoracic Pressures to Arterial Pressures
  - Spontaneous breath
  - Controlled breath

So, let's talk about you……….

Airway Pressure – Arterial Waveforms



Pulsus Paradoxus: The Origin of SVV



IN a normal individual who is breathing spontaneously, blood pressure decreases on inspiration, but the peak decrease of systolic pressure does not exceed 5 mmHg. The exaggeration of this phenomenon, called *pulsus paradoxus*, was initially reported by Adolf Kussmaul in constrictive pericarditis and was described as a 'pulse disappearing during inspiration and returning during expiration' despite the continued presence of the cardiac activity during both respiratory phases.[1]

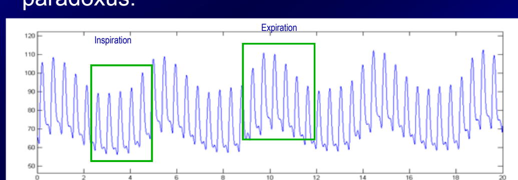
Michard Anesthesiology 2005

- Pulses Paradoxus is the origin of SVV value.
  - Occurs with spontaneously breathing patients.
- Reverse Pulses Paradoxus
  - Occurs during positive pressure ventilation.
- Clinical use of this phenomenon remains "marginal"

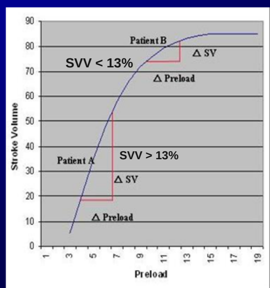
Normal Variation & Pulsus Paradoxus

Normal with spontaneous breathing, SBP decreases on inspiration, but the peak decrease does not exceed 5-10 mmHg.

Exaggeration of this phenomenon = pulsus paradoxus.



Starling Curve for Preload Responsiveness



- Patient A is preload responsive
  - On steep part or fluid responsive portion
  - Fluid bolus results in significant increase in SV
- Patient B is not preload responsive
  - No preload recruitibility
  - Same bolus volume does not result in significant increase in SV

So…..what is important to remember about SVV

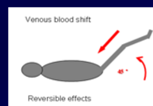
- The higher the SVV (> 13%), the drier the patient
  - They are preload responsive!
- If the SVV is < 13%, the patient is not likely to be preload responsive

Indications:

- Determine or predict the patient's potential response to fluid therapy
- Evaluate the response to fluid interventions
- Significance: Greater the SVV, the greater the predicted response to fluid loading

Passive Leg Raising Maneuvers

- Supine:
  - Raise legs up to 45 degrees
  - Hold for 30 sec to < 4 minutes
  - 150 – 300 mL increase in venous return



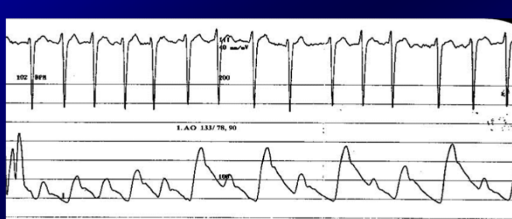
- If see SVV decrease, indicates patients is fluid responsive

PASSIVE FLUID CHALLENGE

Limitations:

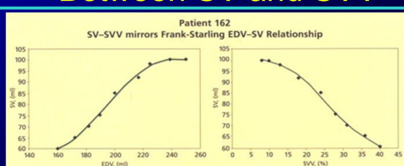
- Irregular rhythms may produce varied results
- *Intubated with controlled ventilation*
- *Fixed tidal volume and respiratory rate*

Impact of Afib on Arterial Pressure



Clinical Indications / Applications

Example of Inverse relationship Between SV and SVV



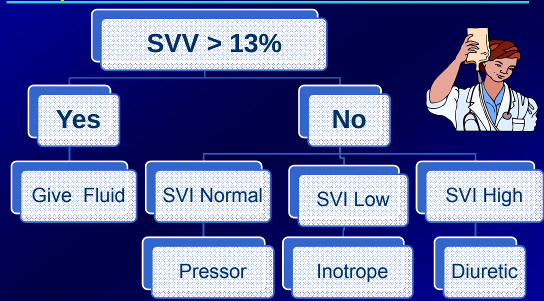
On the right is the Frank Starling Curve plotting the relationship between SV and end-diastolic volume using a PA catheter. On the left is the same patient plotting the relationship between SV and SVV. Notice, the graphic on the left is the reverse of what we see on the right. For this patient, the optimal preload (EDV) was 225 mL associated with a SV of 100 mL. This corresponded to a SVV of 10% or less. As preload increased, SV reaches a plateau and simultaneously, SVV reaches an optimal value.

McGee WT, Horswell JL, Hatib FS, Headley JM. Stroke volume variation to stroke volume relationship using a less invasive arterial pressure based technology. *Critical Care Medicine,* 2006;34 (12) suppl. Abs 227.

Clinical Situations

- Management of CVVHD
- Volume administration with severe sepsis
- Trauma
- Post-operative fluid management
- Cardiothoracic surgery

Decision Tree Using SVV to Optimize Cardiac Performance

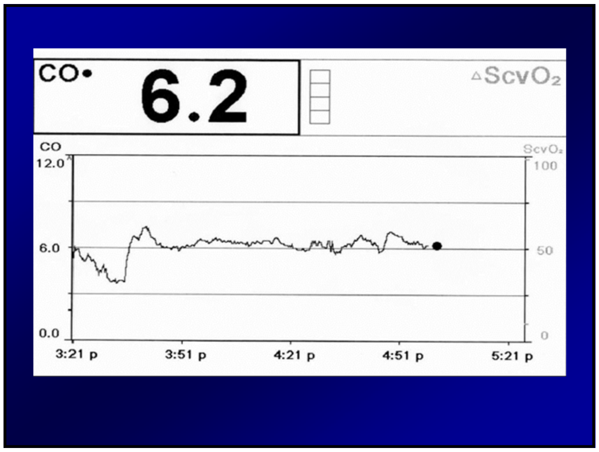


McGee W. 2009

Case Scenarios

Is This Pt Going to Respond to Fluid?

Parameters	3:35pm	3:40pm	3:45pm	4:02pm	4:09pm
CO	3.8	7.3	6.3	6.4	6.4
SV	68	113	99	98	100
SVV	28	20	18	6	6
Est HR	56	65	64	65	64


CO•
6.2
ΔScvO2
CO
12.0
6.0
0.0
ScvO2
100
50
0
3:21 p
3:51 p
4:21 p
4:51 p
5:21 p


THANK YOU