Invasive Arterial Blood Pressure

By:

Mohammad Yusuf
Arterial Blood Pressure

- Two forces generate arterial blood pressure:
  - COP
  - SVR

\[ \text{MAP} = \text{CO} \times \text{SVR} \]
Measurement of ABP

Indirect Cuff devices
- Manual Intermittent Technique
- Automated Intermittent Technique
- Automated Continuous Technique

Direct Arterial Cannulation & Pressure Transduction
- Percutaneous Radial Artery Cannulation
- Alternative Arterial Pressure Monitoring Sites
Invasive Blood Pressure Monitoring

• Invasive (intra-arterial) blood pressure (IBP) monitoring is a commonly used technique in the Intensive Care Unit (ICU) and in the operating theatre.

• It involves the insertion of a catheter into a suitable artery and then displaying the measured pressure wave on a monitor.
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- **Indications of Arterial Cannulation:**

  1. Continuous, real-time blood pressure monitoring
  2. Planned pharmacologic or mechanical cardiovascular manipulation
  3. Repeated blood sampling
  4. Failure of indirect arterial blood pressure measurement
  5. Supplementary diagnostic information from the arterial waveform
  6. Determination of volume responsiveness from systolic pressure or pulse pressure variation
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- Complications of Direct Arterial Pressure Monitoring:

1. Distal ischemia, pseudoaneurysm, arteriovenous fistula
2. Hemorrhage, hematoma
3. Arterial embolization
4. Local infection, sepsis
5. Peripheral neuropathy
6. Misinterpretation of data
7. Misuse of equipment
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- COMPONENTS OF AN IABP MEASURING SYSTEM:
  1. Intra-arterial Cannula
  2. Fluid Filling tube
  3. Transducer
  4. Infusion/Flushing system
  5. Signal processor, amplifier and display

Fig 1. A typical IABP measuring system
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- The normal waveform for an invasive ABP:
  1. Initial sharp rise (left ventricular systole)
  2. Rounded slope represents the peak systolic pressure
  3. Dicrotic notch: represents the closure of the aortic valve
  4. Descending slope signifies the beginning of diastole.
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PHYSICAL PRINCIPLES

• Sine Waves:

1. Amplitude
2. Frequency
3. Wavelength
4. Phase
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- The arterial pressure wave consists of a *fundamental wave* (*the pulse rate*) and a series of *harmonic waves*. These are smaller waves whose frequencies are multiples of the fundamental frequency.

- The process of analyzing a complex waveform in terms of its constituent sine waves  
  
  *(Fourier Analysis)*
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- In the IABP system, the complex waveform is broken down by a microprocessor into its component sine waves, then reconstructed from the fundamental and eight or more harmonic waves of higher frequency to give an accurate representation of the original waveform.

- The IABP system must be able to transmit and detect the high frequency components of the arterial waveform (at least 24Hz) in order to represent the arterial pressure wave precisely.
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- Accuracy of IABP Monitoring:
  1. *Natural Frequency and Resonance*: quantifies how rapidly the system oscillates
  2. *Damping Coefficient*: quantifies the frictional forces that act on the system and determine how rapidly it comes to rest.
  3. *Transducer Zeroing and Levelling*
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• Natural Frequency & Resonance:
  - If a force with a similar frequency to the natural frequency is applied to a system, it will begin to oscillate at its maximum amplitude. This phenomenon is known as resonance.
  - If the natural frequency of an IABP measuring system lies close to the frequency of any of the sine wave components of the arterial waveform, then the system will resonate, causing excessive amplification, and distortion of the signal.
  - So, it is important that the IABP system has a very high natural frequency – at least eight times the fundamental frequency of the arterial waveform (the pulse rate). Therefore, for a system to remain accurate at heart rates of up to 180bpm, its natural frequency must be at least: \((180\text{bpm} \times 8) / 60\text{secs} = 24\text{Hz}\).
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- The natural frequency of a system is determined by the properties of its components. It may be increased by:

1. Reducing the length of the cannula or tubing
2. Reducing the compliance of the cannula or diaphragm
3. Reducing the density of the fluid used in the tubing
4. Increasing the diameter of the cannula or tubing
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• **Damping Coefficient:**
  The amount of damping inherent in a system can be described by the damping coefficient (D) which usually lies between 0 and 1

• **Critical-Damping**
• **Over-Damping**
• **Under-Damping**
• **Optimal Damping**
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- **Transducer Zeroing**: For accurate reading, atmospheric pressure must be discounted from the pressure measurement.

- **Transducer Levelling**: Level with the patient’s heart, at the 4th intercostal space, in the mid-axillary line.
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- *Insertion of a radial arterial line:*

1. Aseptic technique

2. Sterilization with alcoholic chlorhexidine

3. In conscious patients, use local anesthetic
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Systolic pressure

Mean pressure

Diastolic pressure

Dicrotic notch (closure of aortic valve)
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Pulse Contour Analysis:

- **Aortic Stenosis**:
  - Pulsus parvus (narrow pulse pressure)
  - Pulsus tardus (delayed upstroke)
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- Aortic regurgitation:
  - Bisferiens pulse (double peak)
  - Wide pulse pressure
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- **Hypertrophic cardiomyopathy**: Spike-and-dome pattern (midsystolic obstruction)
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- Systolic left ventricular failure:

Pulsus alternans (alternating pulse pressure amplitude)
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• **Cardiac tamponade**:

Pulsus paradoxus
(exaggerated decrease in systolic blood pressure during spontaneous inspiration)
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• Arterial Pressure Monitoring for Prediction of Volume Responsiveness:

systolic pressure variation (SPV)
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Pulse Pressure Variation

(PPV)
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- **Summary:**

  Invasive arterial monitoring is a highly useful tool, which allows close blood pressure monitoring for patients undergoing major surgery and the critically ill. It is also useful for repeated arterial blood gas analysis and as an access point for obtaining other blood samples. It is important to understand the principles of biological measurement systems in order to optimise their performance and allow troubleshooting when performance is poor.
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• References:

1. Miller's Anesthesia, Seventh Edition
2. Ben Gupta: Invasive Blood Pressure Monitoring: Sir Charles Gairdner Hospital, Perth, Western Australia
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• Questions?
Thank You