Invasive Blood Pressure Monitoring

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INVASIVE BLOOD PRESSURE MONITORING

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terial oxygen content, arterial pressures, blood flow velocity, mode of cardiac work and mode of respiration, all are incidental and subordinate; they all combine their actions only in service to the cells"

Pfluger, German Physiologist, about 100 years ago

"Despite the modern technologies of 21st century, we are only able to monitor what pfluger called 'incidental and subordinate'."

PINSKI's Functional hemodynamic monitoring, page 240

1896: Riva Rocci

Sphygmomanometer

Arm encircling inflatable elastic cuff pressure

Only Systolic BP measured-

pressure at which radial artery pulse disappears

1905: Kortokoff

Kortokoff sounds (auscultatory method)

Both Systolic and Diastolic BP measured

Fundamental Principle

Pressure required to obliterate **blood flow**

low flow conditions

shock or high vasopressor doses

can attenuate or obliterate generation of sound

underestimation of BP

non compressible arteries
Severe atherosclerosis

Overestimation of BP

AUTOMATED NIBP

Based on oscillometry (described by Marey in 1876)
Variations in cuff pressure resulting from arterial pulsations during cuff deflation sensed by monitor

Pressure at which peak amplitude of arterial pulsations occur, corresponds closely to directly measured MAP

Systolic and Diastolic BP are derived from proprietary formulas
Systolic and Diastolic BP are less reliable than MAP

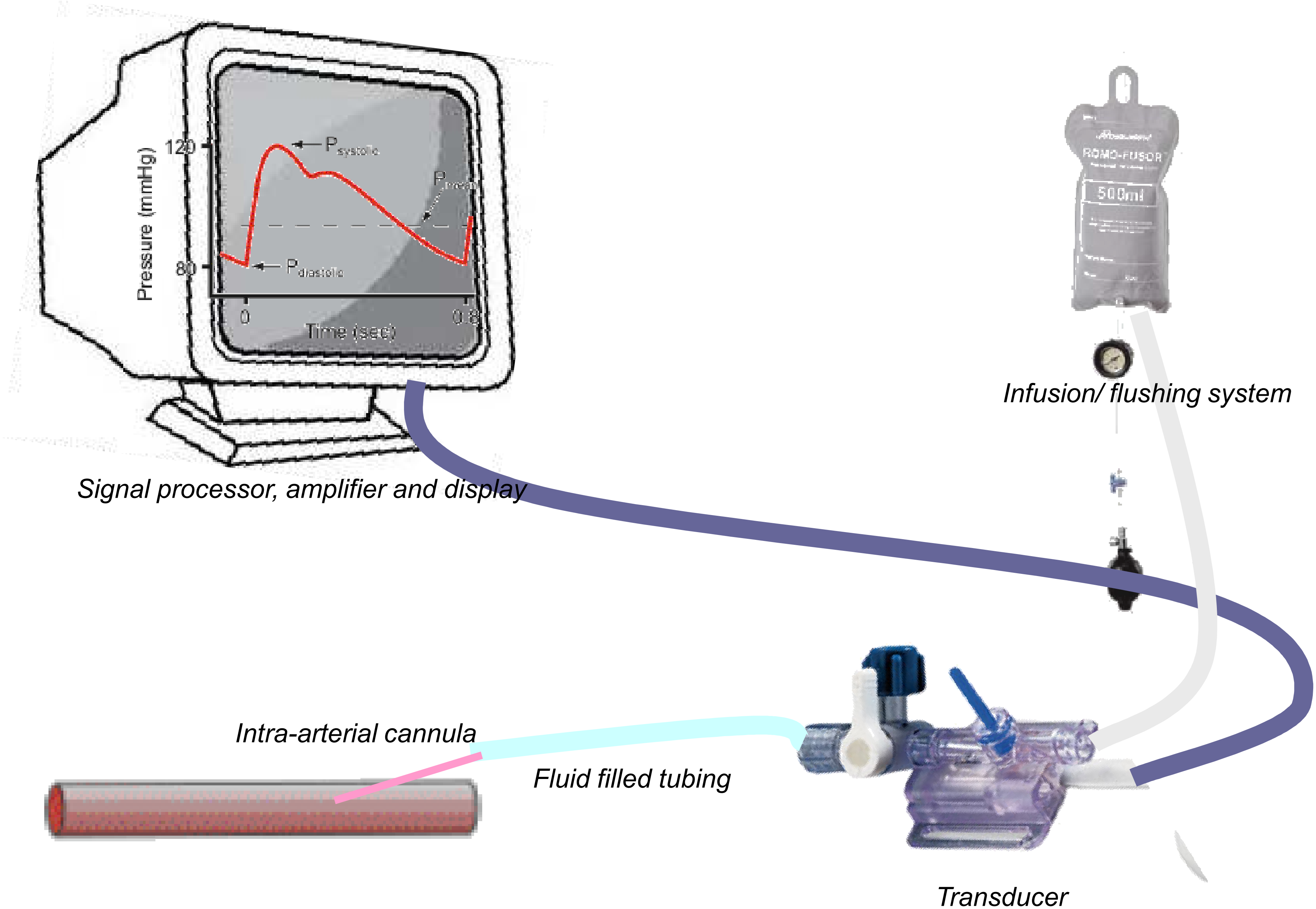
INVASIVE BLOOD PRESSURE MONITORING

The technique involves the insertion of a catheter into a suitable artery
and then displaying
the measured pressure wave on a monitor

ADVANTAGE OF IABP

- continuous beat-to-beat pressure measurement, close monitoring of critically ill patients on vasoactive drugs
- Pulse waveform analysis provides other important hemodynamic parameters
- reduces the risk of tissue injury and neuropraxias in patients who will require prolonged blood pressure measurement
- allows frequent arterial blood sampling
- more accurate than NIBP, especially in the extremely hypotensive or the patient with arrhythmias.

COMPONENTS OF AN IABP MEASURING SYSTEM



COMPONENTS OF AN IABP MEASURING SYSTEM

Intra-arterial cannula

•Should be wide and short

• Forward flowing blood contains kinetic energy.

•When flowing blood is suddenly stopped
by tip of catheter, kinetic energy is partially converted into pressure.
This may add 2-10mmHg to SBP.

•This is referred to as end hole artifact or end pressure product.

•Cannulation sites: Radial, Ulnar, Dorsalis Pedis, Posterior tibial, Femoral arteries

Fluid filled tubing

•provides a column of non-compressible, bubble free fluid between the arterial blood and the pressure transducer for hydraulic coupling.

• Ideally, the tubing should be short, wide and non-compliant (stiff) to reduce *damping.*

•extra 3-way taps and unnecessary lengths of tubing should be avoided where possible

COMPONENTS OF AN IABP MEASURING SYSTEM

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Transducer

Converts mechanical impulse of a pressure wave into an electrical signal through movement of a displaceable sensing diaphragm.

It functions on principle of strain gauze and wheatstone bridge circuit.

COMPONENTS OF AN IABP MEASURING SYSTEM

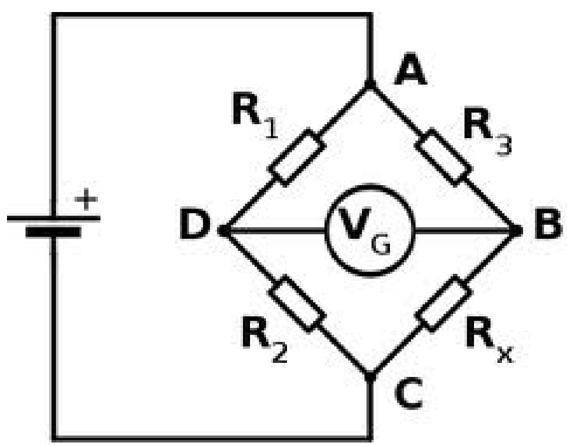
Strain Gauze

Are based on the principle that the electrical resistance of wire or silicone increases with increasing stretch.

The flexible diagram is attached to wire or silicone strain gauges in such a way that with movement of the diaphragm the gauges are stretched or compressed, altering their resistance

Wheatstone bridge

circuit designed to measure unknown electrical resistance



Rx = R2/R1 * R3

COMPONENTS OF AN IABP MEASURING SYSTEM

Signal processor, amplifier and display

The pressure transducer relays its electrical signal via a cable to a microprocessor where it is filtered, amplified, analyzed and displayed on a screen as a waveform of pressure vs. time.

Beat to beat blood pressure can be seen and further analysis of the pressure waveform can be made, either clinically, looking at the characteristic shape of the waveform, or with more complex systems, using the shape of the waveform to calculate cardiac output and other cardiovascular parameters

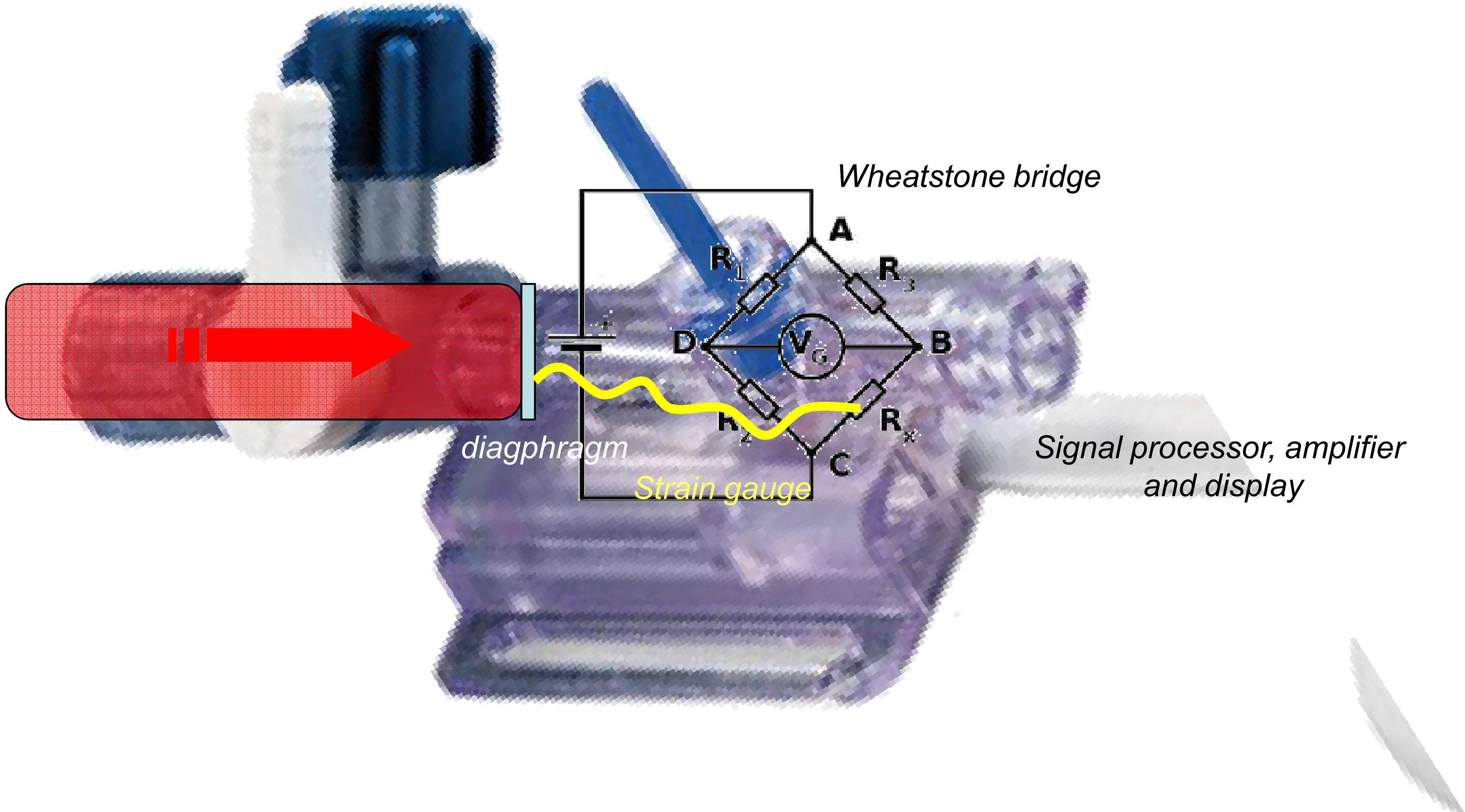
.

Infusion/flushing system

Fills the pressure tubing with fluid and helps prevent blood from clotting in catheter, by continuously flushing fluid through the system at a rate of 1-3ml/hr, by keeping a flush bag at pressure of 300mmHg.

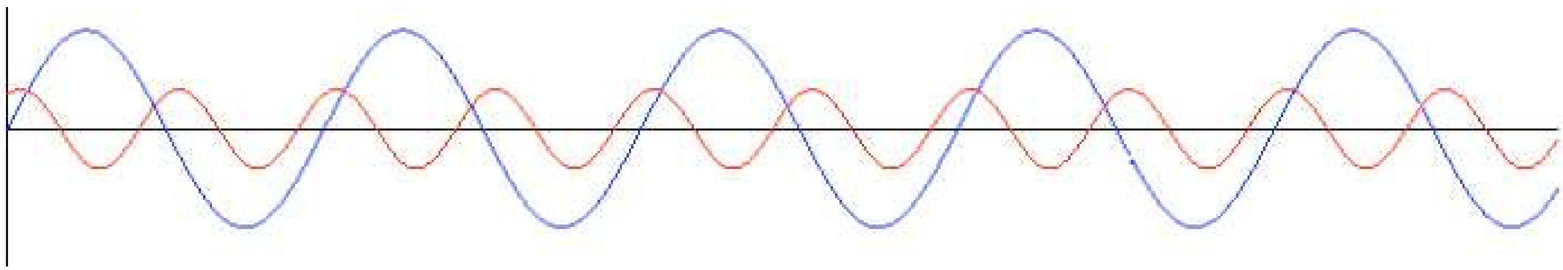
Heparinizing the flush system is not necessary

COMPONENTS OF AN IABP MEASURING SYSTEM

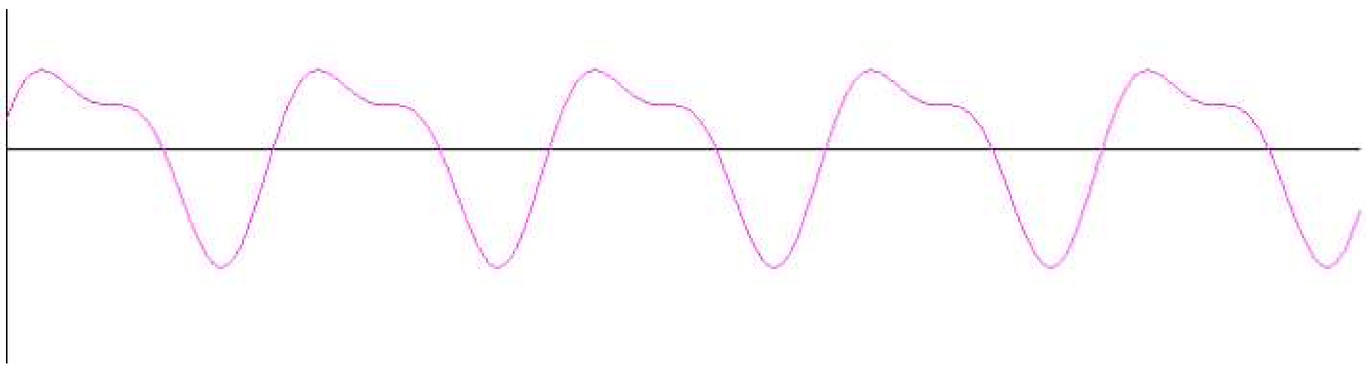


SOME TECHNICAL ASPECTS

Fourier Analysis



Two sine waves of differing frequency, amplitude and phase



sum of the two sine waves

FUNDAMENTAL FREQUENCY

The arterial pressure wave consists of a *fundamental* wave and a series of *harmonic* waves.

Harmonic waves 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 is called ***Fourier Analysis***

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 in order to represent the arterial pressure wave precisely.

This is important to remember when considering the *natural frequency* of the system

FUNDAMENTAL FREQUENCY

The arteiral pressure wave has a characteristic periodicity termed the fundamental frequency, which is equal to the pulse rate.

Although the pulse rate is reported in beats per minute, fundamental frequency is reported in cycles per second or hertz (Hz).

If the heart rate is 60 beats/min, then this equals one cycle per second (1 Hz)
So the fundamental frequency is 1 Hz.

First 10 harmonics for this this waveform would go up to 10 Hz,
so that any recording system would require a frequency response
that was undistorted up to 10 Hz to accurately reproduce the original signal.

If the heart rate were 180/min, then frequency response would need to be 20 Hz.

Therefore most of the information of arterial pressure waveform is contained
in the range of 0-20 Hz.

A properly designed measurement system should therefore produce minimal amplitude and phase distortion for this range of frequencies.

Natural Frequency & Resonance

Every material has a frequency at which it oscillates freely.
This is called its *natural frequency*.

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.*

In 1850, a suspension bridge in France collapsed when soldiers marching across it in time with the natural frequency of the bridge caused it to resonate.
The bridge began to oscillate, swinging wildly as the marching continued until eventually it collapsed.

The natural frequency of a system is determined by the properties of its components.
It may be increased by:

- Reducing the length of the cannula or tubing
- Reducing the compliance of the cannula or diaphragm
- Reducing the density of the fluid used in the tubing
- Increasing the diameter of the cannula or tubing

Most commercially available systems have a natural frequency of around 200Hz but this is reduced by the addition of three-way taps, bubbles, clots and additional lengths of tubing

Pressure monitoring system will have optimal dynamic response
if its natural frequency is as high as possible
.
In theory, this is best achieved
by using short lengths of stiff pressure tubing and
limiting the number of stopcocks
and other monitoring system appliances.

Blood clots and air bubbles trapped and concealed in
Stopcocks and other connection points will have similar adverse influences
on the system's dynamic response.

As a general rule, adding air bubbles to monitoring systems
will not improve their dynamic response
because
any increase in system damping is always accompanied by a decrease in natural frequency.
Somewhat paradoxically, monitoring system resonance may increase and cause
even greater systolic pressure overshoot

DAMPING

Anything that reduces energy in an oscillating system will reduce the amplitude of the oscillations.
This is termed *damping.*

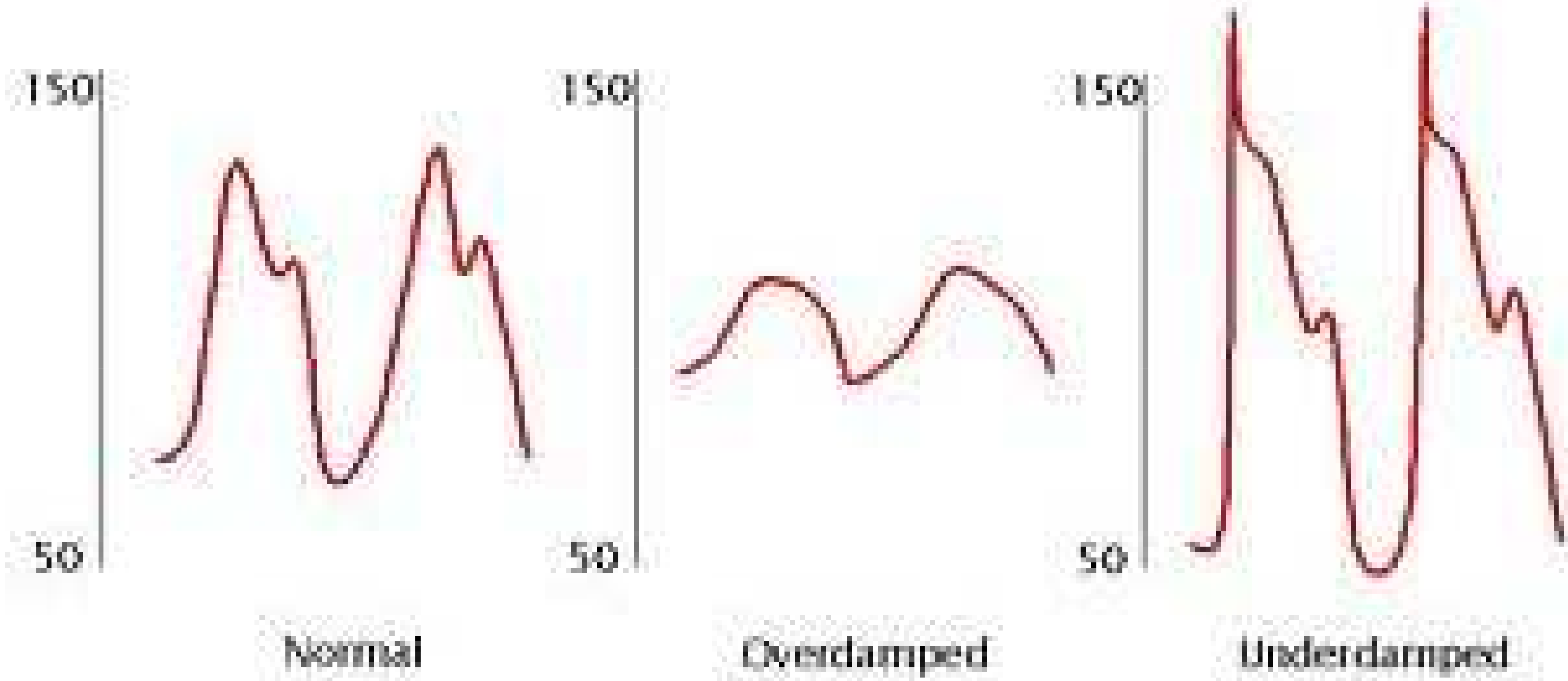
Some degree of damping is required in all systems (*critical damping*), but if excessive (overdamping) or insufficient (underdamping) the output will be adversely effected.
In an IABP measuring system, most damping is from friction in the fluid pathway.

There are however, a number of other factors that will cause overdamping including:

- Three way taps
- Bubbles and clots
- Vasospasm
- Narrow, long or compliant tubing
- Kinks in the cannula or tubing

These may be a major source of error, causing an under-reading of SBP and overreading of DBP although the mean blood pressure is relatively unaffected.

Damping also causes a reduction in the natural frequency of the system, allowing resonance and distortion of the signal.


150
50
Normal
150
50
Overdamped
150
50
Underdamped

FAST FLUSH TEST (SQUARE WAVE TEST)

Performed by opening the valve of continuous flush device such that flow through catheter- tubing system is acutely increased to 30ml/ hr from usual 1-3ml/ hr.

This generates an acute rise in pressure within the system such that a square wave is generated on bedside monitor.

With closure of valve, a sinusoidal pressure wave of a given frequency and progressively decreasing amplitude is generated.

A system with appropriate dynamic response characteristics will return to the baseline pressure waveform within one to two oscillations.

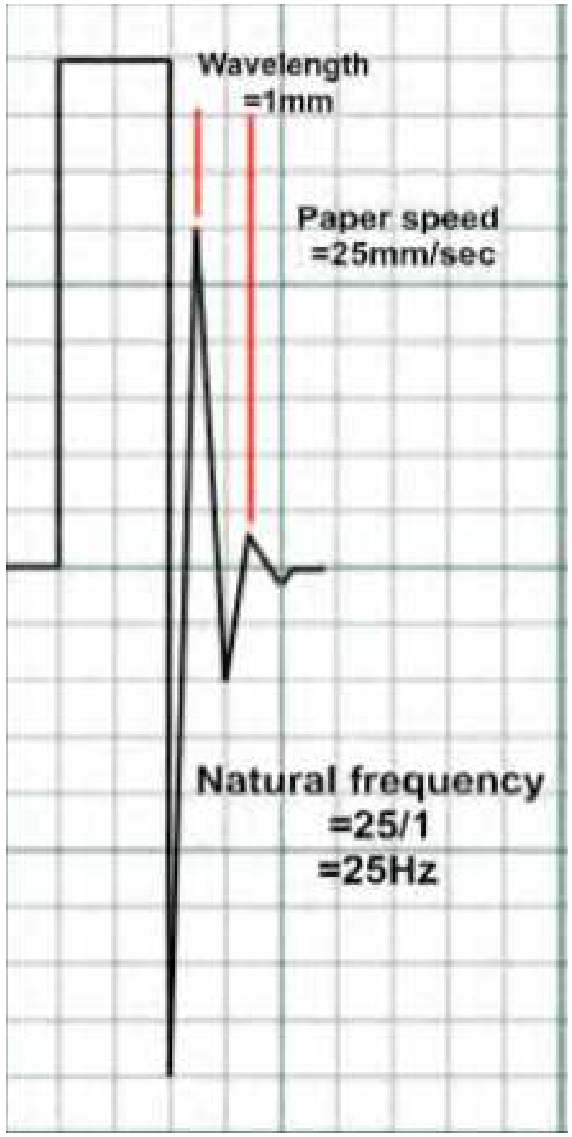
Determining natural frequency (Fn):

Fn = Paper speed (mm/sec)/ wavelength

Eg. Paper speed = 25 mm/ sec; wavelength = 1mm

Fn = 25/1 = 25Hz

FAST FLUSH TEST (SQUARE WAVE TEST)



Optimizing Natural Frequency of monitoring system

- Use wide bore, high pressure tubing no longer than 122 cm (48 in).
- Avoid tubing extensions and minimize stopcocks.
- Ensure that all connections are tightened.
- Eliminate air from the flush fluid and air bubbles from the tubing system.
- Keep continuous flush bag filled and keep external pressure cuff at 300 mmHg pressure.
- Use continuous flush device (with or without heparin) to prevent catheter clotting.
- Keep cannulated extremity in a neutral or slightly extended position to prevent catheter kinking

When to perform FAST FLUSH TEST

•Whenever the waveform seems overdamped or underdamped.

•Whenever physiological changes of the patient (increased heart rate, vasoconstriction) place higher demand on the monitoring system.

•After opening the system
•Before implementing interventions or changes of interventions.

•Whenever the accuracy of arterial blood pressure measurement is in doubt.

•At least every 8-12 hours

ZEROING AND LEVELLING

ZEROING

For a pressure transducer to read accurately, atmospheric pressure must be discounted from the pressure measurement.

This is done by exposing the transducer to atmospheric pressure and calibrating pressure reading to zero.

Note that at this point, the level of the transducer is not important.

A transducer should be zeroed several times per day to eliminate any baseline drift.

ZEROING AND LEVELLING

LEVELLING

The pressure transducer must be set at the appropriate level in relation to patient in order to measure blood pressure correctly.

This is usually taken to be level with the patient's heart, at the 4th intercostal space, in mid-axillary line (PHLEBOSTASIS AXIS)
.
Failure to do this results in an error due to hydrostatic pressure, being measured in addition to blood pressure.

This can be significant –
every 10cm error in levelling will result in a 7.4mmHg error in the pressure measured;

a transducer too low overreads, a transducer too high under reads.

THANKYOU