CARDIAC MONITORING

[Monitoring procedures required for the case of Mr Kennett [see **Cardiac pacing** module] are used as the basis for this module.]

Haemodynamic Monitoring The assessment and observation of cardiac and circulatory function

Terms you will become familiar with in the first section of the module

haemodynamics	non-invasive monitoring
Korotkoff sounds	spectrophotometry
stethoscope	electrocardiography
NIBP	perfusion pressure
pulse oximetry	tendinous cords
left atrium	bicuspid valve
right atrium	tricuspid valve
left ventricle	aortic semilunar valve
aorta	pulmonary artery
right ventricle	pulmonary veins
superior vena cava	pulmonary semilunar valve
inferior vena cava	myocardial infarction
hydraulic monitoring	real time monitoring
femoral artery	brachial artery
inter-cranial pressure	emboli
ischaemia	transducer
calibration	cannula
catheter	venepuncture
systole	diastole
dicrotic notch	damping
zero reference	cardiac output
Swan Ganz catheter	thermodilution
thermistor	

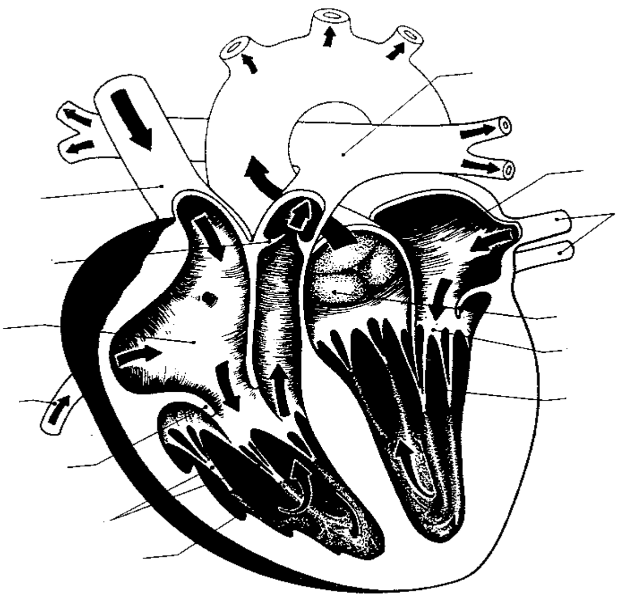
Introduction

The non-invasive assessment of blood flow [**haemodynamics**] involves clinical observation and assessment of the patient's pulse rhythm and rate, skin color, skin turgor, capillary return/refill, blood pressure, heart sounds, and conscious state amongst a variety of other clinical observations. At the simplest level, external or **non-invasive Cardiac monitoring** may involve listening to sounds [**Korotkoff sounds]** as the heart pumps using a **stethoscope**. Non-invasive blood pressure monitoring [**NIBP**] relies on the clinical skill of the operator and adequate **perfusion pressure** to create the sounds. In states of low blood pressure, this form of measurement becomes inaccurate and unreliable because audible sound generation diminishes because of low blood flow rates through the artery. Other disadvantages of the technique are that more frequent measurements require more direct contact with the patient and therefore are more time consuming.

Electronic listening devices, electrical impulse receivers [**electrocardiography**] and **spectrophotometry** [**pulse oximetry**] help to overcome some of these problems and offer alarm settings for blood pressure parameters.

Activity

Using the diagram of the heart below, label each part named in the key



left atrium	bicuspid valve
right atrium	tricuspid valve
left ventricle	aortic semilunar valve
aorta	pulmonary artery
right ventricle	tendinous cords
superior vena cava	pulmonary veins
inferior vena cava	pulmonary semilunar valve

Using the activity you completed in the **Cardiac Pacing** module, revise the regions in which cardiac pacing cells are active, the extent to which each is effective and the impact of a **myocardial infarction** on their ability to 'keep the heart beating'.

Using the diagram above,identify and label the positions of the AV node and the sinus node.

Invasive pressure monitoring

Hydraulic monitoring system: The use of a fluid filled system to relay pressures via an electrical circuit to an oscilloscope and display its corresponding wave/digital value calibrated to mmHg.

The system requires the insertion of a **cannula** [intra-venous [IV] catheter] into the client's blood vessel [artery or central vein depending on the type of pressure to be monitored]. The catheter is then connected to a length of fluid filled length tubing and a transducer system.

The transducer component converts the pressure wave transmitted along the tubing into an electrical signal, which is displayed numerically or as a waveform on an oscilloscope. The system allows **real time monitoring** of blood pressure across a large range of pressures. The system when assembled, **calibrated** and **zeroed** correctly is an extremely accurate and reliable form of haemodynamic monitoring.

Common sites for cannulation include:

Arterial pressure monitoring : radial, femoral, brachial and pulmonary arteries
Venous pressure monitoring : Right atrial or vena cava [central venous]
Other sites for pressure monitoring include : intra-cranial [within the skull] or intra-abdominal for measurement of abdominal pressure.

The advantages of invasive monitoring systems include: accuracy, continuous visual signal, alarm features and the potential for frequent blood sampling from the catheter without frequent venepuncture of the client.

The disadvantages of invasive monitoring systems include: increased risk of infection, **emboli**, **ischaemia** or bleeding. If the system is not used appropriately and/or the clinician is unfamiliar with its operative requirements, incorrect readings may lead to inappropriate treatment.

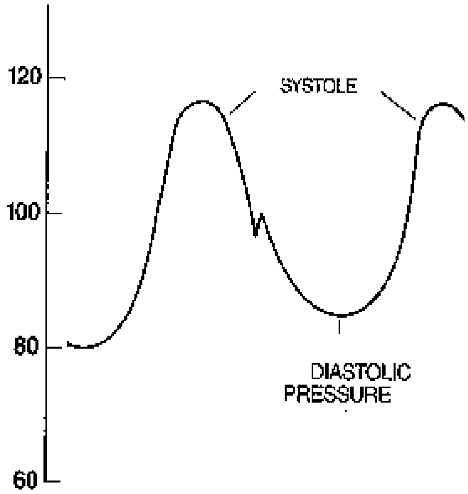
Transducer calibration

For each change in pressure measured, the monitored or displayed value should equal the actual applied pressure. This means that for a 100 mmHg applied pressure to the transducer, the monitor displays a 100 mmHg pressure wave and numerical value of 100 mmHg. Under normal conditions, the transducer and monitor are calibrated together. Drifting can occur with extended use, lack of routine maintenance and/or mistreatment of equipment.

Occasionally monitors and transducers require re-calibration to correct inaccurate display values. Incorrect calibration may result in inapropriate treatment or a failure to recognise changes or deterioration in client status.

Arterial Pressure Waveform

The diagram below [see fig 1] shows the normal arterial presssure wave generated by cardiac contraction measured in the radial artery and displayed on an oscilloscope. The initial rise to the **systolic peak** represents cardiac ventricular contraction, whilst the **diastolic pressure** represents the phase of ventricular relaxation and filling prior to the next systole. The **dicrotic notch** is associated with the closure of the valve betweeen the aorta and the left ventricle at the end of systole.It is important to understand the normal arterial waveform appearance as problem recognition, troubleshooting and treatment are based on the waveform and its associated pressure values.



Questions

What would you expect to happen to the shape and height of the waveform if the catheter and transducer system were partially blocked or kinked?

Would this influence the pressure readings displayed? How?

This phenomenom is known as **damping** and is characterised by loss of the systolic peak and dicrotic notch, elevation of the baseline diastolic pressure but little alteration to the mean pressure. It may be caused by clots, kinking, air bubbles or leaks in the transducer tubing system.

Activities

Using your available reference sources and discussion with intensive care or coronary care clinical staff, find answers to the following questions:

- Why do air bubbles affect the transmission of the pressure waves through the tubing system?
- Does the type of tubing used in this system have an effect on the accuracy of the pressure readings? ie compliant [elastic] or non–compliant [inelastic] tubing.
- What is the difference between 'Calibration' and 'Zeroing'?
- What is important about correct calibration with reference to displayed values on the oscilloscope?

When using hydraulic pressure transducer systems it is essential to regularly **zero reference** the transducer to atmospheric pressure. This process establishes a baseline pressure to which all other measured pressures are referenced. The **zeroing** process involves exposing the transducer membrane to air and referencing the oscilloscope to the measured air pressure. If this baseline pressure is not established, no other pressures measured by that transducer will be able to reflect the actual patient blood pressure.

Cardiac Output Studies

Cardiac output refers to the rate at which blood is pumped around the body by the left ventricle.

Cardiac output [the rate of blood flow around the body] measures the performance of the heart and the supply of blood to the body tissues. Cardiac output is commonly measured with the use of a pulmonary artery [or **Swan-Ganz catheter]** with **thermodilution cardiac output** capabilities. This catheter is inserted into the pulmonary artery via the right atrium [RA] and right ventricle. Located at the tip of the catheter is a **thermistor** which constantly measures blood temperature. When a cold solution is injected into the blood via a hole in the catheter located in the RA, it cools the blood temporarily and as it flows past the tip of the catheter, the thermistor registers this change and creates a graph representing the blood temperature change over time [

Errors in measurement commonly relate to the rate of fluid injection [or the rate of change in temperature of the blood detected by the thermistor as a result of slow injection of fluid] or by large oscillations in the baseline temperature of the blood.

Question

Why would oscillations in baseline temperature affect the measurement?
What factors might affect blood temperature or cause blood temperature to vary?
Consider the location of the pulmonary arteries in relation to the lungs and the positioning of the PA catheter thermometer. Refer to your resource texts for descriptions of the pulmonary anatomy and pulmonary artery catheters. One factor to consider is the effect of air temperature on temperature in the lungs.

Temperature change can only be determined if there is a stable baseline temperature from which to calculate the temperature difference. If the baseline temperature varies considerably [over a range of +/- 0.5^{o}C], the calculation of temperature change cannot be reliably established.

Electrocardiography and ECG monitoring

Electrocardiography: The recording of small electrical voltages generated by the contraction of the heart using a **biopotential amplifier** and paper recorder.

Telemetry: the distance [remote] monitoring of cardiac activity

Haemodynamic Monitoring: The assessment and observation of cardiac and circulatory function

Terms you will become familiar with in the second section of the module

electrocardiography	biopotential amplifier
telemetry	galvanometer
continuous ecg	12 lead ecg
defibrillator	depolarisation
repolarisation	PQRST waves
ECG paper	oscilloscope
AC interference	AC filter
arrhythmia	

Equipment which is ***emphasised***, **referred to or used** in this section of the module includes:

- **Non-Invasive Blood Pressure monitors [NIBP]**
- ***Continuous Electrocardiography [ECG]***
- ***12 Lead Electrocardiography***
- **Telemetry**
- **Cardiac Output Computers**
- ***Defibrillators***

[Many of these are integrated into one device. Some are available as stand-alone monitors]

- **Invasive Pressure Monitors**
  - **intercranial**
  - **pulmonary artery catheter lines**
  - **central venous catheter lines**
  - **Swan-Ganz catheter**

Using the Client Checklist

The Client?

The Client profile is highly variable. More likely to be male than female, middle-aged to elderly. More likely to be caucasian. More likely to be overweight. May be involved in high stress occupation, may be well educated. May be distressed but likely to be familiar with the possibilities of their heart condition.

The referring medical principals?

Likely to be cardiology specialists or registrars

The primary care-givers?

likely to be medical centre nursing staff

What might the Client want to know?

The procedures are not dangerous and do not involve any intrusion. They are a passive measure of what the heart is doing and how well it is doing it. Brief outline of physiology and purpose of ecg.
Description of what you are doing as you apply electrodes, purpose of conductant gel.
Explanation of graph sheet as record of heart's electrical activity.

What does the Client need to know?

That rest and relaxation will assist recovery.
That a full health care team is involved in supporting them and that you are a specialised member of that team.

What do the family and friends need to know?

As for Client.
Need to be advised not to talk with patient during specific monitoring procedures

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A calm, confident approach will reassure the clients, their immediate support base of family and friends - and the rest of the health care team - that you are an essential part of the client's treatment.

Anatomy/Physiology

The only function of the heart is to pump blood through the lungs [[pulmonary circulation] for re-oxygenation and carbon dioxide excretion and then around the body [systemic circulation] to deliver oxygen and collect carbon dioxide.

The reason the healthy heart keeps pumping day in and day out is because of its ability to self stimulate, to contract [therefore pump] and relax [therefore fill up again] with amazing regularity. To create the contractions, the heart has its own electrical generator and conducting system.

The Electrocardiograph is a recording of the electrical activity of the heart's generator and a tracking of electrical impulses along the conduction system in the heart. The electrical impulse stimulates the contraction of the heart muscle forcing blood out of the heart and around the body. When the impulse ends, the heart muscle relaxes.

The electrical activity of the heart is displayed in graphical form as the PQRST waves on continuous rolls of graph paper or using an oscilloscope screen as a display monitor. The speed of the graph paper and the scales used must be calibrated for the output to be interpreted.

The PQRST complexes seen on the ECG [see fig 3] relate to the **depolarisation** and **repolarisation** of cardiac muscle tissue. The letters themselves refer to the phases of cardiac depolarisation and repolarisation. The P wave is produced by **atrial depolarisation**, QRS waves by **ventricular depolarisation** and the T wave by **ventricular repolarisation**. Contraction of muscle tissue follows as a result of and therefore fractionally after electrical depolarisation.

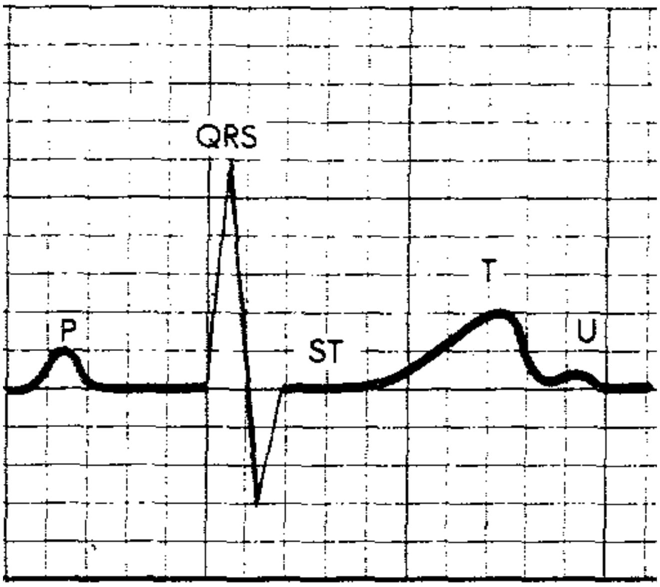


fig 3 Basic ECG graph

The monitor

In monitoring the ECG some important factors determine the ability of the monitor to display and interpret information. These are:

the actual size of the ECG complexes displayed on the monitor
the rate at which the screen 'refreshes' or the sweep speed of the oscilloscope
whether arrhythmia analysis has been activated
alarm parameter settings and alarm response
ECG interference in the form of AC interference [commmonly at 60 Hz in Australia], muscle tremor or patient movement and electrode contact problems.

The ECG size affects the ability of the monitor to detect the QRST complex and therefore determine and display the heart rate. If the heart rate [and rhythm] cannot be identified then alarm functions become inefffective. This problem is easily rectified by maximising the QRS size until detection is possible.

Question

Occasionally, by increasing ECG size the T wave size approximates the QRS size resulting in both waves exceeding the threshold for QRST detection.

What would the displayed heart rate be? Half, four times or twice the the actual heart rate?

Threshold detection refers to the minimum QRST size before the monitor will recognise the complexes as QRST waves. This threshold may be altered manually or set to automatic on some monitors. Threshold does not refer to ECG size but to the minimum millivolt amplitude of deflection on the monitor that results in detection of the QRS complexes.

Question

Consider Mr Kennet's situation after the placement of the pacing wire

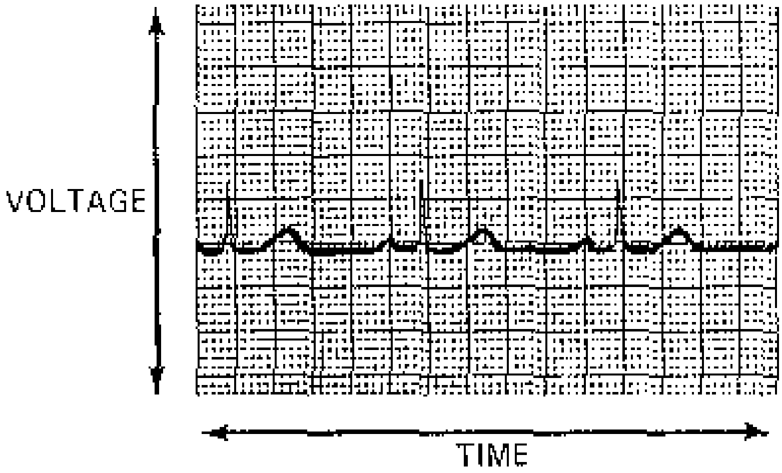
What might happen in the case of a pacemaker spike appearing on the ECG? Could the monitor inappropriately detect pacing spikes as the QRS wave? What effect would this have on calculation of rate and rhythm?

If the pacing spike exceeds the threshold level on the monitor, it can be mistakenly interpreted as a QRS wave and included in rate and rhythm determination. The only way to eliminate this problem is to manually adjust the detection sensitivity for QRS complexes so that the threshold exceeds the amplitude of the pacing artefact, but is less than the QRS amplitude.

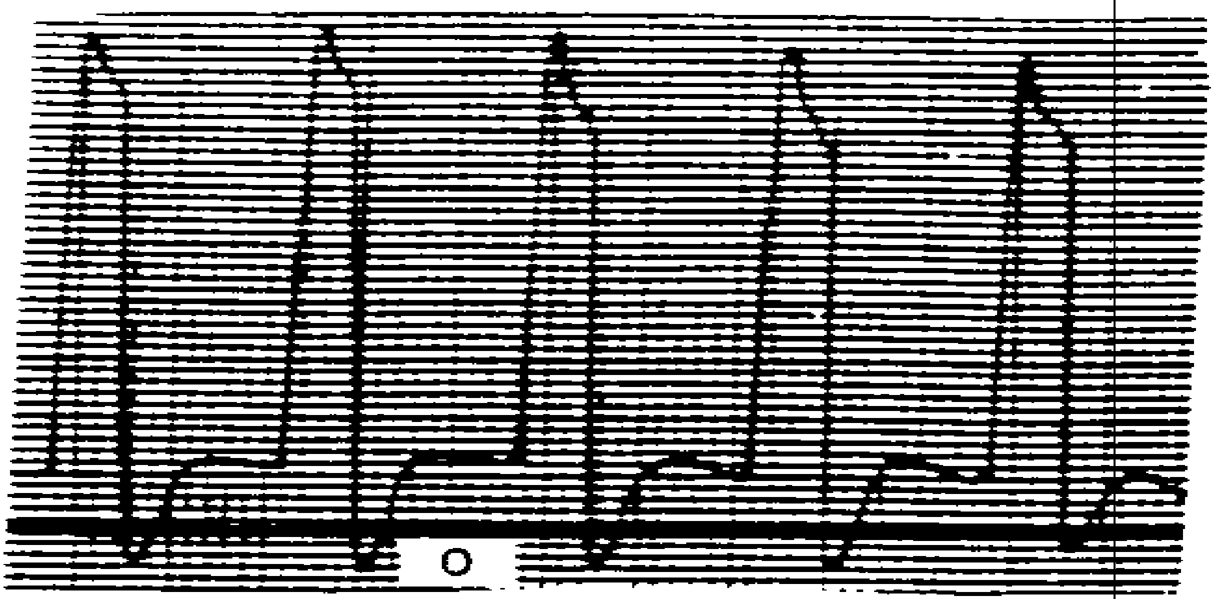
ECG paper

Printout of ECG recording is useful as a form history and event documentation but also for reliable rhythm interpretation. ECG paper is formatted into millimeter and centimeter intervals. The purpose of this is to enable time and voltage estimates to be made in relation to the PQRST waves. Each phase of cardiac depolarisation has a normal duration [in milliseconds] and amplitude. Determination of normal duration and amplitude is essential for ryhthm interpretation. Abnormal variation in duration or amplitude of the various segments of the PQRST relate to anatomical and physiological abnomalities of cardiac conduction. This may represent deterioration or improvement in patient condition or the presence of a potentially lethal cardiac rhythm.

The vertical axis represents voltage [mV] and the horizontal axis time in seconds [mSec]. At a paper speed of 25 mm/sec each 1 mm square represents 0.04 seconds along the horizontal axis [see fig 4]. Each 1 cm represents 0.4 sec. Rate calculation is performed by counting the number of PQRST complexes within a specified time frame. As long as the paper print speed is constant, a predetermined rate calculation is possible. The international standard for print and oscilloscope speed is 25 mm/sec.



Questions

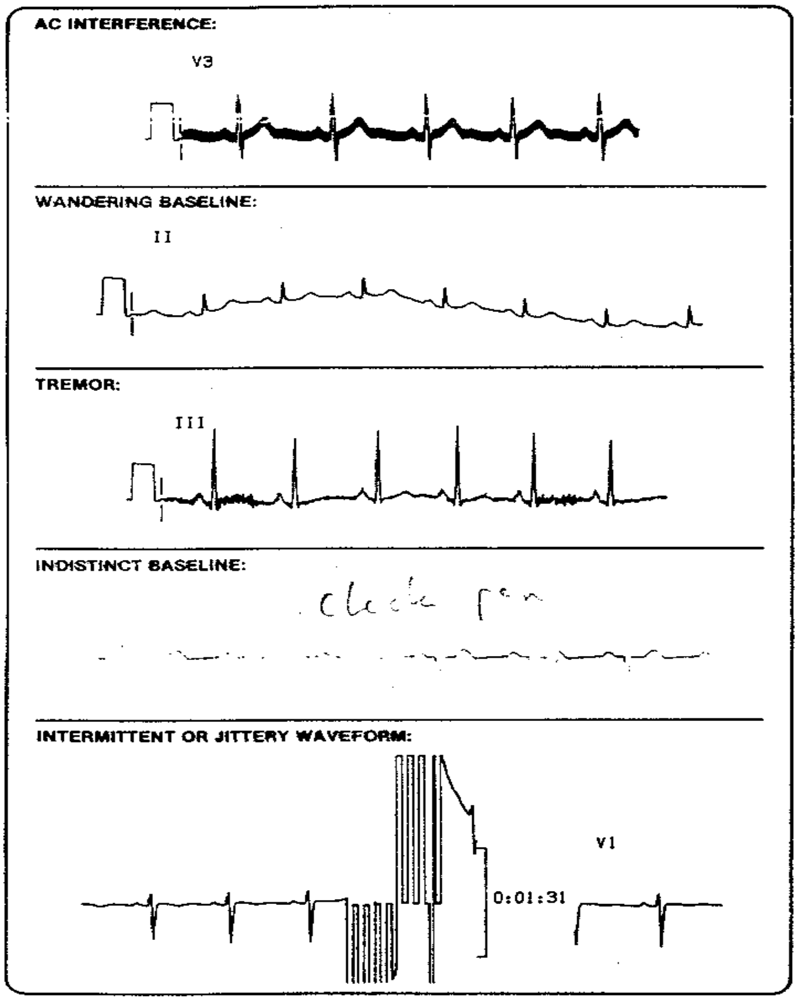


Use the ecg shown above to calculate:
Heart rate in beats per minute.
voltage delivered at systole.
voltage delivered at diastole.
Suggest why the dicrotic notch.

Trouble shooting

The most common problems associated with ECG monitoring relate to AC [alternating current] interference, patient movement and ECG detection.

AC interference is best resolved by removing the interfering electrical equipment but this is not always possible. Selecting the **filter** option on the oscilloscope ECG parameter will usually reduce interference.



Patient movement is difficult to control but locating electrodes centrally on the torso can reduce some of the movement related effects.

If rate detection and ECG acquisition are difficult, it is possible to use the arterial pressure waveform [if arterial pressure is being monitored] as the source for rate detection. This, of course, requires an adequate arterial pulse pressure. Rate detection is possible but not arrhythmia analysis.

REFERENCES

Conover M. B. 1996. **Understanding Electrocardiography**. [7th edn.] Mosby: St.Louis

Darovic, G. O., 1995. **Haemodynamic Monitoring: Invasive and Noninvasive Clinical Application** [2nd Edn.]. Saunders: Pennsylvania.