10 Specialist Monitoring Technology and Skills for the Critically Ill Woman

*Nick Rowe and Mandy Stevenson**

Caring for women whose condition is at risk of deteriorating often requires midwives to use their clinical skills in conjunction with medical technology. Knowledge and understanding of specialist monitoring technology and equipment will assist midwives in providing care for critically ill women as well as enabling them to recognise if the situation starts to deteriorate.

This chapter will explain the principles and practice surrounding the following methods of invasive and non-invasive monitoring which may be appropriate when caring for critically ill women in childbearing:

- Oxygen saturation
- Electrocardiogram (ECG)
- Non-invasive blood pressure
- Venous cannulation
- Arterial cannulation
- Central venous cannulation
- Pulmonary artery wedge pressure

Assumed prior knowledge

- Physiology of the cardiovascular and respiratory systems
- Physiological changes of the cardiovascular and respiratory systems in pregnancy

* With grateful thanks to Barbara Warncken for her valuable input on ECG interpretation.

Introduction

During any phase of critical illness, a range of diagnostic and therapeutic procedures will be required. It is therefore vital that baseline observations are known and viewed in the context of the medical setting. This takes into account all dimensions of physiology and wellbeing, not only those that are directly related to the condition being investigated. Once we have established what might be deemed as 'normal' for an individual, we are able to detect any deviation from the baseline figures.

The primary tool used in monitoring is direct observation. All members of staff within a department possess diagnostic skills to some degree. In dealing with people on a day-to-day basis, we have a natural acumen to detect when something is 'not right' with somebody. Someone who has fallen or who is having difficulty breathing is often noticed by non-medical people who react by getting help. With training and experience, we refine this diagnostic process so that we might pinpoint the cause of the trouble and facilitate prompt action to be taken. Whilst the application of specialist skills and technology can help us to reach diagnoses, it is vital that we do not disregard the skill of direct observation once we apply the available equipment. Despite the technology involved, we still must have knowledge of both patient and machine in order to detect any changes from the 'norm'. All too often in the investigation of incidents, patients attached to monitors have been found to have nobody watching them. The assumption is that simply because a piece of equipment has an alarm fitted, the woman 'should be alright'; this can often lead to complacency on the part of the carer, especially when a unit is busy or understaffed. In light of this, all staff should be equipped with the skills to use those items of equipment commonly used in their department. It must be acknowledged, however, that human error does occur, and in light of this, no culture should make a member of staff feel that it would look ill upon them to seek help or advice when they find themselves in an unknown situation. After all, when the monitor alarm sounds, it is performing exactly that function – drawing attention to something and summoning assistance.

Oxygen saturation: pulse oximetry

Pulse oximetry was introduced in 1976 as a non-invasive method of monitoring the arterial oxygen saturation (SpO_2) of blood. Originally measuring through the ear lobe, the eight wavelength Hewlett Packard ear oximeter eliminated both the need to draw regular blood samples and the expense of pathology analysis. In the early 1980s, technology advanced to enable the units to become more affordable, smaller in size and easier to use.

Technology

- Light-emitting diodes (LEDs) emit light at two wavelengths (visible red, 660 nm, and infrared, 940 nm). These flash every 30 seconds and are picked up by a

photodetector on the opposite side of the clip or probe. A pause in the sequence, during which both LEDs are off, allows ambient light levels to be taken into account. Reflective measurement technology is available for measurement on more proximal anatomy as it uses a single-sided contact.

- The light is transmitted through the pulsatile tissue bed. Only the pulsatile flow is registered, with the non-pulsatile flow that results from venous and capillary flow and the absorption of light by the tissues being ignored. This results from the pulsatile tissues having a non-constant light absorption, whereas the absorption of the non-pulsatile flow is constant.
- The two (or more) light sources are absorbed at different levels dependent upon the oxygenation levels of the haemoglobin present in the arterial blood. One molecule of haemoglobin can carry up to four oxygen molecules. This would register as 100% saturated.
- The average percentage saturation (taken from the total molecules sampled) is processed by the microprocessor every 5–20 seconds and thus gives a saturation reading, expressed as a digital percentage figure.
- The heart rate is measured by averaging the number of emitted LED signals between successive pulsatile signals and an average taken in the same manner as the SaO_2 reading.

Use: performing pulse oximetry

Pulse oximetry can accurately determine SaO_2 in a range of 70–100% (± 2%). Below 70%, readings are extrapolated as the data for calibration were obtained from human volunteers and it was viewed as being unethical to test below this level. Once readings drop below 90%, the shape of the oxyhaemoglobin curve causes saturations to fall rapidly. Due to the time taken by the unit to average its readings, however, it will not measure acute desaturation. Women should have their oxygen therapy aimed at a maintenance level of > 95% to ensure effective oxygen perfusion of the tissues. Pulse oximetry will also provide a pulse rate. However, it has no function in the measurement of carbon dioxide and is therefore unable to provide information relating to ventilation (Fearnley 1995); breathing may stop prior to desaturation occurring.

- Units should be plugged into the mains when possible and have battery back-up.
- Each unit should perform a self-test when turned on. Ensure your unit is functioning correctly. Settings and alarm parameters should be checked. Never turn off an alarm simply because it is making a noise. Look to establish the cause.
- Probes or ear pieces should be fitted according to manufacturers' instructions. Normally, finger probes will measure 'top to bottom' through the finger tip. Ensure the area is clean and preferably free of nail varnish. If false nails are present, use an ear probe or rotate the finger probe 90° to measure 'side to side'. Do not cause pressure damage or reading impairment by applying force. Do not tape probes to extremities unless they are specifically designed for the purpose. If monitoring is intended to be long term, move the probe on a

regular basis to prevent pressure damage or burns, which have previously been reported.
- Ensure the unit displays a waveform in addition to providing a saturation figure. Without this, the figure cannot be trusted. Measurements have been observed from inanimate objects such as drip stands and bedside lockers in the past, when someone has 'parked' the probe for a moment whilst doing something else!
- Record the readings immediately. If possible, ensure that a printout accompanies the record sheet to verify any measurements taken.
- As in the use of all monitors, if there is a suspected discrepancy between the patient's clinical condition and those figures displayed by the unit, then you should trust clinical judgement rather than technology.

Complications

In any situation, check the woman first!

If no reading is obtained, check the unit is properly connected and that the probe is correctly positioned. Most units will show that no signal is being detected in the event of set-up problems.

Low readings can be caused by a variety of factors. Peripheral vasoconstriction can reduce pulsatile blood flow and so produce an inadequate signal. Venous congestion, high airway pressures and forced pressures such as the Valsalva manoeuvre during childbirth might cause venous pulsation, which can have a similar effect. Shivering will also cause signal interruption. Women with methaemoglobin presence will not show accurate readings, with the Sao_2 showing approximately 85%. High ambient light levels and the presence of false nails or nail varnish can also cause a falsely low reading (Pedersen et al. 2004).

False high readings can be obtained when haemoglobin is combined with carbon monoxide (CoHb or carboxyhaemoglobin). This is picked up as being 90% oxygenated haemoglobin and 10% desaturated haemoglobin, and as such, any readings are overestimated.

Electrocardiograms

An electrocardiogram (ECG) is a graph of the electrical activity of the heart. It is therefore a two-dimensional picture of something that occurs in three dimensions. In order to show a clearer picture of electrical activity, views are taken from a variety of places or leads. The same activity will therefore give a different picture from different leads. Electrical activity of the heart is recorded on the graph as movement away from the isoelectric line. An upward movement from the isoelectric line is called a positive deflection. A downward movement from the isoelectric line is known as a negative deflection.

As the ECG is attached to the body by electrodes, it will record any electrical activity inside (and sometimes outside) the body. All body muscles move by electrical impulses and activity; as a consequence if the woman makes any

movement or shivers there will be resultant non-cardiac muscle movement. This will be recorded on the ECG as a jagged line and is known as an artefact. An artefact is anything appearing on the ECG trace that is not cardiac in origin.

Related cardiac physiology

To enable a practitioner to appreciate the relevance of ECG recording, an understanding of the related cardiac physiology is required. A brief overview of such physiology follows.

The cardiac cycle is divided into three main phases (Tortora & Derrickson 2005):

- Ventricular diastole (relaxation)
- Ventricular filling
- Ventricular systole (contraction)

For ease of reference the left side of the heart will be explained:

- *Ventricular diastole (relaxation).* This follows ventricular systole (contraction). The ventricles relax, resulting in pressure within the left ventricle falling below that of the aorta and thus the aortic valve closes and all valves within the heart are now closed (Tortora & Derrickson 2005). Simultaneously, blood is passively flowing into the left atrium via the pulmonary system. As the pressure and volume within the left atrium increases, the mitral valve opens and the second phase of the cardiac cycle begins.
- *Ventricular filling*. Ventricular filling has three phases (Tortora & Derrickson 2005). The first is referred to as rapid ventricular filling and involves passive filling of the left ventricle from the left atrium. The second stage of ventricular filling is known as diastasis and refers to slow ventricular filling. At the end of diastasis, the pressures in the left atrium and ventricle are now equal. The third stage of ventricular filling is due to the contraction of the atrium, with blood being forced into the left ventricle.
- *Ventricular systole (contraction).* As the left ventricle starts to contract, the mitral valve closes. The left ventricle is now a closed chamber. The muscles within the left ventricle begin to contract with an increasing resultant pressure. Once the pressure in the left ventricle is greater than that of the aorta, the aortic valve opens and blood is ejected out (known as the stroke volume). As pressure in the left ventricle falls with the expulsion of the blood, the aortic valve closes and the cardiac cycle begins again.

Electrical conduction system

The electrical conduction system consists of the sinoatrial (SA) node, the internodal pathways, the atrioventrical (AV) node, the bundle of His, the right bundle branch and the left bundle branch and its anterior and posterior divisions and the Purkinje fibres. All are necessary to initiate and continue rhythmic contraction of the heart.

Notable physiological adaptations in pregnancy

Pregnancy is characterised as a hyperdynamic (high flow), low resistance state. This occurs through an adaptive response in blood volume, cardiac structure, cardiac output, vascular resistance and heart rate. Other than blood volume changes, cardiac structural changes may occur that may affect the recording and interpretation of subsequent ECG recordings.

- The heart is displaced to the left and upwards and rotates anteriorly.
- There are no characteristic ECG changes (except left axis deviation may be seen).
- Left axis deviation may occur because of mechanical displacement.
- Cardiac volume increases slightly because of increased circulating volume and hypertrophy.

Cardiac ausculatory changes include the following (Thelan et al. 1998):

- Physiological S1 (first heart sound) split
- S3 (third heart sound) development is considered normal
- Systolic murmurs develop in 90% of all pregnant women
- Diastolic murmurs develop in 20% of all pregnant women
- Murmurs are physiological in nature and disappear after delivery

Use: performing an ECG

The basic three-lead ECG consists of three electrodes on bipolar leads, placed on the right shoulder (red), left shoulder (yellow) and the left lateral chest wall (black/green), in line with the apex of the heart. These detect impulses between a sensing point and a reference point, so triangulating across the heart using paths labelled as I, II and III. Used in routine cardiac monitoring, the three-lead ECG is standard on many defibrillators. Higher levels of information can be obtained by adding further unipolar leads to create a 12-lead ECG. This is more appropriate for the screening of high risk patients, and in reaching diagnoses in those with suspected or proven cardiac anomalies. All clinical staff should be comfortable in recognising the components of sinus rhythm (Lee 2000). Further to this, staff should be able to detect increases or decreases in normal heart rate, together with common rhythms that require emergency treatment. All hospital staff should have formal training in hospital basic life support, with clinical staff trained to immediate life support level. In addition, advanced life support (ALS) providers must be available to respond to any emergency situation.

How to undertake a 12-lead ECG

- Place the 10 electrodes onto the patient. While each of the six chest electrodes record one lead each, the three limb electrodes record six different views of cardiac electrical activity.
- Limb electrodes are colour coded to aid correct placement: right arm is red, left arm is yellow and left leg is green. When recording a 12-lead ECG the fourth limb electrode (black) is placed on the right leg.

- Lead I represents electrical activity from the right arm to the left arm.
- Lead II represents electrical activity from the right arm to the left leg. The bundle of His follows the main vector of electrical activity in the heart: the SA node to the AV node and down the bundle of His. This lead is the standard lead for understanding the principles of ECGs.
- Lead III represents electrical activity from the left arm to the left leg.
- The picture of electrical activity in the heart remains constant at any point in the limb (Woodrow 1998). An electrode placed on the right wrist will show the same waveform as one placed on the right elbow or shoulder.
- Leads AVR, AVL and AVF are known as unipolar leads. They read electrical impulses from one electrode, with the ECG machine calculating the effect of the other limb leads to give an average reading between the points of the triangle formed by the bipolar leads.

Components of a normal ECG

The ECG complex is made up of a sequence of electrical events occurring within the heart. As the atria depolarise, the P-wave is created, and because impulses spread from muscle fibre to muscle fibre, rather than through specialized conduction tissue, conduction is relatively slow in relation to the muscle mass of the atria. This makes a normal P-wave appear broad in relation to its height. A normal P-wave lasts 0.08 seconds (2 small squares wide on the ECG) (Marieb 2003).

The AV node filters and holds the atrial impulse to allow significant ventricular filling time prior to contraction. This is represented as a straight line (isoelectric line) on the ECG and is measured on the ECG by the distance from the start of the P-wave to the start of the R-wave, called the PR interval. The PR interval will normally last between 0.12 and 0.2 seconds (3–5 small squares) (Aehlert 2002).

The Q-wave, a negative deflection, is not always seen on ECGs; however its absence does not usually indicate a problem. A normal Q-wave (less than 1 small square wide) is caused by electrical activity moving across the muscle fibres of the septum (depolarisation).

The direction of the impulse travelling along the bundle of His is similar to that of lead II so the deflection is strongly positive; however, towards the end, the Purkinje fibres allow conduction to spread rapidly throughout the ventricular mass causing a final negative deflection of the RS line below the isoelectric line. The S-wave completes the electrical impulses through the muscle (Woodrow 1998). A normal QRS width lasts 0.12 seconds (within 3 small squares) (Aehlert 2002).

This illustrates the speed of ventricular impulses and allows coordinated contraction of the large ventricular muscle mass, ensuring an effective stroke volume (felt by the pulse). After the S-wave the ECG should return to the isoelectric line.

Repolarisation is represented by the T-wave; a normal T-wave should be positive and separated from the S-wave by a return to the isoelectric line. A normal T-wave lasts 0.16 seconds (4 small squares) (Marieb 1995). If the ST segment appears raised or depressed from the isoelectric line there is a problem with depolarisation, commonly due to infarction, ischaemia or abnormal potassium (or other electrolyte) levels.

Basic rhythm recognition

To analyse accurately cardiac activity, a 12-lead ECG is required. A rhythm strip shows only one view of the heart, which is dependent on the electrode positioning and, as such, myocardial stress or damage can be missed.

ECG tracings are standardised. Most ECG machines are set to pass paper through at 25 mm/s. As graph paper is standardised, one small square represents 0.04 seconds (1 mm of paper), one large square represents 0.2 seconds (5 mm of paper) and five large squares represent 1 second (25 mm of paper) (Schamroth 1990). Once the 12-lead ECG is obtained it is necessary to review each lead individually, examining each waveform to ensure any changes/abnormalities are recognised.

The application of a systematic framework will assist the health care professional in interpreting the ECG recording (Resuscitation Council UK 2005).

Is there any electrical activity?

If no electrical activity is identified, obviously the woman requires checking to ensure that there is no acute change in her condition; the gain control, ECG leads and electrical connections must be checked to ensure position and connection. A completely straight line usually demonstrates that a monitoring lead has become disconnected, because atrial and ventricular asystole usually coexist and this line is not usually completely straight as it becomes distorted by baseline drift, electrical interference, respiratory movement or resuscitation attempts. However, atrial activity (P-waves) may continue for a limited time after the onset of ventricular asystole. This P-wave asystole may respond to pacing.

If electrical activity is present, the activity should be examined for any recognisable complexes. If there are no recognisable complexes then the likely diagnosis is ventricular fibrillation – either coarse or fine, dependent on the amplitude of the complexes. If electrical activity is present and there are recognisable complexes then the following five questions should be applied in turn.

What is the ventricular rate?

The fastest approach to determine ventricular rate is to count the number of large (5 mm) squares between two consecutive QRS complexes and divide this number into 300; e.g. if there are four large squares between adjacent QRS complexes the rate is $300/4 = 75$ per minute (Antunes et al. 1994).

Two alternative approaches are:

- To count the number of QRS complexes in a defined number of seconds and calculate the rate per minute. This approach can be useful if the rhythm is irregular; e.g. if 15 QRS complexes occur in 50 large squares (10 seconds) the rate is $15 \times 6 = 90$ per minute.
- Count the number of small (1 mm) squares between two consecutive QRS complexes and divide this number into 1500; e.g. if there are 15 small squares between adjacent QRS complexes the rate is $1500/15 = 100$ per minute.

Is the rhythm regular or irregular?

This requires careful comparison of an adequate length of rhythm strip, as the faster the heart rate the beat-to-beat variation of irregular rhythms become less pronounced. Careful comparison of the R-R intervals of adjacent beats at different places in the recording will allow the detection of an irregular rhythm. Another option is to mark on a piece of paper two adjacent identical points in the cardiac cycle (e.g. the tips of the R-waves) and this paper can then moved along to another section of the rhythm strip. If the QRS rhythm is irregular, is it totally irregular with no recognisable pattern of R-R interval or is there a cyclical variation in the R-R intervals? A basic regular rhythm can become irregular by the occurrence of extra systoles (ectopic beats). Extra systoles can arise from any part within the heart and the position from which they arise will determine their morphology.

Is the QRS complex width normal or prolonged?

The normal upper limit for the QRS interval is 0.12 seconds (3 small squares). If the QRS width is less than this the rhythm originates from above the bifurcation of the bundle of His and may be from the sinoatrial node, atria or any part of the atrioventricular junction but not from the ventricular myocardium. If the QRS duration is 0.12 seconds or more the rhythm may be arising in the ventricular myocardium or may be a supraventricular rhythm with an aberrant conduction (Resuscitation Council UK 2005).

Is atrial activity present?

Having defined the rhythm in terms of rate, regularity and QRS width, a rhythm strip should then be examined carefully for atrial activity (Resuscitation Council UK (2005). The P-wave rate and regularity are determined in the same way as for the QRS complexes and any difference between the two identified. The shape of the P-wave may help to determine the rhythm. If atrial depolarisation originates in the sinoatrial node the P-wave will be upright in leads II and AVF. If the atria are being activated retrospectively (junctional or ventricular in origin), the P-waves will usually be inverted in these leads because atrial depolarisation takes place in the opposite direction to normal.

How is atrial activity related to ventricular activity?

If the time interval between each P-wave and the nearest QRS complex is constant, it is very likely that the atrial and ventricular depolarisation is linked. Inspection of the relationship between the P and QRS complexes should be made and if necessary the timings of the P-waves should be plotted separately and compared with the timings of the QRS complexes. Any recognisable patterns between the two should be identified, as well as the occurrence of any missed or dropped beats and PR intervals that vary in a repeated trend.

Complications

In any situation, check the woman first!

In matters of cardiac emergency, assumption is truly the mother of all errors. It cannot be presumed that simply because a member of staff is employed in critical care, they are necessarily competent to deal effectively with an emergency, or to detect important changes in cardiac state. To this end, all staff should maintain their knowledge and skills. Common errors stem from poor lead placement, which gives a distorted image of the actual cardiac conductivity, and a lack of knowledge on the part of staff who are monitoring the woman. The ECG will give no information in regard to cardiac output or efficiency. As with all clinical situations, if there is any doubt, seek help immediately.

Non-invasive blood pressure monitoring

In order to enable the function of vital organs and tissues, adequate perfusion must be maintained. Measurement of the blood pressure is therefore vital in the monitoring of the critically ill woman. First attempted by Stephen Hales in 1733, the non-invasive measurement of blood pressure became possible with the development of the blood pressure cuff by Scipione Riva-Rocci in 1896. Whilst it is possible to form some idea of a patient's blood pressure by observation (a radial pulse requires a systolic pressure of > 80 mmHg and capillary reflexes greater than 2 seconds suggest inadequate perfusion); no numerical data can be obtained without apparatus.

Technology

The basic equipment used to measure blood pressure is a sphygmomanometer. A cuff is applied to the woman's arm level with the heart; it is then inflated to a pressure higher than the expected reading. This will be shown on a dial. Mercury-filled apparatus should not be used due to the potential health and safety risks of mercury spillage. By means of using a stethoscope over the brachial artery; as the cuff is slowly released, tapping noises (Korotkoff sounds) can be heard (Ur & Gordon 1970). These will manifest in five phases: an initial sound, an increasing intensity, maximum intensity, progressive muffling and an absence of sound. The emergence of the initial tapping sound represents the systolic pressure, whilst the point of disappearance represents the diastolic pressure. A variation of this theme is the oscillotonometer, developed by Von Recklinghausen, which uses two cuffs – the smaller of the two amplifies pulsations caused as the larger cuff is released. By controlling a hand leaver, readings are shown on a dial as the pressure comes down.

More common in the modern health care scenario is the DINAMAP (indirect non-invasive automatic mean arterial pressure) machine. A microprocessor controls the inflation and deflation of the cuff. Pressure changes are detected by a transducer, which results in a digital reading being displayed. This concept is often inbuilt into the multifunction monitors seen for use in both routine and

critical care. Monitors range from integrated critical care modules to smaller units that wrap around the wrist.

Use: performing non-invasive blood pressure monitoring

The woman should be in a non-disturbed area and either seated or lying down so that the mid-point of the upper arm is at the level of the heart. Cuffs should be selected in relation to the size of the woman's anatomy. In adults, the internal bladder of the cuff should encircle 80% of the arm's circumference. The width of the cuff should cover approximately two-thirds of the upper arm. The centre of the cuff should overlay the brachial artery. Large adult-size cuffs of 35–44 cm should always be available to prevent inaccurate readings being obtained from ill-fitting equipment. If a cuff is wrapped too loosely, it will produce a falsely high reading. Conversely, if the cuff is too tight, the reading will be seen as falsely low (Manning et al. 1983). Ensure manual equipment is set at zero prior to starting. Automatic monitors will self-test and calibrate. Any inadvertent stress or exercise during measurement is likely to give a higher reading. If using a stethoscope to detect Korotkoff sounds, ensure it is well fitting and in good order and that manual equipment is at eye level to provide accurate sightings.

Complications

Blood pressures differ between individuals and are subject to many facets of the person's condition. It is important to establish what is to be considered as 'normal' for each individual, prior to commencing any measurements. Individual measurements on the same person are also subject to change, so it is best to take more than one reading, so as to confirm the data obtained as being fair and accurate. It is not unusual to find that your referral for hypertension is sometimes based on anxiety or technique, as opposed to any direct clinical condition. Careful assessment and application of correct procedure is important when taking vital signs. To reduce the potential for error, the equipment, patient and clinician should all be considered when faced with readings that on initial examination appear to be outside those bounds that have been established as normal for the current phase of the patient's condition. It is also important for staff to maintain their skills of manual blood pressure measurement, despite the now commonplace usage of automated equipment, as it is an invaluable tool with which to corroborate those readings that are a cause for concern.

Peripheral venous cannulation

Venous cannulation is of vital importance when dealing with any critical care situation and should be maintained at all times. To this end, careful thought should be applied prior to cannula selection and insertion. In the standard setting, intravenous access is required principally for routine drug and fluid administration.

As such, it is not anticipated that the cannula will remain *in situ* for any long period of time, or be expected to allow rapid infusion. In this instance, a smaller gauge cannula may be acceptable, as would the selection of a vein of smaller lumen.

In cases of haemodynamic instability, long-term drug or infusion therapy or a potential for sudden deterioration in the patient's condition, venous cannulation requires more in-depth consideration. Cannulae larger than 18 G are best suited for rapid infusion, with larger cannulae up to 14 G allowing higher infusion rates to be achieved. As peripheral veins become obstructed or shut down, it requires the clinician to locate broader lumens, which are harder to cannulate. If a perfectly good vein is rendered unusable by failed cannulation, the situation is made more difficult, so increasing the risk potential of the patient. All staff with responsibility for cannulation should therefore receive formal training and maintain their practical skills.

Use: performing peripheral venous cannulation

- Determine the level of urgency and use for which the cannula is required. If there is someone better suited to the task, have them either perform the procedure or be available to provide assistance.
- Use an aseptic technique and employ universal precautions, ensuring you have a full range of cannulae and sundries available. Use types of cannulae that you feel comfortable with when possible (e.g. winged styles or those that employ a 'bloodless' insertion technique).
- Apply a tourniquet that prevents venous return, whilst allowing arterial flow to the area. This can be checked by the palpation of a pulse, distal to the applied tourniquet.
- Study the anatomy. Only what you see is available for use in the first instance, so take your time in selection. Whilst choosing a vein, try to optimise the following criteria:
  - Make sure the vein is proportionate in size to the cannula you wish to insert and away from jointed areas that might compromise the patency of flow in flexion. Do not waste a large vein access site (e.g. the median cubital vein or the larger veins of the forearm) by inserting cannulae that are too small to perform the required function. Seek assistance if needed.
  - Ensure the vein has a length that will accommodate the cannula, and which is free from obstructions such as evident valves or narrowing and as straight as possible.
  - The vein should be as healthy in appearance as the patient's condition permits. This reduces the likelihood of vascular rupture ('blowing') or shortened life of the cannula.
  - In palpation, the vein should be stable in its surrounding tissues to reduce movement. Gentle traction on the surrounding skin area can aid stabilisation. Stimulation of the vein through a rubbing or gentle tapping technique can induce spasm of the wall of the vessel, so giving form and structure to the target. Note that excessive force in technique is painful and should be avoided.

- The use of alcohol wipes to disinfect the local area is debatable with regard to the reduction of infection rates (Franklin 1999). In dark skin there is the added benefit that vasculature becomes more readily visible as light is reflected from the shining, curved surfaces. Ensure that any applied cleansing solution has dried prior to venepuncture. With smaller cannulae especially, the predominant pain experienced by patients occurs not directly from the penetration, but from the reaction of alcohol with the skin tissue as it is introduced by the cannula.
- Venepuncture can best be achieved by careful visualisation of the anatomy. A positive, brisk insertion of the cannula at an angle of approximately 15–20° should ensure that the skin is fully penetrated. Insertion continues until a flashback of blood is seen in the central chamber of the cannula, indicating that the tip of the cannula is in the vascular lumen. Gentle withdrawal of the introducer leaves the atraumatic cannula positioned for insertion up the vein. If resistance is met, ensure that attempts to continue insertion do not compromise the vessel. It is better to have a cannula that is only partially inserted but patent, as opposed to a failed attempt. This can be used and maintained until a more optimal access is established. After two failed attempts at cannulation, assistance should be sought prior to proceeding. If no success is achieved in transdermal cannulation, venous cut-down by a medical practitioner may need to be considered.
- Cannulae should be properly maintained and checked, so as to ensure patency of function and reduce the incidence of phlebitis. If a cannula needs to be replaced, it is best to site the new cannula prior to the old one becoming unusable, so ensuring that venous access is present at all times.

Complications

Known complications of intravenous therapy fall into three main categories (Campbell 1997):

- *Phlebitis*. This inflammation of the vessel can be caused by a number of factors. The size and material of the catheter, the manner in which it was inserted and also the type, duration and rate of infusion, will all influence the longevity of the cannula, together with any inflammation resulting from infection. Redness, pain or irritation may be early indicators of phlebitis and may require new access to be established. Changing the cannula every 1–2 days is recommended where practical.
- *Infection*. Contamination of the intravenous site or line can result from inadequate skin preparation, poor on-going cleansing, contaminated infusions and host factors. The introduction of these contaminants often stems from poor technique on the part of the carer.
- *Extravasation*. The stability of intravenous cannulae depends upon various factors. The age of the woman may reflect skin or tissue condition and the conscious care of the woman in regard to ensuring the device remains firmly *in situ* and undisturbed. If the cannula is sited in an awkward position such as the

dominant hand, in a high profile area prone to being caught, or directly over a mobile joint such as the wrist or antecubital fossa, then there is a greater potential for displacement. If on-going infusions are present, these might also provide another area where inadvertent traction or catching can displace the cannula. Care must be taken to ensure that the entire intravenous line is secure, and that the woman is fully aware of the various components that may inadvertently become caught or dislodged.

Arterial cannulation

Arterial cannulation is a clinical procedure that is generally reserved for situations where the potential for rapid variations in blood pressure is anticipated. It is also employed where non-invasive blood pressure monitoring is not possible (e.g. morbid obesity, trauma or burns) (Anderson 1997). Whilst *in situ*, the presence of an arterial cannula facilitates easy sampling of arterial blood for gas analysis and acid base balance, so preventing repeated arterial perforation. Women with arterial cannulae require close supervision as the mere employment of the technique indicates an unstable and potentially life-threatening condition. In addition to this, should the line become disconnected, there is the danger of massive haemorrhage occurring.

Technology

A cannula is inserted into an artery. This is connected to a sterile system, primed with heparinised saline and fitted to a transducer. The tubing of the system must be non-compliant so as to ensure that pressures remain constant from the point of reception to the point of transduction. Pulsations that reflect the arterial pressure pass through the system until they reach a membrane. The reverberation against this membrane is detected by sensors and is transduced into an electronic impulse that is displayed on a monitor in both waveform and digital reading.

Technique and practicalities of the procedure

It is often peripheral arteries that are selected for the placement of arterial lines. Whilst larger arteries such as the femoral artery are usually readily accessible, should significant damage occur to the vessel, the blood supply to the distal limb can be compromised if the chosen artery is the sole or principal supply. Commonly, therefore, the radial and ulnar arteries are often chosen for their convenience, clean location and the fact that they are not end arteries. It is imperative, however, to establish that a collateral supply exists between them in case of inadvertent damage being caused. In testing, 3% of hospitalised patients have an inadequate collateral flow. This is commonly established by performing Allen's test (Husum & Berthelsen 1981):

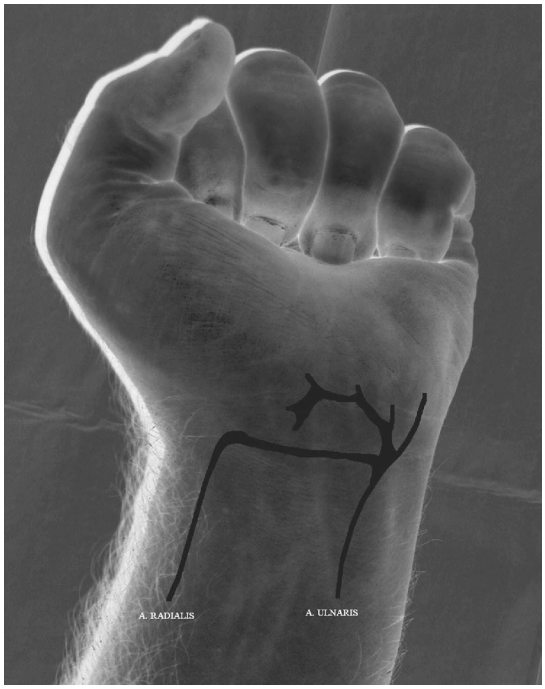

Figure 10.1 Position of the radial and ulnar arteries.

- Palpate both the radial and ulnar arteries (Fig. 10.1).
- Occlude both arteries with the patient's hand both raised and clenched. After 20 seconds, significant blanching should occur.
- Release one side and watch for refill within 5–7 seconds. Repeat for the other side.
- An even refill will indicate a safe colateral supply. If the test is negative, do not proceed.

The following items are required for arterial cannula insertion: sterile gloves, skin preparation, arterial cannula, dressing ± suture and heparinised saline flush.

Once the area has been cleaned and infiltrated with local anaesthetic as required, the cannula may be inserted in one of two ways. By the direct puncture method, the same technique as used in venous cannulation is employed. The cannula is advanced until flashback is obtained and then, as the introducer is withdrawn, passed up the lumen of the vessel. Using the transfixion technique, the cannula is advanced until flashback is seen and then advanced further, so transfixing the artery. The introducer is then removed. The cannula is then slowly withdrawn until clear pulsatile blood flow is obtained, and then advanced up the lumen.

Having ensured there is no air present in the system and that it is boldly marked as arterial, the system can be connected. It is important to ensure that the system is pressurised so that it does not fall below that exerted within the artery. The system must then be set at 'zero'. This will calibrate it to atmospheric pressure (760 mmHg at standard sea level). Close the system to the patient input and open

the transducer tap to allow air entry. Zero the transducer at the monitor. Close the transducer tap and ensure it is returned to allow patient line input. With the transducers set at the level of the heart, a pressure wave produced by a left ventricular systole will be seen. It is transmitted faster than the arterial blood flow. The standard waveform will commonly display an initial peak (marking systolic pressure), a descent, interrupted by the dicrotic notch (closure of the aortic valve) and a final trough that marks diastole. Normal values in females (age 19–50 years) range respectively from 100–140 mmHg systolic to 60–90 mmHg diastolic. Levels above this threshold are considered as hypertensive (National Institute of Clinical Excellence 2004). Abnormal waveforms can indicate aortic stenosis, regurgitation or left ventricular failure. If a patient is hypovolaemic, the dicrotic notch will appear lower in its placement on the curve of the downstroke. Collapsing waveforms can show a hyperdynamic circulation sometimes seen during sepsis, anaemia, aortic regurgitation or pregnancy. Arterial blood gas analysis shows the partial pressures of gasses contained in the sample. The range of normal values (as seen in 95% of healthy adults) is as follows:

- *P*ao$_2$: 11.3–14.0 kPa/85–105 mmHg
- *P*aCO$_2$: 4.7–6.0 kPa/35–45 mmHg
- *S*aO$_2$: 95–99%
- H^+ concentration: 36–43 nmol/L
- pH: 7.35–7.45
- Bicarbonate: 20–30 mmol/L

Transducer set-up

The following items are required for the set-up of most modern transducers: 500 ml NaCl + heparin at 1 iu/ml, single/double transducer set and a pressure infusion bag (only arterial lines need to be pressurised unless wedge pressure monitors are to be used).

Close all three-way taps and clamps prior to starting. Insert the system inlet into the bag port and fill the chamber. Run through each section in turn ensuring all air is displaced in an upward direction (air rises and will interfere with readings if not removed). Maintain an aseptic technique at all times so as not to contaminate the system.

Complications

Disconnection and subsequent haemorrhage are a very real risk to women with arterial monitoring. Whilst we might normally presume that we will notice any significant haemorrhage, arterial cannulae once disconnected can provide a patent pathway for blood loss. Under arterial pressure this can be very rapid. To put this into perspective, 280 ml is the approximate circulating blood volume of a 3.5 kg baby. This can be lost within 1 minute. It only takes a short period of distraction to miss a potentially fatal occurrence.

Inadvertent arterial drug administration can occur if the set-up is not clearly labelled. Most systems are colour coded; however great care should be taken to ensure that all monitoring and infusion lines are kept in an ordered manner. In an emergency, a three-way tap on the arterial line might look just like any other, so always err on the side of caution.

Arterial occlusion occurs in less than 50% of cases and, as has been outlined in discussing the criteria for insertion site selection, can have grave consequences in single-supply arteries. Other potential complications associated with arterial lines include embolisation and infection or contamination. Aneurysm formation relative to the size and condition of the femoral artery has also been reported. Haematoma upon insertion/withdrawal is common; however, it should be noted that whilst bleeding at a site such as the radial artery can be readily observed and controlled, vessels such as the femoral artery can often be more difficult to view as they often lie deeper in the tissues and thus present a restricted access for the application of direct pressure in the control of haemorrhage.

Inaccurate sample readings can lead to missed diagnoses or inappropriate treatment being undertaken, so it is important that samples are drawn in a controlled manner. To obtain a sample, the three-way tap closest to the woman should be closed. Using a sterile 10 ml syringe, aspirate the system so that the distal section is filled with fresh blood. The volume of the dead space should then be drawn off a minimum of five times, prior to the sample being taken. The technique will depend upon the equipment or method used for processing the sample. Having checked for the presence of air or clotting, the system can then be flushed and zeroed to recommence monitoring.

Central venous cannulation and central venous pressure monitoring

Central venous pressure (CVP) was first recorded in a horse by Stephen Hales in 1733. Experimental progression to human recording was not achieved until 1902, and in 1910 the introduction of CVP measurement in the clinical setting was seen (Kalso 1985). In 1945, the first polythene venous catheters were introduced, so establishing CVP insertion as a common practice although the more common aim at the time was for resuscitation as opposed to routine clinical measurement. There is the ability, however, to use the line for rapid infusion, whilst monitoring the volaemic state.

As previously established, whilst an ECG recording gives an image of the electrical conductivity across the heart, it provides no information with regard to cardiac output. CVP measurement, in reflecting right atrial pressure, provides a means of assessing a patient's haemodynamic status. Cardiac performance may be determined by the combined relationship between preload, afterload and contractility. Preload is the level of ventricular filling and pressure generated by venous return in the left ventricle following diastole. Afterload represents the pressure against which the flow from the left ventricle is subjected at the end of the systolic phase. Both of these are dependent upon the function of the heart and the vascular system. Contractility reflects upon the cardiac tissue alone. The net

result from the interaction of these three factors is the stroke volume (volume ejected per minute from the left ventricle). This then circulates in the normal manner. Although catheters are positioned on the right side of the heart, placement of a catheter in the pulmonary artery reflects left ventricular pressures as during diastole the pulmonary venous bed and the left ventricle are in direct communication.

The preload relationship between right atrial pressure and ventricular output are described in Starling's law which states that cardiac output increases as left ventricular end-diastolic volume increases. There is a limit, however, as to how high the filling pressure can be increased. This is due to the tensile limitations of myocyte fibres. Also, and perhaps more commonly, seen is the process that large increases in left ventricular filling pressure (and subsequently increased pulmonary venous pressure) can lead to the occurrence of pulmonary oedema. It has been shown, however, that when patients are undergoing mechanical ventilation in the intensive care setting as a direct result of cardiogenic pulmonary oedema, normal pulmonary artery wedge pressures (PAWPs) have been recorded after ventilation was initiated. In such a case, patients may benefit from additional fluid challenges, despite the presence of pulmonary oedema. The oedema is quickly resolved when cardiac function and performance improves, often within the first 24 hours.

Vasodilatory drugs may be directly monitored for their right-sided effects, so allowing informed titration and optimal control. Parenteral nutrition and concentrated drugs also benefit from the high flow rates and subsequent rapid dilution into the central venous system, so reducing the incidence of local irritation.

Figure 10.2 shows the cardiac cycle in relation to CVP and the ECG.

Technique and practicalities of the procedure

CVP insertion

The internal jugular vein (IJV) is often the favoured point of insertion for CVP lines. A lesser risk of pneumothorax exists in this technique, as the point of insertion is further away from the apex of the lung during the initial stage of the procedure when traumatic introducers and dilators are used. Insertion into the IJV has a less direct path than the subclavian technique. Whilst easy to compress in the event of haemorrhage, a higher incidence of arterial puncture exists as it lies lateral to the common carotid artery and may also prove difficult to cannulate in hypovolaemic patients. The site is also prone to infection, possibly as a result of catheter or neck movement (Hocking 2000).

Whilst the alternative subclavian route tends to increase patient comfort post-placement and allows a more direct route to the heart, it has incurred a high rate of morbidity due to the incidence of damage to the pleural, vascular and neural tissues encountered during insertion. In considering the placement site, poor coagulopathy may render bleeding difficult to control, and the potential for lung damage during insertion may further compromise those with existing lung disease or impaired oxygenation. Catheters in the region of 20 cm in length are used for IJV and subclavian insertion. If femoral or brachial veins are to be

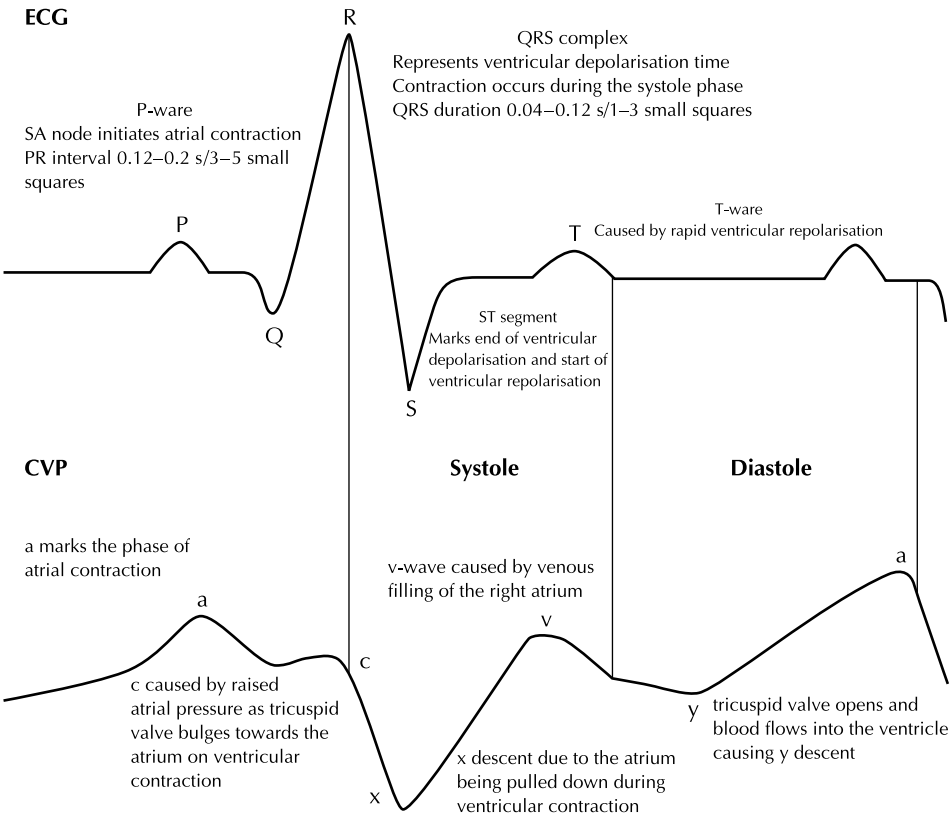

Figure 10.2 Cardiac cycle in relation to central venous pressure (CVP) and electrocardiograms (ECGs).

considered, longer catheters of 60 cm are required to ensure that the tip of the catheter reaches the correct placement area.

For neck or subclavian placement, the woman is placed in the Trendelenberg position or supine with a support placed between the shoulders. An aseptic field is established and it is important to monitor that this is maintained throughout the procedure. With long guidewires and multiple lumen catheters, it is easy to contaminate items that will then be passed directly into the central system. Each component of the chosen line is then checked and flushed, and the local area can be infiltrated with local anaesthetic as required. Full monitoring should be in operation and good venous access established prior to starting the insertion procedure.

Insertion technique is commonly limited to two methods. Direct cannulation, as used in peripheral cannulation, allows simple insertion with relatively little ancillary equipment. The catheter is passed over the needle and so reduces the bleeding from the insertion site due to its greater size. The diameter of the needle however, is also relatively large, and carries an increased risk of over-insertion and bleeding from accidental arterial puncture.

The more common method of insertion, especially for multilumen catheters is the Seldinger technique, which employs the use of a guidewire to direct the catheter placement (Hocking 2000). The chosen vein is located with a small-diameter needle. Once in the vein, a guidewire is inserted, and the needle removed. The tip of the wire is commonly J-shaped and flexible, so as not to perforate or traumatise the vessel as it passes through the lumen. Care should be taken not to kink the guidewire as this can cause damage to both the vessel and the catheter as it passes over. It may also prevent the catheter being inserted and require either a new guidewire or abandonment of the procedure. Overinsertion of the guidewire may cause cardiac arrhythmias. In this case, a slight withdrawal should stop stimulation and allow insertion to continue. A dilator can then be passed over the guidewire to open the puncture site to enable the larger catheter to be passed. The dilator (if used) is then removed and the catheter inserted. The guidewire (in multilumen catheters) will appear through the central lumen as the catheter is passed and is removed once correct placement is confirmed. The catheter is then sutured to prevent kinking and movement, and a sterile dressing applied.

A possible third technique of passing the catheter through a large-diameter needle for antecubital insertion is seldom used. The size of the needle leads to bleeding at the point of insertion, and if the catheter needs to be withdrawn through the needle, there is the risk of catheter embolisation should part of the catheter be sheared off by the needle tip.

Once *in situ*, the catheter may be connected to a primed monitoring system. This may be a simple fluid manometer that consists of a line from the woman, a monitoring limb and infusion set, controlled by a three-way tap. Once the entire system is primed, and the monitoring limb filled slightly above the estimated CVP reading, the tap is closed to the infusion set, allowing passage from the CVP line to the monitoring limb. The fluid in the column is then balanced against the CVP and a reading obtained by measurement of the top of the fluid against a scale. If the porous plug at the top of the column is blocked, measurements will be incorrect as the fluid movement will be restricted. It is vital that the base of the system at the level of the three-way tap is level with the woman's heart. This effectively 'zeros' the system against atmospheric pressure to ensure an accurate reading (Woodrow 2002).

More common, however, is the electronic transducer system that converts the action of fluid pressure against a membrane to an electronic signal, so providing both a waveform and numerical data. Opening pressures should then be recorded along with the woman's other observations. Infusion bags should be changed every 24 hours, with system components being changed at least every 72 hours. All waveforms achieved will share the principle of a-, c- and v-waves, with x-y descents.

Interpreting a CVP recording

- A *normal CVP range* is 3–10 mmHg (5–12 cmH_2O) (Mooney & Comerford 2003).
- A *low CVP reading* is usually a sign of hypovolaemia or dehydration. This can be as a consequence of haemorrhage or excessive diuresis.

- A *high CVP recording* can indicate the following:
  - Hypervolaemia: defined as an abnormal increase in the volume of blood circulating in the body and often a result of excessive fluid infusion.
  - Cardiac failure, for example right ventricular failure.
  - Pulmonary embolism.
  - Mitral valve failure/regurgitation.
  - Cardiac tamponade.
  - Catheter lumen occlusion/obstruction, for example thrombus, or the catheter lying against the vein wall.

CVP removal

The catheter should be removed with the woman lying flat and having fully exhaled in an attempt to reduce the risk of air entering the catheter upon removal thus causing an air embolus. Withdrawal should be constant and direct pressure applied for at least 5 minutes to the puncture site to prevent bleeding. If any difficulty is experienced during the process, appropriate assistance should be sought (Drewett 2000).

Pulmonary artery pressure monitoring

All too often in the treatment of the critically ill woman, unstable haemodynamics, pulmonary compromise and changing cardiac output require the placement of invasive monitoring to direct the continuing balance of treatment therapies. To obtain optimal data in regard to cardiac output, a pulmonary artery (PA) catheter may be inserted. Often performed in the intensive care setting, the safe use of PA catheters has been documented for many years with good effect. However, recent evidence has suggested that the use of PA catheters has neither increased overall mortality rates nor conferred benefit for critically ill patients (Hall 2005; Shah et al. 2005). A balloon-tipped catheter is inserted through a central vein and 'floated' through the right side of the heart until it comes to rest in the pulmonary artery. Multiple lumens allow for measurement at different levels and the options for infusion or pacing if required. The inflation of the balloon effectively 'wedges' the branch of the pulmonary artery and records the pulmonary capillary wedge pressure (PCWP) or pulmonary artery wedge pressure (PAWP). The use of PA or Swan–Ganz catheters provides the following:

- Indirect measurement of left ventricular end-diastolic pressure
- Central vascular pressures in the presence of decreased cardiac output
- Access to mixed venous blood samples to determine the degree of blood passing unoxygenated from the lungs to the left atrium

Combined, these assist in the determination of shock levels and fluid volume status, the presence of heart disease and any compromise in cardiac output.

CVP can be measured via the proximal port sited 30 cm from the catheter tip. The port is often colour coded blue and can also be used for intravenous infusion. Continual PA pressures are measured via the distal port, which is often coded

yellow. Pressures are differentiated as PAS (pulmonary artery systolic) and PAD (pulmonary artery diastolic). This port should never be used for infusions or medication administration. When the balloon is inflated, PAWP is also measured (McHale 1997; Bindels et al. 1999). The balloon port is situated in the distal end of the catheter. Inflated with 0.8–1.5 ml of air (never liquid); the port is usually coded red. Using slow inflation with the specialist syringe supplied with the system (this will not allow itself to be filled with more than 1.5 ml of air), the balloon should inflate using 1.25–1.5 ml of air. Less than this indicates that the catheter has advanced too far into the PA. If the balloon is overinflated, the balloon lumen may rupture. Measurement should not exceed periods of 2–3 respiratory cycles or 10–15 seconds, with the measurements taken being kept to a minimum. If PAWP and PAD are similar (within 4 mmHg difference), then PAD readings can be substituted for PAWP, so reducing the number of required measurements and potential harm being caused. By removing the syringe from the port, the balloon will passively deflate and the PA pressure trace will return. Do not actively withdraw air as this can damage the balloon. Once deflated, the gate port or tap can be closed to avoid inadvertent inflation of the balloon. To prevent loss of the restricted syringe, leave it attached. This will also guard against staff using the port for incorrect purposes.

Table 10.1 lists the expected range of recordings for cardiac monitoring.

Changes in pressure measurements can be caused and influenced by changes in preload, afterload and contractility and can therefore have different indications. It is vital, however, from the onset of treatment to establish what is normal for the woman in question.

A low CVP might indicate a decreased venous return or hypovolaemia due to haemorrhage or polyuria. In shock scenarios, this will be partially offset by peripheral vasoconstriction. Fluid challenges or fluid resuscitation may raise CVP

Table 10.1 Expected range of recordings for cardiac monitoring.

Reading	'Normal' range
CVP (right atrial pressure)	3–10 mmHg
Right ventricular pressure	20–30 mmHg (systolic) and 0–5 mmHg (diastolic)
PA pressure (mean)	10–25 mmHg
PAS pressure	20–30 mmHg
PAD pressure	08–12 mmHg
PAWP	05–15 mmHg

Whilst these figures represent a range within which 'normal' readings can fall, it should be recognised that 'normal' is subject to a combination of many variant factors. As such, pressures should be looked at in regard to trend patterns and the patient's response to therapeutic measures such as fluid challenges, not in a rigid comparison to 'normal' values.

CVP, central venous pressure; PA, pulmonary artery; PAD, pulmonary artery diastolic; PAS, pulmonary artery systolic; PAWP, pulmonary artery wedge pressure.

readings to high levels, and once partial peripheral dilatation occurs, values can appear normal. In conditions of full peripheral dilatation, however, especially with the influences of general anaesthesia, the CVP can then plummet to expose a large volume deficit. Spinal anaesthesia can also have a dramatic effect upon central pressures, as can sepsis, vasodilator overdoses and systemic dysfunction.

A raised CVP can indicate many possible causes. Cardiac factors include left or right heart failure and valve disease. Sympathetic nervous stimulation can give a raised reading, as can increases in venous and cardiac muscle tone. Other cardiac-related causes are tamponade, pulmonary vascular hypertension and embolism. In cases of constrictive pericardial disease, the CVP will rise on inspiration and fall during expiration, in paradox to normal observations. Hypervolaemia resulting from overvigorous fluid therapy is a common source of raised pressures. Intrathoracic causes include intermittent positive pressure ventilation, C-PAP (continuous positive airway pressure) and obstructive airway disease. Whilst no formula exists to calculate the effect of these pressures, if they remain constant in application, then the resulting trends should also remain constant. In the critical care setting, haemo- or pneumothorax should not be ruled out. Other raised pressures can result from abdominal splinting, pregnancy or ascites.

PA catheters can be used to derive a large amount of variable data that cannot otherwise be predicted by clinical examination. Cardiac output (using thermodilution techniques) or stroke volume is measured in millilitres or in beats. Increased stroke volume can indicate increased circulating volume or the use of inotropic agents. Decreases can indicate compromised valve function or cardiac contractility. This could progress to heart failure. Systemic vascular resistance figures can be computed; however, figures are dependent on variable factors such as peripheral resistance and heart rate. Much information can be obtained by analysing the waveforms. As previously discussed, invasive pressure waveforms have similar characteristics, but tend to differ in form in relation to the measurement point.

Complications

The potential complications arising from CVP and PA catheters are similar to those covered under arterial pressure monitoring. Haemorrhage, occlusion and false readings are commonly shared with all invasive monitors. In addition, the placement of lines in the heart can lead to dysrhythmias and altered cardiac function and circulation, with possible cardiac arrest. Bleeding and perforation or rupture can cause haemopneumothorax, cardiac tamponade and pulmonary artery haemorrhage, rupture or infarction. Should the woman cough up blood, or blood be noticed in the airway, a pulmonary artery rupture should always be suspected and expert help sought immediately. Whilst a CVP catheter can be flushed regularly, a PA catheter can rupture the pulmonary artery if flushed for longer than 2 seconds whilst under pressure (Connors 1983; Cruz & Franklin 2001).

Due to the complex nature of PA catheters, equipment can fail with examples such as balloon rupture or microshock, which stems from exposure of the thermistor connector tip. Air or thromboembolisms can also occur. It cannot be

stressed enough that if invasive monitoring is genuinely required, then women should be placed in a critical care setting, where staff are familiar with the procedures to be undertaken and their on-going management. In all cases of shock, the initial treatment is fluid therapy. This should not be curtailed for fear of the emergence of pulmonary oedema, and is indeed preferable to the use of vasoactive drugs. As the body redistributes fluids, pulmonary oedema often settles very quickly with any excess fluids being dealt with naturally by the kidney or by giving reducing agents such as nitrates or diuretics. The complex relationships that govern cardiac function need direct study and careful analysis to ensure that findings are taken in the context of a woman's condition and the therapeutic measures undertaken in the course of treatment.

Conclusion

Midwifery practitioners may perform intensive monitoring for the critically ill woman on an infrequent basis. However, the skills and knowledge required to use and interpret the results remain a crucial part of accurate and prompt diagnosis and management. It is important to ensure that such attributes are updated on a frequent basis. If practitioners experience difficulties in undertaking monitoring, it may be easier for experienced practitioners to support midwives within the maternity environment (Ball et al. 2003) or for women to be transferred to a unit which provides such care and management on a regular basis.

References

Aehlert, B. (2002) *ECGs Made Easy* (2nd edn). Mosby, St Louis.

Anderson, J. (1997) Arterial cannulation. *British Journal of Hospital Medicine*, **57** (10): 497–9.

Antunes, E., Brugada, J., Steurer, G., Andries, E. and Brugada, P. (1994) The differential diagnosis of a regular tachycardia with a wide QRS complex on the 12 lead ECG: ventricular tachycardia, supraventricular tachycardia with abberant intraventricular conduction, and supraventricular tachycardia with antegrade conduction over an accessory. *Pacing and Clinical Electrophysiology*, **17**: 1515–24.

Ball, C., Kirkby, M. and Williams, S. (2003) Effect of the critical care outreach team on patient survival to discharge from hospital and readmission to critical care: non-randomised population based study. *British Medical Journal*, **327**: 1014.

Bindels, A., Van der Hoeven, J. and Meinders, A. (1999) Pulmonary artery wedge pressure and extravascular lung water in patients with acute cardiogenic pulmonary oedema requiring mechanical ventilation. *American Journal of Cardiology*, **84** (10): 1158–63.

Campbell, J. (1997) Intravenous cannulation: potential complications. *Professional Nurse*, **12** (Suppl. 8): S10–3.

Connors, A. (1983) The role of right heart catheterisation in the care of the critically ill: benefits, limitations and risks. *International Journal of Cardiology*, **4** (4): 474–7.

Cruz, K. and Franklin, C. (2001) The pulmonary artery catheter: uses and controversies. *Critical Care Clinics*, **17** (2): 271–91.

Drewett, S. (2000) Complications of central venous catheters: nursing care. *British Journal of Nursing*, **9** (8): 466–78.

Fearnley, S. (1995) Pulse oximetry. *Update in Anaesthesia*, Issue 5: Article 2.

Franklin, L. (1999) Skin cleansing and infection control in peripheral venepuncture and cannulation. *Nursing Standard*, **14** (4): 49–50.

Hall, J. (2005) Searching for evidence to support pulmonary artery catheter use in critically ill patients. *Journal of the American Medical Association*, **294** (13): 1693–4.

Hocking, G. (2000) Central venous access and monitoring. *Update in Anaesthesia*, Issue 12, Article 13. http://www.nda.ox.ac.uk/wfsa/html/u12/u1213_01.htm

Husum, B. and Berthelsen, P. (1981) Allen's test and systolic arterial pressure in the thumb. *British Journal of Anaesthesia*, **53** (6): 635–7.

Kalso, E. (1985) A short history of central venous catheterisation. *Acta Anaesthesiologica Scandinavica*, **81** (Suppl.): 7–10.

Lee, J. (2000) ECG monitoring in theatre. *Update in Anaesthesia*, Issue 11. http://www.nda.ox.ac.uk/wfsa/html/pages/up_issu.htm

Manning, D., Kuchirka, C. and Kaminski, J. (1983) Miscuffing: inappropriate blood pressure cuff application. *Circulation*, **68** (4):

Marieb, E. (2003) *Human Anatomy and Physiology* (6th edn). Addison Wesley, San Francisco.

McHale, L. (1997) Obtaining a pulmonary artery wedge pressure. *Critical Care Nurse*, **17** (5): 94–5.

Mooney, G. and Comerford, D. (2003) What you need to know about central venous lines. *Nursing Times*, **99** (10): 28–9.

National Institute of Clinical Excellence (2004) *Hypertension: Management of hypertension in adults in primary care.* Clinical Guideline No. 18. National Institute of Clinical Excellence (NICE), London.

Pedersen, T., Dyrlund-Pedersen, P. and Moller, A. (2004) Pulse oximetry for peri-operative monitoring. *Cochrane Library*, Issue 4.

Resuscitation Council UK (2005) *Advanced Adult Life Support*. Resuscitation Council UK, London.

Schamroth, L. (1990) *An Introduction to Electrocardiography* (7th edn). Blackwell Scientific, Oxford.

Shah, M., Hasselblad, V., Stevenson, L. et al. (2005) Impact of the pulmonary artery catheter in critically ill patients: meta-analysis of randomized clinical trials. *Journal of the American Medical Association*, **294** (13): 1664–70.

Thelan, L., Urdan, L., Lough, M. and Stacy, K. (1998) *Critical Care Nursing: Diagnosis and management* (3rd edn). Mosby, St Louis.

Tortora, G. and Derrickson, B. (2005) *Principles of Anatomy and Physiology.* Wiley & Sons, Chichester.

Ur, A. and Gordon, M. (1970) Origin of korotkoff sounds. *American Journal of Physiology*, **218**: 524–9.

Woodrow, P. (1998) An introduction to the reading of electrocardiograms. *British Journal of Nursing*, **7** (3): 135–42.

Woodrow, P. (2002) Central venous catheters and central venous pressure. *Nursing Standard*, **16** (26): 45–51.