CONTINUING PROFESSIONAL DEVELOPMENT

This article describes the use of central venous pressure (CVP) monitoring in clinical practice. The cardiovascular anatomy and physiology, as well as the indications and means of access, for the procedure. The mechanics and practicalities of measuring CVP are discussed and information for troubleshooting is provided.

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**Keywords**

Central venous pressure, heart function, intravascular volume

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**Aims and intended learning outcomes**

This article describes the use of central venous pressure (CVP) monitoring in clinical practice. The cardiovascular anatomy and physiology underpinning CVP monitoring is reviewed and provides a foundation for the interpretation of CVP readings. The principles of haemodynamic monitoring are discussed and the practical procedure for performing CVP monitoring in adults is explained. After reading this article and completing the time out activities you should be able to:

- Define CVP and the factors that influence it.
- Zero and level a CVP transducer using the correct anatomical reference point and explain why this is important in clinical practice.

> Draw and label a diagram of a normal CVP waveform.
> State the normal range for CVP in health.
> Consider the clinical situations that might cause an alteration in a patient’s CVP measurement.

**Time out 1**

**Define the following terms:**

- Central venous pressure.
- Venous return.
- Vascular tone.

**Introduction**

CVP is the term used to describe the pressure of the blood in the great veins that supply the venous return to the right side of the heart (Guyton and Hall 2006).

Veins carrying the venous return from the head, neck, arms and upper thorax converge to form the superior vena cava (SVC), while the veins carrying the venous return from the legs, abdomen and lower thorax converge to form the inferior vena cava (IVC) (Scales 2008a).

The venae cavae are in continuity with the right atrium and consequently the pressure of the blood in the great veins is essentially the same as the pressure in the right atrium (Magder 2006) (Figure 1). Normal right atrial pressure (RAP) has a range of 1-10 millimetres of mercury (mmHg) and the mean pressure is 5 mmHg (Muralidhar 2002). In effect, CVP=RAP.

The volume of blood returning to the heart and the pressure in the right atrium determine the filling of the right ventricle (Magder 2006). In health, it is assumed that the CVP also reflects
the filling of the left ventricle (Scales 2008b) because blood flows from the right ventricle, through the pulmonary bed and back to the left side of the heart. An estimation of the filling of the left ventricle is important because the left ventricle pumps blood around the systemic circulation.

Intravascular volume—the amount of blood in the circulation—is an important component of CVP. In health, intravascular volume is primarily maintained by controlling the body’s fluid balance (Scales and Pilsworth 2008). Fluid imbalances can result in either volume overload or volume depletion. Volume overload is most commonly seen in patients with renal or cardiac failure and results in an increase in CVP. Volume depletion can be caused by loss of blood, for example haemorrhage, or loss of water. Reduced body water is termed dehydration and can be caused by inadequate fluid intake or excessive water loss (Scales and Pilsworth 2008) (Table 1).

Intravascular volume depletion can occur if the body’s fluid compartments are disrupted, for example in sepsis when capillary permeability increases, causing the capillaries to ‘leak’ fluid into the surrounding tissues (Marx 2003). Fluid compartments are also disrupted by conditions that reduce serum albumin, for example patients with liver failure, malnutrition, nephrotic syndrome and burns (Scales and Pilsworth 2008). Intravascular volume depletion reduces CVP.

CVP is also affected by vascular tone—the degree of constriction or dilation of the blood vessels. If the patient’s venous system is dilated, blood will pool in the peripheral circulation and venous return to the heart will be reduced; this in turn will reduce the CVP. Vasodilation occurs in patients with fever, sepsis and anaphylaxis. It also occurs in patients receiving vasodilating drugs (Morton et al 2005). Vasoconstriction prevents peripheral pooling, increases venous return to the heart and so increases the patient’s CVP. Vasoconstriction most commonly occurs in patients with hypothermia and hypovolaemia.

Right heart function also affects CVP. In right ventricular failure, the patient’s right ventricle is unable to pump the venous return forward into the pulmonary artery. This leads to congestion and the RAP rises as blood accumulates in the right side of the heart. The increased RAP creates back pressure in the great veins, causing an increase in CVP.

### Indications for CVP monitoring

In clinical practice, CVP is used to estimate the patient’s intravascular volume and heart function (Hocking 2000). CVP monitoring is performed in acute and critical care settings to provide additional physiological information to assist with the patient’s clinical management. It is used to monitor and guide fluid therapy in the following clinical situations:

- Fluid resuscitation in major trauma.
- Cardiac surgery.
- Thoracic surgery.
- Major abdominal surgery.
- To optimise fluid replacement in acute renal failure.

### Table 1 - Causes of dehydration

<table>
<thead>
<tr>
<th>Reduced fluid intake</th>
<th>Increased fluid loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nausea</td>
<td>Vomiting</td>
</tr>
<tr>
<td>Altered consciousness</td>
<td>Nasogastric drainage</td>
</tr>
<tr>
<td>Nil by mouth states</td>
<td>Wound drainage or fistula</td>
</tr>
<tr>
<td>Swallowing difficulties</td>
<td>Polyuria or diuretics</td>
</tr>
<tr>
<td>Immobility</td>
<td>Sweating</td>
</tr>
<tr>
<td>Mental illness</td>
<td>Diarrhoea</td>
</tr>
<tr>
<td>Frailty</td>
<td>Fever</td>
</tr>
</tbody>
</table>

### Figure 1

Direction of blood flow through the heart showing the convergence of the superior and inferior vena cavae.

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**Time out 2**

Reflect on the reasons why patients may require CVP monitoring, and in what settings. Compare your answers with the text below.
FIGURE 2
Normal central venous pressure waveform

Note that the wave has three peaks, a, c and v, and two descents, x and y.

a – the rise in right atrial pressure caused by atrial systole.
c – the ventricular contraction causes the tricuspid valve to bulge upwards into the right atrium (RA).
x – the decrease in pressure in the RA as the tricuspid valve moves away from the RA during ejection of blood from the right ventricle.
v – the peak in atrial pressure during ventricular systole when the tricuspid valve is closed.
y – the tricuspid valve opens and blood rapidly empties into the right ventricle during diastole.

To optimise fluid replacement in sepsis.
To guide fluid replacement in heart failure.

CVP monitoring can also be used for diagnostic purposes. It is performed in critical care to assess right heart function and during cardiac catheterisation to aid or confirm a diagnosis.

Vascular access for CVP monitoring

CVP is a haemodynamic measurement used routinely in critical care areas to guide fluid replacement and vasoactive drug management. Increased use of CVP monitoring for post-operative surgical care has been recommended (National Confidential Enquiry into Perioperative Deaths (NCEPOD) 2001).

To measure CVP a central venous catheter (CVC) is placed in a central vein and connected to a monitoring device; real-time information about the cardiovascular system can then be obtained. Measurement of CVP is usually an acute intervention and a temporary single or multiple lumen CVC is usually selected.

The most common CVC insertion sites are the internal jugular veins, the subclavian veins and the femoral veins. The subclavian site has the lowest infection risk (Pratt et al 2007), but is associated with an increased risk of pneumothorax (Scales 2008b). The right internal jugular is one of the most popular sites for central venous access because it provides relatively straightforward access into the SVC and has a high success rate (Muralidhar 2002).

The femoral site is associated with the highest risk of infection (Pratt et al 2007), but provides useful clinical information if an alternative route is not available (Alzeer et al 1998).

The National Institute for Clinical Excellence (NICE) (2002) recommends the use of two-dimensional ultrasound for elective and emergency CVC insertion. Two-dimensional ultrasound allows the clinician to visualise the subcutaneous anatomy and locate the vein before CVC insertion. Following thoracic CVC insertion, a chest X-ray should be performed to confirm the position of the catheter tip.

Internal jugular and subclavian vein CVCs should be positioned correctly with the tip of the catheter located in the lower third of the SVC (Royal College of Nursing (RCN) 2010). Tip position is not routinely checked for femoral CVCs, because they do not usually enter the heart and therefore there is less risk of misplacement.

CVP can be measured using a pressure transducer or a water manometer. A water manometer measures CVP in centimetres of water (cmH₂O) while haemodynamic monitoring using a pressure transducer records the information in mmHg. Therefore the information is not directly comparable (Scales 2008b). To convert cmH₂O to mmHg the value in cmH₂O must be divided by 1.36. To convert mmHg to cmH₂O the value in mmHg must be multiplied by 1.36 (Morton et al 2005).

The use of continuous transduced CVP monitoring is recommended to improve accuracy (NCEPOD 2001), and it is this technique that is described in this article.

Haemodynamic monitoring

Haemodynamic monitoring involves two distinct elements: electronic equipment and a fluid-filled tubing system (McGhee and Bridges 2002). The electronic equipment has three components (Scales 2008b):

- A transducer to detect physiological activity.
- An amplifier to increase the size of the signal.
- A recording device to display the information, for example a monitor screen.

Connecting a CVC to a fluid-filled tubing system allows the pressure in the vein to be transmitted through the tubing to a transducer. The transducer links the tubing to the electrical system and converts the mechanical pressure wave from the blood into an electrical signal (McGhee and Bridges 2002). The signal is transmitted along a pressure cable to the monitor where the signal is amplified and displayed as a waveform (Scales 2008b).

The rhythmic contraction of the heart affects the pressure within the great veins and produces the typical CVP waveform (Figure 2). Practitioners caring for patients with transduced CVP monitoring should be able to recognise a normal CVP waveform.
assessment of the peripheral perfusion will reveal whether the patient’s vasculature is vasodilated, vasoconstricted or normal. This information, coupled with fluid balance and CVP readings, will provide a balanced reflection of the patient’s intravascular volume.

When recording haemodynamic information three conventions are observed (McGhee and Bridges 2002):

- Cardiovascular pressures are expressed in mmHg.
- Cardiovascular pressures are referenced to the height of the atria.
- Monitoring devices are zeroed to atmospheric pressure.

Care needs to be taken to ensure the accuracy of haemodynamic monitoring. Four key aspects require special attention. These are priming the system, levelling, zeroing and dynamic response testing.

**Priming the system**
The transducer set must be carefully primed using a 500ml bag of 0.9% sodium chloride. The use of heparinised sodium chloride for haemodynamic monitoring is no longer recommended (Tuncali et al 2005, Scales 2008b). Priming purges the air from the tubing system. If CVP is the only pressure to be measured then a single transducer set should be selected. The electrical pressure cables that connect the transducer to the monitor are not disposable and should be cleaned after use (RCN 2010). The equipment needed to transduce CVP is listed in Box 1.

Transducer sets are constructed with high pressure manometer tubing and contain an in-line rapid flush device that can be manually activated (Morton et al 2005). Modern transducer systems are single-use, disposable items calibrated under factory conditions. They are available as single, double, triple or quadruple transducer sets depending on the number of haemodynamic pressures to be recorded. If CVP is the only pressure to be measured then a single transducer set should be selected. The electrical pressure cables that connect the transducer to the monitor are not disposable and should be cleaned after use (RCN 2010). The equipment needed to transduce CVP is listed in Box 1.

Transduced information has a rapid response time. This means there is no delay between a physiological event and the information being displayed on the monitor. By analysing the haemodynamic wave form clinicians can gain valuable additional information that would not be available using a water manometer. An isolated CVP reading is of little clinical benefit; analysis of CVP trends is much more helpful (Morton et al 2005). CVP readings should be interpreted in conjunction with other clinical information. For example, assessment of the peripheral perfusion will reveal whether the patient’s vasculature is vasodilated, vasoconstricted or normal. This information, coupled with fluid balance and CVP readings, will provide a balanced reflection of the patient’s intravascular volume.

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**Time out 3**

Draw and label a normal CVP waveform. Explain why the wave is this shape. Make a note of which patients might be expected to have a low CVP and which might have a raised CVP. Give the rationale for your answer and compare your views with this article.

**Time out 4**

Explain why a pressure bag is needed for haemodynamic monitoring. How much pressure should be used and why? If you have the opportunity to observe or care for a patient with a transduced CVP, practice levelling and zeroing the transducer with a more experienced colleague.

**Box 1**

**Equipment required to transduce central venous pressure**

- Monitor and invasive pressure cable.
- Drip stand.
- Transducer board or other device for mounting the transducer.
- Sterile single transducer set.
- Pressure bag.
- 500ml 0.9% sodium chloride.
- Spirit level.
- 2% chlorhexidine in 70% isopropyl alcohol wipe.

Priming the system The transducer set must be carefully primed using a 500ml bag of 0.9% sodium chloride. The use of heparinised sodium chloride for haemodynamic monitoring is no longer recommended (Tuncali et al 2005, Scales 2008b). Priming purges the air from the tubing system. After priming it is important to check for air bubbles and expel them because bubbles reduce the accuracy of the pressure readings (McGhee and Bridges 2002). Particular attention must be paid to the transducer and the in-line flush device as these are areas where bubbles most commonly can become trapped. After priming, all stopcocks/taps should be closed to air and all connections checked and tightened (McGhee and Bridges 2002). To prevent blood from tracking into the haemodynamic monitoring system, the bag of fluid must be pressurised using a pressure bag. Once the system has been primed, the pressure bag should be inflated to 300mmHg for adult patients. This provides a constant flush through the device of approximately 3ml per hour and also provides the pressure needed to manually activate the in-line flush device.
Levelling  The transducer must be level with the patient's right atrium. With the patient in the supine position, the position of the patient's right atrium is estimated using external landmarks on the patient's thorax (Figure 3). An imaginary vertical line is drawn down from the fourth intercostal space (A) and an imaginary horizontal line is drawn midway between the anterior and posterior surfaces of the chest (B). Where the lines intersect is considered to be the approximate height of the right atrium (Figure 3). This landmark is known as the phlebostatic axis and is more accurate than using the mid-axillary line (Keckeisen 2004). Some patients are unable to lie flat. If this is the case the CVP should be measured in a semi-recumbent position. Levelling should be performed every time the patient's position is changed.

Zeroing  This is a bedside quality control test to ensure that the equipment is calibrated correctly. Modern disposable transducers are calibrated by the manufacturer and their calibration is usually maintained throughout their short lifespan. It is important to check that the calibration is correct, however, as treatment decisions may be made on the basis of CVP measurements. Transducers are sensitive and are easily damaged. Calibration to zero should therefore be checked frequently to ensure the transducer's accuracy (Scales 2008b).

To zero the transducer, the three-way stopcock positioned immediately above the transducer should be switched off to the patient and opened to the atmosphere. The stopcock is an interface where the fluid meets the atmospheric air pressure. Providing the monitor recognises atmospheric air pressure as zero, no further action is required, and the tap should be closed to air and opened to the patient's vascular system. If the monitor does not recognise atmospheric air pressure as zero then the monitor's zero function button should be pressed (McGhee and Bridges 2002). Zeroing and levelling are usually performed together at the beginning of a nursing shift and whenever the patient's position changes.

Dynamic response testing  Because clinical decisions are made on the basis of haemodynamic information it is essential to know that the monitoring system reproduces the patient's cardiovascular pressures accurately. The dynamic response of the system must be tested to ensure the accuracy of the information displayed on the monitor (McGhee and Bridges 2002). The dynamic response test has two elements: the natural frequency and the damping coefficient. The natural frequency tests the speed with which the pressure wave from the patient's blood vibrates within the system. The damping coefficient reflects the number of oscillations before the vibration stops (McGhee and Bridges 2002).

The dynamic response can be checked using the square wave test. When the in-line rapid flush device is activated for one to two seconds the normal CVP wave on the monitor will be replaced by a square wave (Scales 2008b) (Figure 4).
Table 2

Troubleshooting central venous pressure monitoring

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible causes</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVP measurement is abnormally high.</td>
<td>Transducer is lower than the patient's right atrium. Transducer not zeroed.</td>
<td>Use a spirit level to level the transducer with the phlebostatic axis.</td>
</tr>
<tr>
<td></td>
<td>Cather is obstructed or partially obstructed.</td>
<td>Recheck the zero.</td>
</tr>
<tr>
<td></td>
<td>Other infusions may be running through the same lumen.</td>
<td>Activate the in-line flush device. Check the flow of fluid in the drip</td>
</tr>
<tr>
<td></td>
<td>Right heart function may have changed, for example in pulmonary embolism,</td>
<td>chamber beneath the pressure bag. If the catheter is patent the fluid</td>
</tr>
<tr>
<td></td>
<td>myocardial infarction, heart failure or volume overload.</td>
<td>should flow in a constant stream when the in-line flush is activated.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Switch off or turn taps off.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Medical review of patient. Analysis of fluid balance and urine output.</td>
</tr>
<tr>
<td>CVP measurement is abnormally low.</td>
<td>Transducer is higher than the patient's right atrium. Reduced intravascular</td>
<td>Use a spirit level to level the transducer with the phlebostatic axis.</td>
</tr>
<tr>
<td></td>
<td>volume. Increased vasodilation.</td>
<td>Check for fluid or blood loss; the reading may be correct.</td>
</tr>
<tr>
<td>CVP waveform is a flat line; transducer reads zero +/- 2.</td>
<td>System is open to air somewhere. Tubing may be cracked or punctured.</td>
<td>Check for loose connections that allow the pressure to dissipate.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check that all taps are correctly positioned. Check that the tubing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>is connected to the patient.</td>
</tr>
<tr>
<td>In-line rapid flush device does not work.</td>
<td>Fluid bag may be empty. Roller clamp may be closed. A tap may be switched off.</td>
<td>Check thoroughly for small cracks, particularly where Luer threads may</td>
</tr>
<tr>
<td>Blood is backtracking up the tubing.</td>
<td>Pressure bag is not pressurised. Fluid bag may be empty.</td>
<td>have been overtightened.</td>
</tr>
<tr>
<td>The pressure wave has changed, it has a larger range and the waveform appears very dynamic with loss of the standard a, c and v waves.</td>
<td>Cather may have advanced into the right ventricle.</td>
<td>Inform doctor on-call. The catheter may need to be withdrawn and</td>
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<tr>
<td></td>
<td></td>
<td>re-secured. Monitor the patient as there is an increased risk of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>complications, for example dysrhythmias or cardiac tamponade.</td>
</tr>
</tbody>
</table>
Check that the transducer recognises atmospheric zero. If not press the zero button and obtain atmospheric zero before proceeding.

Ensure that any additional infusions running on the same access port are switched off.

Flush the device and ensure good flow by checking the flow in the drip chamber beneath the pressure bag.

Observe the waveform on the monitor. Are the key features of the wave visible? If not, flush the device again to ensure the catheter is not obstructed.

Record the CVP and recommence any infusions that were stopped.

Provided the equipment is zeroed and levelled, and the waveform is clear, the reading should be accurate.

Conclusions

CVP is influenced by blood volume, right heart function and vascular tone. CVP measures the pressure in the right atrium and provides an estimate of intravascular volume. An isolated CVP recording is of little clinical value. Trends in CVP results are more useful clinically, but CVP must be interpreted in conjunction with other clinical information. The patient’s fluid balance and peripheral perfusion should also be evaluated to ensure that a holistic clinical assessment is obtained.

CVP is an important element of haemodynamic monitoring and is relied on in critical care areas. The increased use of CVP monitoring is recommended to improve the post-operative care of surgical patients. It is important that nurses understand the equipment they use and how to test the accuracy of the monitoring system. Accurate measurement of CVP is essential as the results will be used to guide clinical decision making. Nurses caring for patients with CVP monitoring should ensure that the equipment is correctly primed to eliminate air and zeroed to ensure the correct calibration of the equipment. The transducer must be level with the phlebostatic axis to ensure the accuracy of the CVP readings. The CVP waveform provides an indication of the quality of the CVP measurement, and nurses should be able to recognise the features of a normal CVP waveform. CVP monitoring is a useful and valuable skill for practitioners in acute care areas and it is recommended that CVP is measured using a transducer to provide continuous, accurate information to guide clinical decision making NS

References


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