Nursing Practice

Review

Vital signs

Regulation of the blood pressure is a vital physiological process enabling the body to respond to immediately changing demands such as ‘fight or flight’, or resting

The physiology of blood pressure regulation

ORTHOSTATIC HYPOTENSION: PART 2 OF 2

In this article...

- Anatomy and physiology of blood pressure
- Why regulating blood pressure is so important
- Factors that affect the functioning of the baroreceptor reflex

Author
Mike Lowry is former lead for clinical skills and simulation at The School of Nursing, University of Bradford; Julie Windsor is patient safety clinical lead – medical specialties/older people at NHS Improvement; Sarah Ashelford is former lecturer in biosciences at The School of Nursing, University of Bradford.

Abstract

In response to certain situations, a series of actions take place in the body that can either raise or lower blood pressure. It is vital that nurses understand these actions and why they take place. This second article in a two-part series on orthostatic hypotension covers the anatomy, physiology and regulation of blood pressure. Part 1 (nursingtimes.net/Hypotension1Nov9) highlighted how the condition is linked to falls, why it occurs, who is at risk and how it can be identified and managed.

In healthy people, each heartbeat forms a pressure wave that travels down the arterial system. The peak of the wave occurs during systole when blood is under pressure from cardiac contraction making the arterial wall expand. During diastole – when the heart is briefly relaxing – the arterial walls recoil, delivering a pulse (Lowry and Ashelford, 2015).

Systemic circulation (Fig 1) provides oxygenated blood to all organs in the body. It is essential that this blood supply is maintained at all times. After perfusing the organs, blood is returned to the right atrium of the heart through the systemic venous system.

Blood pressure (BP) adapts according to altered needs. For example, when an increase is needed due to altered demands – such as in a ‘fight or flight’ response – BP increases quickly until either the demand changes or needs for increased pressure are fully met. Conversely, when less pressure is needed to ensure adequate supply of blood – for example, at rest – BP reduces to its normal resting value. These rapid, short-term adjustments to BP are controlled by the autonomic nervous system (ANS) through the baroreceptor reflex.

Blood pressure regulation
BP is the result of:
- Cardiac output (CO): the volume of blood that is pumped out of the left ventricle per minute;
- Systemic vascular resistance (SVR): the total resistance opposing blood flow within the systemic circulation.

This can be written as BP = CO x SVR.

CO is a major factor determining BP; however, as blood flows into the arterial system it meets resistance (in the form of friction) from contact with blood vessel walls. The main resistance to blood flow occurs in the arterioles, which are smaller vessels formed from the branching of arteries; they are referred to as resistance vessels (Tortora and Derrickson, 2014). Resistance from all blood vessels in the systemic circuit combines to produce the SVR, which increases BP in the systemic arterial system. These two factors together – CO and the SVR – generate actual BP in the systemic arterial system.

Role of autonomic nervous system
CO and SVR are adjusted on a moment-by-moment basis to ensure BP meets the...
body’s needs. CO is the product of heart rate and stroke volume, which can be represented as $CO = HR \times SV$.

Heart rate is the number of heartbeats per minute and can be measured by assessing the pulse, which is regulated through the ANS (Lowry and Ashelford, 2015). The heart has a dual nerve supply from the two branches of the ANS: sympathetic and parasympathetic.

Increasing sympathetic stimulation to the heart increases the heart rate and the force with which it contracts. This leads to an increase in stroke volume, producing an increase in CO. The same increase in heart rate and force of contraction occurs in response to increased levels of the hormone adrenaline. These effects occur, for example, during exercise or a ‘fight or flight’ response. The force with which the heart contracts also depends on the volume of blood returning to it. Increased force of contraction of the heart is often felt as palpitations and can lead to a feeling of anxiety.

Decreases in heart rate occur through decreasing sympathetic activity and reductions in circulating levels of adrenaline. Increasing the parasympathetic stimulation to the heart reduces the heart rate. The sympathetic and parasympathetic actions oppose each other and allow the heart rate to be ‘fine-tuned’.

Role of venous return

The volume of blood returning to the heart is called venous return. If this increases, more blood returns to the heart, stretching the myocardium (muscle making up the wall of the heart). The more the myocardium is stretched, the more forcefully it contracts – an increase in venous return causes an increase in stroke volume and CO.

Increases in venous return are important during exercise, when skeletal muscles contract more often and forcefully. This squeezes blood in the veins and results in a greater volume of blood returning to the heart. In contrast, if there is loss of blood through haemorrhage, it will result in decreased blood volume and a decrease in venous return. This is why BP drops after significant blood loss.

Understanding the physiology underlying BP is vital to understanding the baroreceptor reflex and its importance in BP control.

The baroreceptor reflex

This is an autonomic reflex that acts to maintain BP in the short term and, in particular, in response to changes in posture, such as when moving from sitting or lying down to standing, when gravity can cause BP to fall. The baroreceptors are receptors located in the walls of the arteries at the carotid sinus and aortic arch. They act as pressure sensors, detecting changes in arterial BP through the stretch of the arterial wall. When BP rises, arterial walls are stretched more and the baroreceptors are stimulated to fire more frequently. If BP drops, the stretch of the arterial walls decreases and the baroreceptors fire less frequently.

The nerve impulses pass from the baroreceptors to the medulla in the brainstem where nerve centres regulate activity of the sympathetic and parasympathetic nerves.

A sudden decrease in arterial pressure will decrease baroreceptor firing, increase the sympathetic outflow and decrease the parasympathetic outflow. These changes will cause vasoconstriction of the arteries and arterioles, which increases SVR. Sympathetic outflow to the heart causes an increase in heart rate and force of contraction, increasing CO. Increased systemic vascular resistance and increased CO together raise the BP.

In contrast, if the BP increases, the baroreceptors will be stimulated to fire more frequently. The medulla will respond by increasing parasympathetic output and decreasing the sympathetic output. This will result in a decreased CO and systemic vascular resistance and, thus a drop in blood pressure.

The following are clinically relevant situations in which the baroreceptor reflex may be compromised.

Orthostatic hypotension

Orthostatic hypotension occurs when there is a sudden drop in BP due to a change in a person’s position. On moving from sitting to standing, or from lying down to standing, gravity acts on the vascular system to reduce the volume of blood returning to the heart and blood pools in the leg (Fig 3). The lower venous return reduces the volume of blood that is available to pump out of the heart, which causes a drop in CO and a momentary drop in BP. This drop can be particularly marked when moving from lying down to standing and can increase the risk of falls (see part 1 of this series at nursingtimes.net/HypotensionNov9).
Transient diminished cerebral perfusion. Carotid sinus hypersensitivity is an exaggerated response to carotid sinus baroreceptor stimulation in the neck, resulting in dizziness, falls and/or syncope from transient diminished cerebral perfusion.

Box 1. Glossary Definitions

- **Adrenaline** - hormone, also called epinephrine, produced by the adrenal gland to prepare the body for flight or fight
- **Arteriole** - small blood vessels formed from the branching of arteries
- **Baroreceptor reflex** - coordinates changes in blood pressure
- **Cardiac output** - volume of blood pumped out of the left ventricle per minute
- **Diastole** - period in the cardiac cycle when the heart refills with blood
- **Orthostatic (postural) hypotension** - sudden drop in blood pressure that occurs after posture change, such as from lying down to standing
- **Vasovagal syncope** - fainting caused by a sudden drop in heart rate and BP
- **Stroke volume** - volume of blood ejected by the left ventricle with each contraction
- **Sympathetic and parasympathetic nervous systems** - the two branches of the autonomic nervous system
- **Syncope** - loss of consciousness caused by a fall in blood pressure
- **Systemic circulation** - circulation from the left ventricle of the heart into the aorta and systemic arteries
- **Systemic vascular resistance** - total resistance opposing blood flow within the systemic circulation
- **Systole** - period in the cardiac cycle when blood is pumped out of the heart
- **Valsalva reflex** - sudden rise and drop in blood pressure occurring when a person strains, for example when opening one’s bowels
- **Venous return** - veins return blood from the systemic circulation to the right atrium of the heart

Characterised by a sudden drop in BP and/or pulse (ventricular pauses of 1.5 seconds and/or fall in systolic BP of >50mmHg), typical triggers include shaving, turning the head, extending the neck and wearing tight collars.

**Postprandial hypotension**

Postprandial hypotension (PH) or low BP after a meal is commonly defined as a decrease in systolic BP of 20mmHg or more, and observed within two hours after meal ingestion. This can occur because eating diverts blood to the stomach and intestines to help with digestion, which, in turn, reduces venous return (as well as stroke volume and CO) and lowers BP. A compromised baroreceptor reflex may not be quick enough to counter this drop in BP, so patients must be advised to take care when getting up after a large meal, especially if they have been immobile for long periods.

Along with orthostatic hypotension, PH can often occur in healthy people – usually there are very modest drops in BP and no symptoms. In older adults, especially those with reduced autonomic and baroreceptor responses, this may cause falls, syncope, dizziness and fatigue (Jansen et al., 1995).

Patients with confirmed PH should eat small, frequent meals that are light in carbohydrates. These patients may also need extra support after meals to ensure they mobilise safely. Given the potential prevalence of this condition among hospital inpatients, nurses should review and take into account the timing of routine observation rounds, which typically occur within two hours of mealtimes.

**Valsalva reflex**

The Valsalva reflex or manoeuvre is a sudden rise then drop in BP occurring when a person strains to open their bowels and can, in some cases, lead to vasovagal syncope (fainting). While straining, exhalation with a closed mouth, nose or glottis occurs, which increases pressure in the chest cavity. This increase in thoracic pressure decreases venous return, which can decrease the heart rate and therefore BP, leading to collapse.

Analysis of a random sample of 200 falls reported to the National Reporting and Learning System showed that 15% occurred while the patient was using the toilet or commode (National Patient Safety Agency, 2007). Although it is reasonable to assume that most of these falls occurred while the patient was trying to attend to personal hygiene, nurses need to be mindful of the potential for vasovagal episodes in these circumstances.

**Conclusion**

BP is a vital bodily function and nurses need to understand its anatomy and physiology to assess the risks of blood pressure becoming too high or too low and to then take the necessary precautions to reduce risk of harm to the patient. NT

References


Articles in the Series

- Part 1: effect of orthostatic hypotension on falls risk, 9 November (nursingtimes.net/Hypotension1Nov9)
- Assessing and managing primary hypertension
- Bit.ly/NTHypertension

For more on this topic go online...