Keywords Anatomy and physiology/ Respiratory rate/Respiration

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In this article...

- Summary of the anatomy and physiology of breathing
- The importance of measuring ventilation
- The effects of ill health on breathing

Respiratory rate 2: anatomy and physiology of breathing

Key points

Breathing has two essential components – ventilation and gaseous exchange

Nurses need to understand the anatomy and physiology of breathing before conducting a respiratory assessment

Ventilation is the cyclical movement of the chest wall and is observed when respiratory rate is measured

Pulse oximetry is used to measure oxygen saturation

A change in respiratory rate is often the first sign of patient deterioration

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Abstract Measurement of respiratory rate is a vital sign. Nurses need to understand the anatomy and physiology of normal breathing to measure respiratory rate and interpret findings. The second in our six-part series on respiratory rate describes the process of breathing and how it is affected by ill health.

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To understand the process of breathing it is important to be familiar with the anatomy of the thorax and the physiology of the respiratory system. Breathing has two essential components:

- Ventilation: the process of physically moving air in and out of the lungs;
- Gas exchange: the process of getting oxygen (O_2) into the body and carbon dioxide (CO_2) out.

Anatomy and physiology

The lungs are situated within the ribcage enclosed by two pleural membranes (Fig 1). At the base of the thorax, separating it from the abdominal cavity, lies the diaphragm. This is the main muscle of inspiration, and is innervated by the phrenic nerve.

The lungs are made up of large and small airways – the trachea being the largest and first of 23 generations of airways. The airways in each generation arise from the previous one by a system of irregular dichotomous branches (Davies and Moore, 2010). The smaller airways (respiratory bronchioles) contain alveoli in their walls. Alveoli are the site of gas exchange and their presence increases as the airways become smaller. This allows for the total surface area of the lung to increase exponentially allowing maximum opportunity for gas exchange.

Central and peripheral chemo receptors sensitive to hypoxia (low O_2 levels) and hypercapnia (increased CO_2) control the drive to breathe (Davies and Moore, 2010).

Ventilation

Air naturally moves from an area of high pressure to an area of low pressure. During normal breathing, inspiration occurs by the contraction and flattening of the diaphragm and the contraction of the external intercostal muscles, causing a rise and outward movement of the ribcage. This increases the size of the thoracic cavity. These changes cause the parietal pleural layer of the lungs to move with the ribcage and diaphragm, creating a negative pressure. The visceral pleural layer attached to the surface of the lungs follows and the lungs expand, drawing air in.

Expiration at rest is a largely passive process; inspiratory muscles relax and there is elastic recoil of the lungs giving rise to a state of pressure equilibrium before the cycle begins again (Bourke and Burns, 2015). This movement of the chest wall is observed when respiratory rate (RR) is measured. Changes in RR occur in response to exercise, emotions and during sleep; those changes in RR associated with exercise and anxiety may be greater than 25 beats per minute but will usually return to normal in a resting, calm state.

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Fig 1. **The respiratory system**

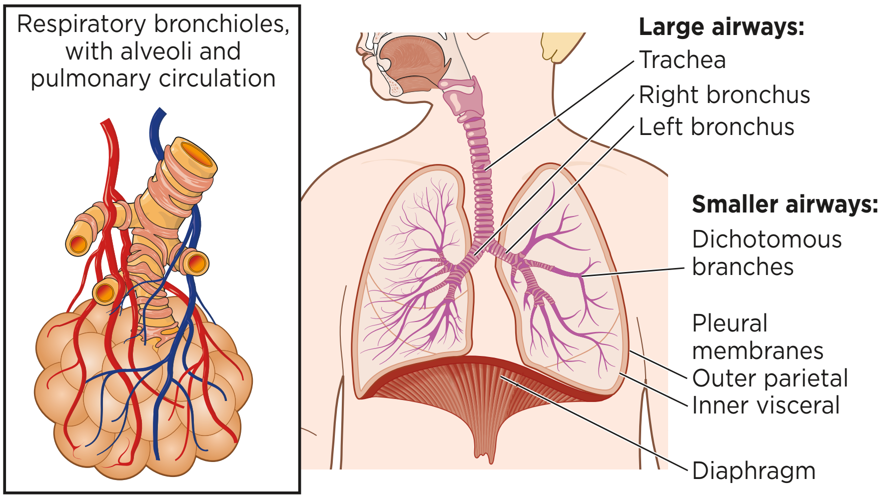
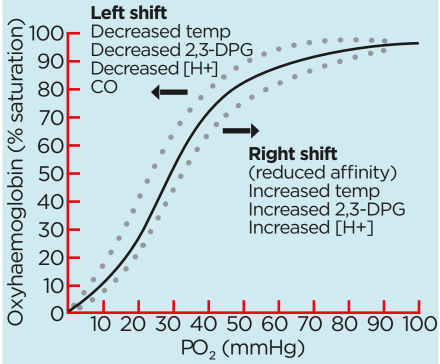


Fig. 2. **Oxyhaemoglobin disassociation curve**



2,3-diphosphoglycerate (2,3-DPG): controls the movement of oxygen from red blood cells to body tissues. H+ = hydrogen ions: increase in H+ results in a fall in pH and acidosis; decrease in H+ results in rising pH and alkalosis. CO = carbon monoxide: binds to haemoglobin in the same way as O_2 but has a much higher affinity

Gaseous exchange

The process of ventilation delivers air to the alveoli where gaseous exchange occurs by a simple process of diffusion. A gas will move from an area of high concentration to an area of low concentration. The partial pressure of O_2 in the atmosphere is higher relative to that in the body and the bloodstream contains a higher partial pressure of CO_2 than the atmosphere. For effective gas exchange to take place, air breathed into the lungs must travel to the alveolar membrane where the capillary walls are thin and there is an overall large surface area.

What is a baseline RR?

When ventilation and gas exchange occur, the normal range of oxygen saturation of the blood (SpO_2) is 94-98% (O'Driscoll et al, 2017) and this can be maintained at rest with a RR of 12-20 breaths per minute.

Fig 2 shows the oxyhaemoglobin disassociation curve. This illustrates how physiological factors may lead to a change in RR as a result of a change in SpO_2. For example, if there is a decrease in the available atmospheric O_2 (PO_2) at altitude, SpO_2 will fall, triggering an increase in RR. In illness where temperature or blood pH levels are altered, shifting the oxyhaemoglobin disassociation curve to the right or left, RR will be affected as the body attempts to restore homoeostasis.

Effect of ill health on baseline RR

It is important to question whether RR as part of the National Early Warning System (NEWS) (Royal College of Physicians, 2017) is more useful in patients who have no known respiratory condition where a score of 0 (12-20 breathes per minute) is a true baseline.

In lung conditions where gas exchange and/or ventilation is impaired at rest, the hypoxic and hypercapnic drives will increase RR to maintain SpO_2. Poor gas exchange, as seen in conditions such as pulmonary fibrosis or emphysema (caused by a thickening of the alveolar wall and destruction of the lung tissue respectively), results in a higher resting RR. It is therefore important to consider the patient's 'normal' baseline.

Common obstructive lung conditions such as chronic obstructive pulmonary disease or asthma are characterised by an increased resistance to airflow as the small airways are narrowed, reducing oxygen delivery to the aveoli. During acute exacerbations this resistance is increased leading to a rise in RR. Administering bronchodilators relaxes the smooth muscle in the wall of the airways reducing resistance and returning the RR to normal levels.

Neuromuscular conditions affecting the lungs often lead to hypoventilation as the mechanisms needed for normal ventilation do not function properly. In this case a low RR (bradypnoea) can lead to respiratory failure.

During surgery and post-operative recovery, RR must be monitored closely as anaesthetics, which usually contain opioids, can depress respiration and reduce RR (Koo and Eikermann, 2011). They act on the central chemoreceptors supressing the drive to breathe.

It is important to remember that pulse oximetry measures oxygen saturation while RR measures ventilation. During early stages of deterioration, patients' SpO_2 may appear to be in the normal range, but the RR will increase in response to inadequate gaseous exchange. Changes in RR is often the first sign of deterioration (see part 1).

The future

RR is an early indication of patient deterioration, and early identification of change ensures that patients receive meaningful clinical interventions. For RR to be useful as an early warning sign in patients with known respiratory disease, we need to know what is normal for that patient.

As will be discussed later in the series there are technologies that can objectively measure a patient's resting RR and we need to consider whether these should be used routinely in practice as with measurement of SpO_2 or blood pressure. **NT**

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CLINICAL SERIES

Respiratory rate series

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