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CASE REPORT

Hypoxia in the rural emergency department: Discussion and case report

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INTRODUCTION

The cardiorespiratory system is responsible for oxygen delivery to the body. Abnormalities in either system can lead to hypoxaemia and its detrimental effects on every organ system. Oxygenation begins in the alveolus and diffuses passively into the pulmonary capillaries, binding to red blood cells and then beginning transportation to the peripheral tissues.[1]

Oxygenation is commonly measured non-invasively with pulse oximetry to get oxygen saturation (SaO_2). This measures the proportion of red blood cells whose haemoglobin is bound to oxygen.[2] This is typically 94%–99% in healthy individuals and lower in disease states.[2] An unexpected low SaO_2 level should trigger an investigation into the cause, and subsequent treatment, given the pathological consequences of hypoxia.[3]

The rural family physician should be familiar with the approach to hypoxaemia, which has a broad differential diagnosis and includes life-threatening causes. An uncommon cause of hypoxaemia is a right-to-left shunt, caused by pulmonary arteriovenous malformations (AVMs), abnormal communications between a pulmonary artery and vein.[4] The incidence is quite rare, ~2.5/100,000; most are congenital and occur as part of hereditary haemorrhagic telangiectasia (HHT).[4,5] In this paper, we present the case of a 25-year-old female with hypoxaemia and discuss the differential diagnosis and management of hypoxia in the clinic and rural emergency department.

CASE REPORT

A 25-year-old Caucasian female presented to her family physician in Banff, Alberta, with complaints of feeling unwell when riding a gondola up to altitude for snowboarding. She attested to headache, nausea and malaise when at altitude. This improved as she descended the mountain. She felt much better by the time she was seen by her family physician. When not dyspnoeic, her SaO_2 measured at the family clinic was 82% on room air. She was then sent urgently to the local rural emergency department for evaluation.

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The Banff Emergency Department had 24/7 access to X-ray imaging and basic laboratory investigations. The closest access to computed tomography (CT) imaging at that time was 120 km away in Calgary, Alberta.

The patient's presenting vital signs were temperature 36.3°C, heart rate 82, blood pressure 114/74, respiratory rate 18 and SaO_2 of 94% on 5 L nasal cannula. The patient had no distress, no increased work of breathing and no infectious symptoms. Her physical examination was unremarkable, with normal heart sounds, normal breath sounds with no adventitious sounds and no signs of deep venous thrombosis.

Pertinent laboratory results were as follows: complete blood count was normal, with a haemoglobin of 157 g/L and a normal white blood cell count. Electrolytes and creatinine (78 umol/L) were normal. A venous blood gas on oxygen showed a pH of 7.39, pCO_2 of 42, PO_2 of 46 and HCO_3 of 25. Her D-Dimer was negative at 0.36 (normal <0.50). Beta-HCG was negative. Electrocardiogram (ECG) showed sinus bradycardia with a heart rate of 57 beats/min. Her chest X-ray showed a rounded opacity in the left lower lobe ~1.7 cm, interpreted as indeterminate aetiology [Figure 1].

Differential diagnosis of hypoxaemia

The differential diagnosis of hypoxaemia can be subdivided into five aetiologies: decreased inspired oxygen tension, hypoventilation, ventilation–perfusion (VQ) mismatch, right-to-left shunt and diffusion impairment.[1,6,7] Often, hypoxaemia is due to a combination of these aetiologies.

Decreased inspired oxygen tension (PiO_2)

Inspired oxygen tension (PiO_2) is influenced by both the fraction of inspired oxygen (FiO_2) and the atmospheric pressure (P_{atm}). Changes in either variable will result in a decrease of PiO_2.

$$PiO_2 = FiO_2 \times (P_{atm} - PH_2O)$$

A reduction in PiO_2 will reduce the PAO_2 or the alveolar oxygen tension. A reduction in PAO_2 will directly affect the $PA\text{-}aO_2$ gradient and will result in reduced transfer of oxygen from the alveoli to the arteries, ultimately causing hypoxaemia.

The most common cause of reduced PiO_2 is high altitude travel, i.e. a reduction in atmospheric pressure, as might occur during aircraft travel.[8] Other less common causes include asphyxiation, or exposure to low-oxygen environments.

Hypoventilation

Hypoventilation refers to a mismatch between the elimination of CO_2 and the metabolic production of CO_2. It is conventionally defined as the pCO_2 above the normal limits of 35–45 mmHg in a conscious patient. As $PaCO_2$ (arterial CO_2) rises, so does the $PACO_2$ (alveolar). The rising partial pressure of CO_2 in the alveoli displaces the alveolar tension of O_2 (PAO_2), reducing the diffusion of O_2 into the pulmonary capillaries and ultimately resulting in hypoxaemia. Hypoxaemia caused by hypoventilation will result in a normal A-a gradient in isolation.[6]

Hypoxaemia due purely to hypoventilation can be recognised by two features: elevated $PaCO_2$ and rapid response to an increase in FiO_2.

Clinical presentations include[9]: CNS depression from respiratory centre ischemia, structural lesions, or drug overdose, impaired neural conduction such as in amyotrophic lateral sclerosis, Guillain- Barré Syndrome, high cervical spine injury, phrenic nerve paralysis, or aminoglycoside blockade. Muscular or mechanical pathologies include diaphragmatic paralysis, myasthenia gravis, Eaton-Lambert syndrome, polymyositis, muscular dystrophy,

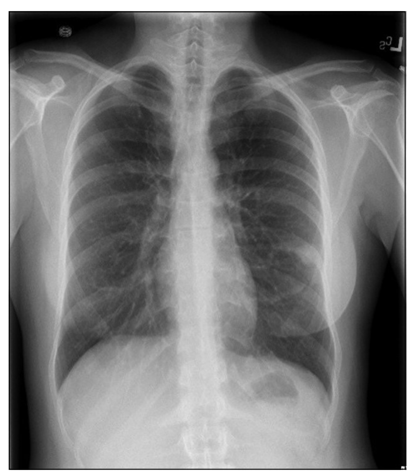

Figure 1: Posterioranterior chest X-ray showing a small rounded mass in the left lateral mid lung zone, not typical for pneumonia.

severe hypothyroidism, obesity hypoventilation, flail chest and kyphoscoliosis.

Right-to-left shunt

A right-to-left shunt occurs when blood passes from the right heart to the left heart without being oxygenated. Right-to-left shunts can be divided into physiologic or anatomic shunts.[6]

Physiologic shunting occurs when non-ventilated alveoli are perfused with blood. Common causes include pneumonia, atelectasis and acute respiratory distress syndrome. Anatomic shunting occurs when ventilating alveoli are bypassed, such as in intracardiac shunts, pulmonary AVMs and hepatopulmonary syndrome.

Ventilation–perfusion mismatch

VQ mismatch occurs when the ventilation and perfusion of the lung are imbalanced.[10,11] Both ventilation and perfusion of the lung vary from the apices to the bases in a normal patient. These changes allow for the A-a gradient, which is essential for proper gas exchange across the lung. When either perfusion or ventilation is abnormal, the VQ ratio is disrupted and hypoxaemia may result. Common causes of abnormal VQ mismatch include chronic bronchitis, asthma, pulmonary embolism (PE) and emphysema.

Diffusion impairment

Diffusion refers to the movement of oxygen from the alveolus to the pulmonary capillary. It is most often limited or impaired by alveolar inflammation or fibrosis, as in interstitial lung disease.[10-12] Patients with diffusion abnormalities often present with exercise-induced hypoxaemia. At rest, blood traverses the lung slowly allowing for sufficient oxygenation regardless of diffusion limitations. With exercise, however, the impaired oxygen diffusion is more apparent and when fibrotic alveoli cannot compensate hypoxaemia results. Diffusion impairment is often accompanied by VQ mismatch.[12]

Case management

At this point, the differential diagnosis included atypical pneumonia, PE (uncommon but possible despite a negative D-dimer) and right-to-left shunt from a pulmonary AVM or cardiac source. Because she had hypoxaemia requiring supplementary oxygen, the decision was made to arrange a CT pulmonary angiogram of the chest. It was late evening in winter with limited local ambulance resources, so the patient was admitted overnight for observation and CT was arranged for the next day in Calgary.

Later that evening, the emergency physician was called to reassess the patient in hospital. Although still asymptomatic and with no increased work of breathing, she had developed oxygen saturations of 92% on 10 L non-rebreather mask. Her examination was unchanged, aside from the increased oxygen requirements. The decision was made to transfer her immediately to Calgary for CT imaging.

CT pulmonary angiography demonstrated multiple bilateral pulmonary AVMs, the largest in the left lower lobe 2.1 cm × 3.0 cm [Figure 2]. She was admitted in Calgary for percutaneous transcatheter embolisation with good clinical outcome. Diagnosis of HHT was made clinically based on a history of epistaxis, telangiectasias and pulmonary lesions. A magnetic resonance imaging brain scan showed no cerebral AVMs.

Managing the hypoxic patient in the rural emergency department

What to look for

SaO_2 is an essential vital sign and should be closely scrutinised for any cardiorespiratory chief complaint. Low SaO_2 necessitates an emergent workup and evaluation for the cause, unless known to be a chronic finding (e.g. a patient with chronic obstructive pulmonary disease [COPD] and known SaO_2 89%–92%).

Evaluate the airway, breathing and circulation of the patient.[13] Assess for airway obstruction, increased work of breathing and accessory muscle use. Apply additional oxygen to the patient using nasal cannula, a non-rebreather mask and if necessary with other advanced airway manoeuvres such as bag-valve mask ventilation, non-invasive positive pressure ventilation and establishment of a definitive airway through endotracheal intubation.[14] These therapies are outside the scope of this discussion, but in general, practitioners should be aware of temporising manoeuvres to supply a critically ill patient with oxygen when awaiting specialist consultation or transport.

Basic investigations include venous or arterial blood gas, complete blood count, serum chemistry, ECG and chest X-ray. Further investigations and simultaneous treatment should be directed at the suspected underlying cause. Consider life-saving treatments during the primary assessment as indicated, such as needle decompression or placement of a chest tube for pneumothorax, or antidotes such as naloxone for suspected opioid toxicity. The chest radiograph is invaluable at diagnosing acute and chronic cardiorespiratory disease, such as pneumonia, congestive heart failure, complications of COPD or other structural lesions. Similarly, a normal chest X-ray might suggest hypoventilation, right-to-left shunt or VQ mismatch and necessitate further investigations.

The stable versus unstable patient

Smaller emergency departments often have limited access to CT scanning, making it necessary to transfer a patient to a centre with such capabilities. This often requires significant logistical decisions regarding timing (immediate or next day) and local resources (access to ground or flight transport). In general, the unstable or very ill patient should be transferred for definitive imaging and management immediately. The stable patient without major vital sign abnormalities or work of breathing can often be treated for the presumed diagnosis when awaiting next-day definitive imaging. This decision should be made in consultation with local experts, including radiology, emergency medicine or other specialist consultants. The timing should take into consideration the patient's clinical trajectory, work of breathing, vital signs, oxygen requirements and suspected underlying diagnosis. For example, a suspected small PE without supplemental oxygen requirements may be suitable to be treated empirically until next-day imaging, whereas an undifferentiated patient with a high oxygen requirement may be approaching the maximal medical care available at the local hospital.

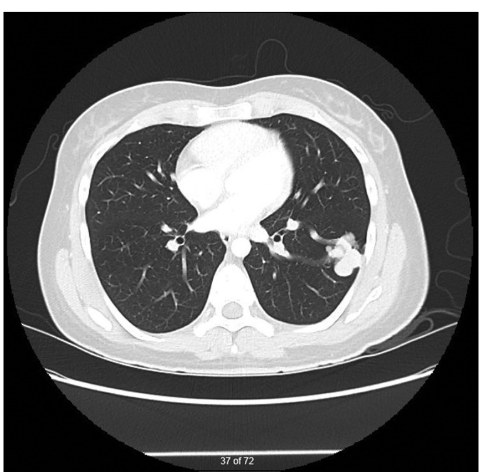

Figure 2: Computed tomography pulmonary angiogram showing a large pulmonary arteriovenous malformation in the left lower lobe, 2.1 cm × 3.0 cm.

CONCLUSION

This case highlights the importance of measuring SaO_2 in the family medicine clinic and then having an approach to the hypoxaemic patient. Consider the five aetiologies of hypoxaemia when initiating therapy and diagnostic testing. The ability to do advanced imaging (example, CT) is often limited in rural settings, which necessitates making difficult decisions about empiric treatment, transportation and timing of investigations. In general, stable patients with low oxygen requirements and a projected clinical course that can be managed with current resources can have next-day imaging arranged. These decisions are complex, depend on local resources and should be made with specialist consultation.

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