Effect of High Altitude on Functional Residual Capacity, Hemoglobin, Lung Capacity, and Anaesthesia Practice

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Abstract: ***High-altitude environments impose distinct physiological challenges that significantly affect respiratory and cardiovascular parameters. These changes directly influence anaesthesia management, particularly lung volumes, oxygen delivery, and the pharmacokinetics of anaesthetic agents. This review summarises the effects of high altitude on functional residual capacity (FRC), haemoglobin concentration (Hb), lung capacity, anaesthetic techniques, and anaesthetic gas delivery, with emphasis on clinical implications for safe perioperative care.***

Keywords: High altitude, Anaesthesia, Functional residual capacity, Haemoglobin, Lung capacity, Vapouriser performance

1. Introduction

Anaesthesia practice at high altitudes (>2,500 m above sea level) differs markedly from that at sea level due to reduced atmospheric pressure and partial pressure of oxygen. Knowledge of these physiological adaptations is essential for ensuring patient safety and optimising perioperative management in hypobaric hypoxic environments.

1) Functional Residual Capacity (FRC)

Effect:
At high altitudes, FRC tends to decrease, mainly due to reduced barometric pressure and hypoxia-induced pulmonary vasoconstriction, which increases pulmonary blood volume and decreases alveolar volume. In acclimatised individuals, chronic hypoxic hyperventilation may lead to a modest increase in FRC due to compensatory lung expansion.

Clinical Implication:
Reduced FRC diminishes the body's oxygen reservoir, increasing the risk of rapid desaturation during apnoea, particularly in obese or critically ill patients.

2) Haemoglobin Concentration (Hb)

Effect:
High-altitude exposure stimulates erythropoietin production, leading to increased haemoglobin concentration and secondary polycythaemia. This enhances oxygen-carrying capacity in low-oxygen environments.

Clinical Implication:
While beneficial for oxygen transport, polycythaemia increases blood viscosity, predisposing patients to thrombotic complications that may affect perioperative outcomes.

3) Lung Capacity and Ventilation

Effect:
Chronic high-altitude exposure can cause a slight increase in total lung capacity (TLC) and vital capacity (VC) through chest wall remodelling and respiratory muscle strengthening. Hypoxic ventilatory drive leads to hyperventilation and respiratory alkalosis during initial ascent. Diffusing capacity (DLCO) increases due to enhanced pulmonary capillary recruitment.

Clinical Implication:
Ventilation–perfusion mismatch is more likely at altitude, necessitating vigilant oxygenation monitoring, especially during sedation or general anaesthesia.

4) Anaesthetic Techniques

Effect:
Regional anaesthesia is generally preferred due to its minimal effect on ventilation and oxygenation. General anaesthesia requires adjustments because hypoxia and hypobaria can alter the pharmacodynamics of anaesthetic agents.

Clinical Implication:
Rapid desaturation risk is higher at altitude, and the performance of volatile agents may be altered. Intravenous anaesthetic agents (e.g., propofol) are often favoured over volatile agents in these settings.

5) Anaesthetic Gas Flow and Vapouriser Performance

Effect:
At high altitudes, reduced barometric pressure affects the partial pressure—but not the volume percent—of volatile anaesthetic agents. Standard vapourisers, calibrated for sea level, may under-deliver anaesthetics at altitude.

Clinical Implication:
Anaesthetists should adjust vapouriser settings or use altitude-compensated vapourisers. Low-flow anaesthesia may be less effective due to oxygen delivery constraints, and oxygen concentrators may function suboptimally, requiring alternative oxygen sources.

2. Conclusion

Anaesthesia at high altitudes demands an understanding of physiological adaptations to hypobaric hypoxia. Alterations in FRC, haemoglobin concentration, lung capacity, and anaesthetic pharmacokinetics necessitate tailored strategies and meticulous monitoring. Regional anaesthesia remains preferable when feasible, while general anaesthesia should be administered with careful adjustments for vapouriser performance and rapid desaturation risks.

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