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Equipment Challenges During Critical Care Aeromedical Evacuation

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Equipment used during aeromedical evacuation (AE) must meet airworthiness standards, and the interactive effects of the AE environment on the equipment and patient should be considered. Recommendations for AE practice are provided.

The aeromedical evacuation (AE) environment is characterized by the stresses of flight, including changes in barometric and partial pressure, humidity, temperature, gravitational forces, vibration and noise. In addition to equipment airworthiness testing, the interactive effects of the stresses of flight on the patient and AE equipment should be considered. This article addresses equipment challenges during long-distance, military critical care AE.

Mechanical ventilation and suctioning at altitude are complicated by decreased barometric pressure and hypoxia (Beninati and Jones 2002; Kashani and Farmer 2006). A standard, ground-based protocol, which was performed using the Impact Uni-Vent® Eagle 754 Transport Ventilator, was effective in preventing suctioning- induced hypoxemia at 6,000 to 10,000 feet (Schmelz et al. 2000); yet, a safety modification caused repeated, unexpected ventilator failures during suctioning at altitude. A suction pressure of 80 to 120 mm Hg is recommended for optimal suctioning. However, higher pressures, which were required to maintain the optimal suction flow rate at altitude, caused a ventilator-induced safety shutdown. In-flight providers must be aware that increasing altitude decreases flow rates, that 80 mm Hg suction pressure is inadequate at any altitude, and that suction pressures greater than 115-125 mm Hg in a closed-suction system may cause ventilator failure at higher altitudes (Bridges et al. 2000).

Liquid oxygen is used onboard the aircraft, but supplies may be rapidly exhausted (Alkins and Reynolds 2002). Oxygen generators offer a solution; however, producing 100% O2 is challenging. Under a worst-case scenario (ARDS model at 10,000 feet) pre-oxygenation with 90% O2 prevented suctioning-induced hypoxemia (Schmelz, personal communication); thus, a generator that produces a lesser O2 concentration may be adequate.

SpO2 monitoring is imperative during AE, as the P AO2 decreases and occult pulmonary compromise (e.g. pulmonary blast injury) may become manifest (Alkins and Reynolds 2002). The cold environment onboard military cargo aircraft (50°F - 59°F/10°C - 15°C) causes thermoregulatory vasoconstriction (Bridges 2003), which may interfere with pulse oximetry. In a study comparing peripheral oximetry to a forehead sensor

(Nellcor®, MAX-FAST), healthy subjects were acclimated to 57°F - 62F° (14°C - 17°C) followed by two bouts of transient hypoxemia (SaO2 to 70%) (Bebout et al. 2001). In 68% of the observations, the lag time for the peripheral sensors to detect the desaturation, compared to the forehead sensor, was 60 to 120 seconds. This lag is of concern in AE, where critically ill patients may have altitude-induced worsening in pulmonary status, along with compensatory and thermoregulatory vasoconstriction. Recognition of the effects of the stresses of flight on pulse oximetry and interpretation of discrepant vital signs (e.g. an acute increase in heart rate, suggesting hypoxemia, without an acute decrease in the SpO2) is essential.

Invasive pressure monitoring systems are not affected by barometric pressure changes, due to the transducer design; however, the fluid-filled pressure line requires special preparation (Bridges et al. 2005a). Ground-based protocols for pressure line preparation do not effectively remove all microbubbles, and these microbubblesexpand at altitude, causing an under-damped system. Modification of ground-based protocols to include use of < 50 mm Hg pressure during line priming, completely filling the drip chamber, and performance of a "rocket flush" (i.e. rapid bolus of 10 ml of saline through the system before attachment to the patient) to flush out the microbubbles significantly improves the dynamic response characteristics of the system at sea level and flying altitude.

Prevention of hypothermia in trauma victims is imperative. A common hospital-based intervention (i.e. forced-airwarmer) is neither safe nor effective during AE. Under AE conditions, passive heat loss prevention (i.e. space blankets and wool blankets) do not prevent hypothermia in a hemorrhagic shock model (Bridges et al. 2005b; Schmelz and Bridges 2003). A combined approach, using passive methods and active heat transfer via an intravenous fluid warmer (Blizzard Blanket™ + Thermal Angel™), was effective in preventing hypothermia under AE conditions (10C/airflow = 0.3 m/sec) (Bridges et al. 2005b), and the passive Blizzard Blanket™ plus active warming from the ReadyHeat™ (a combined non-woven blanket, chemical heating element and a polybag) prevented hypothermia under more rigorous conditions, consistent with rotary wing transport (2C/airflow = 3.6 m/sec) (Schmelz, personal communication 2006).

Equipment used for long-distance critical care air transport must meet airworthiness standards. Ongoing research has identified equipment limitations, as well as recommendations to optimize its use during AE.

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