Aero-medical Considerations in Casualty Air Evacuation (CASADEVAC)

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Introduction

Modern conflict, short of a full scale war is characterised by rapid, short duration, high intensity combat resulting in a large number of casualties. Unlike conventional warfare, where deaths in combat are acceptable, there is a strong socio-political imperative to absolutely minimize casualty rates in military operations short of war. This has prompted armed forces the world over to develop a highly efficient casualty air evacuation (CASADEVAC) system that can exceed the standards of care available at field medical units and even transport unstable patients with one or more organ dysfunction. Two missions which exemplify this philosophy are the evacuation of five critical battle casualties from Bagdad and Talil to Kuwait with 'on board' ventilatory support using a C-130 aircraft [1] and the transport of four mechanically ventilated burns patients from Gaum to Brooke Army Medical Centre in a C-141 aircraft, a flight which lasted for 20 hours [2]. It is important to understand the stress of the flight environment and its effects on the patient and medical equipment for a successful CASADEVAC.

Aero-Medical Considerations

CASADEVAC is dominated by two factors; a hypobaric environment and patient preparation, which could determine success or failure. CASADEVAC presents no problems as long as one remembers that changes in pressure with increasing altitude not only affect physiological processes but may also affect the functioning of life support and monitoring equipment.

Common problems likely to occur in flight are listed in Table 1. There are no absolute contraindications to CASADEVAC. Important relative contraindications are listed in Table 2 [3]. A suggested checklist of patient preparation for flight is shown in Table 3.

Increased altitude with associated decrease in atmospheric pressure imposes two major stressors – hypoxia and gas expansion in body cavities [4]. Physiological responses to either of these two can be immediate and life threatening [5]. Transport aircraft have a cruising altitude of 25000 to 30000 feet with a cabin altitude of 5000 to 8000 feet. At 8000 feet the partial pressure of inspired oxygen is around 108 mmHg which is adequate to maintain an oxygen saturation of over 90% in a healthy individual. However, a critically

Table 1
Common Problems Experienced in Flight

Environmental problems

- Hypoxia and its effects on haemodynamics
- Swelling of limbs beneath plaster casts with resulting neurovascular compromise
- Loss of intravenous access, accidental extubation, bleeding due to vibration/turbulence
- Increased volume of air filled cuffs and body cavities
- Nausea, vomiting because of motion sickness and/or abdominal distention
- In mechanically ventilated patients:
 - Increased incidence of ventilator lung injury
 - Airway obstruction with mucus plugs due to decreased humidity
- Patient anxiety because of noise/vibration, temperature changes

Problems in Monitoring

- Difficulty in manual measurement of pulse and blood pressure due to noise/vibration
- Inaccurate reading of automatic non-invasive blood pressure
- Electromagnetic interference between avionics and monitors
- Difficulty in hearing audio alarms
- Inaccurate delivery of tidal volume in mechanically ventilated patients

Miscellaneous Problems

- Exhaustion of oxygen supply
- Difficulty in performing procedure
- Disposal of patient body fluids and excreta

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Table 2**Relative contraindications of CASA EVAC**

- Pneumothorax, unless reduced by chest tube
- Bowel obstruction from any source (commonly postoperative)
- Laparotomy or thoracotomy within previous one week
- Eye surgery within previous 7-14 days
- Haemorrhagic cerebrovascular accident within previous week
- Severe uncorrected anaemia (haemoglobin <7.0 g/dl)
- Acute blood loss with haematocrit below 30%
- Uncontrolled dysrhythmia
- Irreversible myocardial infarction
- Congestive heart failure with acute pulmonary edema
- Acute psychosis
- Spinal injury unless immobilized

ill patient with pulmonary or non pulmonary respiratory compromise could suffer from hypoxemia. Gas expansion accounts for the majority of contra-indications to CASA EVAC. A change from sea level to altitude of 8000 feet will expand the volume of trapped gas by approximately 35% [6]. In vulnerable patients, this can provoke a tension pneumothorax, dehiscence of surgical wounds, intracranial haemorrhage or irreversible ocular damage. Whereas hypoxia can be detected with pulse oximetry and managed with supplemental oxygen and positive end-expiratory pressure (PEEP), the consequences of gas expansion are difficult to recognize and reverse aboard an aircraft. Expansion of air in the tracheal tube at altitude can cause ischemic tracheal mucosal necrosis and collapse of the cuff during descent could cause a loss of inspired tidal volume. This problem can be circumvented by replacing air with saline in the cuff of the tracheal tube. Decreased barometric pressure can lead to changes in the delivered tidal volumes by ventilators which are not pressure compensated resulting in possible volutrauma [7].

Other aero-medical issues pertain to forces of acceleration, noise, vibration and decreased humidity. In a supine patient, gravitational forces (G forces) during acceleration as in 'take off' will act in a horizontal axis and will result in pooling of blood in the lower extremities if loaded head first. Healthy humans will be able to mount a compensatory sympathetic response. Patients with labile haemodynamics or impaired autonomic function could have a fall in cardiac output. A patient with a head injury could have raised intracranial tension during 'take off' if positioned feet first. The G forces will act in the opposite direction while landing. Patient positioning therefore requires careful consideration.

Noise and vibration, apart from causing fatigue and anxiety can contribute to motion sickness and interfere with communication, which can seriously jeopardize monitoring of vital parameters. The most basic of monitoring skills require nothing more than a stethoscope

Table 3**Checklist of Patient Preparation****Head injuries**

- Careful positioning of patient to avoid rise in intra cranial pressure (ICP)
- Use of eye pads/ointment/artificial tears in unconscious patient

Maxillofacial injuries

- Quick release mechanism for wired jaws or easy access to wire cutters

Chest injuries

- Ensure functional status of inter costal drainage (ICD) tube
- Never clamp in flight

Abdominal injuries

- Ensure all drainage tubes are unclamped or on continuous suction

Orthopaedic injuries

- Avoid use of pneumatic splints
- Ensure optimal stability of the fracture segments

Haemorrhagic shock

- Ensure minimum haemoglobin of 7.0 gm/dl
- Likely to have increased IV fluid requirements in flight
- Availability of pressure bags

Burn injuries

- Ensure escharotomies for full thickness circumferential burns

Airway management

- Use saline for filling cuff of endotracheal/tracheostomy tube
- Use tube fixator for endotracheal tube
- Supplemental oxygen to maintain saturation > 90%

Liaison with aircrew

- Cabin altitude
- Weather en-route

and a sphygmomanometer. In a flight environment, noise significantly limits the ability of the caregiver to use these simple tools to assess blood pressure and heart / breath sounds. The noise level in many of the currently used transport aircrafts approach 90 decibels, similar to that of a helicopter, which is approximately 2000 times louder than heart/breath sounds [8]. Noise also precludes appreciation of auditory alarms of ventilators and monitors, necessitating continuous eye contact with the patient and equipment. Vibration can interfere with graphic displays of electrocardiogram, pulse oximetry and ventilatory parameters. Decreased humidity causes respiratory secretions to dry up resulting in atelectasis and blockage of tracheal tubes. Flight is thus an austere, hostile environment comprising of the deadly trinity of hypobaria, G forces and noise with vibration which are of no consequence on the ground but assume an important role in the management of patients in the air.

Air evacuation with on board intensive monitoring and care is the preferred method of evacuation of the critically ill and will become routine in future. Advancements in the field of aviation (tilt rotor aircraft) and medical technology (user friendly, sophisticated, miniature monitoring and life support equipment) can

create an intensive care unit (ICU) in the sky which can offer state of the art critical care to casualties right from the battlefield to tertiary care centres. However these technological advancements need to be backed up with properly trained medical teams who are well versed with aspects unique to aero-medical evacuation including the effects of flight physiology on medical conditions, oxygen limitations and distinctive medicare requirements.

Conflicts of Interest

None identified

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Journal Scan

JE Smith, EJ Hall. The use of plain abdominal x rays in emergency department. *Emerg Med J* 2009; 26: 160-3.

Investigations are useful when the results affect clinical management by confirming or excluding a diagnosis, or when they aid risk stratification of a potentially serious condition. The plain abdominal radiograph (AR) is a commonly requested investigation in the emergency department (ED). The average AR exposes the patient to 35 times the radiation dose of a chest radiograph (0.7 mSv). Anecdotally, the AR is overused and unhelpful in the majority of conditions presenting to the ED. In the past, surgeons have requested an AR as part of the routine work-up of patients with undifferentiated abdominal pain. There are also more specific reasons for requesting this investigation, for example in the case of an ingested foreign body, intestinal obstruction, renal colic, pancreatitis and suspected appendicitis. The Royal College of Radiologists (RCR) have recently updated guidelines for the use of plain abdominal radiography in the hospital setting, although they do not specify whether this is applicable to ED patients in most cases and many of the recommendations are made on the basis of poor quality evidence or expert opinion. In this review authors aim to unearth the evidence supporting the use of the plain AR as a diagnostic test in the ED by performing a structured literature review. A comprehensive search of the literature was carried out by authors, using Medline and Pre-Medline (OVID platform) from 1966 to June 2007, Embase, evidence-based medicine reviews and the Best BETS database. Search terms included “plain abdominal radiograph”, “abdominal X rays”, “abdominal films”, “abdominal roentgenogram”, “abdominal imaging” and “abdominal pain”. The

MeSH heading searched was “radiography, abdominal”. The bibliographies of relevant papers were examined and cross referenced. Papers were critically appraised for the quality of evidence presented. Studies were preferred in accordance with the usual hierarchy of evidence, namely controlled clinical trials, prospective studies (including case-control studies) and case reports. Review articles were examined for their reference lists. A total of 38 original papers were found that were relevant to the research question and these have been examined in detail.

A recurring problem throughout the studies was the lack of a consistent gold standard with which to compare the plain AR as a diagnostic test. Some recent studies have used computed tomography (CT) as the gold standard. Many of the retrospective chart reviews had no methodological control and were simply the author’s subjective interpretation of the results. No evidence was found to support the use of plain AR in patients with pancreatitis, inflammatory bowel disease, renal failure or haematuria. The authors concluded that abdominal radiographs expose patients to significant doses of radiation and have limited use in emergency medicine. They said that this review explores the evidence supporting the use of abdominal radiographs in the emergency department, with particular reference to recent guidelines published by the RCR and the author’s recommendations for the use of abdominal radiographs in the emergency department are given.

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