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Monitoring during aeromedical evacuations: limitations and concerns

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Abstract

Aeromedical Evacuation (MEDEVAC) of critically ill patient is a risky business. The hostile and unsavory environment of the aircraft subjects not only the patient and the Critical care air transport team (CCATT) but also the monitoring equipment carried to tremendous amount of stress and strain. The monitoring standards required in such alien environment cannot be compromised and in-fact is required a step higher than required in the ground. However most of the equipments are not designed to compensate for such austere conditions. Hence it becomes imperative to understand the nuances of this alien environment on the monitoring equipments which are exposed to changes in pressure, temperature, gravitational forces, noise,vibrations etc.

Keywords: Blood urea, Creatinine, Diabetes, Nephropathy, Proteinuria.

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INTRODUCTION

Armed Forces Medical services care for military and civilian patients injured in hostilities, accidents, or with acute illnesses. Depending upon the nature of injury or illness these patients need to be evacuated by the fastest means of transport i.e aeromedical evacuation (MEDEVAC). These patients need not only require resuscitation but stabilization and maintenance of their vitals while been transferred. Monitoring of these patients enroute is the key for any desired intervention or outcome. Patient monitoring during air evacuation need to be of the standards set by professional bodies such as the Indian Society of Anesthesiologists[1], although monitoring required is often enhanced to compensate for the environment. There is little, if any, published information on monitoringin the field which would meet today's 'evidence-based'criteria, nor is there ever likely to be.

The Environment and its effects on monitoring

The majority of medical devices are designed to be used in hospitals with minimal regard being given to function in extreme hostile environmental conditions which these equipments are subjected to when patients are transferred by air. The variations in temperature, vibration, g forces and pressure on these equipments is tremendous and these equipments are not calibrated against these variables. Equipment casings, seals, components and adhesives can degrade rapidly, which may interfere both with the functioning and longevity of equipment. Service requirements of these equipments are increased and the overall life span of devices is reduced. Unreliability of monitoring equipment may result in critical incidents and patient harm[2]. The shelf life of consumables for monitors may be reduced as well. In the austere environment of aircraft the familiar audible and visual indicators which indicate machine malfunction may be lost because of increased background noise, low light conditionsor other distractions. In these circumstances the monitors which monitor the medical devices themselves need tobe observed more closely. These 'machine monitors' provide information regarding the status and function of the electromechanical devices in use. The indicators which provide informationa bout normal status are as important as those indicating malfunction. Machine-monitored variables depend on thetype and function of the equipment involved and include indicators of pressure variation, device cycling or of delivery of gas or fluid (Table 1). Intensity of monitoring varies, escalating orreducing, according to the nature and stage of the patient's illness. Patient-monitored variables used inroutine monitoring are shown in (Table 2). Ideal monitoring equipment usually used should measure all ofthe variables required to deliver full care. In addition it must be reliable, rugged, have the capability to utilize multiple power supplies, be economic to run and comply with all of the relevant regulations governing it if any. Changing batteries or power supplies preferably should not interrupt the device's function. Some of the most important characteristics of ideal transfer equipment are summarized in (Table 3). Devices must also be able to be restrained

Table 1: Machine monitored variables

Multifunction Monitor	Ventilator	Syringe pump	Suction Apparatus
ECG leads	Oxygen Pressure	Pressure	Pressure
Artifact indicator	FiO_2	Delivery rate	Battery charge indicator
Defibrillator energy selector	Air Pressure	Infusion volume (total)	Power mains indicator
Power Status(Battery/Mains)	Power Status	Power status	
Mode	Turbine Function	Air block indicator	
Malfunction indicator	Malfunction indicator		

Table 2: Patient- monitored Variables

ECG
Non-invasive and Invasive blood pressure
End tidal carbon di oxide
Oxygen saturation
Neuromuscular blockage
Temperature
Tidal Volume
Respiratory frequency
Inspiratory pressures (peak,mean,plateau pressures ,positive end expiratory pressure)

Table 3: Characteristic of an ideal transfer equipment

Characteristic	Note
Type	Measures Variables required
Weight	Lightweight and portable
Size	Easy storage , Display large enough to be visible
Fixation	Can be fixed to the required standard in any ambulance, patient transfer unit
Shape	Low centre of gravity. Easily fixed and held
Simplicity of operation	Controls easily manipulated, Accepted modes and settings
Consumables	Should be user friendly and universal
Safety	Loss of function reverts back to the least hazardous mode
Indications	Should indicate all normal and abnormal function
Alarms	All visual and audible alarms
Power Supply	Worldwide voltage and frequency, able to fit with aircraft auxiliary power Supply, exchangeable internal battery covering external power failure
Rugged	Compatible with all environments
Reliability	Low failure risk
Training	Supplied with complete training package.

appropriately while in use, as they may be subjected to 'g' forces and vibration in aircraft. Suitable tie-down systems, straps and clamp systems are needed. Most developed countries have medical doctrine stating that care should be seamless, continuous and progressive monitoring throughout the evacuation chain. Unfortunately, such doctrine is not there with Armed Forces Medical Services of India.

Air evacuation of the casualties may be fixed or rotary wing aircraft and may be tactical or strategic. Tactical transfers vary from a few minutes to 1 or 2 h. Longer missions are usual, specifically due to the non-availability of tertiary care centers specially in north eastern India. It is also more difficult to provide increasing levels of care with acontinually moving patient with long distance aero medical evacuations (MEDEVAC).

Minimal monitoring standards and its concerns in medevac

In flight patient care is progressive and proactive as it isin the hospital and monitoring that would be appropriate tothat setting must also be available. Patients who are criticallyill may deteriorate despite best efforts, but this should not beattributable to the transfer itself [3]. The concept is of a continuous chain of high-quality care, reducing morbidity andmortality to an absolute minimum. Minimal monitoring standards require the monitoring of inspired oxygen and end-tidal CO_2 in ventilated patients. Polarographic oxygen analyzers consume less power and areless likely to be susceptible to electromagnetic interference (EMI) than equivalent paramagnetic analyzers[4]. The disadvantage is that they measure the partial pressure of oxygen and rely on an algorithm to calculate percentage. Partial pressure decreases as an aircraft gains altitude, even with pressurized cabins, although the percentage of the gases remains the same as those at sea level. As a result the devices under-read the oxygen percentage at altitude, although thevalue on the readout gives the 'equivalent' sea level. With portable devices a correction factor may need to be applied to obtain the correct concentration or a manual recalibration at ambient pressure may be possible. Unlike oxygen monitors, end-tidal CO_2 monitors are unaffected by altitude in the ventilated patient. All end-tidal devices (even those that display percentages and not partial pressure) actually measure partial pressure and as this is constant for CO_2 they will read virtually the same at altitude as they do at sea level. In a spontaneously breathing patient, who is compensating for hypoxia at higher altitudes, end-tidal CO_2 will decrease as a result of hyperventilation, but this is not an issue at normal cabin altitude unless lung function is abnormal to begin with, and is negated by adding inspired oxygen. Side-stream capnography is susceptible towater in sample tubes and machines using this system arenot usually designed for anything other than short transfers. The pumps used in these systems often consume a lot of power. Main stream measurement is practical, but also uses considerable power which needs to be allowed for and adds weight to tracheal tube connections. On volume preset

ventilators delivered tidal volumes will be less than set tidal volumes unless these compensations are undertaken in ventilators with compressors or turbines supplying air to the system. Gas-driven constant flow generators will be less susceptible to these effects because of the high pressure driving gas for their fluidic circuits, but the lower partial pressure of entrained air for the inspired gas will affect tidal volume and minute ventilation. To avoid these issues close monitoring of these variables must be undertaken. When power is a consideration for a monitor, regular measurement of arterial blood gases is the best option, provided other disconnect alarms are adequate. Hand-held devices like I Stat are commercially available to measure blood gases and other variables.

Change in pressure affects equipment and components which contain air in it. As ambient pressure reduces bubbles may expand in fluids within monitoring transducers andcause dampening of arterial or venous pressure waves leading to inaccurate readings. Most fluids contain some dissolved gas which will come out of solution at altitude and will form bubbles which may coalesce and present further hazard. In this situation the use of air detection monitoring in fluid delivery systems and the use of air traps is of value.

Balloons on catheters in the pulmonary circulation present a potential problem if they expand. Deflating them and reviewing the need for these devices reduces the hazard. Monitoring and support equipment also have items such as touch control pads which contain air and may be vulnerable to pressure change.

The standards are more rigorous for equipment carried in aircraft as it must be able to resist damage due to three-dimensional inertial forces which are encountered during flight. Noise is a particular problem with aircraft. It poses health and safety hazards to the patient and attending staff and interferes with communication. It is a greater problem in rotary wing, small aircraftand larger military aircraft, designed for the transport of freight. The disorientation caused by constant loud noise with varying frequencies compounds the lack of normal feedback from familiar sounds. Increasing the volume of alarms may assist, but it is often negated by protective equipment and communication headsets. Clinical monitoring such as palpating the pulse, measuring blood pressure, viewing respiratory patterns and seeing colour changes is often impossible in aircraft. This is because of reduced or altered lighting, noise andvibration. The effects of coarse and fine vibration generated by aircraft have not been studied on any type of monitor. To reduce the effect of inertial forces and vibration, impact resistant and absorbent foam materials should be incorporated into equipment. Fans for cooling equipments also draw contaminants into equipment and require protection with filters.

Aircraft Authorities such as the Civil Aviation Authority have regulations that deal with the carriage of equipment inaddition to that integral to the aircraft. These regulations also cover equipment which is not related to and may potentially interfere with aircraft function. At present restrictions relating to medical equipment are such that 'carry on' equipmentis usually exempt. Presently there is no Airworthy Medical Equipment(AME) test programme being carried out by any agency in the country and it is entirely on request basis. In fact all equipment procured henceforth should be air worthy and should be tested for variables given in (Table 4).

Table 4: Variables for Test for equipment

Electromagnetic compatibility
Altitude
Sudden decompression
Explosive decompression
Vibration (low and high frequency conducted susceptibility)
Acceleration/Deceleration
Humidity
Salt Corrosion
Water-proofers
Temperature
Fluid contamination
Requirements of aircraft electrical and mechanical interface requirements
Shock drop and topple survivability
Electrostatic discharge
Radioactive susceptibility
Dust and sand proofing

Organization and Training

Human factors are extremely important in aeromedical evacuation as it is ahigh-stress environmentand should only be undertaken by those who are specifically trained and equipped. If the human factors are not addressed, regardless of how effective the monitors are,there will be a failure to recognize abnormalities and noaction will be taken. Organization and high-quality training are the keyto success [5]. Each item must be understoodin detail to avoid making fundamental errors regarding capability, function, mode selection and alarm indications. The commonest mistakes usually made during transfers are over estimating battery life and misunderstanding mode settings. Training reduces errors and allows standards to be properly assessed and maintained.

CONCLUSION

Effective monitoring in aeromedical evacuation demands the appreciation of a number of factors. It depends on having an understanding of the rigors' of the environment and a thorough knowledge of the capabilities and limitations of devices being used. Personnel must be properly trained to survive and function in the environment, as well as be able to care for and protect their patients. This requires that they are current in clinical practice and have undertaken a detailed training. Meeting these requirements reduces the risk to patients and personnel and allows for advanced patientcare in the field.

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