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Critical Care Air Transport: Experiences of a Decade

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Abstract

Advances in critical care medicine in recent times has led to favourable outcomes of critical patients, although at a high cost. Military operations along with natural or manmade disasters are two scenarios where critical patients are left in austere environment. Providing advanced ICU facilities in the austere environment may not prove to be economical or sustainable, hence the need arose for mobile ICU or the CCAT for immediate air transport of critical patients to advanced ICU centres. Firstly, by doing this the critical patient is not denied the best available post resuscitation care and secondly the burden on medical resources at the periphery is reduced and they can concentrate on managing the less critical patients. Aeromedical transport has its own challenges and constraints. This requires proper planning and prior training of the CCAT. Although optimal strategy are not formulated, endeavour is to integrate initial resuscitation of critical causalities at the peripheral medical set up with optimal post resuscitation care at advanced ICUs. Critical care air transport has evolved considerably over the past one decade since its inception in the IAF. The current paper can be useful in getting an overview of this new field. Meanwhile, the reader also gets to know the basic aspects to keep in mind, the technical details and important considerations before carrying out such missions.

Keywords: Critical care, Air ambulance, Patient transport.

INTRODUCTION

Since its birth in the late 1950s, critical care medicine has evolved rapidly both in terms of medical knowledge and equipment expertise in management of critical patients [1]. Recent studies have elucidated a significant impact on patient outcomes that result from Intensive care Unit (ICU) physician staffing models [2]. A modern ICU represents a complex assembly of skilled personnel and physical infrastructure. This infrastructure must include space to support patients and staff, temperature control, secure oxygen, electricity, water, and vacuum sources, medical supplies, pharmaceutical agents, and equipment [3]. ICUs also have ready access to surgical, radiographic, transfusion, and laboratory capabilities. The level of care available in an ICU establishes a standard of care for unstable patients.

Natural disasters, man-made disasters and human conflict are the occurrences, wherein, the caregivers need to develop the capability to extend this standard of care into austere environments.

The concept of critical care air transport team was developed in the U.S. Air Force in the year 1988. Presently, it comprises of teams of specialists in critical care, emergency medicine, anaesthesiology or surgery with support staff trained in critical care that operates a portable ICU on a transport aircraft [4, 5].

This paper is meant to give an insight into this domain of critical care wherein a portable ICU is used and critically ill patients are transferred by air. The challenges faced will be discussed and the scope and future of transporting critically ill patients in India will be addressed.

CRITICAL CARE IN FIELD HOSPITALS IN INDIAN ARMED FORCES

An overview of hospital setup in armed forces

Field hospitals have been developed by military medical services, civilian governments, and non-governmental organizations to serve the population affected by war, unrest, or disaster. From a critical care perspective, these hospitals must prepare not only to address trauma or direct effects of a disaster, but also to treat pre-existing disease and decompensation of patients with comorbid conditions. Field Hospitals are the first surgical facility for life and limb salvage. Evacuation from Forward locations to these

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field hospitals is done by ambulances, air, mules or stretcher bearers. The Field Hospitals are manned by a single surgical team able to hold 45 patients and undertake 10 -12 surgeries in 24 hours. There is no provision of ICU beds at this level of care.

The Core Level Hospital, a medical re-engineering initiative is 84 bedded modular hospital having 24 ICU beds having 2 operation theatres and is capable to perform 36 surgeries per day. The staff is 56 officers and 112 men as compared to 16 men in the Field Hospital.

In case of a battle casualty or a disaster, a patient is first moved to the primary care facility that is a Field Hospital and primary care is given. If the patient is critically ill, or needs ICU support, he/she has to be transported to the Core Level Hospital [6]. Transportation by air is fastest and with the availability of critical care air transport team it gets proficient.

Critical Care Air Transport in the Indian Air Force

CCAT in IAF took off a decade ago in the North Eastern sector with Jorhat (Assam) as the nodal centre from where CCAT missions were managed. It was an ideal centre because of its availability of aircraft resources. There was a great demand and positive feedback, firstly, because of the remoteness of the entire North Eastern region with little advanced medical setup, and secondly, due to the terrain which made travel by road exhausting and time consuming.

CCAT teams were also setup at Hindon (near Delhi), since the last 2 years, to cater to the needs of the units in the Northern sector of India. At Hindon, CCAT missions have gained momentum and in the last year itself have undertaken about 50 evacuations of critical patients both in peace, mostly due to very harsh environmental conditions and in Anti-Terror Operations hostilities.

Over the time, CCAT with its PTU (Patient Transfer Unit) has evolved with experiences. In the Indian Air Force, CCAT team consists of an Anaesthetist, 4 ORAs (Operating room assistants) who are something similar to the EMS personnel, along with the PTU. Drugs as in Table 1 are arranged in labelled compartmentalised backpack (Fig-1). The team is equipped with an I-stat for arterial blood gas analysis apart from a multiple parameters monitor and a defibrillator. The ventilator is turbine driven with oxygen supplies totally independent of the Aircraft systems. PTU is self-sustainable in terms of power and oxygen supplies for about 3.5 hours. This suits Indian conditions as the flying time is not more than 3 hours duration. Military aircrafts generally used are both the Fixed Wings and Rotary based on the place from where medical evacuation has to be carried out.

Table 1

	Drugs (Injectables)	
Anaesthesia	**Cardiac**	**Miscellenous**
Atropine	Adrenaline	Ondansetron
Glycopyrrolate	Nor Adrenaline	Ranitidine
Midazolam	Vasopressin	Metoclopramide
Fentantyl	Amiodarone	Pantoprazole
Thiopentone sodium	Xylocard	Sodium Phenytoin
Propofol	Dopamine	Potassium chloride
Succinyl choline	Dobutamine	Calcium gluconate
Vecuronium	Adenosine	Furosemide
	Metoprolol	Hydrocortisone
	Esmolol	Deriphylline
	Nitroglycerine	Sodium bicarbonate
	Atropine	Diclofenac sodium
		Pheniramine maleate
		Promethazine
	Equipment	
Airway and Ventilation	**IV Access**	**Accessories**
Guedels Airway (3, 4; each- 01)	Spirit	ECG Electrodes
ET Tube (6, 6.5, 7, 7.5, 8 each- 02)	Swabs	Suction Catheter
I-Gel (3,4,5)	IV Cannula (S-22,20,18,16)	NIV Mask
Nasopharyngeal Airway (6.5,7,7.5)	Extension Line (100cm & 50cm) -03 each	Gloves
Cricothyroidectomy Set- 01	3 Way stop cock	Surgical Mask
Laryngoscope Set	Central Venous Cannulation Set-01	Suction Tube
Macgill forceps -01	Syringes (2cc,5cc,10cc)	ECG Gel
Endotracheal Combitube Adult -01	IV Fluids(RL, Starch, Haemaccel)	Biomedical waste boxes
ET Tube connector- 01	IV Fixator	
Bain’s Circuit- 01	Sterillium	
Re-breathing Bag- 01	IV Set	
ET Tube holder- 01	Elasto plaster	
AMBU bag complete set- 01		
Catheter mount- 01		

Figure 1

Unlike civilian retrieval, challenges are different by the fact that, it's a risk to yourself and within norms of ethics, to the patients as well. The request for aeromedical evacuations comes from the peripheral medical units through higher command formations, where along with liasoning with other branches for aircraft availability, the CCAT team is informed.

Reasons for air evacuation include gunshot & blast injuries, burns, intra cranial bleeds, post myocardial infarction, trauma, and complications of snakebite which mandate advanced ICU care at higher medical centres. Sometimes air evacuations are carried out even in cases not indicated purely on medical grounds but just to keep the troops at the borders in good spirit i.e. for morale boosting. Air evacuations are also carried out to decongest the limited medical resources at the periphery.

With the experience of over 300 medical evacuations, the CCAT team headed by the authors have developed a scoring system for assessment of patients and requirement of transfer to a higher centre. Based on a scoring system the CCAT team marks the casualty and decisions are taken accordingly. This tool has been found to be useful and is under further research. Table 2 shows the scoring system in its present form.

CCAT teams are always at standby and are prepared to be launched at a short notice, any time during day or night. With optimal planning and work distribution, the CCAT team functions within the aircraft environment and its limitations.

Table 2: Scoring system for evaluating severity of casualty for deployment of PTU

S no.	Clinical Condition	Score	Patient Score
1.	**Nature of Morbidity**		
	a) Priority III	1	
	b) Priority II	2	
	c) Priority I	3	
2.	**Hemodynamic stability**		
	a) Stable	0	
	b) Stable with fluid resuscitation/ ionotropic support	1	
	c) Unstable	2	
3.	**Airway integrity**		
	a) Airway uncompromised	0	
	b) Airway compromised and requires one of the following:		
	i) Oro/Nasopharyngeal Airway	1	
	ii) Supraglottic device	2	
	iii) Intubation/tracheotomy	3	
4.	**Requirement of oxygenation**		
	a) No oxygen supplementation	0	
	b) Oxygen supplement at low FiO_2	1	
	c) Oxygen supplement at high FiO_2	2	
	d) On ventilator	3	
5.	**Chest Injuries**		
	a) No chest injury	0	
	b) No active interference	1	
	c) Chest tube in situ	2	
	d) Flail chest/ perforating chest injury	3	
6.	**Risk of ongoing hemorrhage**		
	a) No hemorrhage	0	
	b) Bleeding controlled with pressure bandage	1	
	c) Retracted Bleeders	2	
	d) Concealed hemorrhage(thoracic, abdominal or intracranial)	3	
7.	**Cranial Injuries**		
	a) No head injury	0	
	b) GCS > 13	1	
	c) GCS 9- 12	2	
	d) GCS <8	3	
	Total	20	

Maximum score = 20
Definite requirement of CCAT with PTU = 12 or above/20
PTU without CCAT = 9 to 12/20
Reconsider decision = less than 8/20
PTU- Patient transfer unit
GCS- Glasgow coma scale
FiO_2- Fraction of inspired oxygen
Priority I- Critical life threatening – needs immediate attention
Priority II- Serious injuries – needs attention
Priority III- Less serious injuries – needs attention but can wait

After every CCAT mission, a case report is prepared in which difficulties and suggestions for improvement are discussed and changes incorporated subsequently. Follow-up of the patients transferred are carried out quarterly.

Over the past decade, CCAT has evolved and incorporated changes in a wide range including issues like the uniforms worn by team members, the team component, training, change in equipment, kitbags and preparation and up gradation of standard operating procedures. This has been a dynamic process throughout. Training is imparted at the prestigious Indian Aerospace Medicine (IAM) Centre at Bengaluru and the team members are also involved in any procurements of advanced equipment for CCAT.

ISSUES IN AEROMEDICAL EVACUATION

Providing critical care in a fully functioning ICU at a tertiary care centre is a challenging job in itself. Providing same level of care in a transport aircraft adds onto the challenges. Aeromedical evacuation faces challenges on two major fronts which can be broadly divided into two categories; medical and environmental.

Medical Factors

Generally, transport aircrafts have a cruising altitude between 30000 to 40000 feet. The cabin air pressure is maintained as the pressure is between 6000 and 8000 feet. Increased altitude with associated decrease in atmospheric pressure imposes two major stressors namely, hypoxia and gas expansion in body cavities [7]. Physiological responses to either of these two can be immediate and life threatening [8]. In an already compromised state in a critical patient these stresses adds on to the challenging task of in transit stabilization.

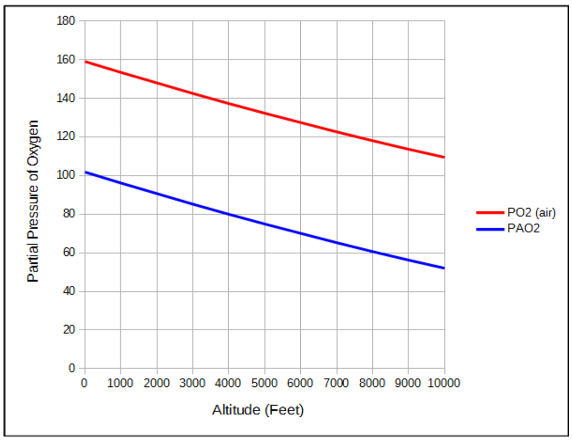
To understand the hypobaric hypoxemia analysis of the alveolar air equation is necessary:

$$PAO2=(FiO2\times(P_B-P_{H2O}))-PaCO2\times(FiO2+\frac{1-FiO2}{RER})$$

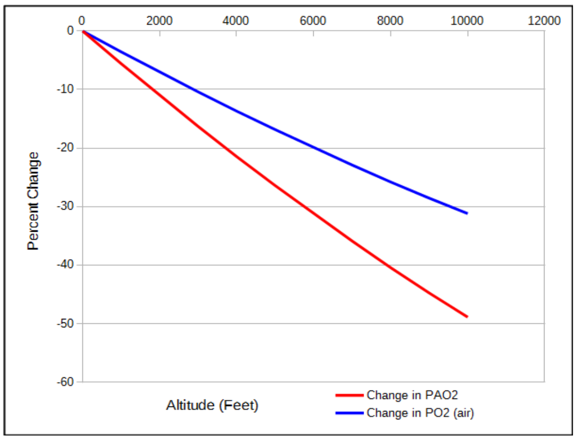
When normal values are plugged into the alveolar air equation it looks like this:

$$PAO2=(0.21\times(760-47))-40\times(0.21+\frac{1-FiO2}{0.8})$$

Increase in altitude reduces barometric pressure (P_B) which in turn results in decreased partial pressures of oxygen both in the inspired air and alveoli. The percentage decrease is more at alveoli because the partial pressures of water vapour and carbon dioxide are relatively constant as illustrated below in graphs 1 and 2.This implies that although the atmospheric pressure at 2000 feet is 7% less than at sea level, alveolar PO2 is 11% less.



Graph 1



Graph 2

Results from studies indicate that the A-a (Alveolar-arterial) gradient decreases with altitude. The decrease is roughly 1 mm Hg per 2000 foot increase in altitude.

Table 3 [9]

Altitude (ft):	PAO2:	A-a Gradient:	PaO2:	SaO2:
0	107.8	19.0	88.8	98.0%
2000	96.7	18.0	78.7	95.6%
4000	86.0	17.0	69.0	93.8%
6000	76.1	16.0	60.1	90.9%
8000	66.7	15.0	51.7	86.3%
10000	58.0	14.0	44.0	79.6%

Aircrafts are usually pressurized to an equivalent altitude of 6000 to 8000 feet and the lower limit of normal for the SaO2 of airplane travellers is usually considered to be between 89% and 91%. However, chance of hypoxemia are increased in a critical patient with respiratory or non-respiratory compromise at lower SaO2.

Gas expansion accounts for the majority of contraindications to aeromedical evacuation. A change from sea level to altitude of 8000 feet will expand the volume of trapped gas by approximately 35% [10]. 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 endotracheal tube at higher altitudes 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 endotracheal tube. Decreased barometric pressure can lead to changes in the delivered tidal volumes by ventilators which are not pressure compensated resulting in possible volutrauma [11].

Decreased humidity which exists in aircrafts results in drying of respiratory secretions leading to atelectasis and tracheal tube blockages. Acceleration forces or G forces of the aircraft during take-off and landing result in pooling of blood in the lower extremities or head respectively if the patient is loaded head first. These forces are bound to effect critical patients whose physiological systems are compromised especially in the haemodynamically unstable, head trauma and intracranial bleed patients. Therefore, patient positioning becomes an important consideration.

Environmental Factors

Apart from the effect of altitude on physiology, certain environmental aspects too come into play in an aircraft. Noise and vibration may cause accidental extubations, fatigue, anxiety and motion sickness of both the CCAT team as well as the patients [12]. This also interferes in the intercommunication among the medical staff. Constraints of space in the aircraft also is a limitation during patient interventions. There is also some compromise in maintenance of sterile conditions during interventions. Disposal of bio medical waste is another important aspect to take care as there are no fixed segregation bins in the aircraft. In comparison to an advanced ICU on ground, the flying ICU does not have access to radiological investigations, emergency transfusion, emergency surgical or endoscopic facilities. Diagnostic imaging in flight is currently possible only with portable ultrasound. This technology has an emerging role in critical care practice and could advance the level of care available in flight. Expert opinions can be made available using a telephonic patch through the aircraft communication systems, but this is not perfectly reliable.

CONTRAINDICATIONS TO AEROMEDICAL EVACUATION

There are no absolute contraindications to CCAT. Majority of contraindications are because of gas expansion at high altitude. Important relative contraindications are listed in Table 4 [13].

Table 4: Relative contraindications to CCAT

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

Table 5: Pre-flight Patient considerations [14]

1.	Careful positioning of patient to avoid rise in intra cranial pressure (ICP) for head trauma
2.	Quick release mechanism for wired jaws or easy access to wire cutters in maxillofacial trauma
3.	Ensure all drainage tubes unclamped or on continuous suction
4.	Ensure minimum haemoglobin of 7.0 gm/dl in haemorrhagic shock
5.	Ensure escharotomies for full thickness circumferential burns
6.	Use saline for filling cuff of endotracheal/tracheostomy tube
7.	Use tube fixator for endotracheal tube
8.	ICD to be functional and unclamped throughout flight in cases of chest trauma
9.	Avoid use of pneumatic splints in fractured bones
10.	Likely to have increased IV fluid requirements- in flight, availability of pressure bags
11.	Supplemental oxygen to maintain saturation more than 90%

Aeromedical evacuations over the last few years have increased and are likely to increase in future. The quality of care during transit has evolved and improved considerably over a short period of time. Advancements in medical equipment in terms of their weight, sophisticated technology to work efficiently in a flying environment, good battery backups, along with trained manpower who understand the flying effects on human physiological systems have resulted in delivering effective critical care during aeromedical evacuations.

As compared to Civilian counterparts, Indian Armed Forces Medical Services have a slight edge in the field of aeromedical evacuation, firstly due to the demand that is present & secondly because of the availability of resources, both, human & material. It was as recently as June26th 2017 that the first aeromedical facility came up in a Civil Hospital in Coimbatore (Tamil Nadu). Natural disasters and adventure activities have increased the number of rescue missions carried out by the armed forces and need for aeromedical support in civilian setup too has started to be felt. It will not be surprising to find dedicated air ambulances with ICU support in future hovering over Indian skies and lessons learned from CCAT in IAF will prove to be propitious for it to become a reality.

CONCLUSION

As elucidated in the article, Critical Care Air Transport presents with some unique issues and challenges. Though, it is a relatively new field, yet the results are promising and precious lives are being saved using air evacuations. In the short span of ten years considerable progress has been made and routinely new advances are being made. A scoring system for consideration of patient transfer has been developed and it is being used successfully in the IAF. We can see a brighter future for CCAT in the armed forces and it can be useful in civilian populations in areas with difficult terrain. Further research and innovations in this field are advocated.

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