



## REVIEW ARTICLE

# Risk factors in air transport for patients

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## Abstract

**Background:** The units that are used for an air transport are: the helicopter which covers distances up to 250 km and the aircraft used for longer distances. By air, the time needed is reduced to half or even to one third compared to terrestrial transportation.

**Aim:** The aim of this review was to investigate the risk factors in air transport for patients via seeking literature.

**Method and Material:** Literature review based on studies and reviews derived from international (Medline, PubMed, Cinahl, Scopus) data bases concerning risk factors in the context of air patient transfer.

**Results:** Important disadvantages of air transports are stress during flight, Oxygen partial pressure reduction – hypoxia, reduction of the barometric pressure, temperature reduction, moisture reduction – dehydration, noise, vibrations, acceleration forces G and fatigue. The right selection of the staff and the equipment is very important in transports. Attention should be paid before and during transports, and at the arrival at the area of destination. During the transport a bag with the right equipment should accompany the patient. Anything that it may need to be done during the transport must be done before the start of the transport. Finally, we shouldn't forget that the key for a safe transport is the stabilization of the patient before the transport and the safest transport is the one that never happened.

**Conclusions:** It is very for healthcares who transfer patients by air to be trained on indentifying factors that can be proved dangerous for the patient.

**Keywords:** Air transport, barometric pressure, hypoxia, acceleration forces, noise

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## Introduction

Over the past 40 years a large amount of scientists and health professionals have shown interest in the way in which ambulance services could be implemented as safe as possible for the patient. According to the current law (Article 7 of law 1579/85) the EKAB has the responsibility to coordinate emergencies in order to provide immediate assistance and emergency medical care to citizens. It is also responsible for their transport these citizens to health service units, with its own transport units (Ambulances, Mobile Units, Motorcycles, Aviation Media), which is used by specialized and trained staff.<sup>1,2</sup>

## Historical data

In the year 1944 a helicopter was used, for the first time, as an ambulance. Later on, this helicopter was named flying ambulance. The importance and the contribution of the air transports to the medical services is emphasized by the fact that during the World War II the amount of air transports was over 1 million, while during the War in the Vietnam and the Gulf the amount was about 400,000. The foundations of the system of air transports came from the hospital St. Antonio during transportation of patients in Denver, Colorado in the year 1972.<sup>1,2</sup>

## Air transports

The means that are used for an air transport are: the helicopter which covers distances up to 250 km and the aircraft used for longer distances.<sup>2</sup> The helicopter flies at an altitude of 1.000-1.500 ft and the plane at 35.000-40.000 ft, and this is why the aircraft can fly even in bad weather.<sup>2-5</sup> Diaz et al.,<sup>6</sup> argue that aerial transports should be chosen over terrestrial transports when the distance covered is over 120 km. By air, the time needed is reduced to half or even to one third compared to terrestrial transportation. The helicopter can reach inaccessible areas or islands, where the use of an ambulance is impossible. The plane is limited by the absence of an airport. The air transports

require usually more qualified and specialized staff, better communication with the reference center. Furthermore, the airplane can carry persons that accompany the patient, which reduces stress to the patient in flight. By plane specific patient groups can be transferred, such as disease of divers, because a cabin decompression can be transported, which is not possible by other units. Also the transport of more than one patient is possible, and this is what makes planes indispensable in cases of mass disasters.

The helicopter engines, combined with poor insulation, produce 69-75 db noise inside the cabin, which sets difficulties in assessing the patient and in communication-collaboration between health professionals. The movement and maintenance costs for a helicopter are greater than those of an ambulance, and even greater are the movement and maintenance costs for an airplane.<sup>7</sup>

## Criteria of air transport of trauma patients

In the year 1986, Rhodes et al.,<sup>8</sup> pointed out the need for specific criteria for the air transport of patients. The Emergency Nurses Association, using the trauma severity score ISS and other clinical parameters established the following criteria:<sup>9</sup>

- ISS < 12
- 10 < RR < 29
- Systolic blood pressure < 90 mmHg
- 60 < BPM < 120
- GCS < 13 or rapid deterioration of the patients neurological status
- Airy trauma at head, neck, chest, abdomen, pelvis, groin
- Unstable pelvic fractures and signs of bleeding or Shock
- Open 2<sup>nd</sup> or 3<sup>rd</sup> degree fractures
- Fractures of two or more long bones
- Spinal injuries.
- Burn area of over 15% of the total body surface, or in areas such as face, upper and lower extremities, perineum



- Electrical or chemical burns or suspected inhale burn
- Age of trauma patient between 12 and 55 years
- History of respiratory or cardiac problems
- Pregnancy
- Sepsis and any degree of organ failure and tissue necrosis

### Stress during flight

An important disadvantage of the aerial units is the changes in air pressure due to the change of the altitude. The atmospheric pressure decreases as the altitude increases. Reduce of the pressure leads to stretching or increasing the volume of air. As a result, some changes appear in the state of the patients which is called stress. The Association of Air Medical Services has recorded eight categories of stress:

- Reduction of the partial pressure of oxygen-hypoxia
- Reduction of the barometric pressure
- Reduction of temperature
- Moisture reduction - dehydration
- Noise
- Vibrations
- Acceleration forces
- Fatigue

### Oxygen partial pressure reduction – hypoxia

The first to note signs of hypoxia in flight was James Glaisher 1862 at an altitude of 29.000 ft with a balloon.<sup>10</sup> The signs of hypoxia include disorders in the crisis, personality changes, confusion, hypotension, sleep, anesthesia, coma, arrhythmias, and cyanosis.

The saturation of arterial blood oxygen at sea level is 98%, at 10.000 ft 90% and at 22.000ft 60%.<sup>2</sup> This drop at the saturation values leads to respiratory difficulty and strain of the already overburdened respiratory patients. Bendrick et al.,<sup>2</sup> in the transport of 24 patients with ischemic heart disease in a helicopter, observed reduction of the saturation of arterial blood oxygen (SaO<sub>2</sub>)

at 5.5%, Vohra & Klocke recorded a reduction of 5.8% (from 93.2% to 87.5%) in patients with obstructive lung disease. Flabouris et al.,<sup>11</sup> found that the respiratory status of patients improved after they were placed in a prone position.

For these reasons health professionals should always use oxygen to patients, and also raise the seatback to the bedridden. Furthermore, many times it is necessary to reduce the altitude of the aircraft at fewer than 10.000ft and increase the pressure in the cabin.

### Reduction of the barometric pressure

The barometric pressure decreases when altitude increases. The barometric pressure is reduced from 760 mmHg at sea level to 380 mmHg at 18.000ft. As a result the volume of gas is doubled, because the change of pressure follows the law of Boyle ( $V_2 = V_1P_1/P_2$ ).<sup>12</sup> The changes in the volume of air in various body cavities, creates several problems:

Middle ear: it is an airway cavity that communicates with the pharynx through the Eustachian tube and is separated from the external environment with the tympanic membrane. The trapped air expands when altitude increases and shrinks altitude decreases. In cases where there is an obstacle at the entry of air at the Eustachian tube and the pressures cannot be balanced (such as HPC, swelling, sore throat, CSF outflow, skull base fracture, weakness, swallowing), great pressure is exerted on the tympanic membrane and causes varotrauma which appears as a sense of weight in the ears, pain, tenderness, dizziness, nausea, hearing loss and epistaxis.<sup>13</sup> To avoid audible varotrauma Valsava, Frezzel, Taybee manipulations and swallowing movements should be used during the descent of the altitude of the aircraft. In cases where these manipulations are not feasible (eg HPC) vasoconstrictors drugs in aerosol form are used for 15 minutes before the descent of the altitude of the airplane. If the symptoms are very

intense, the aircraft should increase altitude to balance the pressures.

**Airway cavities at skull:** a blockage of these holes prevents the free passage of air, thereby increases the pressure inside. Symptoms that appear are: local tenderness, acute pain, headache, watery eyes and epistaxis. These symptoms are rare, but at their appearance, they should be treated with decongestants. Also in fractures of the facial skull, subcutaneous emphysema may occur. In such cases the suggested solution is increasing the pressure of the cabin of the aircraft and reducing the altitude of the aircraft at 8.000ft. In case that the airplane needs to increase altitude, the increase should be slow and gradual rather than abrupt. At cases of skull fractures, where air may be trapped in the skull, the airplane should fly at sea level.

**Teeth:** there is pain (aerodontalgia) during the ascent. Relief comes with the reduction of the height of the aircraft or the increase of the pressure of the cabin.

**Perforating wounds of the eye:** air can pass through the wound in the intraocular space. The expansion of trapped air can cause extrusion of the lens or the vitreous of the eye through the trauma.

**Lungs:** an increase of the volume of air can cause distension of the lung tissue and blood vessels, pulmonary hemorrhage, pulmonary embolism, arrhythmias, displacement of the diaphragm and pneumothorax.<sup>13</sup> Special attention should be given in patients with chest injuries and, in these cases, the lung should be decompressed and decongested before flight by a drain, which must remain at least 24 hours (to decompress and decongest the lung completely) before flight. At an altitude of over 10.000ft, supplemental oxygen is required. Especially, in patients with COPD the altitude of the aircraft should be reduced at below 10.000ft.

**Gastrointestinal tract:** at 9.000ft the volume of air in the gastrointestinal tract is increased by 150%. Signs that may occur are flatulence, abdominal pain, anxiety, shortness of breath due

to elevation of the diaphragm and parasympathitikononia with hypotension, tachycardia and fainting. Patients with injuries from side to side are at high risk for embolism, while patients with surgical abdominal trauma are at risk of rupture sutures. For all these reasons, stomach should be decompressed and gas at the gastrointestinal tract should be drained by placing nasogastric tube (Levin). All tight clothing should be removed or relaxed, and 24 hours before the flight foods that cause gas should be avoided.

**Decompression illness:** it is caused by the release of free air bubbles in the tissues and body fluids, due to rapid and sharp reduction in barometric pressure. Symptoms can range from skin (itching, warts, cold feeling or cold and dotted rash), the CNS (muscle weakness, headache, visual hallucinations, difficulty speaking, mental confusion and paralysis), muscle aches and joint pain or around them, choking feeling (deep and stabbing pain under the sternum, productive cough and a feeling of suffocation). In the presence of such symptoms after sudden decompression of the cabin, oxygen should be given at 100%, any painful joints should be stopped and descent to sea level and landing at the nearest airport is suggested, to provide appropriate medical care and treatment in a hyperbaric chamber.<sup>14,15</sup>

As the volume of air increases with altitude, the air that is in the Tracheal cuff should be replaced with saline solution or an amount of air should be removed because the pressure will be exerted by the dilation and could lead to injury, ischemia or necrosis of the trachea. Similarly, the cuff of uro catheter should be filled with saline solution rather than air.

### **Temperature reduction**

Temperature decreases when altitude increases. Increasing the altitude of the aircraft at 1000ft leads to a decrease of 2°C temperature. The change in temperature increases the metabolic needs of patients, and especially trauma patients and patients with HPC and patients with burns



may experience hypoxia and hypothermia. In this case oxygen must be given and body temperature must be maintained within acceptable levels, by the use of blankets, warm clothes and drinks or solutions.<sup>12</sup>

### **Reduction of moisture - dehydration**

The higher the altitude, the more cold and dry is the air. In an increase in altitude, the humidity in the cabin of the aircraft is lost with the air that evaporates. After two hours of flight, there is only 10.5% of the relative humidity into the cabin, which leads to dehydration. With this percentage of moisture, patients with respiratory problems during the flight feel discomfort. Patients who take oxygen present more problems, because oxygen is a dry gas. At first mucous membranes get dry, bradycardia and hypotension appear which makes humidifying with nebulizing humidifiers and fluid intake necessary. Later, appear pasty secretions, obstruction of Tracheal and hypoxia.<sup>13</sup> In patients with endotracheal tube 2ml of saline should be instilled in the trachea at regular intervals. Humidifying, with the instillation of artificial tears, should be done on the cornea, whereas surgical or open wounds should be covered with wet sterile dressings.

### **Noise**

Creates problems in communication and leads to a progressive decrease in hearing, while prolonged exposure can cause deafness. It can also lead to stress. It increases adrenal function and heart rate and causes peripheral vasoconstriction, hypertension, increasing blood flow to the brain and intracranial pressure. The intensity of the noise should not exceed the 90db.<sup>16</sup> Health professionals have problems in communicating with each other and with patients. Also they cannot properly assess the patient because they cannot hear or measure blood pressure.<sup>4</sup>

### **Vibrations**

New aircrafts have fewer vibrations than the old ones, because they have better design and materials. Vibrations are caused mainly due to the operation of engines, flaps, landing gear and take off and the general resistance of the air caused by movement of the aircraft. Vibrations of low frequency of 8-10 Hz lead to a fall in BP, bradycardia and bradypnoia. Moderate vibrations of frequency of 11-12 Hz causes increased heart rate, peripheral vasoconstriction, fatigue, abnormal temperature, nausea, abdominal and chest pain. High frequency vibrations of over 12 Hz cause dangerous arrhythmias, muscle twitching, pain and bleeding.<sup>12</sup> Vibrations make it difficult to assess the patient because his pulse BP and cannot be measured, while there is an increased risk of disconnection from the ventilator.

Patients should be transported in a comfortable position, which should often be changed to relieve them, and they should also be located away from the machines and wall board. Earplugs, tranquilizers and antiemetic can be especially used in patients with HPC just before the flight. Special attention should be paid to accident prevention by stabilizing the equipment (machines, oxygen cylinders, suit and dress) with straps, and seatbelts for the patient's safety. Frequent checks should be made to both patients and equipment.

### **Acceleration forces**

There are two types of acceleration, linear and angular. The linear accelerations move body fluids and internal organs towards their direction, and may cause an increase in the ICP, hypotension or tachycardia with the location of the patient. The angular accelerations can increase cardiac output, tachycardia, vasoconstriction, impaired vision and intracerebral hemorrhage. The only solution to the problem is select properly the position of the patient.<sup>12</sup>

**Fatigue**

It is the final result of all the physiological and psychological stress of the flight because of the altitude.

**Staff for secondary transports**

The staff that will accompany a patient must be experienced and properly trained. Everyone must know cardiopulmonary resuscitation and be prepared to intervene if necessary. If the patient will be transported from an ICU, the persons accompanying him are a nurse, a call doctor and a paramedic. Each hospital follows its own policy on the transport of seriously ill patients and on what and how many people need to accompany them.

**Equipment in transports**

The devices used in transports should have some specific characteristics. They should be properly designed, portable, easy to use, durable in distress, small in volume, and able to operate with power and battery. Also, they should have wide base and low center of gravity and be fitted with alarms, video and audio. It is necessary to put the equipment on a special shelf and not onto the patient. The necessary technical equipment for transports is as follows:

- Recording of vital signs and ECG
- Defibrillator
- Portable respirator and capnograph (for patients in ventilation)
- Pulse Oximeter
- Suction device
- Pumps for liquids and medicines
- Intubation and ventilatory support set (laryngoskopio, ambu, masks, tracheal tubes etc.)
- Source of O<sub>2</sub>
- Chargers and spare batteries
- Medicines (resuscitation, analgesics, tranquilizers, muscle relaxants etc.)
- Solutions and devices

**Procedure before transports**

- Detailed planning for the transport

- Stabilization of the patient
- Contact with the destination to inform managers and designated time of arrival
- Collection and testing of equipment used
- Collection of patient data (file)
- Connection with the monitoring equipment and check of parameters recorded
- Reassessment of the patient and quick checks of vital signs, central lines, charts, etc
- Access to veins should be easy and comfortable
- Correct and safe transfer to the stretcher and correct and comfortable position of the patient
- **During transports**
  - The followed route should be easy and short. Lifts should be available and assured.
  - Means of communication with the destination part should be available.
  - Check and record continuously the patient's condition and configuration of devices.
- **Arrival in the area of destination**
  - Reception of the patient.
  - Connection with new recording equipment and transfer from the stretcher.
  - Reassessment of the situation.
  - Informing the medical staff to take responsibility.
  - Stay of the group as long as required in the reception section.
  - Recording and documentation in specific forms of all incidents
- **Important issues**
  - 1. Anything that it may need to be done during the transport must be done before the start of the transport.
  - 2. The key for a safe transport is the stabilization of the patient before the transport.
  - 3. The safest transport is the one that never happened.

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