DANGERS OF DEFIBRILLATION IN FLIGHT

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ABSTRACT

Aim

Defibrillation is a critical aspect of advanced life support, but the inherent risks in the procedure are increased when used during an aeromedical retrieval. The dangers of defibrillation in flight can be divided in to fire, electrical, avionic interference and physical carriage and packaging. A limited body of evidence exists concerning defibrillation in flight, in part, due to under-reporting. Changes in incident reporting, increased team based simulation training and awareness of the dangers of defibrillation should allow aeromedical teams to defibrillate patients safely and expediently.

INTRODUCTION

Defibrillation is the termination of ventricular fibrillation (VF) or ventricular tachycardia (VT) after the delivery of an electrical current across the myocardium enabling restoration of coordinated electrical activity.[1]

The use of electricity to resuscitate a patient was first described in animal models in the 1770s, however it was not until 1960s that Zoll demonstrated the effective use of externalised electricity to resuscitate a patient.[2] Due to severe pain and burns, several years passed before technology allowed for defibrillation to be carried out safely and effectively.

Early defibrillation has now become a core aspect of advanced life support and is one of the few interventions proven to improve outcomes from cardiac arrest secondary to ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT).[3]

Since the probability of successful defibrillation is time dependent, advances in technology and reduction in cost has allowed the procedure to be conducted outside of hospital.[4] The rate of cardiac arrest during aeromedical transport is between 3.4-

5% with a requirement for defibrillation occurring in 0.8% of all missions.[5]

Defibrillation can cause significant harm to both patient and health practitioners unless appropriate measures are undertaken to reduce the risk. When defibrillation is attempted during an aeromedical transport the risk increases. The dangers of defibrillation can be divided into four main categories: fire, electrical, avionic interference and physical carriage and packaging.

FIRE

Fire is a rare but devastating consequence of defibrillation however this risk is not mentioned in standard critical care or cardiology literature.[6,7] If fire were to occur during an aeromedical evacuation, it could result in the loss of the patient and crews' life and loss of the aircraft.

The causes of fire can be further divided into two categories:

1. Electrical Sparks and Arcs

The production of any spark in an oxygen rich, enclosed environment has the risk of igniting a catastrophic fire. A case report from 2003 demonstrated a fire from a spark formation during defibrillation. The anterior-posterior placement of defibrillation resulted in a spark which set the bedding, cotton wool and wool cap on fire.[8]

Sparks can form when pads are improperly placed resulting in a reduced electrode-chest wall interface. The spark produced can 'jump' between conductors. This is called an electrical arc. Arcing of electricity during defibrillation can occur from several scenarios:

- Poor skin electrode interface
- Excess conducting gel forming a conduit between the pads
- Paddles/pads placed too close to ECG electrodes
- Other conduits present – saline soaked pads (surgical/open wounds)

The spark or electrical arc is a source of heat and the first part of the triangle of fire.

Oxygen, the second part of the triangle of fire, is always in close proximity to the patient during defibrillation and all case reports of fires during

defibrillation have occurred in oxygen rich settings.[9,10,11] Within an aircraft cabin, space is limited and moving oxygen far enough away from the patient may not be enough to reduce the oxygen concentration around the defibrillation paddles. Lower barometric pressure may reduce the combustion potential; however, this is potentially offset by the presence of oxygen delivered to the patient.

The final part of the triangle of fire is fuel which, in effect, is anything that can burn. Many potential fuel sources exist at the beside including cleaning agents, linens, dressings, ointments and patient body hair.[12] Specific fuel sources within the aeromedical environment include aviation fuel, medical dressings, patient hair/skin and a variety of rubber supplies.

2. Lithium battery failure

Lithium-ion batteries have revolutionised portable medical devices providing increased power and longer life with reduced size and weight. Fires occur when one of the battery cells are damaged, punctured or overheated by overcharging or external heat. Due to the configuration of the lithium-ion batteries, external damage can cause contact between the positive and negative electrodes leading to short circuit and rapid electrical discharge.

When a single cell becomes unstable, it causes a cascade overheating of adjacent cells causing in a chain reaction known as thermal runaway which can become an explosive inferno.[13]

113 air incidents involving smoke, fire, extreme heat or explosion have been reported to the Federal Aviation Administration between 1991 and 2011.[14] The highest profile of these incidents was the catastrophic lithium-ion battery fire which resulted in the crash of a cargo plane in Dubai in 2010, killing the 2 pilots on board.[15] More recently, during an aeromedical transport of a patient in Utah, smoke was identified originating from a bag containing an oxygen cylinder. Investigation identified a smoking spare ventilator lithium-ion battery. The battery was removed from the vehicle and the transport continued uneventfully; however it took over 60 minutes to fully extinguish the battery.[16]

The risk of fire from lithium ion batteries is well documented and has become an accepted risk during aeromedical evacuation. Recommendations including appropriate charging and storage have been well documented by the manufacturers, however due to operational constraints these are colloquially known to be compromised.

The paucity of evidence on fires associated with defibrillation does not reflect the absence of these events, in part due to the litigious nature of the event.[6,9] No reports exist of fires due to defibrillation during aeromedical evacuations. It could be argued part of the reason for the lack of reported cases could stem from a variety of reasons including a lower incidence of defibrillation during flight.

ELECTRICAL

Medical practitioners suffering an electrical shock from defibrillation is a recognised if rare occurrence.[17] Although several case reports describe accidental defibrillation of medical practitioners or bystanders, the UK Medicines Health Regulatory Agency (MRHA) has received only a single report of an electrical shock to a paramedic during patient transport.[18]

The risk of electrical shock is increased during aeromedical transport due to the constricted environment within the cabin. Depending on the configuration of the aircraft it may be impossible to move or see around the entire stretcher increasing the risk of accidental defibrillation of crew-members. Getting clear of the metal stretcher, including but not limited to, IV poles and infusion pumps can also be a challenge. Flight can be unpredictable and unexpected turbulence can present a significant risk to health practitioners. All these risks make the requirement for clear, effective communication and teamwork paramount.

The Medicines and Healthcare products Regulatory Agency (MHRA) suspects a significant amount of under-reporting of electrical events during defibrillation and to date, no accidental bystander defibrillation events have been reported during an aeromedical evacuation.[18]

Automated external defibrillators (AEDs) are commonplace both inside and outside of hospital but their use when transporting a patient is not recommended in current resuscitation guidelines.[19] AEDs can interpret artefact rhythms arising from movement within the ambulance as VF resulting in an inappropriate shock.

In 2011, Sang *et al*, demonstrated AEDs can correctly identify shock delivery for cardiac rhythms during helicopter flight.[20] However, despite an increasing body of evidence, there is a level of disagreement on whether AEDs can be used safely during aeromedical retrieval. It is important to note AEDs have been adopted and used successfully in many commercial airline operations with no reported injuries or inappropriate shocks delivered.[21]

AVIONIC INTERFERENCE

All electronic devices carried aboard aeromedical aircraft are subject to approval by the Civil Aviation Authority within the UK. An approval assessment is carried out to demonstrate the equipment, installation and operation will not adversely affect the proper functioning of the aircraft.[22]

When a defibrillator is activated, it discharges 5000 volts of electrical energy over 1-2 seconds. During this discharge, a small but distinct electromagnetic pulse is emitted, similar to a lightning bolt. It is best practice to inform the pilot prior to activating the defibrillator in case of any interruption to the avionics.

In most modern aeromedical aircraft, there is no effect on the avionics however, in the past, a 'blip' would occur in the cockpit depicting an unknown, unexpected signal. This would require the pilot to check all avionics if they had not been informed prior to defibrillation.

Informing the pilot has the additional benefit of improving safety during the mission. During critical moments of the flight, the pilot can instruct the defibrillation to be paused until it is safe to continue. An example is during flight (particularly take-off and landing) using instrument flight rules (IFR). Discharging the defibrillator can interrupt the instruments and make landing/take-off significantly more dangerous. With knowledge of impending defibrillation, if safe to do so, the pilot can maintain straight and level flight rather than manoeuvring, increasing the safety for the patient and health practitioners.

PHYSICAL CARRIAGE AND PACKAGING

Despite all the safety testing undertaken prior to a defibrillator being certified fit for use within an aircraft, the physical carriage of a defibrillator is the most common cause of injury to patients and medical staff. Two main categories exist:

1. Falling Equipment

Within an aircraft, unless all equipment is secured there is a high propensity for equipment falling and causing injury. The most common time is during disembarkation from the helicopter or aeroplane. Additionally, turbulence in-flight can cause equipment to shift and fall causing injury to both patient and medical team. As mentioned before, lithium batteries are a significant source of risk and falling equipment can damage batteries resulting in a catastrophic fire.

Most established aeromedical services have integrated monitors and diagnostic equipment which are housed either on the stretcher or permanently in the aircraft. This significantly reduces the risk of individual pieces of equipment becoming dislodged and falling.

If a service does not have specific housings, extra care must be taken by the crew to ensure all equipment is accessible but appropriately secured to prevent injury.

2. Equipment Failure

Failure of defibrillators have reduced significantly since they have become smaller and single use pads have been introduced. This has reduced the risk of exposed wires and subsequent electrical accidents.

The MRHA dictates all equipment should be serviced regularly and maintained to a high order.[22] However it remains the responsibility of the flight team to remain vigilant and inspect defibrillators regularly to ensure they remain in good working order.

CONCLUSION

Defibrillation is a critical resuscitative tool that requires time efficient use to maximise patient survival. Multiple factors present risk during defibrillation in the aeromedical environment and therefore appropriate training and effective teamwork is imperative. Despite few to no reports of any adverse events from defibrillation, factors unique the aeromedical environment, including turbulence and a confined environment magnifies the risk. A limited body of evidence exists to recommend specific measures to be taken to prevent risk beyond a 'common-sense' approach adopted by all health practitioners. Even more debate exists surrounding whether AEDs can be used safely during aeromedical retrieval and whether this will reduce the risk to patient and healthcare practitioner. Further research will be required to provide a definitive answer.

With ever increasing aeromedical missions, defibrillation will occur in flight more often and it is crucial health regulatory agencies work with aeromedical teams to promote safe practice and blame-free incident reporting.

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