Case reports

Investigation of a cluster of decompression sickness cases following a high-altitude chamber flight

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Abstract

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Although relatively safe, hypoxia exposure is a mandatory training requirement for aircrew that carries the risk of decompression sickness (DCS). Usually DCS affects only one individual at a time. Here, a cluster of three simultaneous cases is reported. Since these numbers were well in excess of the usually encountered incidence rate, the purpose of this work was to identify the most likely reasons using the epidemic DCS investigation framework which involves four main considerations: time; place; population; and environment. Based on time and place observations, this cluster clearly falls into the individual-based classification, where the environment is a primary concern. Indeed, equipment analysis allowed us to identify the most likely reason for two out of three cases (perforations in the oro-nasal oxygen masks worn during training). It led to replacement of damaged equipment and modification of teaching to prevent such damage. It is recommended that this investigative template may be used for any future occurrences of DCS in clusters.

Introduction

Hypoxia training in the high-altitude chamber is a part of the physiological training of aircrew, where trainees experience the symptoms of hypoxia and the changes of volume of gas-filled cavities within the body, akin to what can occur during actual flight. The aim of such training is to make them aware of the problem of hypoxia and their respective hypoxic signatures.[1,2] In theory, should an in-flight hypoxic event occur, it may prepare aircrew members to take necessary remedial measures and exercise better control over the aircraft, as required in actual flight conditions.

Although relatively safe, sometimes decompression sickness (DCS) can occur during this training. This is a condition arising from dissolved gases coming out of solution to form bubbles inside the body on depressurisation, which is the case when flying an unpressurised aircraft at altitude. Usually, DCS affects aircrew on an individual basis. This is consistent with the experience of our centre as we only record one or two DCS cases every year, always happening as single case.

Rarely, however, DCS may occur in clusters, affecting more than one person at a time. When four or more individuals are affected, this has been called "*epidemic DCS*".[3] According to Butler, who first coined the term, there must be an exposure compatible with DCS and the incidence of the event must be higher than normal baseline incidence.

This report presents three simultaneous cases, which were evaluated for mild ('Type I') DCS after a high-altitude chamber exposure. Although, this does not correspond to the exact definition of DCS epidemic, we decided to investigate this cluster within the epidemic DCS investigation framework. Indeed, by definition an epidemic of a disease is an outbreak that exceeds the normal incidence of that disease, which is the case here. Therefore, the purpose of this work was to search for and identify the most likely reasons for those cases through a well-coordinated, thorough and systematic approach.

Cases

All cases discussed in this report gave written consent to use of their medical data for this purpose.

Hypoxia training is a standardised procedure (Table 1). A group of trainees (typically 10) are exposed to a pressure equivalent of 25,000 feet above sea level. Training starts with ascent to altitude and finishes with descent to ground level. An inside observer/instructor officer (IO), acting as safety officer, also participated in the chamber flight. All participants underwent a medical examination, including

Table 1
Standard altitude hypoxia training profile

Phase	Procedure	Altitude (ft)	Ascent and descent rate (ft·min^{-1})	Pressure (mmHg)	Pressure (kPa)	Mask position	Inspired oxygen %
1	Denitrogenation	2,000	–	706.6	94.2	On	100
2	Sinus check	2,000–7,500–2,000	5,000	–	–	On	100
3	Ascent	2,000–25,000	5,000	–	–	On	100
4	Hypoxia training	25,000	–	288.6	38.4	Off	20.9 (Air)
5	Descent	25,000–22,000	5,000	–	–	On	100
6	Descent	22,000–2,000	2,500	–	–	On	100

Table 2
Epidemic DCS investigation framework. IO – instructor officer

	Focus	Factors	Sub-factor
1	Time	NA	–
2	Place (location)	NA	–
3	Population (person)	Trainee and IO	Medical checks DCS risk factors
4	Environment	Training programme	Profile (alterations of procedures)
		Equipment	Maintenance (failure) Oxygen system

a detailed otorhinolaryngology (ear, nose, and throat) examination the day before the altitude chamber training. They were further checked by the flight surgeon in relation to current health status, particularly with respect to the upper respiratory tract, just before entering the chamber. Following the mandatory safety briefing, the training began.

During the descent three individuals developed symptoms: the IO (aged 31) experienced right wrist pain; one of the trainees (aged 24), whose time of useful consciousness during hypoxia was 201 seconds, developed left wrist pain and another trainee (aged 29),whose time of useful consciousness was 224 seconds, noted right knee pain. The flight surgeon overseeing the hypoxia training examined each individual and diagnosed Type I DCS. The IO and both trainees, now patients, were treated in accordance with US Navy Treatment Table 5 within 15 minutes of reaching ground level. All three patients recovered completely after treatment and were completely symptom free.

Follow-up of all the three affected personnel did not reveal any sequelae of DCS. The trainees were routed back to their units and the IO resumed his attendance at altitude chamber training.

Investigation

In our centre, approximately 1,500 trainees are exposed to a total of 200 altitude chamber flights per year, with a DCS incidence of 0.067%. Here, there were three cases from one exposure of a total of 11 individuals (27%). Symptoms were noticed following an altitude exposure plausibly consistent with causing DCS. Subsequent symptom resolution with hyperbaric oxygen reinforced the diagnosis. Since these numbers were well in excess of the usually encountered altitude chamber DCS incidence rate, this event was considered a cluster that needed proper investigation. It was considered that the epidemic DCS investigation methodology was the right approach and would, in all probability, reveal the cause thereby enabling the authors to prevent recurrences.

Epidemic DCS falls into two classes, individual-based (Epi-I) and population-based (Epi-P). Epi-I is defined as four or more DCS patients as a result of a solitary exposure, and Epi-P is defined as four or more DCS patients over an extended time frame.[3,4] In classical infectious disease outbreak/epidemic investigations, the time, place, population and environment must be examined. As pointed out by Butler, this methodology is not altogether useful for epidemic DCS, in particular Epi-I.[3] Therefore, a new template was created by adapting the classical framework to investigate our cluster of DCS. This template is named 'Epidemic DCS Investigation Framework' (Table 2) and includes four main foci: time; place; population; and environment. In this cluster of DCS cases, the most relevant foci were population and environment. 'Population' relates to the affected patients and factors such as medical status

Figure 1
Oronasal mask used during hypoxia training. The tear in the mask can be seen in the right nasal finger recess

Figure 2
Close up of the tear in the right nasal finger recess in one of the training masks

and DCS risk factors, including hydration, in-chamber exercise, injury, fatigue, obesity, lack of pre-oxygenation and pre-chamber exercise. 'Environment' relates to equipment (maintenance and oxygen systems [hose, mask, breathing gas etc.]) and the training program (flight profile).

After creating the Epidemic DCS Investigation Framework the investigation was initiated according to this template.

Time and place: In a situation like this, where a cluster of DCS cases occurs with one altitude exposure, time and location are not generally helpful. This was the situation with the present cluster where all the cases occurred at a single location. However, based on these observations, our cluster clearly falls into the Epi-I classification, where the environment is generally a primary concern.[3]

Population: Analysis of the susceptible population often reveals some tell-tale evidence. The various DCS-specific risk factors, including hydration, in-chamber exercise, injury, fatigue, obesity, lack of pre-oxygenation and pre-chamber exercise were looked into.[5–11] However, nothing significant was discovered in these physically well-conditioned young men. Both trainees underwent a thorough medical examination the day before the training and the IO, an instructor with 14 years' experience in the altitude chamber, passed his yearly medical examination. None of them reported any medical problem before the training.

Environment: Although no procedural discrepancies before, during or after the altitude chamber training were identified, the operational procedures were reviewed in detail. This review revealed no untoward practices. Trainees were under close supervision of two outside operators and one IO. So it was not possible to remove their masks in the first (denitrogenation) phase (Table 1).

The focus then fell on equipment issues. Although, periodic maintenance requirements were met, close scrutiny of the equipment revealed holes (Figure 1 and Figure 2) in the trainees' masks (MBU-12/P Oxygen Mask). Further investigation revealed that during their initial training both trainees had performed Valsalva manoeuvers and pinched their noses by pushing their fingernails into their mask, leading to tears in the mask material. When discussed with the IO, it was learned that he checked all masks before the training and there were no problems with the masks. However, during phase 1, the Valsalva manoeuvre was used. The demand valve and hose were also checked with no failure found. Analysis of the respired gases occurs before they are breathed in the chamber. If the oxygen level is less than 99.8% or any toxic gas detected, the system is alarmed. The system didn't give any alarm the day of the event. It was felt that these tears were likely an important causal factor in the trainee's DCS. Inward leakage of ambient chamber air through the tears during inhalation may have diluted the oxygen content of the inhaled gas, and resulted in insufficient negative pressure inside the mask to fully trigger delivery of 100% oxygen from the demand valve, thus compromising denitrogenation.

Two different types of masks are used in our centre. These holes were formed in only one type of masks. These masks were replaced with newer ones of a sturdier design. In addition, Valsalva manoeuvre training in training lectures was revised. At the same time, the safety teams were advised to be more cautious while inspecting masks, hoses, and related equipment before commencement of altitude chamber training.

Since the replacement of the defective masks and revision of training protocols, no instances of DCS, above the incidence rate, have occurred during our high-altitude chamber exposures. As to the IO, the authors were unable to discern a specific aetiology for his DCS.

Conclusion

Although this cluster of DCS cases did not meet the definition of epidemic DCS, using the epidemic DCS investigative framework allowed identification of the most likely reason for two out of three cases. It also led to replacement of damaged equipment and improvement of training. It is recommended that this investigative template may be used for any cluster of DCS cases encountered henceforth.

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