Case reports

Fatal air embolism in a breath-hold diver

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Abstract

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Cerebral arterial gas embolism (CAGE) from breath-holding or inadequate exhalation during ascent is a well-recognised complication of scuba diving. It does not usually occur with breath-hold (BH) diving in those with normal lungs, as the volume of gas in the lungs on surfacing cannot exceed what it was on leaving the surface. However, a BH diver who breathes from a compressed gas supply at depth essentially becomes a scuba diver and is at risk of pulmonary barotrauma (PBt) and CAGE on ascent. In this case, a 26-year-old male experienced BH diver breathed from a scuba set at approximately 10 metres' sea water depth and ascended, sustaining massive PBt and CAGE with a fatal outcome. BH and scuba divers, especially those with less experience, need to be well-informed about this potential risk.

Introduction

Breath-hold (BH) diving has increased in popularity over the past decade, with some participants being certified scuba divers and others not. Scuba training includes an explanation and reinforcement of the effect of Boyle's Law in the context of scuba diving. A scuba regulator delivers breathing gas to the diver at ambient pressure and, unless vented sufficiently during ascent, gas inspired at depth will expand and can over-distend the lungs. This can cause pulmonary barotrauma (PBt) which may lead to cerebral arterial gas embolism (CAGE) as a result of gas passing from ruptured alveoli into the pulmonary veins and distributing in the systemic circulation. CAGE can and has occurred from a depth as shallow as one metre.[1,2]

Similarly, BH divers who breathe from a scuba diver's breathing gas supply at depth are at risk of PBt and CAGE unless sufficient gas is exhaled during their ascent. For the unaware and untrained, this practice can be precarious.

There appear to be few published cases of PBt and/or CAGE in BH divers who have breathed from a scuba supply so the frequency of it occurring is unknown.[3,4] A recent report did describe PBt and CAGE in an unconscious BH diver who was rescued from 24 metres' sea water (msw) and sustained arterial gas embolism when given ventilations via air purged from a rescuer's alternate air supply during ascent.[5]

Case report

A physically fit 26 year-old experienced BH diver was 'free diving' with a buddy who was diving with scuba in sheltered waters at a popular shore dive site. While the buddy was at a depth of approximately 10 msw, the victim dived down and breathed from the scuba regulator before ascending. He became unconscious upon reaching the surface and was noted by the buddy to have blood coming from his mouth. Resuscitation at the scene and subsequently in a nearby hospital was unsuccessful.

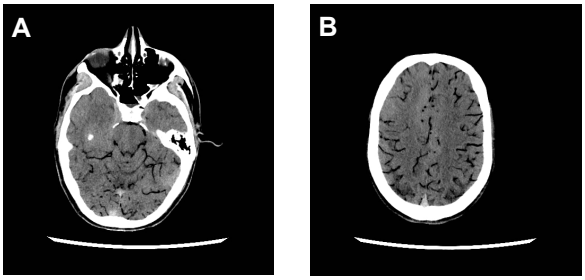
A CT scan performed immediately post cessation of resuscitation attempts showed evidence of massive pulmonary barotrauma, with bilateral pneumothoraces, pneumopericardium, pneumomediastinum, subcutaneous emphysema and intravascular gas in the brain (CAGE), liver, spleen and kidneys. Extensive alveolar-interstitial pulmonary opacification was also evident, radiating from central to peripherally along the broncho-vascular structures likely as a result of aspiration of seawater but possibly also from pulmonary haemorrhage (Figures 1,2).

Discussion

Pulmonary barotrauma with subsequent CAGE is a well-recognised complication of compressed gas diving and of submarine escape training.[6] It does not occur in recreational BH divers with normal lungs unless the diver has breathed compressed gas from a scuba regulator as in this case, or

Figure 1
Coronal chest CT scan image performed immediately after cessation of resuscitation attempts showing evidence of massive barotrauma, with bilateral pneumothoraces, pneumopericardium, pneumomediastinum, subcutaneous emphysema and intravascular gas in the liver. Extensive alveolar-interstitial pulmonary opacification is also evident, likely as a result of aspiration of seawater but possibly also from pulmonary haemorrhage. An endo-tracheal tube is in situ

Figure 2
Axial brain CT images showing extensive intracerebral intravascular gas (CAGE)



from a compressed air-pocket underwater, such as in a wreck or cave. During escape training, submariners enter the water column at a given depth via an air lock and free ascend to the surface, usually in a specially-designed submarine escape immersion suit.[7] In Australia, this typically occurs from depths of nine and 20 msw, but such free ascent training has recently been discontinued. CAGE as a complication of submarine escape training has been reported in 0.01–1.9% of practice ascents,[6] which mandated the presence of an operational recompression chamber adjacent to the tower.

Breathing from scuba at 10 msw, the BH diver in this case would have inhaled air at a pressure of two atmospheres absolute. Unless some of this air was exhaled during ascent to the surface, the combination of increasing lung gas volume and rising transmural pressure would have combined to cause pulmonary tissue damage (barotrauma). It may have been that he held much of his breath during ascent, which would have been his usual and generally safe practice with normal BH diving. However, failure to adequately exhale during this ascent after breathing compressed air resulted in massive barotrauma.

During scuba diving training and certification, "*entry level divers are taught that the most important rule in scuba diving is to breathe normally at all times and never hold your breath*".[7] This rule applies especially during ascent. Some certification programs include training in an emergency ascent without an on-going breathing gas supply to specifically reduce the likelihood of breath-holding.[8] This needs to be strictly controlled to minimise the risk. However, the risk to a BH diver taking a breath from a regulator at depth may not be expressly taught in scuba courses. Likewise, although there are now specific BH diving courses, some of these may also not highlight the risk of taking a breath of compressed air at depth.

Conclusions

Breath-hold divers are at risk of PBt and CAGE should they take a breath of compressed air at depth during a dive. Education of both scuba divers and BH divers is needed to avoid similar cases occurring in the future.

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