

Case reports

Vomiting and aspiration of gastric contents: a possible life-threatening combination in underwater diving

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Abstract

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Vomiting and aspiration of gastric contents into the airways and lungs is a common and well-known clinicopathological entity. This phenomenon might also occur in underwater diving, where it can lead to life-threatening or fatal situations. This article presents two incidents involving diving-related vomiting with associated aspiration of gastric contents. One case, a 39-year-old commercial diver using a full-face diving mask, was fatal and the other was a 33-year-old, female recreational scuba diver in whom underwater vomiting was complicated by pulmonary aspiration of a solid foreign body (a peanut) into the right lower lobe bronchus. The peanut was successfully removed and, following bronchoscopic pulmonary lavage, the patient made an uneventful recovery. The causes and consequences of nausea and vomiting within the underwater environment are discussed and possible interpretative problems are highlighted.

Introduction

Vomiting with possible aspiration of gastric contents is a well-known clinicopathological phenomenon. Sequelae associated with aspiration include pulmonary obstruction, chemical pneumonitis, secondary infection of airways or lung parenchyma and possible death.^{1,2} Morbidity following aspiration is enhanced with an increased volume of aspirate, more acidic pH, high particle content and bacterial contamination. Aspiration is most likely to occur in subjects with a decreased level of consciousness. Multiple physiological, pharmacological and pathological conditions are associated with aspiration. In divers, vomiting and aspiration of gastric contents can have a somewhat different pathophysiological background and frequently leads to a fatal outcome.^{3,4} This article presents two diving incidents involving vomiting with associated pulmonary aspiration of gastric contents.

Case 1

A 39-year-old, healthy, trained, male commercial diver descended with a partner to a depth of 42 metres in a

hydroelectric power station to perform a planned task. The diving equipment included a surface-supplied breathing apparatus, full-face diving mask (FFM) with a built-in oronasal mask (Figure 1), a ceramic microphone for bilateral hard-wire communication, protective plastic helmet with a light, fixed over the FFM, and a drysuit with attached hood.

The descent of both divers was slow, without equalization problems, and the breathing of both divers was deep and regular. After 10-minutes bottom time, the victim suddenly reported to the surface that he had stomach problems and his breathing became irregular, noisy and after a few seconds stopped. The buddy swam to the victim almost immediately, found him unconscious with free-flow of the FFM regulator. The rescue of the victim to the surface took approximately seven minutes. The oronasal mask of the FFM and the mouth cavity of the victim were almost completely filled with reddish gastric contents containing particles of a semi-digested meal. He was declared dead at the scene. Further investigation revealed that the deceased has consumed barbecued meat with a mixed vegetable salad several hours prior to the dive.

Figure 1
Diver's full-face mask and diving helmet



AUTOPSY

The autopsy was performed the next day, following the standards of diving fatalities investigation.^{3,5,6} A huge amount of a semi-liquid red/brown material was found in the trachea and peripheral bronchi. The gross appearances were consistent with aspiration of gastric contents. Examination of the brain showed tiny gas bubbles within cerebral arterial vessels. Circumscribed foci of barotrauma were noted in the lung parenchyma. Additionally, sections of the brain stem showed multiple asphyxia-induced haemorrhagic foci. Microscopy did not disclose any other conditions other than those noted macroscopically. Postmortem toxicological analysis was negative for drugs and alcohol. Based on the above, the cause of the death was given as asphyxiation due to obstruction of the tracheobronchial tree by gastric contents, with pulmonary barotrauma and cerebral arterial gas embolism (CAGE) serving as contributory factors.

Case 2

A 33-year-old, inexperienced, female recreational scuba diver performed a dive with a group of divers in a freshwater flooded quarry. Her diving equipment included open-circuit scuba with a 12 litre single tank, primary and secondary breathing regulators, a buoyancy compensator and a 7 mm wetsuit. According to the analysis of her dive computer-generated profile and the dive buddy's report, after 13 minutes at a depth of 24.5 metres, the victim suddenly dropped her primary breathing regulator out of her mouth and, in obvious panic, ascended rapidly toward the surface. At some point during the ascent, she became incapacitated and began to sink again. Immediately after being brought

to the surface, brownish semi-digested material was noted around her mouth. She was resuscitated and intubated at the scene. With pharmacological support, the patient was transported to the district hospital by the air rescue service.

On admission to hospital, the patient was unconscious and hypothermic. Acute respiratory distress syndrome and severe acidosis were diagnosed. Brain computed tomography (CT) revealed brain oedema. No signs of CAGE were seen on CT. A pulmonary CT scan showed ground-glass opacities at the level of the aortic arch with multiple nodules throughout the lung parenchyma. With intensive treatment, neurological and respiratory status improved; however, she became pyretic. Urgent bronchoscopy showed a large amount of semi-liquid yellowish-brown gastric contents within the bronchial tree and a solid oval foreign body lodged firmly in the right lower lobe bronchus, completely obstructing its lumen. The foreign body, which proved to be an aspirated peanut, was successfully removed. A careful bronchoalveolar lavage followed. The clinical course after removal of the foreign body, supplemented by intravenous antibiotic therapy, was uneventful. No recompression therapy was indicated, and the patient was discharged seven days post bronchoscopy. At a nine-week follow-up, she was symptom free. Later interview with the afflicted diver disclosed that approximately one hour before the dive she had eaten a full packet (100 g) of roasted peanuts.

Discussion

According to the American Gastroenterological Association, vomiting is defined as a forceful oral expulsion of gastric contents associated with contraction of the abdominal and chest wall musculature.² It is an important reflex, which may be provoked by many conditions that can be classified as visceral (e.g., stomach distension or traction on abdominal organs), pharmacological (e.g., any recreational drugs with emetic properties, anaesthesia, surgery or radiotherapy), metabolic (e.g., pregnancy, uraemia), central nervous system or psychological (e.g., sea sickness, panic, anorexia nervosa).⁷ The vomiting reflex is controlled by the vomiting centre within the reticular formation of the medulla at the level of the nucleus olivaris,⁸ and mediated mainly via the fifth, seventh, eleventh and twelfth cranial nerves and the spinal nerves. Immediately prior to vomiting, a large breath is taken, the glottis is closed and the diaphragm is fixed. Forced contraction of the abdominal muscles follows. This increases the pressure in the stomach, the cardiac sphincter relaxes and gastric content is expelled.⁸

Potential causes of vomiting underwater are as follows:

FRESH/SALTWATER ASPIRATION

Water aspiration while diving occurs most commonly due to accidental loss of the scuba mouthpiece. In rebreathers, this might happen due to the weight of the mouthpiece chamber with back-up regulator second stage (up to 450 g)

leading to tiring of the jaw muscles, or loss of consciousness underwater.⁹ Leakage of water into the second stage via an incompetent exhalation valve of the scuba regulator may also cause vomiting.¹⁰ A frequent cause of water aspiration, mostly seen in recreational diving, is the voluntary removal of the scuba regulator out of diver's mouth, both underwater (gas switching or buddy breathing), or whilst swimming on the surface. Aspiration of even a small amount of fresh/salt water to the upper airways evokes a cough reflex, when the jerky movements of the diaphragm may trigger vomiting. Coughing underwater, in the novice diver in particular, might lead to panic and possible drowning.

SEA SICKNESS

Sea sickness is another plausible stimulus for vomiting during diving. Swimming on the surface in choppy seas as well as disorientation and tumbling underwater from heavy swells may lead to severe in-water sea sickness.

ERUCTATION

Eructation is the reflux of small quantities of acidic fluid from the stomach to the mouth.² As the diver moves, being compressed by a tight-fitting wetsuit and breathing apparatus harness, particularly the abdominal belt, the risk of involuntary eructation triggering vomiting and aspiration of gastric contents increases.^{11,12} Irritation of the laryngeal mucosa by acidic gastric contents also may provoke severe coughing. Even small amounts of gastric contents stuck on the exhaust valve may lead to water leakage or obstruction of the regulator's lever system leading to a possible free-flow. All these unpredictable situations may lead to panic and an uncontrolled ascent and possible drowning.^{11,13}

AEROPHAGIA

Some air is unavoidably swallowed while eating, drinking, or swallowing saliva in normobaric conditions.^{1,14} While underwater, a diver physiologically swallows saliva together with small gulps of air at elevated pressure, equivalent to the depth of dive. When the diver ascends to the surface, the gas in the stomach expands, and typically escapes from the stomach cavity freely. However, some risk of sudden eructation and vomiting remains. Aerophagia is more pronounced when using a scuba regulator, as the mouthpiece leads to increased salivation and aerophagia. This may lead to abdominal discomfort and nausea which may also induce vomiting with aspiration of gastric contents.¹⁴

Another source of increased aerophagia in diving is the use of FFM or diving helmet with internal oronasal mask. The advantages of a FFM/diving helmet in operational diving are many and well known.^{11,15} However, ear clearing in some types of FFM is more complicated than in an ordinary dive mask. The divers using FFM perform Valsalva or other manoeuvres more frequently, while the frequency

of swallowing gas also increases. A more voluminous aerophagia in FFM/diving helmet divers appears also when the underwater communication system is used.¹¹ Some talkative divers are at risk of not only premature consumption of breathing gas if the FFM is with open-circuit scuba, but also of increased salivation. If vomiting occurs when using an FFM or diving helmet, the oronasal mask could trap the vomitus in immediate proximity to the mouth making aspiration more likely, as in the first case.

ALCOHOL AND MEALS

The consumption of alcohol around the time of diving activities is common in recreational diving.¹⁶ Excess consumption of alcoholic beverages leads to an increased risk of vomiting. In addition, alcohol-related hangover the day after excessive alcohol consumption places divers at significant risk of gastrointestinal symptoms including nausea and vomiting. In regard to food, it is advisable to avoid meals which may produce excess gas in the stomach or bowels in the process of digestion (freshly baked bread, beans, peas, etc.) before a dive. It is also suggested that divers not eat meals which are generally difficult to digest such as cellulose-containing vegetables or barbecued or smoked meats. As the process of digestion does not stop underwater, digestive gases are being produced almost continuously. If in abundance, the intestinal gas might induce abdominal discomfort, nausea, and even vomiting.¹⁴ Eating a packet of peanuts immediately before the dive, leading to regurgitation, aspiration and panic in an inexperienced diver was the likely scenario in the second case.

MEDICATIONS

Nausea and vomiting underwater may result from seasickness medication, non-steroidal anti-inflammatory drugs, aspirin, antihypertensives, diuretics, and oral contraceptives.^{2,12}

POSITION

Nausea induced by positional changes and dysorientation may occur in diving (e.g., ascent vertigo). Vomiting might be provoked in divers who frequently change their swimming position from prone to head-down. In this situation, the gastric contents are being mixed and pushed to the gastric fundus, inducing an unpleasant sensation. A diver with an incompetent gastroesophageal sphincter might suffer from gastroesophageal reflux inducing vomiting.^{2,7,8}

INNER EAR LABYRINTHINE STIMULATION

Nausea and vomiting may also be induced by ear problems while diving. The most frequent is alternobaric vertigo, provoked by asymmetric pressure changes in the middle ear cavities, leading to rotational nystagmus, typically during ascent.¹⁷ Rupture of an eardrum may lead to caloric-induced nystagmus and vertigo.¹⁸ Less frequent causes of vomiting

underwater are acute perilymphatic fistula and inner ear decompression sickness.^{19,20}

In an early report of scuba diving deaths, four out of 34 divers had pathological evidence of aspiration of gastric contents and debris.³ When sudden vomiting hits the recreational diver, it is not necessarily a catastrophic event. A well-trained diver can remove the mouthpiece from the mouth, expel the bolus of vomit to the surrounding water and continue normal breathing. If vomit passes through the primary regulator, it is strongly advised to switch to the secondary regulator. In contrast, the FFM or diving helmet with internal oronasal mask may become a risky piece of equipment for a vomiting diver. The oronasal mask fits rather snugly over the nose and mouth, and the whole FFM is firmly fixed on the diver's head by the 'spider' head straps. The diver in case one was also equipped with a protective helmet and, thus, was unable to remove such complicated equipment from his face and head by a simple manoeuvre and then restore the FFM back again after the episode of vomiting. The oronasal mask in the diving helmet is also fixed firmly, and it is difficult to remove in the event of vomiting.¹⁵

Finally, to reduce the risk of vomiting underwater, we would like to suggest several precautions. Divers should avoid hard-to-digest foods and carbonated beverages before any dive. Other precautionary principles include strict avoidance of alcohol, drugs or emetogenic medications, and to avoid aerophagia as much as possible. Recreational divers should be cautioned to stay well-hydrated and rested, without any digestive or ear problems and dive within the limits of their training. Divers should not enter the water if severely affected by sea sickness.

Conclusions

In the case of a fatal diving accident, vomiting with asphyxiation has to be taken into account as the possible cause of death. Thus, while examining the diving equipment of the deceased, the diving regulator or oronasal mask (FFM/diving helmet) should be carefully inspected. The passive vomiting which happens either following removal of the diver's body from the water or after bringing the victim from depth (expansion of gas in the stomach) should not represent a diagnostic problem for a qualified medical examiner.

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