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Decompression Illness Associated with Underwater Logging: 6 Case Reports from Kenyir Lake, Malaysia

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Summary

The formation of Kenyir Lake as part of a hydroelectric project in the 1980s caused much forest area to be submerged. From 1991, underwater divers were employed to log these sunken trees at depths of up to 100 meters. At least 6 mishaps involving underwater logging personnel were recorded from March 1994 to August 1996. We retrospectively reviewed 5 cases who were managed in Hospital Kuala Terengganu. The patients presented with marked cardiorespiratory and neurological disturbances. One diver died in the Hospital while another died at the recompression chamber. Three divers were treated with recompression and improved. Average delay before the start of recompression was 14 hours. Underwater logging has definite dangers and steps must be taken to ensure that both the divers and the equipment are appropriate for the task. Availability of a nearby recompression facility would greatly enhance the management of diving accidents, not only for commercial divers but also for recreational divers who frequent the islands nearby.

Key Words: Decompression illness, Diving accidents

Introduction

In the 1980's the development of the Sultan Mahmud Hydroelectric dam project involved submersion of large areas of forest in the state of Terengganu. This led to the formation of a 23.6 million m^3 manmade collection of water known as the Kenyir Lake. The sunken trees were considered to be viable sources of timber and from 1991 onwards, logging companies started work in the area. Commercial divers were sent down to log these trees at depths of up to 100 m.

At least 6 diving accidents involving these divers were recorded form March 1994 to August 1996. Two

fatalities occurred in the 5 cases that were initially managed in Hospital Kuala Terengganu. In this report we have highlighted the interesting clinical features of decompression illness (DCI) so that Malaysian medical personnel can become more conversant with the diagnosis and management of this infrequently seen disorder. Our evaluation of the dive profiles and background of the divers involved also suggests that further accidents in underwater logging could be prevented by improved safety procedures, training and equipment.

Case Reports

Table I shows the details of the 5 cases involved in the mishaps. The divers were all foreign nationals from neighbouring countries and had variable degrees of training – one had only dived 6 times prior to the incident which led to his death. None of them were able to produce documents of certification from professional diving bodies and their training appears to have been unofficial.

All the divers were supplied with air via an umbilical hose from a surface compressor (known as a Hookah). None of them carried a back up auxiliary gas supply to use in the event of the piped supply being suddenly cut off. The available history suggests that in cases A, B and C inadvertent termination of the air supply occurred, possibly due to the hose being caught up in the trees. The unfortunate divers would have been forced to make emergency rapid ascents without being able to follow decompression protocols and they may have inadvertently been breath holding at this time. The other 2 cases (D and E) made repetitive dives to times and depths exceeding the recommended standards.

As shown in Table I, cardiorespiratory, cutaneous and nervous system involvement were the key clinical features in these patients. Two of the patients who were treated with recompression at the Naval Base showed good recovery and did not come for further follow up after their discharge from hospital. One patient demonstrated steady improvement from his paraparesis but decided to leave the hospital before the treatment was completed. The two fatalities occurred in patients who were already comatose at presentation; one died shortly after arriving at the recompression chamber while the other died before he could be transported there.

As no recompression chamber is available in Hospital Kuala Terengganu the patients had to be transported by road to chambers at either the Kuantan or Lumut Naval Bases (200 and 500 km away respectively) and this led to several hours delay. Air transport in an unpressurised helicopter between Terengganu and the Lumut Naval Base was considered to be potentially hazardous as the aircraft would have had to ascend above 300 metres over some mountainous terrain.

Discussion

This group of patients, with their fascinating spectrum of signs & symptoms provide a good illustration of the diffuse, multifocal nature of diving related disease. Two main mechanisms of damage, both of which may occur in a patient, are well demonstrated here. The first one, pulmonary barotrauma, is related to Boyle's law where a volume of gas will expand when the applied pressure is reduced. Divers A, B & C who carried out emergency rapid ascents when their air supply was cut off would have experienced rapid expansion of the gas in their lungs. If the air was not exhaled, then its expansion could lead to distension and rupture of the lungs, with resultant complications of pneumothorax and pneumomediastinum as seen in two of our cases[1]. Furthermore, passage of gas into the pulmonary veins and into the systemic circulation could lead to arterial air emboli occluding the coronary and cerebral vessels. This may result in a stroke-like syndrome known as Cerebral Arterial Gas Embolism (CAGE), which presents with neurological features such as hemiparesis and dysarthria soon after the diver surfaces[2].

The other mechanism of injury is related to Henry's law where the amount of gas which is dissolved in liquid depends on the partial pressure of the gas. Repeated dives, as in Divers D and E, increases the nitrogen load in the tissues, particularly in areas of high fat concentration where nitrogen is extremely soluble. As the diver surfaces, reduction in pressure occurs and causes the dissolved nitrogen to be liberated as bubbles from the tissues. Formation of these gas

Table I
Details of the 5 patients

	A	B	C	D	E
Age	24	23	18	58	40
Experience	Dived 6 times before	1.5 years	Newly trained	5 years	1 year
Training	On-site by foreman	From brother	From father	From relatives	From relatives
Dive profile	Rapid ascent from 40 m	Rapid ascent from 20 m	Rapid ascent from 30 m	Multiple dives over 210 minutes, up to 50 m	Seven dives over 360 minutes, up to 50 m
Glasgow Coma Scale	3	15	10	3	15
CNS features	Unconscious	Paraparesis	Confused Right hemiparesis	Unconscious Hyporeflexic	Paraparesis Urinary retention
Cardiopulmonary involvement	Marked hypotension Haemoglobin > 20 g/dl	Pheumothorax Haemoglobin > 20 g/dl	Pneumomediastinum Haemoglobin > 20 g/dl	Hypotension Pulmonary oedema	None
Cutaneous	Marbling	Subcutaneous emphysema	Subcutaneous emphysema	Subcutaneous emphysema + marbling	Subcutaneous emphysema
Symptom onset after surfacing	Became semi-conscious within a few minutes	Lost consciousness within a few minutes	Lost consciousness on surfacing	Myalgia initially, but lost consciousness 1 hr later	Arthralgia initially, then paraparesis 30 mins later
Delay before arriving at recompression chamber	Died before being transported	9 hours	18 hours	14 hours	19 hours
Outcome	Death	Well	Well	Death	Improved

bubbles may compress tissue locally as well as obstruct the arteries, veins and the lymphatics[1]. If insufficient time is allowed for these bubbles to disperse, their presence in the skin and connective tissues leads to painful symptoms known as "the bends". The manifestations include arthralgia, myalgia and cutaneous features of pruritus, rash and marbling. Also, the presence of bubbles in the bloodstream & vasculature can lead to complications such as haemoconcentration pulmonary oedema, circulatory collapse and neurological deficits.

Clearly, underwater diving, whether of a recreational or a commercial nature, has potential hazards and in order to avoid accidents, safety procedures should be rigorously adhered to. Foreign "experts" from Thailand were brought in to train underwater loggers, but this may have been carried out on an ad hoc basis. The divers should have undergone written and practical diving assessments but we found that none of them were able to produce any evidence of professional certification. Although pre-employment diving medicals are not required by law in Malaysia, some commercial diving companies do require employees to have passed a thorough medical examination.

Advanced age is a predisposing factor to DCI and Diver D, who had a fatal mishap, was already 58 years of age. Lack of adherence to dive table standards appears to be the main factor in Divers D and E who seemed to have ignored the required decompression obligation in their deep and repetitive dives.

Problems with the air supply equipment may have played a major role in the accidents, especially with regards to the quality and reliability of the surface compressor which is pumping the air down to the diver. Furthermore, in an environment where logs and branches are in abundance, the umbilical hose can be kinked or compressed. Despite the intensity and scale of the underwater logging operations, there were no easily accessible facilities for emergency recompression.

Clearly, availability of the appropriate equipment for a specialized activity such as underwater logging is a problem.

First aid therapy for DCI consists of inhaled oxygen at the highest available concentration as well as proper oral or intravenous hydration. A thorough neurological assessment is imperative, especially in categorizing the severity of DCI and whether it is progressively worsening or not[3]. Whenever possible, immediate transfer to a recompression facility should be carried out as one main determinant of outcome is the time to the administration of recompression therapy. Recompression appears to have some benefits even in cases where there has been significant delay (as seen in divers B, C and E), and thus should still be carried out whenever possible.

Reports on these cases have been submitted to the State Health Director as well as to the authorities in charge of industrial accidents. However, many more cases of DCI in the underwater loggers may have occurred without our knowledge as we believe that only the seriously ill cases were brought up to hospital.

Unfortunately, our cases had marked delay in their treatment as the nearest recompression facility was a few hours drive away. Furthermore, medical staff were not well versed with the diagnosis (one patient was admitted with the diagnosis of "near drowning") and also did not realize the need for immediate transport o the recompression chamber. Some of the patients were first seen in a district hospital and they should have been transferred directly to the recompression facility rather than via our tertiary referral hospital. Lack of familiarity with DCI is clearly a problem among health care staff and it may be prudent to integrate some teaching on the subject into the Emergency Medicine curriculum.

With the proliferation of hydroelectric projects around Malaysia, and the rapidly booming recreational diving industry in the clear waters of Malaysia's islands, it will not be surprising if DCI becomes much more common. Dealing with the problem successfully will not only entail more safety regulations and recompression facilities, but also quicker diagnosis and treatment of this complex multi-system disorder by health care staff. With this article, we hope to raise the level of awareness concerning DCI among Malaysian medical staff so that any further cases will be more efficiently dealt with.

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