

Diving and Immersion Pulmonary Edema Drowning From the Inside Out

Ayisha Hassanali

Immersion Pulmonary Edema (IPE) is a phenomenon that has been gaining attention recently and is not yet well understood. It has afflicted exceptionally fit military endurance swimmers and triathletes as well as divers who are of average to poor fitness. Hypertension, pre-hypertensive findings, as well as cardiovascular dysfunction, have been associated with IPE. Asthma may also contribute to the development of IPE. While many people survive an episode, it is unknown how many deaths due to IPE are mistakenly attributed to drowning due to their similarities. IPE may therefore be under-reported.

Immersion Pulmonary Edema is an accumulation of fluid in the air spaces of the lungs while in the water. There is a sensation of drowning in your own fluid, shortness of breath, an inability to breathe and hyperventilation. There tends to be a persistent, crackling cough; rattling, noisy breathing; and sometimes clear to pink, frothy sputum coughed up. The symptoms of IPE can be differentiated from Cardiorespiratory Decompression Sickness or the “chokes” in a survivor by an absence of chest pain and the tendency for IPE to begin at shallower depths. A lung overexpansion injury can have similar symptoms, but occurs upon ascending, whereas the onset of IPE occurs before ascending. When a diver ascends, the surface does not necessarily provide relief. If the body lacks sufficient oxygen due to the accumulation of fluid in the air spaces of the lungs, confusion, loss of consciousness and even death can occur.

What should be done in a dive-related emergency?

A diver suffering from the symptoms or signs of IPE or any diving-related illness needs to be administered oxygen continuously as soon as possible preferably with a Continuous Positive Airway Pressure (CPAP) device. Anything restricting breathing should be removed and Emergency Medical Services should be initiated (911 or CB Channel #9; VHF Channel #9 or #16). The Divers Alert Network should be contacted at 919-684-9111 (collect calls accepted) for all diving related accidents and incidents and they

will advise as necessary. CritiCall in Ontario can be called at 1-800-668-4357 by physicians or divers regarding SCUBA diving emergencies. The afflicted diver may require diuretics or further treatment, testing and observation at a hospital. Massive pulmonary edema (fluid in the lungs) reduces pulmonary compliance, the interaction between the heart, lungs, and blood circulation system. Pulmonary edema leads to acidosis, which is acidity of the blood, as well as hypoxemia, a decreased partial pressure of oxygen in the blood. Blood testing may show acidosis and hypoxemia. Pulmonary edema can be seen on a chest x-ray.



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What may be contributing factors to IPE?

The exact mechanism for IPE is not yet known, but it is believed to be a combination of factors compromising the integrity of the blood circulation system. There are several theories about what creates the conditions for IPE to happen. Being immersed in water, even if not fully, causes blood to shift from the extremities to the torso. This central shift of blood increases the amount of blood entering the left side of the heart from the lungs. Usually the heart and lungs compensate for such a volume shift, but sometimes it overwhelms the circulation process. Fluid then leaks into the lungs.

Although IPE has occurred in warm water, it usually occurs in cold water, considered to be less than 25C/77F . Cold water, particularly for an extended time, as well as the high density of water, aid in the central pooling of blood and cause the constriction of small arteries. This constriction increases resistance to the flow of blood, which can cause the fluid to leak from the pulmonary capillaries to the alveoli, which are the airspaces of the lungs. People with hypertension, or who are pre-hypertensive, may have an elevated vasoconstrictive response to cold, making them more susceptible to IPE.

Another theory in the development of IPE is that forceful inhalation or acute airway obstruction may cause the capillaries to leak fluid into the alveoli resulting in IPE. This type of strong inhalation may be in response to overexertion, over-breathing a regulator or snorkel, or a poorly tuned or maintained regulator, increasing the work of breathing. Strenuous exertion before, during, or after diving can contribute to the incidence of IPE. Being drastically over-weighted, diagonal trim in the water and quickly finning or sculling increases the work of breathing. Being underweighted and kicking hard in a head-down position to descend increases the work of breathing. Other factors could be low tank pressure with an unbalanced regulator, a tank that is not completely turned on, respiratory irritants in the compressed gas or exposure to cigarette smoke. A tank valve failure, although rare, can also increase breathing resistance. Aspiration of water can cause an airway obstruction and resistance conducive to IPE but victims sometimes aspirate water as they reach the surface gasping for air rather than precipitating the incident. Panic can also increase the effort of breathing. Wearing an overly tight wetsuit can constrict the chest and decrease the lung volume. This chest constriction reduces the intrathoracic pressure and increases the resistance to breathing. Breath-hold diving can result in bilateral pulmonary vascular injury and intra-alveolar hemorrhaging, possibly increasing susceptibility to IPE. Any activity or material that increases the work of breathing can contribute to the pulmonary leakage of fluid into the lungs, so should be avoided.

The position of a diver in the water can contribute to the development of IPE. When a diver maintains horizontal trim in the water, the regulator delivers gas to the mouth at about the same hydrostatic pressure as the centre of the lungs. When a diver is upright or diagonal in the water, there is a pressure differential between the mouth and

Reduce Your Risk of Immersion Pulmonary Edema:

- Maintain a nutritious, well balanced diet
- Engage in an active lifestyle and moderate exercise every day or at least several times per week
- Ensure blood pressure is not above 120/70, a new benchmark
- Avoid smoking
- Keep regulators well maintained and tuned
- Avoid increasing resistance on user-adjustable regulators
- Avoid over-breathing or overexerting
- Strive for neutral buoyancy and avoid overweighting
- Maintain tanks with current visual inspection and current hydro testing
- Maintain proper but not excessive hydration levels
- Discuss the use of beta-blockers and other medications with a doctor prior to diving
- Ensure that exposure protection is not overly tight
- Maintain horizontal trim while diving for minimal water resistance
- If using a rebreather, consider the placement of the counterlung and maintain trim
- If using a rebreather, consider using a manual diluent valve
- If a diver is feeling unwell before a dive, the dive should be aborted
- If a diver has sudden shortness of breath, persistent coughing or difficulty breathing, the dive should be aborted immediately and safely and 100% O₂ breathed on the surface
- Take your time, relax and have fun!

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lung centroid, creating a negative pressure. In a severely head-down position (more than 40%), the regulator delivers the gas at the hydrostatic pressure of the mouth, rather than the centre of the lungs, creating a positive pressure. This pressure difference can cause decreased lung compliance and increased pulmonary capillary pressure, potentially resulting in fluid leaking into the alveoli.

Rebreathers can elevate the risk of developing IPE due to the typically increased work of breathing in addition to the negative pressure caused by the placement of the counterlung and the functionality of an Automatic Diluent Valve. Back-mounted counterlungs increase the pressure differential since the counterlung is at a lower hydrostatic pressure than the lung centroid which causes the pulmonary capillary pressure to increase. If an automatic diluent valve has insufficient flow, the work of breathing increases. The hydrostatic pressure changes on a rebreather user can be greatly affected by the design of the rebreather, the placement and stability of the counterlung and the diver's trim. All of these factors can increase the preload on the left side of the heart, causing pulmonary fluid to leak into the alveoli.

IPE has been associated with over-hydration, especially prior to high-exertion swimming. Divers are advised to be properly hydrated but not over-hydrated and to not exert themselves. There are interactions between the lung and stomach contents that can induce pressure to vary, affecting the circulation process.

Medications are being examined for their potential role in some incidents of IPE, such as those for Erectile Dysfunction and thyroid regulation, which may increase hypertension or blood pressure.

What if a diver has experienced IPE before?

The risk of reoccurrence of IPE is not known. Someone who has experienced IPE should consult a doctor familiar with the condition prior to diving again. The physician may evaluate the risks for a particular patient based on their medical history and the potential triggers to be avoided. The doctor may advise lifestyle changes in the area of diet and fitness to lower blood pressure and improve cardiovascular function. Some doctors advise patients with hypertension to take anti-hypertensive medication prior to diving. The physician may order tests to evaluate if there are heart valve or heart muscle abnormalities or blocked arteries. Divers who have been afflicted with IPE may be advised to avoid particularly cold, deep or aggressive dive profiles. A drysuit may be recommended for engaging in cold water diving. A diver who has experienced IPE or exhibits the risk factors associated with IPE should assess the potential risks and if possible, consider ways to reduce the risk in consultation with a knowledgeable doctor.



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Did You Know?

The Alice G sunk on December 8th, 1927. Likely the most -dived of the 5 'Tugs' in Fathom Five National Park in Tobermory, it has shore access and, at a depth of only 23', is shallow enough for divers of all skill levels to enjoy.

Why not visit a couple of the other tugs at the same time?

Photo © [ScubaQ](#)

In the News

AGM is on Sunday, November 25th at 12:00pm.
Visit www.underwatercouncil.com for more details.

OUC is now accepting nominations for the following 4 (out of a total of 5) Board of Directors positions:

1. Director of Sport Safety (2 year term) - Mar Smith is standing for re-election

ouc.safety@underwatercouncil.com

2. Director of Membership (2 year term)

ouc.membership@underwatercouncil.com

3. Director of Communications (2 year term)

ouc.communications@underwatercouncil.com

4. Director of Finance (2 year term) - David Taylor is standing for re-election

ouc.finance@underwatercouncil.com

All positions listed above will become vacant at the 2012 AGM on Sunday, November 25th. Anyone who is a member of the greater Ontario scuba community (diver, professional, club, retailer, charter operator, etc.) and who is capable, committed, and motivated about serving the sport is eligible to be nominated. The nomination form and instructions may be found on OUC's website www.underwatercouncil.com on the Volunteering Opportunities page <http://www.underwatercouncil.com/?action=cms&cmspage=careers>

If you are interested in serving on the OUC Board in one of these capacities, and would like to know more about the role and its responsibilities, please visit our website at www.underwatercouncil.com and look in the Volunteering section, or contact the existing Board Members directly via the e-mail addresses provided. Naturally the outgoing members are all fully committed to helping the incoming members take on

Interested in giving back to the sport?

Q: Who can be a Director of the OUC?

A: Anyone who wishes to help support Scuba Diving in Ontario!

Q: What do I need to be on the Board?

A: You need to be/become a member of the OUC.

A: You need to be nominated.

Q: How can I be nominated?

A: You can approach an OUC club member and be put forward by the club's executive.

A: You can approach a current Director of the OUC and be nominated.

Q: When are the elections?

A: Elections are held every fall at the AGM (Annual General Meeting).

Q: How else can I help if I don't want to be a Director?

A: There are numerous areas where OUC can use your help and enthusiasm, such as with committees, events, and portfolios. To learn more about volunteer opportunities in OUC, please visit: www.underwatercouncil.com/?action=cms&cmspage=careers