



The Mysterious Issue of Immersion Pulmonary Edema

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INCIDENT

Like many other dives in the 47-year-old male's uneventful 450-plus dive career, there had been no problems on this wall dive. "John" descended to 19 metres/62 feet and swam one direction for about 15 minutes. He headed back with his buddy, slightly shallower (15 metres/50 feet), but after about five minutes began to feel more out of breath than he should. At first he thought maybe they're swimming into a current; no, no current. After another minute, he's more breathless and coughing a lot. John's chest began to feel wheezy and wet. He thought he was coughing fluid through his regulator but can't really tell underwater.

Fighting panic, John signaled

Cases of immersion pulmonary edema (IPE) seem to be increasing; partly, this may simply be better recognition.

"something is wrong" and "surface." They avoided a rapid ascent, but at the surface John was very distressed and out of breath. He could barely speak and coughed pink, frothy sputum. John's buddy made sure he was positively buoyant and waved the boat, which sped over and helped them out of the water. John looked quite blue, so the crew put him on oxygen – probably saving his life. They called the EMS and immediately headed in. During the 30-minute ride back, John's symptoms settled a little; his distress subsided, his breath came back a bit and his coughing became less

frequent. On reaching shore, he went to the nearest hospital.

CAUSE

This diver suffered immersion pulmonary edema (IPE). Pulmonary edema refers to fluid in the lung air sacs (alveoli), which in this case comes from the patient's own blood. For some reason, fluid leaks from the lung's tiny capillaries and into the air-containing alveoli. IPE is, in a sense, "drowning in your own fluid." If fluid fills the alveoli, then you can't exchange gas between the alveoli and the blood in the normal way. An IPE victim can become hypoxic (lack oxygen) severely enough to be life threatening.

Pulmonary edema can arise in various

ways, but is typically seen in patients with significant heart disease. However, there's rising awareness that pulmonary edema can occur in people with *no* obvious underlying heart or lung disease during water sports activities – like swimming and diving – involving complete immersion. Some victims have minor but potentially relevant medical problems like high blood pressure – hypertension. But, many victims have no obvious medical problems at all.

Why divers develop IPE seemingly out of the blue during a dive remains a mystery – although we have some ideas (see below) – especially considering many victims have made many dives over a long period with no problems. This suggests that many factors contribute together, and IPE can occur when enough of these factors become relevant on a particular dive. Explaining the detailed pathophysiology could fill a book, but here are some of the suspected potential contributors.

On land, gravity causes blood to pool a little in areas that are lower in the body (typically the legs), but this stops when immersed. Consequently, there is more blood in the “central” circulation (core), including in the lungs. Any blood vessel constriction in the arms, legs and skin elsewhere in response to cold adds

to this. Thus, in an immersed diver, a greater volume of blood circulating in the chest distends the lung capillaries. These changes also put some strain on the heart, which receives more blood to pump, and must pump against the higher resistance caused by constricted peripheral blood vessels. A healthy heart can cope with this, but a heart with abnormalities may struggle to keep up. If this happens “back pressure” in the lung circulation further distends the capillaries surrounding the alveoli.

At the same time, there may be significant changes in the airways and alveoli. A regulator supplies gas at the ambient pressure of the second stage. So, if the diver is upright, the regulator is about 25 centimetres/10 inches shallower than the lungs, meaning the breathing pressure supplied by the regulator will be lower than the water pressure actually surrounding the lungs. This so-called *negative static lung load* (which also occurs when a rebreather diver is horizontal with a backmounted counterlung that is shallower than the diver's lungs) creates a negative pressure in the alveoli and airways relative to the surrounding water. If the regulator is poorly tuned, or a rebreather has high breathing resistance, and breathing requires significant effort, then there will be cyclical

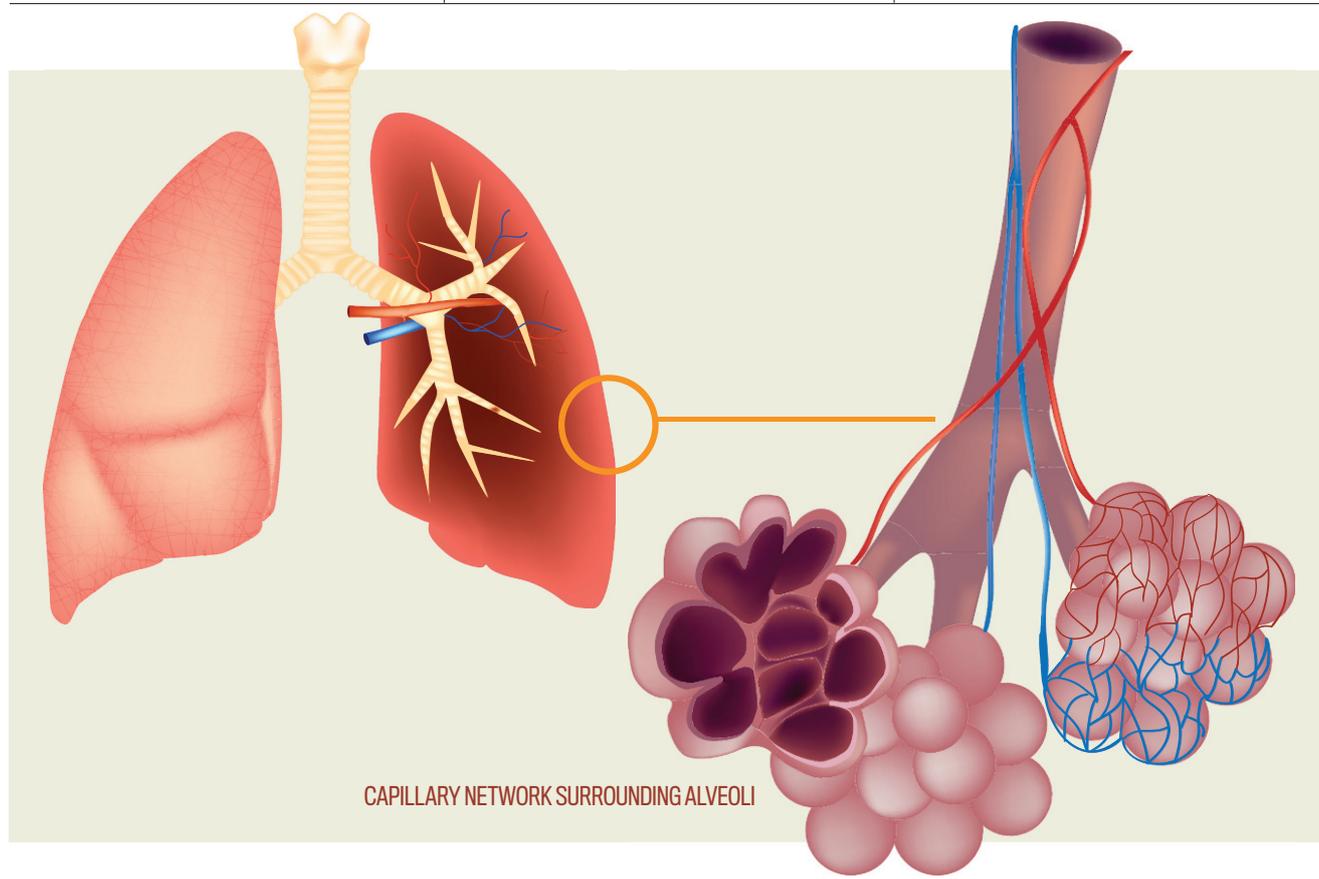
exaggerations of this negative pressure in the airways and alveoli with each breath.

Bringing these events together: If extra blood distends the lung capillaries and there is simultaneously a relatively negative pressure inside the alveoli that are in contact with those capillaries, the pressure imbalance might “pull” fluid from the blood into the alveoli, creating pulmonary edema.

This helps explain why IPE risk might be quite variable, potentially being affected by: position in the water, water temperature, heart health, breathing resistance, exercise level, overhydration, possibly some types of drugs, various medical conditions, and other things. It explains why, after many event-free dives, someone may suddenly experience IPE “out of the blue.” Because most of the key factors are directly related to the immersion effects, it's understandable why many cases improve once the patient leaves the water (as in the scenario above).

RESPONDING TO IPE

Interestingly, IPE cases seem to be increasing. Partly, this may simply be better recognition. Previously, IPE cases might have been attributed to near drowning, salt-water aspiration or other medical events. The increase may also reflect our



aging diving population, in which the prevalence of heart issues is probably increasing. Moreover, IPE-contributive medical issues can be quite subtle and go unnoticed, like increased heart muscle stiffness (quite common in people with high blood pressure) or elevated blood pressure in the lung arteries (possible in obese people).

Recognizing IPE underwater may be difficult, particularly for a buddy who will probably see a problem like not keeping up, distress, or erratic behavior – but no obvious reason. These have several possible causes (e.g. overexertion), some of which will respond to the “stop and rest” intervention prescribed in the PADI® *Rescue Diver Manual*. But, IPE symptoms will likely not improve and may continue to worsen despite resting. This means that if a distressed diver does not respond quickly to rest, the dive should be terminated.

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The best hope for quickly recognizing IPE lies with affected divers knowing the symptoms. As in the opening example, the key symptoms are likely to be fatigue and breathlessness that are disproportionate to the exertion level, followed by wheeze or a sense of “rattling” in the chest, with a cough. If a diver recognizes such symptoms, the dive should be immediately terminated with minimal exertion.

Someone with possible IPE should leave the water as soon as possible, and receive oxygen. Victims may be more comfortable sitting up. Anyone suspected of suffering IPE should get EMS care and be evacuated to a hospital as quickly as possible.

Although IPE can sometimes be confused with the respiratory symptoms (“chokes”) of serious decompression sickness, what usually rules out the latter are that IPE symptoms often start at depth, and the particular dive has very low decompression stress.

PREVENTION

Preventative strategies for IPE focus on the diver, the dive and dive equipment. A physically fit diver is probably less likely to suffer IPE, though being fit does not rule it out if enough of the other risk factors combine. Cases of fit but *overhydrated* swimmers suffering IPE have been interpreted by some to mean that divers should avoid pre-dive hydration when in fact it's



overhydration you want to avoid. As a guide, drinking one litre/30 ounces of fluid over the hour before a dive is probably fine, but drinking litres or quarts is probably neither wise nor necessary.

Some medications may increase IPE risk and should perhaps be avoided. For example, beta blocker drugs reduce the heart's ability to respond to increased demand so may not be the best choice for high blood pressure in an active diver. In all cases, avoid overexertion while diving, and keep dive equipment maintained and adjusted for optimal low-breathing resistance. (Note that while back-mounted rebreathers' counterlungs create a potential risk factor, it's not sufficient reason to avoid them. They bring other advantages, not the least of which is an excuse to do long decompressions vertically – I dive one!)

CONTINUING TO DIVE

Arguably the most controversial IPE issue is diving again after an event. This requires a complex evaluation of the individual case and the diver's motivation; factors beyond the scope of this article. However, a diver should certainly *not* dive again (even if the diver recovers spontaneously before medical intervention) before having a very thorough discussion of risk versus benefit with a diving physician. This would include investigation for modifiable risk factors (e.g., lack of fitness, overweight, high blood pressure, heart disease), and reducing them if possible.

Returning divers must understand that

repeat events can never be ruled out, and have occasionally proven fatal. Many divers who suffer IPE are advised against diving or choose not to dive again for this reason, particularly if risk factors either can't be modified adequately, or if none are found. Early evidence suggests that certain drugs may reduce IPE risk, but we still don't know enough for physicians to recommend this as a reliable strategy.

IPE was almost certainly under-recognized or misdiagnosed in the past. It is now recognized as a diving disorder of emerging importance. Understanding its pathophysiology, diagnosis, and management is important to PADI Professionals who are dealing with an aging diving population with a growing number of people likely to be at greater risk.

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Editor's note: IPE may explain some incidents in which a diver signals to end a dive for no apparent reason, starts up and becomes unresponsive during the ascent or shortly after surfacing. Therefore, with an apparent trend toward more IPE incidents, if a diver seems to be having discomfort or indicates an unexplained desire to ascend, it may be best that the diver be accompanied by his or her buddy, or the dive guide, all the way back to the boat or shore, even in circumstances where a solo-observed ascent and exit may seem reasonable.