Shallow-Water Arterial Gas Embolisms

By Joseph Gessert

IN FALL 2013, MY WIFE, LIV, and I were supervising 16 new divers who were experiencing low visibility for the first time. Our training site had a maximum depth of 20 feet and protection from the currents that render many urban waterways challenging to shore divers. Two experienced rescue divers with excellent buoyancy control were with us. They planned to dive recreationally in the area during our training.

We marked the corners of our site with dive flags, laid out transects for divers to follow and hoped that the threatened autumnal rains would hold off for one more day.

We took students underwater in groups of two, waiting for their anxious breathing to subside before swimming with them along the transect. When divers' fins fluttered too close to the soft bottom, we signaled for them to adjust their trim and buoyancy to avoid silt plumes. By late afternoon we had guided all the students through their first low-visibility dives without incident. Liv and I retrieved one dive flag, the rescue divers recovered the other, and we went home feeling good about a long and successful day of diving.

Later that night one of the rescue divers called and told Liv that his chest hurt. Their dives had maxed out at 15 feet. We had no out-of-air emergencies and no equipment failures, so Liv asked if anything unusual happened.

"When pulling out the dive flag, I ran into the bottom and came up a little," he said. "Could that be it?"

It seemed unlikely that would cause a problem, but chest pains can potentially indicate a serious injury. The diver called DAN® and got a recommendation to go to the emergency room. Four hours and several X-rays later, he received a diagnosis of pneumomediastinum, also known as mediastinal emphysema. Pulmonary overinflation caused a rupture in the lungs that led to air releasing into the chest cavity. The doctor put him on oxygen and kept him in the hospital overnight. [*DAN note: Recompression is not indicated for this dive injury.*]

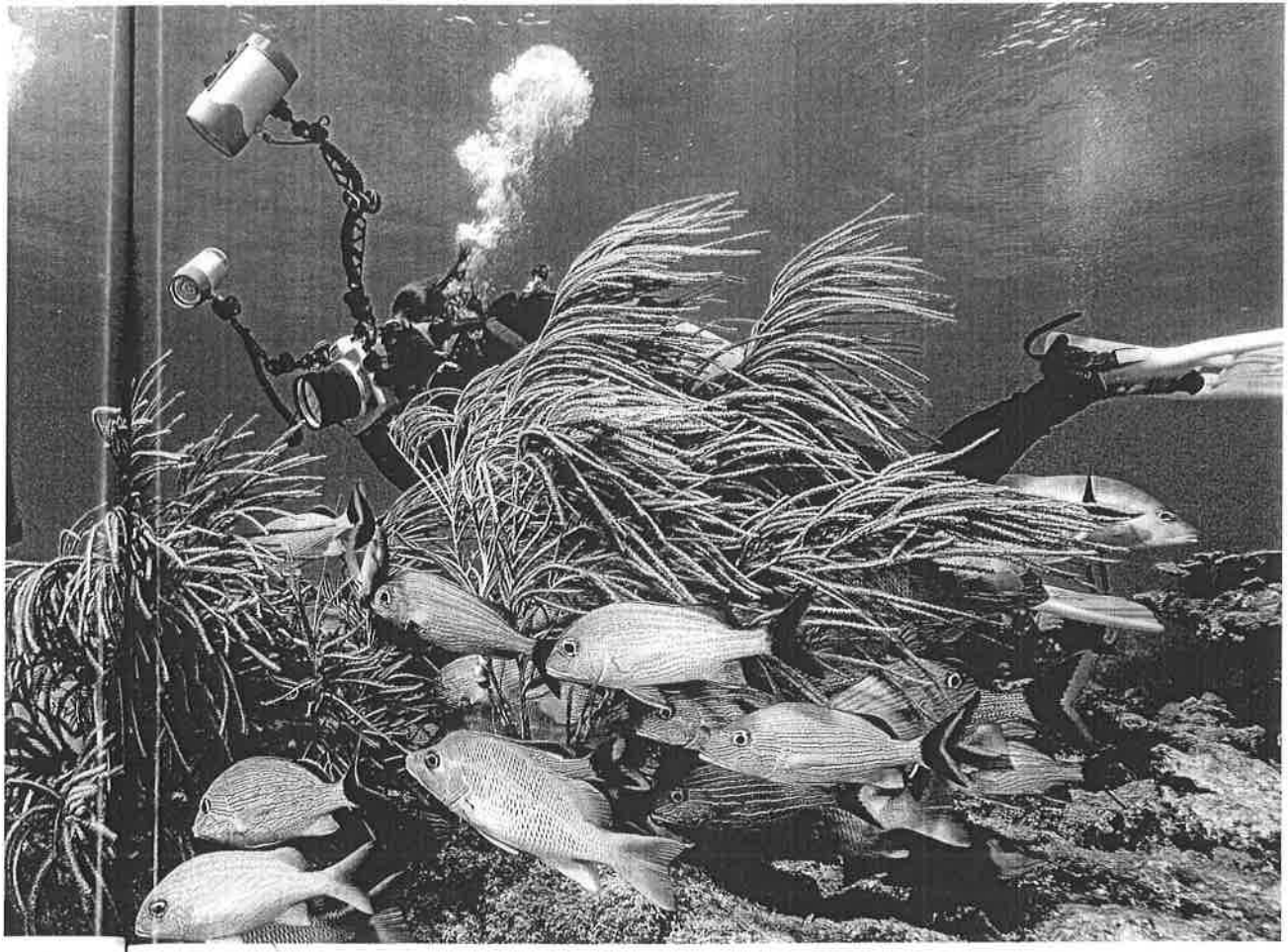
His pulmonary overinflation was minor, and he made a full recovery, but the injury meant no further diving until he healed. If he hadn't received medical help, the condition could have been life-threatening.

Liv and I were shaken by this incident. We never expected something like that to happen to one of our most confident divers at our safest local dive site in the best possible conditions other than reduced visibility. If this could happen, what else could go wrong with our less-accomplished students diving in more challenging conditions?

At the time, I dismissed depth as a factor, but after talking about the dive and understanding more about what likely happened, I soon realized how wrong I was. We had anchored the dive flags in 11 feet of water. To recover the flags, you had to hover above the soft substrate with your fins up and head down to unclip and reel them in. The injured diver had felt ear pain and possibly run into the bottom and then inhaled and likely held his breath for some portion of his ascent. Despite the shallow water, it turned into a very brief rapid ascent, bringing him toward the surface faster than intended.

All dive instructors learn that decompression illness (DCI) can occur even in shallow water. It's important to remember that shallow water is the easiest place to suffer an arterial gas embolism (AGE) or pneumothorax, which are among the most serious potential dive injuries. As we know, every 33 feet of salt water is an atmosphere of pressure. During a dive at 11 feet, you're breathing pressurized gas at 1.33 atmospheres absolute (ATA). If you hold a breath of pressurized air during ascent, it will expand by a third with the decrease in pressure from 1.33 ATA to 1 ATA.

Most of us would take proper measures for a rapid ascent of 33 feet while holding our breath, but an accidental 11-foot ascent is easier to imagine. Even a 5-foot ascent in shallow



Even in shallow water and while preoccupied with other tasks, it is important to breathe continuously. Relax and breathe normally during ascent to help avoid pulmonary barotrauma.

water while holding your breath could be enough to cause an AGE. Because of the relatively more dramatic pressure change in shallow water, our buoyancy changes more and makes accidental ascents more likely. Perhaps one way to gently emphasize the dangers of relative pressure changes would be to add an occasional four-word clause to diving's golden rule: "Breathe continuously, especially in shallow water."

While supervising scuba divers at New York Aquarium, I hear refrains of my past ignorance. Most divers are careful and take every dive seriously. But when they don't follow standard procedures, they invariably cite depth as a rationale. Spare weights stowed in zipper pockets? "But it's only 11 feet." No buddy checks? "It's only 11 feet." Low on air? "You know, it's only 11 feet." When diving the same exhibits every week with limited variables and always favorable conditions, it's easy to become complacent.

Fatalities are extremely rare in the scientific diving community, but in a fairly recent accident an experienced scientific diver conducting surveys in shallow water had drysuit problems, lost buoyancy control and experienced pulmonary overinflation syndrome following a rapid ascent. The community was surprised that such a serious incident and fatality happened in shallow water. Scientific divers learn the physics and physiology of diving but over time may become more comfortable in certain environments — warmer, clearer, calmer and shallower.

As the world slowly emerges from the pandemic, many of us will begin to plan the dive trips we have deferred. As responsible divers, we will likely plan our first dives at easier sites with less current and better visibility. Our initial depth limits will probably be a little shallower than usual, which will reduce our nitrogen exposure and the likelihood of suffering DCI. We must be careful, however, to not equate shallow dives with risk-free dives. We need to follow safe diving procedures every time we venture underwater and remember that shallow water has its own unique dangers.

NOTE FROM DAN

Pulmonary barotrauma can occur in a shallow swimming pool if a diver holds their breath during ascent or inadvertently floats to the surface while holding their breath. Most dive-related pulmonary barotraumas occur in compressed-gas diving due to pulmonary overinflation during a breath-hold ascent. Pulmonary barotrauma can occur even with normal breathing if there is an obstruction in the bronchial tree that prevents one lung segment's normal ventilation.

The pressure change during ascent is greatest closer to the surface. But since it doesn't take much overpressure to cause barotrauma, it can also occur if divers hold their breath at depth, especially if they experience bronchospasm or have blebs or bullae in their lungs.

The diver in this incident may have held his breath while straining or exerting himself at depth to pull out the flag, which could have been sufficient action to rupture preexisting bullae in his lungs. AD