

Negative Pressure Pulmonary Edema Occurring While Snorkeling

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ABSTRACT

Our story begins on a tropical island, in which infectious disease physician Dr. John Guilfoose spent his vacation to partake in underwater photography and snorkeling. Dr. Guilfoose describes the story that began when he saw a large sea turtle as he was snorkeling in the bay.

Puerto Rico has two major islands, Culebra, which is known for wealth- very touristy. And then there's Vieques, which I think was originally a bombing strip for American military. But it turns out it has an incredibly redeemed component from a tourist perspective of bioluminescent bays. So, I just got there, checked into the hotel, and wanted to go snorkeling. Did not bring any of my own stuff. And so, I went out and just rented some cheapy snorkel. Do not know if this is pertinent, but it could be. I hyper- hydrated right before going snorkeling. So, I drank like five big glasses of water. It might have something to do with the expansion of positive volume right before I went into the water.

INTRODUCTION

Yeah! Highly likely. And then, I also did not wear a wet suit or anything like that. The water was very cold.

Vasoconstriction...wow.

Yes, vasoconstriction and increased central volume. It was the perfect set up. So, I got in the water with my camera. And it turned out that the water was icy cold as I mentioned, which means it was in the seventies and I like it in the eighties or nineties. So, I was swimming around. I was about a thousand feet offshore at least- quite a way away from shore alone. And I see a turtle, maybe fifty feet in front of me. I had flippers on my feet and the flippers on my hands that you use for surfing that let you go much faster than you can get without them. I swam towards it not to harass the turtle, but to get a good picture.

Yes, I had a water-proof camera and wanted to get close. And so the turtle was obviously effortlessly able to stay in front of me. But I was booking! I was going a genuinely good speed and staying on the surface, because I had a snorkel and mask. And I was getting closer and closer to this turtle. Swimming further out at that point. By the nature of the exertion I was putting in, I was feeling tired and dyspneic, but that was part of the exertion. I did not think much of it. I was working hard; trying to catch

this turtle. And I was following him for a good couple of minutes, so it was a prolonged bit of exertion. I kept hearing significant crackling. It sounded like water was seeping into my snorkel. I stopped a couple of times and repositioned the snorkel and tried to dump out water, but there was no water in it. I would put it back in and would hear that noise—a real loud noise that sound. Because if you remember, snorkels go past your ear and can magnify all the noise. It turns out all that noise was my lung parenchyma crackling. So, I went along and tried to empty out my snorkel twice and the second time I stopped and realized that while I was breathing, I was hearing that same exact thing that sounded like water-rattling noise not in the snorkel running past my ear, but in myself.

METHOD

I thought “Oh no! Am I getting bronchospasms?” But it did not sound like bronchospasm, it sounded like rales that you would hear through a stethoscope. But you could hear them audibly to the world around you. It was incredibly loud. I started getting a significant cough and began panicking a little bit too.

The first thing that came to mind was that the swimming gloves were latex. I thought I was getting a latex allergy or something. I ripped them off and my hands had no swelling. Nothing! I did

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not really have a differential for what was going on. I just knew that it was not good. The cough kept up and a little bit of what looked like frank blood was in the water as I was spitting it out. And I thought, "Oh jeez!" I do not know what I did. Did I have a pulmonary embolism from being on the plane recently? But again, this extensive, harsh crackle was present and was primarily expiratory, which went against pulmonary edema in my own mind. It was mostly when I was breathing out, which is what made me think that it was bronchospastic, but it was not that at all. And I got really dyspneic and started to get lightheaded. And I was about a thousand feet from shore.

My goodness!

It is not a crowded island at all. It is not a huge tourist attraction. So, I just slowly drifted because exertion was challenging. I was kicking slowly and did eventually work my way into shore. It took me a while. I was incredibly weak and lightheaded and just really had to work hard to breathe. I have never really experienced the sensation of dyspnea before; it was incredibly effortful to fill my lungs. I had to brace on my knees and breathe extremely hard.

There was no one around. I slowly walked back to a road and then walked back to my hotel. I tried to take a shower, but nothing was working to get better. I just thought that time out of the water would help. So, I drove myself to the emergency shop that they had. It was like an urgent care center there on the island. I went in and was assessed with tachycardia, normal or slightly low blood pressure, my oxygen saturation was in the low eighties.

Wow.

I was offered a chest x-ray, but I did not want it. I do not know why. I was diagnosed initially by the first doctor who saw me. He said, "Oh, you just have asthma," and gave me a breathing treatment, which had no effect. So, she deferred to this other doctor to look. He was like, "I think you have pneumonia." I told him, "Sir, I

promise you that I don't have acute onset pneumonia." He said, "Well maybe it's an atypical pneumonia" [laughter]. So, they just put me on oxygen, gave me breathing treatments, and steroids. It took the better part of two or so hours before the course turned and things were getting better. There were still crackling and dyspnea for the better part of that day. The strange expiratory crackles stayed until the morning but the dyspnea gradually resolved.

I tried to research all sorts of causes and found a form of pulmonary edema that happens to triathletes when they jump into a body of water. They get pulmonary edema from sudden vasoconstriction. It did not really fit totally. When I was talking to Dr. John Parker [who is a Pulmonary Critical Care Physician] later, he was asking if there was any way that the snorkel could have been kinked at all. And the answer was "Absolutely."

The snorkel I rented was cheap and did not have the attachment to the mask that most snorkels have that keeps the tubing from bending at the curvature. So, the external end was floating behind me. I would periodically lift it and try to keep it straight, but the rubberized part was kinking. The theory goes that as I

was trying to inspire quickly while biting down on the snorkel to keep it from floating away and kinking it with my teeth. I was aware of its malposition. I took a large calibre tube and bit down on it, it kinks, and I was doing massive amounts of inspiration on a tiny airway. It generated such intrathoracic pressure that I was able to suck my own plasma volume into my alveoli.

I talked to some anaesthesiologists and they said that they saw that in intubated patients with endotracheal tubes on mechanical ventilation, usually men, who generate enough intrathoracic pressure to overcome the threshold of pressure to suck interstitial fluid into their alveoli. The treatment should have been.

CPAP, or some form of positive pressure. I do not think that the facility I went to had that. They said that if I did not get better, they would have to evacuate me [1].

They did not have the ability to intubate there. They were worried, because my oxygen saturation was low, and I was in incredible respiratory distress. I literally sat hunched over and worked hard to breathe for a while. I eventually got better. It was worth knowing what pulmonary edema feels like. It feels like you are genuinely drowning. You certainly sound like you are drowning. And it was cool in hindsight to see how poorly my brain processed what it was. I tried to just blame a leaky snorkel. With the crackles being primarily expiratory, I blamed the airway. But nothing really fit except negative pressure pulmonary edema [2].

DISCUSSION

The etiology of negative pressure pulmonary edema is multifactorial. Per UpToDate, the phenomenon is related to the generation of negative intrathoracic pressure by forced inspiration through a partially occluded airway as seen in kinked endotracheal tubes or vocal cord stenosis. This has been documented in operating rooms in which highly negative intrathoracic pressure leads to transudation of fluid from pulmonary capillaries into the interstitium [3].

This forced inspiration is referred to as Müller's Maneuver or reverse Valsalva maneuver. As the intrathoracic pressure becomes more negative, blood flow to the right heart increases. This causes the pulmonary vascular bed to dilate and the interstitial pressure around the capillaries becomes more negative as well [4]. Vascular fluid is drawn into the interstitial space and eventually into the alveoli.

This loss of alveolar surface area impedes gas exchange triggering a cascade of hypoxemia and catecholamine release which furthers systemic and pulmonary hypertension. The result is an acute increase in afterload by vasoconstriction, which worsens trans-capillary fluid efflux and increases interstitial and thus alveolar edema. This presents as pulmonary hypertension caused by negative pressure. Treatment is CPAP and bronchodilators.

Bronchodilators made me feel worse because it made me more anxious. I had never taken breathing treatments before and was already scared. Then after the treatments, I felt terrified. It was a unique experience to learn what genuine dyspnea was like.

Often the divergent evolution of animals can offer insight into human physiology and disease by showing evolution's response to similar dilemmas. Modern elephants are the only animal that can remain submerged for long periods of time while snorkeling. Their trunks coevolved with unique lung anatomy, in which the visceral and parietal pleura have been replaced with dense connective tissue and are separated by looser connective tissue. This characteristic prevents large shifts in intrathoracic pressure that could rupture small blood vessels in the pleura that could lead to pulmonary edema. Instead, the visceral and parietal pleura are less susceptible to sudden shifts in extracorporeal and intrathoracic pressure.

For a patient that could be experiencing Negative Pressure Pulmonary Edema (NPPE), the patient will likely have bilateral diffuse crackles and diminished resonance on percussion as well as egophony and whispered pectoriloquy on physical exam.

Patient may produce cough pink frothy sputum. What may have been helpful during the diagnostic efforts in the above story would have been a chest radiograph, which would have likely shown diffuse interstitial hazy opacities in both lungs akin to acute pulmonary edema. However, it is likely that the chest radiograph may have appeared normal.

Ruling out aspiration pneumonitis would require careful history. Echocardiogram can rule out cardiogenic cause of acute pulmonary edema.

In the setting of acute respiratory failure after snorkeling, clinicians should consider obstructive airway on the differential among other causes. This could occur from a partially occluding bend in the snorkel itself. In patients who have had prolonged intubation in the past but were not intubated at the time of

acute onset of pulmonary edema, vocal cord stenosis may be observed with bronchoscopy.

For practical purposes in the setting of snorkeling, the authors recommend snorkels that can be affixed to the eye mask and without flexible curvatures that may kink, which would narrow the caliber for airflow and require increased negative intrathoracic pressure for compensatory air exchange. In case of dyspnea, lightheadedness, dizziness, or any concerning symptoms while snorkeling, we recommend immediately leaving the water and seeking medical attention. Treatment may require intubation and mechanical ventilation with positive end-expiratory pressure (PEEP). Blowing up a balloon repeatedly can offer some PEEP when more sophisticated equipment is unavailable. Future investigation can consider self-administration of PEEP by exhaling through pursed lips along with CPAP administration, diuretics, supplemental oxygen, bronchodilators, IV albumin administration, warming, and other approaches.

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