

# Oxygen

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The end of my internship year in San Diego at UCSD approached! When it started in June of 1973, I felt certain I would never finish the stressful gauntlet of critically-ill medical patients. But as the year was coming to a close, the Stygian tunnel of internship showed signs of ending and ahead... yes!—was light, peace, and bird song! Where I had trembled with fear as emergency patients arrived when internship began, now I was confident. Did my new-found confidence result from my methodical and rational approach to sick patients? Yes, I concluded, careful attention to my patients' pathologic physiology must have done the trick! EKG's, blood gases, lab tests, X-rays—all the necessary clinical data—were the keys to my success!

On the first terrifying day of my internship I had inherited 25 sick inpatients, and I never was able to lower my patient count during the year, but as the year was ending, my service shrank rapidly, my patients were getting well, finishing their examinations, getting referred to other services, getting discharged, and heading home in droves. My current patient load was down to four patients! The medical floor had so few patients they had to close down one of the four pods!

With the luxury of time, I leisurely reviewed the charts of my four remaining patients. Only one of them was likely to have a problem in getting a discharge. His name was Billy Boyle. Billy was a 61-year-old man with end-stage chronic obstructive pulmonary disease (COPD) who had been admitted to the ICU for a serious COPD exacerbation and despite three weeks' of intubation and intense treatment, his arterial blood oxygen level ( $p_aO_2$ ) remained at 45 mm of mercury even while receiving oxygen through his nasal cannulae! He was feeble and unable to eat or undertake any physical efforts without help. According to the pulmonologists, this was inconsistent with life. When

I saw him in the ICU he was cyanotic, but didn't seem to be otherwise discommoded by his low oxygen level. Even after his COPD exacerbation and excess sputum production improved, his  $p_aO_2$  remained at 45. This was a serious problem! But before I describe Billy's problem and its resolution I will try to explain how oxygen became such a vital ingredient of human survival.

Oxygen is an incredibly reactive substance, and because of its amazing ability to react chemically with almost any substance, it shouldn't be able to exist in its free state in earth's air. But somehow it does. The entire panoply of oxidation reactions in nature takes their name from this element and its voracious electrons. Teamed with its energetic electromagnetic ally, light, they drive the mechanisms that changes dross matter into life!

When life first began billions of years ago the earth's atmosphere was without oxygen, creating life required a reducing atmosphere to be present. Oxygen was initially a poison for life, and there was no oxygen in earth's atmosphere until 2.5 billion years ago when cyanobacteria (Archaea) started using the  $CO_2$  that was present in the atmosphere and invented photosynthesis. These invisible animalcules poured out oxygen as a waste product. Bacteria and Archaea are the true heroes of evolution; they developed all the enzymes to perform essentially any chemical reaction that their little prokaryotic cells required, including harnessing oxygen for oxidative phosphorylation and energy production as well as light for photosynthesis. Bacteria were so good at this work that eukaryotic cells (like ours) engulfed them to become slave laborers known as chloroplasts and mitochondria—the main energy sources for all eukaryotic cells. After another billion years or so about 20% of the earth's atmosphere was oxygen. The existing life forms, of necessity, accommodated themselves

to the free oxygen. This atmospheric change was convenient for animal evolution since we require oxygen to survive.

Early animals evolved through stages in which oxygen had to be absorbed directly through contact with water in which it was dissolved. However, larger animals had to develop systems to bring oxygen to all the cells of their bodies. When the fish wanted to spend more time on land with ambient oxygen they had to adapt their swim bladders to become the lungs of amphibians. This permitted them to bring oxygen from the air to their cells. There, in their cells, they built themselves an interior fire and in the fire forged tissues and life. We humans do the same thing unless a disease affects the function of our lungs.

Billy Boyle's lungs suffered from just such a problem: COPD, an awful, fatal disease, but in practical terms he had a more immediate problem. The ICU staff needed his bed for acute patients, and they needed to discharge Billy from the unit, in spite of his poor prognosis. I received a call from the unit director notifying me that they were transferring Billy to my service on the medicine ward. The ICU attending sadly warned me (over the phone) that "*Mr. Boyle, unfortunately, we believe, will not be leaving the hospital alive because of his lung failure and  $p_aO_2$  of 45, but he will be more comfortable during his last days on the ward than in the burly burly of the unit*".

And so Billy arrived on five South of the La Jolla VA hospital, and with him came his 55-year-old sister Milly Boyle who had waited patiently each day outside the ICU, visiting Billy whenever permitted, and whispering confidently to him without any evidence that he heard her. On the ward, I would see Billy every day, while his sister Milly fed him and whispered to him about what was going on. I spoke confidently to Billy about continuing his therapy and getting him home, but he never spoke to me. I wasn't sure he heard me.

Even with his oxygen mask or nasal cannulae, his oxygen level couldn't be brought above 45. I believed what the pulmonologists told me, namely, that Billy was going to die, probably sooner rather than later. The pulmonologist instructed me to do a radial artery puncture every day to measure his blood gases in a desperate search for therapies that could raise his arterial oxygen level or perhaps just to show that we were aware of his situation. The arterial puncture was a daily ordeal for Billy. I had to wield a large-bore needle and a special heparin-rinsed glass syringe with its glass plunger that would smoothly slide back as the arterial pressure filled the syringe with blood. When the sample was adequate, I would remove the needle and put

firm pressure on the artery. The syringe would be sealed and the sample would be placed in ice in an ice bucket and rushed to the lab to measure the fateful arterial blood oxygen.

No matter what we did in terms of chest physiotherapy (pounding on his chest), IPPB (pushing air into his lungs), and aerosolizing medications into his lungs, Billy's  $p_aO_2$  remained at 45. The pulmonologists were hanging crepe and demanding that we keep assessing and documenting our vigorous efforts to salvage Billy by continuing to measure his blood gases each day. After another two weeks on the ward, his radial arteries were pretty beaten up, without providing any good news.

I can't help sending a time capsule back to 1973 to let you know that today, in 2012, putting a clip with a pulse oximeter on a patient's finger can, in most people, make the oxygen measurement in a few seconds without any invasive intervention. So don't give up on scientific progress. Back is 1973; however, things were getting a bit grim. I only had four patients on my service, but one of them was, according to my consultants, circling the drain no matter what I did.

I had to understand this fatal situation better, so I conspired to spend a half-hour each day with Billy and Milly Boyle in his hospital room. Of course, since I only had four patients, this was not difficult to arrange. With all the ward rounds and work rounds and procedure sessions we had each day, I thought that I had been seeing and communicating adequately with them (although Billy had never spoken or responded to me), but I was mistaken, and simply by sitting there in Billy's room and talking with Milly and doing my chart work and observing his interactions with Milly, I began to find out many things that I had never realized.

Billy and Milly were able to communicate quite effectively, and the information that Milly gave me about what Billy thought and felt had been accurate all along! And Billy understood what I was telling him but just didn't have the energy to respond to me and could do it with much less energy with Milly. I started looking differently at Billy; he knew that I knew that he was aware and that he could communicate his urgent messages to me by Milly. I told them about the seriousness of Billy's low arterial oxygen level and the conclusion that the experts came to about his impending death.

The next day, Milly came to me and told me that Billy had concluded that he didn't need any further care in the hospital and wanted to go home. I again summarized the situation to both of them that we had not succeeded in

improving Billy's oxygen, and we were very concerned that he would not survive at home. Milly nodded but said they were willing to take that chance. Billy, with a major effort, nodded. Yet it was clear that Milly believed the grave prognosis was the doctors' view and not her own, or Billy's view.

The medics had given up on Billy in the ICU and had sent him to me and the ward to die, which he refused to do, but now I was officially giving up on him on the ward. Milly calmly said that she would be there to feed and assist Billy at home (which she was already doing in the hospital) and would sustain him; he would be fine, she said. I agreed to discharge Billy.

This news caused the hospital to have a bureaucratic convulsion. The pulmonologists said that any person with a  $p_aO_2$  of 45 needed to be hospitalized so that they could die while receiving medical care, and to send him home was reckless. The VA hospital director also didn't want to discharge Billy. In those days the VA hospitals would more or less let any patient stay as long as they wanted, and he thought that to discharge someone with a  $p_aO_2$  of 45 would not look right. He told me that they had also noticed that I was discharging all my patients and they were beginning to wonder if they had really been ready to be discharged!

In responding to the hospital, I rearranged the mandate

of the pulmonologists by explaining that Billy and Milly accepted the danger of discharge, and that Billy understood he was going home to die, but that he would be more comfortable at home, which is what he and Milly wanted. This was all true, except for the part about dying, but the hospital bought it, and with lots of oxygen flowing and ambulance workers taking good care of Billy and allowing Milly to ride with him in the ambulance with its sirens blaring, Billy returned home. I'd never seen an ambulance leaving in emergency mode to take a patient home from the hospital! I suppose they didn't want the morbid event to occur in transit.

Lo and behold, two weeks later at my VA medicine outpatient clinic, Billy and Milly appeared, Milly pushing Billy's wheel chair holding its oxygen canister and both of them looking pleased with themselves; Billy was as cyanotic as ever but smiling, feeling fine, and whispering back and forth with Milly. She tells me that he is afebrile and breathing better. The nurse asks if I want to do an arterial puncture for blood gases. I look at Billy and Milly, think for a moment, and then ask the nurse "Why?"

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