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diving medicine

the facts°

IN THE LAST COLUMN I DISCUSSED PULMONARY BAROTRAUMA IN NORMAL LUNGS. TO SUMMARIZE, THE DIVER HOLDS THEIR BREATH WHILE ASCENDING. THE LUNGS EXPAND UNTIL THEY HAVE REACHED THEIR MAXIMUM SIZE. IF THE DIVER ASCENDS AS LITTLE AS ONE METER MORE FROM THIS POINT, THE PRESSURE IN THE LUNGS WILL RISE AND AN AREA OF THE LUNGS WILL RUPTURE CAUSING ARTERIAL GAS EMBOLISM, MEDIASTINAL OR SUBCUTANEOUS EMPHYSEMA. THE CAUSES ARE USUALLY PANIC, BUDDY BREATHING (HOLD BREATH ASCENDING WHILE BUDDY HAS THE REG) AND LAYNGOSPASM (ASCENDING WHILE COUGHING). THIS TIME I WILL FOCUS ON THE EQUALLY COMMON PROBLEM OF PULMONARY BAROTRAUMA IN ABNORMAL LUNGS.

PART TWO

Pneumothorax

In the last column I mentioned that the lungs are covered in a very tough membrane called the visceral pleura. As a result, when an area of lung ruptures the gas is almost always contained inside the lung and forced into the circulation or back towards the mediastinum. On rare occasions however the gas escapes from the lung and enters the potential space between the lung and the chest wall. This is called a pneumothorax (air in the chest).

Pneumothorax is relatively common in medicine. Frequent causes are trauma (knife wound to the chest, broken rib that tears the lung, etc.), ventilation of seriously damaged lungs, and various medical procedures (subclavian venous catheters, esophagoscopy, etc). Occasionally it happens without any obvious cause.

This 'spontaneous' pneumothorax occurs in individuals who are born with or develop blebs or blisters on the surface of the lungs. These air sacks represent areas where the visceral pleura is very weak, and they are like a giant alveolus on the surface of the lung. They communicate with the bronchi, but usually through a very small opening. The blebs are almost always near the tops of the lungs, the effects of gravity stress them and sometimes they rupture, causing the pneumothorax.

A diver with this problem could be very unlucky and have it happen while they are diving simply due to chance, but there are reasons diving might cause the blister to rupture. As the diver descends the air in the blister will compress, when the diver returns to the surface the air will expand and refill the blister. No problem. However, during the dive the blister can slowly refill with the compressed air the diver is breathing. When the diver ascends to the surface in this situation, the gas in the blister will expand to greater than the original volume and the blister can rupture. Because the connection from the blister to the airways of the lungs is so small, the gas in the blister will not have time to escape into the lungs, even if the diver does a normal or slower than normal ascent.

Anyone who has a spontaneous pneumothorax is at greatly increased risk of having a second or third spontaneous pneumothorax (people with one bleb usually have many). Therefore, most diving medical experts consider a history of spontaneous pneumothorax a lifetime contraindication to scuba diving. Most divers also have a chest x-ray before they start diving. If the x-ray is done when the person has exhaled as much air as possible from their lungs, large blebs will be visible. If one is seen, the person should not dive, ever.

For these reasons, pneumothorax is very rare in divers during or shortly after a dive.

Excessive Exhalation

To try and prevent pulmonary barotrauma, divers are taught to always breathe out while they are ascending. This should prevent the lungs from ever expanding to their maximum volume. Sometimes however a diver develops pulmonary barotrauma even though they claim to have breathed out all the way to the surface. If the lungs are abnormal, this can happen as we will see in the next section. Sometimes however no abnormalities of the lungs can be found. In this situation the proposed explanation is as follows.

The normal lung is like a very soft sponge built around a mesh of elastic tissue. The alveoli and smallest airways have walls that are only one cell thick and therefore they have no internal support. As the lungs expand, the elastic tissue is stretched and it helps pull the alveoli and smallest airways open. When the lung is collapsed this elastic support is removed. Therefore, if the diver vigorously exhales to minimum lung volumes some of these small airways might completely collapse, trapping air in the alveoli they supply. As the diver ascends these alveoli could over inflate and rupture causing pulmonary barotrauma.

I am not convinced this really happens (as the air in the alveoli expands it should force its way out through the small airways without causing lung damage) but the only other explanation for the situation described above is that the diver had abnormal lungs that we could not detect.

Abnormal Lungs

We have already discussed one form of abnormal lungs above (blebs causing pneumothorax). There are a very large number of other lung problems that can cause pulmonary barotrauma including but not limited to cysts, asthma, bronchospasm, infection of any type, inflammation, mucous plugs, sarcoidosis, tumors, reduced pulmonary compliance (stiff lungs), pleural adhesions, fibrosis, and scars from any reason.

These multiple causes all share a common mechanism of injury. They partially obstruct a bronchus, leaving only a very small opening through which air can move into and out of the portion of lung supplied by that bronchus. Either the airway is partially filled with debris (mucous, inflammation, infection, etc.), the bronchus is partially collapsed from pressure on the outside of the bronchus (sarcoidosis, tumors, etc.), or both.

So what happens when this person goes diving? As they descend the portion of the lung isolated by the partial obstruction collapses. When they return to the surface it re-expands. If the bronchus is completely obstructed the diver will probably be OK. However, if the bronchus has a small opening a very serious situation develops.

As the diver descends the portion of the lung supplied by the mostly obstructed bronchus will collapse. During the dive air will slowly move past the obstruction and the collapsed section of lung will inflate. When the diver ascends to the surface, the gas in the isolated section of lung will expand. Because the opening in the partially obstructed airway is so small, the gas will be unable to escape fast enough, that section of the lung will become over pressurized, alveoli will rupture and the diver will suffer pulmonary barotrauma, most likely AGE.

It should be obvious that the critical factors are the size of the remaining opening in the bronchus and the volume of lung supplied by that bronchus. If the opening is large enough relative to the volume of lung supplied, the diver will be OK with a normal ascent and will only get into trouble with a rapid ascent. If the opening is smaller, the lung will rupture even with a slow ascent. If the bronchus becomes completely obstructed at depth, the lung will rupture even with the slowest ascent to the surface.

One additional piece of information is required. In cases of fatal AGE in divers with normal lungs, the area of damage is usually only the size of the tip of your finger and it is often impossible to find at autopsy. Therefore, a single small abnormality in the lung can be fatal.
Obviously, a person with any detectible abnormalities of the lungs should not scuba dive.

Return to Diving

Pulmonary barotrauma is not always fatal. If the person survives, can they return to diving and if so when?

If the person has been left with any residual problems, everyone agrees that they should not return to diving. If the person appears to have made a complete recovery the situation is more controversial.

There are two ways to look at this question. The diving medical literature contains a couple of dozen cases of divers who have suffered pulmonary >

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barotrauma, apparently made a complete recovery, returned to diving, and then suffered a second pulmonary barotrauma. In most cases the second incident had no apparent cause (the diver had done a normal ascent) and the results were very bad (the diver died or had serious neurological damage).

It seems most likely that the diver had suffered some lung damage with the first incident and that damage caused the second incident. Therefore, many diving medical experts believe that that anyone who suffers pulmonary barotrauma should be banned from scuba diving for life. I have been involved in two cases of Canadian military divers who suffered pulmonary barotrauma and were returned to diving (against my recommendations). The first died a year or two later in a diving accident where it is unknown if pulmonary barotrauma was a factor or not. The second voluntarily gave up diving.

As technology has evolved, there is now a second way to look at whether these divers can return to diving. If you wait until the diver has completely recovered from the first incident and then do a high resolution spiral CT scan of the lungs, you should be able to detect any abnormality down to a few millimeters in size. If ANY abnormality is discovered, the person should not return to diving. However, if the CT scan is completely normal diving MIGHT be an option. Their risk is most likely still increased by some unquantifiable but most likely small amount.

So what happened to the 65 year old instructor who died? She had suffered a serious lung infection a few weeks before. We know that in cases of pneumonia (the infection involves the small airways and alveoli) the person still has visible abnormalities on a routine chest x-ray for up to six weeks after all their signs and symptoms resolve. Therefore it is most likely that she still had abnormal lungs and at least one partially obstructed bronchus when she did her dive. Even though she did a normal slow ascent, it was too fast for the air to escape from the partially isolated section of the lung, it ruptured, she suffered AGE and died. After pneumonia you need to wait for at least six weeks and until the chest x-ray is completely normal before you return to diving.