A CLASSIC CASE OF DIVER AIR EMBOLISM AT THE SURFACE FROM HIGH WAVE ACTION

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On 25 September 1975 a 36 year old professional scuba diver and aquanaut with 17 years of diving experience, whom we shall call “Joe”, and who was a member of the First International Saturation Study of Herring and Hydroacoustics, died of an arterial air embolism to the heart and brain, as the apparent result of a surface re-entry accident. The accident occurred following a 3 day saturation dive (in the German underwater laboratory/habitat HELGOLAND in 110 feet of water, off Rockport, Massachusetts), and after a correct decompression phase, a proper instantaneous recompression for exiting the underwater laboratory/habitat, and a normal ascent, at least until the dive team was about 15' to 18' from the turbulent surface, where 10' to 12' waves were breaking against structures and equipment on the surface.

The three aquanauts were returning to the surface from the HELGOLAND via the buoy cable line attached to the relatively fixed and stable decompression buoy at surface. As observed from below, the decompression buoy extended about eight feet into the water below the surface in good weather conditions. But this day the weather conditions were not good, and the sea was not calm. Because of the pounding waves, the froth, foam and splash, the normally submerged portion of the stabilized decompression buoy was at one moment deeply submerged under the crest of a great wave and at the next moment nearly exposed above the surface as the trough of the wave would fall away from the base of the tethered buoy.

During the ascent up the decompression buoy line, all three divers exchanged several “OK” hand signals signifying that everything was under control and normal. This was done at the start of the ascent, at about midway, and again near the surface before exiting the water. One of the three divers later reported that he had likewise also exchanged “OK” signals with each of the other two divers immediately upon surfacing. Two of the divers surfaced in the heavy seas within a few feet of the decompression buoy, while Joe was first observed at the surface clinging to the buoy.

When the divers were rising to the surface together along the decompression buoy line, Joe was the first or uppermost diver on the line. When the last diver was about 10' from the submerged bottom of the fixed or stable decompression buoy, he and the diver just above him kicked away from the buoy and swam freely to the surface, bobbing like corks upon the crests and down into the troughs of the turbulent sea. Before swimming over to the pickup craft, one of the other divers looked back to see Joe clinging to the buoy with his Cressi full-face mask off and his mouthpiece (regulator) out of his mouth. He was apparently trying to attach a blue plastic bag to the decompression buoy, and was struggling with a Nikonos camera and strobe light at the same time.

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Finally he dropped the bag and camera and clung tightly to the fixed buoy staff with both hands as the heavy seas intermittently covered him. While he was relatively fixed in position, the waves were submerging him at crest and suddenly dropping away from him at trough. When he was next observed he was calling for help. He took a dunking and then cried out again in distress. A support diver reached him very quickly, hit the purge button of Joe's emergency (octopus) regulator to clear it of water, and immediately placed it back in Joe's mouth. At this juncture Joe relaxed and released his grip on the buoy. As he and the support diver slipped away from the buoy on the crest of a wave, the support diver fully inflated Joe's unisuit. He was then towed on his back by two support divers, unisuit inflated, regulator in his mouth, with his head out of the water.

Although he was virtually incapacitated on the return to the support vessel, there was an occasion when some of the seas washed over causing Joe's mouthpiece (regulator) to come out, and he personally replaced it with his right hand and held it in place momentarily: but, then both hand and mouthpiece fell away. One rescue diver later commented, "His eyes were open, although I can't recall seeing him blink as the water passed across his face." Another diver reported that when Joe was being towed a white frothy foam was bubbling from his mouth.

When he was placed aboard the support vessel, Joe showed no signs of life. He was pulseless and not breathing. Cardiopulmonary resuscitation was administered immediately and continuously aboard the support vessel as it proceeded directly to port. A Coast Guard helicopter was dispatched, but transfer of the casualty with the necessary life-support equipment in the rough sea conditions was determined to be unsafe. Upon arrival at Rockport Harbour, Joe was rushed to a recompression chamber by ambulance and was compressed to an equivalent depth of 165 feet (50 meters) of seawater for decompression treatment. After a time, when it was quite apparent that Joe was dead, the decompression phase and vigorous attempts at resuscitation were terminated. and the attending physician in charge officially pronounced him dead. Although a period of 3:19 hours elapsed from the time of the accident until the medical personnel on scene declared Joe dead and terminated resuscitation and recompression/ decompression treatment, it is probable that Joe was in fact dead within minutes of the embolism.

An autopsy confirmed the cause of death as an air embolism to the arteries of the heart and brain - presence of air forced into the cardiovascular system by changing pressure. More specifically, considerable quantities of air were found in the right and left ventricles of the heart, and air was present in all of the coronary arteries. In addition, an abundance of air bubbles was found in the vascular supply to the surface of the brain, and in the branches of the middle cerebral arteries. The embolism causes a sudden blocking of the artery by an obstructive air bubble which has been moved to its location in the vascular system by the blood flow. The tissues beyond the embolus become deprived of their blood supply, of course. Incidentally, it was especially noted that no gas could be forced out of the muscle tissue or subcutaneous fat by the application of great pressure or compression, which indicated that decompression had been quite complete prior to death.

According to the report of the Board of Investigation, the precise cause of the embolism could not be clearly established. The report indicated two reasonable possibilities:

a. "The high seas passing could have caused a momentary change of pressure sufficient to cause air embolism if the diver was holding fast to the mooring lines of the buoy and had just taken a full breath of compressed air.

b. “If the diver was rising to the surface with water in his mask and caught a relatively minute quantity of water in his larynx, this could produce laryngospasm with an associated constriction of air flow, or reflex breath-holding. Examination of the Cressi full-face mask on shore indicated that the right half of the face plate was out of its seal, leaving an opening over about 70% of the right side. There was also evidence of an impact on the top of the mask. It should be noted that this could have happened in the course of the rescue operations.”

The Board concluded that the actions which caused the embolism in the final ascent were those of the diver alone, and indicated that these actions were not what should have been expected of a diver of Joe’s long and distinguished record of diving under severe conditions. The Board questioned why Joe decided to surface at or on the buoy structure, for it was clearly hazardous because of the heavily surging sea and the attendant possibilities for impact or sudden changes in emersion.

One can only surmise from the available pieces of information precisely what happened to Joe. Not having been there, I can only attempt to reconstruct what might have occurred. Thus, as pure conjecture on my part, from a careful reading of the depositions, medical reports and supporting documents, and through personal discussions with other divers and support personnel involved in the incident, I am of the opinion that Joe must have received at least a glancing blow to the right side of his head near the temple as he attempted to surface, as a result of being thrown by wave action into the submerged portion of the decompression buoy. If he were dazed and disoriented this would account for his otherwise unexplainable actions at the buoy. It seems entirely logical that Joe’s full face mask with affixed regulator could possibly have been knocked away from his face. Accordingly, he certainly could have gulped a sufficient quantity of water to cause the laryngospasm with an associated breath-holding reflex. If this occurred at the precise moment when Joe was holding fast to the mooring lines of the buoy, and he had just taken a full breath of compressed air as the crest of a 10' or 12' wave fell completely out from under him, the momentary change of pressure in his lungs could have been sufficient to cause an air embolism. Obviously, this would be identical to a diver swimming up to the surface and holding his breath during the last 10' of the ascent.

Assuming nearly a one-half pound change in hydrostatic pressure for each foot of change in depth (actually it is 0.445 lbs change of pressure), there could have been about a five pound (250 mm Hg) immediate pressure differential in a 10' to 12' sudden change in wave height before Joe could expel the denser, compressed air which filled his lungs. Little more than 2 psi (pounds per square inch) or 100 mm Hg pressure differential would have been sufficient to force air into his circulatory system and cause the fatal embolism.

Perhaps it can be explained as follows. Air can be forced out from the alveoli of the lungs into the circulatory system when the air in the alveoli is at a higher pressure than that in the blood vessels surrounding the alveoli. Thus if a true pressure differential of about 100 mm Hg were to exist between the alveoli and surrounding capillaries, an embolism could occur; but there might be no clinical evidence of a rupture. 100 mm Hg pressure differential is equivalent to only 4 feet change in seawater depth, or only 2 psi of atmospheric pressure change. On the other hand, a true pressure differential of greater than 100 mm Hg could cause actual rupture of the alveolar capillary membranes.

The point is that such a critical pressure variation could have occurred each and every time a surging wave passed over Joe and then almost simultaneously fell away

below him as he held tightly to the buoy cable. If he inhaled a full lung capacity of compressed air at any such instant, a massive air embolism could surely occur. The same kind of danger of an air embolism can occur, of course, when a working diver attaches himself by magnets or otherwise to the side of a rolling ship, so that he is first immersed and then suddenly lifted above the surface when the sea drops out from under him.

The tragic lesson to be learned here is that a true pressure differential or change of only 4 feet of saltwater can cause an embolism, if one holds his or her breath in a maximum inhalation of compressed air, and a lung rupture might or might not occur in such a circumstance. Also, it is clear that a fatal air embolism can indeed occur to a diver after he reaches the surface if the necessary combination of circumstances conspire to occur at a common moment. If for any reason an emerging diver does not remain on the surface in turbulent wave conditions, and becomes alternately immersed and then lifted out of the water, it would be exceedingly important that only short, shallow and frequent breaths of compressed air be taken, so that the lungs are never filled to capacity and lose elasticity. Even though some elasticity remains in the lungs after a maximum inhalation, there is a danger of exceeding the elastic limit of the lungs and their alveoli if at this moment an expanding volume of air is introduced by a sudden decrease in depth and pressure. Also, it is important to emphasize another self-evident point, to wit: all divers should be cautioned to avoid fixed or stable structures when near the surface in rough weather. One other admonition bears mention. In heavy seas it is important to refrain from carrying objects if at all possible, so as to keep the hands free to use as necessary in any crisis situation.

In my view, this is a classic case of an air embolism occurring to a scuba diver as the result of a surface accident involving a fixed or stable structure in rough seas. It should be brought to the attention of all novice scuba divers as a part of their basic instruction. An understanding of the inherent dangers of diving in turbulent seas may save lives in the future. Somehow, I think Joe would have wanted it that way.

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Pots not natural habitat?

There is an interesting case simmering up in Newcastle at present. A man has been charged with stealing lobsters from another man's pots. As his defence he has claimed that the lobsters are the property of whoever first lifts them from the water, being still wild animals "free for the taking" until the owner lifted his pots. It was also claimed, naturally, that the State had no jurisdiction as the action occurred beyond the high water line. Legal evidence was offered to the effect that larceny could be committed on wild animals that are fit food for man. Sergeant Richards assured the Court that it is undisputed that lobsters are fit for human consumption. There is no mention of the lobsters pending the resumption of Court hearings ....

Cold gives little warning of the onset of Hypothermia. Abnormal behaviour (forgetfulness) may occur. 70% of the human body is within 2.5cms of the surface. Activity increases heat loss. Danger period continues after the victim has been removed from the water. Heat loss occurs even in "warm" water. Severe but reversible hypothermia may produce a death-like appearance and therapy be wrongly thought useless.