How do marine mammals avoid the bends? Study offers new hypothesis, highlights role that sonar plays in strandings

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Deep-diving whales and other marine mammals like these Pacific white-sided dolphins can get the bends--the same painful and potentially life-threatening decompression sickness that strikes scuba divers who surface too quickly. Credit: Lance Wills, © Woods Hole Oceanographic Institution

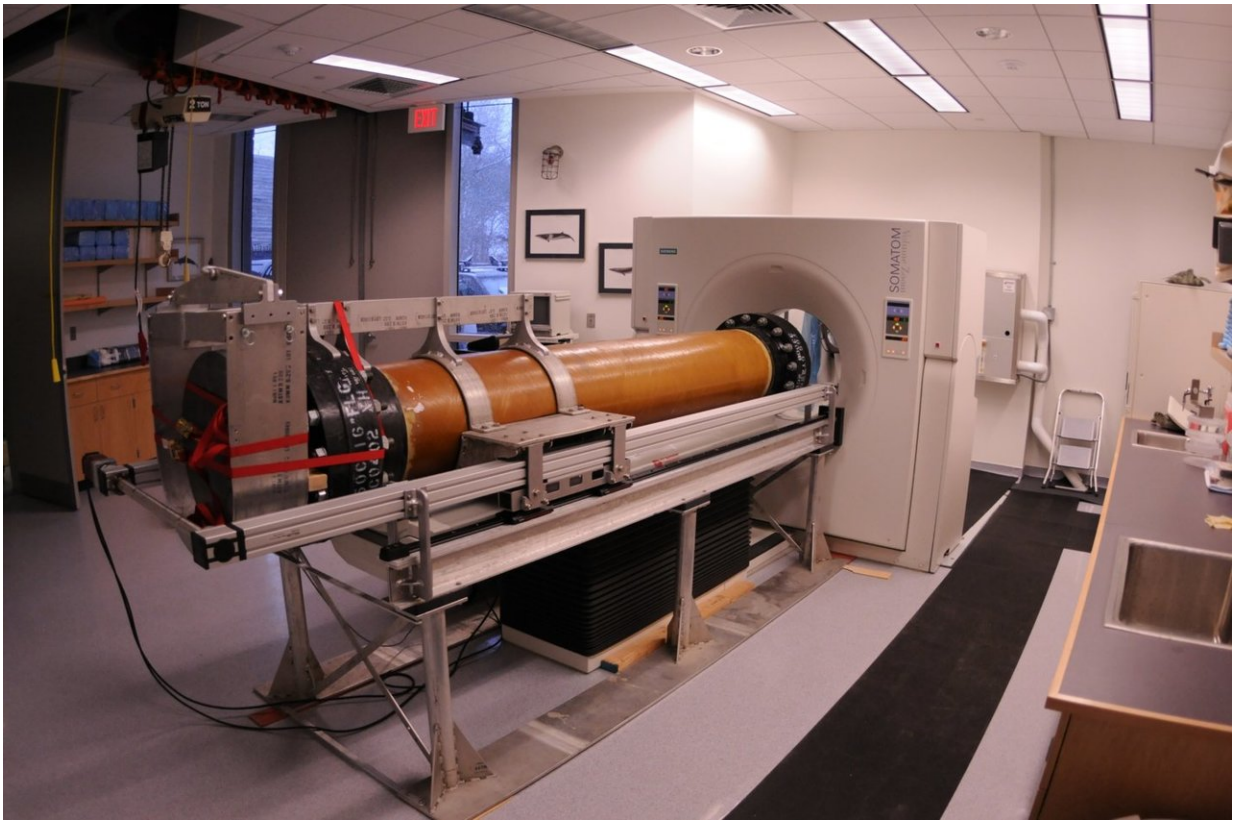
Deep-diving whales and other marine mammals can get the bends—the same painful and potentially life-threatening decompression sickness that strikes scuba divers who surface too quickly. A new study offers a hypothesis of how marine mammals generally avoid getting the bends and how they can succumb under stressful conditions.

The key is the unusual lung architecture of whales, dolphins and porpoises (and possibly other breath-holding diving vertebrates), which creates two different pulmonary regions under deep-sea pressure, say researchers at the Woods Hole Oceanographic Institution (WHOI) and the Fundacion Oceanografic in Spain. Their study was published April 25, 2018, in the journal *Proceedings of the Royal Society B*.

"How some marine mammals and turtles can repeatedly dive as deep and as long as they do has perplexed scientists for a very long time," says Michael Moore, director of the Marine Mammal Center at WHOI and co-author of the study. "This paper opens a window through which we can take a new perspective on the question."

When air-breathing mammals dive to high-pressure depths, their lungs compress. That collapses their alveoli—the tiny sacs at the end of the airways where gas exchange occurs. Nitrogen bubbles build up in the animals' bloodstream and tissue. If they ascend slowly, the nitrogen can return to the lungs and be exhaled. But if they ascend too fast, the

nitrogen bubbles don't have time to diffuse back into the lungs. Under less pressure at shallower depths, the nitrogen bubbles expand in the bloodstream and tissue, causing pain and damage.

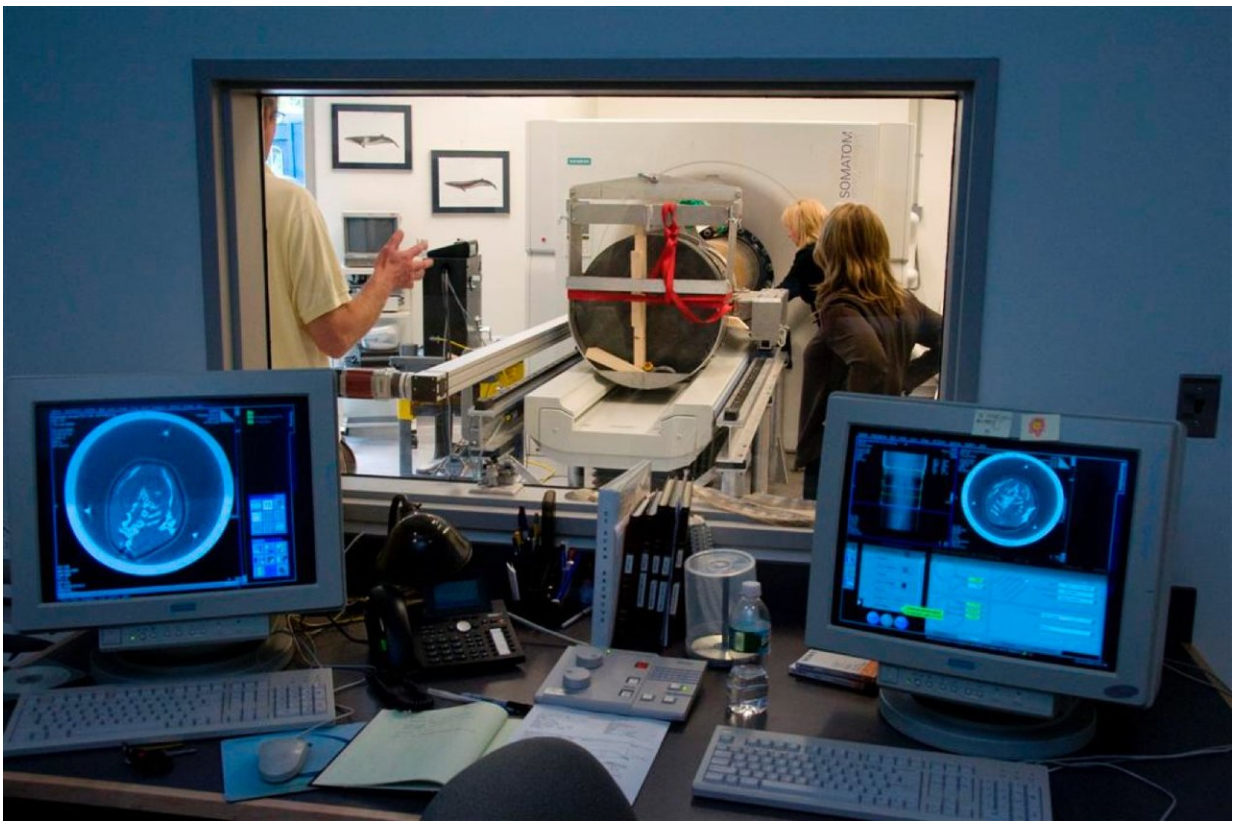


In their study, the researchers took CT images of a deceased dolphin, seal, and a domestic pig pressurized in a hyperbaric chamber. Credit: Michael Moore, © Woods Hole Oceanographic Institution

Marine mammals' chest structure allows their lungs to compress. Scientists have assumed that this passive compression was marine mammals' main adaptation to avoid taking up excessive nitrogen at depth and getting the bends.

In their study, the researchers took CT images of a deceased dolphin, seal, and a domestic pig pressurized in a hyperbaric chamber. The team was able to see how the marine mammals' lung architecture creates two pulmonary regions: one air-filled and the other collapsed. The researchers believe that blood flows mainly through the collapsed region of the lungs. That causes what is called a ventilation-perfusion mismatch, which allows some oxygen and carbon dioxide to be absorbed by the animal's bloodstream, while minimizing or preventing the exchange of nitrogen. This is possible because each gas has a different solubility in the blood. The terrestrial pig did not show that structural adaptation.

This mechanism would protect cetaceans from taking up excessive amounts of nitrogen and thus minimize risk of the bends, says lead author Daniel García-Parraga of the Fundacion Oceanografic.



The team was able to see how the marine mammals' lung architecture creates two pulmonary regions: one air-filled and the other collapsed. The researchers believe that blood flows mainly through the collapsed region of the lungs. The terrestrial pig did not show that structural adaptation. Credit: Andreas Fahlman, © Woods Hole Oceanographic Institution

However, he said, "Excessive stress, as may occur during exposure to human-made sound, may cause the system to fail and increase blood to flow to the air-filled regions. This would enhance gas exchange, and nitrogen would increase in the blood and tissues as the pressure decreases during ascent."

Scientists once thought that diving marine mammals were immune from decompression sickness, but a 2002 stranding event linked to navy sonar exercises revealed that 14 whales that died after beaching off the Canary Islands had gas bubbles in their tissues—a sign of the bends. The researchers say the paper's findings could support previous implications of decompression sickness in some cetacean mass strandings associated with navy sonar exercises.

The team says further research will require the development of tools to analyze how lung blood flow and ventilation patterns change with various stressors during diving.

More information: Pulmonary ventilation-perfusion mismatch: A novel hypothesis for how diving vertebrates may avoid the bends, *Proceedings of the Royal Society B*, rspb.royalsocietypublishing.or … .1098/rspb.2018.0482

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