Case #155

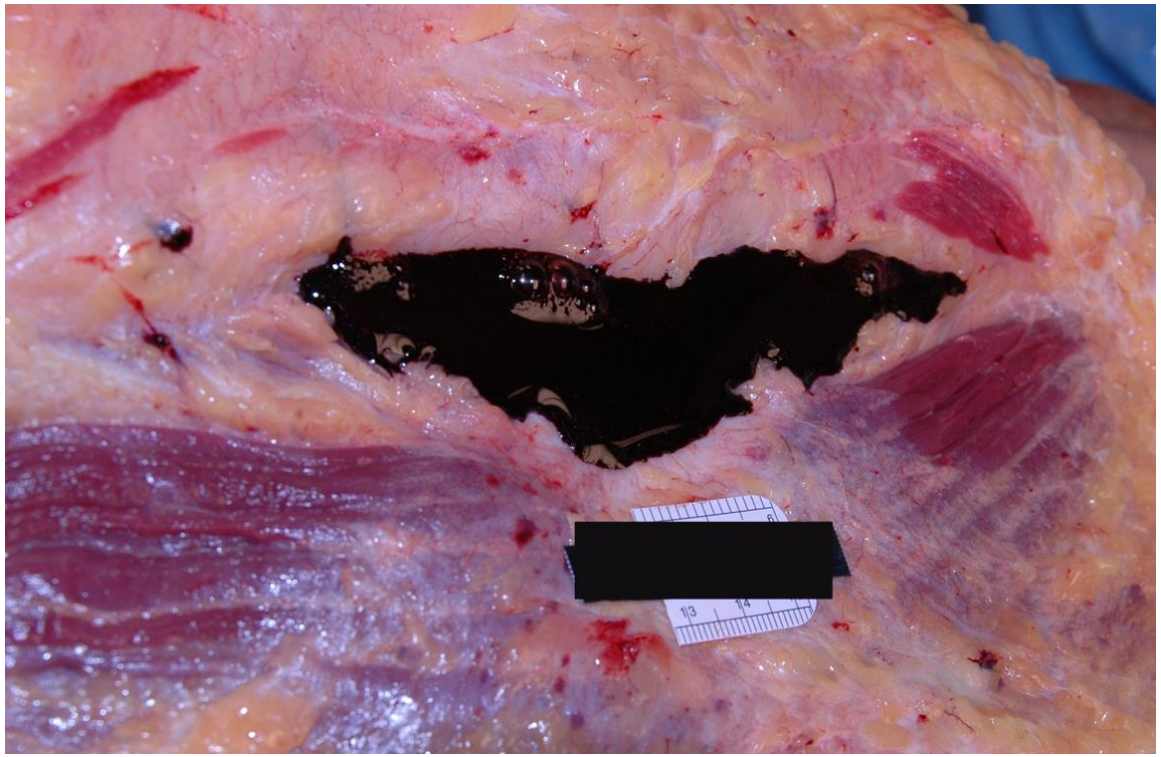
NAME Educational Activities Committee

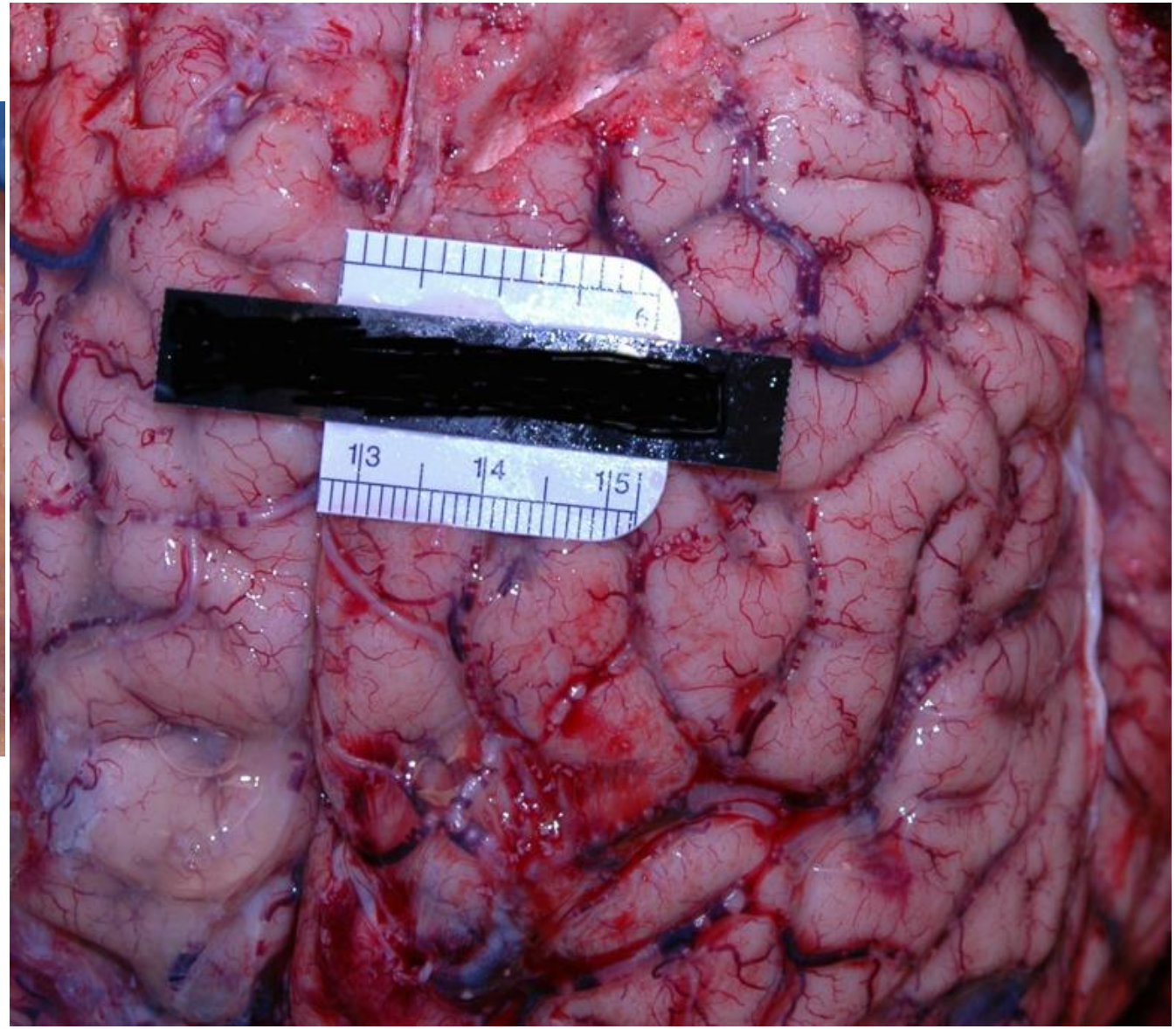
Case provided by:

Hannah P. McQueen, M.D.
AP/CP Resident Pathologist, PGY-3
Medical University of South Carolina (MUSC)
Member, NAME Educational Activities Committee (EAC)

Will Boggs, B.S.
Medical Student, MS-4
Medical University of South Carolina (MUSC)

Nicholas I. Batalis, M.D.
Professor, Department of Pathology and Laboratory Medicine
Medical University of South Carolina (MUSC)
Member




13
14
15

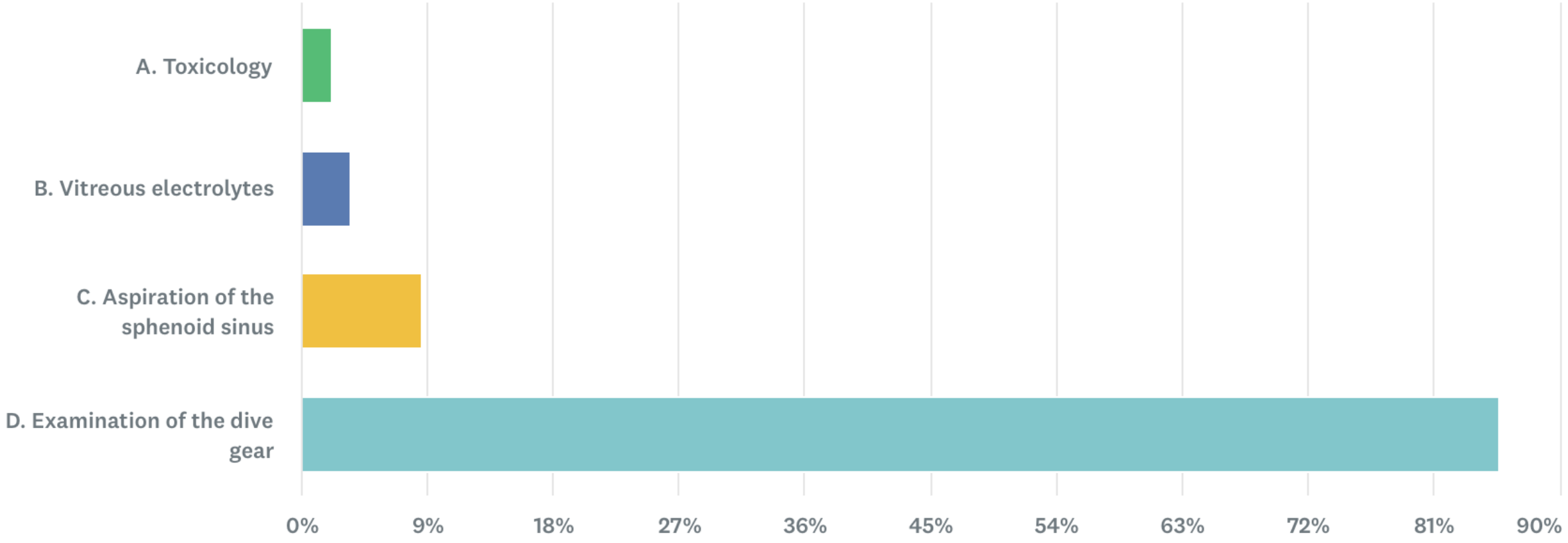
A 48-year-old man dies shortly after presenting to the emergency department. The decedent was an experienced diver who had been SCUBA-diving and spearfishing with a friend at a depth of about 95 feet. During the dive, the friend lost sight of the decedent, and found his spear gun on the ocean floor. He ascended to discover the decedent thrashing around in distress, who then submerged before the boat could reach him. The decedent was located and pulled out of the water approximately 20 minutes later. He was unresponsive.

At autopsy, the decedent had conjunctival and mucosal petechiae, scattered facial abrasions and contusions, and crepitant skin of the chest and neck. Internal findings included multifocal subscalpular hemorrhages, hemorrhages of the sinuses and petrous ridges, and the findings demonstrated in the photos on the previous slide.

Which investigation would provide the greatest diagnostic value in establishing the cause and circumstances of death?

A. Toxicology
B. Vitreous electrolytes
C. Aspiration of the sphenoid sinus
D. Examination of the dive gear

Answers...


A. Toxicology
B. Vitreous electrolytes
C. Aspiration of the sphenoid sinus
D. Examination of the dive gear
0%
9%
18%
27%
36%
45%
54%
63%
72%
81%
90%

D. Examination of the dive gear (Correct: 85.7%) – (1)

Demonstrated autopsy findings included numerous bubbles in the peripheral blood and cerebral vessels. These findings are suggestive of gas emboli, the most serious and feared complication of diving. Pulmonary barotrauma during ascent (pulmonary overpressurization syndrome, POPS) can lead to the release of air into tissues and blood vessels. Introduction of gas into pulmonary veins can result in a systemic arterial gas embolism (AGE). POPS is typically associated with rapid, uncontrolled ascent to the surface and/or breath-holding.

Dive gear holds critical information about the terminal dive and should be examined by an unbiased dive expert. The examination of the dive gear should include inventory, final tank pressure (then close valve), tank and regulator condition, air samples from the tank, weight of the weight belt, and computer chip analysis.

Potential experts to perform the evaluation of the equipment may be found at local dive shops, through local dive squads affiliated with local authorities, and/or through larger resources such as the Divers Alert Network (DAN).

Examination of the decedent's gear revealed that all components were functioning properly, and that the reserve air tank was empty and the main air tank was full. Computer chip analysis revealed an ascent from the maximum depth of 95 feet to the surface within seconds.

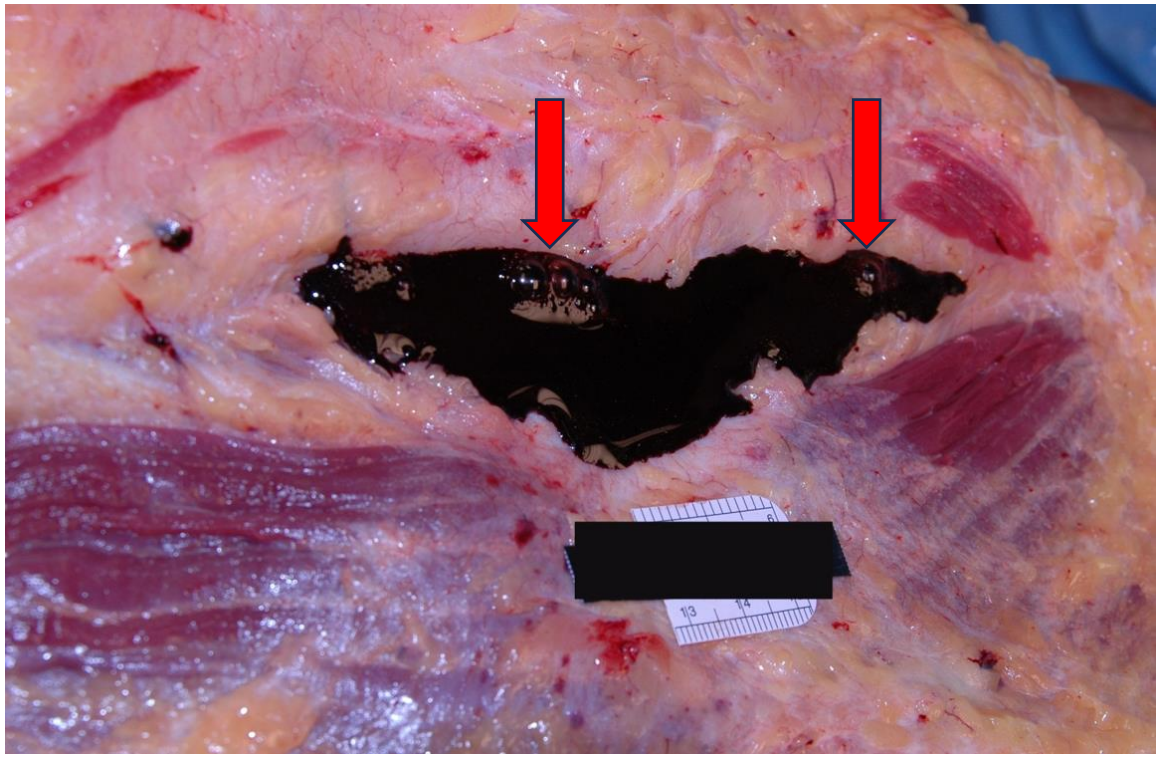
D. Examination of the dive gear (Correct: 85.7%) – (2)

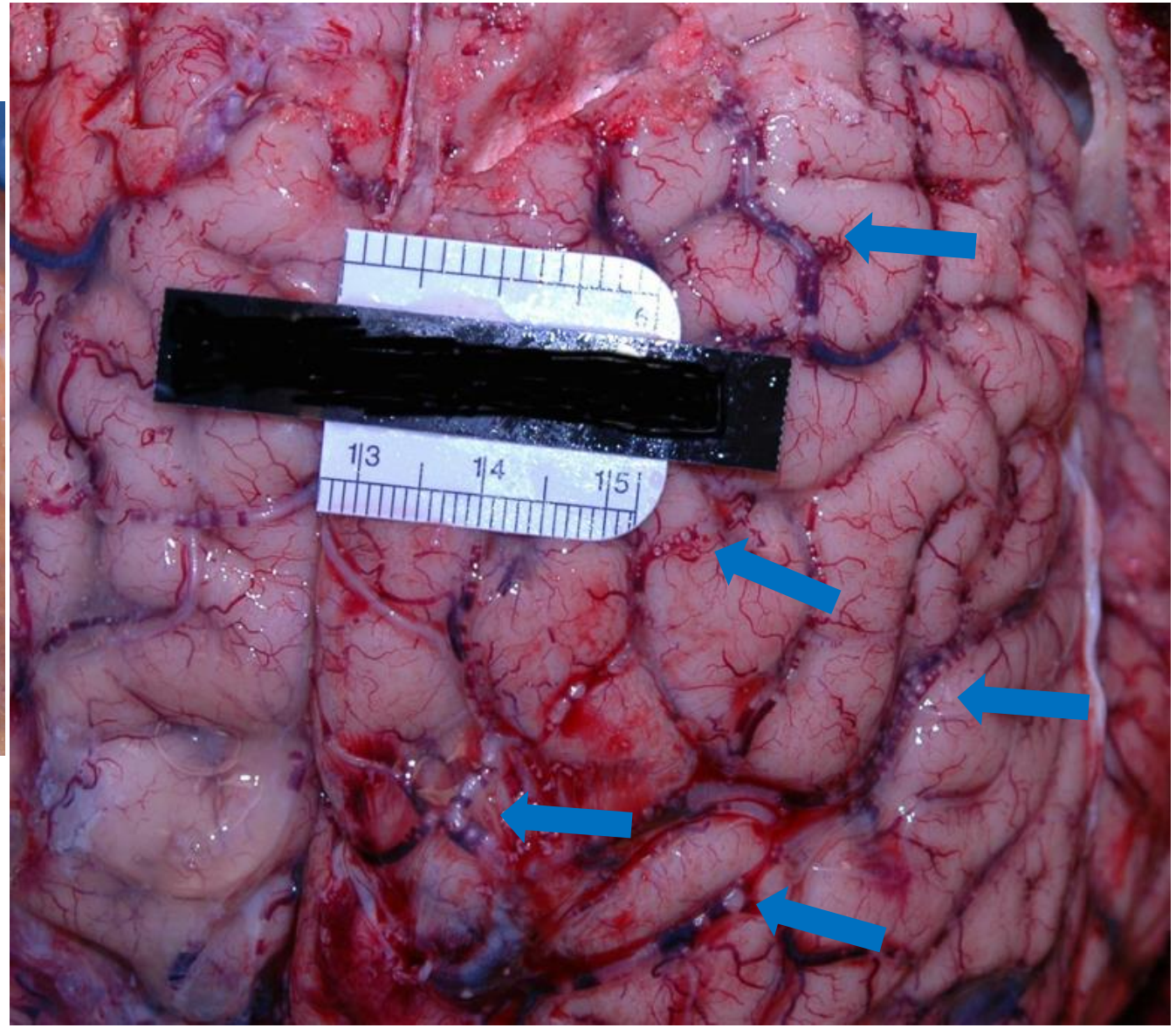
Rapid ascent caused compressed gas to expand as the ambient pressure decreased. Overexpansion of the alveoli led to septal rupture and allowed air to escape into the tissues and vasculature, leading to fatal gas embolism.

The death was certified as follows:

- Cause: Gas embolism due to pulmonary barotrauma sustained while scuba diving
- Manner: Accident

In addition to examination of the dive gear, an extensive history and scene investigation is imperative in understanding SCUBA-related deaths. Information about the diver, including experience level and certification, as well as past medical history, is of paramount importance, along with a thorough scene investigation, to include weather and water conditions, water depth and temperature, and witness accounts of the terminal dive.





Demonstrated autopsy findings included **numerous bubbles in the peripheral blood** (red arrows) and **cerebral vessels** (blue arrows).

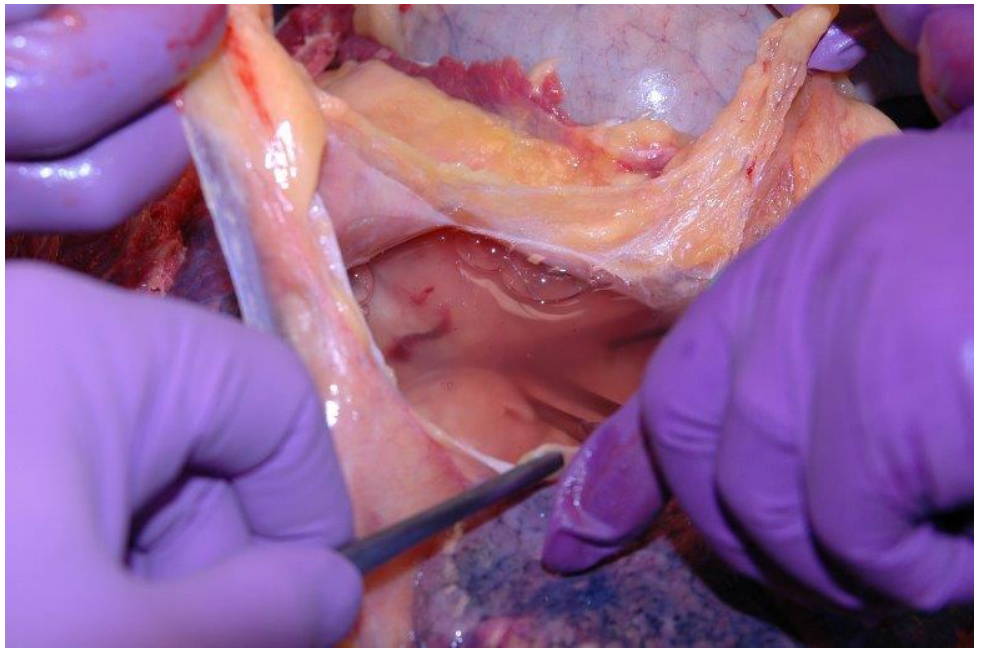
A note on ancillary procedures at autopsy (1)

Several ancillary procedures can be helpful in these deaths, including radiographic studies, which can assist in diagnosing extra-alveolar air in the pleural or pericardial cavities or intravascular locations. X-Rays of the head, neck, thorax, and abdomen are advised; postmortem CT imaging can be obtained as an alternative.

To check for possible pneumopericardium, fill the chest cavity with water and open the pericardium, noting any air bubbles.

A similar approach can check for intracardiac gas by filling the pericardial sac with water prior to incising the right atrium and other chambers.

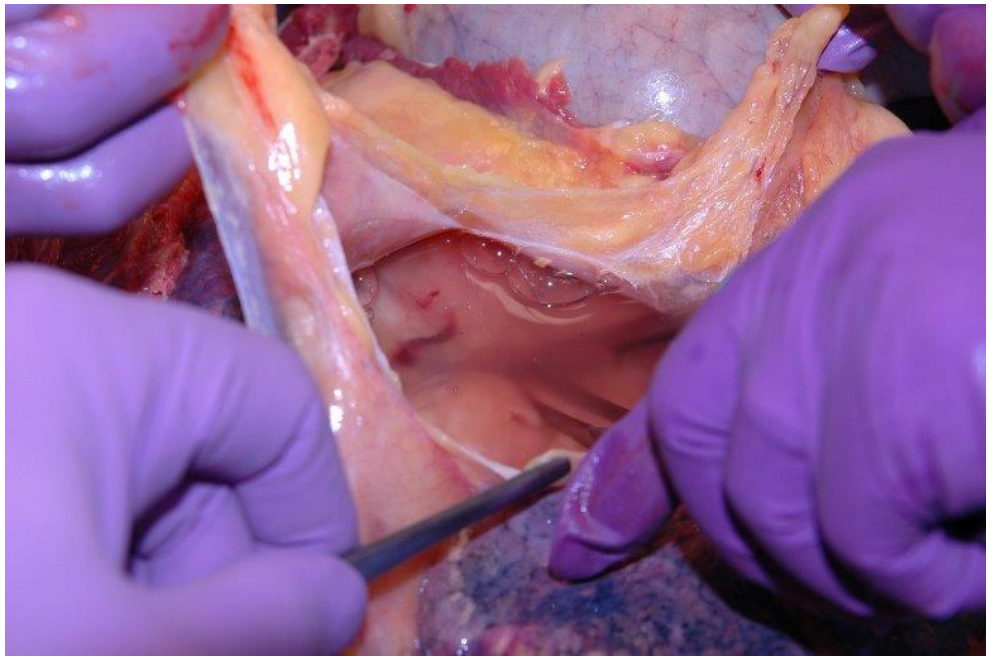
Several methods have been described for the assessment of pneumothoraces, including modification of the initial chest incision to make a “tent” or “pocket” out of the soft tissue, and then filling this area with water. A large bore needle can be inserted into the second intercostal spaces on each side, and if desired, any escaping air can be captured in an inverted, water-filled, graduated cylinder for measurement and analysis. As the chest plate is removed, note any gas escaping from vessels.



Autopsy methods of the presented case included assessment for intracardiac gas. The heart floated when the pericardial sac was filled with water, and incisions into chambers released bubbles, as pictured above.

A note on ancillary procedures at autopsy (2)

It is important to interpret all of the above findings with caution, as they are prone to artifact. The presence of gas in any organ or vessel at autopsy of someone who breathed compressed gas just prior to death, as in SCUBA-related deaths, is not conclusive evidence of decompression sickness or air embolism. During a dive, inert gas dissolves in tissues, and this gas will come out of solution when the body returns to atmospheric pressure. This, combined with postmortem gas production, as well as additional possible intracardiac gas introduced during cardiopulmonary resuscitation efforts, can all lead to the production of bubbles in tissues and vessels. Intravascular bubbles present predominantly in arteries and observed during autopsy after a short postmortem interval are suspicious for air embolism, and a thorough dive history, including interrogation of the dive equipment (which in this case revealed a supportive finding of rapid ascent) can be confirmatory.



Autopsy methods of the presented case included assessment for intracardiac gas. The heart floated when the pericardial sac was filled with water, and incisions into chambers released bubbles, as pictured above.

Other responses…

A. Toxicology (Incorrect: 2.2%)
Many substances could be contributory or causative in the setting of a SCUBA-related accident, and therefore toxicology studies should absolutely be pursued and considered prior to death certification. However, given the autopsy findings and answer choices available, examination of the dive equipment is of higher investigative yield.

B. Vitreous Electrolytes (Incorrect: 3.5%)
Vitreous electrolyte studies can be a useful adjunct in many medicolegal death investigation settings, and studies have been done on their use in fresh versus saltwater drownings, but overall they lack specificity and can have significant postmortem interval effects, making examination of the dive equipment a much more informative choice.

C. Aspiration of the sphenoid sinus (Incorrect: 8.6%)
There is some support in forensic literature that presence of aqueous fluid in the sphenoid sinus, in conjunction with other supportive findings, can be regarded as a sign of drowning; however, this finding is subtle, subject to artifact, and nonspecific. There are some studies that suggest fluid composition analysis, including for distribution and number of diatoms, can be a valuable piece of information in drowning deaths, but supportive data is limited and not scientifically reliable. Given the significant internal and external findings at autopsy, the most valuable information in certification of this death was found in examination of the dive equipment.

REFERENCES

1. Bell MD. Scuba diving. In: Dolinak D, Matshes EW, Lew EO, editors. Forensic Pathology: Principles and Practice. 1st ed. Burlington (MA): Elsevier; 2005. Chapter 9, p. 234-237.
2. Spitz DJ. Injury and death associated with SCUBA diving. In: Spitz WU, Spitz DJ, editors. Spitz and Fisher's Medicolegal Investigation of Death: Guidelines for the Application of Pathology to Crime Investigation. 5th ed. Springfield (IL): Charles C Thomas; 2020. Chapter 10, p. 490-495.
3. Armstrong EJ, Erskine KL. Investigation of drowning deaths: a practical review. Acad Forensic Pathol. 2018;8(1):8-43. doi:10.23907/2018.002.
4. Byard RW, Summersides G. Vitreous humor sodium levels in immersion deaths. J Forensic Sci. 2011;56(3):643-644. doi:10.1111/j.1556-4029.2011.01735.x.
5. Caruso J. Autopsy protocol for recreational scuba diving fatalities. Appendix F. In: Recreational Diving Fatalities Workshop Proceedings. Durham (NC): Divers Alert Network; 2010. p. 279-281.