APPENDIX F

Autopsy Protocol for Recreational Scuba Diving Fatalities

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Since most pathologists and autopsy technicians rarely perform an autopsy on someone who died while scuba diving, few medical examiners' offices will have significant experience in performing appropriate postmortem examinations. The following is a guideline that can be followed with the understanding that some of the recommended procedures will be impractical and may only take place in a facility with significant laboratory resources available.

History

This is absolutely the most important part of the evaluation of a recreational diving fatality. Ideally, one should obtain significant past medical history with a special focus on cardiovascular disease, seizure disorder, diabetes, asthma and chronic obstructive pulmonary disease. Medications taken on a regular basis as well as on the day of the dive should be recorded, and information regarding how the diver felt prior to the dive should be obtained. Any history of drug or alcohol use must also be noted.

The dive history is extremely important. If possible, the investigator should find out the diver's experience and certification level. The most important part of the history will be the specific events related to the dive itself. The dive profile (depth, bottom time) is an essential piece of information, and if the diver was not diving alone, eyewitness accounts will be invaluable. With the near-universal use of dive computers, the computer used by the deceased diver should be interrogated, and if it has a download function all recent dives should be reviewed. Not only will the last dive or dive series be invaluable to the investigation, much can be learned about the diver by looking at previous dives made, including frequency, depth, ascent habits and with certain computers even breathing gas usage. Written dive logs are also a valuable source of information related to the diver's experience level and dive habits.

Questions to be asked include:

- When did the diver begin to have a problem (predive, descent, bottom, ascent, postdive)?
- Did the diver ascend rapidly (a factor in air embolism and pulmonary barotrauma)?
- Was there a history of entrapment, entanglement or trauma?
- If resuscitation was attempted, what was done, and how did the diver respond?

External Examination and Preparation

A thorough external examination including documentation of signs of trauma or animal bites or envenomation should be carried out. Palpate the area between the clavicles and the angles of the jaw for evidence of subcutaneous emphysema. X-rays of the head, neck, thorax and abdomen should be taken to look for free air. Postmortem CT imaging can be obtained as an alternative.

Modify the initial incision over the chest to make a "tent" or "pocket" out of the soft tissue (an "I" shaped incision) and fill this area with water. A large bore needle can be inserted into the second intercostal spaces on each side; if desired, any escaping air can be captured in an inverted, water-filled, graduated cylinder for measurement and analysis. As the breastplate is removed, note any gas escaping from vessels. An alternative test for pneumothorax consists of teasing through the intercostal muscles with a scalpel and observing the relationship between the visceral and parietal pleura as each pleural cavity is entered. If the two pleural layers are still adjacent until the pleural cavity is breached, there is no evidence of a pneumothorax. If a pneumothorax had occurred during the final dive, the lung would already be at least partially deflated and not up against the parietal pleura.

The pericardial sac can be filled with water and the chambers of the heart may be incised with a scalpel to look for any intracardiac gas. As was possible for the pleural cavities, escaping gas may be captured and analyzed, but most medical examiner offices do not have the resources for such endeavors. After the mediastinum, heart and great vessels have been examined under water for the presence of gas, the water may be evacuated and a standard autopsy may be performed.

Carefully examine the lungs for bullae, emphysematous blebs and hemorrhage.

Note any interatrial or interventricular septal defects. Carefully check for evidence of cardiovascular disease and any changes that would compromise cardiac function.

Toxicology: Obtain blood, urine, vitreous, bile, liver and stomach contents. Not all specimens need to be run, but at least look for drugs or abuse. If an electrolyte abnormality is suspected or if the decedent is a diabetic, the vitreous fluid may prove useful for analysis.

Prior to opening the skull, tie off all the vessels in the neck to prevent artifactual air from entering the intracranial vessels. Tie the vessels at the base of the brain once the skull is opened. Disregard bubbles in the superficial veins or venous sinuses. Examine the meningeal vessels and the superficial cortical vessels for the presence of gas. Carefully examine the Circle of Willis and middle cerebral arteries for bubbles.

Have an expert evaluate the dive gear. Are the cylinders empty? If not, the gas should be analyzed for purity (a little carbon monoxide goes a long way at depth). All gear should be in good working order with accurate functioning gauges.

Possible Findings

Air embolism: Intra-arterial and intra-arteriolar air bubbles in the brain and meningeal vessels, petechial hemorrhages in gray and white matter, evidence of COPD or pulmonary barotrauma (pneumothorax, pneumomediastinum, subcutaneous emphysema), signs of acute right heart failure, pneumopericardium, air in coronary and retinal arteries

Decompression sickness: Lesions in the white matter in the middle third of the spinal cord including stasis infarction, if there is a patent foramen ovale (or other potential right to left heart shunt) a paradoxical air embolism can occur due to significant venous bubbles entering the arterial circulation

Venomous stings or bites: A bite or sting on any part of the body, unexplained edema on any part of the body, evidence of anaphylaxis or other severe allergic reaction

Drowning: While drowning essentially remains a diagnosis of exclusion, there are some anatomic findings that are observed with considerable frequency. The lungs usually appear hyperinflated and can even meet at the midline when the anterior chest wall is removed. Lungs are typically heavy and edematous, and pleural effusions may be present. A moderate amount of water and even some plant material may be present, not only in the airway but also in the esophagus and stomach. Dilatation of the right ventricle of the heart is commonly observed as is engorgement of the large central veins. Fluid is also often found in the sphenoid sinus.

Carbon monoxide poisoning: Deaths due to carbon monoxide poisoning are rare in recreational diving, but they do occur. Autopsy findings are similar to carbon-monoxide-related deaths in other settings, with the classic finding of a cherry red color to the organs and blood. A carboxy-hemoglobin measurement should be obtained as routine toxicology in all diving-related deaths to exclude the contribution of contaminated breathing gas.

Interpretation

The presence of gas in any organ or vessel observed at the autopsy of someone who breathed compressed gas just prior to death is not conclusive evidence of decompression sickness or air embolism. During a dive, especially one of considerable depth or bottom time, inert gas dissolves in the tissues, and the gas will come out of solution when the body returns to atmospheric pressure. This, combined with postmortem gas production, will produce bubbles in tissue and vessels. The phenomenon has caused many experienced pathologists to erroneously conclude that a death occurred due to decompression sickness or air embolism.

Intravascular bubbles present predominantly in arteries and observed during an autopsy performed soon after the death occurred is suspicious for air embolism. The dive history will help support or refute this theory.

Gas present only in the left ventricle or if analysis shows the gas in the left ventricle has a higher oxygen content than that present on the right side would also be supportive for the occurrence of an air embolism.

Intravascular gas from decomposition or off-gasing from the dive would contain little oxygen and be made up of mostly nitrogen and carbon dioxide.

Deeper, longer dives can cause decompression sickness and significant intravascular (mostly venous) gas. Decompression sickness is rarely fatal and more commonly causes significant morbidity (illness and injury) in severe cases. Rapid ascents and pulmonary barotrauma are associated with air embolism.