



SNORKEL SAFETY STUDY: SUMMARY OF FINDINGS

2025





Background

The Hawai'i State Department of Health formed the Snorkel Safety Sub-Committee in October 2017 in response to frequent snorkel-related drownings, particularly among non-residents. Many of these incidents were puzzling, as they often occurred in calm waters, sometimes shortly after the individuals entered the water, and typically without any visible signs of distress. These silent snorkel-related drownings were occurring at other snorkeling locations worldwide.

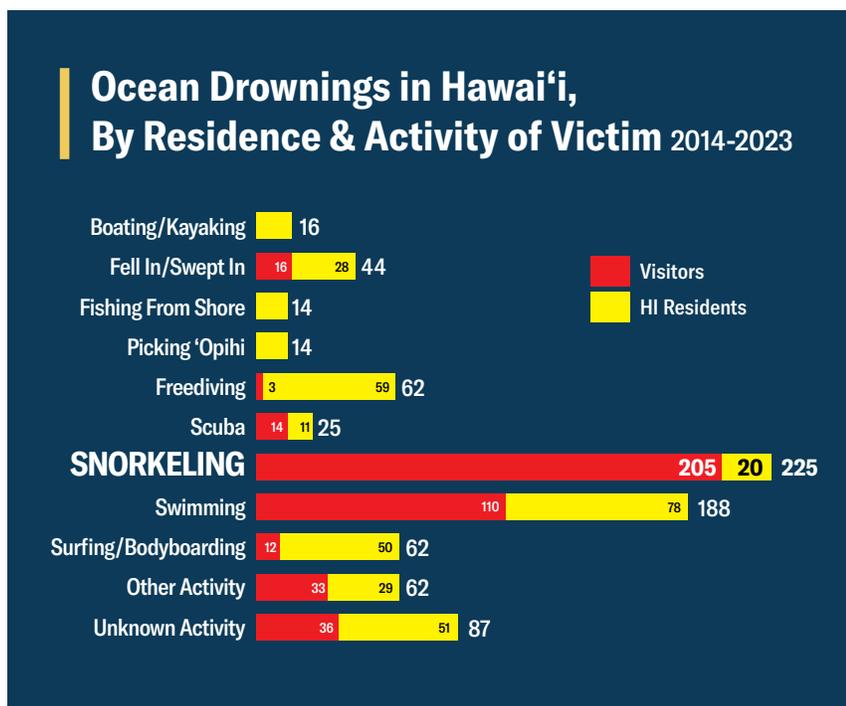
Philip Robert Foti M.D.

Dr. Philip R. Foti, Pulmonologist and Principal Investigator of the Snorkel Safety Study, passed away in December 2024. Dr. Foti was committed to uncovering the causes of unexplained snorkeling fatalities, leveraging his expertise and dedication toward this endeavor.

*The lives saved through the identification of **Snorkel Induced Rapid Onset Pulmonary Edema** can be attributed to his professional contributions.*

Our Mission

To determine the causes and risk factors associated with snorkel-related fatal and non-fatal drownings and develop appropriate safety messages.



Source: State of Hawai'i Department of Health

After extensive meetings with interested parties, the Sub-Committee proposed the **Snorkel Safety Study (SSS)**. In January 2019, the Hawai'i Tourism Authority funded the Snorkel Safety Study, led by Ralph Goto, Philip R. Foti, M.D., and Carol Wilcox.



The Study designed four investigations which are summarized in this report:

Snorkel Airways
Resistance Analyzer
(SARA) Investigation

Medical Examiner's
Office Reports
Investigation

Snorkel Safety
Survey

Case Studies
Investigation

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Taken together, the findings of the investigations showed that the **problem is the snorkel**, and that Snorkel Related Rapid Onset Pulmonary Edema (SIROPE) is a common factor in many, if not most, snorkel-related fatal and non-fatal drownings.

SNORKELING ITSELF IS A HAZARD.





What is Drowning?

1

Drowning is a Process

In 2005, the World Health Organization broadened the definition to include the **process** of drowning, which can be either fatal or, if interrupted, non-fatal.

“Drowning is the process of experiencing respiratory impairment from submersion/immersion in liquid.”

- WHO, 2005



2

Drowning by Aspiration

Drowning is commonly understood to be a fatal event caused by inhaling water while submerged. This is called **Aspiration Drowning**.

3

A Second Way of Drowning: Snorkel-Induced Rapid-Onset Pulmonary Edema

The SSS has identified a second way of drowning—specific to snorkeling, called Snorkel-Induced Rapid-Onset Pulmonary Edema (**SIROPE**).

- **Pulmonary:** Pertaining to the lungs
- **Edema:** Excess fluid accumulation in the body’s tissues
- **Pulmonary Edema:** The infiltration of fluids into the lungs
- **Hypoxia:** Insufficient oxygen levels in the system

The lungs have a fine, permeable membrane allowing liquids and gases to move both ways.

During inhalation, lung pressure increases, and oxygen moves from the lungs to the bloodstream, reaching body tissues.

During exhalation, lung pressure decreases and carbon dioxide transfers from the blood to the lungs, then is expelled.

Breathing through a narrow tube, such as a snorkel, creates resistance during inhalation, leading to a decrease in lung pressure. This results in a vacuum phenomenon within the lungs that draws bodily fluids from surrounding capillaries



into the air spaces. This is known as Negative Transthoracic Pressure (NTP). If the subject continues to breathe through a tube, each subsequent inhalation draws more fluid into the lungs, progressively diminishing oxygen intake into the capillary blood. Consequently, the blood oxygen level is critically lowered, and the snorkeler experiences shortness of breath.

Insufficient oxygen, known as *hypoxia*, leads to loss of muscle strength, confusion, and indicators of imminent death. The heart works harder in attempts to pump blood through the body. If the heart is weak or the edema is severe, hypoxia results in loss of consciousness and clinical death, sometimes within minutes after the snorkeler shows the first signs of hypoxia.

Hypoxia is the ultimate cause of death in drowning, whether by aspiration or SIROPE, though the snorkeler's experience differs. Externally, the most significant difference is the apparent absence of a struggle.

Note: Pulmonary edema has been identified as a risk in various sports. In SCUBA diving, it is known as Immersion Pulmonary Edema (IPE), in long-distance swimming as Swimming Induced Pulmonary Edema (SIPE), and in mountain climbing as High-Altitude Pulmonary Edema (HAPE). In snorkeling, it has been termed Snorkel Induced Rapid Onset Pulmonary Edema (SIROPE).

Death by hypoxia occurs in both Aspiration and SIROPE, but there is an absence of struggle during SIROPE due to the snorkeler's weakness. The transition from distress to unconsciousness is quick, often within minutes, leaving little time to react. Exertion while trying to reach shore or escape a current while continuing to breathe through a snorkel worsens the situation. The better response is to remove the snorkel, turn on your back, and get help to shore the best way possible.



NOT ALL DROWNING LOOKS THE SAME

ASPIRATION

Usually accompanied by signs of distress

Typical drowning sequence:

Submersion, Struggle,
Aspiration (inhalation of water),
Hypoxia (lack of oxygen), Death

SIROPE

Few, if any, signs of distress

Typical drowning sequence:

Hypoxia, Shortness of Breath,
Loss of Strength, Loss of Consciousness,
Death and Possible Aspiration



Four SSS Investigations Summary of Findings

Snorkel Airway Resistance Analyzer (SARA)

The study aimed to assess the resistance of various snorkel designs, from simple tubes to those with pleats, purging valves, wet/dry mechanisms, and full-face masks (FFM). Dr. Foti created the Snorkel Airway Resistance Analyzer (SARA) to measure snorkel resistance during inhalation. He tested 49 snorkels: 16 simple ones, 29 with wet/dry mechanisms, and four FFMs, at three airflow levels.

Conclusion: The study showed a wide range of airflow resistance among snorkels and FFMs. Simpler snorkels generally had lower resistance. However, because there may be narrowing within the tube itself, a visual assessment of the size of the narrowest opening does not necessarily identify which snorkels have the least resistance.

Coroner's Office Investigation

Dr. Foti examined Coroner's Office records from 2018-2019 to determine if autopsies could differentiate between drowning by aspiration from drowning by SIROPE.

Conclusion: They could not, as both cases involved liquid-filled lungs and death by hypoxia. However, autopsies did reveal pre-existing health conditions and a correlation between drownings and cardiac disease, especially elevated Left Ventricular End-Diastolic Pressure (LVEDP) in older individuals. Notably, drugs or alcohol were rarely factors.

Snorkel Safety Survey

The SSS developed a survey for individuals who had faced difficulties while snorkeling. These firsthand reports from survivors of non-fatal incidents, and companions of fatal drowning victims, provide valuable data. The survey collected information on swimming proficiency, snorkeling experience, ocean conditions, equipment, travel history, health status, and first responders.

Conclusion: Most respondents reported experiencing symptoms associated with SIROPE rather than Aspiration. SIROPE incidents happened equally among experienced and inexperienced swimmers. Non-fatal snorkel-related incidents appear more common among residents and occur to females almost as frequently as males.

Individual Medical History Case Studies

Dr. Foti interviewed selected survey participants and reviewed their medical records.

Conclusion: Elevated Left Ventricular End-Diastolic Pressure (LVEDP) is identified as a risk factor for SIROPE.

Details of investigations
can be found in the
technical papers available at
snorkelsafetystudy.com





Additional Findings



Recent Prolonged Air Travel

On long-distance flights at high altitudes, the cabin is pressurized to simulate conditions between 8,500-9,500 feet. Passengers to Hawai'i often experience this pressure for five to nine hours or more. Extended time at in this environment can weaken lung walls and cause edema, often noticeable in swollen ankles. This is more common in older individuals and those with heart issues. Lungs usually recover after a few days at sea level.



Full Face Masks

The study tested four full-face masks. They offer no inherent advantage or disadvantage for inhalation resistance compared to other devices. However, full-face masks have several drawbacks: difficulty in urgent removal, inability to spit out the mouthpiece, trouble clearing water with a sharp breath, and unsafe diving beneath the surface. Valve malfunction can lead to serious aspiration risks.

CO₂ Buildup: It has been suggested that CO₂ accumulation in the mask and snorkel, leading to increased blood CO₂ levels, causes unconsciousness in snorkelers. However, CO₂ buildup is not a physiologically viable explanation for snorkel-related drownings.



Safety Messages

Risk Factors



The Snorkel



Heart Health



Inexperience



Recent Prolonged
Air Travel



Exertion

Safety Tips for Snorkelers

Recreational snorkeling is NOT a benign, low-risk activity. This is true both for experienced and inexperienced swimmers and snorkelers.

- 1 Swim at a lifeguarded beach.
- 2 If you can't swim, don't snorkel.
- 3 Familiarize yourself with your equipment in shallow water.
- 4 Swim with a buddy and keep an eye on your buddy.
- 5 Stay where you can touch the bottom and be confident before moving to deeper water.
- 6 If you have a heart condition, consider not snorkeling.
- 7 Check your location frequently - every 30 seconds.
- 8 If you unexpectedly become short of breath, remove your mask, get on your back, signal for help, and get out.
- 9 Do not exercise or increase exertion while breathing through a snorkel.
- 10 Consider waiting 2-3 days after extended air travel before snorkeling.



Acknowledgements

The study team extends sincere thanks to those who contributed to this study, and apologies to those we missed. We are deeply grateful for your contributions. Mahalo!

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STAY AWARE, SNORKEL SMART

Informed Snorkelers Are Safer Snorkelers.



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