

Sonographic Measurements of Inferior Vena Cava Collapsibility in Recreational Divers

David Pardue, DO, Brandon Bowers, DO, Scott Chewning, DO, Casey Wilson, MD

Background

- An estimated 28 million diving certifications have been obtained since 1967 through the Professional Association of Diving Instructors (PADI).
- Dehydration can place recreational divers at increased risk of diving-related emergencies.
- Inferior Vena Cava (IVC) collapsibility measured sonographically can be used as a surrogate for hydration status and fluid responsiveness.
- Field assessment of diver hydration status via IVC collapsibility could assist with more timely interventions and hypothetically reducing adverse outcomes.
- Handheld Point-of-Care Ultrasound (POCUS) provides a portable mode of obtaining sonographic measurements.

Objective

- In this study, we sought to identify the change in sonographic IVC collapsibility in recreational divers measured with handheld POCUS before and after dives.
- A secondary aim of this study was to identify and describe the challenges to using handheld POCUS devices at the dive site for both clinical and research purposes.

Methods

- This was a prospective, observational study using a convenience sample of recreational divers participating in dives in Belize.
- Pre-dive and post-dive measurements of IVC diameter during inspiration and expiration were obtained to calculate a Collapsibility Index (CI):

$$CI = (d_{exp} - d_{ins}) / d_{exp}$$

- IVC images were obtained with the portable Butterfly iQ Ultrasound probe connected to an iPhone.
- Image acquisition was performed with subjects in the supine position on the dive boat or the dock.
- Supplementary data included the dive sequence for the day, in total for the trip (i.e. "first dive of the day, fifth dive of the trip"), maximum depth for the dive and total dive time for each subject
- Descriptive statistics were used to identify the change in CI from pre- and post dive, with a calculated mean and standard deviation of change.

Results

Subject #	Pre CI	Post CI	Diff (Post – Pre)
1	11%	8%	-3%
19	59%	53%	-6%
22	13%	9%	-4%
40	29%	72%	43%
42	17%	11%	-6%
45	57%	25%	-32%
49	11%	15%	5%
Mean	28%	28%	-0.0038%
SD (±)	21%	25%	22%

Table 1: 1st dive of the day for each diver; 1 dive was completed, maximum depth 111 feet, total dive time 38 min

Subject #	Pre CI	Post CI	Diff (Post – Pre)
1	9%	9%	0%
19	18%	18%	0%
22	26%	27%	0%
40	61%	20%	-41%
42	58%	16%	-42%
45	14%	22%	8%
49	8%	23%	15%
Mean	28%	19%	-0.087%
SD (±)	22%	6.0%	23%

Table 2: 3 dives completed except for subject 1, maximum depth 136 feet, total dive time 115 min for all dives

Discussion

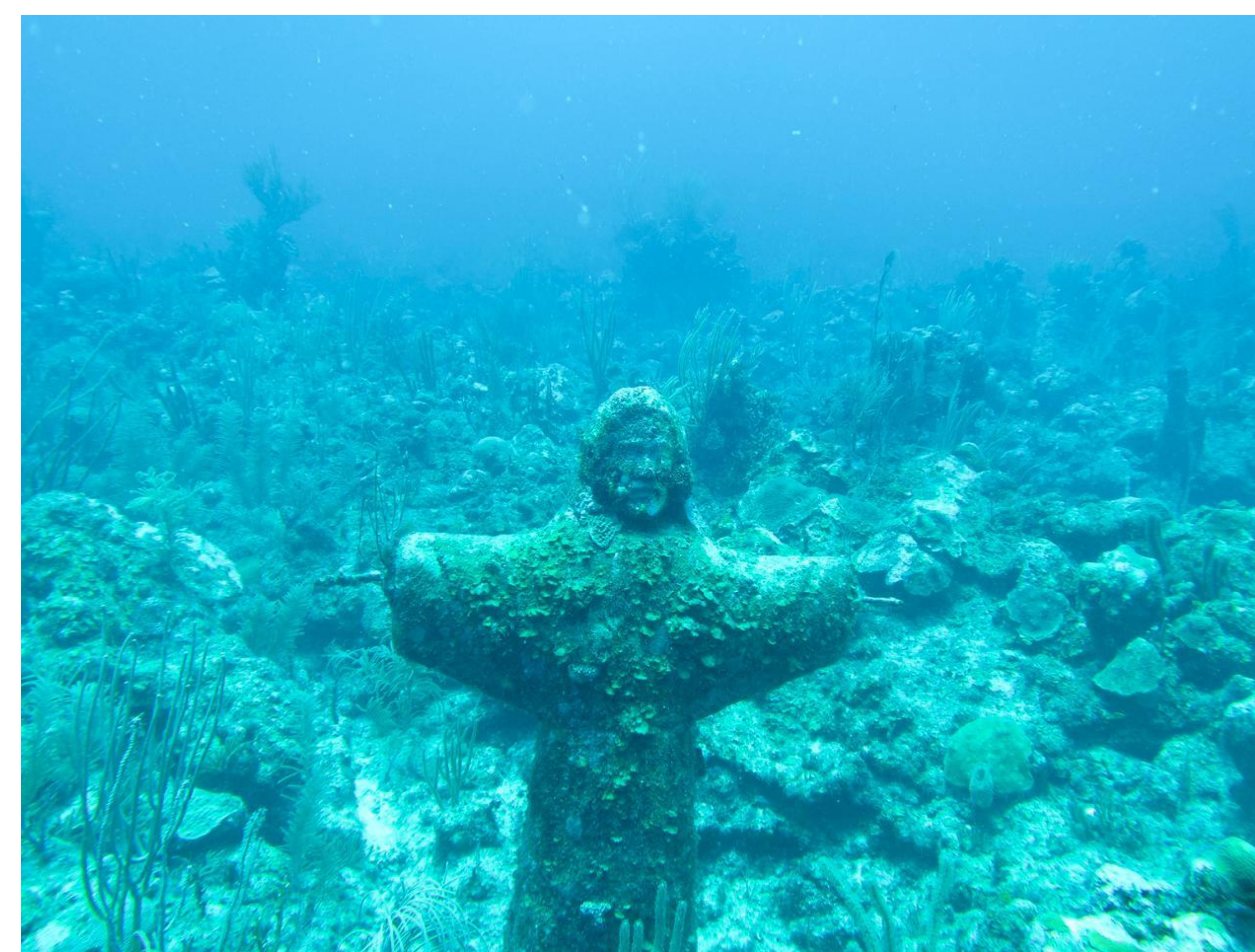
- We did not identify a meaningful change in the sonographic IVC collapsibility after diving.
 - All of our subjects were healthy and asymptomatic, and our findings may not represent changes in patients with diving-related pathology.
 - We did not control for the effects of oral intake between measurements, nor level of exertion during the dive.
 - Some participants had a post-dive decrease in CI, but had an increase in the absolute IVC measurements, which we hypothesize could be related to the phenomenon of Immersion Pulmonary Edema.
- We can summarize the challenges of handheld POCUS in this study as difficulties with image acquisition and image storage.
 - Time allotted for image acquisition was limited to the free time available on the boat in between dives.
 - Boat movements made images more technically difficult to obtain.
 - Due to the remoteness of the dive sites, images had to be frozen in real time, interpreted concurrently with acquisition and measurements recorded on paper.
- Future studies could benefit from having a handheld device with a larger screen to help the operator better visualize images. Future diving studies may be limited in convenience samples to the logistics constraints of the recreational dive schedule.

Conclusion

- In our limited pilot study of a small convenience sample of healthy recreational divers, we did not identify a meaningful change in the sonographic IVC collapsibility after diving.
- Handheld POCUS did prove to be feasible for transport to dive locations and use aboard boats; however, it still requires logistical support for image acquisition and storage.

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Personal photo of D. Pardue