B 1
The Dewey Monitor: Characterization of a pulse oximeter to independently detect hypoxia during rebreather diving
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Introduction / Background: Rebreather diving is the second most dangerous activity in the world per hour, after base jumping. The most common cause of death is hypoxia (39%), with almost double the number of fatalities of the next most common cause, hypercapnia. This high rate is because every commercial rebreather model has at least one single point of failure that can lead to the simultaneous failure of the oxygen detection, injection, and alarm systems. The purpose of this study was to assess the utility of pulse oximetry to detect hypoxia in a diver who was immersed in cold water, independently of rebreather electronics, and characterize the amount of warning time it provides.

Materials and Methods: Thirty (30) divers pedaled on a bicycle ergometer for five minutes while fully immersed in a water tank until they reached physiological equilibrium. They continued pedaling while their gas supply was switched so they were breathing on an Innerspace Megalodon rebreather that had been powered off and had no oxygen supply. Pulse oximeters were affixed to the forehead, nasal ala, scapula, mastoid process and/or sternum. The subjects were monitored via EKG, and their inspired pO2 was monitored via mass spectrometer until they reached one of four predetermined cutoff criteria. The test was repeated four times for each subject, varying either water temperature, exercise rate, or depth with each repetition.

Results: Pulse oximeters attached to the forehead and nasal ala show a useful response time of approximately one minute regardless of water temperature or depth at a moderate rate of exercise. Sensors on the mastoid process, sternum, and scapula showed useful responses in warm water only, and were also subject to frequent motion artifacts.

Summary / Conclusion: Pulse oximeters are useful tools to prevent hypoxia-related deaths in rebreather divers even when immersed in cold water if they are positioned on the forehead or nasal ala.

B 2
Reliability of Philips Lumify® ultrasound at hyperbaric conditions
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Introduction / Background: The portability, versatility, and low cost of point-of-care ultrasound (POCUS) make it a valuable tool, especially in isolated environments where access to other diagnostic imaging is limited. A POCUS device capable of operating in a multiphase chamber could assist clinicians in diagnosing pneumothorax, urinary retention, volume status, cardiac activity, bubble load and may be used to guide invasive procedures such as central venous catheter and arterial line placement in critically ill patients. Unfortunately, there is little safety data available for POCUS devices at hyperbaric conditions.

Materials and Methods: We tested reliability of the Philips Lumify® ultrasound at hyperbaric conditions. Using nitrogen purge, probe (Philips Lumify sector-array probe, Koninklijke Philips N.V., Amsterdam, the Netherlands) and tablet (Samsung Galaxy Tab A® SM-T590, Samsung Electronics, Suwon, South Korea) were subjected to 2.0 ATA, 2.45 ATA, and 2.8 ATA. Test images were obtained at pressure using a quality assurance ultrasound phantom (Gammex® 405 GSX, Sun Nuclear, Melbourne Florida).

The Lumify probe (without tablet) was then tested using modified Navy p9290 protocols for explodable items over three exposures:
1. Helium soak at 2.8ATA for 230 minutes, followed by decompression at 1.5 times normal USNTT6 decompression rate (1.5 fsw/minute).
2. Helium soak at 2.8ATA for 250 minutes followed by rapid decompression at maximum chamber decompression rate (33.3 fsw/minute).
3. Helium soak at 6ATA for 60 minutes followed by decompression at 1.5 times the normal decompression rate for USNTT6A 6 ATA segment (4.5 fsw/minute).

Results: The Philips Lumify demonstrated unchanged axial and lateral resolution, vertical and horizontal distance accuracy, and image uniformity in clinical hyperbaric conditions. Performance of the probe was unaffected, and no external deformity was noted after exposure to hyperbaric helium environments with decompression according to modified Navy p9290 protocol.

Summary / Conclusion: Philips Lumify performed reliably in hyperbaric conditions. Further testing of the Samsung tablet is required and warranted.

B 3
A survey of hyperbaric chamber cleaning practices
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WITHDREW

B 4
Point-of-care ultrasound in a multiplace hyperbaric chamber
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Introduction / Background: Electronic devices are generally prohibited from use during hyperbaric oxygen (HBO2) treatment due to risk of fire in a pressurized oxygen-rich environment. Over the past two decades, point-of-care ultrasound (POCUS) has emerged as a useful imaging modality in many clinical environments. However, fire risk has prevented widespread POCUS use during HBO2 therapy. To date only heavily modified POCUS devices have been tested, preventing adoption in general practice. Multiplace chambers treating critically ill patients may benefit from the application of POCUS at depth to make real-time patient assessments. Here we demonstrate proof of concept, safety, and successful performance of an off-the-shelf handheld POCUS system in the hyperbaric environment.

Materials and Methods: The SonoSite iViz was initially tested for safety in a Class C chamber in a 100% nitrogen atmosphere. Temperature, image quality, and touchscreen functionality were tested before and after compression to 280 kPa, (2.8 ATA). Second; the iViz was pressurized to 240 kPa (2.4 ATA) in a multiplace chamber (21% oxygen) while simulating clinical use until the battery was spent. This was then repeated at 280 kPa (2.8 ATA). Device temperature, image quality, and touchscreen functionality were evaluated at both pressures.

Results: The SonoSite iViz performed well throughout all tests without degradation in functionality or image quality. The device did not overheat, nor did it reach temperatures concerning for fire hazard. Of note, the touchscreen worked at pressure without evidence of malfunction.

Summary / Conclusion: Our results suggest that the SonoSite iViz can safely be used off the shelf without modification in a multiplace hyperbaric chamber. Further study is warranted to determine how hyperbaric physicians may improve clinical care during HBO2 therapy as well as explore research applications using POCUS.

B 5
Gunshot testing to a pressurized monoplace hyperbaric chamber
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Introduction / Background: Health care workers are vulnerable to workplace violence, including active shooter incidents. Little is known about how firearms could damage monoplace chamber acrylic and whether a breached pressurized chamber presents additional threat to the patient or bystanders.

Materials and Methods: In a remote area where firearm discharge is permitted we tested the durability of sections of monoplace hyperbaric chamber acrylic under various firearm discharges. Firearms were discharged at acrylic sections from distance of 17 feet at 45 degrees and 10 degrees from perpendicular while wearing protective gear. Firearm calibers ranged from a 9 mm handgun to a 5.56 mm AR-15 rifle. We also conducted similar testing on a monoplace hyperbaric chamber pressurized with >99% oxygen to a differential pressure of 14.7 psig (2.0 atmospheres absolute at sea level). Handguns were remotely fired at a distance of 12 feet from the chamber (30 degrees from perpendicular), while the rifles and shotguns were fired at a distance of 60 feet from the chamber.

Results: Higher-caliber handguns penetrated or fractured the acrylic sections only after multiple shots. The tested rifles caused full-thickness penetration and fracture with a single shot. However, the pressurized monoplace hyperbaric chamber required two shots from the AR-15 rifle, separated by approximately 60 mm, to penetrate the acrylic, resulting in rapid depressurization. The chamber otherwise remained intact, with no explosion or conflagration observed.

Summary / Conclusion: An intact or pressurized chamber performs differently than stand-alone acrylic sections under firearms testing. In a worst-case active shooter scenario, the pressurized monoplace chamber tested posed no additional threat to bystanders beyond the significant risk of ricochet.

A comparison between B-mode imaging and tissue harmonic imaging on the detection of decompression bubbles
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Introduction / Background: B-mode ultrasound imaging is normally used for VGE grading of post-dive echocardiography. Tissue harmonic imaging (THI) is a newer imaging method generating higher resolution images in tissue and has been used in several studies for VGE grading. To date, only Blogg, et al. (Diving and Hyperbaric Medicine, 2014) have compared the two methods for VGE grading and found a strong agreement between VGE grades for both methods using consecutively collected human data. Here, we investigate differences in decompression bubble quantification between B-mode and THI using a programmable ultrasound scanner and degassing laboratory setup to allow for concurrent imaging of the same micobubbles.

Materials and Methods: Nitrogen-saturated pressurized water (2.2 atm) was injected into an open water column through a jet nozzle, forming decompression bubbles. The bubbles were imaged at a height of 42 cm using ultrasound and microscopy. We collected ultrasound data using a Verasonics research scanner with a pulse-inversion sequence and generated both B-mode and THI images using the same data. Imaging was performed at 60 fps, 5 MHz and 1250 kPa using an L12-3v linear array transducer, collecting 2,032 frames total. Bubbles on each generated frame were detected using the ImageJ particle analysis tool. The average bubble area and count per frame were compared between THI and B-mode using a Wilcoxon matched-pairs signed rank test.
Results: Bubble diameters from optical measurements ranged from 2.78 to 79.83 µm. Average bubble count per frame was 51.3 ± 8.18 for B-mode and 16.36 ± 5.59 for THI (p < 0.0001). Average bubble area was 230 ± 20.5 pixels for B-mode and 82 ± 18.34 pixels for THI (p < 0.0001).

Summary / Conclusion: Our in vitro experiments show that THI reduces the amount of detectable bubbles compared to B-mode imaging while improving resolution as seen in the decreased bubble area. Next, we will study the effect of imaging pressure and frequency on decompression bubble detection using THI.

Machine learning classification of Doppler ultrasound of venous gas emboli after decompression: a feasibility study using published audio
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Introduction / Background: Decision models trained by machine learning (ML) algorithms are regularly used in audio applications. Having an annotated and validated data set as ground truth is one of the most important components today in developing useful applications. In diving and decompression the largest studies on venous gas emboli (VGE) has used audio rather than visual detection. We hypothesized that ML could detect and score bubble grade from Doppler audio of VGE.

Materials and Methods: We used data sets developed by DCIEM and Quinetic to train human operators in scoring doppler audio of VGE. The datasets were divided into one resting (27 recordings) and one active moving one leg (24 recordings). Both subsets were then further divided into two subsets based on the pre-existing expert’s rating of VGE: low-moderate for recordings rated 0-2 on the Spencer scale, and severe where the expert rated it as 3-4. This resulted in four different subsets.

In order to investigate the potential of using machine learning models to differentiate between low-moderate and severe levels of bubbles in subjects’ blood we included five different supervised learning algorithms in the experiments. These were DecisionTree, K-NearestNeigbors, MLPClassifier, RandomForest and SVN.

Results: Resting: scoring low versus severe in the non-moving group gave sensitivities from 0.58-0.75 and specificities of 0.49-0.74. The best performance was the MLPClassifier with a sensitivity of 0.75 and a specificity of 0.74. Active: scoring low versus severe gave high sensitivities but also low specificity (sens 1, spec 0). Models trained by the DecisionTree algorithms showed best performance, with a sensitivity of 0.77 and a specificity of 0.67. Thus, the models could not separate sounds from activity to VGE in this limited data set.

Summary / Conclusion: It is possible to use machine learning to score doppler of VGE. Further development is needed, including a larger data set.

iPad with case for wireless access to medical records inside the hyperbaric chamber
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Introduction / Background: Medical record charting using EPIC and use of the internet-based translation service Marti have not been possible during chamber operations at UC San Diego Medical Center due to the exclusion of computers and personal electronic device use inside the chamber. This has created a deviation in the ability of nurses and technicians to chart in real time during high-acuity treatments and has presented challenges when attempting to communicate with patients who speak a language other than English.
Methods and Materials: A commercially available housing for an iPad, along with an iPad, was donated to the hyperbaric department. A regulator and small scuba bottle containing argon gas were also donated. The electronic medical record EPIC was installed on the iPad utilizing the clinical web portal, which allowed full charting access. The app for Marti was also installed with no issues. The iPad case was filled with argon. The touchscreen capabilities were tested under a pressure of 2.36 ATA, and function and connectivity tests performed.

Results: Preliminary results; the iPad worked as hoped inside of the sealed case. Because the case was filled with argon the risk of fire was eliminated. Pressure and the steel hull of the chamber did not affect the devices ability to connect via Wi-Fi signal and work. The iPad worked normally at 1 ATA following the initial pressurization.

Summary / Conclusion: More testing at 2.8 ATA and subsequent tests at 2.26 ATA are needed to ensure the reliability of the iPad after repeated pressure exposures. Battery life must also be tested with longer exposures under pressure.

B 9
Development of a portable, flexible and collapsible double-lock recompression chamber for conducting treatments in accordance with Navy treatment tables to 6 ATA
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Introduction / Background: The Hyperlite 1, manufactured by SOS Limited in the UK, is a 23.5-inch diameter, 3 ATA-capable, portable, collapsible single-lock chamber. That chamber was developed in the 1990s and is used by many navies and several U.S. government agencies. However, its small size and single-lock format limit its use to transport applications. The purpose of this project was to develop a larger (42-incg inside diameter), 6-ATA double-lock chamber that could support U.S. Navy recompression tables yet be lightweight.

Materials and Methods: Working with the ASME Committee on Pressure Vessels for Human Occupancy (PVHO) and the Navy, SOS developed PVHO Case 18 to cover the material technologies and criteria for establishment of the 80 psig maximum allowable working pressure (MAWP) rating required to support 6-ATA treatments.

Case 18 requires:
1. Successful tests of 10 consecutive builds to 4.5 times MAWP, (320 psig)
2. Five successful 300 hour creep tests at 3.64 x MAWP (291 psig)
3. Cyclic hydrostatic tests to 1.5 times MAWP for 4,000 cycles
4. Cyclic folding test for minimum of 500 cycles
5. Successful assembly of two units after a 24-hour soak at 0°F

Results: A combination of liquid polymer fiber fabric and custom-made reinforced polyurethane bladder was found to work for the flexible elements. A clamp mechanism was developed capable of holding onto the flexible elements at test pressure where the pull is about 5,000 pounds per lineal inch. The shell was found to be remarkably rugged. Penetration with Mk15 rounds at MAWP produced only small holes that were easily patched. The weight of the largest component was held to 470 lbs. with a total system weight, including cases of less than 1700 lbs.

Summary / Conclusion: The technology developed was found to be sound. The chamber developed will make full-service recompression therapy practical in many applications where that has not previously been possible.

End Session B