Pressure and the lung: EIT's role to help diver breathing at depth

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Abstract: We developed a portable, water-proof EIT system for studying respiratory mechanics and lung gas distribution in water and during breath-hold diving up to 20 m. EIT data can be readily collected from divers. Our data suggest that posture results in lung gas re-distribution with gravity.

1 Introduction

Breath-hold divers are exposed to increasing pressure as they descend, which results in compression of gas filled spaces. The respiratory mechanics during breath-hold diving has long been of interest to respiratory physiologists since the relatively stiff chest of humans has suggested that negative intrapulmonary pressures should develop at depths as shallow as 20 m, resulting in an edema formation called lung squeeze. There are limited studies that have investigated the mechanism of lung squeeze, and EIT provides a new and novel opportunity to better understand how gas is distributed during diving.

To further investigate the possible use of EIT to study lung mechanics during breath-hold diving, our goal here was to determine the feasibility of wireless EIT data collection in two minute breath-hold dives up to 20 m.

2 Materials & Methods

We built a water-proof case (Fig. 1A) for a commercially available EIT system (VTM 100, Midas medical, Beijing, China) that was pressure tested to 50 m. To reduce loss of EIT signal in water and to assure thermal comfort, the diver wore a neoprene suit over the EIT belt. The cable connecting the EIT belt to the water/pressure-proof exited the neoprene suit by the neck to allow the diver to hold the EIT system.

This system was used to evaluate its ability to measure lung gas distribution during 2 minute breath-hold dives to 1, 5, 10 and 20 meters. Dives were performed in a 20 m deep freshwater pool in Madrid, Spain (YoBuceo), with human-research ethics clearance. The session was supervised by an experienced breath-hold diver that was certified by AIDA.

For breath-holds to 1 m, the diver submerged to the bottom of a ledge in a horizontal position. For dives to 5, 10 and 20 m, the diver descended head first and then turned to be head up when arriving at the target depth.

3 Results

The results from this pilot study clearly indicate that EIT is a useful tool to evaluate lung gas distribution during breath-hold diving. The results from the dives to different depths indicate that posture has a large effect on pulmonary gas distribution. During the breath-hold to 1 m, the gas volume decreased as the diver descended and then remained low, with a slight temporal increase (Fig. 1B). During dives to 5, 10 and 20 m, there was a similar decrease in pulmonary gas volume during descent, followed by a rapid increase upon reaching the target depth as the diver changed posture, i.e. head down to head up (Fig. 1C). This suggests that gas moves by gravity to the upper regions of the lung as posture changes.

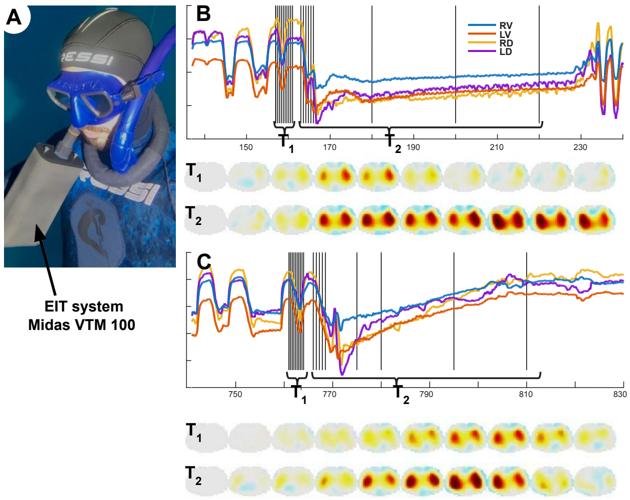

Fig. 1: EIT measurements from a diver (A) showing EIT signals in 4 ROIs from (B) a dive to 1 m depth and (C) a dive to 20 m depth. EIT images at times T1 (breathing at surface) and T2 (dive) correspond to vertical lines.

4 Discussion

The results from this pilot study clearly indicate that EIT is a useful tool to evaluate lung gas distribution during breath-hold diving. The results from the dives to different depths indicate that posture has a large effect on pulmonary gas distribution. During the breath-hold to 1 m, the gas volume decreased as the diver descended and then remained low, with a slight temporal increase (Fig.1C). During dives to 5, 10 and 20 m, there was a similar decrease in pulmonary gas volume during descent, followed by a rapid increase upon reaching the target depth as the diver changed posture, i.e. head down to head up. This suggests that gas moves by gravity to the upper regions of the lung as posture changes.

EIT is possible in water and provides a unique opportunity to study pulmonary mechanics in breath-hold divers. This tool may help provide increased safety for the growing number of people engaged in the sport of breath-hold diving.

References

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