EIT monitoring of breathing dolphins

Andy Adler[1], Andreas Fahlman[2], Martina Mosing[3]

[1]Systems and Computer Engineering, Carleton University, Ottawa, Canada, adler@sce.carleton.ca
[2]Fundación Oceanogràfic de Valencia, Spain
[3]Anaesthesiology and Perioperative Intensive-Care Medicine, Vetmeduni, Vienna, Austria

Abstract: We show first EIT images of breathing in dolphins. Several technical solutions are described to permit EIT imaging in water. Early results show interesting changes in air distribution with breathing.

1 Introduction

Diving mammals seek to maximize time underwater but must eventually surface to exchange metabolic gasses. We want to understand the respiratory and cardiovascular adaptations to diving in marine mammals, and then compare to human breath-hold divers, and how factors affect diving capacity [2]. Here we report on the feasibility of EIT studies of lung function and mechanics in diving dolphins.

2 Methods and Results

EIT data were collected with the Sentec pioneer set, using a custom neoprene belt with conductive polymers electrodes. Tests of the first prototype belt showed the conductivity of the water to be an issue, since electricity will preferentially flow through the water ($\sigma_{\text{seawater}} \approx 5$ S/m), rather than the body ($\sigma = 0.1$–0.7 S/m) [1]. This issue was solved with the design of a belt/vest system which covers and insulates the electrodes from the water.

Using our EIT belt, EIT data were collected from dolphins in several orientations. Our goal was to evaluate the feasibility of our test configuration and the equipment developed.

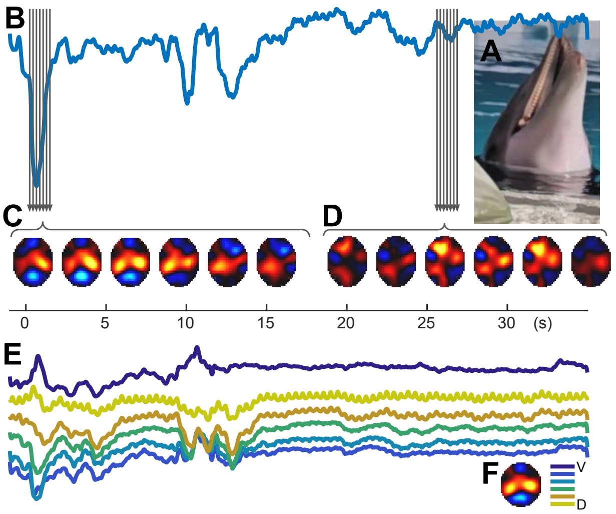

Figure 1: Sample EIT images and waveforms from (A) dolphin oriented vertically in the water. (B) Global EIT signal for a 30 s data window. C & D: EIT images during breath (C) and apnea (D). Conductivity changes (+=red, –=blue). (E) EIT waveforms for ROIs (Ventral to Dorsal) indicated in (F)

Data from a dolphin holding its position vertically in a pool is shown in Fig 1. In the bottom panel, regions of interest are shown. Detailed images are shown for two 1.5 s intervals in the data. The first shows a breath (expiration then inspiration in the dolphin) and the second shows a heart beat and the EIT-associated pulsatility.

After the breath, the dolphin maintains the vertical posture without breathing, and sequential segments of these data are shown as images. In this configuration, the dolphin is making muscular efforts to maintain itself in position in the water, and a 140 cycles/minute signal is shown in the dorsal region of the image, which may be musclular activity to move the tail.

In Fig 2, we show a detail of a breath in a dolphin positioned horizontally: waveforms at regions of interest show the different time courses. In the six central ROIs, there is a progressive expiratory delay. Expiration starts in the ventral lung and moves dorsally. Interestingly, inspiration shows little delay. This effect is similar to expiratory flow limitation in humans, especially at high flows and in lung disease (asthma). The lateral regions of the image show an increase in air content. This could be due to a pendelluft-type effect, or due to abdominal gas pushed into the image plane by the diaphragm.

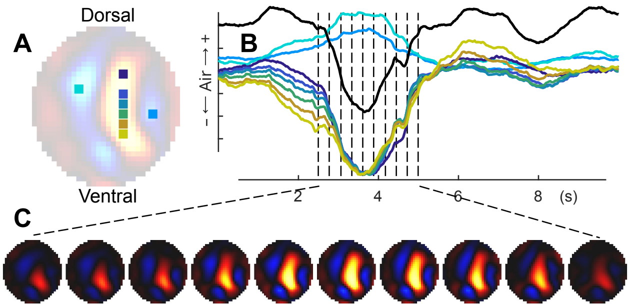

Figure 2: Sample EIT images and waveforms from a dolphin oriented horizontally, (A) color-coded points corresponding to waveforms. (B) EIT signals vs time (s) during a breath and the global signal (black). Waveforms are normalized to the same maximum value. (C) EIT images corresponding to vertical lines in (B). Note the phases during expiration, where dorsal regions respond 0.5–1.0s later than ventral regions. Much less phase difference occurs during inspiration. The red indicates decreased air in the central region, with some blue (air) lateral spaces.

3 Discussion

Results demonstrate the feasibility of EIT-based monitoring in dolphins. In the very short and forceful breathing of dolphins, there is considerable heterogeneity between lung regions. In addition to our results, several challenges have been identified. One is that the movement of dolphins does interfere with the data quality. It will therefore be important to develop protocols in which we can identify and segment data corresponding to quiet activity in the animals. (Acknowedgement: ONR Award #: N000142312002)

References

[1] "Feasibility of Thoracic Impedance Measurements in Seawater", A Adler *et al* p.68, Conf EIT 2021

[2] A Fahlman *et al*, "Cardiorespiratory coupling in cetaceans; a physiological strategy to improve gas exchange?", J Exp Biol 223:jeb226365, 2020