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Case report

"Lung packing" in breath hold-diving: An impressive case of pulmo–cardiac interaction

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ABSTRACT

There is a complex interaction between the heart and the lungs. We report on a healthy female who performs breath hold diving at a high, international level. In order to optimize pressure equalization during diving and to increase oxygen available, apneists employed a special breathing maneuver, so called "lung packing". Based on cardiac MRI we could demonstrate impressive effects of this maneuver on left ventricular geometry and hemodynamics. Beyond the fact, that our findings support the concept of pulmonary –cardiac interrelationship, it should be emphasized, that the reported, extreme breathing maneuver could have detrimental consequences due to reduction of stroke volume and cardiac output.
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1. Introduction

Changes in lung volume alter autonomic tone, pulmonary vascular resistance and might compress the heart in the cardiac fossa [1]. These pulmo–cardiac interactions are meaningful in several clinical conditions, e.g. mechanical ventilation, in chronic obstructive lung disease or sleep apnea syndromes, the latter characterized by severe intrathoracal pressure variations.

For demonstration of pulmo–cardiac interaction, we report on the cardiac response to an extreme respiratory maneuver, which has been recently established in breath hold diving. This maneuver, the so called "lung packing" (glossopharyngeal insufflation, GI [2]) helps to increase the volumes of air in the lungs up to 2.59 l above total lung capacity [3].

We hypothesized, that this extreme breathing maneuver might have distinct effects on cardiac geometry and aortal blood flow.

2. Case report

We report on a 40-year-old, non-smoking female (1.75 m, 62 kg, BMI 20 kg/m2) who performed competitive breath hold (BH) diving for about 3 years holding several national records. Within the scope of a medical check up, we performed cardiac MRI measurements at rest and after a breath hold with subsequent 2 min apnea following glossopharyngeal insufflations.

Cardiac magnetic resonance imaging (cMRI)

Steady-state free precession imaging and 2D aortic valve flow measurements were performed using a 1.5 T MR scanner (Achieva, Philips, Best, the Netherlands). Quantitative flow analysis was performed retrospectively with a dedicated software (EWS, Philips, The Netherlands) to determine stroke volume and cardiac output.

During apnea the heart rate increased from 50 to 66/min. The stroke volume when breathing normally was 92 ml. After glossopharyngeal insufflation and at the end of apnea, stroke volume was decreased to 48 ml. Hence, cardiac output was decreased by almost one third (4.6 l/min to 3.2 l/min). At the end apnea, both right and left ventricular volumes were significantly reduced (Fig. 1), likely due to both reduced venous return and increased intrapulmonary pressure. Thus, ventricular wall thicknesses were markedly increased. Fig. 2 shows the impact of "lung packing" and dry apnea on ascending aortic flow patterns.

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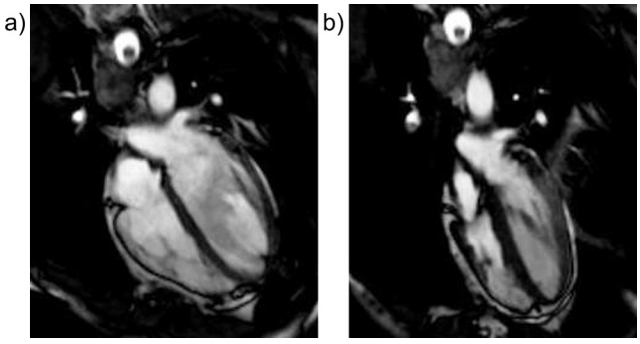

Fig. 1. Cardiac MRI (MR Phillips 1.5 T, 4-chamber view) was performed at rest (a) and after "lung packing" with a subsequent 2-min apnea (b). At the end apnea, both right and left ventricular volumes were significantly reduced, likely due to both reduced venous return and increased intrapulmonary pressure. Thus, ventricular wall thicknesses were markedly increased.

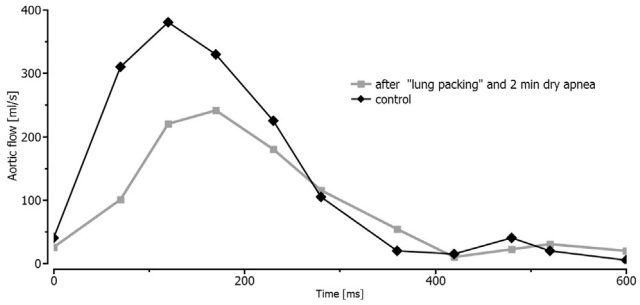

Fig. 2. Aortic valve flow measurements were performed at rest (labeled as "control", black) and after lung packing and subsequent 2 min apnea. "Lung packing" was associated with a decrease of aortic flow (grey).

3. Discussion

There is an interdependence between pulmonary and cardiac function which is mediated for example by intrathoracal pressure changes, lung volumes, left- and right ventricular pre- and afterload or left ventricular geometry. We report on an otherwise healthy woman who performs breath hold diving at a high, international standard.

Only recently, BH divers have begun to employ the technique of glossopharyngeal muscle contractions ('lung packing') [2] to increase the volume of air in the lungs above TLC, thereby increasing the volume of gas available for pressure equalization at great depth [4] and the amount of oxygen available [5]. After experimental GI and dry apnea, our patient had added 1 l to her TLC giving a surface lung capacity (SLC) of 7.06 l. This additional volume was achieved by about 30 subsequent mouthfills, i.e. one mouthfill equaled 33 ml. Now the ratio of SLC to blood-shift corrected RVFE + BS (0.74 l) was equal to 9.5 bar (depth 85 m). The cardiovascular consequences of this BH technique suggest that caution is advised [6]. The increased intrathoracic pressure likely impedes venous return, thus inducing hypotension with associated consequences varying from dizziness to even fainting just prior to a dive attempt [6]. On the other hand, cardiac output is already reduced by BH [7], and GI will further decrease cardiac output albeit by a small amount compared to maximal inspiratory apnea in a study using cardiac MRI [8]. In concord with this study, we found an impressive, nearly half reduction of stroke volume and a decrease of cardiac output by almost one third.

Beyond the fact, that our findings support the concept of pulmonary –cardiac interrelationship, it should be emphasized, that the reported, extreme breathing maneuver could have detrimental consequences due to reduction of stroke volume and cardiac output.

Conflict of interest

The author(s) declare(s) that there is no conflict of interests regarding the publication of this paper.

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