

## Breath-hold times in patients undergoing radiological examinations: comparison of expiration and inspiration with and without hyperventilation

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**Background.** Breath-holding is necessary for imaging studies of the thorax and abdomen using computed tomography, magnetic resonance imaging or ultrasound examinations. The purpose of this study was to compare the breath-hold times in expiration and inspiration and to evaluate the effects of hyperventilation.

**Patients and methods.** Thirty patients and 19 healthy volunteers participated in this study after informed consent was obtained in all. The breath-hold times were measured in expiration and inspiration before and after hyperventilation.

**Results.** The mean breath-hold times in expiration (patients:  $24 \pm 9$  sec, volunteers:  $27 \pm 7$  sec) were significantly shorter than those in inspiration (patients:  $41 \pm 20$  sec,  $p < 0.001$ ; volunteers:  $62 \pm 18$  sec,  $p < 0.001$ ). Additional hyperventilation resulted in a significant increase (range: 40-60%,  $p \leq 0.005$ ) of the mean breath-hold times either in expiration and in inspiration and for both patients and volunteers.

**Conclusions.** Although breath-holding in expiration is recommended for various imaging studies particularly of the thorax and of the abdomen, suspending respiration in inspiration enables the patient a considerable longer breath-hold time.

**Key words:** tomography, X-ray computer; magnetic resonance imaging; ultrasonography; breath holding

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### Introduction

Respiratory motion may degrade imaging studies particularly of the thorax and of the abdomen. Therefore breath-holding is crucial during thoracic and abdominal examinations

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using different modalities such as computed tomography, magnetic resonance imaging, digital angiography, or Doppler sonography.

Breath-holding in expiration is regarded to result in more consistent organ positioning and is therefore recommended for various imaging studies particularly of the abdomen.<sup>1</sup> However, in the clinical experience it is easier to hold the breath in inspiration than in expiration. This is of clinical importance when the clinician has to make the decision whether the examination should be performed in expiration or inspiration.

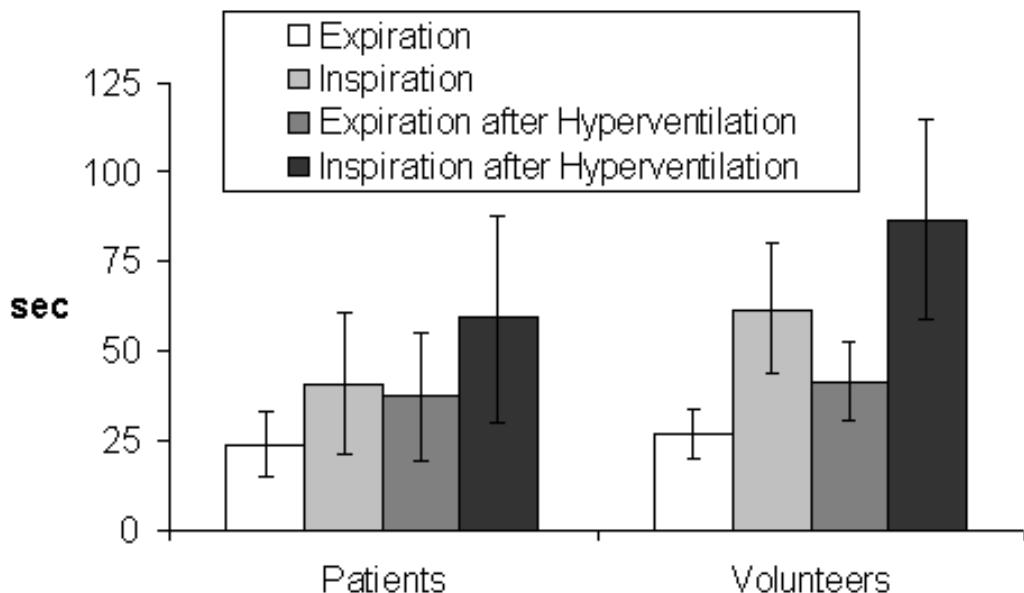
Previous reports have shown that the maximum breath-hold time may be increased by hyperventilation and by administration of oxygen.<sup>2,3</sup> However, a comparison of breath-hold capabilities between expiration and inspiration has - to our knowledge - not been performed yet. This prompted us to prospectively evaluate and compare the breath-hold capabilities of patients and of healthy volunteers in expiration and inspiration without and after hyperventilation.

### Patients and methods

The study population consisted of 30 outpatients and 19 healthy volunteers. The patients (15 female, 15 male; mean age:  $64 \pm 15$  years, range: 31-85 years) were referred to abdominal ultrasound for various clinical reasons. The majority ( $n=17$ ) of them were examined in routine screening. Six of the patients were smokers with a smoking history of more than ten pack-years. Four patients had a medical history of chronic obstructive pulmonary dis-

ease (COPD) and two of them additionally had chronic heart failure (CHF), the patients received medical therapy for these conditions. The healthy volunteers (8 female, 11 male; mean age:  $32 \pm 5$  years, range: 23-43 years) were employees of our institution. Two of them were smokers with a smoking history of more than ten pack-years. None of the volunteers had known diseases of the cardio-respiratory system.

All patients and healthy volunteers gave informed consent to the performance of this study. For the patients the measurements were performed while the patients were waiting for their ultrasound examination. During the study all participants were lying in the supine position. The patients were instructed to hold their breath in expiration ("breathe in, breathe out, hold your breath") and in inspiration ("breathe in, breathe out, breathe in, hold your breath"). Then the same respiratory maneuvers were performed following six deep inhalations of room air (corresponding to approximately 20-30 seconds of hyperventilation). A time span of at least 2 minutes



**Figure 1.** Mean breath-hold times in patients and healthy volunteers without and after hyperventilation.

was kept between the breath-holds. The order of inspiration and expiration was changed alternately among different subjects to minimize the effects of training.

Statistical comparison of different respiratory maneuvers was performed using a Student t-test with a 5% level of statistical security. Multivariate analysis was performed to evaluate the influence of age, sex, smoking history, cardio-pulmonary diseases, or of the order of examinations (expiration performed before inspiration or vice versa) on the measured breath-hold times.

## Results

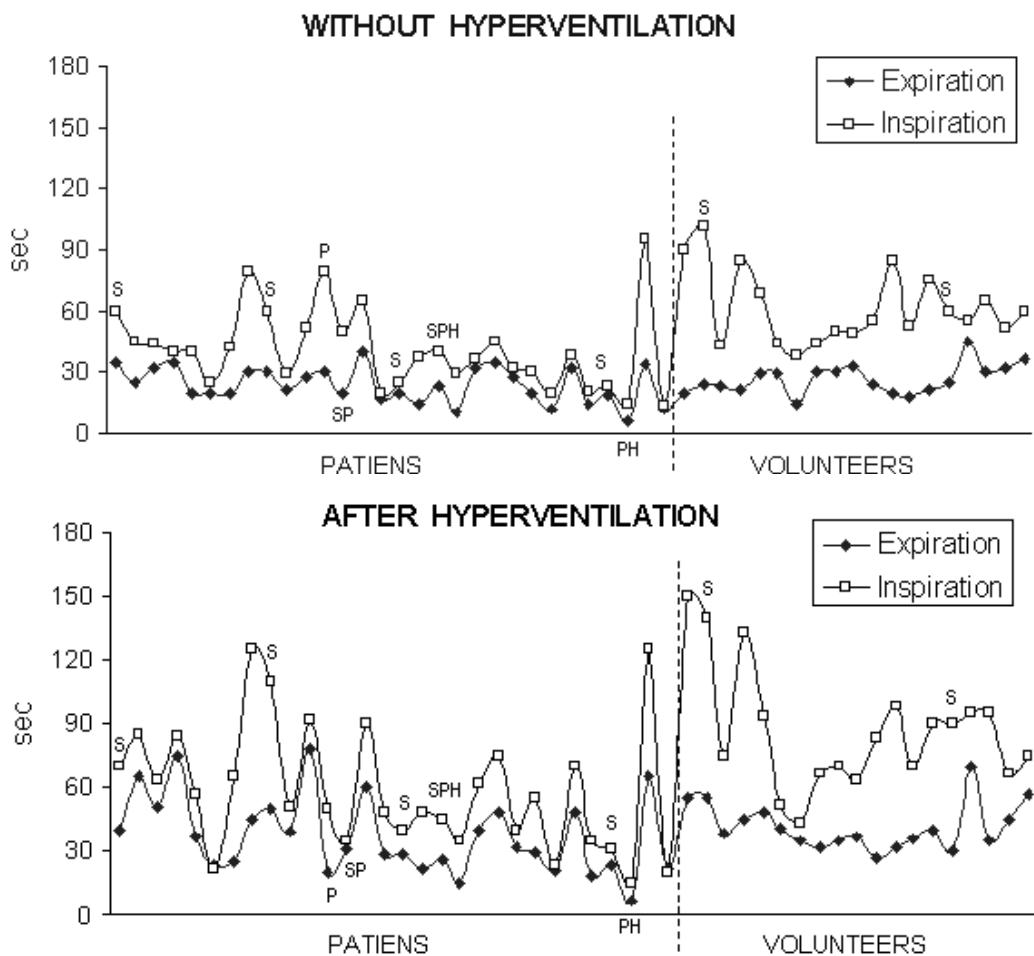
The mean breath-hold times in expiration were significantly shorter than those in inspiration both without hyperventilation (patients:  $24 \pm 9$  sec vs.  $41 \pm 20$  sec,  $p < 0.001$ ; volunteers:  $27 \pm 7$  sec vs.  $62 \pm 18$  sec,  $p < 0.001$ ) and after hyperventilation (patients:  $37 \pm 18$  sec vs.  $59 \pm 29$  sec,  $p < 0.001$ ; volunteers:  $42 \pm 11$  sec vs.  $87 \pm 28$  sec,  $p < 0.001$ ) (Figures 1,2). Hyperventilation resulted in a significant increase of the measured mean breath-hold times in expiration (patients:  $24 \pm 9$  sec vs.  $37 \pm 18$  sec,  $p < 0.001$ ; volunteers:  $27 \pm 7$  sec vs.  $42 \pm 11$  sec,  $p = 0.005$ ) and inspiration (patients:  $41 \pm 20$  sec vs.  $59 \pm 29$  sec,  $p < 0.001$ ; volunteers:  $62 \pm 18$  sec vs.  $87 \pm 28$  sec,  $p = 0.002$ ). In expiration the mean breath-hold times were not statistically different ( $p > 0.23$ ) between patients and healthy volunteers either without or after hyperventilation. However, in inspiration the breath-hold times of the healthy volunteers were generally longer than those of the patients ( $p < 0.003$ ). Multivariate analysis revealed that in patients with COPD or CHF the breath-hold times without hyperventilation were not statistically different from those of patients without such diseases (Figure 2). After hyperventilation, the mean breath-hold times were lower in the patients with COPD or CHF (expiration:  $21 \pm 10$  sec vs.  $40 \pm 18$  sec,

$p = 0.02$ ; inspiration:  $37 \pm 16$  sec vs.  $62 \pm 30$  sec,  $p = 0.05$ ), however this comparison is limited by the small number of patients with COPD or CHF (total:  $n = 4$ ). While there were no significant sex differences in breath-holding without hyperventilation, after hyperventilation lower breath-hold times were observed in women than in men ( $p < 0.03$ ). Age ( $p > 0.2$ ), smoking history ( $p > 0.4$ ), or the order of examinations (expiration performed before inspiration or vice versa,  $p > 0.1$ ) showed no significant influence on the measured breath-hold times.

## Discussion

In various radiological modalities the optimal image quality is achieved when the patients hold their breath during the entire study. With the advent of fast imaging modalities such as spiral computed tomography or rapid magnetic resonance imaging more and more studies may potentially be acquired within a single breath-hold. Frequently the study time lies in the order of the breath-hold time with some variations in either direction. These variations, however, may considerably influence the success of the examinations. Thus, to optimize the quality of the examination, the radiologist has to consider the breath-hold capabilities of the patient. Breath holding in expiration is reported to allow a more reproducible organ positioning than breath holding in inspiration.<sup>1</sup> That is why many studies, particularly of the abdomen, should primarily be performed in expiration. Although thoracic studies usually benefit from maximal distention of the lungs as it occurs in inspiration, expiratory scans may be necessary e.g. in patients with obstructive lung diseases to document possible air trapping.<sup>4</sup>

Reviewing the literature, we found three radiological studies that evaluated the breath-hold capabilities of adults either in expiration



**Figure 2a,b.** Scatter graphs showing the breath-hold times in expiration/inspiration without (Figure 2a) and after (Figure 2b) hyperventilation. The data points are connected for each of parameter of ventilation. The graphs indicate smokers (S) with a history of more than 10 pack-years, patients with COPD (P), and patients with chronic heart insufficiency (H).

or in inspiration and two of these studies documented the benefit of hyperventilation and of administration of oxygen.<sup>2,3,5</sup> We found no report that compared breath-holding capabilities between expiration and inspiration that could be transformed to the conditions in a radiological setting. Some reports have investigated the physiological changes that occur during suspended respiration with special interest in oxygen saturation and heart rate, most of these studies were performed in divers.<sup>6-8</sup> As part of the physiolo-

gic diving reflex a decrease in the heart rate can be observed during breath-holding which was also observed by Gay and Marks.<sup>2,5</sup>

With and without hyperventilation the breath-hold times in inspiration exceeded those in expiration by approximately 50-130%. Although it is a wide-held belief that it is easier to hold the breath in inspiration than in expiration, the amount of these differences exceeded our expectations.

All of the patients investigated in this study were outpatients and none of them was

severely pulmonary-compromised, although four patients had a medical history of COPD and two of them additionally had CHF. The healthy volunteers were generally considerably younger than the patients, and most of them were physically active. This may explain the longer mean times in the group of volunteers than in the patient group. In our study population hyperventilation increased the maximum breath-hold capabilities in expiration and inspiration, however these effects were less pronounced in patients with cardiac or pulmonary diseases (Figure 1). This confirms the results of Marks et al. who demonstrated that the effects of hyperventilation were less beneficial in pulmonary-compromised patients while administration of oxygen resulted in increased breath-hold times even in pulmonary-compromised patients.<sup>2</sup> Similar to the observations of Gay et al. we found no significant influence of smoking on the maximum breath-hold times.<sup>5</sup>

In conclusion, suspending respiration in inspiration results in considerably longer breath-hold times when compared to breath-holding in expiration. The radiologist has to decide which respiratory maneuver is best suitable to optimize the performance of the specific imaging studies.

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