# Gravity dependent ventilation of rats measured by hyperpolarised helium MRI and electric impedence tomography

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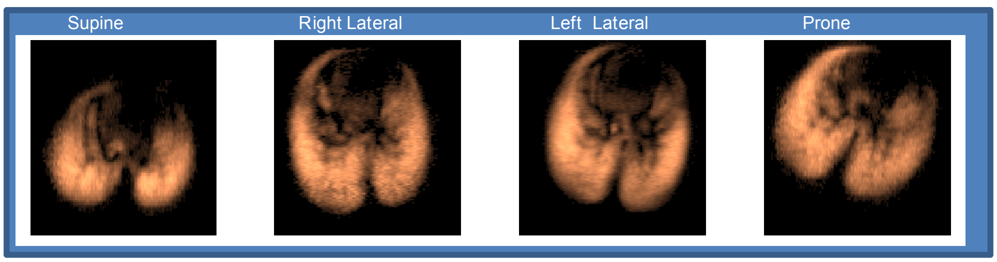
## Introduction

Ventilation in larger animals and humans is gravity dependent and mainly distributed to the dependent lung. Little is known of the effect of gravity on ventilation distribution in small animals such as rodents. A report by Mansson et al[1] investigated gravity-dependent ventilation distribution in the rat measured by HP3He MRI and showed that in the supine position, the dependent lung received more ventilation than the dependent lung, whereas in the prone position the ventilation was more uniformly distributed. The aim of this study was to investigate gravity-dependent ventilation distribution in rats, in vivo, using both hyperpolarised helium-3 magnetic resonance imaging (HP3HeMRI) and electrical impedance tomography (EIT)[2]. While HP3HeMRI is becoming known as a 'gold standard' for imaging ventilation, EIT has the advantage of ability to be used at the bedside on a continuous basis. EIT measurements were performed during the entire breathing cycle, and HP3HeMRI spin density images were performed during apnoea following peak inspiration, for rats in four body positions (supine, prone, left and right lateral.)

## Method

Male Wistar rats (8–10 weeks of age and a weight of 300± g) were anaesthetized and intubated with a 16-Gauge (G) intravenous catheter , then mechanically ventilated with an MRI compatible ventilator based on the design of Hedland et al[3]. HP3He produced using spin exchange optical pumping[4] was administered during apnoea and HP3He 2D axial projection spin density images obtained (FLASH, short TE, image resolution 0.45×0.313 $mm^2$). For each image, the rat received 4x2ml breaths of HP3He followed by an apnoea of 2 seconds, 2ml during which spin density MRIs were obtained. Images were obtained for each rat in prone, supine, left lateral, and right lateral lying positions.

Following MRI scans, the rats were shaved around the chest and 16 epicardial pacing wires (Medtronic Inc., Minneapolis, MN, USA) were sutured equidistantly around the chest, directly under the forelegs of the animal which correspond to the midsection of the lungs. The principle of EIT is based on the rapid cyclic acquisition of potential differences on the surface of the body produced by repetitive injections of a small electrical current. The current is injected and the voltage measured between sequential pairs of electrodes placed circumferentially around the body segment of interest. Functional images (32 × 32 matrix) are generated from the collected potential differences[5]. Each pixel represents the instantaneous relative local impedance change relative to a baseline generated from the entire time course of the measurement. The majority of the measured impedance change is caused by local air volume change, and hence, the measured impedance change of each pixel correlates closely to local (tidal) volume change[6]. EIT data was acquired with 100 kHz injected current and a frame rate of 44 Hz for each rat in prone, supine, left and right lateral positions.

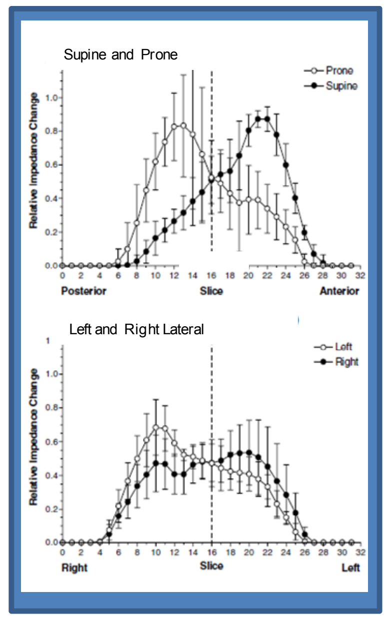



(a)

**Figure 1**: (a) 2D 3He spin density images of rat lungs, (b) EIT Profiles of relative impedance change, and (c) spin density image areas for rats in supine, right lateral, left lateral, and prone body positions.

| Image Crossectional Area in $mm^2$ | | | | |
|---|---|---|---|---|
| Rat | Supine | Right Lateral | Left lateral | Prone |
| 1 | 387 | 449 | 445 | 552 |
| 2 | 548 | 538 | 629 | 724 |
| 3 | 588 | 698 | 693 | 703 |
| 4 | 599 | 767 | 794 | 792 |
| 5 | 514 | 570 | 630 | 604 |
| 6 | 458 | 649 | 676 | 648 |

(b)




(c)

## Results and discussion

The effect of gravity on regional ventilation distribution was assessed with EIT during the dynamic breathing cycle and with HP3HeMRI during apnoea. EIT data is analysed to produce profiles of relative impedance change and calculations of the geometric centre. Regional filling was measured by calculating the slope of the plot of regional versus global relative impedance change on a breath-by-breath basis. Ventilation was significantly distributed to the non-dependent lung regardless of body position and tidal volume used. The geometric centre was located in the dependent lung in all but prone position. The regional filling characteristics followed an anatomical pattern with the posterior and the right lung generally filling faster. Gravity had little impact on regional filling. 3He spin density images provide profiles of gas density and estimates of cross sectional lung area. 3He data agreed with EIT data and showed that in the supine position, the dependent lung received more ventilation than the dependent lung, whereas in the prone position the ventilation was more uniformly distributed. For all animals, image cross sectional area was least in the supine position.

Ventilation distribution in rats was shown to be gravity dependent, from time averaged EIT data and HP3HeMRI images of apnoea, whereas regional filling characteristics are dependent on anatomy. HP3He MRI and EIT data agree where they can be compared. HP3He MRI provides data on real geometry which EIT cannot as tomograms are reconstructed to a circular image. EIT provides data on filling characteristics at temporal resolution (44 frames per second) that has not been matched by 3He to date. Dynamic imaging of the breathing cycle with HP3He is needed to make a full comparison of the two methods.

## References

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