# Reproducibility of quantitative parameters derived from dynamic hyperpolarized 3He MRI

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**Introduction** Dynamic $^3$He MRI may supply information in diseases such as asthma and CF [1] pertaining to changes in airway recruitment / change in resistance to airflow. The signal intensity in dynamic HP gas MRI is dependent upon a variety of related factors including RF history and rate of flow. If dynamic imaging is to be used quantitatively to assess intervention then quantification and normalization of the measured parameters needs to be addressed. The aim of this work was to **(i)** determine whether quantitative parameters derived from dynamic $^3$He MRI are reproducible with respect to gas inhalation variability by means of flow phantom and volunteer repeatability studies and **(ii)** investigate dynamic $^3$He MRI as a tool to evaluate efficacy of respiratory intervention in preliminary studies in asthma and CF.

**Methods. Measurements** were conducted on a 1.5T whole body MRI system (Eclipse-Philips Medical System). A flexible twin saddle quadrature RF coil was used for in vivo work in adult asthmatics (n=3), a quadrature elliptical birdcage coil for the work in healthy volunteers (n=3) and CF children (n=4), and a circular small birdcage for the flow phantom work. The $^3$He gas (Spectra Gases) was polarized on site to around 30% with rubidium spin exchange apparatus (GE). Dynamic imaging was performed during the inhalation maneuver with a 2D radial pulse sequence described in detail previously [2]. Flip angle ≈ 7° used to bias both distal airspaces and small airways. Flow phantom repeatability studies were performed by connecting a 20 cm length of Tygon tubing, inner diameter 4mm, to a Tedlar bag containing 100 ml $^3$He with 900 ml $N_2$. The tubing was routed along the birdcage axis and gas flow was set up by slowly extracting 50 ml at a steady flow rate of approx. 10 ml/s, using a syringe connected to the other end of the tube. In vivo studies were performed during inhalation of a 300 ml $^3$He/ 700 ml $N_2$ mixture from a Tedlar bag from a starting point of resting expiratory level. The volunteers repeated the exam in quick succession without any intervention, the asthmatics received bronchodilator therapy between exams and the CF children received chest physiotherapy between exams.
**Analysis:** The slope of the signal rise as measured in a ROI in the trachea has previously been used as an input function to normalize a given data set for spatially dependent flow variability within different regions of the lungs [1]. In this analysis of ***inter exam reproducibility*** we focus on the ***integrated*** signal intensity in a ROI in the trachea as a possible parameter for normalization for gas polarization change between studies and velocity dependent signal intensity variations. Assuming all gas is inhaled and passes via the trachea then the RF depolarization history in the trachea should be well defined, and a possible hypothesis is that the integrated signal intensity should be constant between exams performed with the same volume of polarized gas irrespective of flow rate relating to inspiratory effort. The signal integral with time was measured from the same ROI (10mm x 8 mm in the trachea, 4 mm x 3 mm in the phantom) on separate occasions. A pixel-pixel fit of the integrated signal intensity was also performed.

**Results & Discussion Fig.1** shows the time integral from the same ROI in the flow phantom on 3 occasions. Note the variability (3%). **Fig. 2** is a parametric pixel map of the integral of the signal from one of the flow phantom data sets. The dashed lines represent the limits of the birdcage sensitive region, note the spatial gradient in integrated signal intensity reflecting the different RF history of the flowing gas as a function of path length. This is consistent with image intensity variations previously described in flow experiments with HP $^{129}$Xe [3,4]. The positional dependence of the integral (despite a steady flow in the tube) indicates a source of spatial variability when choosing an ROI based integral input function for intra-exam normalization. This is also evident in the in vivo example of the integral from the trachea in **Fig. 3** with a well defined depolarization gradient in the integral along the flow direction - the message is that an ROI placed in the trachea is prone to spatial variability and is not constant as hypothesized. This source of error could explain partially the variability in flow curves from the same volunteer (not shown for space) and in the pooled data from all in vivo exams (mean variability 25%) -**Fig. 4.**

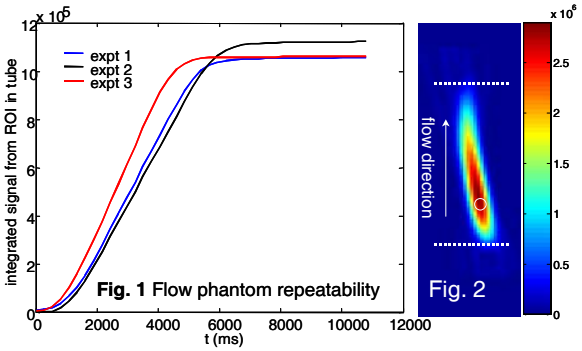


**Fig. 1** Flow phantom repeatability



Fig. 2

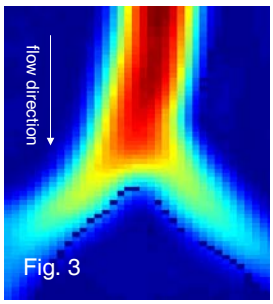
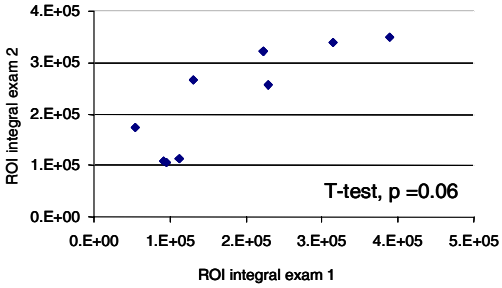


Fig. 3

**Fig. 4** in vivo reproducibility of ROI integrals




The pre and post intervention studies in ***asthmatics***(**Fig. 5)** and ***CF*** patients (**Fig. 7)** show substantial changes in qualitative visual appearance and in the flow curves as measured in different parts of the lungs. This is exemplified by the ROI measurements made in the asthmatic with an improved gas flow post therapy in the upper left lung –see Fig. 6. Similarly, spatio-temporal changes are evident in the CF patients following physio-therapy – see arrows in Fig. 7. However, with a 25% variability in our proposed normalization parameter, quantification of intervention related parametric changes will be prone to error due to flow velocity. This could be resolved by the use of a controlled flow rate gas delivery system and will be investigated in future work.

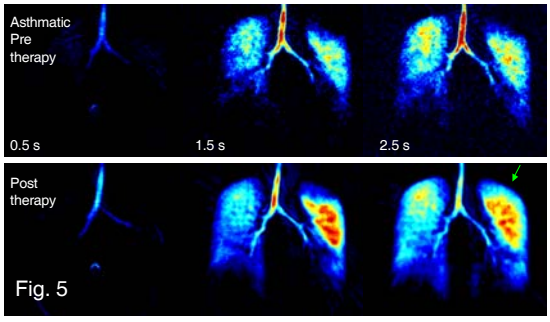
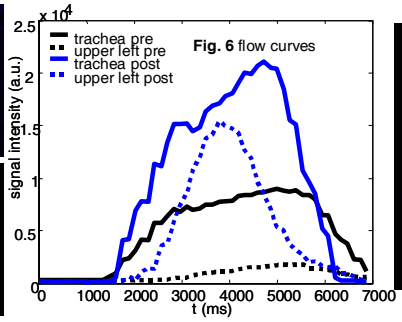
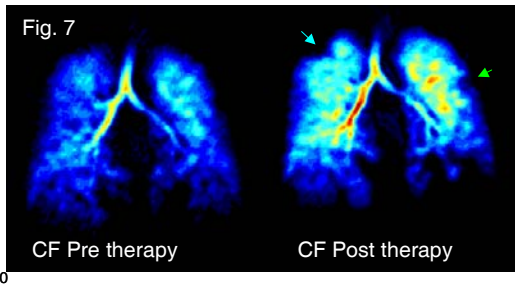


Fig. 5




**References** [1] J Magn Reson Imaging. 2005;22(3):420-6. [2] Magn. Reson. Med 2003;49(6):991-7. [3] Magn. Reson. Med 1999; 41, 1058-1064 [4] J Magn Reson, 2002, 159, 68-75.
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