3He Regional Volumetry in Pediatric Cystic Fibrosis: Pre and Post Physiotherapy

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Introduction: Cystic fibrosis (CF) is the most common autosomal recessive life threatening condition in Caucasians affecting 70,000 people worldwide. Most CF patients suffer from chronic respiratory infections, usually from an early age. The viscous mucus in the airways is particularly prone to bacterial infections which, once established, are difficult to eradicate. CF Patients typically suffer from chronic respiratory infections, causing gradual destruction of lung tissue. This leads to progressive lung disease, a reduction in ventilated volume and eventually, respiratory failure. Chest physiotherapy is one of the most important daily treatments in CF, helping patients to loosen and clear sticky mucus from their lungs. Previous Helium-3 (^{3}He) studies of CF have used visual scoring systems [1, 2]. We have used a more objective method of measuring regional ventilation. We have previously demonstrated the reproducibility of ventilated volume measurements in this population [3]. We used hyperpolarized ^{3}He MRI to measure regional ventilated volume changes in paediatric cystic fibrosis patients before and after physiotherapy.

Materials and Methods: 7 Children with CF were imaged before and after a session of physiotherapy. MR images were acquired after inhaling a dose of 5ml/Kg body weight of hyperpolarized ^{3}He diluted with an equal quantity of N_2 using a 3D gradient recalled echo sequence [4]. The oxygen saturation (SpO_2) of all patients was monitored throughout the examination. The images from the ^{3}He scans were segmented into 6 zones [1] (Fig.1). Each segmented area was binarized using a signal to noise derived threshold [5] (Fig.2) and a volume was calculated for each zone. The regional and total ventilated volumes were compared. Spirometry was also performed pre and post physiotherapy.

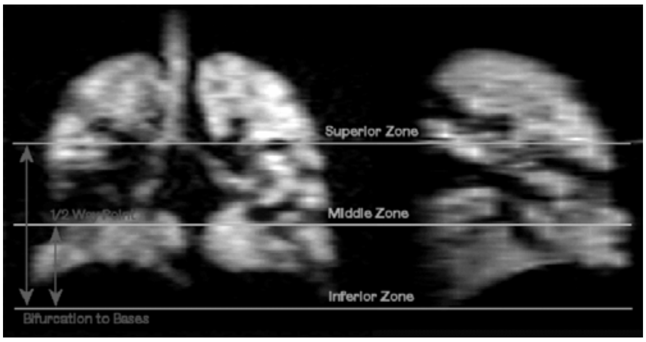

Fig. 1: ^{3}He ventilation images were segmented into 3 zones based upon the bifurcation of the bronchi and the lung bases; each of these zones was then subdivided into anterior and posterior zones based upon position relative to the bronchial bifurcation.

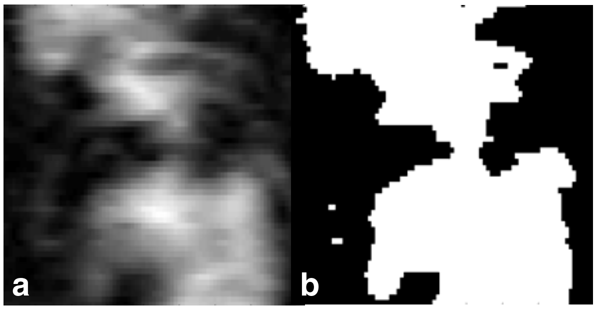

Fig. 2: The segmented area from each slice (a) was binarized using an SNR based threshold and the pixels in the resultant image (b) were counted to give a ventilated volume for each lung zone. The total ventilated lung volume and the volume for each zone was compared to itself post physiotherapy.

Results: There was no significant increase in total ventilated volume after physiotherapy although the trend was for a slight increase with a mean change of 3.23% of the initial ventilated volume (p=0.36). There was some resolution of ventilation defects seen pre-therapy and new defects were also observed. There was a difference in the distribution of ventilation defects post-therapy (Fig. 3), and these changes were quantified by the regional volumetry, with significant changes in ventilated volume observed in at least 3 zones in each patient ($p<0.05$). There was an altered response in SpO_2 post physiotherapy (Fig. 4), the maximum decrease in mean SpO_2 from baseline pre-physiotherapy was 2.51% at 40 seconds (p=0.01), post-physiotherapy SpO_2 dropped by 4.59% at 40 seconds (p=0.05). There was no significant change recorded in spirometric indices.

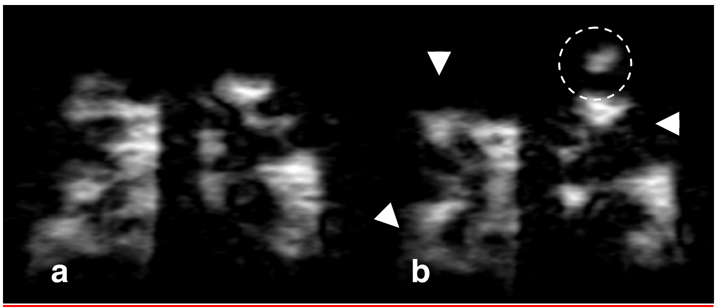

Fig. 3: There was a redistribution of ^{3}He ventilation pre (a) and post (b) physiotherapy with partial resolution of some defects (circle) and the extension of others (arrows).

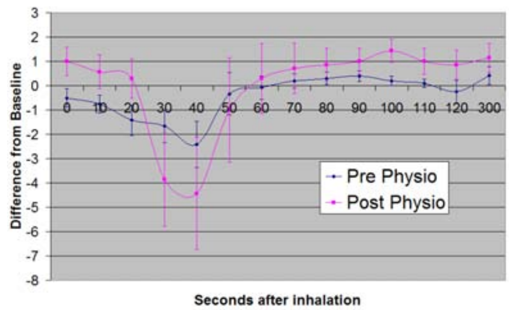

Fig. 4: There was a change in SpO_2 response to the hypoxic $^{3}He/N_2$ breath hold observed post physiotherapy

Discussion: Regional volumetry using ^{3}He can demonstrate and quantify regional changes in ventilation distribution post physiotherapy in a paediatric CF population. These changes are most likely due to the shifting of mucus plugs following physiotherapy. The altered SpO_2 response post physiotherapy may reflect changes in ventilation perfusion matching and further studies using PO_2 sensitized sequences [6] are planned. Perfusion imaging with gadolinium enhanced proton MRI may also be of value.

References: [1] Radiology, 1999. **212**(3): p. 885-9. [2] Acad Radiol, 2005. **12**(11): p. 1423-1429. [3] Proc. *RSNA*. 2005: p.685. [4] Magn Reson Med, 2004. **52**(3): p. 673-8. [5]J Magn Reson Imag, 2005. **21**(4): p. 365-9. [6] J Appl Physiol, 1999. **87**(6): p. 2043-2052.

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