Static Lung Volumes Assessed on MRI with Spirometry Control in Comparison to Body-Plethysmography

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Introduction: Lung volumes such as total lung capacity (TLC), functional residual capacity (FRC) and residual volume (RV) are used clinically to quantify restriction, hyperinflation and gas trapping. Absolute static lung volumes are often measured using a body-plethysmograph; however, measurements are indirect, derived based upon Boyle's Law, and can be imprecise because of intestinal gas(1) and based on the use of the simplified versions of the Boyle Marriot (2). We tested the reproducibility of lung volumes measured directly on MRI with concomitant spirometry control and tested their validity compared to body-plethysmograph measurements.

Methods: Following institutional review board approval, six healthy volunteers, ages 35-50 were enrolled. All MRI was conducted on a 1.5T GE scanner. Coronal 3D spoiled gradient recalled (SPGR) imaging with whole lung coverage was performed with TR/TE=2.6/0.8ms, Flip angle =20 degree, FOV=48x48 cm, and a matrix=256x160. Lung volumes were measured 3 times at maximal inspiration or expiration (TLC or RV) and normal expiration (FRC) for 15 sec, with repeatable depth of breathing guided using an ultrasonic spirometer (ndd EasyOne). Software was developed in house for quantifying the MRI lung volumes with auto-segmentation. Lung contours were manually drawn on one slice, then the range of the lung intensity was estimated by the software to further refine the contour. The result was propagated to all slices automatically. For other regions where signal intensity matched lung parenchyma, a manual segmentation was used to exclude them. Vessels in the lung were manually removed. Abdominal gas, which is included in body-plethysmography measurements, was measured on MRI using the same approach. Body-plethysmography was performed separately following ATS/ERS guidelines. In addition, vital capacity was compared in sitting and supine spirometries to account for positional volume differences. Tests were considered to meet repeatability criteria if they met the ATS/ERS goal of <150 ml difference between the largest 2 measures. Validity was assessed by Bland-Altman methods.

Results: Fig. 1 shows representative 3D models of the lungs of one subject at RV, FRC and TLC with volumes of 3.1, 3.7, and 7.5 liters respectively. TLC and RV measured by MRI met ATS/ERS criteria for reproducibility (Table), as did TLC and FRC by body-plethysmography. TLC on MRI and body- plethysmography were highly correlated (r=0.97; P<0.001); however TLC on body-plethysmography was higher by a mean of 880±87 ml. Bowel gas was highly variable across subjects, accounted for 0-157 ml of the difference. Position accounted for another 418±193 ml of the difference, based upon measures of vital capacity on spirometry in the sitting vs supine position.

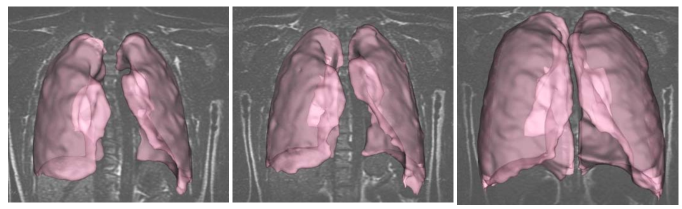

Fig 1. 3D models of lungs at RV, FRC and TLC

Discussion and Conclusions: In healthy subjects, lung volumes on MRI can be measured reproducibly. Measures of TLC by MRI are lower than those by body-plethysmography due to bowel gas (which is included in body- plethysmography measurements), supine assessment, and, likely, assessment of volumes with a closed glottis and relaxed respiratory muscles during the suspended inspiration. Correlations of these techniques in patients with obstructive and restrictive pulmonary disorders remains to be determined.

Table 1. Precision of lung volumes on MRI and plethysmography.

	MRI		Plethysmography	
	CV (%)	Mean difference (ml)	CV (%)	Mean difference (ml)
TLC	1.9	116	1.2	70
FRC	8.8	404	2.7	58
RV	4.3	124	8.7	253

CV=coefficient of variation; TLC=total lung capacity; FRC=functional FRC= FRC = functional residual capacity; RV= residual lung volume.

Reference:

1. Brown R, Hoppin FG, Ingram RH, Saunders NA, Mcfadden ER. Influence of Abdominal Gas on Boyles Law Determination of Thoracic Gas Volume. *J Appl Physiol* 1978; 44: 469-473.
2. Coates AL, Desmond KJ, Demizio DL. The simplified version of Boyle's Law leads to errors in the measurement of thoracic gas volume. *American journal of respiratory and critical care medicine* 1995; 152: 942-946.

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