Collection of Helium-3 for Recycling from Human Imaging Studies

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<u>Introduction</u>: The rising cost and limited supply of helium-3 threatens the field of hyperpolarized helium-3 lung MRI. However, unlike some uses of helium-3, medical imaging applications do not alter the properties of this rare resource, and thus "used" helium-3 recovered from the exhaled breath of MRI subjects can be recycled and re-used for non-human applications. Recovery/recycling efforts are currently underway at several helium-3 imaging centers [1-3]. Our group has begun collecting the exhaled breath from human imaging studies and storing this gas for future recycling. Here we present the equipment and methods used for collection and storage, and estimate the collection efficiency of our procedures based on an analysis of the stored gas.

<u>Materials and Methods</u>: The apparatus used for collection and storage of exhaled breath is shown in Figs. 1 and 2. The breath-collection apparatus consists of a mouthpiece, microbial filter, two one-way valves, and various connectors and tubing, and was assembled from off-the-shelf parts purchased from Amici Inc. (Spring City, PA). The mouthpiece is connected to one branch of a tee connector. Each of the other two branches contains a one-way valve, one of which is open to the room and allows fresh air to be drawn in during inhalation, while the other directs exhaled air through a microbial filter and into a low permeability collection bag developed by Conservation Design Services Inc. (Chapel Hill, NC). A nose clip is placed on the subject prior to each image acquisition, to ensure that none of the exhaled breath escapes through the nose, but otherwise the helium dose is administered according to our standard procedure, by inhaling from a Tedlar bag through ¼-inch tubing, and imaging is performed at breath hold. Immediately after the pulse sequence ends, the subject is instructed to continue their breath hold as the mouthpiece is placed in their mouth. The subject exhales through the mouthpiece, then 3-5 deep purging breaths are also collected in the bag. The exact number of captured exhalations varied in these initial subjects, and was determined by the operator based on subject tolerance and volume available in the collection bag. The mouthpiece is then removed from the subject's mouth. The process is repeated for additional helium doses.

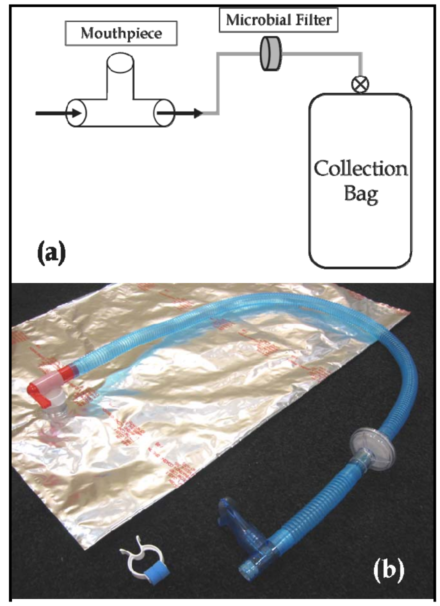

Figure 1: The collection system: (a) schematic and (b) photograph.

At the end of the imaging session the mouthpiece, valves, and filter are discarded and the bag hose is connected to the inlet port of the compression and storage system shown in Figure 2 (CDS Inc. Chapel Hill, NC). The compressor increases the pressure of the input gas to ~20 psi above the current tank pressure, which causes gas to flow out of the collection bag and into the tank.

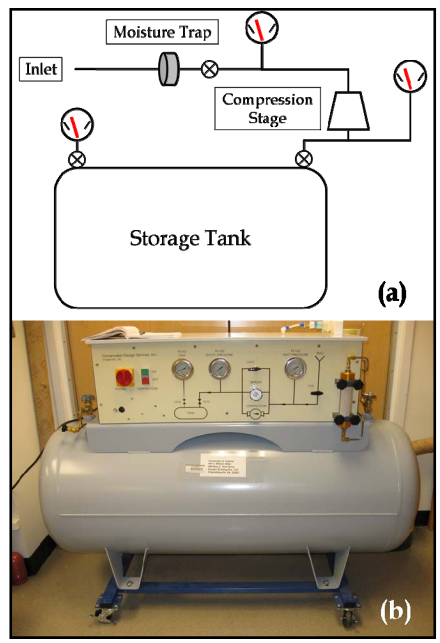

Figure 2: The storage system: (a) schematic and (b) photograph.

<u>Results</u>: To date we have collected gas from 23 human studies. After the 20th subject, we removed a small sample of gas from the storage tank and had it analyzed for gas composition by TRI- Air Testing Inc (Austin, TX), using the technique of gas chromatography with a thermal conductivity detector (TCD). Since helium-3 is not commonly tested using this technique, we also prepared a sample of 5.0% helium-3 in room air for calibration. Table 1 shows the results of this analysis, which measured 3.5% helium-3 in our tank sample. At the time of measurement, a total volume of 42.5L of helium-3 had been administered in the collected studies. The pressure in the storage tank was approximately 14.5psig (1.99atm total gas pressure). Based on the 3.5%, this implies a helium-3 recovered volume of 31.6L, representing 74% collection efficiency.

<u>Discussion</u>: In ~90% of subjects, the recovery procedure was completed as described. Only one subject could not tolerate the collection procedure, a COPD patient who also had the lowest FEV1 (< 50% predicted) of all subjects studied. Two of the subjects exhaled some of the gas from their lungs before the mouthpiece was in place. We believe there is considerable opportunity for increasing collection efficiency, by improving collection procedures and by collecting more than 3-5 purging breaths per scan. It would be ideal to integrate gas administration and collection, so that both occur through the same mask or mouthpiece [3]. This would likely improve collection efficiency for all subjects, and should enable collection from the sickest patients.

<u>Conclusion</u>: Recovery of helium-3 in the exhaled breath of hyperpolarized-gas MRI subjects is entirely feasible, and high collection efficiencies are easily attainable for healthy subjects. Similar collection efficiencies should be possible for sick patients using appropriate procedures. Our group has begun collecting exhaled breath from all helium-3 human scans. Analysis confirms that so far we have captured more than 30 liters of used helium-3 for eventual recycle. Extracting this helium for use in other applications should be achievable, and viable procedures have already been documented [1, 3].

Calibration Sample		**Tank Sample**	
Methane	**2.0ppm**	**Methane**	**3.5ppm**
CO	**<1ppm**	**CO**	**9.2ppm**
CO2	**570ppm**	**CO2**	**2.44 %**
Oxygen	**20.2%**	**Oxygen**	**15.7%**
Nitrogen	**74.7%**	**Nitrogen**	**78.0%**
Helium-3	**5.0%**	**Helium-3**	**3.5%**

Table 1: Results of Gas Composition Analysis

<u>Acknowledgments</u>: Supported by NIH grants R21 HL089525 and R01 HL079077, and by Siemens Medical Solutions.

<u>References</u>: [1] Cadman et al. ISMRM 2007; 1267.

[2] Nouls et al. ISMRM 2010; 2559.

[3] Salhi et al. MRM 2011; doi:10.1002/mrm23154