Reproducible, Realistic and Stable Lung Phantom for CT and MR

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Purpose/Introduction:

MRI is being increasingly used for lung imaging with the advantage of no radiation dose. Nevertheless, CT still remains the gold standard and newly developed MR techniques should preferentially be validated against it [1]. However, to our knowledge, no CT-MR lung phantom has been reported. Developing such a phantom is challenging because both techniques measure different effects. In CT, tissue and air cavities cause low average electron density and therefore low HU values. In MR, this structure causes a combination of low proton density and susceptibility effects (measured by R2*). We propose a reproducible, realistic and stable CT-MR phantom for lung imaging using a gel foam.

Subjects and Methods:

Phantom fabrication:

The gel foams are composed of gelatin (200Bloom, type A) (12%(w/w)), sodiumdodecylsulphate (SDS) (0.15%w/w), bis(tetrakis(hydroxymethyl)phos-phonium]sulphate (THPS) (10mM), and de-ionized water (83%(w/w)). The fabrication procedure is based on a previous study [2]. Foam fabrication was repeated three times and four samples were obtained from each batch.

Imaging Technique:

MR data was acquired using a Bruker 7 T. MSE (TR/TE=2500ms/11-99ms, echo-spacing=11ms, resolution=156μm, acquisition time=8'00"), 3D-UTE (TR/TE=8ms/0.5-2.0ms, echo-spacing=0.25, resolution=390μmx390μmx550μm, acquisition time 6'50") and RAREVTR (6 TR/TE=8000-1173.76/11-99ms, echo-spacing=22ms, resolution=156μm, acquisition time=36'16") sequences were used for R2, R2* and T1 calculation respectively. In addition, micro-CT images were acquired with 75kVp and 360μAs. To assess stability over time, samples were scanned for four consecutive days with the previously described sequences.

Data processing:

CT data was reconstructed with IMPACT algorithm that intrinsically removes beam hardening effects [3]. First, all images were co-registered and 5 VOIs were selected in each sample. Then, the average and standard deviation of R2, R2*, CT and T1 values in the VOIs for each sample and each day was calculated.

Results:

Phantom appearance is shown in Figure 1. Figure 2 presents the average R2*, R2, T1 and HU values on four consecutive days in all three batches. The global mean values for R2, R2*, T1 and HU were 0.055±0.014ms^{-1}, 2.55±0.69ms^{-1}, 1210±223ms and -605.94± 138.64HU respectively.

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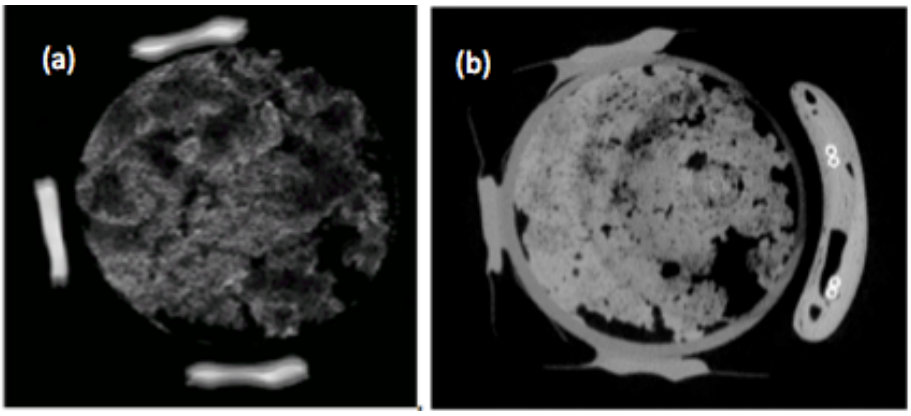

Figure 1. (a) MR (T2-weighted) and (b) CT image of the phantom

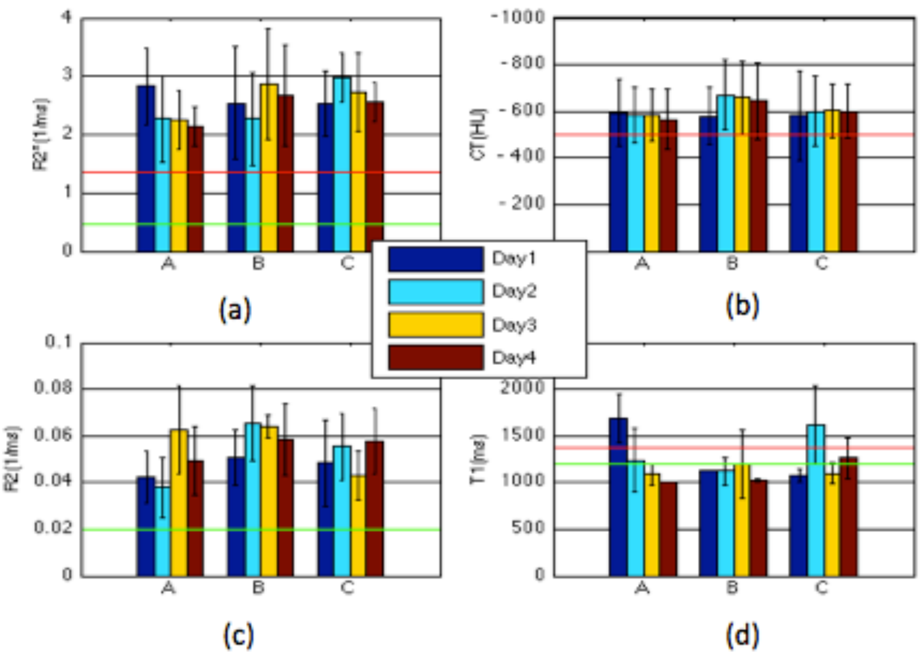

Figure 2. Average values and standard deviation in samples from 3 batches on 4 consecutive days. (a) R2* values, green and red line represent literature healthy human lung values at 1.5T and 3T [4], respectively. (b) CT (HU) values, red line defines the maximum HU for healthy human lung [5]. (c) R2 values, in green the reported R2 value at 1.5T[6]. (d) T1 values, green and red line represent literature values at 1.5T [7] and 3T [8], respectively.

Discussion/Conclusion:

The obtained CT Hounsfield units values were realistic compared to human lung. MR parameters were compared to lower field values, due to the lack of data in literature at 7T. All parameters were expected to be higher than at lower field strength. This was the case for R2* and R2 but not for T1. Because, R2* and HU are the most relevant parameter, we conclude that the proposed lung CT-MR phantom is reproducible, realistic and stable over the scanned period.

References

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