Comparison of under-sampled Cartesian pulmonary perfusion MRI reconstructed with either view sharing or HYCR

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Introduction

Lung perfusion MRI is clinically useful in…
...pulmonary embolism²³
...pulmonary hypertension
...cystic fibrosis³
...other lung diseases
However, true absolute quantitation is limited by the need for both high temporal-spatial resolution and full-lung coverage.

Purpose

To compare the performance of
• 3 different Cartesian undersampling methods combined with
• 2 alternative reconstruction methods
for both qualitative pulmonary perfusion imaging and assessment of contrast dynamics.

Methods

• 22 healthy subjects (10 male, age 22-61yrs)
• 1.5T scanner (MR450w, GE Healthcare, Waukesha, WI)
• 8-channel cardiac coil

Acquisition

• Scan parameters and injection protocol in Table 1
• 3 interleaved Cartesian undersampling schemes (Fig. 3, top row)
  1) Cartesian Acquisition with Projection Reconstruction-like (CAPR)⁶ sampling
  2) Differential Subsampling with Cartesian Ordering (DISCO)⁷ sampling
  3) Interleaved Variable Density (IVD)⁸ sampling
• Scanned in randomized order
• ≥ 20 min between scans to allow contrast wash-out
• 22 sec breath-hold

Reconstructions

1) view-sharing (VS)
2) HighY Constrained Cartesian Recon (HYCR)⁸

Qualitative Analysis

• 3 cardiothoracic radiologists independently ranked the recons for each subject in order of image quality
• Kruskal-Wallis tests for differences in image quality

Contrast Dynamics Analysis

• Region Of Interest (ROI) in the main pulmonary artery
• gamma variate fit of mean signal in ROI
• Normalized to initial (baseline) value
• Measured:
  1) maximum value
  2) maximum slope
  3) rise time (20%-80%)
• Linear mixed effects model was used to compare the effects of
  1) injection order, 2) sampling scheme, and 3) reconstruction method

Results

• All recons generated good quality perfusion images (Fig. 1 & 3).
• No differences between the acquisition-reconstruction methods (Fig. 3).
• Image quality depended slightly on injection order (p=0.04, 0.12, 0.01 for the 3 readers)

• higher max and slope on earlier injections (p<0.001)
• 23% higher max, 5% steeper slopes, and 6% shorter rise times with HYCR than with VS recons (Fig. 2 & Table 2).
• Differences were greater at 0.5 sec than at 1.0 sec temporal resolution (only rise time was statistically significant at p=0.036)
• Rise time with Scheme 3 sampling was shorter than with Scheme 1 (p=0.003), but no other significant difference between the undersampling methods

Conclusion

All 6 acquisition-reconstruction methods evaluated in this study produced images of similar quality.
Shorter rise times, greater maximum intensities, and steeper slopes of contrast enhancement curves suggest that suggest HYCR recon may yield higher accuracy than view-sharing for whole-lung quantitative perfusion MRI.

Table 1. Scan parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>FOV</td>
<td>40 cm SI x 28 cm RL x 40 cm AP</td>
</tr>
<tr>
<td>Pulse Sequence</td>
<td>3D spoiled gradient echo</td>
</tr>
<tr>
<td>Excitation</td>
<td>sagittal</td>
</tr>
<tr>
<td>True resolution</td>
<td>4 mm isotropic</td>
</tr>
<tr>
<td>TR/TE</td>
<td>1.7 ms / 0.6 ms, fractional readout</td>
</tr>
<tr>
<td>Flip Angle</td>
<td>12°</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>±125 kHz</td>
</tr>
<tr>
<td>Parallel accel. (2D)</td>
<td>2 x 2 (AP x RL)</td>
</tr>
<tr>
<td>Contrast Agent</td>
<td>gadobenate dimeglumine (Multihance™)</td>
</tr>
<tr>
<td>Injection</td>
<td>0.05 mmol/kg @ 4 mL/sec with 35 mL saline flush</td>
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</tbody>
</table>

Table 2. View shared vs HYCR recon metrics. HYCR showed larger max and max slope with shorter rise times than view sharing. (Maximum and max slope are in arbitrary units.)

<table>
<thead>
<tr>
<th>Metric</th>
<th>View Shared</th>
<th>HYCR</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>26.3 ± 11.5</td>
<td>29.6 ± 11.0</td>
<td>0.005</td>
</tr>
<tr>
<td>Max Slope</td>
<td>8.5 ± 4.4</td>
<td>10.0 ± 4.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Rise-Time (sec)</td>
<td>1.3 ± 0.3</td>
<td>1.2 ± 0.2</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Fig. 1. Lung Perfusion. Typical 3D recon at time of peak lung signal. 4 mm isotropic, 0.5-1.0 sec temporal resolution.

Fig. 2. Contrast Dynamics. Higher max, steeper slope, and shorter rise times on HYCR compared with view-shared (VS) recon.

Fig. 3. Perfusion Reconstructions. No difference in image quality was seen between the 3 Cartesian k-space undersampling schemes (top row) reconstructed with either view-sharing (VS) or HighY constrained Cartesian Reconstruction (HYCR).

References


Funding for this project was provided by the UW School of Medicine and Public Health from the Wisconsin Partnership Program, the UW Department of Radiology R&D Committee, and the Clinical and Translational Science Award (CTSA) program (NIH 1UL1RR025011 and 9U54TR000021).