Truncation Artifacts and their Impact on Morphological and Quantitative Lung Imaging

Daniel Stäb[1], André Fischer[1], Christian Oliver Ritter[1], Dietbert Hahn[1], and Herbert Köstler[1]
[1]*Institute of Radiology, University of Würzburg, Würzburg, Germany*

Introduction:

Pulmonary MRI is well-known to be susceptible to artifacts resulting from cardiac or respiratory motion. Furthermore, flow artifacts can occur if large pulmonary vessels are present in the imaging slice. However, truncation artifacts or Gibbs ringing introduced at the boundaries between lung and surrounding body tissue when imaging with low resolution have up to now been neglected in the literature. In this work, we demonstrate the effects of Gibbs ringing on reconstructed images and its influence on quantified lung parameters such as T1 or pulmonary perfusion.

Methods:

Data were acquired on a 0.2 T Magnetom Open clinical low field scanner and a 3.0 T Magnetom Trio scanner (both: Siemens Healthcare, Erlangen, Germany). T_1 mapping was performed at 0.2 T according to (1) using an IR-Snapshot FLASH (2) sequence ($\alpha = 8°$, $T_R = 3.6$ ms, $T_E = 1.4$ ms, $T_I = 11.5$ ms, FOV 500 x 500 mm², slice thickness: 15-20 mm). The measurements were performed with different spatial resolutions, i.e. matrix sizes and reconstructed without k-space filtering. T1 values were quantified using simple exponential fitting. Dynamic contrast-enhanced (DCE) MRI for quantitative pulmonary perfusion imaging was performed at 3.0 T as described in (3) utilizing a 3-fold accelerated 3D FLASH sequence (α=19°, T_R=1.69ms, T_E=0.64ms, asymmetric echo, FOV 480 x 435 x 140mm³, matrix: 252 x 128 x 28). Image reconstruction was performed using GRAPPA (4). Prior to the examination, 4ml (Prebolus: 1ml) of contrast agent (Gadovist, Bayer Healthcare, Leverkusen, Germany) were administered, followed by a saline flush.

To reproduce the observed artifacts, a simplified digital lung phantom (512 x 512 pixel) consisting of two homogeneous lungs ($M_0 = 90$; $T_1 = 650$ ms), homogenous body tissue ($M_0 = 340$; $T_1 = 350$ ms) and homogenous background was generated. The k-space data were truncated to the desired matrix size, zerofilled to 512 x 512 pixels and Fourier transformed to visualize the effects and to compare the results to corresponding in-vivo data.

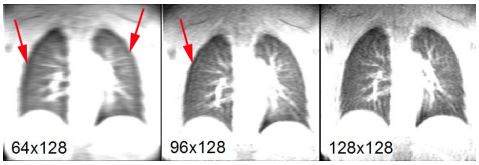

Fig. 1: *T1-weighted images acquired at 0.2 T with different spatial resolutions. The truncation artifacts manifest as a dark rim close to the lung boundary (arrows).*

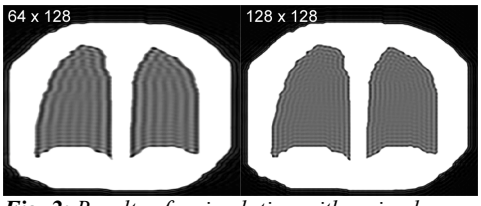

Fig. 2: *Results of a simulation with a simple digital lung phantom. The k-space of the phantom was truncated to the specified matrix size, zero-filled and reconstructed. The resulting Gibbs ringing is clearly visible.*

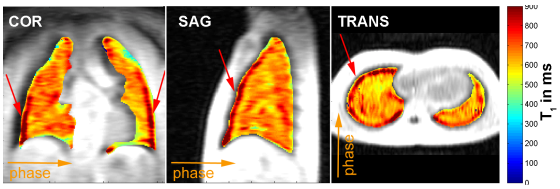

Fig. 3: *Quantitative T1-maps of the lung acquired at 0.2 T. Due to the truncation artifact (Fig. 1), T1 values are significantly overestimated in the lung periphery (arrows).*

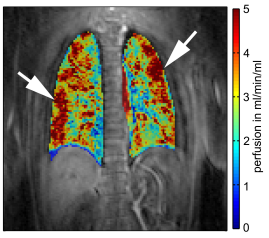

Fig. 4: *Quantitative perfusion map for 3D DCE imaging at 3.0 T. In the region of the truncation artifact, perfusion values are overestimated (arrows).*

Results:

Figure 1 shows T_1-weighted images of the in-vivo T_1 measurements at 0.2 T. The corresponding matrix sizes are depicted in the images. Especially for the lower resolutions, the truncation or Gibbs artifacts are clearly visible near the boundary of the lung (arrows). For comparison, results of the simulations are displayed in Fig. 2. Again, the utilized matrix sizes are depicted. During T_1 quantification, the truncation artifacts lead to an overestimation of T_1 and manifest as a rim of significantly enhanced T_1 values, as can be seen in Fig. 3. The matrix size for all maps is 64 (phase) x 128 (read). The artifact hence is typically observed in phase encoding direction, i.e in the direction of lower spatial resolution. Similarly, truncation artifacts also result in an overestimation of blood-flow in 3D DCE MRI. A representative perfusion map is shown in Fig. 4. The area with enhanced perfusion values is clearly visible (arrows).

Discussion and Conclusion:

In this work, the importance of truncation (Gibbs) artifacts in pulmonary MRI has been demonstrated. The artifacts arise from truncating the outer part of k-space, i.e. imaging with low spatial resolution. In-vivo measurements and simulations were performed, identifying the rims of low signal nearby the lung boundary as truncation artifact. Since pulmonary imaging often suffers from low spatial resolution and low Signal-to-Noise-Ratio, paying attention to the artifact is essential. In general, dark rim artifacts might be confounded with peripheral lung tissue. Moreover, in quantitative MRI, such as T1 mapping and perfusion imaging, the artifact can cause significant systematic errors.

Ringing can, of course, be prevented by increasing the resolution. As far as short acquisition times are required in the experiments restricting the spatial resolution, the effects of Gibbs ringing can generally be compensated by Hanning filtering. However, this comes at the cost of reduced spatial resolution.

References:

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