Multiple Volume Coverage in Continuously Moving Table Acquisitions Applied to Free Breathing STIR Imaging

U. A. Ludwig[1], H-P. Fautz[1], G. Sommer[1], S. Harter[1], N. Ghanem[2], J. Hennig[1]

[1]Diagnostic Radiology, Medical Physics, University Hospital Freiburg, 79106 Freiburg, Germany, [2]Diagnostic Radiology, University Hospital Freiburg, Freiburg, Germany

Introduction

Short Tau Inversion Recovery (STIR) imaging is highly sensitive to the detection of unknown primary tumors [1] and widely used for whole body tumor screening [2]. A single shot variant based on a Half Fourier TSE sequence has already been applied to continuously moving table imaging [3]. However, STIR imaging is challenging in covering a volume by multiple slices without gaps in between due to non-ideal slice profiles and non-ideal inversion profiles that have to completely contain the slice of interest. Therefore, successively excited slices must have a certain separation that typically increases for fast TSE sequences where short refocusing pulses produce rather smoothly varying slice profiles. The situation tightens up in free breathing multislice acquisitions where the inverted magnetization may leave the slice of interest and move into neighbouring slices. Our approach to reduce the loss of information due to gaps between acquired slices in continuously moving table multislice acquisitions is to oversample the total FOV along the slice direction. By adjusting the table speed properly slices can be acquired in an interleaved fashion in subsequent measurements with any arbitrary or even overlapping positioning.

Method

For axial extended FOV imaging with continuous table motion, multiple multi slice packages are acquired subsequently and stitched together afterwards to cover the full FOV. For a gapless coverage of the human body, the maximum table speed is given by $v_{max} = N*D/T_A$, where N denotes the number of slices within one package, D the slice distance and T_A the time needed to acquire a package of N slices. For $v=v_{max}$ the total volume is covered with equidistant slices separated by D (Fig. 1a). Additional slices can be acquired within the range of a single multislice package by reducing the table speed. Fig 1b displays an exemplary setup where the slice distance D equals two times the slice thickness d. Each gap is filled by 2 additional slices in following measurements reducing the table velocity to $v={}^1/_3 * v_{max}$. Concerning all acquired slices along z the slices have an overlap of 33% of their thickness. In our experiments an acquisition pattern analogous to Fig 1b was applied to a 2-shot STIR-weighted TSE sequence with the following parameters: TR/TI/TE = 4s/140ms/100ms. 10 slices of thickness 5mm, separated by 10mm were acquired within TR. The table speed was v=4mm/s. To account for the table motion, adaptive slice shifting was applied [4]. All experiments were performed on a 1.5T whole body scanner (Magnetom Sonata, Siemens Medical Solutions, Erlangen, Germany) using local coil arrays. The moving table (AngioSURF, MR-Innovations, Essen, Germany) was controlled by a homemade RF shielded electrical drive.

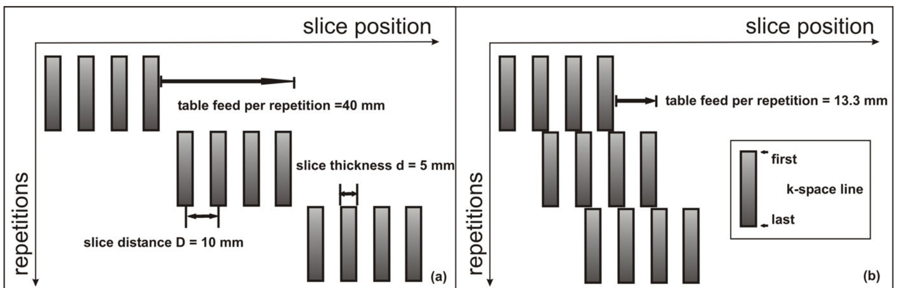

Fig.1: Axial moving table multislice acquisitions: (a) sequential slice acquisition using maximum table velocity v_{max} (b) three times interleaved slice acquisition at $v={}^1/_3 v_{max}$.

Results

Fig 2 shows five axial slices acquired with the multiple volume coverage setup. They are all taken from the upper abdominal region and are separated by distances of 3.3 mm along z. The FOV is 400x300 mm^2 with a matrix size of 256x192. As the common slice thickness is 5 mm, there is a spatial overlap of 1.7 mm between each couple of adjacent slices. While the slices 1 and 3-5 show a high intensity in aqueous abdominal tissue like the spleen, there is a distinct lack of signal in slice 2. This is a well known effect with STIR-sequences applied to tissue that is subject to free breathing. In datasets that cover the volume of interest only once, this is tantamount to a loss of information. The multiple volume coverage approach can compensate for this due to the spatial overlap between adjacent slices.

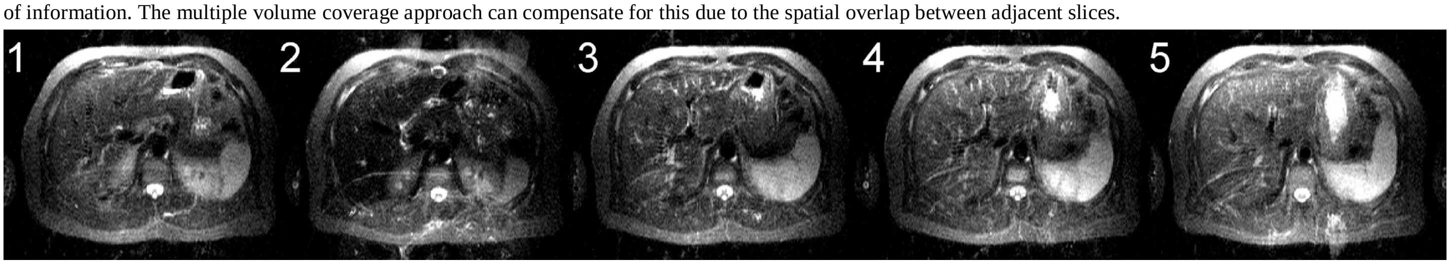

Fig 2: Neighboring axial slices from the upper abdomen with a spatial separation along z of 3.3mm. The slices of 5mm thickness are arranged from caudal to rostral. The second picture features a distinct lack of signal in the spleen due to free breathing.

Discussion

Continuously moving table multislice acquisition is capable to acquire slices at any positioning along z and even overlapping slices. The use of overlapping slice acquisition was demonstrated for free breathing STIR imaging: Gaps between slices that are widely separated in each single measurement are closed by subsequent measurements and corrupted images may be replaced by images of nearby or overlapping volume sections. The nominally redundant data of overlapping slices may also be used to either increase virtually the slice resolution by decreasing partial volume effects or for averaging purposes to increase the SNR of the images. The shown STIR images do not fit the requirements of clinical routine examinations in terms of resolution so far. However, particularly for whole body screening techniques like STIR that are used in axial continuously moving table MRI it might be a promising approach to increase the slice density along the z-axis. Coronal reformations of the axial slices might be used as a second viewing plane for rapid diagnosis, which then could be validated in the high resolution axial plane.

References

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