Dynamic Volumetric Imaging of an Area of Interest with Interleaved Acquisition of Intra-Oblique Slices

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Introduction: One of the unique features of MRI in guiding interventions ability to collect oblique three dimensional (3D) or multislice images. Since 3D imaging is slow for guiding interventions, a limited number of slices can be collected instead, which in the general case maybe oblique to each other (1-3). These slices can be reconstructed in a 3D space for volumetric appreciation of the area of interest (2). In this work, we present an acquisition scheme termed volumetric imaging with interleaved acquisition of intra-oblique slices (VINAOS) which collects temporally and spatially matched composing planes for dynamic imaging of an area of interest.

Methods

VINAOS Sequence and Visualization: VINAOS has two components, the acquisition of time matched oblique to each other slices (the "composing" slices), and their reconstruction in a 3D space. With VINAOS the same k-space lines or segments of k-space lines (Fig. 1) are collected during similar time instances along the timeline of the object motion and are temporally matched. Thus, all composing slices depict the objects in almost identical spatial positions. Image reconstruction and 3D visualization of VINAOS acquisitions were performed with in-house developed software on a dedicated dual CPU personal computer, using the raw data transferred via a TCP/IP connection from the scanner. The software reconstructs the composing planes inside a 3D volume using the current header of the raw data, so any change in the orientation of the planes is automatically reflected on the current cycle of the 3D scene. The 3D reconstructed volume can be rotated and zoomed by the user during the real-time reconstruction.

Simulations: Simulations were performed to assess the effect of segmentation and motion on the 3D reconstructed image, using a virtual box subjected to translational motion of speeds up to 125 mm/sec. Fig 2 shows the volume reconstructed images of the object from two composing planes (SL1 and SL2) with no segmentation ($N_{SEGM} = 1$) and with VINAOS ($N_{SEGM} = 128$) at speed 100 mm/sec (0.20 voxels/TR). With sequential acquisition there is a clear spatial mismatch of the two views of the object. With VINAOS the volume reconstructed image of the object shows excellent edge and object matching at any speed tested.

In Vivo Study: VINAOS was tested with healthy volunteers (n = 3) on a 1.5 Tesla Siemens Maestro for abdominal and contrast enhanced studies using a GRE sequence (TR/TE/ = 3.97/1.74/40^{O}; FOV = 295x295 mm2; matrix = 192x192; N_{SEGM} = 96 Slice Thickness = 10 mm). In the contrast enhanced cardiac studies, Gd-based contrast agent (Omniscan®, Amersham Health, Princeton, NJ) was administered in four consecutive injections (volume = 10 ml each and 2 ml/sec infusion rate).

Results and Discussion:

Figure 3 shows results of VINAOS imaging of the human abdomen using three (oblique to each other) composing planes. (A) and (B) show the two different views of the three planes reconstructed in the scanner coordinate system. (C and D) show the details (zoomed) of the 3D reconstructions highlighting the accurate matching of the structures in the composing planes, despite the subjects free breathing. VINAOS can be used for volumetric visualization of interventions in the abdomen, such as biopsies and ablations, collection composing planes prescribed to image specific structures or dynamically following the interventional tool. Figure 4 illustrates a two-composing slices VINAOS imaging of the great vessels and heart during the pass of Gd-based contrast agent. Such dynamic VINAOS cardiac images can be used for guiding transmyocardial interventions. The latter can be enhanced considering that at least a composing plane which orientation is dynamically updated to follow the motion of a catheter while the other are imaging the myocardial boundaries providing a 3D appreciation of the procedure unavailable with other modalities, such as x-ray fluoroscopy.

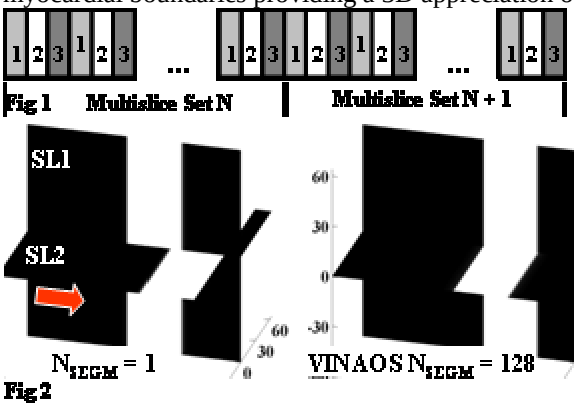

Fig 1 Fig 2

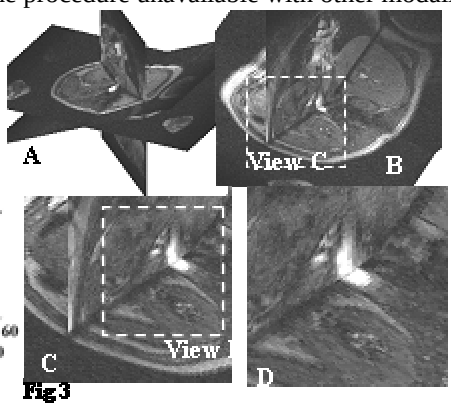

Fig 3

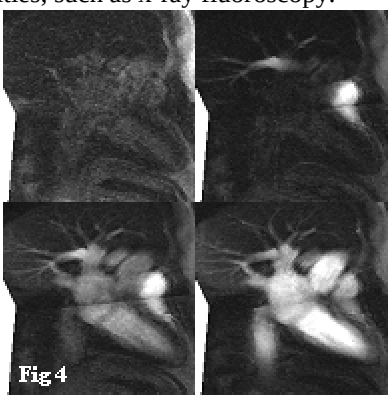

Fig 4

Conclusions. VINAOS, by employing interleaved and segmented acquisition of the composing planes and 3D reconstruction, provides dynamic volumetric imaging of spatially matched structures in the composing planes.

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References:

[1] Gering et al JMRI 13: (2001) [2] Jolesz et al JMRI 13 69-77 (2001). [3] Quick et al. MRM 49, 129-137 (2003).