Projection Reconstruction reduced FOV Imaging

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Introduction
MR fluoroscopy has already shown its potential for the visualisation of dynamic processes such as the guidance of biopsies and intravascular procedures. For such applications a high temporal resolution is mandatory. Techniques as keyhole imaging increase the temporal resolution at the cost of spatial resolution [1], but clinical practice shows that a high spatial resolution is essential for most dynamic imaging applications. The reduced FOV (rFOV) technique increases the frame rate without loss of spatial resolution by exploiting the fact that dynamic change is often confined to a certain area (rFOV) within the full FOV [2].

In this abstract the rFOV technique is applied to the projection reconstruction technique. Its advantages compared to the cartesian approach are described and its performance is demonstrated by in-vitro and in-vivo experiments.

Methods
The acquisition divides k-space (N radial projections) into n subsequently interleaved measured subsets S_{k,n}, each comprising N/n uniformly distributed projections. A subset S_{k,n} covers a reduced FOV at full spatial resolution. A dynamic image can not be reconstructed directly from it due to aliasing signal from outside the rFOV. Calculation of S_{diff} = S_{k,n} - S_{ref} with S_{ref} being some previously acquired reference data set yields a data set that only holds information from the desired rFOV, if no dynamic change occurs outside the rFOV.

After reconstruction it is added to the reference image to yield the dynamic image.

Results & Discussion
(a) Comparison of cartesian and radial rFOV:
In clinical practice it will be difficult to strictly satisfy the “nothing changes outside” condition. Phantom experiments were executed to compare the robustness for a radial and a cartesian FFE sequence (TR/TE 10/3, 256 k-space lines, n=4). To mimic local change a phantom consisting of two bottles and a tube filled with water was used, where a small ferrimagnetic particle causing a signal void could be pulled through the tube. Additional to changing the position of the particle, the entire phantom was moved slightly. This causes predominant aliasing in the spin-warp approach [c.f. Fig 1a] whereas the image content is hardly disturbed by aliasing in the radial case [c.f. Fig 1b]. Here the artifacts only result in a much less obvious increase of the apparent noise level due to streaking artefacts.

Additionally, the radial window could be oversized by 80% without severe artefacts demonstrating the robustness of the projection reconstruction approach with respect to undersampling.

(b) MR-guided biopsies
MR-guided biopsies demand for high spatial resolution for needle tip localisation as well as sufficient temporal resolution for optimal feedback and to avoid motion blurring. The projection reconstruction rFOV sequence was tested under biopsy conditions by penetrating an ox leg phantom with an MR-compatible 19G biopsy needle. From identical raw data a series of rFOV images and a series of images using the sliding window technique was reconstructed. In the rFOV images the susceptibility artifact at the needle tip can be exactly localised [c.f. Fig 2b], whereas the sliding window images suffer from strong blurring due to needle motion [c.f. Fig 2a]. During reconstruction the rFOV window was adapted to contain the location of the needle tip.

(c) rFOV cardiac imaging
Though navigator techniques allow the acquisition of cardiac images during breathing, the quality of images acquired during breath-hold is still superior. However, the raw data acquired during a patients breath-hold typically do not suffice to reconstruct a movie of the cardiac cycle by profile reordering. The radial rFOV technique is well suited for this problem since motion is confined to a circular region and only the fraction 1/n of the full data is required to reconstruct one cardiac phase image.

For verification projection data as well as the ECG was acquired during a 10s breath-hold with a healthy volunteer (TR/TE 3/6/1.8). After reordering of the data 12 images (256') over the cardiac cycle were reconstructed using the rFOV approach and compared to images reconstructed from the whole data set. The rFOV movies depicted quick changes during the early heart phases much more pronounced and less motion blurred than the conventional movie. Two sample images of a transversal and a coronal cross section are given in Fig 3.

Conclusions & Outlook
We have shown that the projection reconstruction rFOV technique can be applied to rapidly update images if change is confined to a restricted area.

The robustness of this rFOV approach regarding the condition of no change outside the rFOV makes it superior to the spin-warp based approach. This robustness is considered to be crucial for clinical applications.

Moreover, radial projections provide a simple means to check for such signal changes which can trigger a reference update without disturbing the sequence. If using an interventional device equipped with a μ-coil these projections might even be evaluated to position the rFOV.

References