Non-contrast-enhanced 4D Intracranial MR Angiography with 4D NATIVE TrueFISP

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Introduction: Conventional non-contrast-enhanced (NCE) MRA approaches including time-of-flight and phase contrast methods yield single frame static images or are limited in spatial resolution (typically by reverting to 2D rather than 3D methods) if multi-phases ECG triggered acquisitions are used in the case of phase contrast. By administering T_1-shortening contrast agents, time-resolved three-dimensional (4D) images can be acquired to depict morphological structure of vasculature as well as functional information of blood circulation. Typically temporal and spatial resolutions have to be compromised in order to synchronize data acquisition to the short first pass of contrast agent. While such tradeoff is acceptable for numerous applications, there are cases where both high spatial and temporal resolution are required in the same setting (e.g., to investigate the feeding and draining of blood into intracranial arterial-venous malformation). The purpose of this work was to develop a NCE 4D MRA technique providing both high spatial and temporal resolution images in the same measurement. The feasibility of such approach for intracranial MRA was validated in consecutive volunteer studies.

Methods: A magnetization-prepared, ECG-triggered 3D TrueFISP cine sequence (4D NATIVE TrueFISP) was implemented on a 1.5T scanner (MAGNETOM Espree, Siemens AG, Erlangen, Germany) to acquire NCE 4D MRA data. Each 4D MRA measurement is composed of two 3D cine data acquisitions with alternating magnetization preparation: one with global labeling of spins (nonselective inversion) and another with regional labeling (selective inversion of the imaging volume), respectively, before data readout. Corresponding 3D datasets of two acquisitions with identical ECG trigger time were subtracted. Maximum-intensity-projection (MIP) was performed inline on subtracted data sets to visualize vessels in three orthogonal views for each temporal phase. Seven consecutive volunteers were scanned using a 12-channel head matrix coil for signal reception. Images were acquired with a temporal resolution of 51.4 msec and spatial resolution of $1.25\times1.25\times1.25$ mm^3, without any temporal or spatial interpolation of the data. Other imaging parameters included: flip angle = 50°, TR/TE = 3.2/1.4 ms, parallel imaging (GRAPPA) factor of 2, FOV = 180×240 mm^2, 48 partitions.

Results: NCE 4D MRA images were successfully acquired from all subjects. Fig. 1 illustrates representative MIP images from a volunteer in three orthogonal views. Note anatomical structure of main intracranial vessels as well as dynamic filling of blood is well depicted by paging through different temporal phases. The average total imaging time for NCE 4D MRA is 5.9 minutes.

Conclusion and Discussion: A NCE 4D intracranial MRA approach was developed and the feasibility for intracranial MRA was demonstrated in volunteer studies. By eliminating constraints from contrast agent kinetics as in conventional contrast-enhanced studies, high spatial and temporal resolution are simultaneously achieved without trading against each other. Without using contrast agent, repeated measurement on the same subject becomes possible to explore different regions of interest or by targeting particular flow directions. Clinical evaluation of this technique is planned as next step especially for indications where both high temporal resolution and spatial resolution images are required, such as arterio-venous malformation. Application of the technique to small volumes will allow targeted visualization of afferent and efferent vessels in complex vascular malformations and may give additional information for treatment planning with a simple, time efficient technique. The true four dimensional nature of the data allows retrospective evaluation of complex anatomy and flow with suitable 4D visualization tools.

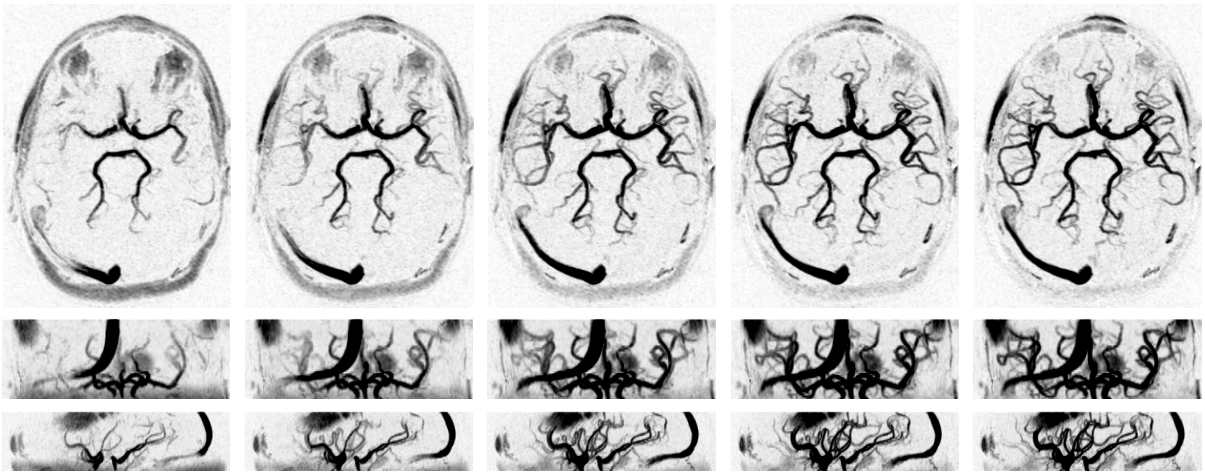

Figure 1. Five selected temporal phases of non-contrast-enhanced intracranial 4D MRA images from a volunteer. Dynamic filling of blood into vessels is depicted from different reformatted views with a 51.4 msec temporal resolution and $1.25\times1.25\times1.25$ mm^3 spatial resolution.