# HydRA: Highly Constrained Regridded Angiography

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**Introduction**

MR is an inherently slow method that benefits from undersampling. To achieve the time resolution required for dynamic angiography applications undersampling alone results in poor image quality. The goal is therefore to enhance the image quality of severely undersampled images using additional information.

HyPR (Highly constrained Projection Reconstruction) is a method that enhances drastically undersampled dynamic 3D radial data using as input the time averaged fully sampled data set [1]. In HyPR, highly undersampled interleaved 3D data sets are acquired and combined into a fully sampled time averaged image called composite. Then images of dynamic weights are calculated by dividing the unfiltered backprojections of a single frame by the unfiltered backprojections extracted from the composite image. The individual time frames are calculated by multiplying the dynamic weights images with the composite image, yielding a high quality time resolved image. This method has three disadvantages: Using back projection limits the scope to purely radial imaging excluding other possible trajectories. Secondly, recalculating backprojection data out of the composite image, which is on a Cartesian grid, is time consuming and may be unnecessarily complex. Thirdly, the use of unfiltered backprojection minimizes the localization of dynamic information.

**Materials and Methods**

HydRA presents a simpler and more flexible processing scheme based on a regridding algorithm: HydRA (like HyPR) relies on the idea that vessels are sparsely distributed in space, i.e., around every vessel there is a substantial signal void. Therefore it is possible to define the time dependent intensities with highly undersampled data. The exact positions of the vessels are delineated in the composite image which is created by regridding all the time frames into one data set. Much of the complexity of the HyPR algorithm results from the idea that a single time frame should provide pure dynamic weighting coefficients. This step may not be necessary since the information in MR images is contained in relative contrasts between different points in space or time, but not in absolute values. Therefore the weighting step could be omitted. Instead individual high quality dynamic frames are created by simply multiplying the averaged image with the low quality time resolved image. To achieve an approximately linear intensity scale the final images are scaled by taking their square-root.

In HydRA the point spread function (PSF) used for reconstructing the time resolved images can be tailored to the application needs by varying the density compensation function (DCF). One extreme is using a constant DCF which is equivalent to an unfiltered backprojection as applied in HyPR which provides the highest SNR but lowest spatial resolution (PSF of maximum width). However, depending on the spatial distance between vessels with a different dynamic behavior it may be necessary to reduce the width of the point spread function to avoid dynamics of one vessel showing up on the position of the other vessel. The other extreme is using a full rho filter as DCF. This would lead to low SNR and streaking artifacts. The streaks would mix dynamic information of far separated vessels. The optimum solution is an intermediate DCF with reduced slope at high k-space values which optimizes the tradeoff between SNR, spatial resolution and undersampling streaking artifacts.

A chest dynamic angiography data set was acquired with a 3D radial symmetric echo FLASH sequence ($T_{acq}$=40s, 16384 projections, TR=2.4ms, 16 frames, $\Delta$t=2.4s, $\Delta$x=2mm) on a clinical scanner (Magnetom Avanto, Siemens AG Medical Solutions, Erlangen). To demonstrate the advantage of an intermediate DCF this data set was reconstructed with $DCF \propto \begin{matrix} k^2 & for \ k < k_0 \\ k_0^{\ 2} & for \ k \geq k_0 \end{matrix}$ with $k_0 = \infty, k_{Nyq}, k_{Nyq}/2, k_{Nyq}/4, k_{Nyq}/8 \ and \ 1$.

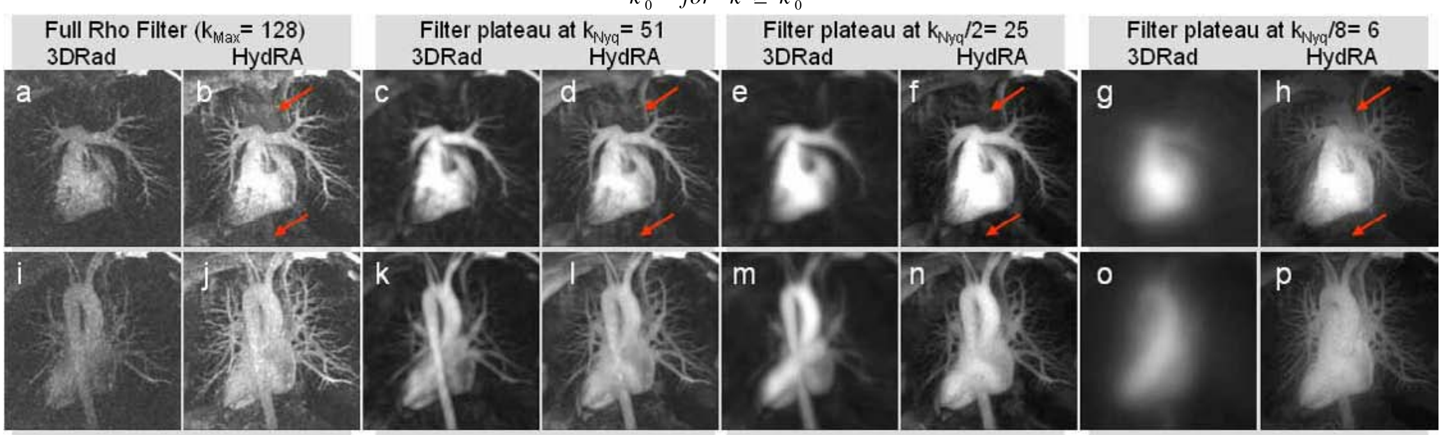


***Figure 1.*** *Two mipped frames of a dynamic angiography data set reconstructed using both 3D radial regridding of each frame and HydRA.*

**Results**

Figure 1 shows two mipped time frames of a 3D dynamic angiography data set reconstructed using both standard 3D radial Gridding of each single frame and HydRA reconstruction with four different sampling density compensation filters. In the standard 3D radial images, the SNR improves with decreasing $k_0$, at the expense of blurring. In the HydRA images the SNR also improves with decreasing $k_0$, but instead of increased blurring, an increased signal bleeding between arteries and veins takes place. For $k_0 > k_{Nyq}$, streaking artifacts appear that mix arterial and venous signals. The optimum is presented by an intermediate DCF which plateaus at $k_{Nyq} < k_0 < k_{Nyquist}/2$.

**Discussion**

A new method of creating high SNR, high temporal and spatial resolution dynamic angiography images based on a regridding algorithm has been described. The artifact behavior in the dynamic information can be controlled by adjusting the density compensation: a constant DCF can be used to maximize SNR at the cost of smearing in the radial direction, while a near full DCF ($k_0 > k_{Nyq}$) reduces SNR and creates sharp boundaries with the streaking artifacts starting outside a certain radius around the objects. An optimal filter represents a tradeoff between these extremes and minimizes signal bleeding between arteries and veins while maintaining a high SNR. A further suppression of this bleeding may be achieved by combining this technique with conjugate gradient techniques [2].

**References** [1] Mistretta et al. MRM 55:30-40(2006) [2] Griswold et al. International MRA Club 2006

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