7D DSA : A Dual Modality Combination of 4D DSA and 4D Flow MRI

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Target audience: Those interested in diagnostic and interventional angiography.

Purpose 4D DSA provides fully time-resolved angiographic volumes having spatial and temporal resolution greater than that achievable with CTA or MRA (1,2). 4D DSA allows viewing of a contrast bolus passing through the vasculature **at any time** during its passage, and at **any desired viewing angle.** Although time-concentration curves can easily be extracted from a 4D data set, direct measurement of velocity or velocity-derived quantities is not possible. We have developed a second-order constrained reconstruction method that combines, in a single display, the high resolution anatomic detail provided by 4D DSA with the instantaneous blood flow information (velocity and velocity-derived quantities) provided by 4D Flow MRI.

Methods The schematic of this method is shown in Figure 1. The PC velocity constraint is obtained by multiplying the speed volume (length of the three-directional velocity vector) by a binarized version of the complex difference volume (aka PC angiogram from the 4D MR Flow data). Subsequently, a color scale is applied. These data need to be spatially registered with the 4D DSA exam. 4D DSA and 4D Flow MRI data of the neck and head were acquired in a canine experiment. 4D DSA parameters: 133 angular projections, single contrast-enhanced rotational acquisition, 4D flow MRI parameters: radially undersampled trajectory with 5-point velocity encoding (PC VIPR[4,5]), isotropic acquired spatial resolution: 0.5 mm, # of cardiac phases: 14, VENC = 80 cm/s.

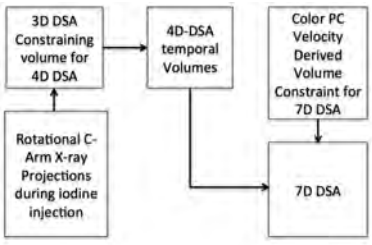

Figure 1 *As a first step, 4D DSA frames are formed from 2D projections acquired with a flat panel detector. These are convolved and a dynamic series is generated by backprojecting through a time-averaged 3D DSA constraining volume which provides high spatial resolution and SNR. In a second step, 7D DSA volumes are reconstructed by a color preserving multiplication of the 4D DSA volumes with the time-averaged MR speed map. The speed map is convolved so that the SNR and spatial resolution are provided by the 4D DSA. The result of the second order constrained reconstruction is a dynamic display of inflowing contrast agent showing iodine concentration and arrival time as well as blood velocity.*

Results

Figure 2 shows a PC-VIPR velocity constraint from an MRA of a canine's cranial vasculature. Three selected times frames from the 4D DSA and 7D DSA series are compared in Figure 3. The velocity color scale is also shown. The 7D DSA display shows the arrival dynamics as well as providing the speed information in each voxel. Other velocity derived information such as flow vectors, velocity components and color coded pressure drop information could be substituted for the speed information.

Figure 2 *PC VIPR velocity constraint shown in a coronal view representing the whole volume. The length of the velocity vector is encoded in color and shows signal from the arteries and veins while most of the background and static tissue is suppressed.*

Discussion and Conclusions Here we have described a new imaging modality that combines quantitative 4D flow MRI with high resolution 4D DSA. Such comprehensive information can provide the interventional radiologist with a means to examine complex structures from arbitrary angles with a temporal resolution of 30 volumes per second while also providing physiological velocity-derived information Potential applications include treatment planning for arterio-venous malformations with complicated filling and draining patterns, fistulas, and aneurysms.

[References [1] CA Mistretta, Medical Physics International, 2013. [2] B Davis et al., AJNR epub 2014. [3] M Markl et al. JMRI 36(5), 1015-36, 2012; [4] T Gu et al, AJNR 26(4):743-9; [5] K Johnson et al., MRM 60(6), 1329-36, 2008;

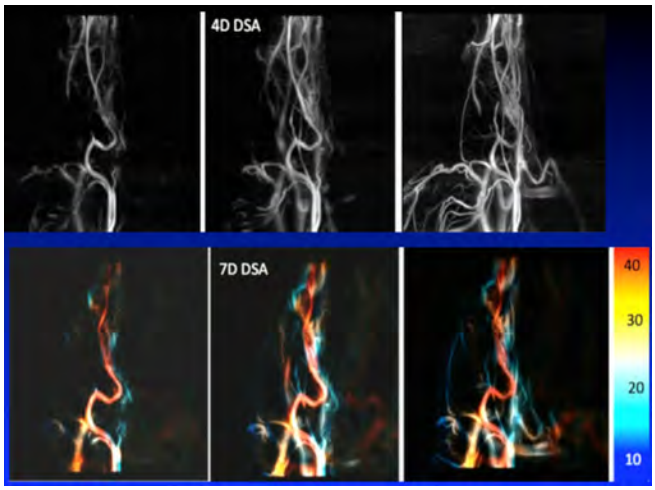

Figure 3 *Comparison of selected 4D DSA (top) and 7D DSA (bottom) frames in sagittal views. The time series shows the passage of the bolus through arteries and veins. In the 7D DSA images, the color represents speed in cm/s.*