A dual-velocity acquisition method for continuously-moving-table contrast-enhanced MRA

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Introduction:

Single velocity moving table acquisitions have been shown to be effective in imaging the vasculature from the abdominal aorta to the tibial vessels [1-3]. However, in a significant number of these scans, the moving FOV appears to have reached the ankles before the contrast bolus. In studying bolus phenomena, temporally-resolved runoff acquisitions of volunteers have been able to track the contrast bolus over an extended FOV. These studies have shown a significant (i.e. two fold) reduction in arterial flow velocity distal vs. proximal to the popliteal arteries [4]. Therefore, we have developed a dual-velocity moving table acquisition method to more closely track this general reduction of flow. The method begins with a relatively rapid table velocity when acquiring data at the torso and thighs and then later slows when the moving FOV approaches the knees.

Methods:

Motion control software was developed that allows near instantaneous (<10 msec) changes in table velocity as the acquisition proceeds. As with the single velocity scan, the acquisition sub-FOV (FOV_S) is initially placed in the thorax. Contrast is injected and the operator awaits contrast arrival in the aorta by real-time display of 3D MR fluoroscopy. Table motion is initiated at a relative "high" velocity and when the leading edge of the moving FOV_S reaches the knees, table motion is switched to a "low" velocity. This lower velocity is maintained until FOV_S reaches the ankles at which point the table stops. Data continues to be acquired until hybrid space is filled. As can be seen from an alternative version of the reference velocity equation [1]: $N_Y \cdot N_Z = \frac{FOV_S}{V_{ref} \cdot TR}$, a secondary effect of a reduction in table velocity is that a significantly greater number of phase encodes can be collected without undersampling. A 50% reduction in velocity allows a two-fold increase in the number of phase encodes with its associated increase in spatial resolution. Elliptical centric (EC) phase encoding was chosen for the acquisition. EC phase encoding begins each FOV_S at the center of k-space in k_y and k_z and spirals out to the highest resolution values. In moving table acquisitions by the time all of k-space has been covered, the table has moved one FOV_S and the EC encoding order then repeats. This can be seen in the hybrid space representation of Figure 1. This figure shows only the central k-space "slice" in k_z (k_z=0). The acquisition starts at the top and progresses downward in time. The single yellow line represents the position of one phase encode view that has been Fourier transformed along x. For this example the table is slowed as the third EC cycle begins and the encoding is allowed to sample further out into k-space. Four FOV_S distances are covered in this mapping. Not shown in this figure is the filling of the lowest parabolic shape in hybrid space after the table stops. Because the table cannot slow instantaneously there are two regions of deceleration. For each of these regions (fast-slow, and slow-stop), hybrid space position along X is mapped by calculating position by a constant deceleration. Acquisition parameters were TR/TE = 5/1.3 msec, Nx = 1024. For the faster velocity region Ny = 128-180, Nz = 16-20. For the slower velocity region Ny = 192-256 and Nz = 24-32. FOV_S ranged from 28 to 36 cm. These parameters allowed a high velocity range of 2.6 – 3.6 cm/sec and a low velocity range of 1.17 - 1.6 cm/sec. Thus far 15 volunteers have been scanned with the method. Twenty to thirty ml of contrast agent is typically injected at 1.5 ml/sec.

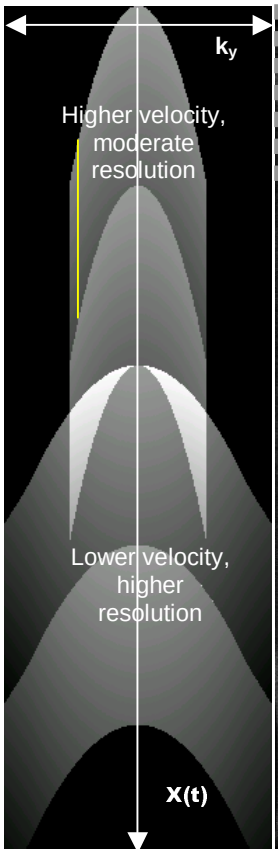

Figure 1.

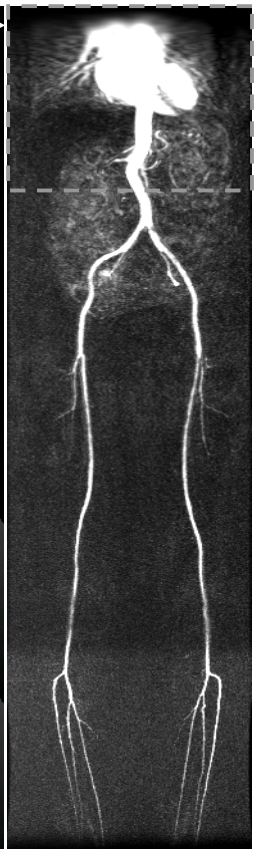

Figure 2.

Results:

Figure 2 shows an example of the dual-velocity acquisition with the vertical scale approximately matching that of Fig. 1. Also outlined by the gray dashed box is the size of FOV_S in its initial position. Including two volunteer acquisitions in which technical problems were identified and addressed, the tibial arteries of 13 of 15 volunteers contained good contrast when FOV_S was positioned over the calves. This compares with approximately 50% success for the single velocity method where it appears that the moving FOV_S reached the ankles before the contrast bolus.

Conclusions:

The dual-velocity moving table acquisition better tracks the actual dynamics of the contrast bolus in-vivo than does the single-velocity method and provides improved lateral resolution in the lower legs. In the future, an extended FOV continuous contrast arrival measurement 4 might be performed with a test bolus on a patient-by-patient basis to determine the high and low table velocities.

1. DG Kruger et. al, Magn. Res. Med. 47(2) 224-31, (2002).
2. SB Fain et. al, Proc. 10th Mtg. ISMRM, #212, (2002).
3. DG Kruger et. al, Proc. 10th Mtg. ISMRM, #294, (2002).
4. AJ Madhuranthakam et. al, Proc. 11th Mtg. ISMRM, #256 (2003).