A Method for Rapid Reconstruction of a Single Image Volume From a Time-Resolved CE-MRA Exam

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Introduction

Contrast Enhanced MRA (CE-MRA) is a minimally invasive method that is widely used for obtaining high quality angiograms. Gadolinium is used to shorten the T1 of blood in order to provide a contrast mechanism that is less sensitive to turbulent or complex flow than time-of-flight or phase contrast techniques. Acquiring the central portion of k-space during peak arterial enhancement is critical to the success of a contrast enhanced exam [1]. Several methods for coordination the central k-space acquisition and peak arterial enhancement exist [4-6]. Time-resolved methods [2-3] do not require coordination of image acquisition and contrast injection. Instead they acquire multiple time frames throughout the passage of the bolus. The simplification afforded by this technique is desirable, but requires the computationally intensive reconstruction of numerous 3D volumes of data. The current implementation of the time-resolved 3D TRICKS technique requires up to one hour to reconstruct ten frames of a phased array data set. Clearly, the clinical utility of time-resolved techniques would benefit from the ability to display an image which indicates the technical success of an exam or provides rapid feedback for an initial diagnosis. We present a method by which the information necessary to reconstruct a single high quality vascular image can be extracted from a time-series of contrast-enhanced k-space data. This image can be immediately presented for physician review.

Methods

Our method provides a global estimate of the arrival time of contrast agent directly from MR k-space data, prior to any computationally intensive image reconstruction. The time course of the bolus is then used to combine segments of k-space together to form a single volume for reconstruction. We have applied our method as a post-processing step to 3D TRICKS time resolved data sets. 3D TRICKS is a T1 weighted pulse sequence that segments k-space into three regions along the phase encoding direction. Each region of k-space is repeatedly reacquired during the passage of a bolus of contrast agent. The central region of k-space is updated every alternate time frame, thus assuring at least one acquisition of the central region of k-space during peak arterial enhancement. At each point in time, the acquired k-space segment is combined with the non-acquired regions which have been temporally interpolated, to form a complete 3D k-space volume for reconstruction.

The passage of the bolus of contrast agent was determined by measuring changes in the magnitude of the detected signal from each acquired k-space segment. We summed the magnitude of the MR signal over the points acquired in each k-space segment. These values were then renormalized region-by-region in k-space. The resulting estimate of the signal versus time was used to guide the reconstruction. All k-space segments that were acquired prior to the arrival of contrast are averaged to form a pre-contrast mask. Segments acquired near to the peak arterial signal are combined in a like manner and form a contrast-enhanced k–space volume. The pre-contrast mask k-space is subtracted from the contrast-enhanced k-space. The post-processing algorithm was applied to existing MRA exams from patients with peripheral vascular occlusive disease or symptomatic carotid artery disease [7]. The time-series of MIP images were filmed in a random order along with the rapidly reconstructed image. Image quality of the rapidly reconstructed image was compared to that of the peak arterial time frame to determine if our technique produced images which were of lower quality than the standard reconstruction. Images were ranked by two experienced radiologists using a four point scale (1= lowest quality, 4= highest quality). The ranks of the peak arterial time frames from the time-series of images were compared to the ranks of the rapidly reconstructed images using a Wilcoxon signed pair comparison.

Figure 1 shows the exam of a 54 year old patient with peripheral vascular disease. The acquisition parameters were: FOV= 48 x 36 x 10.5 cm, TR/TE/flip = 7.8ms/1.7ms/50, acquisition matrix = 312x144x24, reconstruction matrix =512x384x48, gadolinium dose = 17 ml @ 0.5 ml/sec. Frames (a)-(c) are 3 of 15 time frames acquired 36, 63 and 90 seconds after the initiation of the scan. Frame (d) is the image that was reconstructed using the present algorithm, which automatically includes all precontrast k-space segments in its mask. This time-series of images was acquired as the second station in a three station exam. A ranked comparison of the peak arterial frame images (mean rank = 3.3 +/- 0.6) and the image generated using the present technique (mean rank =3.2 +/- 0.8;P=0.13) acquired from patients (n=23) and normal volunteers (n=3) showed no significant difference.

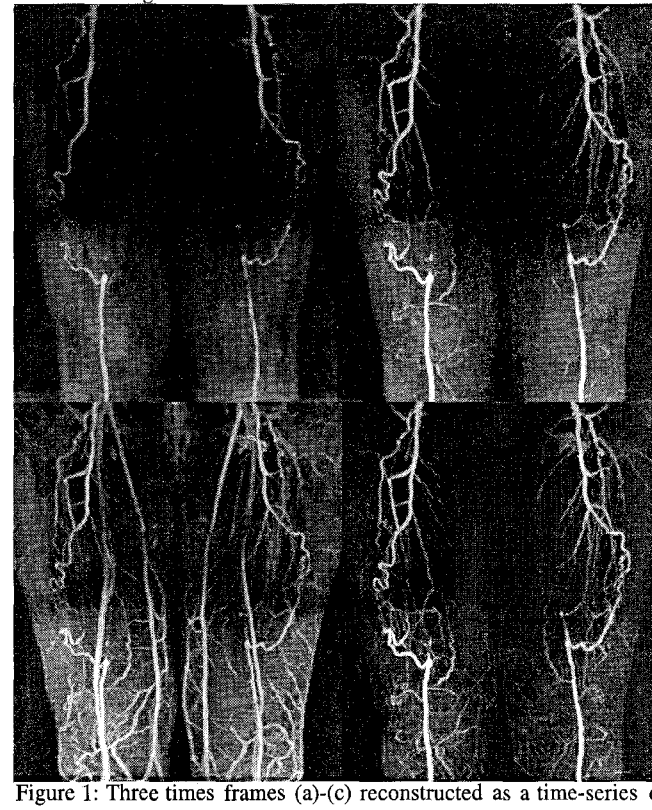

Figure 1: Three times frames (a)-(c) reconstructed as a time-series of images from a 3D TRICKS exam. (d) is the rapid reconstruction.

Conclusions

We have developed a post-processing algorithm for time-resolved CE-MRA. Our technique provides a means to rapidly produce an image without the lengthy delay normally associated with reconstruction of multiple 3D images. Implementation of this post-processing technique will increase the clinical utility of time-resolved MRA.

References

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