Analysis of Renal Artery Motion During Free Breathing

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Introduction

Recently, several approaches that rely on indigenous contrast rather than a Gd-based bolus have been proposed for MR imaging of the renal arteries. Some of this work has been motivated by the need for alternatives to contrast-enhanced MRA (CE-MRA) for patients with impaired kidney function due to the occurence of NSF [1]. These techniques are frequently based on bSSFP sequences [2-4] and the imaging time extends beyond a breathhold. Therefore, respiratory gating based on navigators or bellow readings is imperative to limit data acquisition to periods around end expiration. Both techniques rely on a threshold for the respiratory motion measure in order to reject or accept the current position for data acquisition. While others have studied the maximum displacement of renal arteries during free breathing [5], there is a lack of data that describes the motion patterns during free breathing. Here we investigate these motion patterns for an improved selection of gating thresholds.

Methods

Five healthy volunteers (4 male, 1 female, average age = 27 years) were imaged on a 1.5 T clinical system (Signa HD, GE Healthcare, Waukesha, WI, USA) after obtaining consent according to our IRB protocol. The renal artery anatomy was assessed with a volumetric, non contrast-enhanced MRA acquisition centered over the renal arteries [2]. From this angiogram, dynamic sagittal 2D bSSFP image series were prescribed at the proximal and distal left and right renal artery in order to follow the superior-inferior (SI) and anterior-posterior (AP) motion of the renal arteries through multiple breathing cycles. Typical acquisition parameters were: TR/TE = 3.0/1.3 ms, FOV = 350 x 350 mm^2, acquired resolution = 1.6 x 1.4 mm^2, reconstructed resolution: 1.4x1.4 mm^2, Δz = 8 mm, flip = 40°, receiver bandwidth = 62.5 kHz, 8 element phased array cardiac coil, parallel imaging (ASSETT) with acceleration factor = 2. , scan time per image: 300 ms, total scan duration: 30 s. The SI and AP displacements of the renal arteries were analyzed by manual tracking of the vessel center in the image series and net displacement was calculated by triangulation. The displacement was recorded with respect to the position at end expiration of the first breathing cycle because the longest quiet period is expected at end expiration.

Results

Figure 1a shows the net renal artery displacement for the distal right (square) and left (triangle) renal artery over four breathing cycles for a representative subject. In this plot, the distance to the origin indicates the displacement while the polar coordinate represents the time in the acquisition. It can be seen that the shape of the motion pattern is similar between the breathing cycles while the amplitude varies. In this subject, the displacement of the distal left renal artery is significantly smaller than that of the distal right renal artery. Figure 1b shows the maximum net displacement versus data acceptance threshold for another subject. If data were only acquired during the 50% of the respiratory cycle were displacement is closest to the end expiration position, then the maximum displacement for the distal right (left) artery would be 3.1 (1.4) mm. Figures 1c and d show maximum net displacement of the distal left (c) and right (d) renal arteries versus data acceptance threshold for all five subjects. The average of the maximum net displacements for the four vessel locations over all 5 patients were 3.7 ± 1.3 mm (R. proximal), 9.0 ± 4.2 mm (R. distal), 2.9 ± 0.9 mm (L. proximal), and 7.3 ± 3.0 mm (L. distal). These values agree well with previous reports on motion of the renal artery [5].

Discussion and Conclusions

This motion study on 5 volunteers provides several insights into the motion patterns of the renal arteries during free breathing. Fig. 1a illustrates inter-breath variability, and indicates higher variability at end-inspiration. This justifies our data acceptance window centering on end-expiration, as is common clinical practice. Our analysis showed that the greatest net displacement is usually encountered for the distal right renal artery (4 out of 5 subjects, see Figs 1c-d)). As expected, in all subjects the limiting factor for data acceptance was a distal artery. Figures 1c-d show that a data acceptance threshold of 40% limits the net displacement to a maximum of 3 mm. When increasing the data acceptance threshold to 50%, some views with more than 4 mm of displacement will be accepted. While this may cause issues in a Fourier-encoded acquisition (depending on where in k-space these views are acquired), it should have less of an effect on image quality in radial acquisition, where central k-space lines are inherently averaged. From our data we conclude that an acceptance threshold of 40% of all acquired views based on a respiratory motion measure (bellow or navigator) will limit the maximum displacement of the renal arteries to less than 3 mm. Such a displacement is on the order of motion observed from cardiac pulsatility [6] which is also present in those acquisitions. Therefore, a 40% threshold seems to be a the 'sweet spot' for limiting renal artery motion while keeping the penalties in scan time reasonable.

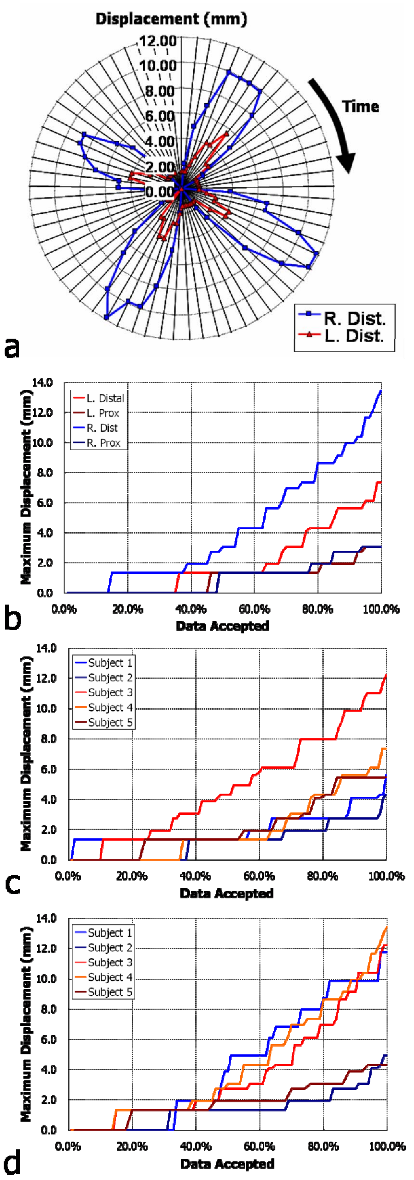

Figure 1 a-d – Results of renal artery motion analysis.

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