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Technique for retrospective respiratory and cardiac-gated phase contrast flow measurements

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Summary

A technique for evaluation of respiratory impact on cardiac-gated phase contrast flow acquisitions is proposed. An example study was performed showing the effect of active respiration on CSF flow through the spinal canal.

Background

The effect of the respiratory cycle on flow is well documented for cerebrospinal venous return [1] and CSF flow [2]. However, cranial phase contrast (PC) MR flow measurements neglect the influence of respiration. Breath-held acquisitions are possible, but mask physiological flow changes that occur during active respiration. Here we demonstrate a technique to evaluate the effects of active respiration on CSF flow measurements throughout the cardiac cycle for 2 respiration states.

Methods

Our approach relies on pseudo-random sampling of radial projections, which allows reconstruction of subsets with little artifact due to even filling of k-space (Fig. 1a). Cardiac triggers and respiratory position are recorded throughout the acquisition. Each projection then has a corresponding cardiac position (time since last trigger) and respiratory position. In the current implementation, all projections are sorted into 2 respiratory phases based on the median respiratory position. Each phase corresponds to the plateau surrounding end-inspiration or -expiration. Each respiratory phase is represented by a cardiac gated image series that is reconstructed using a temporal filtering similar to view sharing in Cartesian acquisitions [3].

Three volunteers were scanned on a clinical 3T system with 2D radial PC acquisitions [4] between the C2 and C3 vertebrae: TR/TE = 9.4/6.1 ms, tip = 5°,

resolution = 0.9x0.9x5 mm, and Venc = 8cm/s. Data were acquired during inspiration and expiration breath holds (1500 projections, 30 s), and during regular free and deep breathing (8000 projections, 2:32 min). Triggering was accomplished with pulse oximeter and below signals.

Results

Fig. 2 shows the resulting flow waveforms acquired during deep breathing for two volunteers. Though the waveforms show variation, the trend of increased flow during inspiration holds in both examples. Average forward (Qf), reverse (Qr), and net (Qnet) flow were calculated for both phases in the free breathing scans. For the inspiration phase, these values were: Qf = 3.06, Qr = 1.53, and Qnet = 1.53 ml/min. For the bin surrounding end-expiration, these values were: Qf = 2.53, Qr = 2.02, Qnet = 0.51 ml/min.

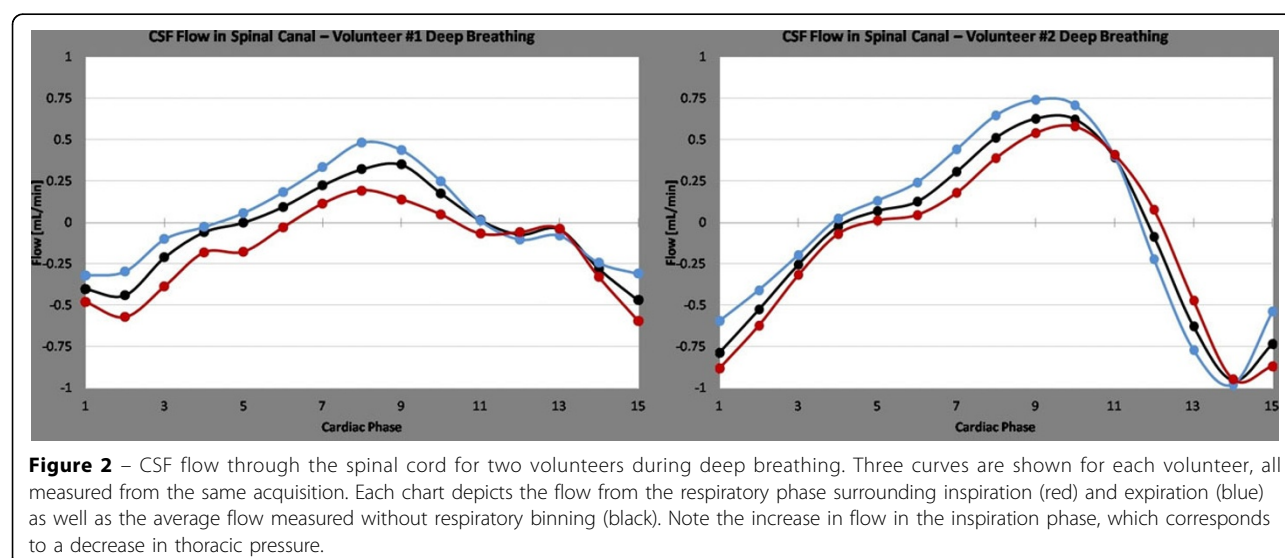
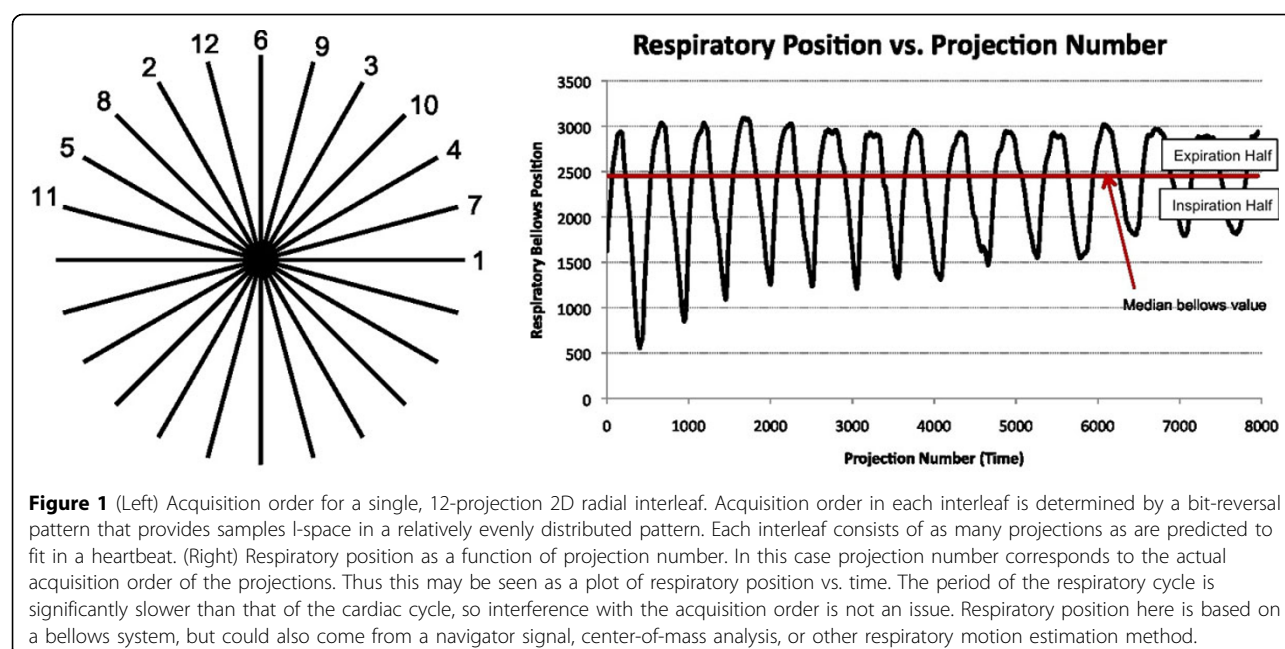
Conclusions

This study shows the feasibility of double retrospectively gated PC MR imaging for assessing flow in respiratory phases. The reconstruction scheme can be easily adjusted to capture additional respiratory phases at the expense of additional scan time. Our initial results demonstrate changes in CSF flow due to respirator phase, namely an overall increase in forward flow, as well as a decrease in reverse flow, leading to a significant increase in net flow during inspiration. This method can also be used to assessing venous and other flow affected by respiration.

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