Suppression of Streak Artifacts in a Radial Scanning

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Introduction

In regards to dynamic MRI, several methods that produce high-quality and high-speed images have been demonstrated. Radial scanning is suitable for dynamic MRI because of its robustness against subject motion. Another method, sliding-window scanning, can show moving images smoothly. With these methods, however, streak artifacts arise from rotating data gap position at the boundary between the first echo and the last echo. In response to these problems, the authors have proposed a new method for controlling the artifact's frequency by using an interleaved scanning and suppressing the artifacts with a band-pass filter. To optimize the number of interleafs, the relation between the number of interleaves and the frequency of the artifacts was formulated. The method can be easily combined with other methods for dynamic MRI(1).

Theory

In this section, first streak artifacts caused by using a sliding window for radial scanning are investigated. Secondly, the dependence of the frequency of artifacts on the number of interleaved scans is determined.

The source of streak artifacts is mainly a data gap at the boundary between the first echo and the last echo in a radial scanning. When the sliding-window technique is used for a radial scanning, the position of data gap begins to rotate. Then, the streak artifacts also begin to rotate and obstruct the clear view. The frequency of the streak artifacts F is written as follows.

$$F = Fo / Ns \qquad \text{(Eq. 1)}$$

Here, Fo is the original frame rate (1/s), and Ns is the number of times the frame rate is increased by the sliding window.

The frequency of streak artifacts, F, changes when an interleaved scanning is performed. The number of interleaves is indicated as Ni. The new frequency of the streak artifacts F' becomes as follows.

$$F' = F \times (Ni + 1) \qquad \text{(Eq. 2).}$$

The derivation of Eq. 2 is given in the following. On the Nith interleaved radial scanning, the scanning line rotates Ni + 1 times faster than in a sequential radial scanning. The data gap thus rotates Ni + 1 times faster and the frequency becomes Ni + 1 times higher.

Method

In the previous section, it was shown that the frequency of streak artifacts depends on the number of interleaves Ni. To separate the artifacts, the frequency of streak artifacts must be high because almost all data have a low frequency. The frequency of streak artifacts becomes high enough for the artifacts to be diminished with low-pass filter when Ni is set up with proper value.

Furthermore, a combination of the new suppression method with the UNFOLD technique generates a synergistic effect because both techniques use a frequency filter. A certain decrease in time resolution both suppresses the streak artifact caused by rotating data gap position and the artifact caused by under-sampling.

Experiment

The proposed methods were tested by simulation. Figure 1 shows a model of the heart, which pulsates with a simple harmonic oscillation. The oscillation frequency is 1 Hz. The parameters are TR = 4ms, matrix = 128×128, number of echoes = 64, sliding window rate = 8 echo.

Result

Figure 2 shows the simulation results. All images are the first frame of a sequence of moving pictures. Figure 2(a) is an image reconstructed from conventional sequential scanning data. Figure 2(b) is an image reconstructed from three-interleaved radial-scanning data and filtered with a low-pass filter. Figure 2(c) is an image reconstructed in combination with conventional technique which suppresses the artifacts from under-sampling and a three-interleaved radial scanning. Figure 2(b) shows that the proposed method successfully suppress the streak artifact caused by the data gap. Figure 2(c) shows that the artifact caused by under-sampling in the peripheral zone is slightly diminished.

Discussion

The streak artifacts tangential to the edge of an object (Fig. 2(a)) were successfully suppressed by using the proposed method (Fig. 2(b)). This means that the method suppresses the artifacts caused by motion during a radial scanning. To suppress the other type of artifacts caused by under-sampling, the conventional technique is useful and can be combined with our new method. In Fig. 3(c), however, little effect of conventional technique appears because the whole phantom is moving and the effect of under-sampling is less. For further investigation a more complicated model and in vivo experiment is therefore needed.

Conclusion

A new method to suppress streak artifacts caused by motion in a radial scanning was proposed. Simulation showed that the method successfully suppresses the streak artifacts and that it can be combined with the conventional technique.

Reference

1. Bruno Madore, Gary H. Glover, and Norbert J. Pelc. Magn Reson Med 1999; 42:813-828.

Fig. 1: simulation model

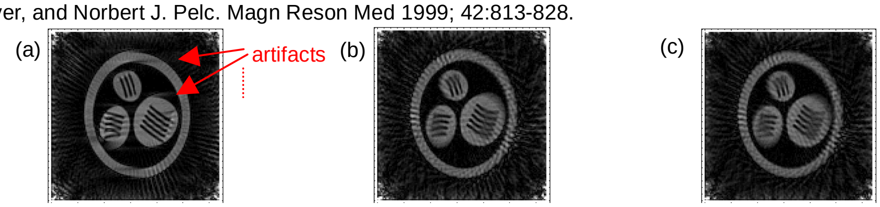

Fig. 2: (a) Image reconstructed from conventional sequential scanning data. (b) Image reconstructed from three interleaved radial scanning data and filtered with low-pass filter. (c) Image reconstructed with combination of conventional technique and three interleaved radial scanning.