Automatic retrospective correction of regional differences in navigator scale factors

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Background

Free breathing cardiac imaging depends on navigator gating and tracking. Navigator tracking uses a linear scaling factor to relate diaphragm motion and cardiac motion. Usually this linear scaling factor is assumed to be a constant 0.6, even though it is well known that the factor varies considerably across the heart and from patient to patient (1). The limited validity of the scaling factor is usually overcome in coronary angiography by using a narrow navigator gating window and imaging a limited portion of the heart. In applications where the whole heart is imaged at high resolution, e.g. 3D acquisitions for virtual reality surgical planning (2) or whole heart coronary angiography (3), it is more difficult to overcome these problems, not only because of the extended field of view, but also because the prolonged scan time makes it preferable to widen the gating window. In this project we present an automatic retrospective approach for correcting some of the artifacts caused by intra- and inter-patient variations in navigator scaling factors.

Materials and Methods

The automatic correction algorithm used in this study is based on the fact that acquisitions with navigator tracking can be reconstructed with different navigator scaling factors using the Fourier shift theorem. When such alternative reconstructions are made one may observe that in some regions blurring is decreased at one scaling factor while others become more blurred and the reverse may be the case at other scaling factors. This is illustrated on figure 1. The upper image (A) is reconstructed using the standard factor of 0.6; the lower image (B) is reconstructed with a factor of 0.0. Notice how the regions closer to the diaphragm are focused on the upper image while regions closer to the base of the heart are focused on the lower image. The objective of the automatic correction algorithm is to create the final reconstructed image using the most optimal scaling factor for every region of the image.

The imaging volume is divided into smaller overlapping volumes (32x32x32). For each of these volumes and for each of the tested scaling factors (-0.2 to 1.0 with an interval of 0.2) an image metric is calculated to evaluate the image quality. In this study a gradient entropy measure (M), defined below, was used (g denotes modulus pixel value):

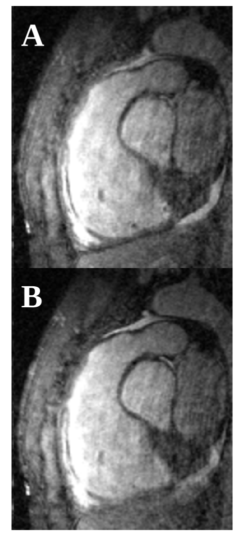

Figure 1. Alternative reconstruction results with scale factor 0.6 (A) and 0.0 (B)

$$M = \sum_{ij}\left(\frac{h_{ij}}{\sum_{ij} h_{ij}} \cdot \ln\left(\frac{h_{ij}}{\sum_{ij} h_{ij}}\right)\right) \quad \text{where} \quad h_{ij} = g_{ij} \otimes \begin{bmatrix} -1 & -2 & -1 \\ -2 & 12 & -2 \\ -1 & -2 & -1 \end{bmatrix}$$

For each sub-volume, the reconstruction with the maximum gradient entropy was chosen and the final reconstruction result was assembled as a patchwork of all the optimal sub-volumes.

To test the algorithm *in vivo* datasets were acquired in four volunteers. The imaging volume covered the whole heart with a resolution of 1x1x1 mm^3. Navigator gating window was set to 50 mm to speed up acquisition.

Results

In all of the volunteer datasets, there was a general improvement in image quality, and none of the datasets showed degradation in image quality after the optimization. Figure shows two example slices from one volunteer. The top row shows the result of the normal reconstruction (A1 and A2) and the bottom row shows the images optimized for regional differences in the navigator scale factor (B1 and B2). The optimized images show general improvement in image quality. Notice how especially the more cranial parts (indicated by the arrows) of the images show improvement, indicating that the original 0.6 scale factor, in this volunteer, is only close to optimal in the apical part of the heart, near the diaphragm.

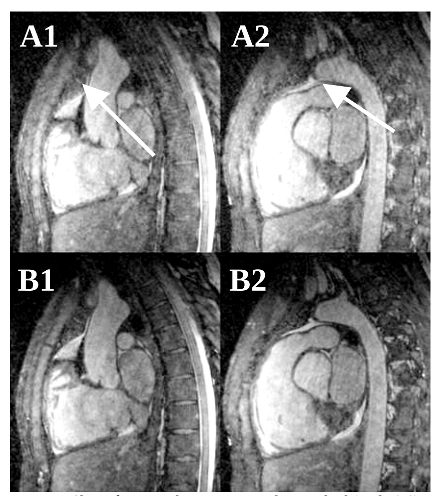

Figure 2. Slices from a volunteer. Using the standard (scale 0.6) reconstruction (A1 and A2) and using the regionally optimized reconstruction (B1 and B2).

Conclusions

We have shown that the regional difference in the navigator scale factor causes degradation of image quality when a global 0.6 scaling factor is used. An algorithm that recovers some of the lost image quality has been suggested and shown to increase image quality *in vivo*.

References

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