An image intensity correction method without body coil reference

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[Introduction]

Image intensity correction schemes by using homogeneous image as a reference template give accurate correction result, once the exact coil sensitivity information can be obtained. These methods usually assume that images acquired with body coil are homogeneous and use it as a reference images, but shading may appear in body coil reference images due to the electrical coupling with phased array coil or other reason. These shading will degrade intensity correction result. This study will show a robust and accurate image shading correction without body coil reference image.

[Materials and Methods]

MR image signal intensity can be written as follows

$$S(x,y) = I(x,y)H(x,y) \qquad \text{[eq.1]}$$

where *S(x,y)* is signal intensity of measured image data at position *(x,y)*, *H(x, y)* is defined as image shading function, and *I(x,y)* is ideal image function. So image intensity correction problem can be formally stated as determining *I(x,y)* for given *S(x,y)*. Image shading function *H(x,y)* represents coil sensitivity in case of array coil image acquisition. *H(x,y)* represents the image shading caused by dielectric effect in case of high field MRI. For conventional spin echo acquisition, the ideal image function *I(x,y)* can be estimated by the following well known formula.

$$I(x,y) = \rho(x,y)(1 - e^{-TR/T_1(x,y)})e^{-TE/T_2(x,y)} \qquad \text{[eq.2]}$$

According to [eq.1] and [eq.2], we have

$$S(x,y;TR,TE) = H(x,y)\rho(x,y)(1 - e^{-TR/T_1(x,y)})e^{-TE/T_2(x,y)} \qquad \text{[eq.3]}$$

Equation 3 indicates that one can estimates the image shading function *H(x,y)* from measured spin echo image data *S(x,y)*, if scan parameter TR and TE are known, and T_1, T_2 and proton density map of the object to be scanned are available. By measuring spin echo image data at different TE and other scan parameters are fixed, $T_2(x,y)$ can be estimated even image shading exists. If proton density variation in image can be obtained, then image shading function *H(x,y)* can now be estimated from measured values.

$$H(x,y) = \frac{S(x,y,TE)}{\rho(x,y)\exp(-TE/T_2(x,y))} \qquad \text{[eq.4]}$$

To obtain proton density map, simple linear correlation between proton density and T2 value was estimated and used as 1st order approximation in this study. Long TR Spin echo sequence was used so that T_1 recovery effect term in [eq.3] can be ignored. After obtaining image shading function in the object, *H(x,y)* was extrapolated to the outside of object and filtered to reduce noise. Since shading special variation is smaller than image intensity variation, all calculation of shading function was performed in low special resolution matrix (64x64). After getting image shading function *H(x,y)*, image intensity correction can be achieved by using [eq.1].

Phantom and volunteer experiment was performed on 1.5T MRI scanner (SIGNA EXCITE ver.11, GE Healthcare) with 8channel phased array head coil. FSE split echo acquisition was used to acquire both short and long TE image data simultaneously for reference scanning (TR=3000ms EffTE=11, 99ms, 256x128, FOV24). Apparent T_2 value was estimated from two points linear fitting from the FSE images. Reference slice location was prescribed to cover the whole region to measure image shading function *H(x,y)*.

[Results and Discussion]

Processing time for reference map calculation was less than one second for 30slice reference images and processing time for intensity correction process was also less than one second for 30slice images to be corrected. Relation between proton density and T_2 value was calculated for two volunteer head images from QD head coil (rho = 0.018 * T2 – 0.34, r=0.68). To see whether image shading affects the estimation of apparent T_2 value by two points method, phantom experiment was performed. The result showed no significant difference between T_2 value at the position near the PA coil element and at the position far from PA coil element. To validate intensity correction accuracy, a quantitative study was performed for 1.5T images acquired with phased array coil. Body coil reference intensity correction and the proposed correction method were compared with homogeneous image acquired with body coil at same location. The result showed that contrast ratio between gray and white matter in T_1 weighted image was preserved as shown in Figure.1. Statistical test showed no significant difference between body reference type method and the proposed method, even though there was significant difference between original un-corrected image and homogeneous image acquired with body coil ($p < 0.05$). Figure.2 shows the result of image intensity correction of volunteer image. T_1 and FLAIR images were corrected with the proposed method and the images have good homogeneity same as body coil reference method.

[Conclusion]

A novel image intensity correction method without body coil reference image was demonstrated. The result showed this correction scheme had good correction capability same as body coil reference method.

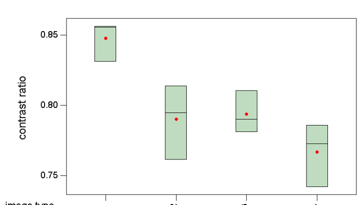
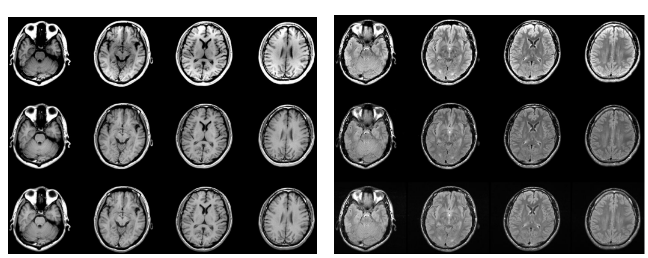


Figure.1 intensity correction accuracy analysis
1.original image without correction,
2.body coil reference intensity correction
3. proposed method, 4. body coil



A B

Figure.2 Intensity correction result for volunteer images
A: T1 weighted head image, B: FLAIR head image.
Top: 8channel PA head image without correction.
Mid: corrected image by body coil reference method
Bottom: corrected image by proposed method.