To Investigate the Motion Artifact of Diffusion Weighted MRI in Parotid

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Introduction: Diffusion-weighted imaging (DWI) is a common tool for investigating water molecular motion in tissue. Recently, DWI has been a clinical examination for diagnostic characterization of head and neck cancers [1]. It is also applied to monitor treatment response in head and neck cancer [2]. DWI generally combines echo-planar imaging with strong diffusion gradient (DWEPI) to generate magnetic resonance signal sensitive to the water molecular motion. The DWI signal is described as a monoexponential decay S(b)=So exp(-bD), where b is a function of the evolution of diffusion gradient and D is the apparent diffusion coefficient (ADC). However, the bulk motion, such as the respiratory motion and the cardiac motion, could cause prominent signal drop in DWI images. As a result, the ADC could be overestimated [3]. The DWI signal loss in liver-related studies has been reported, but the signal loss has not been thoroughly investigated in head and neck regions. The human behaviors such as, swallow, twisted lips, odontoprisis, mouth breathing and automatism opening mouth are irregular and rapid onset. These behaviors could cause motion artifacts in DWI images obtained around head and neck regions. In general, DWEPI scans are acquired using NEX higher than 4, which increases the SNR of DWI images. In this case, the signal loss of DWI images caused by the irregular and rapid mouth motion is less prominent. We reviewed the studies of the parotid-related diffusion imaging and found widely varied parotid ADC results, even in healthy volunteers [4]. In this study, we systematically investigated the motion artifact effect in parotid DWI measurement.

Method: Experiment design: Three healthy participants (mean age 30 yrs) underwent DWEPI scans using a 1.5T whole-body system (Signa HDx; GE Healthcare, Milwaukee,Wis) and an eight-channel neurovascular head and neck array coil. Axial MR images were acquired using a DWEPI sequence with the diffusion-sensitizing gradients applied along three orthogonal directions. The b factor was 1000 s/mm^2 applied on three directions (DWIx, DWIy, DWIz), and reference images (T2WI) with the b factor of 0 s/mm^2 were acquired. DWEPI measurements were performed using parameters (TR/TE= 4000/95 ms; flip angel=90°; matrix size=128x128 interpolated to 256x 256; FOV 240x240; NEX=1; slice thickness=5mm, 17 slices, no acceleration factor). The T2WI, DWIx, DWIy and DWIz scan were interleavely performed and 8 repetitions were continuously acquired. **Data analysis:** Figure 1 shows a typical example of the DWI signal void in the parotid (Fig.1.E). To evaluate the error caused by motion artifacts, we first construct reference standards which are less affected by motion artifacts. 5 to 7 contiguous slices with large parotid areas were selected and a region of interest (ROI) of the parotid was drawn on the mean DWI image (Fig 1.C). We calculated the SNR of ROIs were computed using each image of the 8 repeated scans, and then obtained mean (μ_{SNR}) and standard deviation (σ_{SNR}) of the SNR across the 8 repeated scans. The data sets with SNR smaller than μ_{SNR} - σ_{SNR} were presumably hampered by motion artifacts and were rejected. Finally, the mean T2WI, DWIx, DWIy and DWIz images averaged across the rest data sets were regarded as reference standards, and ADCx, ADCy, and ADCz were calculated using the standard data sets. We then have 7 types of images, which are T2WI, DWI(x, y and z) and ADC(x, y and z). The next step is to evaluate the errors in images acquired using different number of averages. The mean T2WI, mean DWI(x, y and z) and ADC(x, y and z) images were respectively averaged using different number (4 to 8) of images from the data sets to mimic the different number of averages in real DWI scan. The resulted images were referred to as NEX4 if four images were averaged. The DWI signal drop was evaluated pixel-by-pixel in ROI using the mean image (SI_{ORI}) and standard image (SI_{SNR}) , the error percentage computed by ($|SI_{ORI} - SI_{SNR}|$)/ (SI_{SNR}) x 100% for T2WI, DWI(x,y,z) , ADC(x,y,z) image, respectively.

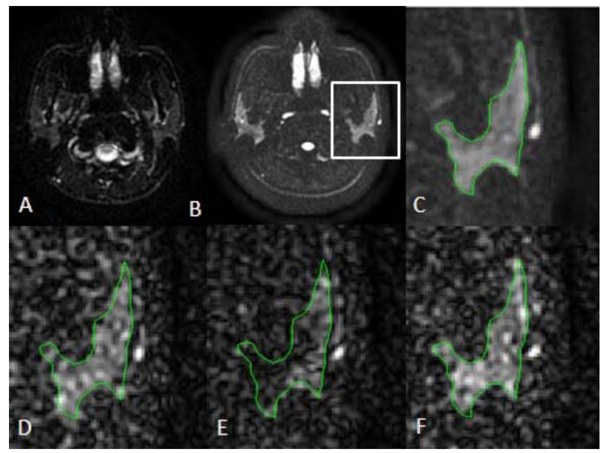

Fig 1. A typical example of parotid signal void. (A) Mean T2WI (B) Mean DWI (C) enlarged area of the rectangular in (B). The parotid ROI is outlined by the green line. (D,E,F) Selected DWI images in the 8 repetitions. Significant signal void in partial parotid is found in (E).

Results: Figure1 (D,E,F) displays a typical example of signal variations in parotid DWI images. Notice the prominent signal drop in Fig.1.E. Figure 2 shows the error percentage of T2WI, DWIx, DWIy , DWIz , ADCx, ADCy and ADCz, (mean and standard deviation) under different NEX number.

Discussion: The results indicate that the error is decreased with increased NEX number for T2WI, DWI and ADC images. It is reasonable that the noise is reduced using image average. The mean errors in T2WI are smaller than 5% even in 4-NEX data sets; it indicates that the signal intensities are stable during MR scans. However, the mean errors in DWI or ADC are more than 2 times higher that those in T2WI and are more than 10% in 4-NEX data sets. It demonstrates that the bulk motion was most likely occurred during MR scans. The physiology motion does not significantly alter the signal intensities in T2WI, but caused prominent signal variations in DWI due to motion sensitivity of DWI, especially in the high b-value scan. Although the participants were asked to remain their head and neck static as possible during MR scans, their mouth motions are not generally avoided. We identified the mean errors in DWI and ADC are approximately 5% for 8 NEX. DWEPI scan is generally performed with NEX of 4 in clinical protocols and the DWI images and ADC maps are automatically generated by the vendors' software. According to the results of this study, a 4-NEX DWI scan could overestimate more than 10% in ADC. In previous studies, the wide variations of parotid ADC measurements in healthy volunteers have been partly attributed to the different strengths (b values) of the diffusion gradients used in these EP-DWI studies [5], imaging distortion, chemical shift artifacts [6] and fat content [4]. The results of this study suggest that the mouth motion also plays a major role in the variations.

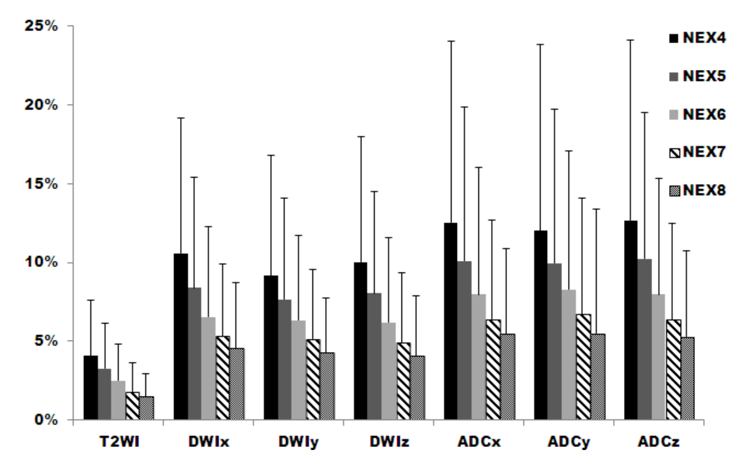

Fig 2. Mean and standard deviation of the error percentage of T2WI, DWI(x, y and z) , ADC(x, y and z) using different NEX numbers.

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