Non-Gaussian Analysis of Diffusion-Weighted Imaging in Nasopharyngeal Carcinoma at 3T
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Introduction: Diffusion-weighted imaging (DWI) and the extracted apparent diffusion coefficient (ADC) based on the mono-exponential diffusion model have been widely studied and used for lesion detection, characterization and treatment response in head and neck (HN) region. However, water in biological tissues usually displays non-Gaussian diffusion behavior at extended b-value ranges that leads to the deviation of DWI signal fitting by using the mono-exponential diffusion model based on the Gaussian distribution assumption. Several non-Gaussian diffusion models [1-4] have been proposed to study the non-Gaussian diffusion behavior, but majorly in brain. The non-Gaussian models for HN-DWI analysis have rarely been explored [5]. The purpose of this pilot study is to investigate the feasibility of non-Gaussian diffusion models, including diffusion kurtosis imaging (DKI) [1], stretched exponential model (SEM) [2], intravoxel incoherent motion (IVIM) [3] and statistical model (STM) [4], for 3T DWI analysis in patients with nasopharyngeal carcinoma (NPC).

Methods: 16 patients with NPC received DWI scan at 3T using a fat-suppressed SE-EPI DWI sequence with a 16-channel HN coil (TR/TE=561ms/46ms, FA=90°, NSA=3, FOV=230mm, matrix=364x262). ROIs were drawn on primary tumors (PT, n=13) and metastatic nodes (MN, n=9) by a senior neuroradiologist (Fig. 1). Pixel-wise DWI signal in the ROIs were fitted by using the normal mono-exponential and non-Gaussian models. Mono-exponential ADC and non-Gaussian parameters maps within lesion ROIs were reconstructed (Fig. 2).

Results: Except for one MN, all PTs and MNs exhibited non-Gaussian diffusion behaviors at the extended b-value range up to 1500s/mm². All four non-Gaussian diffusion models obtained significantly better (p<0.05, F-test) goodness of fit for DWI signal fitting for both PTs and MNs (Fig. 1) than the mono-exponential model. The statistics of the extracted mono-exponential ADC and non-Gaussian parameters for PTs and MNs were listed in Table 1. Spearman correlation showed that KurtDKI, D IVIM , D IVIM , σSEM, and ADCSTM had weak correlations with ADCmono and may reveal new information about NPC lesion characteristics different from ADCmono.

Discussion and Conclusion: The influence of the limited DWI SNRs at high b-values on the accuracy of signal fitting for non-Gaussian models should be further investigated in the future. The use of non-Gaussian modeling to fit DWI data acquired with an extended b range is feasible and yields significantly better fit than does mono-exponential modeling, and has potentials for lesion detection, characterization for NPC in future clinical practice.

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Table 1. The statistics of the extracted mono-exponential ADC and non-Gaussian parameters for PTs and MNs

<table>
<thead>
<tr>
<th></th>
<th>ADC mono (10⁻³ mm²/s)</th>
<th>ADC DKI (10⁻³ mm²/s)</th>
<th>Kurt DKI</th>
<th>D IVIM (10⁻³ mm²/s)</th>
<th>D IVIM (10⁻³ mm²/s)</th>
<th>D IVIM (10⁻³ mm²/s)</th>
<th>σSEM (10⁻³ mm²/s)</th>
<th>ADC STM (10⁻³ mm²/s)</th>
<th>σSTM (10⁻³ mm²/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Tumors</td>
<td>0.61±0.19</td>
<td>1.05±0.37</td>
<td>1.63±0.44</td>
<td>0.43±0.23</td>
<td>0.23±0.17</td>
<td>3.21±2.39</td>
<td>0.66±0.31</td>
<td>0.70±0.06</td>
<td>1.20±0.33</td>
</tr>
<tr>
<td>Metastatic Nodes</td>
<td>0.54±0.11</td>
<td>0.95±0.28</td>
<td>1.76±0.29</td>
<td>0.40±0.24</td>
<td>0.21±0.19</td>
<td>3.30±2.21</td>
<td>0.55±0.19</td>
<td>0.69±0.07</td>
<td>2.46±0.76</td>
</tr>
</tbody>
</table>

Fig.1. DWI signal fitting using the mono-exponential and non-Gaussian models

Fig.2. ADC mono and non-Gaussian parameter maps in a NPC primary tumor (overlaid on the DWI image with b=0)