The Application of Diffusion-Weighted Magnetic Resonance Imaging in the Differential Diagnosis of Orofacial Lesions

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（拡散強調像の顎口腔領域への応用）

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論 文 内 容 の 要 旨

Diffusion-weighted imaging (DWI) is known to be an important protocol that is useful for evaluating pathology throughout the human body. The apparent diffusion coefficient (ADC) obtained by the mono-exponential (ME) model based on the Gaussian distribution (free diffusion) has been closely studied due to its potentially important role in the differential diagnosis of lesions, post-treatment tumor observation, and prognosis prediction in the head and neck region. However, in biological tissues, diffusion is restricted by the presence of various barriers, such as cellular compartments and organelles. Therefore, several non-Gaussian distribution models have been proposed.

In the preliminary study, a total of 215 patients who underwent single-shot echo-planar imaging (SS-EPI) DWI with four b-values were included. EPI-DWI is the most frequently used among radiologists due to the rapid readout sequence. The ME model and diffusion kurtosis imaging (DKI) model were applied to EPI-DWI. The DKI model can clarify the deviation from the Gaussian distribution (free diffusion). Its two independent parameters, i.e. the deviation from a Gaussian form (apparent kurtosis parameter, K_{app}) and the diffusion coefficient (corrected apparent diffusion coefficient, D_{app}) were obtained. The Kapp parameter has been thought to indicate the complexity of the tissue; however, its interpretation has been considerably difficult.

In the initial study, the results showed that the D_{app} and K_{app} were also useful for distinguishing benign tumors from malignant tumors. Nevertheless, the quantitative values of the DKI parameters obtained from each pathological category still overlapped considerably. Thus, these results did not support the superiority of the DKI model over the ME model in the differential diagnosis of orofacial tumors. Furthermore, one major drawback was the poor image quality of EPI-DWI. Ninety-nine cases were excluded due to susceptibility artifacts that resulted in severe image distortion and signal loss. Therefore, improving the image quality of DWI, which is insensitive to susceptibility artifacts is essential for subsequent studies.

In the second study, the improvement in the image quality of DWI was assessed using turbo spin-echo (TSE) DWI. The distortion ratio (DR), signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR) and detection rate between TSE-DWI and EPI-DWI in the orofacial lesions were compared. The results revealed that TSE-DWI provided a lower DR and a higher SNR and CNR than EPI-DWI. The observer was able to visually identify all 38 lesions (100%) on TSE-DWI and 34 of 38 lesions (89.5%) on EPI-DWI. In addition, little divergence (less than 1 mm) was seen between TSE-DWI and the anatomical images (T2-weighted imaging), which made it possible to compare the two images and to superimpose the DWI on the anatomical images. Therefore, TSE-DWI was thought to be a good alternative to EPI-DWI for the diagnosis of lesions in the orofacial region.

As the final step, two non-Gaussian models–(gamma distribution [GD] and intravoxel incoherent motion [IVIM])–were used with TSE-DWI with six b-values. A total of 75 lesions were included in this study. The IVIM model was able to discriminate the perfusion in the capillary network from the true diffusion. The GD model presumes the continuous distribution of diffusion coefficients within an imaging voxel. The histological interpretation of diffusion data seems possible with the assumption that the areas of the fractions of diffusion coefficients of $\leq 1.0\times10^{-3}$ mm^2/s and $\geq 3.0\times10^{-3}$ mm^2/s represent intracellular diffusion and perfusion, respectively.

The correlations and effectiveness in the differential diagnosis among the parameters of the GD model (κ, shape parameter; θ, scale parameter; fractions of diffusion: f_1, cellular component; f_2, extracellular diffusion; f_3, perfusion component) and IVIM model (D, true diffusion coefficient; D*, pseudo-diffusion coefficient; f, perfusion fraction) were analyzed. It was striking that f_1 had a strong negative correlation with D; however, this finding seems reasonable given that the high cellularity hinders water movement. f_3 had a strong positive correlation with f, highlighting f_3 as a good alternative to f.

Regarding the comparisons among representative lesions, malignant lymphoma (ML) had the highest f_1, followed by squamous cell carcinoma, granulation, and pleomorphic adenoma (Pleo). Vascular abnormalities (VAs) had relatively small f_1 values. This trend was opposed of the trend in D. The high f_2 in Pleo, high f_3 in VAs, and low f_3 in ML were also unique findings.

In conclusion, both the GD and IVIM models were useful for characterizing the pathological structure, and the results obtained using the GD model were easy to interpret in the clinical settings.