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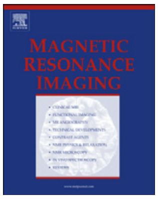

Comparison of accuracy of intravoxel incoherent motion and apparent diffusion coefficient techniques for predicting malignancy of head and neck tumors using half-Fourier single-shot turbo spin-echo diffusion-weighted imaging

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ABSTRACT

Purpose: To evaluate the use of the intravoxel incoherent motion (IVIM) technique in half-Fourier single-shot turbo spin-echo (HASTE) diffusion-weighted imaging (DWI), and to compare its accuracy to that of apparent diffusion coefficient (ADC) to predict malignancy in head and neck tumors.

Patients and methods: HASTE DW images of 33 patients with head and neck tumors (10 benign and 23 malignant) were evaluated. Using the IVIM technique, parameters (D, true diffusion coefficient; f, perfusion fraction; D^*, pseudodiffusion coefficient) were calculated for each tumor. ADC values were measured over a range of b values from 0 to 1000 s/mm^2. IVIM parameters and ADC values in benign and malignant tumors were compared using Student's t test, receiver operating characteristics (ROC) analysis, and multivariate logistic regression modeling.

Results: Mean ADC and D values of malignant tumors were significantly lower than those of benign tumors ($P < 0.05$). Mean D^* values of malignant tumors were significantly higher than those of benign tumors ($P < 0.05$). There was no significant difference in mean f values between malignant and benign tumors ($P > 0.05$). The technique of combining D and D^* was the best for predicting malignancy; accuracy for this model was higher than that for ADC.

Conclusions: The IVIM technique may be applied in HASTE DWI as a diagnostic tool to predict malignancy in head and neck masses. The use of D and D^* in combination increases the diagnostic accuracy in comparison with ADC.

1. Introduction

Intravoxel incoherent motion (IVIM), initially described by Le Bihan et al. [1], is a method of evaluating diffusion that separates diffusion and perfusion by calculating several diffusion- and perfusion-related parameters in biological tissues. In diffusion-weighted imaging (DWI), signal attenuation in tissue with increasing b values reflects tissue diffusivity and reduces the effect of tissue microcapillary perfusion. This signal attenuation can be measured quantitatively. The most common quantitative evaluation of DWI is by apparent diffusion coefficient (ADC). ADC has been used for normal and pathological tissue characterization. The use of ADC has been shown in diagnosis, prognosis, and treatment monitoring of tumors arising from various sites. However, ADC values are influenced by both tissue diffusivity and pseudorandom motion caused by microcapillary perfusion. The perfusion effect is difficult to eliminate. In contrast, the IVIM technique estimates parameter values for those effects separately, measuring DWI over multiple b values and employing bi-exponential fitting. The IVIM technique was initially applied to brain ischemia [2]. It has since been applied to other sites including hepatic lesions [3], liver cirrhosis [4], renal perfusion [5,6], and prostate tumors [7]. Recently, the IVIM technique has also been used in the head and neck region for purposes such as predicting malignancy, cancer staging, monitoring

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Table 1
Diagnosis and location of 33 head and neck mass lesions.

Category	Diagnosis	Location
Benign tumor ($n = 10$)	Myoepithelioma ($n = 2$)	Palate ($n = 2$)
	Pleomorphic adenoma ($n = 4$)	Palate ($n = 3$), parotid gland
	Vascular malformation ($n = 4$)	Upper lip ($n = 2$), buccal space, tongue
Malignant tumor (n = 23)	Basaloid squamous cell carcinoma ($n = 1$)	Mandible
	Carcinoma ex pleomorphic adenoma ($n = 1$)	Palate
	Adenoid cystic carcinoma ($n = 1$)	Submandibular gland
	Squamous cell carcinoma ($n = 18$)	Mandible ($n = 6$), tongue ($n = 7$) Palate ($n = 3$), maxilla ($n = 2$)
	Verrucous carcinoma ($n = 2$)	Mandible, tongue

of treatment response, and detecting nodal metastases [8–14]. These studies indicate that the IVIM technique has use for tissue characterization. As it obtains information for tissue diffusivity and microcapillary perfusion separately, the IVIM technique may allow for better tissue characterization than ADC.

Echo-planar imaging (EPI) is the most common sequence for DWI. However, EPI has several inherent drawbacks, including susceptibility, chemical shift, and N/2 artifacts [15–18]. Although such drawbacks had been improved by recent magnetic resonance imaging (MRI) innovations as represented by parallel imaging, severe image distortion may occur in the head and neck region in the presence of dental restorations and air pockets.

An alternative acquisition technique to EPI is half-Fourier single-shot turbo spin-echo (HASTE), which is also known as SSFSE or FASE. HASTE is generally used for ultrafast abdominal T2-weighted imaging. This technique can be applied to DWI in combination with diffusion-sensitive stimulated echo preparation. The advantage of this technique over EPI is that it is relatively unaffected by dental work or air [16–20]. This advantage may improve quantitative evaluation of diffusion. Application of this technique to the head and neck region and its use had been reported in several previous studies [18–21]. HASTE DWI is used for head and neck lesions at our institution.

There have been no studies in which a non-EPI sequence was applied to evaluate head and neck tumors using the IVIM technique. The purpose of this prospective study was to evaluate the use of the IVIM technique in HASTE DWI, and to compare the diagnostic ability of the IVIM technique to that of ADC for the prediction of malignancy in head and neck masses.

Table 2
Mean IVIM parameters and ADC of benign and malignant tumors.

	D ($\times 10^{-3}$ mm^2/s)	*f* (%)	*D** ($\times 10^{-3}$ mm^2/s)	ADC ($\times 10^{-3}$ mm^2/s)
Benign ($n = 10$)	1.16 ± 0.238	16.9 ± 5.48	7.34 ± 1.76	1.33 ± 0.212
Range	(0.993–1.33)	(13.0–20.9)	(6.08–8.60)	(1.18–1.48)
Malignant ($n = 23$)	0.813 ± 0.172	17.6 ± 7.93	10.5 ± 4.92	0.993 ± 0.157
Range	(0.738–0.887)	(14.2–21.0)	(8.34–12.6)	(0.925–1.06)
P value	<0.001	0.79	0.012	<0.001

An unpaired *t* test was used for statistical analysis.
Each value is expressed as the mean ± SD, and the 95% confidence intervals are given in parentheses.

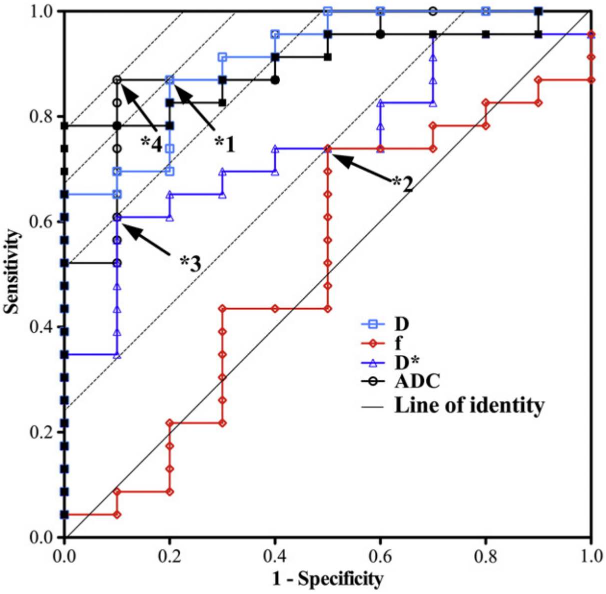

Fig. 1. ROC curves for the IVIM parameters and ADC for predicting malignancy. ***1**, a ***D*** of 0.977 × 10^{-3} mm^2/s was the suitable threshold value. *2, an *f* of 18.6% was the suitable threshold value. ***3**, a ***D**** of 8.42 × 10^{-3} mm^2/se was the suitable threshold value. ***4**, an ADC of 1.18 × 10^{-3} mm^2/s was the suitable threshold value.

2. Patients and methods

2.1. Patients

A total of 65 patients with head and neck mass lesions who visited our hospital between November 2011 and December 2012 underwent MRI. Informed consent was obtained from all patients, and the study protocol was approved by our institutional review board. Within this group, 24 cases were excluded from this study for the following reasons: lack of final diagnosis ($n = 13$), superficial squamous cell carcinomas ($n = 6$) not visible on conventional MR images, and image distortion because of motion artifacts on DWI images ($n = 5$). Eight patients with mucous cysts (ranula) were also excluded. A total of 33 patients with 33 head and neck masses were included. Patients comprised 16 men and 17 women with a mean age of 58.9 y (range, 14–89 y). In 31 of 33 lesions, final diagnoses were made histologically with either surgery or biopsy. Vascular malformations were diagnosed in the other two patients by their characteristic clinical, MRI, and ultrasonographic features. Of the 33 lesions, ten were benign, and 23 were malignant as listed in Table 1.

2.2. MRI techniques

A 1.5 T MRI scanner (Magnetom Symphony Maestro Class, Siemens, Erlangen, Germany) with a head and neck coil were used to obtain all MR images. The standard MRI protocol for head and neck lesions used at our institution includes T1-weighted spin-echo images (TR [ms]/TE [ms] = 500/15; number of signals averaged [NSA] = 1) in the axial and coronal planes, and T2-weighted turbo spin-echo imaging (TR/TE = 4600/90; TI [ms] = 110; turbo factor = 19; NSA = 1) with fat suppression by short inversion time inversion-recovery and chemical-shift selective saturation (Dual-FS-STIR-CHESS) in the axial and coronal planes [22]. T1- and T2-weighted images were obtained with a matrix of 384 × 384 and 320 × 320, respectively, an FOV of 230 × 230 mm, and a section thickness of 4–6 mm with an intersection gap of 0.8–1.2 mm.

HASTE DW images without parallel imaging acceleration (TR/TE = 3000/101, receiver bandwidth [Hz/pixel] = 630, NSA = 3)