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Comparison of diffusion-weighted imaging findings in brain metastases of different origin

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ABSTRACT

Our purpose was to estimate apparent diffusion coefficient (ADC) values from brain metastases (BMs). Our patient sample included 159 patients with 948 BMs. Magnetic resonance imaging was obtained with a 1.5-T device. For diffusion-weighted imaging, a multislice single-shot echo-planar imaging sequence was used (*b* values of 0, 500, and 1000 s/mm^2). The mean ADC value of BMs was $0.98\pm0.32\times10^{-3}$ mm^{2}s^{-1}. A total of 72.8% of BM lesions showed ADC values under 0.90×10^{-3} mm^{2}s^{-1}. Small-cell lung cancer had the lowest ADC values (0.86 ± 0.27) in comparison to BMs from non-small-cell lung cancer (1.17 ± 0.49), breast carcinoma (0.97 ± 0.21), and malignant melanoma (0.99 ± 0.36).

1. Introduction

Brain metastases (BMs) are frequent in several malignancies and are associated with high mortality [1–3]. Imaging findings, especially magnetic resonance imaging (MRI) features of BMs, have been described in detail previously [2–4]. According to the literature, BMs from different primary tumors also showed different MRI patterns [2,3]. For example, BMs from breast cancer occurred more frequently in the cerebellum, whereas in non-small-cell lung cancer, BMs predominated in the parieto-occipital lobes [2]. As reported previously, there were no significant differences in the size of BMs between several primary tumors [2–4].

Diffusion-weighted imaging (DWI) can provide additional information regarding tissue structure [5,6]. DWI was previously used to investigate different cerebral tumors [5–7].

The aim of this retrospective study was to estimate apparent diffusion coefficient (ADC) values from BMs in a large sample and to compare them in different malignancies.

2. Materials and methods

2.1. Patients

In the time period from 2006 to 2014, 209 patients with BMs which were investigated by MRI were identified at our institution. Patients without DW images ($n=34$) and hemorrhage ($n=16$) were excluded from the study. Therefore, our patient sample included 159 patients. There were 80 (50.3%) women and 79 (49.7%) men with a median age of 58 years (mean age, 58.2 ± 11.7 years; range, 23–83 years).

In the 159 patients, 1665 BMs were identified. Due to hemorrhage ($n=187$) and/or artifacts on DW images/ADC maps ($n=530$), 717 lesions were excluded from the analysis. Therefore, 948 cerebral metastases were included into the study. The mean size of the included BMs was 9.3 ± 7.0 mm; median size was 7 mm.

Histopathology was defined by biopsy or surgery of the primary tumor.

Her-2 status was obtained by immunohistochemistry. A value of 3+ was considered as Her2 positive. A value of 1 or 0 was considered as negative for Her2 expression, as reported previously [8]. Overall, Her-2 status was available for 26 patients (Her-2 positive, $n=12$; Her-2 negative, $n=14$).

2.2. Imaging

MRI was obtained with a 1.5-T device (Magnetom Vision Sonata Upgrade; Siemens, Erlangen, Germany). The standardized imaging protocol consisted of axial T2-weighted (T2-w) fat-suppressed short tau inversion recovery images and axial T1-weighted (T1-w) spin echo images before and after intravenous administration of contrast

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Table 1
Primary tumors in the patients with brain metastases

Primary tumors	n	%
Lung cancer	65	40.9
Breast cancer	41	25.8
Malignant melanoma	24	15.1
Urological tumors	8	5.0
Renal cell carcinoma	4	
Prostate cancer	3	
Urothelial cell carcinoma	1	
Genital tumors	8	5.0
Cervical cancer	3	
Ovarian cancer	3	
Fallopian tube cancer	1	
Testicular cancer	1	
Gastrointestinal tumors	5	3.2
Esophageal cancer	3	
Colorectal cancer	2	
Other	8	5.0
CUP	3	
Neuroendocrine tumor	2	
Mesothelioma	1	
Rhabdomyosarcoma	1	
Thymic carcinoma	1	

CUP, cancer of unknown primary.

medium (gadopentate dimeglumine, Magnevist; Bayer Schering Pharma, Leverkusen, Germany) with a dose of 0.1 mg/kg.

For DWI, a multislice single-shot echo-planar imaging sequence was used (repetition time/echo time: 5900/96 ms; field of view: 250×250 mm; slice thickness: 5 mm; acquisition matrix: 128×128). DWI was performed with *b* values of 0, 500, and 1000 s/mm^2. ADC maps were generated by the implemented software. A polygonal region of interest (ROI) as large as possible was drawn inside the contrast-enhancing margin of BMs on ADC maps (whole lesion measurement) without risking partial volume effects in the integrated PACS software (Centricity PACS; GE Medical Systems, Milwaukee, WI, USA). The position of every ROI was automatically placed also on all other images (T2-w, and pre-and postcontrast T1-w).

The estimated ADC values ($\times 10^{-3}$ mm^{2}s^{-1}) were categorized as follows: very low: <0.70; low: >0.70<0.90; intermediate: >0.90<1.20; high: >1.20 mm^{2}s^{-1}, as reported previously [9].

Furthermore, an intrapatient BM variability (range) of ADC values in patients with two or more BMs was calculated as follows: intrapatient BM variability = maximal ADC value − minimal ADC value.

2.3. Statistical analysis

For statistical analysis, the SPSS statistical software package was used (SPSS 17.0; SPSS Inc., Chicago, IL, USA). Collected data were evaluated by means of descriptive statistics (absolute and relative frequencies). Categorical variables were expressed as percentages. Analyses of ADC values were performed by one-way analysis of variance, and post hoc Bonferroni tests were performed between tumor groups. *P* values <.05 were taken to indicate statistical significance in all instances.

3. Results

3.1. Primary tumors

Most of the included BMs arose from lung cancer (65 patients, 40.9%), followed by breast cancer (41 patients, 25.8%) and malignant melanoma (24 patients, 15.1%).

Furthermore, metastatic lesions from these three malignancies accounted for 81.8% of the analyzed 948 BMs. In detail, 409 lesions (43.1% of 948 BMs) originated from patients with lung cancer, 391 (41.2%) from patients with breast carcinoma, and 68 lesions (7.2%) from patients with malignant melanoma. Other primary malignancies were rare (Table 1).

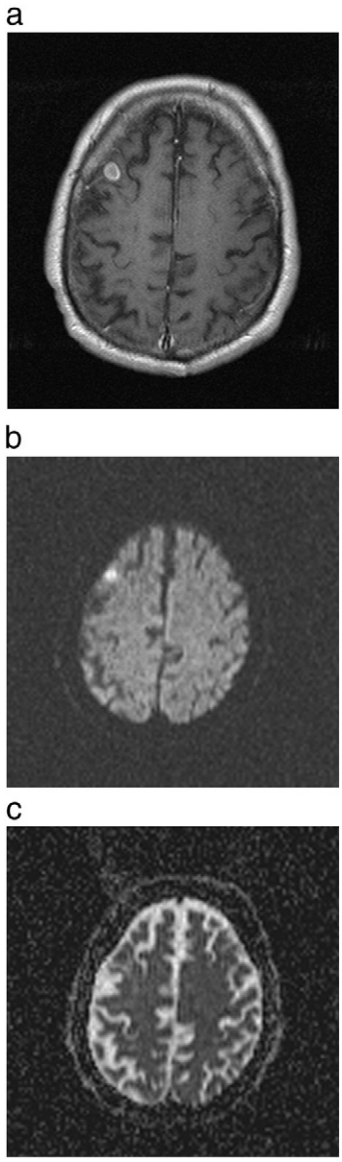

Fig. 1. Cerebral metastasis in known small cell lung cancer. (a) T1-weighted image after intravenous administration of contrast medium showing a round lesion with homogenous enhancement in the right frontal lobe. (b) The lesion is hyperintense on *b*1000 image. (c) ADC map. The calculated ADC value of the metastasis is 0.53×10^{-3} mm^{2}s^{-1}.

Fifty-eight patients (36.5 %) had one BM; 101 (63.5 %) patients had two or more BMs. Overall, the mean value was 6.0±11.05; median, 2; and range, 1–73. The mean value did not differ significantly between the groups.

The lung cancer group was divided into two entities: non-small-cell lung cancer (NSCLC) and small-cell lung cancer (SCLC). The NSCLC group consisted of 41 patients (63.1% of 65) with 154 lesions (37.7% of 409), and the SCLC group had 20 patients (30.8% of 65) with 245 lesions (59.9% of 409). Four patients (6.1% of 65) with 10 lesions (2.4% of 409) could not be specified.

The patients with breast cancer were further divided into Her2 + receptor expression and Her2 −. The Her2 + group had 12 patients (29.3% of 41) with 156 lesions (39.8% of 391); the Her2 − group had 14 patients (34.1% of 41) with 123 lesions (31.4% of 391). In 15 patients (36.6% of 41) with 112 lesions (28.6% of 391), the receptor expression was unclear.