Diffusion-Weighted Imaging Characteristics of Primary Central Nervous System Germinoma with Histopathologic Correlation:

A Retrospective Study[1]

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Rationale and Objectives. The aim of this study was to quantify, using diffusion-weighted magnetic resonance imaging, the microscopic rate of water diffusion in pure germinoma and to determine whether or not the apparent diffusion coefficient (ADC) values correlated with the different histologic components.

Materials and Methods. A retrospective analysis of echoplanar diffusion-weighted magnetic resonance images was conducted on 10 patients with 11 germinoma lesions. All images were obtained using 1.5-T magnets with a b value of 1000 s/mm^2. Regions of interest were drawn separately within the solid and the cystic or necrotic components of each germinoma, as well as within the normal gray and white matter of the respective cases, to calculate ADCs. The diffusion characteristics of the germinomas were assessed using mean and normalized ADC values. Histologic samples from all cases were blindly reviewed and then correlated with the ADC values.

Results. Data are expressed as mean $\pm$ standard error. Evaluation of the solid components revealed that 36% of germinomas (4 of 11) had predominantly restricted diffusion (ADC_{solid}, $694.71 \times 10^{-6} \pm 74.54 \times 10^{-6}$ s/mm^2; ADC ratio, 0.84 ± 0.07) compared to normal brain. The majority (55% [6 of 11]) had normal diffusion (ADC_{solid}, $947.64 \times 10^{-6} \pm 54.38 \times 10^{-6}$ s/mm^2; ADC ratio, 1.14 ± 0.10). Only 9% (1 of 11) had increased diffusion (ADC_{solid}, $1172.30 \times 10^{-6} \pm 48.52 \times 10^{-6}$ s/mm^2; ADC ratio, 1.67 ± 0.16). The cystic and necrotic components had a mean ADC ratio of 2.55 ± 0.25. There was no significant correlation between the histologic components and the ADC values of germinomas.

Conclusions. The vast majority of germinomas demonstrated predominantly restricted (36%) or normal (55%) diffusion. The histologic components were not correlated with the ADC values.

Key Words. Germinoma; germ cell tumor; diffusion; central nervous system; magnetic resonance (MR); mean diffusivity.

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Primary intracranial germinomas are rare tumors of children and young adults (1). They make up the bulk of central nervous system (CNS) germ cell tumors and account for approximately 0.06% to 2.24% of all intracranial neoplasms (1,2). Like other germ cell tumors, germinomas are situated in the midline, with the majority of lesions occurring in the pineal and suprasellar regions. Histologically, they are characterized by variable proportions of cellular sheets or lobules of uniform germinoma cells with large round nuclei, prominent nucleoli, and clear cytoplasm interspersed by septal bands of connective tissue rich in capillaries, lymphocytes, and at times granulomas (1,3). Cystic degeneration

and necrosis may be features of germinoma. Necrosis can be in the form of single cells, small microscopic foci, or in the most extreme cases, geographic zones.

Magnetic resonance (MR) imaging plays a vital role in the diagnosis of germ cell tumors (1,4–9). Diffusion-weighted (DW) imaging is a fairly recently developed MR sequence that has been used for the evaluation of neurologic diseases (10–12). With fast echoplanar technology, DW imaging has become widely clinically available and is part of the routine brain imaging protocol at our institution. It is highly resistant to motion, and imaging times are <30 seconds. DW imaging provides image contrast that is dependent on the molecular (Brownian) motion of water (10–12). The apparent diffusion coefficient (ADC) is a rotationally invariant measurement of the amount of total diffusion within a given tissue (11,13), and quantification of the degree of water motion requires ADC maps (10,12). The rate of molecular water diffusion as depicted on DW imaging may be altered in various diseases (10,12). Although DW imaging has had its major impact in the evaluation of hyperacute infarctions (12,14), it is assuming an increasingly important role in the evaluation of other intracranial pathologies, such as infections (15–19) and neoplasms (15,20). DW imaging has been proposed as a mechanism for producing contrast in the demarcation of different brain neoplasms (21–24). Recent studies have demonstrated hyperintense DW imaging signal in certain primary CNS neoplasms, such as lymphoma, pineoblastoma, medulloblastoma, high-grade gliomas (17,19,20,22), and two germinoma cases (25). However, the single study that investigated germinoma included only two cases and did not report ADC signal or value. The purpose of this study was to quantify the diffusivity of germinoma as reflected by ADC values and to determine if the ADC values correlated with the various histologic components. We hypothesized that the ADC values would correlate with the different histologic components.

MATERIALS AND METHODS

Patients

The archival pathology files and tumor registry of this medical center were searched over a 6-year period for biopsy-proven germinomas. This study was approved by the institutional review board, and the requirement for informed consent was waived.

Inclusion criteria were (1) histopathologic confirmation of the diagnosis of pure germinoma, (2) the availability of DW images in electronic format prior to any treatment, (3) the ability to generate ADC maps, and (4) the ability to calculate ADC values. Exclusion criteria were (1) lesions < 1 cm^3 situated along the hypothalamic-hypophyseal axis and (2) the presence of susceptibility artifacts on the DW sequences.

A search of the radiology database yielded 15 patients in whom DW imaging was performed. Five patients were excluded. In three patients, the images were not in electronic format, and ADC values could not be retrospectively generated; in one patient, susceptibility artifacts from a shunt catheter were present; and in another, a hypothalamic-hypophyseal axis lesion was <1 cm^3. There were therefore 10 patients in whom trace DW imaging, ADC maps, and ADC values were available for analysis. Of these, two had synchronous lesions situated in the pineal region and along the hypothalamic-hypophyseal axis, resulting in a total of 12 lesions. However, one of the synchronous lesions situated along the hypothalamic-hypophyseal axis measured <1 cm^3 and was excluded. Consequently, we studied 11 lesions for which DW images, ADC maps, and ADC values were available. Three lesions (27%) were located in the pineal region, and eight (73%) resided along the hypothalamic-hypophyseal axis. The study population of 10 patients comprised an equal number of male and female patients (mean age, 11 years; range, 5-22 years).

Imaging Protocol

All studies were performed using 1.5-T GE Genesis Signa magnets (GE Healthcare, Milwaukee, WI) equipped with a head coil. A typical examination consisted of T1-weighted (repetition time [TR], 450 ms; echo time [TE], 14 ms), T2-weighted (TR, 3000 ms; TE, 105 ms), and single-shot echoplanar DW images (TR, 7000 ms; TE, 118 ms). The DW images of the whole brain were obtained in three orthogonal directions, with b values of 0 and 1000 s/mm^2 (field of view, 220 × 220 mm; slice thickness, 5 mm; interslice gap, 0.6 mm; matrix size, 256 × 256 [$n = 5$] or 128 × 128 [$n = 6$]; number of signals acquired, 1). T1-weighted (TR, 450 ms; TE, 14 ms) and/or magnetization transfer (TR, 500 ms; TE, 9 ms; flip angle, 90°) images were obtained after the infusion of gadopentate dimeglumine (Magnevist; Berlex Laboratories, Wayne NJ). In addition to these routine sequences, high-resolution precontrast and postcontrast T1-weighted (TR, 550 ms; TE, 20 ms) sagittal and coronal images (field of view, 160 × 160 mm; slice thickness, 3 mm; interslice gap, 0.3 mm; number of signals acquired, 1) were obtained for lesions located along the hypothalamic-hypophyseal axis. Images were in electronic format on a picture archiving and communication system (GE Healthcare) and were transmitted to an Advantage workstation (GE Healthcare), on which ADC maps were generated.

Quantitative Analysis of the ADC Maps for Each Germinoma

The trace DW imaging and ADC maps were loaded into ImageJ, a medical image-processing software package (National Institutes of Health, Bethesda, MD). All images were interpolated to a 768 × 768 matrix to ensure the visualization of finer details of the lesions. Because the DW images were