

Oncologic Applications of Diffusion-Weighted Imaging

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In the 1990s, a series of technologic advances made it possible to translate DWI measurements to extracranial sites, including the abdomen and pelvis. The developments of echo-planar imaging (EPI), high-gradient amplitudes, multichannel coils, and parallel imaging have been instrumental in extending the applications of DWI. In particular, the introduction of parallel imaging, which enabled reduction in the TE, the echo-train length, and the k-space filling time, led to substantially less motion artifact at image acquisition, thus enabling high-quality DW images of the body to be obtained.

DWI yields qualitative and quantitative information that provides unique insight into tumor characteristics, and there is growing evidence for its use in the assessment of the patient with cancer.

1. Tumor detection: In general, tumors have lower ADC values, whereas normal/benign/reactive tissues have correspondingly higher values.
 - DWI is being applied for the detection of liver metastases which appear as high-signal-intensity foci at DWI.¹
2. Tumor characterization: Apparent diffusion coefficient values for distinguishing malignancy from normal/reactive tissues and benign disease are dependent on histologic characteristics such as tumor type, differentiation, and necrosis
 - Benign liver lesions, such as cysts and hemangiomas, have higher mean ADC values (e.g., $2.45 \times 10^{-3} \text{ mm}^2/\text{s}$) than malignant lesions, such as metastases and hepatocellular carcinoma (e.g., $1.08 \times 10^{-3} \text{ mm}^2/\text{s}$).^{2,3}
 - In prostate cancer, differentiating tumor from other causes of a low-signal-intensity lesion in the prostate gland is difficult on conventional T2-weighted MRI. DWI has shown potential for tumor identification⁴⁻⁸.
 - In colorectal cancer,⁹ DWI showed high sensitivity and specificity for detecting tumors¹⁰, and several studies found that DWI detected was tumors in of the pancreas¹¹ and gall bladder¹² with high sensitivity and specificity.
3. Several studies have indicated that DWI may be useful for tumor staging, including lymph node, bone and distant metastases¹³⁻¹⁷.
4. It has been suggested that there is a prognostic significance of pretreatment ADC values stems from the relationship between necrosis and poorer patient outcomes.

- Studies in rectal carcinoma^{18, 19} have shown that tumors with low baseline pretreatment ADC values respond better to treatment compared to tumors with high pretreatment ADC values.
5. Treatment response: DWI may be an effective early biomarker for treatment outcome for both antivascular drugs and therapies that induce tumor cell apoptosis. While DWI protocols and analysis methods need be tailored to individual tumor types, anatomic sites, and therapies, successful treatment is generally reflected by an increase in ADC values; however, transient early decreases in ADC values can be seen after treatment.
 - Animal studies showed that an increase in ADC after treatment correlated with response in subcutaneous gliosarcoma²⁰, colon cancer, Prostate cancer xenografts²¹, colon carcinoma²², Breast tumor xenografts²³ and mammary tumors²⁴.
 - Similar results have been found in humans with hepatocellular carcinoma²⁵⁻²⁸, soft tissue sarcomas²⁹, uterine leiomyomata⁵, breast cancer³⁰, cervical cancer³¹, prostate cancer^{6, 7}, rectal carcinoma³²
 6. Diffusion-weighted MRI has the potential to assist in new drug development and in clinical practice.

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