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Diffusion-Weighted Imaging in Head and Neck Cancer

Technique, Limitations, and Applications

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KEYWORDS

- Diffusion-weighted imaging • Intravoxel incoherent motion • Apparent diffusion coefficient
- Head and neck cancer • Head and neck squamous cell carcinoma (HNSCC)

KEY POINTS

- Diffusion-weighted imaging (DWI) of head and neck represents a distinct method of MR imaging with far ranging current and potential applications.
- New and better technology, scanners, and software have allowed DWI to become available across the globe.
- Research continues to hone the capabilities of DWI in characterization, prediction, monitoring, assessing response to treatment, and detecting posttreatment and recurrent changes.
- Pretreatment apparent diffusion coefficient values can suggest the likelihood of response to treatment, and delineate certain malignant masses from one another.

INTRODUCTION

The roots of diffusion-weighted imaging (DWI) of the head and neck owe their origin to the liver, where Turner and Le Bihan first hoped to use DWI to distinguish benign versus malignant lesions. DWI is an MR imaging sequence that measures the diffusion of water molecules in human tissues and attempts to assess the intrinsic cellularity of tissues by using the diffusion values as a surrogate marker for tissue cellularity. The amount of signal loss depends on the diffusion of water, and the intensity of that signal depends largely on the *b*-value of the diffusion encoding gradients. One of the factors contributing to this signal loss is the flow of water molecules through vascular structures such as capillaries. To this end, intravoxel incoherent motion (IVIM) is a technique used to account for the underlying perfusion, allowing the separation of perfusion and diffusion effects.

Although early studies and findings led DWI to the brain and detection of acute stroke, recent advancement in MR imaging technology has made routine use of DWI a widespread reality with use throughout the body. In the past 25 years, DWI has become more practical in its acquisition as higher performance field gradients have been introduced. The advent of echo planar imaging and IVIM allows for the rapid acquisition necessary to collect DWI data with significant reduction in motion artifact. Echo planar imaging has allowed DWI to branch out beyond the confines of brain imaging to head and neck, where limitations existed to good quality DWI owing to geometric variations in contour and patient motion (eg, swallowing). In addition, revisions to postprocessing software have also allowed for easier feasibility.

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Magn Reson Imaging Clin N Am ■ (2017) ■–■
https://doi.org/10.1016/j.mric.2017.08.011

In simplistic terms, the data from a DWI sequence are used to quantify the average magnitude of diffusion for a specific voxel, and within each voxel this can be expressed as a metric called apparent diffusion coefficient (ADC). Although there are many factors that can influence the ADC of a voxel, it is generally accepted that the ADC of a voxel is inversely proportional to the cellularity of the tissue represented by that voxel. Therefore, highly cellular tissues typically restrict free diffusion of water, and would thus have a lower ADC owing to relatively decreased extracellular space and increased area of cell membranes that act as a boundary for water diffusion. Chen and colleagues[1] discussed the available research showing that higher ADC values for a specific voxel do in fact correlate with lower cellularity.

It is well-known that MR imaging can characterize tissues better than computed tomography owing to higher contrast resolution, and this is also applicable to head and neck mass characterization. DWI adds another dimension to conventional MR imaging sequences owing to its ability to act as a potential marker for tissue cellularity. We discuss how this underlying principle can potentially be used to characterize head and neck lesions as either benign or malignant, predict the response of head and neck cancer to various types of treatment, monitor tumor to determine the effectiveness of treatment, and determine whether a residual mass detected after treatment represents scar or recurrence.

TECHNIQUES

Routine DWI in the head and neck is performed as a single shot echo planar technique owing to its shorter acquisition time. There are advantages and disadvantages to performing both echo planar and non–echo planar diffusion techniques that are explained in detail.

Echo Planar Diffusion

Owing to its relative insensitivity to motion, echo planar diffusion is widely used for head and neck imaging. Single shot and multi shot echo planar sequences differ in the number of repetition times used for filling K-space, with the former using 1 repetition alone to fill K-space and the latter using many repetitions. The single shot technique, although shorter in acquisition time, suffers from greater susceptibility effects, geometric distortion, and reduced spatial resolution, which are all improved with the multishot technique.

Non–Echo Planar Diffusion

Non–echo planar diffusion can provide further improvement in image quality with lesser susceptibility artifacts and higher spatial resolution but take longer to acquire than echo planar diffusion (which can introduce more motions artifacts on the images owing to both gross patient motion and intrinsic visceral motion like vessel pulsatility) and have lower signal-to-noise ratio, which necessitates multiple averages and prolongs scanning time. Hence, non–echo planar diffusion is usually reserved for problem solving rather than routine clinical practice.

CLINICAL APPLICATIONS

Benign Versus Malignant

Biopsy with pathologic examination remains the gold standard for assessing the malignant potential of a head and neck lesion. However, tissue sampling in the head and neck is not without risk, and certain regions of head and neck are difficult or relatively impossible to access.

Multiple studies have tested the ability and reliability of DW in characterizing the malignant potential of a lesion based on ADC measurement. These were based on the hypothesis that malignant tumors would demonstrate lower ADC values compared with benign tumors owing to their relatively higher cellularity. Wang and colleagues[2] demonstrated that benign and malignant lesions at multiple sites in the head and neck (including parotids, thyroid, parathyroid, nasal cavity, lymph nodes) yielded significantly different ADC values, and when an ADC value of 1.22×10^{-3} mm^2/s was used to categorize lesions as benign (above the cutoff) or malignant (below the cutoff), the investigators were able to do so with an accuracy of 86%, sensitivity of 84%, and specificity of 91%.

In the orbit, Razek and colleagues[3] demonstrated an ADC cutoff value of 1.15×10^{-3} mm^2/s to distinguish benign from malignant tumors. This study yielded a sensitivity of 95%, a specificity of 91%, and an accuracy of 93%.

Similarly, Srinivasan and colleagues[4] compared 33 patients with head and neck masses on a 3T magnet and found that there was a significant difference between benign and malignant lesions, with the latter showing lower ADC values than the former. In their study, the threshold value of 1.3×10^{-3} mm^2/s provided the best differentiation.

Although these studies demonstrate the usefulness of ADC, it remains unclear whether there is a specific threshold that is applicable in different magnet strengths and with different ‘b’ values.