Advanced Imaging Techniques of the Skull Base

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KEYWORDS

• MR perfusion • CT perfusion • Diffusion-weighted imaging • Head and neck imaging
• Head and neck squamous cell carcinoma

KEY POINTS

- Magnetic resonance (MR) diffusion-weighted imaging is helpful in staging head and neck squamous cell cancer, especially possible sites of nodal metastasis. Major challenges to diffusion-weighted imaging are susceptibility artifact in the neck as well as variability in acquisition parameters between different scanners.
- MR perfusion is helpful in staging as well as predicting response to radio/chemotherapy: higher K^{trans} before therapy is associated with a better response to chemoradiation.
- CT perfusion is helpful in staging as well as in predicting response to radio/chemotherapy: higher blood volume before therapy is associated with a better response to chemoradiation.

INTRODUCTION

Since the advent of computed tomography (CT) and MR imaging, cross-sectional imaging has played a crucial role in the evaluation of the skull base in patients presenting with symptoms that can be localized to this region. Although conventional imaging can depict the anatomy of this region with exquisite detail, it often falls short in its ability to characterize tissue physiology and abnormality; this is especially seen in the posttherapy setting where benign posttreatment changes and recurrent tumors can both show intense postcontrast enhancement and similar features on conventional imaging.

Advanced imaging includes a variety of CT, MR imaging, and nuclear medicine–based techniques that can evaluate tissue physiology and, along with conventional imaging, provide a more accurate assessment of the skull base. In this article, the technical details and clinical applications of different advanced imaging techniques are described with a primary focus on diffusion-weighted imaging.

DIFFUSION-WEIGHTED IMAGING

- Take-home points
  - Technical
    - An MR sequence with 2 equal, opposed gradients to dephase and rephase spins over a narrow slice; protons with restricted diffusion will remain in place and susceptible to rephasing and producing signal
    - Diffusion images are mathematically transformed into apparent diffusion coefficient (ADC) maps
    - Major problems in head and neck:
      - Susceptibility
      - Motion artifact

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- Lack of standardization in ADC values between scanners and vendors
- Clinical
  - Tumor often restricts diffusion
  - Major applications in head and neck squamous cell carcinoma:
    - Initial staging
    - Differentiating recurrent tumor from treatment effect
    - Developing frontiers: monitoring response to therapy

Technical Background

DWI describes the rate of Brownian motion of water molecules in tissue. Pure water will demonstrate a high degree of diffusion, but barriers such as cell membranes and attachment of water to cellular macromolecules (proteins, and so forth) restrict diffusion. Clinical DWI identifies regions of diffusion restriction such as the damaged, swollen cells of a brain infarct where water shifts from the extracellular spaces to become bound within cellular walls (acute stroke imaging) or in oncologic imaging due to the tendency of many malignancies to restrict diffusion due to a proliferation of closely packed cellular walls[1] (**Fig. 1**).

Although DWI imaging is well established for intracranial processes such as acute stroke, DWI of the skull base and neck presents several important challenges: susceptibility artifact arises from several sources, including air/tissue interfaces as the many irregular surfaces of the neck and metal in some patients (cervical spinal hardware, dental fillings, and so forth).[2] Compared with the intracranial compartment, the neck is heavily affected by physiologic movements, including breathing and swallowing. Approaches being developed to minimize susceptibility artifact include parallel imaging and readout-segmented DWI, which fills k space over multiple excitations rather than the single-shot methods in traditional DWI.[3] Another important challenge is limited reproducibility of diffusion thresholds between scanners and institutions; the

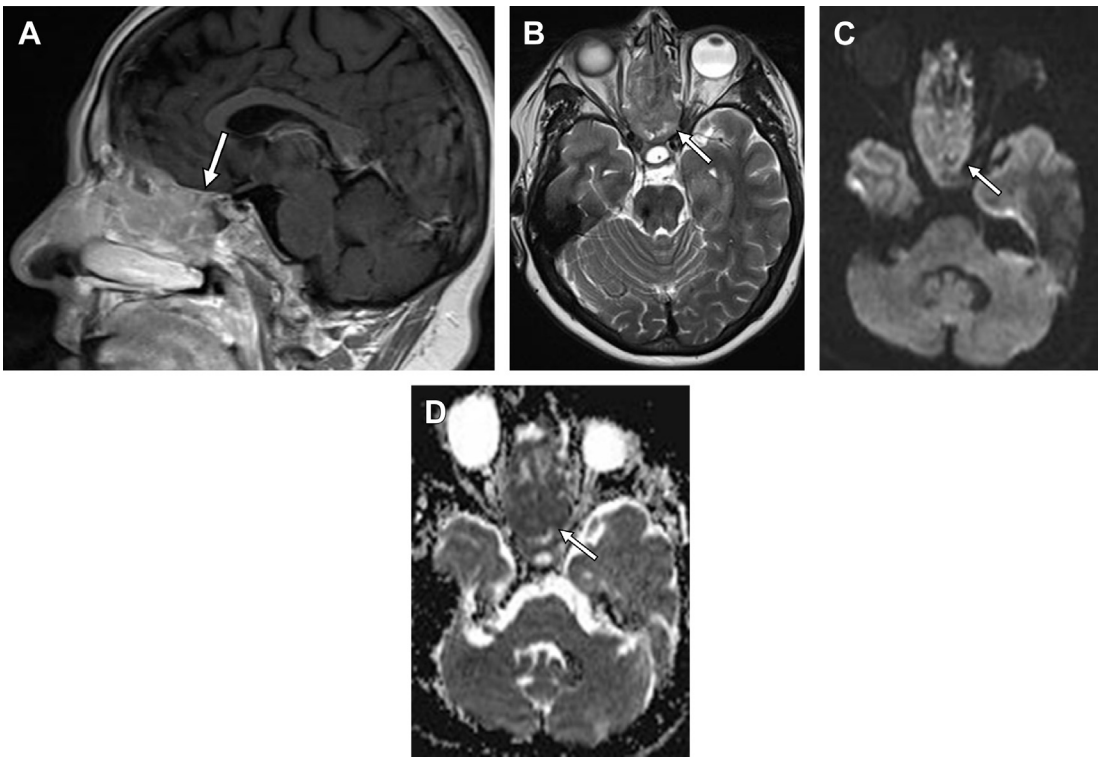

Fig. 1. A 48-year-old woman with nasal lymphoma. Sagittal T1 postcontrast (*A*) and axial T2 images (*B*) demonstrate an avidly enhancing, T2 hypointense mass (*arrows*) filling the ethmoid sinuses with destruction of the osseous walls of the ethmoid sinuses. Note the hyperintensity of this mass relative to the brain on a diffusion-weighted (high b value, B-900) image (*arrow*) (*C*) and hypointensity on the ADC map (*D*). The brain serves as a useful internal control in DWI; the brain generally restricts diffusion to a greater extent than most physiologic tissues in the head and neck. This patient's densely cellular tumor (nasal lymphoma) restricted water diffusion to a greater extent than the brain and well above other skull base and neck soft tissues at this level.