Imaging of Brain Tumors

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KEYWORDS

- Brain tumors • Magnetic resonance imaging • Diffusion imaging
- Perfusion techniques • Magnetic resonance spectroscopy
- Functional magnetic resonance imaging

KEY POINTS

- A prerequisite for the diagnosis of brain tumors is knowledge of their incidence and prevalence, histopathological classification, and clinical course.
- Different tumors occur in different age groups, and the likelihood of malignancy is influenced by the age of the patient. The location of a lesion is critical to narrowing the differential diagnosis.
- Neuroimaging plays a crucial role in establishing a diagnosis and is involved in the decision-making process for therapy.
- On computed tomography and magnetic resonance imaging (MRI), findings such as calcifications, cystic components, contrast enhancement, and signal intensity on T1-weighted images and T2-weighted images allow characterization of the tumors. However, the introduction of advanced imaging techniques into clinical practice places new tools into the hands of neuroscientists.
- Functional imaging techniques can reflect cellular density (diffusion imaging), capillary density (perfusion techniques), and tissue biochemistry (MR spectroscopy). In addition, cortical activation imaging (functional MRI) can identify various loci of eloquent cerebral cortical function. Combining these new tools can increase diagnostic specificity and confidence.
- Familiarity with conventional and advanced imaging findings facilitates accurate diagnosis, differentiation from other processes, and optimal patient treatment.

CONVENTIONAL IMAGING TECHNIQUES IN BRAIN TUMORS

Intracranial tumors are a significant health problem. The annual incidence of primary and secondary central nervous system (CNS) neoplasms ranges from 10 to 17 per 100,000 persons.[1]

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Brain tumors include a variety of subtypes with a broad range of histopathological characteristics, molecular and genetic profiles, clinical spectra, treatment possibilities, and patient prognoses and outcomes.[2]

The diagnosis and grading of brain tumors follows the World Health Organization (WHO) classification.[3] Also, neuroimaging plays a critical role in the diagnosis of brain tumors and pre-operative planning.

Unenhanced computed tomography (CT) of the brain is considered the first line of imaging for patients with suspected brain tumor who present with acute symptoms. Contrast-enhanced CT can be helpful in detecting areas of blood-brain barrier (BBB) breakdown and defining the contrast-enhancing tumor border. However, even multidetector CT using intravenous contrast agent is inferior to magnetic resonance imaging (MRI) in terms of soft tissue resolution. Yet, the presence and distribution of calcifications in a mass and bone remodeling adjacent to a tumor are better shown on CT than MRI.

MRI is the most useful imaging technique and the imaging test of choice for patients with brain tumor. In clinical practice, numerous different MRI protocols exist for imaging brain tumors. The most widely accepted imaging protocol includes at least the following sequences: T2-weighted imaging (T2WI), fluid-attenuated inversion recovery (FLAIR), T1-weighted imaging (T1WI), and contrast-enhanced T1WI. However, conventional MRI suffers from nonspecificity with respect to different pathological processes that appear to be similar on imaging.

Discrimination of extra-axial from intra-axial brain tumors is easy with only conventional anatomic imaging; however, the major diagnostic challenge is to reliably, noninvasively, and promptly differentiate intra-axial tumors to avoid biopsy and follow-up imaging studies.

Conventional MRI provides information about peritumoral edema/mass effect, cystic/necrotic changes, the presence of hemorrhage, and distant tumor foci. These findings are often associated with aggressive tumors. However, the absence of or minimal peritumoral edema, absence of necrotic or hemorrhagic foci, lack of a mass effect, and no contrast enhancement is sometimes observed in high-grade tumors.[4] Therefore, novel functional imaging techniques are being increasingly applied to patients with brain tumors.

The implementation of echo planar imaging (EPI) allowed the development of advanced imaging techniques, providing physiological information that complements the anatomical information available with conventional MRI. Neuroimaging in neuro-oncology is no longer a tool simply evaluating structural abnormalities and identifying tumor-related complications but it has evolved into a science that incorporates functional, hemodynamic, metabolic, cellular, and cytoarchitectural alterations.[5] Functional imaging techniques can reflect cellular density/tissue microarchitecture (diffusion imaging), capillary density (susceptibility perfusion techniques), and tissue biochemistry (MR spectroscopy [MRS]). In addition, cortical activation imaging (functional MRI [fMRI]) using techniques that are dependent on blood oxygen levels can identify various loci of eloquent cerebral cortical function.[6–8]

ADVANCED MRI TECHNIQUES IN BRAIN TUMORS

Diffusion-Weighted Imaging and Diffusion Tensor Imaging

Diffusion-weighted MRI is based on a unique contrast mechanism reflecting the differences in the diffusion of water molecules within the brain tissue.[9] The technique uses ultrafast pulse sequences similar to EPI, to freeze macroscopic patient motion, and makes use of strong gradient pulses to diphase and subsequently rephase water