Practical Neuroimaging of Central Nervous System Tumors for Surgical Pathologists

Christine M. Glastonbury, MBBS[a], Tarik Tihan, MD, PhD[b,*]

KEYWORDS

• CNS tumors • Neuroimaging • Neuro-oncology • CNS metastases

ABSTRACT

Imaging has established itself as an irreplaceable component of neuro-oncology, and provided much insight in all aspects of central nervous system (CNS) tumors. Today, similar to some other medical specialties, such as bone and joint disorders, it is an integral part of the diagnosis of CNS tumors. This brief review highlights the critical elements of neuroimaging, especially of MRI, in the study and diagnosis of brain tumors, and considers some of the common entities for the diagnosis, of which a good understanding of imaging characteristics is extremely helpful.

OVERVIEW: YOU CAN'T HAVE ONE WITHOUT THE OTHER!

Over the past 4 decades, the medical world has witnessed impressive progress in disease diagnosis and treatment with the aid of basic sciences, such as physics and chemistry. Some of the greatest advances have been recorded in the field of imaging, with the discovery and rapid development of computerized tomography (CT) and MRI of the human body. The more detailed imaging obtained through multiple modalities has improved our understanding of disease, allowed more precise diagnoses, treatment monitoring, and a greater degree of accuracy in determining prognosis. Specifically, neuroimaging has provided critical information for the diagnosis and treatment of central nervous system (CNS) diseases. Today, it is virtually impossible to imagine diagnosing or treating patients with CNS diseases without imaging.

Imaging has established itself as an irreplaceable component of neuro-oncology, and provided much insight in all aspects of CNS tumors. Today, similar to some other medical specialties, such as bone and joint disorders, it is an integral part of the diagnosis of CNS tumors. Some pathologists, including the coauthor of this article, consider the absence of neuroimaging information almost prohibitive for accurate and realistic diagnosis in surgical neuropathology. There are numerous examples of potential pitfalls of practicing surgical neuropathology without the recognition of neuroimaging information, and the experience of expert neuropathologists suggest that it is not wise to "bet against neuroradiology." The remarkable progress in our understanding of specific entities in neuropathology also aids in a better tomorrow for patients with CNS tumors. There are encouraging developments in the attempt to classify CNS tumors with the combined help of histopathology and molecular pathology. Our recommendation for practicing surgical pathologists is that they make good friends of the neuroradiologists in their institution, because the alternative is

[a] Department of Radiology and Biomedical Imaging, UCSF School of Medicine, Room M551, 505 Parnassus Avenue, San Francisco, CA, USA; [b] Neuropathology Division, Department of Pathology, UCSF School of Medicine, UCSF Medical Center, Room M551, 505 Parnassus Avenue, San Francisco, CA 94143-0102, USA
* Corresponding author.
E-mail address: tarik.tihan@ucsf.edu

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that pathologists achieve a good mastery of neuroradiology; a daunting task for any nonexpert.

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BASIC MODES AND METHODS IN NEUROIMAGING

COMPUTED TOMOGRAPHY

CT imaging was first introduced in 1972 and rapidly replaced plain films and pneumoencephalography as the tool of choice for evaluating the inside of the cranial vault. Although the earliest CT scanners with a simple X-ray tube and detector were revolutionary, they were by today's standards also incredibly slow, with the first-generation CT scanner able to image only the brain, and requiring approximately 30 minutes to image the whole brain in 13-mm-thick slices.[1] Many rapid advances in CT scanner design occurred over the subsequent decade to allow body imaging and reduce the slice time to approximately 20 seconds, with the patient moving 1 slice at a time into the scanner. In 1989, helical CT scanners were introduced, which allowed continuous motion of the patient through the CT scanner during scan acquisition, significantly improving imaging speed and image quality, and creating the opportunity for reconstruction of images in the coronal and sagittal planes. By 1998, 4-detector CT scanners were available, which allowed significantly shorter imaging time and thinner CT slices. Today, most multidetector CT (MDCT) scanners have 64 detectors, and imaging the brain may take as little as 8 seconds with a slice thickness of 0.625 mm and reconstruction of images in any desired plane without image distortion.

CT relies on simple X-ray principles, so that tissues absorbing more x-rays (generally denser tissues, such as bone) will result in a whiter image on a scan, whereas substances such as water that have very little attenuation of x-rays will result in a blacker appearance. Soft tissues, such as muscle and brain parenchyma, attenuate x-rays more than water but much less than bone, so fall in the intermediate-density appearance on CT images. To evaluate brain masses, CT exploits the subtle differences in density between normal brain parenchyma, edematous tissue, a mass, and intrinsic differences in the texture of that mass. Some tumors, such as lymphoma, tend to appear denser than brain parenchyma, whereas other tumors may have cystic low-density components like posterior fossa pilocytic astrocytomas. Similarly, some masses may have denser calcification or recent hyperdense hemorrhage. CT is the imaging tool of choice for not only detecting calcification but also for characterizing the pattern of calcification within a lesion. For example, cavernous malformations (cavernomas) are often described as having "popcorn calcification."

CONTRAST COMPUTED TOMOGRAPHY

Iodinated contrast is given intravenously and will result in a denser appearance of patent arteries and veins. Enhancement also is expected of the extraocular muscles, pituitary gland and infundibulum, and the choroid plexus. Contrast enhancement is often a helpful distinguishing feature between tumors, with, for example, the hyperenhancing nodule and prominent adjacent enhancing small blood vessels key imaging features of cerebellar hemangioblastomas. Although metastatic lesions, abscesses, and subacute infarcts and hematomas are expected to enhance, enhancement of primary brain glial neoplasms and inflammatory masses is variable and often difficult to discern on CT. Iodinated contrast can be nephrotoxic, so is not given to patients with poor renal function, and may precipitate acute renal failure. Anaphylactic reactions also are well described with iodinated contrast, and a previous allergic reaction necessitates premedication with steroids before readministration.

MRI

MRI has significantly greater sensitivity for the detection of tissue contrast enhancement. This feature, coupled with a markedly better ability to distinguish different tissues from each other (known as "contrast resolution"), makes MRI far superior to CT in the evaluation of brain tumors (**Fig. 1**). MRI has greater sensitivity for the detection of intracranial disease and, aside from the detection of calcium (and distinguishing it from blood products), is the preferred imaging modality for nearly all brain diseases.[2] In most clinical practices, the magnetic field strength is 1.5 T or 3.0 T. A higher magnetic field strength brings generally