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CT/MR Perfusion Imaging and Alphabet Soup: An Appeal for Standardized Nomenclature

Michael H. Lev

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Leptomeningeal Tumor: The "Plain Vanilla" Approach Remains the Best

Findings from the most recent studies suggest that the incidence of leptomeningeal tumor continues to increase. Multiple reasons are generally cited. First, methods of diagnosis have improved with respect to the evaluation of cytologic features. Second, as patients continue to live longer with their systemic tumors due to refinements in treatment, ancillary complications of the disease, such as leptomeningeal tumor, have more time to develop. Third, improvements in imaging increase the number of leptomeningeal tumor diagnoses.

The major advance in the imaging evaluation of leptomeningeal tumor occurred with the introduction of contrast agents and their use with routine T1-weighted spin-echo sequences. Previous evaluations with contrast-enhanced CT had been suboptimal. The advent of contrast-enhanced MR imaging, however, has substantially increased the diagnostic rate of leptomeningeal tumor. Studies in which the original techniques are used demonstrate positive imaging findings in approximately one to two thirds of patients with documented leptomeningeal tumor.

While the rate of diagnosis by means of imaging has increased, the potential for diagnosis with the evaluation of the CSF itself remains. The evaluation of the CSF results in positive cytologic findings in approximately 45% of cases after one lumbar puncture, approximately 85% of cases after two lumbar punctures, and approximately 95% of cases after six lumbar punctures. These results are dependent on highly skilled cytologists and the withdrawal of relatively large volumes, approximately 15–20 mL, of CSF at each lumbar puncture. Realistically, in today's clinical setting, very few patients undergo such extensive, invasive, and uncomfortable examinations for the diagnosis of leptomeningeal tumor. Therefore, imaging has become even more important than it was previously.

Although the simple T1-weighted contrast-enhanced spin-echo sequence was the first method in the evaluation of leptomeningeal tumor, other sequences have also been considered. Surprisingly, magnetization-transfer techniques, which proved to be effective in increasing the conspicuity of contrast enhancement in parenchymal lesions, have been somewhat less optimal in the evaluation of suspected leptomeningeal tumor; this limitation is possibly due to the increased depiction of normal cortical veins along the surface of the brain, which make the diagnosis of leptomeningeal tumor more difficult.

Another technique that has been proposed for use with contrast enhancement is three-dimensional spoiled gradient-echo imaging, which allows easy multiplanar reformation. One specific disadvantage with respect to the evaluation of leptomeningeal tumor is that the incidence of normal meningeal enhancement with spoiled gradient-echo images tends to be higher than that of routine T1-weighted spin-echo imaging. Because normal meninges do enhance with spoiled gradient-echo sequences and because this enhancement tends to be more visible than it is with routine T1-weighted spin-echo sequences, spoiled gradient-echo sequences have significantly less specificity in the diagnosis of leptomeningeal tumor, particularly in subtle cases.

Fluid-attenuated inversion recovery (FLAIR) imaging is the first new technique to realistically challenge the role of contrast-enhanced T1-weighted spin-echo sequences in the diagnosis of leptomeningeal tumor. Its success has been controversial. Some have noted improved diagnostic rates, while others have cited problems from lack of appropriate fluid signal suppression, particularly with CSF pulsation in the important region of the basal cisterns. Because leptomeningeal tumor is often diagnosed by noting the enhancement of the cranial nerves in the region of the basal cisterns, the lack of reliable CSF signal suppression in these areas of increased pulsatility has proved highly problematic.

The goal of increasing the imaging sensitivity to leptomeningeal tumor remains. The proposal of the current article by Singh et al in this issue of the *AJNR* is intriguing. Their hypothesis is that, by combining the best of T1-weighted contrast-enhanced sequences with FLAIR sequences, the diagnostic capabilities of MR imaging can be increased even further. In this study, they compared the roles of contrast-enhanced T1-weighted spin-echo imaging with nonenhanced and contrast-enhanced FLAIR imaging. The results, however, are not as they originally hypothesized. Rather, contrast-enhanced T1-weighted spin-echo sequences remain the sequences of choice in the evaluation of suspected leptomeningeal tumor. The combination of nonenhanced FLAIR and contrast-enhanced T1-weighted imaging has proved to be optimal. Happily, nonenhanced FLAIR and contrast-enhanced T1-weighted sequences are already incorporated into most protocols used for the evaluation of suspected leptomeningeal tumor. The sensitivity of MR imaging in the evaluation of leptomeningeal tumor, by using all of the sequences, was 60%; this percentage is near the upper limits of numbers cited in earlier reports.

Given the importance of leptomeningeal tumors and the invasiveness of making the diagnosis by actually examining the CSF, it is unfortunate that our effectiveness in diagnosing this important clinical entity by means of imaging has not increased even further. Nevertheless, the article by Singh et al reinforces

the continued importance of imaging and the relative reliability of these techniques.

One final note is interesting. Our first efforts with contrast enhancement in the evaluation of suspected leptomeningeal tumor involved standard T1-weighted spin-echo sequences. After all these years, "plain vanilla" T1-weighted spin-echo sequences still remain the techniques of choice for use with contrast material.

GORDON SZE, MD
Department of Radiology
Yale University School of Medicine
New Haven, CT

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In this issue of the *AJNR*, Roberts et al describe the dynamic contrast-enhanced CT findings in two patients with metastatic brain tumors. Specifically, the authors demonstrate the feasibility of constructing *quantitative* maps of the microvascular permeability surface area product, as well as more familiar blood volume and flow maps, by using CT datasets. Such maps may provide a numerical estimate for the degree of local disruption of the blood-brain barrier. Because permeability measurements are dependent on the molecular structure of the tracer used for imaging (ie, nonionic iodinated contrast material for CT and gadolinium-based agents for MR imaging), focal variations in permeability were noted between the CT and MR maps in one patient; the CT blood volume maps, however, correlated well with their MR counterparts.

The article by Roberts et al is a well-written report on a novel and timely topic—that of brain-tumor permeability mapping by using CT tracer-kinetic techniques. As with dynamic blood volume imaging, such mapping has the potential to assist in the grading of brain tumors, prediction of outcomes, guidance of stereotactic biopsy, monitoring of treatment responses, and evaluation of anti–angiogenesis agents (as surrogate markers in clinical trials). In distinction to the more thoroughly studied first-pass tracer-kinetic models commonly used to create MR and CT perfusion maps, the method described by Roberts et al uses delayed imaging; the total acquisition time was 5½ minutes, with a radiation dose roughly twice that of a routine nonenhanced head CT examination. Body imagers have applied related methods to study liver and prostate tumors; perhaps this articles will provide an impetus for similar studies by neuroradiologists.

Unlike MR perfusion techniques, CT currently has limited coverage and requires the use of both iodinated contrast material and ionizing radiation. CT, however, can provide convenient, high-resolution, low-cost, and truly quantitative maps of cerebral blood flow (CBF), cerebral blood volume (CBV), mean transit time (MTT), and permeability surface area (PS) product. Drawbacks to MR perfusion imaging include contraindications to imaging in some patients, as well as the confounding effects of susceptibility artifact on image quality and flow quantification.

Abbreviations for perfusion imaging techniques that have appeared in the literature include the following: DCEMR/CT, which is defined as dynamic contrast-enhanced MR or CT imaging (as used in the manuscript by Roberts et al); HI, defined as hemodynamic imaging; PWMR/CT, defined as perfusion-weighted MR imaging or CT; pMRI/CT, defined as perfusion MR imaging or CT; and MRP and CTP, which are generic terms for MR and CT perfusion imaging, respectively—to name just a few. Such varied terminology is not only confusing but also possibly misleading. For example, many articles that describe an MR diffusion-perfusion mismatch in acute stroke have not explicitly clarified that they refer to only arrival time maps, and not to CBF, CBV, or even MTT maps; this distinction is important and sometimes critical in the presence of a fixed carotid artery occlusion. Also, dynamic first-pass MR perfusion imaging of tumors can be performed by using either gradient-echo (common) or spin-echo (uncommon) pulse sequences; each have different implications for the dosage of gadolinium-based contrast agent and the sensitivity for the detection of large-capacitance vessels. Moreover, alternative, non–first pass methods for perfusion CT are available; these include CT perfused blood-volume imaging (CT-PBV), in which CBV-weighted images of the entire brain are obtained—simultaneously with CT angiographic (CTA) images of the complete neurovascular system—by using the same, approximately steady-state administration of a bolus of contrast agent (1, 2). Because of their generality, in addition to their lack of standardization, the acronyms noted earlier fail to adequately distinguish between the various forms of perfusion imaging.

This profusion of perfusion abbreviations suggests that it is time for the neuroradiology community to establish a standardized nomenclature. I would like to open the discussion by proposing the following scheme; perhaps this issue will not prove to be as contentious as the great turn-of-the-millennium CT debates about helical versus spiral terminology, or single versus multislice pitch definitions (3). CTP and MRP are probably appropriate generic abbreviations to use when one is referring to CT or MR perfusion imaging broadly and nonspecifically, just as CTA is a widely accepted acronym for CT angiography. When greater detail regarding the type of perfusion imaging is required, perfusion maps could be specified by using a two-letter prefix to define the modality and a

three-letter suffix to describe the parameter being measured. For example, CT-PBV can be used to indicate CT perfused blood volume maps, and MR-PS can be used for MR permeability surface area maps. When the context is insufficient to discriminate between related maps, an extra lowercase qualifier might be judiciously considered. For example, quantitative scans could be characterized by the addition of the letter "q," as in CT-qCBF for quantitative dynamic first-pass CT perfusion maps, as opposed to CT-MTT for MTT maps constructed by using qualitative or unspecified methods. Similarly, although gradient-echo is the default mode in performing MR-CBV, spin-echo acquisitions could be specified as MR-seCBV.

Such a scheme, if adopted, has the potential not only to reduce the confusion caused by the increasing number of CT and MR perfusion applications but also encourage physicians to become more familiar with the details of these techniques.

MICHAEL H. LEV, MD
Department of Radiology
Massachusetts General Hospital
Boston, MA

References

1. Hunter GJ, Hamberg LM, Ponzo JA, et al. **Assessment of cerebral perfusion and arterial anatomy in hyperacute stroke with three-dimensional functional CT: early clinical results.** *AJNR Am J Neuroradiol* 1998;19:29–37
2. Lev MH, Segal AZ, Farkas J, et al. **Utility of perfusion-weighted CT imaging in acute middle cerebral artery stroke treated with intra-arterial thrombolysis: prediction of final infarct volume and clinical outcome.** *Stroke* 2001;32:2021–2028
3. Silverman PM, Kalender WA, Hazle JD. **Common terminology for single and multislice helical CT.** *AJR Am J Roentgenol* 2001;176:1135–1136