postmenopausal year have a relatively larger deficit of trabecular bone. A precise measurement of their spinal bone mass can hardly be achieved with the present DPA technique, and for the diagnosis of crush fracture it is easier to take an x-ray. The interesting question is, however, how to diagnose mild osteoporosis, and this was the aim of our study. As described in detail our 28 unselected patients had mild osteoporosis and in these patients DPA measurement of the lumbar spine had no advantages over SPA measurement of the distal forearm.

References

1. Nilas L, Pødenphant J, Riis BJ, et al. Usefulness of regional bone measurements in patients with osteoporotic fractures of the spine and distal forearm. *J Nucl Med* 1987; 28:960–965.
2. Pocock NA, Eisman JA, Yeates MG, et al. Limitations of forearm bone densitometry as an index of vertebral or femoral neck osteopenia. *Bone Min Res* 1986; 1:369–375.
3. Ott SM, Kolcoyne RF, Chesnut CH. Longitudinal changes in bone mass after one year as measured by different techniques in patients with osteoporosis. *Calcif Tissue Int* 1986; 39:133–138.
4. Riggs BL, Wahner HW, Melton LJ, et al. Rates of bone loss in the appendicular and axial skeletons of women: Evidence of substantial vertebral bone loss prior to menopause. *J Clin Invest* 1986; 77:1487–1491.

Lisbeth Nilas
University of Copenhagen
Glostrup Hospital
DK-2600 Glostrup, Denmark

Quantifying Intracranial CSF Volume Using MRI

TO THE EDITOR: Chawluk et al. (*1*) described a method of correcting for the presence of cerebrospinal fluid (CSF) in positron emission tomography (PET) estimations of cerebral metabolism per unit mass of brain tissue. They did so using a series of x-ray (XCT) computed tomography images with areas of CSF in sulci and ventricles being identified subjectively using a data tablet operating on a high resolution display. This use of XCT images follows the similar approach taken by Herscovitch et al. (*2*).

We would like to point out that a more accurate correction technique exists that does not involve ionizing radiation. While using magnetic resonance (MR) images, it does not do so in the way suggested by Chawluk et al. (*1*), namely, simply as a substitute for the XCT slices with CSF spaces again being identified subjectively. Rather, it takes a radically different approach by utilizing the significant differences between the relaxation times of CSF ($T_1 > 3{,}000$ ms, $T_2 > 2{,}000$ ms) and those of gray matter (513 ms, 118 ms) and white matter (242 ms, 86 ms) (*3*). Using an IRCP5000/300/400 ($T_R/T_I/T_E$) image contrasts between a unit volume of CSF and a unit volume of brain tissue of > 200:1 are obtained in practice. In other words, images are effectively obtained that show only CSF with the signal from each pixel being proportional to the amount of CSF contained in the corresponding volume element. A reference vial containing a known volume of water that has very similar relaxation times to CSF (*4*), is used to translate this into absolute volume. Slices can be obtained in any orientation and thickness and thus can be accurately matched to the actual PET images to be corrected and estimates of absolute CSF volume (ventricular and extra-ventricular) can be obtained. The method is not subject to the beam hardening effects of XCT, does not suffer from significant partial volume effects (*3*) and does not require either a threshold algorithm (*2*) or subjective observer choice (*1*) to define regions of CSF. Its noninvasive nature and lack of ionizing radiation means that it may be used to establish normal values in volunteers as well as being applied serially to patients with greater frequency than would be possible with XCT. The fact that each pixel in the MR image represents the absolute volume of CSF in the corresponding volume element means that it may also be possible to correct the PET images on a voxel by voxel basis as opposed to the present global correction as described by Chawluk et al. (*1*).

References

1. Chawluk JB, Alavi A, Dann R, et al. Positron emission tomography in aging and dementia: effect of cerebral atrophy. *J Nucl Med* 1987; 28:431–437.
2. Herscovitch P, Auchusa P, Gado M, et al. Correction of positron emission tomography data for cerebral atrophy. *J Cereb Blood Flow Metab* 1986; 6:120–124.
3. Condon B, Patterson J, Wyper D, et al. A quantitative index of ventricular and extra-ventricular CSF fluid volumes using MRI. *J Comput Assist Tomogr* 1986; 10:784–792.
4. Condon BR, Patterson J, Jenkins A, et al. MR relaxation time of cerebrospinal fluid. *J Comput Assist Tomogr* 1987; 11:203–207.

B. R. Condon
D. J. Wyper
J. Patterson
R. Grant
Institute of Neurological Sciences
Southern General Hospital
Glasgow, Scotland

REPLY: We appreciate the interest demonstrated by Condon and colleagues in the issue of quantifying CSF spaces in vivo. Their method is the most promising we have encountered to date, and provides the potential for greater accuracy and ease of implementation than the more subjective and operator-intensive XCT technique which we have employed for the past several years (*1–3*).

The method of quantifying intracranial CSF volume described by Condon et al. (*4*) uses an MR pulse sequence designed to produce a maximal signal from CSF, minimizing the signal from other tissues (gray and white matter). As currently presented, a potential disadvantage of this technique in studies of aging and dementia is the length of time required to obtain a single slice (almost 5 ½ min with a 64 × 64 matrix). The magnitude of this disadvantage is partially counteracted by the use of thicker slices, permissible given the very high signal contrast between CSF and brain.

Data from phantom studies and reproducibility data using this method are quite good (*4*). Several factors limit an uncritical implementation of this method, however, including image nonuniformity, unavoidable residual partial volume averaging effects, and motion during scanning (patient motion as well as CSF bulk flow). Another limitation of this "thick-slice" approach is that measurements of regional atrophy are