Central Nodal Necrosis and Extracapsular Neoplastic Spread in Cervical Lymph Nodes: MR Imaging versus CT

The use of magnetic resonance (MR) imaging in the head and neck has become increasingly widespread. While the implementation of MR imaging in evaluating primary sites of squamous cell carcinomas, particularly the pharynx, floor of the mouth, tongue, nasopharynx, and larynx, has been said to be competitive with, if not superior to, computed tomography (CT), the efficacy of MR imaging in evaluating cervical lymphadenopathy has not been as fully appreciated in the present literature whether MR imaging is as good as CT for identifying cervical metastatic lymphadenopathy. In addition, there have been reports as to the optimal pulse sequences for the detection of central nodal necrosis (CNN) and extracapsular neoplastic spread (ENS) (14-17).

At enhanced CT, until proved otherwise, a central zone of low attenuation in the node indicates the presence of tumor cells and/or nodal necrosis, regardless of the size of the node (18-22). At MR imaging, such nodes may have low, intermediate, or high T2-weighted signal intensity or may be inhomogeneous in appearance (23). This variability of signal intensity overlaps that of hyperplastic lymph nodes. It is unclear whether focal areas of tumor and necrosis that are seen at CT can be accurately and readily identified at MR imaging.

In the case of ENS, several series have indicated that, short of actual pathologic proof, enhanced CT scans deserve to be considered an excellent standard (14-17,23). Because many major medical centers have pathology departments that do not routinely describe the presence of ENS, contrast material-enhanced CT has gained great use as the standard for its detection.

MR imaging with equivalent section thickness is expected to be as accurate as CT in evaluation of lymph node and detection of neoplastic infiltration when lymph nodes are enlarged. The typical MR imaging features of intermediate signal intensity on short-repetition-time (TR) images and hyperintensity on long TR images seen in reactive or neoplastic lymph nodes, however, may obscure the presence of subtle nodal necrosis, particularly in small nodes. The use of gadolinium enhancement has been proposed to increase the sensitivity of MR imaging in detecting nodal necrosis, and fat-suppression techniques have been promoted as a means of detecting ENS into neighboring fat (14,24).

The purpose of this article was to compare enhanced CT scans with MR (T1-weighted, T2-weighted, and enhanced fat-suppressed T1-weighted) images in detecting CNN and ENS and to determine what MR sequences best show these findings. We evaluated the data by using two standards: (a) pathologic findings when nodal sampling or dissections were performed (14 patients) and (b) CT findings in the patients who refused treatment or underwent radiation treatment or chemotherapy alone for the cervical lymph node disease (10 patients).

MATERIALS AND METHODS

Twenty-four patients with suspected malignant cervical lymphadenopathy underwent imaging evaluation with contrast-enhanced CT and MR imaging. Nineteen patients had biopsy-proved squamous cell carcinomas, three patients had adenocarcinomas, one patient had metastatic melanoma, and one patient had lymphoma.

Abbreviations: CNN = central nodal necrosis, ENS = extracapsular neoplastic spread.
CT was performed with a GE 9800 scanner (GE Medical Systems, Milwaukee) after administration of a 50-mL bolus of di- lute iodine-based contrast material followed by a rapid infusion of 250 mL. Scanning was performed in the axial plane without angulation and with 5-mm-thick contiguous sections from the cavernous sinuses to the thoracic inlet. Images were photographed with standard algorithms and soft-tissue windows.

MR imaging was performed with a 1.5-T Signa imager (GE Medical Systems). For the purposes of this study, only axial short TR and short-echo-time (TE) (600–800, 11–30 [TR msec/TE msec], one to two excitations), long TR (2,000–3,500/30–90; one-half to one excitation), and postcontrast short TR (600–800/20–35, one excitation) spin-echo images or postcon- trast spoiled gradient-echo (50/1,2–1,5, one excitation, 40° flip angle) images were provided for interpretation. Gadopentetate dimeglumine (Magnevist; Berlex, Wayne, NJ) was administered at a dose of 0.1 mmol/kg, with imaging performed immediately after injection. Section thickness for all pulse sequences was 5 mm, with contiguous sections obtained in almost all cases from the cavernous sinuses to thoracic inlet. The matrix size was 256 × 192 for all short TR sequences and either 256 × 128 or 256 × 192 for the long TR sequences. Either a Dixon fat-suppression method or frequency-selective chemical fat-suppres- sion technique was applied for the post- contrast images (25–27). A volume neck coil (Medical Advances, Milwaukee) was used in most cases to obtain optimal signal-to-noise ratio while maintaining an adequate imaging range.

Each lymph node was identified on CT scans and MR images by one observer (D.M.Y.), measured in its two largest planes, and assigned an arbitrary number (Table 1). Each MR image and the CT scans were then interpreted by two different observers (P.M.S., D.B.H.) for the presence or absence of CNN and ENS. Proton-density images were presented together with T2-weighted images. After each image was interpreted separately (T1-weighted and proton-density/T2- weighted), the two MR images were interpreted side by side and a combined T1- and T2-weighted evaluation was reported. The postcontrast series was examined alone for CNN and ENS and then with the precontrast T1-weighted and T2-weighted images available. Thus, results were ob- tained in six ways: (a) T1-weighted MR images, (b) T2-weighted MR images, (c) T1-weighted and T2-weighted MR images, (d) enhanced T1-weighted fat-suppressed MR images, (e) T1-weighted, T2- weighted, and enhanced fat-suppressed T1-weighted MR images, and (f) CT scans. If the numbered structure was not be- lieved to represent a lymph node, this finding was also noted.

The presentation for evaluation of the MR images obtained with the different pulse sequences and/or the CT scans was in the order listed above, and the reader was blinded to clinical history and results of other studies. Intervals of 3–5 days be- tween readings of MR images and more than 1 week between readings of MR images and CT scans were used to reduce bias.

Criteria for detecting CNN included the presence of inhomogeneous signal intensity in the node (usually lower on T1- weighted and higher on T2-weighted images) and hypointense nonenhancing central areas of the node on postcontrast images. CNN was diagnosed by means of CT when central low attenuation was visual- ized in the node on enhanced scans. ENS was diagnosed on the basis of nodal capsular enhancement and infiltration of adjacent fat or muscle planes, with capsu- lar contour irregularity at both CT and MR imaging.

The pathology reports of all patients who underwent lymph node biopsies and neck dissections were also retrospectively

### Table 1

<table>
<thead>
<tr>
<th>Node Group</th>
<th>Maximum Transaxial Diameter (cm)</th>
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<tbody>
<tr>
<td></td>
<td>≤ 1.0</td>
</tr>
<tr>
<td>All nodes</td>
<td>16</td>
</tr>
<tr>
<td>Nodes with CNN (CT and pathologic proof)</td>
<td>2</td>
</tr>
<tr>
<td>False-negative nodes by most accurate MR sequence for CNN†</td>
<td>2</td>
</tr>
<tr>
<td>Nodes with ENS (CT proof)</td>
<td>1</td>
</tr>
<tr>
<td>False-negative by most accurate MR sequenc for ENS†</td>
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</tr>
</tbody>
</table>

* Unenhanced T1-weighted and T2-weighted combined reading (reader 1).
† Unenhanced T1-weighted reading (reader 1).

### Table 2

<table>
<thead>
<tr>
<th>Modality or Technique</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Accuracy (%)</th>
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<tr>
<td></td>
<td>Reader 1</td>
<td>Reader 2</td>
<td>Reader 1</td>
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<tr>
<td>CT MR imaging</td>
<td>83</td>
<td>100</td>
<td>94</td>
</tr>
<tr>
<td>Unenhanced T1-weighted</td>
<td>25</td>
<td>16</td>
<td>100</td>
</tr>
<tr>
<td>Unenhanced T2-weighted</td>
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<td>50</td>
<td>93</td>
</tr>
<tr>
<td>ENS</td>
<td>60</td>
<td>57</td>
<td>94</td>
</tr>
<tr>
<td>Enhanced T1-weighted</td>
<td>40</td>
<td>53</td>
<td>100</td>
</tr>
<tr>
<td>Enhanced T1-weighted and ENS</td>
<td>50</td>
<td>50</td>
<td>85</td>
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</tbody>
</table>

* Statistically significant at P < .05 compared with CT.
† Statistically significant at P < .1 compared with CT.

### Table 3

<table>
<thead>
<tr>
<th>Pulse Sequences</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Accuracy (%)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Reader 1</td>
<td>Reader 2</td>
<td>Reader 1</td>
</tr>
<tr>
<td>Unenhanced T1-weighted</td>
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<td>11</td>
<td>100</td>
</tr>
<tr>
<td>Unenhanced T2-weighted</td>
<td>47</td>
<td>53</td>
<td>97</td>
</tr>
<tr>
<td>ENS</td>
<td>50</td>
<td>47</td>
<td>98</td>
</tr>
<tr>
<td>Enhanced T1-weighted</td>
<td>38</td>
<td>37</td>
<td>94</td>
</tr>
<tr>
<td>Enhanced T1-weighted and ENS</td>
<td>47</td>
<td>37</td>
<td>92</td>
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</table>
The nodes were matched to reports with the Rouvier nomenclature location (typically described in pathologic and size. Two pathologists, one on the staff and one in training, reviewed the surgical specimens. The reports were specifically reviewed for descriptions of the presence or absence of CNN. Eleven patients (46%) underwent radical neck dissections, and three patients (12%) underwent limited resection of lymph node masses without radical neck dissections. The remainder of the patients \( n = 10 \) (42%) refused surgery, underwent radiation therapy or chemotherapy without pathologic confirmation, or were lost to follow-up. CT was used for proof of diagnosis in these patients.

The sensitivity and specificity of each pulse sequence individually and in concert with other pulse sequences were determined for CNN in 23 nodes studied pathologically (Table 2). The CNN results based on CT (37 nodes) and pathologic proof (23 nodes) can be found in Table 3. CT proof alone was used to evaluate CNN (Table 4) and ENS (Table 5) in all 60 nodes. Because this was a retrospective study and the pathology reports did not comment on ENS routinely, CT was used as the standard for evaluating the sensitivity and specificity of MR imaging in detecting ENS (Table 5). Statistical analysis was performed with a two-tailed Student \( t \)-test for paired samples (28).

### RESULTS

Sixty lymph nodes were identified on the CT scans of the 24 patients. One reader reported 17 nodes as having CNN on CT scans, and the second reader reported 20. Twenty-five (reader 1) and 22 (reader 2) lymph nodes were believed to demonstrate ENS.

Table 1 shows that the size of lymph nodes in the study population varied widely, but was slightly weighted to those no more than 2.0 cm in diameter (43 of 60 [72%]). This range probably reflects that of nodes found in patients with squamous cell carcinomas. The relatively large number of nodes no more than 1.0 cm in diameter probably included a substantial number of hyperplastic, normal, nontumorous nodes. One can see that false-negative MR imaging interpretations for CNN occurred at all size ranges, including two nodes greater than 3.0 cm in diameter, and both nodes no more than 1.0 cm in maximum diameter. For ENS, all misses were in nodes no more than 2.0 cm in diameter.

The sensitivities (true-positive/true-positive + false-negative), specificities (true-negative/true-negative + false-positive), and accuracies (true-positive + true-negative/true-positive + true-negative + false-positive + false-negative) of the pulse sequences for CNN and ENS, with CT and/or pathologic findings as the standard, are noted in Tables 2–5. The results are summarized below.

### CNN (Tables 2–4)

With pathologic findings as the standard (Table 2), CT was the most sensitive study in detecting CNN (83%–100%). The unenhanced T1-weighted and T2-weighted combined reading for CNN had the highest sensitivity of MR readings (60%–67%), but was much less specific than CT (Figures 1–3). The overall accuracy of CT (91%–96%) was greater than that of any MR imaging reading, with the unenhanced T1-weighted and T2-weighted reading the next most accurate at 86%–87%. When the MR imaging interpretation included the gadolinium-enhanced series with the unenhanced series, the sensitivity, specificity, and accuracy for determining CNN fell. The high accuracy figures and low sensitivity values reflect a predominance of nodes negative for CNN. By itself, the enhanced T1-weighted image was highly specific for CNN.

The data comparing MR imaging findings with CT as the standard (Table 4) for 60 nodes demonstrate that the maximum sensitivity of MR imaging for CNN was only 53%–55%. Unenhanced T1-weighted images were the least sensitive (10%–27%) and accurate (67%–80%) for CNN. No pulse sequence had an accuracy of more than 78%–84%.

When the CT and pathology data were combined as the standard for detecting CNN (Table 3), the same trends were apparent: Sensitivity was low with all MR sequences, and the unenhanced T1- and T2-weighted reading was most accurate (mean value for the two readers). Specificity was relatively high, but MR imaging accuracies were still less than 76%–84%.

In summary, we found that CT was by far the most accurate test in detecting CNN, more so than any MR pulse sequence individually or in combination. Gadolinium did not significantly

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**Table 4**

<table>
<thead>
<tr>
<th>Pulse Sequences</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reader 1</td>
<td>Reader 2</td>
<td>Reader 1</td>
<td>Reader 2</td>
</tr>
<tr>
<td>Unenhanced T1-weighted</td>
<td>27</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Unenhanced T2-weighted</td>
<td>47</td>
<td>59</td>
<td>97</td>
</tr>
<tr>
<td>Unenhanced T1- and T2-weighted</td>
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<td>45</td>
<td>98</td>
</tr>
<tr>
<td>Enhanced T1-weighted</td>
<td>38</td>
<td>45</td>
<td>97</td>
</tr>
<tr>
<td>Enhanced T1-weighted and unenhanced T1- and T2-weighted</td>
<td>53</td>
<td>35</td>
<td>94</td>
</tr>
</tbody>
</table>

**Table 5**

<table>
<thead>
<tr>
<th>Pulse Sequences</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reader 1</td>
<td>Reader 2</td>
<td>Reader 1</td>
<td>Reader 2</td>
</tr>
<tr>
<td>Unenhanced T1-weighted</td>
<td>81</td>
<td>61</td>
<td>96</td>
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<tr>
<td>Unenhanced T2-weighted</td>
<td>70</td>
<td>61</td>
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</tr>
<tr>
<td>Unenhanced T1- and T2-weighted</td>
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<td>61</td>
<td>93</td>
</tr>
<tr>
<td>Enhanced T1-weighted</td>
<td>69</td>
<td>39</td>
<td>100</td>
</tr>
<tr>
<td>Enhanced T1-weighted and unenhanced T1- and T2-weighted</td>
<td>77</td>
<td>57</td>
<td>96</td>
</tr>
</tbody>
</table>
Figure 1. Transglottic laryngeal cancer and two necrotic lymph nodes identified at CT in a 66-year-old man. The CNN was not detected in one node on an MR image 1 week later (confirmed with pathologic findings). (a, b) Axial CT scans obtained after contrast material administration show low-attenuation-center nodes (arrows) in the left high jugular (a) and spinal accessory chains (b). (c, d) Corresponding axial 800/20 MR images show homogenous nodes (arrow). (e-h) No definite central high signal intensity suggesting necrosis is seen on 2,200/30 (e, g) or 2,200/80 (f, h) axial images (arrow). (i) Postgadolinium fat-suppressed 800/33 image shows no inhomogeneity in enhancement to suggest CNN (arrow). (*) Slight inhomogeneity is seen in the larger node (arrow). Both nodes showed central necrosis at pathologic sectioning.

increase the sensitivity or accuracy in detecting CNN.

The \( \kappa \) test result for interobserver variability in the interpretation of the CT scans for CNN was .81, which corresponded to "excellent" or "almost perfect" concordance (28,29).

Extracapsular Neoplastic Spread (Table 5)

Only CT could be used as the standard for ENS (Table 5). The unenhanced T1- and T2-weighted images read together were most sensitive for ENS (61%–83%), and the gadolinium-enhanced T1-weighted image alone was least sensitive (39%–69%) (Figs 2, 3). The most accurate pulse sequence for detecting ENS was the unenhanced T1-weighted study (78%–90% accurate). Gadolinium enhancement did not increase accuracy in detecting ENS.

The \( \kappa \) test result (.64) for interobserver concordance for the two readers' interpretations of the CT scans for ENS was "good" or "substantial" (28,29).

DISCUSSION

Contrast-enhanced MR imaging is rapidly replacing contrast-enhanced CT in evaluation of the brain. The trend toward MR imaging in the head and neck has proceeded at a less rapid rate because imaging times are longer, motion is more of a problem, and the technology of neck surface coils has lagged behind that of brain coils. With more stylized surface coils being produced, however, the fields of view and imaging ranges required for complete neck evaluation are presently available in most major imaging centers. Thus, one surface coil can be used to encompass the cavernous sinus to the thoracic inlet (ie, Medical Advances volume neck coil), or two coils may be employed by using the multcoil (phased array) system provided by GE Medical Systems. At this point, MR imaging can match
CT in range, field of view, section thickness, and soft-tissue discrimination. Many investigators have already published reports on the utility of MR imaging in the larynx, sinonasal cavity, pharynx, and tongue; structures where the plane of neoplastic spread is often in a craniocaudal direction (1,14). Coronal and/or sagittal imaging in these sites becomes a valuable advantage of MR imaging over CT. Similarly, such planes allow easier appreciation of skull base invasion or perineural neoplastic spread through foramina (7,14,30,31). The latter is particularly well seen on contrast-enhanced fat-suppressed MR studies.

While MR imaging has become the preferred imaging modality in the evaluation of many head and neck primary malignancies, its use in evaluating cervical lymphadenopathy has not been as rapidly accepted (23). In part, this lack of acceptance reflects skepticism by head and neck radiologists that MR imaging can be as accurate as CT in the evaluation of CNN and ENS. With comparable section thicknesses (3-5 mm), MR imaging and CT should have equal ability to “size” the lymph nodes, since they have similar resolution and contrast. The only apparent difference in this regard is that MR imaging has a high-intensity background on T1-weighted images, whereas CT has a low-attenuation background for CNN. Fat-suppression techniques now allow fat background to be seen as lower signal intensity, allowing increased conspicuity of the lymph nodes, particularly when enhanced MR imaging is employed.

If one considers both CT and MR imaging to be comparable as described, then they should be equal in evaluating nodes on the basis of size criteria. Whether one uses maximal or minimal nodal diameters, solid, sharply defined nodes contain metastases about 80% of the time when they exceed size criteria. Som, in a recent review, described the accuracy of CT in detecting neoplastic infiltration by size criteria; 80% of jugulodigastric or submandibular lymph nodes greater than 1.5 cm in diameter and 80% of all other nodes larger than 1.0 cm in diameter were found to be infiltrated with tumor (17). Van den Brekel et al used 9-12-mm size criteria for minimal nodal diameter and showed a sensitivity of 87% and specificity of 94% for detecting pathologic nodes (32).

Glazer et al measured T1 and T2 relaxation times in freshly excised mediastinal lymph nodes to see whether one could distinguish malignant from benign lymphadenopathy (33). Although a statistically significant (P < .05) difference in T1 times existed (the benign nodes had lower values), the degree of overlap and large standard deviations preempted preoperative differentiation. This finding was in agreement with those of other in vitro reports about high-field-strength systems; all of them, however, showed overlap of T1 and T2 values (16,34). Another report about axillary lymph nodes noted a prolongation of T2 times in metastatic lymph nodes versus reactive ones, but this finding was not duplicated in the work of other investigators (16,33,35).

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Clearly, the MR imaging issues in determining lymph node metastases beyond size criteria have not been resolved.

The evaluation of CNN is just as complex. CNN occurs as neoplastic infiltration of the medullary portion of lymph nodes outstrips the blood supply (17,21,32,36,37). In van den Brekel’s study, CT was shown to have a sensitivity of 74% and specificity of 94% for detecting CNN greater than 3 mm in diameter (32). CNN occurred in 32% of nodes (46 of 144) in that report (32). The central zone of decreased attenuation on CT scans actually represents both tumor infiltration and necrosis. Whereas both of these pathologic changes cause decreased nodal attenuation at CT, they cause different signal intensities at MR imaging. Most tumor cells have intermediate signal intensity on T1- and T2-weighted images, whereas necrosis is hypointense on T1-weighted images and hyperintense on T2-weighted images. Necrotic areas have low T1-weighted and very high T2-weighted signal intensity (23). These changes are admixed with the signal...
Figure 3. Periparotid nodal mass due to metastatic squamous cell carcinoma (pathologically proved) in a 59-year-old man.
(a) Axial 700/17 MR image shows a low-intensity mass (arrow) infiltrating the posterior aspect of the left parotid gland. (b, c) Axial 2,000/30 (b) and 2,000/90 (c) MR images demonstrate that the mass (arrow) is low in intensity relative to fat, but higher relative to muscle. (d) Axial fat-suppressed gadolinium-enhanced spoiled gradient-echo T1-weighted 52/1,5 image obtained with a 40° flip angle demonstrates irregular enhancement extending into adjacent fat, which is suggestive of ENS (arrow). Areas of lower intensity suggest CNN but are equivocal. (e) Enhanced CT scan demonstrates infiltrative, inhomogeneous mass (arrow) interpreted as nodal necrosis and extracapsular spread.

intensity of the uninvolved nodal tissue, leading to a complex interplay of signal intensities.

Our study demonstrates that, compared with CT, MR imaging is still relatively insensitive to the detection of CNN. The highest sensitivity achievable with MR imaging for CNN was 60%–67% with pathologically proved nodes. The sensitivity of CT was 83%–100%, and its accuracy of 91%–96% was greater than that of any MR reading. Using gadolinium and fat-suppression techniques did not increase accuracy in detecting CNN; both sensitivity and specificity suffered with the combined enhanced and unenhanced reading. MR images false-negative for CNN occurred at all size ranges, including nodes no more than 1.0 cm and greater than 3.0 cm in maximum diameter. The two nodes evaluated that were no more than 1.0 cm in diameter and had CNN were read as negative at MR imaging. We conclude that for the evaluation of CNN, CT is still the most sensitive and accurate study, regardless of the size of the nodes.

Examining aspects of nodal internal architecture and extracapsular disease is not moot; it has been found that patients with CNN and ENS have a 50% lower 5-year survival rate than those without CNN or ENS (17). With regard to ENS, once the capsular barrier is breached, neoplastic infiltration through the fatty tissue of the neck may progress rapidly; one typically will see obscuration of the margins of the lymph node and streakiness to the adjacent fat. Although it was once thought that ENS occurred only in large nodes, it is now known that ENS can occur in 23% of nonenlarged nodes (17). The detection of ENS is helpful in treatment planning and prognostication; its appearance, however, may be simulated by lymphadenitis, cellulitis, postsurgical edema, and post-radiation therapy scarring. MR imaging, because of its greater soft-tissue differentiation, should be more accurate than CT in identifying ENS, yet our study shows that findings at MR imaging disagree with those at CT in 10%–38% of cases, with a maximum sensitivity of 61%–83% with unenhanced T1- and T2-weighted images (Table 5). There is ample evidence in the literature to justify using CT as the standard for ENS, and on the basis of this assumption, we believe that MR imaging is not as accurate as CT for detecting ENS. We found that MR imaging suggested ENS that was not found at CT in fewer than 9% of cases, while CT suggested ENS that was not reported with MR imaging in 17%–61% of cases (Table 5). Either CT has a high false-positive rate or MR imaging is not as sensitive or accurate as CT; we and the literature support the latter theory (17–19,23).

A recent study published in Radiology has shown the ability of MR imaging to help investigate the microarchitecture of lymph nodes in vitro (37). Lee et al found that they could separate the lymphoid follicles from medullary sinuses in the lymph nodes of rodents. Hypercellular areas of the lymph node could be distinguished from connective tissue stroma on T2-weighted images, and this distinction could be enhanced after administration of superparamagnetic iron oxide (37). It is hoped that, in the future, the work of Lee et al will be duplicated in humans, by using high-resolution MR images to eliminate the reliance on size criteria or rim enhancement in the detection of neoplasm in nodes.

In an ideal situation, one would perform one imaging test to evaluate...
the extent of the primary head and neck neoplasm and the associated cervical lymphadenopathy. While the enthusiasm for MR imaging in depicting some head and neck primary tumors seems to be supported in the literature, this study suggests that CT remains, at present, the most accurate means for evaluating lymphadenopathy for CNN and ENS. Therefore, for the optimal evaluation of head and neck malignancies, CT should be performed to evaluate the lymph nodes, even in those primary neoplasms best delineated with MR imaging.

References
22. Dooms GC, Hricak H. Radiologic imaging modalities, including magnetic resonance, for evaluating lymph nodes. West J Med 1986; 144:49-57.
There are excellent books devoted to computed tomography (CT) or magnetic resonance (MR) imaging of either the central nervous system or the head and neck. Specialized texts also exist on imaging of the orbit. This book is unique because it surveys all three areas. Although the publisher proclaims this to be a second edition, it represents more than a mere update, and thus ownership of the previous volume should not preclude scrutiny and/or ownership of this one. The discussions are updated, the illustrations are markedly improved, and numerous cases evaluated with MR imaging are now included. The authors have attempted to integrate pathophysiology with the imaging modalities.

The work is organized into two volumes of approximately equal size. There is a total of 13 sections. Each section is on a general topic and contains one or more chapters. The first three parts are introductory in nature. They are "Physical Principles," with a chapter on producing superior MR images; "Anatomy," with an atlas of the adult cerebrum and cerebral vascular territories; and "Physiology," with chapters on contrast media, cerebral blood flow analysis, and MR flow effects. Parts four through nine are on general topics in neuroradiology, including infarction, trauma, and hemorrhage; inflammatory diseases of the brain; and degenerative disorders and congenital anomalies. The next two parts are on the orbit and MR and CT imaging in otorhinolaryngology. A section covering the spine is 10 chapters long. The final section is unique among books in this field. It discusses interventional techniques in cross-sectional imaging and is entitled "Therapeutic Techniques Using MR and CT."

The figures are reproduced well and clearly depict the abnormalities the authors intended to illustrate. The index is well designed. Although most of the references are current, some chapters have references that are somewhat dated. Although in no way can this book be considered encyclopedic and infinitely detailed, it certainly includes all of the common topics. Overall, it is well written. I believe residents in radiology and general radiologists would find this book useful. For the nonspecialist, it probably represents the best current value for a survey of imaging interpretation in neuroradiology, otorhinolaryngology, and ophthalmology.

Reviewed by David S. Martin, MD