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Revised 2007 (Res. 6)*

PRACTICE GUIDELINE FOR THE PERFORMANCE OF MAGNETIC RESONANCE IMAGING (MRI) OF THE HEAD AND NECK

PREAMBLE

These guidelines are an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the American College of Radiology cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the guidelines, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of the guidelines. However, a practitioner who employs an approach substantially different from these guidelines is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment.

Therefore, it should be recognized that adherence to these guidelines will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

I. INTRODUCTION

This guideline was developed collaboratively by the American Society of Neuroradiology (ASNR) and the American College of Radiology (ACR).

Magnetic resonance imaging (MRI) of the head and neck is a proven and useful tool for the evaluation, assessment of severity, and follow-up of diseases of the head and neck. Head and neck MRI should be performed only for a valid medical reason.

The choice of MRI of a head or neck lesion requires an analysis of the strengths of MRI versus its suitability for the particular patient and particular clinical situation. For suspected lesions requiring a technique to detect subtle soft-tissue contrast, to provide a three-dimensional depiction of a lesion, and to image other than with ionizing radiation, or in a patient with an allergy to iodinated contrast and a need for contrast, MRI might be the procedure of choice provided that the patient does not have a contraindication to MRI (see section V below). Due to the time and patient positioning required for MR imaging, the patient must be able to fully cooperate for a prolonged period of time. Computed tomography (CT) may be a better option if any existing limitations such as severe claustrophobia, altered mentation, or an underlying

medical condition such as congestive failure or a breathing disorder that makes lying flat difficult, cannot be adequately addressed prior to the procedure. Neck lesions associated with production of excessive secretions or clinical conditions that require a quick procedure and answer, such as a fulminant infection [1], may contraindicate MRI as an imaging choice. MR images may also not provide valuable information due to the location of internal metal, such as dental fillings or devices in the teeth adjacent to a potential floor of mouth lesion. In addition, if detection of subtle bone erosion or calcification is important to answer a clinical question, then CT scanning becomes a better option than MRI.

II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the [ACR Practice Guideline for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#).

III. SAFETY GUIDELINES AND POSSIBLE CONTRAINDICATIONS

See the [ACR Practice Guideline for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#) and the [ACR Guidance Document for Safe MR Practices \[2\]](#).

Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis.

IV. SPECIFICATIONS OF THE EXAMINATION

The supervising physician must have complete understanding of the indications, risks, and benefits of the examination, as well as alternative imaging procedures. The physician must be familiar with potential hazards associated with MRI, including potential adverse reactions to contrast media. The physician should be familiar with relevant ancillary studies that the patient may have undergone. The physician performing MRI interpretation must have a clear understanding and knowledge of the anatomy and pathophysiology relevant to the MRI examination.

The written or electronic request for MRI of the head and neck should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state's scope of practice requirements. (ACR Resolution 35, adopted in 2006)

The supervising physician must also understand the pulse sequences to be employed and their effect on the appearance of the images, including the potential generation of image artifacts. Standard imaging protocols may be established and varied on a case-by-case basis when necessary. These protocols should be reviewed and updated periodically.

A. Patient Selection

The physician responsible for the examination shall supervise patient selection and preparation, and be available in person or by phone for consultation. Patients shall be screened and interviewed prior to the examination to exclude individuals who may be at risk by exposure to the MR environment.

Certain indications require administration of intravenous (IV) contrast media. IV contrast enhancement should be performed using appropriate injection protocols and in accordance with the institution's policy on IV contrast utilization. (See the [ACR Practice Guideline for the Use of Intravascular Contrast Media](#).)

Patients suffering from anxiety or claustrophobia may require sedation or additional assistance. Administration of moderate sedation may be needed to achieve a successful examination. If moderate sedation is necessary, refer to the [ACR Practice Guideline for Adult Sedation/Analgesia](#) or the [ACR Practice Guideline for Pediatric Sedation/Analgesia](#).

B. Facility Requirements

Appropriate emergency equipment and medications must be immediately available to treat adverse reactions associated with administered medications. The equipment and medications should be monitored for inventory and drug expiration dates on a regular basis. The equipment, medications, and other emergency support must also be appropriate for the range of ages and sizes in the patient population.

C. Examination Technique

Due to the complexity of the anatomy from the skull base through the neck, and the many available imaging choices, a detailed clinical examination of the patient, with clear communication of the results of the

examination to the radiologist, is of critical importance in designing the best imaging procedure to address the patient's problem.

The multiple technical options developed for MR imaging should be employed when their individual strengths serve the clinical question to be answered. T1-weighted images (short repetition time [TR]/short echo time [TE]) remain best for delineating fine anatomic detail when the structure in question is surrounded by soft tissue [3]. For structures surrounded by cerebrospinal fluid, such as the cranial nerves in the cisterns and internal auditory canals, thin, 3D T2-weighted images provide excellent delineation of detail [4]. Fast-spin-echo (FSE) T2-weighted imaging (long TR/long TE FSE) demonstrates greater detail in a shorter time than conventional T2-weighted imaging and is favored in the head and neck as physiologic and gross patient motion commonly degrade images [5,6]. Because fat remains hyperintense on T2-weighted FSE images, and due to the amount of fat about and between many head and neck structures, employing fat-suppression techniques such as chemical shift or STIR produces images with better delineation of pathology [5].

Many types of pathology in the head and neck exhibit contrast enhancement, and the degree to which a lesion enhances may narrow its differential diagnosis. T1-weighted, contrast-enhanced images should, in most cases, be obtained with fat suppression so that an enhancing lesion will not be rendered difficult to differentiate from surrounding hyperintense fat. But since fat suppression increases magnetic susceptibility artifacts, the presence of a metallic device in the area of interest could obscure pathology. In such cases T1 weighting without fat suppression might be used.

Gradient-echo imaging may be useful where detection of blood becomes important, as FSE imaging is not as sensitive for detecting paramagnetic forms of blood as is gradient-echo or conventional spin-echo imaging. For questions concerning vascular invasion or abnormal vessels, MR angiography or venography may be useful [7].

The choice of imaging planes depends on the anatomy to be demonstrated. For most head and neck lesions, axial and coronal imaging may suffice, although sagittal images are useful for tongue base, palate, nasopharynx, and airway lesions and are critical in temporomandibular joint evaluations. Oblique imaging along anatomic structures in off-axis orientations, such as the temporomandibular joint [8,9] and the optic nerves [10], better depicts local detail.

Surface coils are required to provide the fine detail needed to detect pathology in the skull base and neck. The choice of a head or neck coil depends on the suspected extent of pathology [11] and the extent of coverage of the

available coils. For fine detail of small body parts, such as the globe or temporomandibular joint, a small, specialized coils have been recommended, although studies with such coils may require longer imaging times and are easily degraded by motion [12], especially when the coils are placed on the skin rather than fixed a short distance away [13]. With advances in coil design and phased array technology, the use of brain and head and neck surface coils may produce the good quality thin images needed to display head and neck anatomy and pathology to best advantage [14,15].

The number of averages, the field of view, matrix size, and interslice distance should be adjusted to provide maximum detail and a pixel width of 1 mm or less, while considering the need for short scanning times to avoid motion degradation of the images.

Whatever technique is required for optimal demonstration of an area, MR imaging should be performed, whenever possible, before a biopsy to avoid misinterpretation due to distortions produced by an invasive procedure [16,17].

D. Specialized Techniques and Indications

MRI is the procedure of choice to identify intracranial or perineural spread from a head or neck primary tumor, particularly those arising in the nasopharynx, sinonasal cavity, or temporal bone. MRI is also helpful for evaluating intracranial complications of infections and inflammatory conditions of the sinonasal, middle ear, and mastoid cavities.

1. Orbits

MRI is, in general, the procedure of choice for orbital imaging because of its lack of ionizing radiation, fine delineation of detail, and excellent demonstration of associated intracranial pathology [18-20]. CT is reserved for evaluation of trauma; foreign bodies, especially those with unknown ferromagnetic properties [20]; lesions that might calcify [3,21]; and localized infection, such as orbital involvement by an adjacent aggressive sinus infection, both for the rapidity of the examination and for its evaluation of bone involvement.

Head surface coils are required to study the globes optimally, with smaller coils occasionally useful to examine the globes in greater detail. Thin section, fat-suppressed T2-weighted images or short T1 inversion recovery (STIR) coronal images should be obtained to visualize signal changes in the optic nerves [10,20,22]. Sagittal, coronal, and axial T1-weighted images, and T2-weighted scans with fat suppression in at least one plane, usually coronal, may be supplemented

by sagittal oblique and axial oblique scans for detailed depiction of the optic nerves [10,11,19, 23]. Proper windowing of the images is important, especially on T1-weighted images, to avoid obscuration of detail by hyperintense fat [3]. Contrast-enhanced T1-weighted images are useful for examining neoplastic, infectious, inflammatory, ischemic, vascular [19], demyelinating [21], and infiltrative [12] processes, as well as for evaluating the intracranial extent of a lesion [18,24]. The contrast-enhanced images require fat suppression in at least one plane due to the amount of intraorbital fat [3,11,19,21,23]. One enhanced plane without fat suppression might be useful if pathology is suspected in or adjacent to an area subject to susceptibility artifact, such as an air-filled sinus cavity or dental metal [25]. Imaging of orbital detail usually requires small field of view imaging, and 3 mm image widths [21], with pixels no larger than 1 mm. Small section widths with thin or no interslice gaps are especially useful for studies of the globes and optic nerves [22,23].

If the cranial nerves are involved or if the lesion is likely to involve the brain or subarachnoid space, such as a retinoblastoma, melanoma, or optic glioma, long TR images of the brain, at least in the axial plane [26], and T1-weighted, contrast-enhanced images [24] are needed. Section widths of 4 to 5 mm, with minimal pixel size [21] and a slightly larger field of view (FOV) (i.e., 18 to 20 mm), provide better signal-to-noise ratios [27]. In cases of suspected optic neuritis, inclusion of fluid-attenuated inversion-recovery (FLAIR) imaging of the brain is of value to detect associated demyelination [22].

2. Sinonasal cavities

Computed tomography is the imaging modality of choice for cases of inflammation of the sinonasal cavities, with MRI reserved for evaluating complications of sinus disease [28-30], including orbital, skull base and intracranial extension [17,20,31-33]. For all suspected neoplasms, and to distinguish tumors and polyps from mucosal thickening and secretions, MRI with contrast enhancement is the study of choice [17,24,34,35]. Perineural extension of tumor and meningeal spread are preferably studied with enhanced MR imaging. Surface coils, most commonly a head coil, are used, and 3 mm image widths with a narrow gap (preferably 1 mm or less) are suggested [17,36]. T1-weighted and T2-weighted FSE fat-suppressed images and T1-weighted enhanced scans, employing fat

suppression in at least one plane [34,36], with imaging in at least coronal and axial planes, demonstrate detail adequately. Associated septic venous thrombosis might be detected with magnetic resonance venography (MRV) techniques [34].

3. Suprahyoid neck

MRI is the procedure of choice for most pathology of the suprahyoid neck, which includes the skull base, nasopharynx and oropharynx [1,8,16,37,38].

In the suprahyoid neck, bone infiltration by soft tissue lesions may be detected earlier by MR than by CT [8,39-41] which relies on bone erosion, a later event [42]. Subtle cortical erosion, especially without infiltration of the medullary cavity, and detail of small bones and foramina are, however, better demonstrated by CT [6,43,44]. Contrast enhanced MRI best depicts intracranial extension of tumor from the head and neck, including perineural extension [17,45]. T1-weighted and fat suppressed T2-weighted images, and fat-suppressed T1-weighted sequences in at least axial and coronal planes, with small fields of view, small interslice gaps, and high matrix imaging, provide adequately detailed images of the skull base and nasopharynx [6,38,45-48].

In the oral cavity, masses are best demonstrated by MRI due to its superior contrast resolution and the less severe effect of dental amalgam artifacts [49] relative to CT studies. Sagittal, fat-suppressed, long TR scans are useful to demonstrate the depth of invasion of base of tongue lesions, and sagittal imaging may complement coronal scans in evaluations of the palate, especially its posterior aspect. For infections in adults, contrast enhanced CT is preferred to detect small calculi and to determine the integrity of the mandibular cortex [33], but MR is of value in the early detection of acute medullary bone involvement in mandibular and maxillary osteomyelitis, and in planning surgery for chronic osteomyelitis [49,50].

For imaging of the oropharynx and hypopharynx, slightly hyperextending the neck and instructing the patient to breathe quietly are useful techniques to improve image quality [46]. The use of saturation pulses is helpful to reduce vascular flow artifacts in the area. MR imaging, with MR angiography and venography as needed, is helpful to delineate vascular invasion and compromise [51,52].

4. Infrahyoid neck

Controversy concerning the role of MRI in infrahyoid neck imaging continues, with advocates for CT, in part due to the prevalence of motion in the area related to breathing and swallowing, and MRI, for most pathology. The development of rapid, multiplanar, and volume CT capabilities challenges MRI's former advantage in producing images in multiple planes [53], although MR still provides better soft tissue contrast than CT [16] and is more sensitive and specific than CT in defining cartilage invasion [16,54].

MR imaging of the infrahyoid neck requires the use of surface coils [55] not supported by the neck itself to avoid motion artifacts [13]. A small FOV and large enough matrix to produce detailed images while maintaining short scanning times are additional requirements [55]. The neck should be slightly hyperextended, with the larynx parallel to the table top [13], and with the patient breathing quietly [56]. Inferior and superior saturation pulses are a valuable addition to control for vascular flow artifacts [57].

The detection of lymph node pathology, especially metastatic disease, requires finely detailed imaging with small fields of view and high matrices, with resultant long imaging times and an increased chance of patient motion [58, 59]. Imaging coverage includes from the skull base to at least the supraclavicular fossae so the surface coil employed should be able to evaluate this area in its entirety [32]. For visceral space pathology, especially thyroid and parathyroid, extension of imaging to include the carina is necessary for complete demonstration of potentially involved areas [60]. For detecting lymph nodes in the neck, T2-weighted imaging with fat suppression, either FSE or STIR [61, 62], is preferred, but for detecting nodal necrosis, fat-suppressed, enhanced, detailed T1-weighted imaging is necessary [59].

5. Thyroid and parathyroid

In evaluations of the thyroid and parathyroid glands, ultrasound with aspiration biopsy and radioscintigraphy play primary roles [63-65]. If a thyroid lesion is found to contain a differentiated carcinoma, and delineation of the area is necessary prior to definitive therapy [60], or in the case of initial evaluation of a symptomatic mass in the thyroid area of uncertain etiology [66], MRI with contrast is useful as it avoids

delays in therapy with radioiodine, as would be the case if iodinated contrast for a CT study were used. However, if radioiodine therapy is not a consideration, better detail of the thyroid and parathyroid glands is usually obtained with CT scanning [60] due to breathing and vascular pulsation degradation of MR images. Imaging with MR or CT should include extension inferiorly to include the carina to evaluate the entire area of potential involvement [60,66], using T1-weighted and T2-weighted images in at least the axial plane, and with respiratory [57, 67] and cardiac compensation [67] helpful to reduce motion artifacts.

6. Temporal bone

MRI is the primary imaging modality for evaluating the nonosseous components of the temporal bone region [31] which include evaluations of suspected retrocochlear pathology [17] and cranial nerve dysfunction, most commonly sensory neural hearing loss [4,68, 69]. It is useful to determine if temporal bone pathology such as infections or tumors involve the cranial contents, including perineural spread of tumors. CT is favored if a labyrinthine or cochlear lesion is suspected [70,71], although lesions such as cochlear schwannomas or hemorrhages are better detected by MR. CT is frequently more helpful than MR in evaluations for pulsatile tinnitus or a detected retrotympanic mass [4,72]. If tinnitus is abolished by jugular vein pressure, MRV might be useful. If a systolic bruit is audible, MRA [72] or CT angiography might be helpful.

MRI of the temporal bones requires a head coil and should include axial T1-weighted images, with and without contrast enhancement, and coronal T1-weighted enhanced scans. Fat suppression in at least one enhanced plane is useful to eliminate confusion of fat with enhancement, especially in the area of the petrous apex [31]. A maximum section width of 3 mm with a minimal or no interslice gap and a small FOV are needed to produce images able to depict the fine detail required to detect pathology in this area.

Thin section, 3D T2-weighted techniques are useful in temporal bone imaging to evaluate the relationship of a vestibular schwannoma or other pathology to the surrounding nerves [73], the patency of labyrinthine structures, the size of the endolymphatic sac, and the extent of cochlear dysplasia in cases of congenital or develop-

mental hearing loss. Long TR images of the brain should be included to exclude intracranial processes such as demyelination that might produce symptoms similar to those of temporal bone lesions [69].

7. Temporomandibular joints

MRI is the procedure of choice for most clinical presentations of temporomandibular joint pathology. For optimal imaging, small surface coils are suggested as they depict fine detail most accurately. Dual 3 inch coils allow simultaneous imaging of both temporomandibular joints resulting in an imaging time reduction [9,74-76]. Scanning in an oblique plane perpendicular to the horizontal long axis of the mandibular condyle produces the least distorted images of the menisci in the sagittal plane [77]. Many authors recommend proton density and T2-weighted sagittal oblique imaging in open mouth and closed mouth positions [9,74-76]. The T2-weighted images are preferred to evaluate for joint effusions and capsular inflammation. Coronal oblique imaging with T1 or proton density weighting permits detection of medial and lateral displacements of the menisci [23,50]. Three mm or lower section thicknesses, 0 to 1 mm image gaps, and small FOVs are additional requirements to obtain adequately detailed images [9,75,76,78,79].

Further evaluation of the patient with temporomandibular joint dysfunction might include kinematic MRI procedures to obtain functional information especially in cases of reduced range of motion, malocclusion, mandibular shift and hypermobility. T1-weighted imaging is typically employed and scans are obtained as the mouth is incrementally opened using a passive positioning device [80-88].

V. DOCUMENTATION

Reporting should be in accordance with the [ACR Practice Guideline for Communication of Diagnostic Imaging Findings](#).

The report should address the presence or absence of a mass, the size of the lesion and its composition, signal intensity, and enhancement characteristics. A description of the anatomic location of a tumor, including its relationships to adjacent major muscles, vessels, and nerves, will contribute to the tumor's grading and staging.

VI. EQUIPMENT SPECIFICATIONS

The MRI equipment specifications and performance shall meet all state and federal requirements. The requirements include, but are not limited to, specifications of maximum static magnetic strength, maximum rate of change of magnetic field strength (dB/dt), maximum radiofrequency power deposition (specific absorption rate), and maximum acoustic noise levels.

VII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing elsewhere in the ACR Practice Guidelines and Technical Standards book.

Specific policies and procedures related to MRI safety should be in place with documentation that is updated annually and compiled under the supervision and direction of the supervising MRI physician. Guidelines should be provided that deal with potential hazards associated with the MRI examination of the patient as well as to others in the immediate area. Screening forms must also be provided to detect those patients who may be at risk for adverse events associated with the MRI examination.

Equipment monitoring should be in accordance with the [ACR Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging \(MRI\) Equipment](#).

ACKNOWLEDGEMENTS

This guideline was revised according to the process described in the ACR Practice Guidelines and Technical Standards book by the Guidelines and Standards Committee of the Commission on Neuroradiology in collaboration with the American Society of Neuroradiology (ASNR).

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REFERENCES

1. Som PM. The present controversy over the imaging method of choice for evaluating the soft tissues of the neck. *AJNR Am J Neuroradiol* 1997;18:1869-1872.
2. Kanal E, Borgstede J, Barkovich A, et al. American College of Radiology Guidance Document for Safe MR Practices. *AJR Am J Roentgenol* 2007;188:1-27.
3. Weber AL, Sabates NR. Survey of CT and MR imaging of the orbit. *Eur J Radiol* 1996;22:42-52.
4. Maya MM, Lo WM, Kovanlikaya I. Chapter 25: Temporal bone tumors and cerebello-pontine angle lesions. In: Som PM, Curtin HD, eds. *Head and Neck Imaging*. 4th ed. Philadelphia, Pa: Mosby; 2003:1275-1360.
5. Lewin JS, Curtin HD, Ross JS, Weissman JL, Obuchowski NA, Tkach JA. Fast spin-echo imaging of the neck: comparison with conventional spin-echo, utility of fat suppression, and evaluation of tissue contrast characteristics. *AJNR Am J Neuroradiol* 1994;15:1351-1357.
6. Sigal R. Oral cavity, oropharynx, and salivary glands. *Neuroimaging Clin N Am* 1996;6:379-400.
7. Fordham LA, Chung CJ, Donnelly LF. Imaging of congenital vascular and lymphatic anomalies of the head and neck. *Neuroimaging Clin N Am* 2000;10:117-136.
8. Ng SH, Chang TC, Ko SF, et al. Nasopharyngeal carcinoma: MRI and CT assessment. *Neuroradiology* 1997;39:741-746.
9. Westesson PL, Yamamoto M, Sano T, Okano T. Chapter 18: Temporomandibular joints: anatomy and pathology. In: Som PM, Curtin HD, eds. *Head and Neck Imaging*. 4th ed. Philadelphia, Pa: Mosby; 2003.
10. Weber AL, Caruso P, Sabates NR. The optic nerve: radiologic, clinical, and pathologic evaluation. *Neuroimaging Clin N Am* 2005;15:175-201.
11. Hesselink JR, Karampekios S. Normal computed tomography and magnetic resonance imaging anatomy of the globe, orbit, and visual pathways. *Neuroimaging Clin N Am* 1996;6:15-27.
12. Mafee MF, Ainbinder D, Afshani E, Mafee RF. The eye. *Neuroimaging Clin N Am* 1996;6:29-59.
13. Castelijns JA, Hermans R, van den Brekel MW, Mukherji SK. Imaging of laryngeal cancer. *Semin Ultrasound CT MR* 1998;19:492-504.
14. Hayes CE, Tsuruda JS, Mathis CM, Maravilla KR, Kliot M, Filler AG. Brachial plexus: MR imaging with a dedicated phased array of surface coils. *Radiology* 1997;203:286-289.
15. Henry RG, Fischbein NJ, Dillon WP, Vigneron DB, Nelson SJ. High-sensitivity coil array for head and neck imaging: technical note. *AJNR Am J Neuroradiol* 2001;22:1881-1886.
16. Million RR, Cassisi NJ, Mancuso AA. Hypopharynx: pharyngeal walls, pyriform sinus, postcricoid pharynx. In: Million RR, Cassisi NJ, eds. *Management of Head and Neck Cancer: A Multidisciplinary Approach*. Philadelphia, Pa: J.B. Lippincott; 1994:532-550.
17. Nemzek WR. The Larynx and hypopharynx. *Post Graduate Course, 31st Annual Scientific Conference in Head and Neck Imaging of the ASHNR*. Oak Brook, Ill: American Society of Head and Neck Radiology; 1997:37-43.
18. Barnes PD, Robson CD, Robertson RL, Poussaint TY. Pediatric orbital and visual pathway lesions. *Neuroimaging Clin N Am* 1996;6:179-198.
19. Ortiz O, Flores RA. Clinical and radiologic evaluation of optic pathway lesions. *Semin Ultrasound CT MR* 1998;19:225-239.
20. Zimmerman RA, Bilaniuk LT, Savino PJ. Chapter 11: Visual pathways: embryology, anatomy and pathology. In: Som PM, Curtin HD, eds. *Head and Neck Imaging*. 4th ed. Philadelphia, Pa: Mosby; 2003:735-782.
21. Davis PC, Hopkins KL. Imaging of the pediatric orbit and visual pathways: computed tomography and magnetic resonance imaging. *Neuroimaging Clin N Am* 1999;9:93-114.
22. Belden CJ. MR imaging of the globe and optic nerve. *Neuroimaging Clin N Am* 2004;14:809-825.
23. Weber AL, Klufas R, Pless M. Imaging evaluation of the optic nerve and visual pathway including cranial nerves affecting the visual pathway. *Neuroimaging Clin N Am* 1996;6:143-177.
24. Koch BL. Imaging extracranial masses of the pediatric head and neck. *Neuroimaging Clin N Am* 2000;10:193-214.
25. Mafee MF, Rapoport M, Karimi A, Ansari SA, Shah J. Orbital and ocular imaging using 3- and 1.5-T MR

- imaging systems. *Neuroimaging Clin N Am* 2005;15:1-21.
26. Mark AS. Oculomotor motion disorders: current imaging of cranial nerves 3, 4, and 6. *Semin Ultrasound CT MR* 1998;19:240-256.
 27. Mukherji SK, Pillsbury HR, Castillo M. Imaging squamous cell carcinomas of the upper aerodigestive tract: what clinicians need to know. *Radiology* 1997;205:629-646.
 28. Fatterpekar G, Mukherji S, Arbealez A, Maheshwari S, Castillo M. Fungal diseases of the paranasal sinuses. *Semin Ultrasound CT MR* 1999;20:391-401.
 29. Hahnel S, Ertl-Wagner B, Tasman AJ, Forsting M, Jansen O. Relative value of MR imaging as compared with CT in the diagnosis of inflammatory paranasal sinus disease. *Radiology* 1999;210:171-176.
 30. Larson TL. Sinonasal inflammatory disease: pathophysiology, imaging, and surgery. *Semin Ultrasound CT MR* 1999;20:379-390.
 31. Chakeres DW, Augustyn. Chapter 20: Temporal bone: imaging anatomy. In: Som PM, Curtin HD, eds. *Head and Neck Imaging*. 4th ed. Philadelphia, Pa: Mosby; 2003:1095-1108.
 32. Ishikawa M, Anzai Y. MR imaging of lymph nodes in the head and neck. *Neuroimaging Clin N Am* 2004;14:679-694.
 33. Smoker WR. Chapter 27: Oral cavity: anatomy and pathology. In: Som PM, Curtin HD, eds. *Head and Neck Imaging*. 4th ed. Philadelphia, Pa: Mosby; 2003:1377-1364.
 34. Hudgins PA. Sinonasal imaging. *Neuroimaging Clin N Am* 1996;6:319-331.
 35. Kubal WS. Sinonasal imaging: malignant disease. *Semin Ultrasound CT MR* 1999;20:402-425.
 36. Hermans R, De Vuysere S, Marchal G. Squamous cell carcinoma of the sinonasal cavities. *Semin Ultrasound CT MR* 1999;20:150-161.
 37. Harnsberger HR. Global imaging anatomy of the neck. In: Harnsberger HR, Hudgins PA, Wiggins R, et al, eds. *Diagnostic Imaging: Head and Neck*. Salt Lake City, Utah: Amirsys, Inc; 2004:III-0-1-5.
 38. Vogl TJ, Balzer JO. Base of skull, nasopharynx, and parapharyngeal space. *Neuroimaging Clin N Am* 1996;6:357-378.
 39. Barakos JA, Dillon WP, Chew WM. Orbit, skull base, and pharynx: contrast-enhanced fat suppression MR imaging. *Radiology* 1991;179:191-198.
 40. Chong VF, Fan YF. Skull base erosion in nasopharyngeal carcinoma: detection by CT and MRI. *Clin Radiol* 1996;51:625-631.
 41. Chong VF, Fan YF. Detection of recurrent nasopharyngeal carcinoma: MR imaging versus CT. *Radiology* 1997;202:463-470.
 42. Ginsberg LE. Imaging of perineural tumor spread in head and neck cancer. *Semin Ultrasound CT MR* 1999;20:175-186.
 43. Chong VF, Fan YF. Radiology of the jugular foramen. *Clin Radiol* 1998;53:405-416.
 44. Laine FJ, Underhill T. Imaging of the lower cranial nerves. *Magn Reson Imaging Clin N Am* 2002;10:433-449.
 45. Ginsberg LE. MR imaging of perineural tumor spread. *Magn Reson Imaging Clin N Am* 2002;10:511-525.
 46. Pameijer FA, Mukherji SK, Balm AJ, van der Laan BF. Imaging of squamous cell carcinoma of the hypopharynx. *Semin Ultrasound CT MR* 1998;19:476-491.
 47. Som PM, Curtin HD. Inflammatory lesions and tumors of the nasal cavities and paranasal sinuses with skull base involvement. *Neuroimaging Clin N Am* 1994;4:499-513.
 48. Tomura N, Hirano H, Sashi R, et al. Comparison of MR imaging and CT in discriminating tumor infiltration of bone and bone marrow in the skull base. *Comput Med Imaging Graph* 1998;22:41-51.
 49. Wiggins RH. SCCa, Oral tongue. In: Harnsberger HR, Hudgins P, Wiggins R, et al, eds. *Diagnostic Imaging: Head and Neck*. Salt Lake City, Utah: Amirsys, Inc.; 2004:III-4-34-37.
 50. Schuknecht B, Valavanis A. Osteomyelitis of the mandible. *Neuroimaging Clin N Am* 2003;13:605-618.
 51. Eisen MD, Yousem DM, Montone KT, et al. Use of preoperative MR to predict dural, perineural, and venous sinus invasion of skull base tumors. *AJNR Am J Neuroradiol* 1996;17:1937-1945.
 52. Weber AL, McKenna MJ. Radiologic evaluation of the jugular foramen. Anatomy, vascular variants, anomalies, and tumors. *Neuroimaging Clin N Am* 1994;4:579-598.
 53. Curtin HD. Chapter 30: Larynx: anatomy, pathology, and post operative. In: Som PM, Curtin HD, eds. *Head and Neck Imaging*. 4th ed. Philadelphia, Pa: Mosby; 2003:2239-2272.
 54. Wiggins RH. SCCa, larynx. In: Harnsberger HR, Hudgins P, Wiggins R, et al, eds. *Diagnostic Imaging: Head and Neck*. Salt Lake City, Utah: Amirsys, Inc.; 2004:III-3-18-27.
 55. Kaji AV, Mohuchy T, Swartz JD. Imaging of cervical lymphadenopathy. *Semin Ultrasound CT MR* 1997;18:220-249.
 56. Hudgins PA, Siegel J, Jacobs I, Abramowsky CR. The normal pediatric larynx on CT and MR. *AJNR Am J Neuroradiol* 1997;18:239-245.
 57. Nakahara H, Noguchi S, Murakami N, et al. Gadolinium-enhanced MR imaging of thyroid and parathyroid masses. *Radiology* 1997;202:765-772.
 58. King AD, Lei KI, Ahuja AT. MRI of neck nodes in non-Hodgkin's lymphoma of the head and neck. *Br J Radiol* 2004;77:111-115.
 59. King AD, Tse GM, Ahuja AT, et al. Necrosis in metastatic neck nodes: diagnostic accuracy of CT, MR imaging, and US. *Radiology* 2004;230:720-726.
 60. Harnsberger HR. Visceral space anatomy-imaging issues. In: Harnsberger HR, Hudgins P, Wiggins R, et

- al, eds. *Diagnostic Imaging: Head and Neck*. Salt Lake City, Utah: Amirsys, Inc.; 2004:III-11-12.
61. Glastonbury CM. Squamous cell carcinoma nodes. In: Harnsberger HR, Hudgins P, Wiggins R, et al, eds. *Diagnostic Imaging: Head and Neck*. Salt Lake City, Utah: Amirsys, Inc.; 2004:III-2-28-31.
 62. Ishikawa M, Anzai Y. MR imaging of lymph nodes in the head and neck. *Magn Reson Imaging Clin N Am* 2002;10:527-542.
 63. Glastonbury CM. Thyroid adenoma. In: Harnsberger HR, Hudgins P, Wiggins R, et al, eds. *Diagnostic Imaging: Head and Neck*. Salt Lake City, Utah: Amirsys, Inc.; 2004:III-11-16-19.
 64. MacDonald AJ. Parathyroid adenoma, visceral space. In: Harnsberger HR, Hudgins P, Wiggins R, et al, eds. *Diagnostic Imaging: Head and Neck*. Salt Lake City, Utah: Amirsys, Inc.; 2004:III-11-20-23.
 65. Sherman SI. Thyroid carcinoma. *Lancet* 2003;361:501-511.
 66. MacDonald AJ. Anaplastic thyroid carcinoma. In: Harnsberger HR, Hudgins P, Wiggins R, et al, eds. *Diagnostic Imaging: Head and Neck*. Salt Lake City, Utah: Amirsys, Inc.; 2004:III-11-32-35.
 67. Lee VS, Spritzer CE. MR imaging of abnormal parathyroid glands. *AJR Am J Roentgenol* 1998;170:1097-1103.
 68. Casselman JW. Temporal bone imaging. *Neuroimaging Clin N Am* 1996;6:265-289.
 69. Weissman JL. Hearing loss. *Radiology* 1996;199:593-611.
 70. Schmalfuss IM. Imaging of the hypopharynx and cervical esophagus. *Magn Reson Imaging Clin N Am* 2002;10:495-509.
 71. Wiggins RH. EAC cholesteatoma. In: Harnsberger HR, Hudgins P, Wiggins R, et al, eds. *Diagnostic Imaging: Head and Neck*. Salt Lake City, Utah: Amirsys, Inc.; 2004:I-2-14-15.
 72. Lo WW, Maya MM. Chapter 26: Temporal bone: vascular tinnitus. In: Som PM, Curtin HD, eds. *Head and Neck Imaging*. 4th ed. Philadelphia, Pa: Mosby; 2003:1276-1376.
 73. Schmalbrock P, Chakeres DW, Monroe JW, Saraswat A, Miles BA, Welling DB. Assessment of internal auditory canal tumors: a comparison of contrast-enhanced T1-weighted and steady-state T2-weighted gradient-echo MR imaging. *AJNR Am J Neuroradiol* 1999;20:1207-1213.
 74. Rao VM, Bacelar MT. MR imaging of the temporomandibular joint. *Neuroimaging Clin N Am* 2004;14:761-775.
 75. Sano T, Yamamoto M, Okano T. Temporomandibular joint: MR imaging. *Neuroimaging Clin N Am* 2003;13:583-595.
 76. Tomas X, Pomes J, Berenguer J, et al. MR imaging of temporomandibular joint dysfunction: a pictorial review. *Radiographics* 2006;26:765-781.
 77. Musgrave MT, Westesson PL, Tallents RH, Manzione JV, Katzberg RW. Improved magnetic resonance imaging of the temporomandibular joint by oblique scanning planes. *Oral Surg Oral Med Oral Pathol* 1991;71:525-528.
 78. Rao VM. Imaging of the temporomandibular joint. *Semin Ultrasound CT MR* 1995;16:513-526.
 79. Yamada I, Murata Y, Shibuya H, Suzuki S. Internal derangements of the temporomandibular joint: comparison of assessment with three-dimensional gradient-echo and spin-echo MRI. *Neuroradiology* 1997;39:661-667.
 80. Burnett KR, Davis CL, Read J. Dynamic display of the temporomandibular joint meniscus by using "fast-scan" MR imaging. *AJR Am J Roentgenol* 1987;149:959-962.
 81. Conway WF, Hayes CW, Campbell RL. Dynamic magnetic resonance imaging of the temporomandibular joint using FLASH sequences. *J Oral Maxillofac Surg* 1988;46:930-938.
 82. Dorsay TA, Youngberg RA. Cine MRI of the TMJ: need for initial closed mouth images without the Burnett device. *J Comput Assist Tomogr* 1995;19:163-164.
 83. Drace JE, Enzmann DR. Defining the normal temporomandibular joint: closed-, partially open-, and open-mouth MR imaging of asymptomatic subjects. *Radiology* 1990;177:67-71.
 84. Pressman BD, Shellock FG. The Temporomandibular Joint in MRI of the Musculoskeletal System: A Teaching File. In: Mink JH, A.L. D, eds. New York, NY: Raven Press; 1990:521.
 85. Ren YF, Westesson PL, Isberg A. Magnetic resonance imaging of the temporomandibular joint: value of pseudodynamic images. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1996;81:110-123.
 86. Shellock FG. Kinematic magnetic resonance imaging. *Magnetic Resonance Imaging in Orthopaedics and Sports Medicine*. 2nd ed. Philadelphia, Pa: Lippincott-Raven; 1997.
 87. Shellock FG. *Kinematic MRI of the Temporomandibular Joint in Kinematic MRI of the Joints: Functional Anatomy, Kinesiology and Clinical Applications*. Boca Raton, Fla: CRC Press; 2001.
 88. Shellock FG, Pressman BD. Dual-surface-coil MR imaging of bilateral temporomandibular joints: improvements in the imaging protocol. *AJNR Am J Neuroradiol* 1989;10:595-598.
 89. Sawyer-Glover AM, Shellock FG. Pre-MRI procedure screening: recommendations and safety considerations for biomedical implants and devices. *J Magn Reson Imaging* 2000;12:92-106.
 90. Shellock FG. *Guide to MR Procedures and Metallic Objects: Update 1999*. Philadelphia, Pa: Lippincott Williams and Wilkins; 1999.

91. Shellock FG. *Magnetic Resonance Procedures: Health Effects and Safety*. Boca Raton, Fla: CRC Press; 2001.
92. Shellock FG. *Reference Manual for Magnetic Resonance Safety*. 2002 ed. Salt Lake City, Utah: Amirsys, Inc.; 2002.
93. Colletti PM. Magnetic resonance procedures and pregnancy. In: Shellock FG, ed. *Magnetic Resonance Procedures: Health Effects and Safety*. Boca Raton, Fla: CRC Press; 2001.
94. Runge VM. Safety of MR contrast agents. In: Shellock FG, ed. *Magnetic Resonance Procedures: Health Effects and Safety*. Boca Raton, Fla: CRC Press; 2001.

*Guidelines and standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For guidelines and standards published before 1999, the effective date was January 1 following the year in which the guideline or standard was amended, revised, or approved by the ACR Council.

Development Chronology for this Guideline

2002 (Resolution 7)

Amended 2006 (Resolution 35)

Revised 2007 (Resolution 6)