
ACCURACY OF MAGNETIC RESONANCE IMAGING IN PREDICTING ABSENCE OF FIXATION OF HEAD AND NECK CANCER TO THE PREVERTEBRAL SPACE

Wendy C. Hsu, MD,¹ Laurie A. Loevner, MD,^{1,2} Ronit Karpati, MD,¹ Tabassum Ahmed,¹ Andrew Mong, MD,¹ Madhavi L. Battineni, DO,¹ David M. Yousem, MD,³ Kathleen T. Montone, MD,⁴ Gregory S. Weinstein, MD,² Randal S. Weber, MD,^{2*} Ara A. Chalian, MD²

¹ Department of Radiology, University of Pennsylvania Medical Center, 3400 Spruce Street, Philadelphia, PA 19104. E-mail: loevner@oasis.rad.upenn.edu

² Department of Otorhinolaryngology: Head and Neck Surgery, University of Pennsylvania Medical Center, Philadelphia, Pennsylvania

³ Department of Radiology, Johns Hopkins Health System, Baltimore, Maryland

⁴ Department of Pathology, University of Pennsylvania Medical Center, Philadelphia, Pennsylvania

Accepted 22 July 2004

Published online 30 December 2004 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/hed.20128

Abstract: *Background.* The purpose of this study was to determine the preoperative accuracy of preservation of the retropharyngeal fat plane on magnetic resonance (MR) images in predicting the absence of fixation or extension of head and neck carcinomas to the prevertebral space.

Methods. The MR images of 75 patients with T3 or T4 primary pharyngeal or laryngeal cancers seen over a 5-year period and treated at our Head and Neck Cancer Center were retrospectively reviewed. The MR images were independently and blindly evaluated by two head and neck radiologists for preservation of the retropharyngeal fat plane between the tumor and prevertebral musculature. In cases in which the fat was preserved, the pre-

vertebral muscle complex was assessed for the presence of T2 hyperintensity and enhancement. All patients underwent pan-endoscopy, surgery, or both.

Results. Forty of 75 patients had preservation of the retropharyngeal fat plane between the tumor and the prevertebral compartment on T1-weighted images. In all 40 cases, the prevertebral muscles had a normal appearance on T2-weighted and enhanced MR images. Intraoperative assessment revealed absence of fixation of tumor to the prevertebral fascia in 39 of 40 cases, and these tumors were resectable.

Conclusion. In patients with advanced head and neck carcinomas, preservation of the fat between the tumor and the prevertebral musculature on unenhanced T1-weighted images reliably predicts absence of prevertebral space fixation. © 2004 Wiley Periodicals, Inc. *Head Neck* 27: 95–100, 2005

Keywords: head and neck cancer; magnetic resonance imaging; prevertebral space

Correspondence to: L. A. Loevner

Contract grant sponsor: RSNA Research and Education Fund Scholar Grant, and Medical Student/Scholar Assistant Program

*Current address: Department of Head and Neck Surgery, The University of Texas M. D. Anderson Cancer Center, 1515 Holcombe Blvd., Unit 441, Houston, TX 77030.

© 2004 Wiley Periodicals, Inc.

The diagnosis and staging of head and neck cancer are most accurately achieved by direct endoscopic visualization combined with cross-sectional

imaging. Direct laryngoscopy is most accurate in evaluating the mucosal surface of the aerodigestive tract.¹⁻³ In fact, such examination frequently identifies superficial carcinomas along the mucosal surface that cannot be detected on MRI or CT. However, submucosal extension beyond the obvious mucosal component cannot be accurately assessed by endoscopy and physical examination, and MRI and CT are invaluable in this regard.^{4,5} If staging relied only on clinical examination, disease in patients would frequently be understaged.

Accurate assessment of tumor spread not only determines staging but also is important in counseling the patient regarding prognosis and treatment options. It determines whether conservative surgery (partial laryngectomy, local resection, composite resection) and/or radiation can be performed or whether more radical techniques (total laryngectomy) are necessary.^{6,7} In addition to guiding the surgeon in choosing among surgical options for managing an operable tumor, imaging has been used to identify factors that may preclude surgical resection. These factors include encasement of the carotid artery, fixation to the skull base, intracranial tumor extension, extension to the nasopharynx, or invasion of the brachial plexus.⁸⁻¹⁰

Prevertebral space involvement defined as fixation to or direct invasion of the prevertebral fascia eliminates the option of surgical resection and portends a poor prognosis. Extension to the prevertebral compartment currently is most reliably assessed intraoperatively. In some instances, a barium pharyngoesophagogram may be useful when fixation is clinically suspected on the basis of tumor size. A pharyngoesophagogram may demonstrate absence of normal elevation and contraction of the pharynx and esophagus during swallowing, suggesting fixation to the prevertebral compartment. Only a few studies have investigated the role of imaging in detecting the presence of tumor extension into the prevertebral compartment and showed that CT and MRI cannot accurately predict the presence of such spread.^{11,12} However, in patients who are otherwise surgical candidates, it would be useful if preoperative imaging could reliably predict the absence of prevertebral compartment involvement. This would reduce the need for exploratory intraoperative assessment in these patients.

The purpose of this study was to determine whether preservation of the retropharyngeal fat plane on MRI could reliably predict the absence

of direct tumor spread or fixation to the prevertebral space.

PATIENTS AND METHODS

The MR images of 75 patients with advanced (T3 or T4) primary oropharyngeal ($n = 58$), hypopharyngeal ($n = 11$), or laryngeal ($n = 6$) squamous cell carcinomas being evaluated for possible surgical management in the Head and Neck Cancer Center at our institution over a 5-year period (1993–1998) were retrospectively reviewed. The patients (45 men and 30 women) had a mean age of 65 years (range, 38–77 years).

MRI was performed on a 1.5-Tesla system (GE Medical Systems, Milwaukee, WI) with an anteroposterior neck coil (Medical Advances, Madison, WI). Images of the neck extended from the level of the cavernous sinus to the thoracic inlet. The imaging protocol included sagittal spin-echo T1-weighted images (TR/TE, 600/11-17) followed by axial fast spin-echo T2-weighted images (TR/TE, 3500-4000/85-90) and axial spin-echo T1-weighted images (600/11-17). After the administration of 0.1 mM/kg gadopentetate dimeglumine IV (Magnevist, Schering, Berlin, Germany), axial spin-echo T1-weighted imaging using the same parameters as the unenhanced scans or axial fast multiplanar gradient echo (FMPSPGR) sequences were acquired. Fast spin-echo and contrast-enhanced studies were obtained with the application of frequency-selective fat saturation techniques. For the sagittal T1-weighted localizing MR images, a slice thickness of 5 mm with a gap of 1 mm and a 30-cm field of view were used. For all other sequences, a slice thickness of 5 mm with interleaved images was used. Other imaging parameters included one or two excitations, 24- to 36-cm field of view, a 256×128 matrix for sagittal and contrast-enhanced T1-weighted images, and a 256×192 matrix for axial unenhanced T1- and T2-weighted images.

MR images were reviewed independently and blindly by two neuroradiologists unaware of the surgical findings. All MR images were evaluated for the presence of preservation of the retropharyngeal fat between the tumor and the prevertebral musculature (the longus muscle complex) on axial and/or sagittal T1-weighted imaging. In cases in which this fat was preserved, the prevertebral muscles were also assessed for T2-hyperintensity and enhancement.

All scans were reviewed with ENT surgery before management. Patients underwent panen-

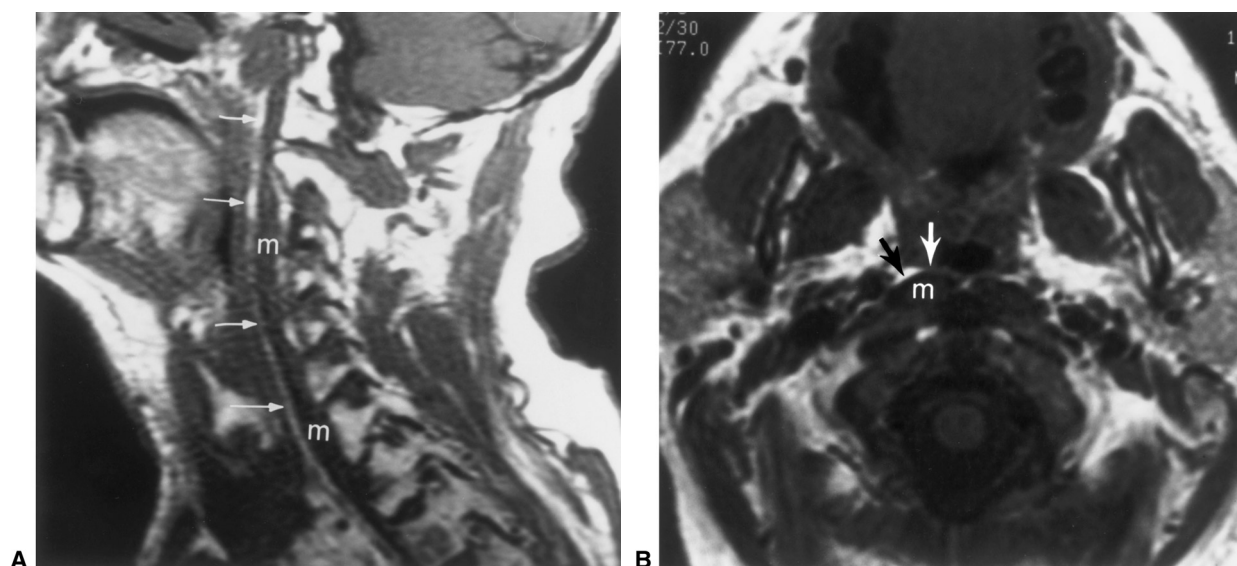


FIGURE 1. Normal anatomy of the retropharyngeal fat and prevertebral space in a 46-year-old man. **(A)** Off-midline sagittal T1-weighted (TR 600/TE 17; section thickness, 5 mm) magnetic resonance (MR) image shows prevertebral compartment of perivertebral space demarcated by precervical retropharyngeal fat seen as hyperintense linear band (arrows). Note longus muscle complex (m). **(B)** Axial T1-weighted (TR 600/TE 17; section thickness, 5 mm) MR image obtained at level of oropharynx shows prevertebral compartment demarcated by the thin layer of precervical retropharyngeal fat (arrows). Longus muscle complex (m).

doscopy and/or surgery, at which time fixation of tumor to the prevertebral fascia was assessed by manual manipulation. A head and neck pathologist analyzed the final histologic findings of the resected specimens for adequacy of tumor margins.

Findings on MRI were correlated with surgical findings. The sensitivity, specificity, accuracy, and negative predictive value of preservation of the retropharyngeal fat plane on T1-weighted imaging were determined. Interobserver agreement regarding image interpretation was based on kappa analysis.

RESULTS

In 40 of 75 patients, there was preservation of the retropharyngeal fat plane between the tumor and the prevertebral compartment on sagittal and/or axial T1-weighted images (Figure 1). It was these 40 patients in whom the preservation of the fat plane in at least one imaging plane was used to test the hypothesis that such preservation would predict operability. Of 80 readings (40 in the axial plane and 40 in the sagittal plane), the observers agreed in 76 (kappa, 0.88) and resolved the four discrepant interpretations by consensus. Specifically, 38 patients had preservation of the retropharyngeal fat on sagittal images, 32 patients had preservation of the fat on images in the axial plane (30 patients had preservation

of the fat plane in both planes). In all 40 cases, the prevertebral longus muscle complex had a normal appearance on T2-weighted and enhanced MR images.

Intraoperative assessment revealed absence of fixation of tumor to the prevertebral fascia in 39 of 40 cases, and the tumors in these 39 cases were resectable with macroscopically clear surgical margins. At pathologic evaluation, all 39 resected tumors had tumor-free surgical margins histologically. Therefore, preservation of the retropharyngeal fat between the tumor and the prevertebral musculature reliably predicted absence of neoplastic fixation with a negative predictive value of 97.5%. In the one false-negative case in our study, there was a delay of 4 weeks between the time of imaging and surgery in a poorly differentiated carcinoma, which might explain the discrepancy between imaging and intraoperative findings (Figure 2).

DISCUSSION

In squamous cell carcinoma of the head and neck, CT and MRI play a critical role in staging. Cross-sectional imaging is used to assess for the presence of nodal metastases,¹³⁻¹⁷ thyroid cartilage invasion,^{18,19} and encasement of the carotid artery that may occur in the presence of large primary tumors or cervical nodal metastases.^{8,9}

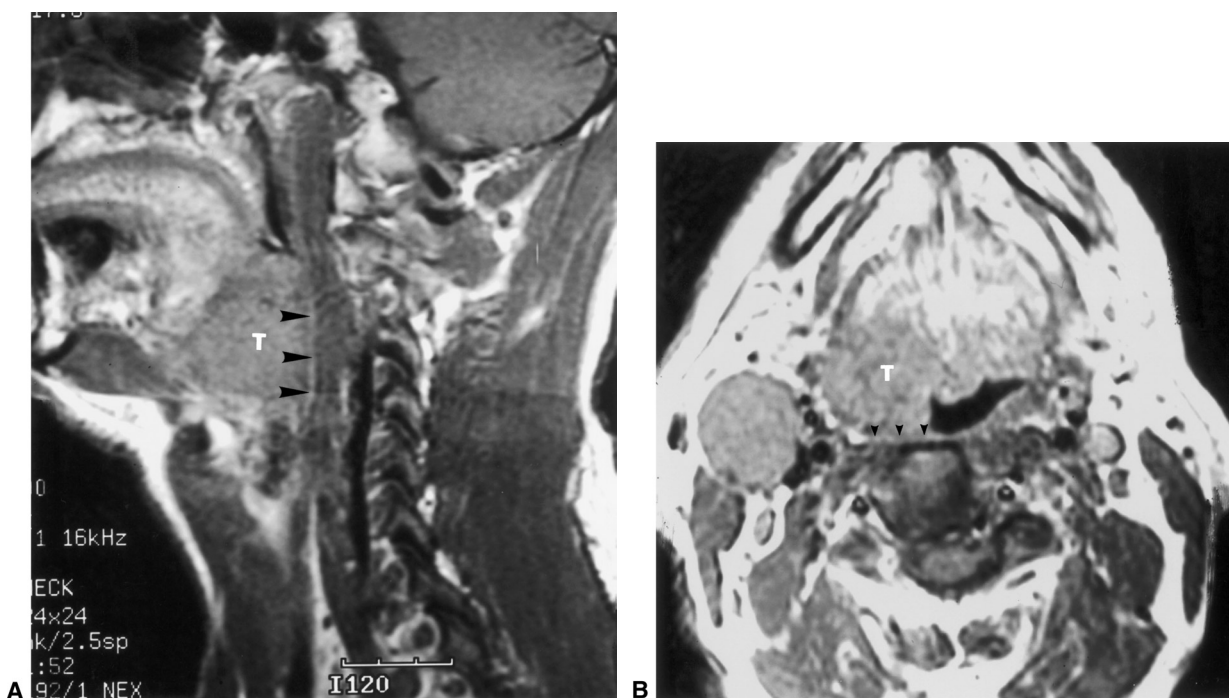


FIGURE 2. Preservation of the retropharyngeal fat between tumor and the prevertebral musculature in a 55-year-old man with right tonsillar carcinoma. The tumor was resected with clean, tumor-free surgical margins. **(A)** Off-midline sagittal T1-weighted (TR 500/TE 14; section thickness, 5 mm) magnetic resonance (MR) image shows preservation of the retropharyngeal fat (arrowheads) between the tumor (T) and longus muscle complex. **(B)** Axial T1-weighted (TR 500/TE 14) MR image shows the retropharyngeal fat plane (arrowheads) preserved along the posterior margin of the tumor (T).

Imaging is also used to detect perineural spread, especially with nasopharyngeal cancers, as well as direct invasion of the mandible that can occur with oral cavity and oropharyngeal neoplasms.²⁰ MRI is also critical in the assessment of tumor extension to the skull base and brachial plexus.¹⁰

The improved soft-tissue resolution and multiplanar capabilities of MRI make it an attractive diagnostic tool for detection of tumor spread into the deep extramucosal spaces of the head and neck.^{11,12,21–23} The role of imaging in mapping tumor extent has important implications in counseling the patient regarding prognosis, treatment options, and potential social and functional losses resulting from surgery. Multiple factors may determine the types of curative surgical options available to patients with head and neck cancer. For example, in base of tongue or epiglottic cancers, the detection of preepiglottic space extension on imaging changes the surgical approach and procedure in surgical candidates.²⁴ In this scenario, rather than just a local resection, a supraglottic laryngectomy may also need to be performed. A supraglottic laryngectomy necessitates that the patient learn to swallow differently. When such tumors extend to the paraglottic

space, laryngectomy may be required for cure. This not only has an impact on eating but also has important social implications, because patients lose their ability to speak naturally. Similarly, the presence of cartilage invasion can preclude speech-conserving laryngeal surgery.^{18,19} In cases of large pharyngeal and laryngeal cancers, surgery is not a viable option if surgeons are unable to obtain tumor-free margins. Encasement or invasion of the internal carotid artery is a relative contraindication for surgery at most institutions, as well as a poor prognostic indicator. When neoplastic invasion is confined only to the adventitia, a curative radical tumor resection can usually be performed. However, tumor invasion into the media may necessitate that the vessel be sacrificed with the tumor.⁸

Inflammatory and neoplastic processes may affect the retropharyngeal and prevertebral spaces.^{11,12,21,25,26} There has been little radiologic evaluation of the spread of neoplastic processes in the prevertebral space. In head and neck cancer, fixation of tumor to the prevertebral fascia or direct extension beyond the fascia into the muscle usually renders the disease inoperable and incurable, because tumor-free margins cannot be

achieved.¹² Surgical resection of the prevertebral muscle or debulking of the tumor in cases of prevertebral space involvement is associated with poor outcomes both clinically and functionally. Therefore, patients with prevertebral involvement are treated with palliative irradiation and, frequently, adjuvant chemotherapy.

The normal prevertebral compartment is enclosed by the deep layer of the deep cervical fascia. It contains the anterior longus capitis and rectus capitis muscle complexes. The prevertebral fascia forms the anterior border of the space and extends laterally from the transverse processes to enclose the deep muscles. The retropharyngeal fat lies immediately posterior to the pharyngeal mucosa and anterior to the prevertebral space between the two layers of the precervical fascia. The prevertebral space, because of its relative proximity to the retropharyngeal space and pharyngeal mucosa, is susceptible to the spread of inflammatory and neoplastic processes.

In patients with cancer of the pharynx, and in some cases the larynx, who are at risk for prevertebral space invasion but are otherwise surgical candidates, determination of tumor fixation to the prevertebral compartment is determined by digital manipulation on panendoscopy with the patient under general anesthesia. If unequivocal fixation of the tumor exists, open exploration is not necessary. Otherwise, open neck exploration is usually performed through the side of the neck not involved by the primary tumor. If both sides of the neck seem to be involved by tumor, the side with less disease is used for access. If the tumor is fixed to the prevertebral compartment, surgery is aborted. If the tumor is freely mobile, surgical resection may be performed. The implications of microscopic invasion (positive margins on histologic analysis) are not the same as that of macroscopic invasion, because all patients are treated with radiation after surgery to eradicate microscopic disease.

Only a few studies have looked at the ability of imaging to determine the presence of tumor extension to the prevertebral compartment. A retrospective study by Righi et al¹¹ looked at the preoperative CT scans of 29 patients with stage T3 or T4 squamous cell carcinoma of the oropharynx or hypopharynx who subsequently underwent open neck exploration. If there was obliteration of the fat plane between the tumor and the prevertebral muscles or asymmetric enlargement of the ipsilateral prevertebral muscle, neoplasms were deemed suspicious for preverte-

bral extension. In 12 of 29 patients, CT scans were interpreted as suspicious for prevertebral invasion on the basis of imaging criteria. Only three of these patients were found to have involvement of the prevertebral space on intraoperative assessment. Overall, the accuracy of enhanced CT in predicting prevertebral muscle invasion was only 55%. In addition, these imaging criteria suffered from both low sensitivity and specificity of 50% and 61%, respectively. The overall positive predictive value was 25%.

Loevner et al¹² assessed the appearance of the prevertebral longus muscle complex on preoperative MRI to determine its accuracy in predicting fixation of the tumor to the prevertebral compartment. In this study, 15 patients with obliteration of the retropharyngeal fat plane between the tumor and the prevertebral musculature on MRI were further evaluated. Four criteria of the prevertebral muscles were assessed, including muscle concavity, irregular tumor-muscle interface, T2 hyperintensity, and enhancement. All of the patients had surgery. None of the MRI criteria individually or in combination were both sensitive and specific for tumor fixation to the prevertebral compartment. Muscle concavity and enhancement had the highest sensitivities (88% individually), but both suffered from low specificity (14% and 29%, respectively). Accuracy of the criteria on MRI individually ranged from 53% to 60%, similar to the accuracy of preoperative CT.¹¹ It was postulated that an inflammatory reaction produced by the tumor accounted for muscle T2 hyperintensity and/or enhancement in cases in which the tumors were not fixed at surgery.

Although neither CT nor MRI reliably detects prevertebral compartment involvement, Righi et al¹¹ suggested that preservation of the retropharyngeal fat plane on CT correlated with absence of involvement of the prevertebral muscle (negative predictive value, 82%). In 17 of 29 patients, CT scans were interpreted as non-suspicious for prevertebral tumor spread. Three patients were found intraoperatively to have prevertebral muscle invasion, and surgery was aborted. In the remaining 14 patients, the fascia and muscles were uninvolved on intraoperative inspection.

The main objective of the two previous studies was to identify those patients whose disease was inoperable. In contrast, our study specifically addressed the role of MRI in selecting patients who were operative candidates. Because of its improved soft-tissue resolution and anatomic detail

over CT, we hypothesized that preservation of the retropharyngeal fat plane on unenhanced T1-weighted imaging in the absence of other imaging criteria would reliably predict those patients whose tumors were not fixed to the prevertebral compartment. T1-weighted imaging in particular is well suited for defining anatomic boundaries. The retropharyngeal fat is clearly visualized as high signal intensity between the pharyngeal mucosa and the prevertebral musculature. The preservation of the fat plane in 40 patients in our study was compared with surgical results. Thirty-nine of 40 were found to be resectable, resulting in a negative predictive value of 97.5%. In the single false-negative case, which was a poorly differentiated carcinoma, a delay of 4 weeks between imaging and surgery may have resulted in an interval progression of tumor, leading to the discrepancy between imaging and intraoperative findings.

In conclusion, our results suggest that in cases of advanced head and neck squamous cell carcinoma in which extension to the prevertebral compartment is an issue, preservation of the retropharyngeal fat plane on MRI reliably predicts those patients whose tumors are resectable. This is significant in that these patients may not need to undergo surgical exploration before definitive tumor resection, thereby avoiding an additional surgical procedure that could increase morbidity.

REFERENCES

- Loveday EJ, Bleach NR, Van Hasselt CA, Metreweli C. Ultrasound imaging in laryngeal cancer: a preliminary study. *Clin Radiol* 1994;49:676–682.
- Madison MT, Remley KB, Latchaw RE, Mitchell SL. Radiologic diagnosis and staging of head and neck squamous cell carcinoma. *Radiol Clin North Am* 1994;32:163–181.
- van den Brekel MWM, Castelijns JA, Snow GB. The role of modern imaging studies in staging and therapy of head and neck neoplasms. *Seminars Oncol* 1994;21:340–348.
- Mafee MF, Schild JA, Valvassori GE, Capek V. Computed tomography of the larynx: correlation with anatomic and pathologic studies in cases of laryngeal carcinoma. *Radiology* 1983;147:123–128.
- Vogl T, Dresel S. Advanced imaging of head and neck tumors. *Acta Radiol* 1995;36:566–580.
- Hoover LA, Calcatera RC, Walter GA, Larrison SG. Preoperative CT scan evaluation for laryngeal carcinoma: correlation with pathologic findings. *Laryngoscope* 1984;94:310–315.
- Sanghvi V. The new combined surgical approach for cancer involving the base of tongue-supraglottic complex. *Laryngoscope* 1994;104:725–730.
- Gritzmman N, Grasl MC, Helmer M, Steiner E. Invasion of the carotid artery and jugular vein by lymph node metastases. *AJR Am J Roentgenol* 1990;154:411–414.
- Yousem DM, Hatabu H, Hurst RW, et al. Carotid artery invasion by head and neck masses: prediction with MR imaging. *Radiology* 1995;195:715–720.
- Wiot JG. Radiographic evaluation of the skull base. *Ear Nose Throat J* 1991;70:563–564, 567–576.
- Righi PD, Kelley DJ, Ernst R, et al. Evaluation of prevertebral muscle invasion by squamous cell carcinoma. *Arch Otolaryngol Head Neck Surg* 1996;122:660–663.
- Loevner LA, Ott IL, Yousem DM, et al. Neoplastic fixation to the prevertebral compartment by squamous cell carcinoma of the head and neck. *AJR Am J Roentgenol* 1998;170:1389–1394.
- Dooms GC, Hricak H, Crooks LE, Higgins CB. Magnetic resonance imaging of the lymph nodes: comparison with CT. *Radiology* 1984;153:719–724.
- Muraki AJ, Mancuso AA, Harnsberger HR. Metastatic cervical adenopathy from tumors of unknown origin: role of CT. *Radiology* 1984;152:749–753.
- Tien RD, Hesselink JR, Chu PK, Szumowski J. Improved detection and delineation of head and neck lesions with fat-suppression spin-echo MR imaging. *AJNR Am J Neuroradiol* 1991;12:19–24.
- van den Brekel MWM, Stel HV, Castelijns JA, et al. Cervical lymph node metastases: assessment of radiologic criteria. *Radiology* 1990;177:379–384.
- Yousem DM, Som PM, Hackney DB, Schwaibold F, Hendrix RA. Central nodal necrosis and extracapsular neoplastic spread in cervical lymph nodes: MR imaging versus CT. *Radiology* 1992;182:753–759.
- Castelijns JA, Gerritsen GJ, Kaiser MC, et al. Invasion of laryngeal cartilage by cancer: comparison of CT and MR imaging. *Radiology* 1988;167:199–206.
- Becker M, Zbaren P, Laeng H, Stoupis C, Porcelini B, Vock P. Neoplastic invasion of the laryngeal cartilage: comparison of MR imaging and CT with histopathologic correlation. *Radiology* 1995;194:661–669.
- Chung TS, Yousem DM, Seigerman HM, Schlakman BN, Weinstein GS, Hayden RE. MR of mandibular invasion in patients with oral and oropharyngeal malignant neoplasms. *AJNR Am J Neuroradiol* 1994;15:1949–1955.
- Davis WL, Harnsberger HR, Smoker WR, et al. Retropharyngeal space: evaluation of normal anatomy and diseases with CT and MR imaging. *Radiology* 1990;174:59–64.
- Freeman DE, Mancuso AA, Parsons JT, Mendenhall WM, Million RR. Irradiation alone for supraglottic larynx carcinoma: can CT findings predict treatment results? *Int J Radiat Oncol Biol Phys* 1990;19:485–490.
- Zeitels SM, Vaughn CW. Preepiglottic space invasion in “early” epiglottic cancer. *Ann Otol Rhinol Laryngol* 1991;100:789–792.
- Loevner LA, Yousem DM, Montone KT, Weber R, Chalian AA, Weinstein GS. Can radiologists accurately predict preepiglottic space invasion with MR imaging? *AJR Am J Roentgenol* 1997;169:1681–1687.
- Paonessa DF, Goldstein JC. Anatomy and physiology of head and neck infections (with emphasis on the fascia of the face and neck). *Otolaryngol Clin North Am* 1976;9:561–580.
- Parker GD, Harnsberger HR. Radiologic evaluation of the normal and diseased posterior cervical space. *AJR Am J Roentgenol* 1991;157:161–165.