Lymph Node Staging in the Neck

Examination of the anatomy and pathology of the lymph nodes of the neck as seen by magnetic resonance imaging (MRI) shows a wide variety of findings and thereby presents a challenging task for the radiologist. Patients with a broad range of clinical presentations and disease states are imaged with MRI due to its rapidly evolving improvements in spatial and contrast resolution, the reduction of artifacts with this technique, and the development of new contrast agents (van den Brekel, 2000).

Although the reasons for performing MRI are numerous, the MR imaging sequences and protocols for the evaluation of lymph nodes are straightforward and allow initial staging of disease and evaluation of the success of therapy.

IMAGING OF THE LYMPH NODES USING MRI

BASIC PROTOCOL

Magnetic resonance imaging scans can be performed at a range of field strengths. In general, the high signal-to-noise ratio (SNR) obtained at high field strengths allows one to scan either faster or with higher resolution compared to lower field strengths. The sequences described within this unit are based on the authors' experience using a Siemens 1.5 T Symphony scanner, but are expected to be equally applicable to scanners from other manufacturers.

Scanning a patient or volunteer is a team effort of the technologists, nurses, and physicians. In most cases, the technologist assumes the lead role in acquiring the appropriate images.

The set of sequences described in the following protocol comprises the preferred method of imaging the soft tissues of the neck. The usual sequences employed include transverse T_1-weighted spin echo and fast spin-echo (FSE) or turbo spin-echo (TSE) fat-saturated T_2-weighted images acquired prior to contrast administration. Contrast enhancement is necessary to assess the extent of any metastatic spread and to determine if the cancerous or diseased lymph node has infiltrated any adjacent structures, most importantly arteries and veins, as well as adjacent nerves. In addition, a better distinction of cystic lesions and abscesses can often be achieved, compared to non-contrast examinations.

All of the sequences in this protocol are non-breath-hold examinations; however, the patient should be advised not to swallow or move his or her head while the sequences are running. The duration for the imaging process, including all preparations, is ~30 min.

Table A7.7.1 lists the hardware necessary to perform the procedure along with appropriate parameters. The available gradient strength will depend on the scanner, and the echo times given later in other tables will have to be varied accordingly (the smaller the gradient strength, the longer the echo time for a particular scan).

NOTE: Be sure that technologists and nurses have immediate access to any emergency equipment that may be relevant to a given study, or that may be needed for a particular patient, such as crash carts or oxygen.

Materials

Normal saline (0.9% NaCl), sterile
Gadolinium-based MR contrast agent (e.g., Magnevist, Omniscan, or Prohance)

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Table A7.7.1 Equipment Parameters

Coil type	Circularly polarized head coil (or phased-array neck coil, if available)
Gradient coil strength	30 mT/m (or whatever the system permits)
Cardiac gating	No
Peripheral gating	For safety only
Respiratory gating	No
Respirator	If required by patient
Oxygen	If required by patient
Motion cushions	Useful
Use of contrast agents	Necessary

Set up patient and equipment

1. Interview the patient to ensure that he or she has no contraindication such as cardiac pacemakers or other implants containing ferromagnetic materials. Also, be sure to find out if the patient has any health conditions that may require the presence of special emergency equipment during the scanning procedure, or that might necessitate any other precautions.

   Generally, standard screening forms (APPENDIX 1) are used for all patients scanned in a magnetic resonance system.

   The presence of any ferromagnetic metals may be a health hazard to the patient when he or she is inside the magnet, and will also affect the imaging. If in doubt as to the exact composition of the items, it is best to exclude patients with any metal implants; see Shellock and Kanal (1998), Shellock and Crues (1998), and Shellock and Shellock (1998) for discussion of what implants may be safely scanned using magnetic resonance.

   Patients may be accompanied into the magnet room by a friend or family member who can sit in the room during the scan and comfort the patient as needed. This companion must be screened as well to ensure the absence of loose metal objects on the body or clothing.

2. If the procedure is a research protocol, have the patient sign any necessary consent forms.
3. Have the patient remove all jewelry and change into a gown to eliminate any metal that might be found in the clothing.
4. Have the patient wash off any mascara and other makeup to avoid local tissue heating and image artifacts.
5. Inform the patient about what will occur during the procedure, what he or she will experience while in the magnet, as well as how to behave. Issues to discuss include the following:

   a. If earphones or headphones are used to protect the ears from the loud sounds produced by the gradients, the patient will be asked to wear these, but will be able to communicate with you at any time during the imaging.

   b. The patient will be given a safety squeeze-bulb or similar equipment to request assistance at any time (demonstrate how this works).

   c. For optimum results, the patient should not talk, and should avoid or minimize swallowing or other movement during each scan—i.e., as long as the banging sounds continue. Between scans, talking and swallowing are allowed in most cases, but should be avoided when comparative positional studies are being performed; the patient will be informed when this is the case.

   d. Nevertheless, the patient may call out at any time if he or she feels it is necessary.

6. Have the patient climb onto the table. Either before or right after the patient lies down, set up any triggering devices or other monitoring equipment that is to be used.

7. Establish an intravenous line through which the contrast agent can be injected. Attach this line securely to the patient so that movement into or out of the magnet will not pull at the patient's arm.

   It is preferable to insert the line prior to imaging and to leave the patient in the magnet so that there is no intervening motion between the scans run before contrast agent injection and those run after injection.

8. Center the patient in a head or neck coil at the region where the key information is desired. Make sure that the head and neck are constrained to prevent motion, especially if high-resolution scans are being performed.

   Generally, the patient's head is fixed so that it is horizontal (not tilted) and the neck and head lie along the long axis of the scanner table. Most scanners have a dedicated neck coil.

9. If needed, place a pillow or other support under the patient's knees to make him or her more comfortable.

10. Use the centering light to position the patient's nasion and put him or her into the center of the magnet.

    Once this step has been performed, so long as the patient does not move on the table, the table itself can be moved and then replaced in the same position as previously without jeopardizing the positioning of one scan relative to another (usually to within ±1 mm accuracy).

11. If the patient is unable to hold still, provide an appropriate sedative.

Sequence 1: The pilot scan

12. To validate the patient's position, run the system's pilot scan to ensure the correct location of the neck in three dimensions, using the imaging parameters given in Table A7.7.2.

Table A7.7.2 Primary Clinical Imaging Parameters for Sequence 1 (Pilot Scan)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Transverse, coronal, and sagittal
Central slice or volume center	Laser light centered on the larynx
Echo time (T_E)	≤5 msec
Repeat time (T_R)	≤20 msec
Flip angle (FA)	40°
Fields of view (FOV_x, FOV_y)	256 mm, 160 mm
Resolution (Δx, Δy)	1.0 mm, 1.0 mm
Number of data points collected (N_x, N_y)	256, 160
Slice thickness (Δz)	5 mm
Number of slices	1 per orientation
Slice gap	Not applicable
Number of acquisitions (N_{acq})	1
Scan time	9 sec

Table A7.7.3 Primary Clinical Imaging Parameters for Sequence 2 (Transverse T_2-Weighted Fat-Saturated TSE)

Patient position	Supine
Scan type	Turbo spin echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Epiglottis
Echo time (T_E)	71 msec
Echo train length (ETL)	11
Repeat time (T_R)	6000 msec
Flip angle (FA)	150°[a]
Fields of view (FOV_x, FOV_y)	192 mm, 153 mm
Resolution (Δx, Δy)	0.75 mm, 0.75 mm
Number of data points collected (N_x, N_y)	256, 204
Slice thickness (Δz)	5 mm
Number of slices	30
Slice gap	1.5 mm
Number of acquisitions (N_{acq})	2
Read direction	Right–left
Fat suppression	Yes
Scan time	233 sec

[a]The system displays the flip angle of the refocusing pulse. The flip angle of the first pulse of this sequence is 90°.

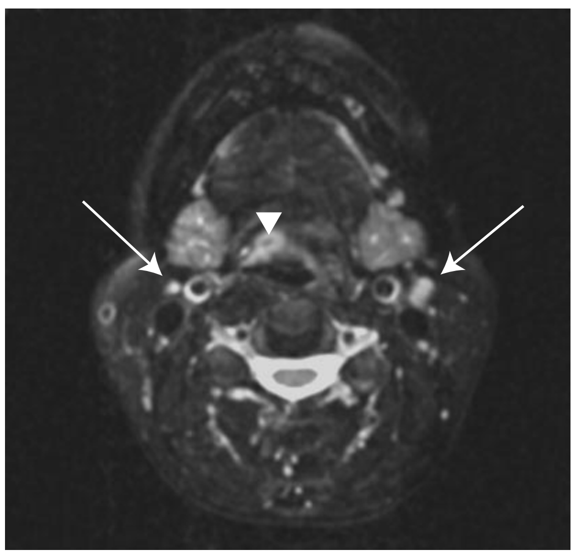

Figure A7.7.1 Mass of the oropharynx on transverse T_2-weighted, fat-saturated, MR image (arrowhead). Bilateral normal-sized internal jugular chain lymph nodes (arrows) are visible, without signs of metastatic spread.

Table A7.7.4 Primary Clinical Imaging Parameters for Sequence 3 (T_1-Weighted Transverse)

Patient position	Supine
Scan type	Spin echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Epiglottis
Echo time (T_E)	12 msec
Repeat time (T_R)	660 msec
Flip angle (FA)	90°
Fields of view (FOV_x, FOV_y)	192 mm, 156 mm
Resolution (Δx, Δy)	0.75 mm, 0.75 mm
Number of data points collected (N_x, N_y)	256, 208
Slice thickness (Δz)	4 mm
Number of slices	25
Slice gap	1.2 mm
Number of acquisitions (N_{acq})	2
Read direction	Right–left
Scan time	279 sec

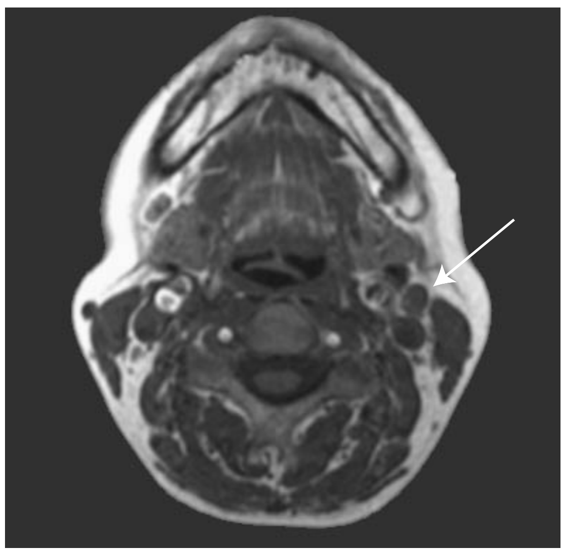

Figure A7.7.2 Imaging of a normal-sized cervical lymph node (arrow) by a transverse T_1-weighted SE sequence.

This sequence usually consists of three orthogonal planes to allow exact localization of the bilateral cervical lymph nodes. These images are often also used later to determine where to place the saturation pulses and to confirm total coverage of the volume of interest.

Sequence 2: Transverse T_2-weighted, fat-saturated turbo spin echo (TSE)

13. Display the coronal, sagittal, and transverse scout images in split-window mode on the scan monitor. Change imaging parameters to those listed in Table A7.7.3. Position the slices to cover the area from the posterior fossa to the thoracic inlet in the coronal and sagittal planes, as well as the anterior, posterior, and lateral margins of the neck in the transverse plane. Let the patient know you are ready, and begin the scan.

An example image is shown in Figure A7.7.1.

Table A7.7.5 Primary Clinical Imaging Parameters for Sequence 4 (T_1-Weighted Transverse Fat-Saturated)

Patient position	Supine
Scan type	Spin echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Epiglottis
Echo time (T_E)	12 msec
Repeat time (T_R)	600 msec
Flip angle (FA)	90°
Fields of view (FOV_x, FOV_y)	192 mm, 156 mm
Resolution (Δx, Δy)	0.75 mm, 0.75 mm
Number of data points collected (N_x, N_y)	256, 208
Slice thickness (Δz)	5 mm
Number of slices	30
Slice gap	1.5 mm
Number of excitations (NEX)	2[a]
Number of acquisitions (N_{acq})	2
Read direction	Right–left
Fat suppression	Yes
Scan time	506 sec

[a]The number of concatenation is set to be 2. This means that only half of the total slices will be excited during a given repeat time.

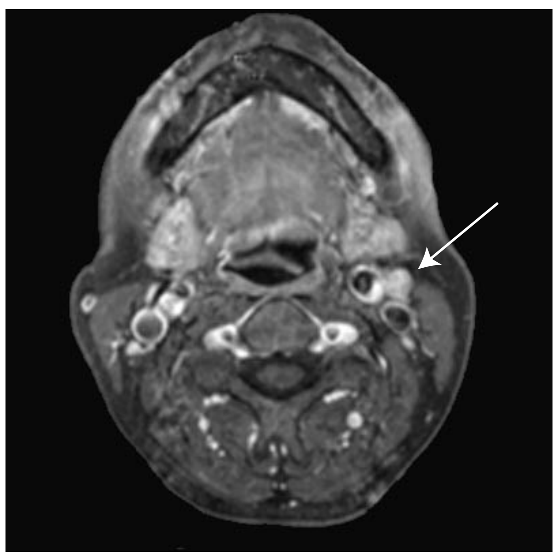

Figure A7.7.3 Imaging of a normal cervical lymph node (arrow) by a T_1-weighted contrast enhanced, fat-saturated SE sequence.

Sequence 3: Transverse T_1-weighted spin echo (SE)

14. Bring the sequence for a T_1-weighted SE scan up on the console. Set the imaging parameters as shown in Table A7.7.4.

15. Use the History function to select slice positions from the previous sequence, Sequence 2 (T_2-weighted, transverse, fat-saturated TSE). Let the patient know you are ready, and begin the scan.

    An example image is shown in Figure A7.7.2.

Sequence 4: Transverse T_1-weighted, fat saturated spin echo (SE), post-contrast

16. Copy the slice parameters, such as number of slices, field of view, dimension of slices, and center of slices from the performed T_1-transverse sequence 3 and change the imaging parameters to those listed in Table A7.7.5.

17. Before proceeding, administer the contrast agent.

    A dose of 0.2 mmol/kg gadolinium is usually given at a rate of 1 ml/sec.

18. Wait 3 min before proceeding. Inform the patient of the 3-min delay.

19. Let the patient know you are ready, and begin the scan.

    An example image is shown in Figure A7.7.3.

20. Take the patient out of the magnet.

COMMENTARY

Background Information

Imaging may be performed for the evaluation of any unknown neck mass, but the use of imaging to detect and evaluate primary or metastatic malignancy within lymph nodes is common in the diagnosis and staging of head and neck disease (Sakai et al., 2000). In children, lymphadenopathy is the most common solid neck mass, with lymphoma ranking third among all the solid neck masses occurring in childhood. In adults in the United States, lymphoma represents the seventh leading cause of cancer deaths (Daehnert, 1999).

Unreliable criteria for differentiating benign from malignant causes of lymphadenopathy, such as increased anteroposterior diameter, prominent calcifications, or marginal contrast enhancement in computed tomography (CT), are being replaced by the successful depiction of the soft tissue microstructure inside the lymph nodes (van den Brekel et al., 1996) by means of MR imaging.

The evolving improvements in spatial resolution, the reduction of artifacts, and the development of new contrast agents allow anatomical visualization to precisely assess the extent of any cancerous spread or infiltration into adjacent structures, most importantly arteries or veins, as well as into adjacent nerves. These routes of extranodal tumor extension are histologically found in 40% of lymph nodes with diameters less than 2 cm, which would thereby be considered normal by size criteria (Cummings, 1993). In 75% of lymph nodes larger than 3 cm, extranodal tumor spread is present.

Furthermore MR imaging has the potential to precisely show anatomic landmarks that make nodal levels reproducible. The lymph nodes in the neck are divided into seven specific anatomic subsites. The level concept is driven by the fact that the extent and level of cervical node involvement by metastatic tumor is prognostically important (Harnsberger, 1995; Fig. A7.7.4).

The imaging findings complement the physical examination, and the imaging-based classification provides the radiologist with clinically acceptable guidelines for classifying the cervical nodes and communicating the findings to clinicians (Som et al., 2000).

The most common indication for performing MRI of the soft tissue of the neck in adults is a strong suspicion or staging of head and neck cancer, especially carcinomas of the upper aerodigestive tract (Lenz et al., 1993). In addition to metastatic squamous carcinoma of the upper aerodigestive tract, the differential diagnosis of enlarged cervical lymph nodes also includes the lymphatico-lymphatic spread as well as the metastatic dispersion via lympha-

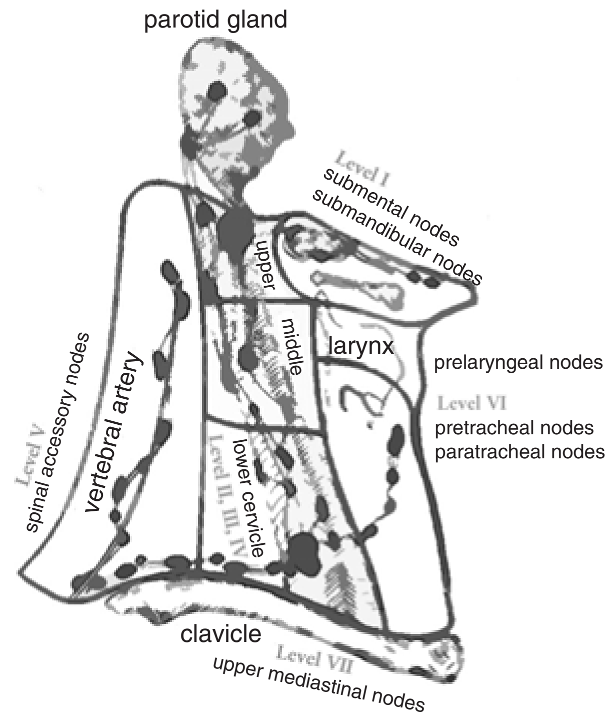

Figure A7.7.4 Seven anatomic subsites of lymph nodes in the neck. Level I contains the submental and the submandibular nodes. Level II includes the upper deep cervical chain nodes. Level III includes the middle deep cervical chain nodes, and analogous Level IV includes the lower deep cervical chain nodes. Level V comprises the spinal accessory nodes and the transverse cervical chain nodes. Level VI contains the pretracheal, the prelaryngeal, and the paratracheal nodes. In Level VII the upper mediastinal lymph nodes can be found. Figure is based on Harnsberger (1995).

tico-venous pathways. If cancer cells invade the reticular and medullary tissue of the lymphatic nodes, a blockage of the lymph flow occurs, leading to an increase of interstitial fluid. Varying amounts of interstitial fluid and infiltrated medullary meshwork results in variable MR appearances; however, lymph nodes such as these are all typically referred to as necrotic (Som, 1987).

Infections of bacterial, mycobacterial, or viral cause are other common reasons for lymphadenopathy. Further indications are granulomatous conditions such as sarcoidosis, as well as primary and secondary involvement in lymphoma, e.g., Hodgkin's as well as non-Hodgkin's lymphomas. Other metastatic neoplasms originating from breast and lung are also common causes of diffuse metastatic enlargement of cervical lymph nodes. Conditions such as sinus histiocytosis and eosinophilic granuloma also occasionally occur (Kaji et al., 1997).

In addition, MR imaging can be utilized for percutaneous MRI-guided biopsies of lymph nodes, using dedicated open scanners accompanied by the development of fast gradient echo pulse sequences to secure the diagnosis by histology (Lewin et al., 2000).

Critical Parameters and Troubleshooting

The high magnetic field strength of 1.5 T magnets and T_1-weighted spin echo sequences with fat saturation and contrast enhancement, as well as T_2-weighted fast spin echo or turbo spin echo techniques, reveal a remarkably intense and precise signal from the lymph nodes.

High spatial resolution is desired so that small areas of signal variation are not missed. The exact anatomical visualization of arteries and veins, as well as of neural structures such as the cervical and brachial plexus, allows a precise diagnosis of whether any cancerous formation has invaded those organs, which are most vulnerable to the spread of cancer. Moreover, it is important to center the planes in order to perform a comparison with the opposite side of the neck, to identify any area of abnormality, and to differentiate between pathology and anatomical variation.

Anticipated Results

A variety of findings concerning the lymph nodes is possible utilizing magnetic resonance imaging. To ensure that the complete anatomical region containing the cervical lymph pathways is imaged, the neck should be visualized from the skull base to the thoracic inlet, thereby clearly indicating the body of the hyoid bone, the cricoid arch, the top of the manubrium, and the back edge of the submandibular gland as important landmarks. Posteriorly, the back edge of the sternocleidomastoid muscle, the lateral posterior edge of the anterior scalene muscle, and the anterior edge of the trapezius muscle should be included in the field of view and should contain both the internal carotid and common carotid arteries and the internal jugular vein.

Anteriorly, the clavicle, the medial margin of the anterior belly of the digastric muscle, and the mylohoid muscle are utilized as important landmarks.

Although in most cases a specific diagnosis can be suggested by other means of visualization, only MRI has the potential to demonstrate the extent of disease with high precision, thanks to the high spatial resolution, thereby allowing competitive and comparable MR imaging, which is crucial to the staging process in estimating the expected success of therapy.

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