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Rheumatoid Arthritis of the Cervical Spine: Surface-Coil MR Imaging

Carl Bundschuh^{1,2}
 Michael T. Modic¹
 Fran Kearney³
 Russell Morris⁴
 Chad Deal⁵

Fifteen patients with classic rheumatoid arthritis were investigated with plain films, pluridirectional tomography, and surface-coil T1-weighted MR imaging at 500/17 (TR/TE). We evaluated the atlantodental interval; basion-dental interval; density or intensity of the dens; dens erosion; cranial settling; anterior, posterior, lateral, or rotatory atlantoaxial subluxation; subaxial subluxation; ligamentous calcification or osteophytes; erosion; cystic changes; joint-space narrowing of the apophyseal articulations; and posterior spinous process erosion. In addition, the cervicomedullary angle and the neuraxis configuration were identified on MR images. To determine its normal range, the cervicomedullary angle was measured in 50 patients whose MR studies were unrelated to the craniovertebral junction. All patients with a cervicomedullary angle less than 135° had evidence of brainstem compression, cervical myelopathy, or C2 root pain. Also, all patients with cervicomedullary junction compression were neurologically abnormal. MR was found to be as good as tomography in evaluating the atlantodental interval, dens erosion, ligamentous calcification or osteophytes of the upper spine, subaxial subluxation, and various subluxations that occur in the occiput-C2 area. MR was less effective than tomography in evaluating the basion-dental interval, erosion of the posterior spinous processes, apophyseal joint disease from C3 inferiorly, and cystic changes of the articular facets of C1-C2. The most clinically important parameters were well seen with MR.

The data show that MR is an excellent imaging procedure for evaluating rheumatoid arthritis of the cervical spine.

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¹ Department of Radiology, Case Western Reserve University School of Medicine, and University Hospitals of Cleveland, 2074 Abington Rd., Cleveland, OH 44106.

² Present address: Department of Diagnostic Radiology, Medical College of Hampton Roads, and Sentara Norfolk General Hospital, 600 Gresham Dr., Norfolk, VA 23507. Address reprint requests to C. Bundschuh.

³ Northern Ohio Imaging Center, 1911 W. River Rd. N., Blyria, OH 44035.

⁴ Division of Rheumatology, University Hospitals of Cleveland, Cleveland, OH 44106.

⁵ Department of Medicine, Division of Rheumatology, Case Western Reserve University, and University Hospitals of Cleveland, Cleveland, OH 44106.

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Previous descriptions of the MR appearance of rheumatoid arthritis of the cervical spine have demonstrated prominent retrodental soft tissue, subaxial subluxation, and flexion-accentuated anterior atlantoaxial subluxation [1-3]. However, it has been suggested that MR is limited in the evaluation of the craniovertebral junction because of the greater accuracy of plain films and/or plain-film tomography in depicting bone changes [3]. In addition, despite anecdotal reports of the ability of MR to detect alterations of the rheumatoid cervical spine, little effort has been made to determine its role in the prediction of neurologic dysfunction.

The purpose of our study was twofold: First, we investigated the bone abnormalities associated with rheumatoid arthritis as seen on surface-coil MR and compared the findings with those produced by pluridirectional tomography, using the latter as a measurement of accuracy. Second, we attempted to obtain a measurement on sagittal MR that could be used to predict clinical evidence of brainstem compression and cervical myelopathy. To accomplish this goal we compared and categorized the MR findings with neurologic signs and symptoms in a group of patients diagnosed as having classic rheumatoid arthritis.

Subjects and Methods

Fifteen patients 44-68 years old (mean, 59 years, 60% males) diagnosed as having classic rheumatoid arthritis [4] were admitted to the study. These patients had varying degrees of

neck pain, generally had long-standing erosive seropositive disease, and were receiving aggressive remittive therapy. Most patients had been treated with corticosteroids at some point in the course of their disease. Complete neurologic examinations were performed in every patient, and the results were tabulated in a manner that highlighted the clinical findings of cervical myelopathy or brainstem compression.

The study group was investigated with plain films, pluridirectional tomography, and MR. Anteroposterior and lateral neutral, flexion, and extension plain films of the cervical spine were obtained in the sitting position with a 6-foot (183-cm) target-film distance. Anteroposterior and lateral complex-motion tomography was performed with 5-mm contiguous sections. Several 2.5- to 3-mm sections were procured through the dens. All measurements were corrected for geometric magnification. Plain films and tomograms were evaluated for the following: (1) atlantodental interval and basion-dental interval; (2) density of the dens; (3) dens erosion; (4) cranial settling; (5) anterior, posterior, lateral, or rotatory atlantoaxial subluxation; (6) subaxial subluxation; (7) ligamentous calcifications or osteophytes; (8) erosion, cystic changes, and joint space narrowing of apophyseal articulations; and (9) posterior spinous process erosions.

The MR examinations were performed on a 1.0-T superconductive unit* with a 5-in. (12.7-cm) surface coil operating in the receive mode. A 50-cm body coil served as the RF transmitter. The MR study consisted of four separate acquisitions. Patient position and coil placement (centered on C2–C3) were first determined with a 500/17/1 (TR/TE/excitations) coronal study with a 1-cm slice thickness. The imaging time was 1.1 min. The remaining three acquisitions, two in the sagittal and one in the coronal plane, were obtained with a 500/17/4 sequence with a 4-mm slice thickness, 2-mm interslice gap, 18.75-cm field of view, and 256 × 256 acquisition matrix. The pixel size was 0.7 × 0.7 mm, and the acquisition time for each sequence was 8.5 min. Sagittal neutral and flexion views, the latter achieved with a pillow or angle sponge placed behind the head, routinely demonstrated the posterior fossa contents and C1–C6. This also applied to the coronal images. A multisection spin-echo technique was used in all patients, and data collection was performed in the two-dimensional Fourier transform mode. Total examination time, including patient positioning and RF tuning, was 35–40 min.

In addition to the nine characteristics listed above (except the density of the dens) MR images were evaluated for: (1) signal intensity of the dens, (2) pannus formation (particularly in a periodontoid location), (3) cervical cord contour, and (4) cervicomedullary angle. The atlantodental and basion-dental intervals, pre- and retrodental pannus, deformity of the neuroaxis, cervicomedullary angle, and all subluxations with the exception of rotatory atlantoaxial subluxation were objective measurements (Table 1). The rest of the evaluation points were subjective and correlated on a 1–5 scale (1 = 100%, 0 = 0% agreement). A score of 1 or 2 was rated as a positive correlation (that is, good agreement).

Fifty patients (age range, 2 months to 82 years; mean, 42.8 years) who had MR for reasons unrelated to the craniocervical junction or its contents were evaluated to determine a normal cervicomedullary angle range. The cervicomedullary angles of rheumatoid patients were then compared with the normal range in an effort to correlate abnormality with clinical evidence of neurologic dysfunction.

MR measurements at the craniocervical junction were performed directly on 10- by 12-in. (25- by 30-cm) four on one hard-copy images computer-magnified two times. Therefore, the anatomic representation and actual anatomic size were identical. Measurements were made to the nearest one-tenth of a millimeter or degree despite the 0.7-mm resolution. Cortical bone of the cervical spine was identified on surface-coil MR as a linear marked hypointensity. Its inner surface

TABLE 1: Objective Measurements Used to Evaluate Rheumatoid Arthritis Changes on Sagittal Sections

Abnormality: Degree	Measurement
Predental pannus, retrodental pannus, and/or thickened ligaments:	
Mild	<5 mm
Moderate	5–8 mm
Marked	>8 mm
Cranial settling:	
Mild	<5 mm above foramen magnum line
Moderate	5–10 mm
Marked	>10 mm
Neuraxis compression:	
Mild	25% reduction in anteroposterior diameter
Moderate	25–60%
Marked	>60%

was defined by the generally bright signal of the atlas ring or less intense cancellous bone of the other cervical vertebrae. The cancellous intensity of the dens appeared more variable. The outer cortical margin was outlined by the intermediate-intensity perivertebral soft tissue on T1-weighted images.

Listed below are pertinent terms and their definitions:

Atlantodental interval—measurement from the posterior inferior cortical margin of the anterior arch of C1 to the anterior cortex of the dens. The measurement line is parallel to the end-plate of C2. The normal measurement is ≤ 2.1 mm, that is, 2.5-mm for a 6-foot (183-cm) target-to-film distance [5, 6].

Basion-dental interval—measurement from the middle of the superior surface of the dens to the midpoint of the anterior lip of the foramen magnum (basion). The upper end of the odontoid process normally lies directly beneath the basion and, on average, is 4 mm from it; that is, 5 mm for a 5-foot (152-cm) target-to-film distance [7].

Cervicomedullary angle—angle subtended by lines drawn parallel to the ventral surfaces of the medulla and upper cervical cord.

Anterior atlantoaxial subluxation—atlantodental interval is more than 2.1 mm.

Cranial settling—two conditions should be met: (1) the superior aspect of the dens is even with or above the McCrae line (foramen magnum), unless there is marked dental erosion [8, 9], and (2) the anterior arch of C1 assumes an abnormally low position in relation to C2 [5, 8, 9]. Cranial settling is also known as vertical atlantoaxial subluxation and pseudobasilar invagination.

Lateral atlantoaxial subluxation—greater than an approximately 2-mm bilateral offset of the cortical surface of the lateral mass of C1 in relation to the articular pillar of C2 [5]. Secondary to the offset there should be asymmetry of the lateral odontoid spaces [9].

Rotatory atlantoaxial subluxation—unilateral offset of the lateral mass of the atlas in relation to the articular pillar of C2. Either the occiput–C1 complex or the axis can be rotated in this type of subluxation. Unless associated with lateral subluxation, the intervertebral line, the bisectrix of the condylar angle, and the midline of the axis vertebra coincide [9].

Subaxial subluxation—displacement between adjacent vertebral bodies of more than 1 mm or more than 15% of the anteroposterior vertebral diameter [4].

Predental pannus—prominent soft tissue anterior to the dens associated with anterior atlantoaxial subluxation and/or unequivocal

* Siemens Magnetom.

odontoid erosion; the latter is defined as a focal or diffusely abnormal odontoid contour.

Retrodental pannus and/or thickened ligaments—prominence of soft tissue in the region of the transverse ligament and associated bursa(e). An anteroposterior measurement greater than 3 mm is considered abnormal [10] (Fig. 1).

Laterodental pannus and/or thickened ligaments—thickened ligament or pannus is inferred if there is lateral dental erosion at regions of soft-tissue prominence.

Supradental pannus and/or thickened ligaments—the fat that normally surrounds the anterior lip of the foramen magnum and caps the

odontoid process is replaced by less intense soft tissue. In addition to the apical ligament, alar ligaments, and superior fascicle of the cruciate ligament, which exists in this region, an inconstant supradontoid bursa has been noted [11].

Results

Five patients had isolated anterior atlantoaxial subluxation, three had cranial settling (Fig. 2), and one had combined lateral and rotatory atlantoaxial subluxation defined by to-

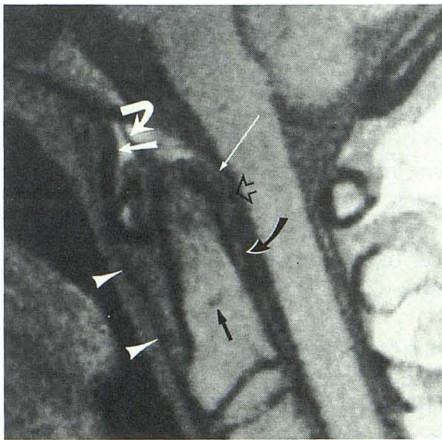


Fig. 1.—Volunteer. T1-weighted midsagittal MR image shows anterior longitudinal ligament (arrowheads), anterior atlantooccipital membrane (short straight white arrow), apical ligament (curved white arrow), transverse ligament (open arrow), inferior fascicle of cruciate ligament (curved black arrow), as well as subdental synchondrosis (straight solid black arrow). Cruciate ligament is slightly more intense than other ligaments. Dura mater, tectorial membrane, and superior fascicle of cruciate ligament are not separately identified (long straight white arrow). Note prominent fat pad, which caps dens and lies beneath basion.

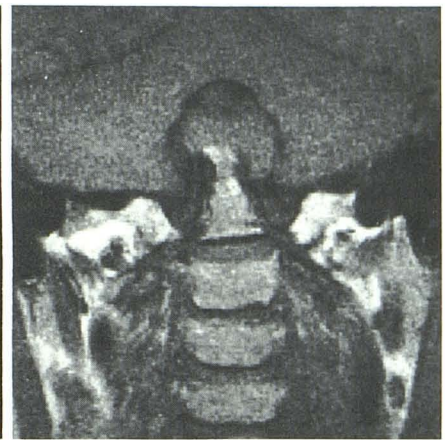
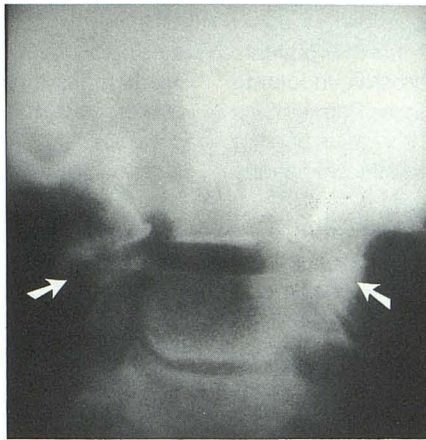


Fig. 2.—Case 2.

A, Coronal pluridirectional tomogram. Cranial settling is seen with C2 vertebra within cranial vault. Occipital condyles articulate with deformed lateral masses of C1 (arrows), which subsequently articulate with superior articular facets of C3. Articular pillars of C2 are completely eroded.

B, Coronal T1-weighted MR image. Coronal section is slightly posterior to tomogram; therefore, deformed lateral masses of C1 are not well appreciated. Ectopic dens is well seen above foramen magnum, as is attendant deformity of brainstem.

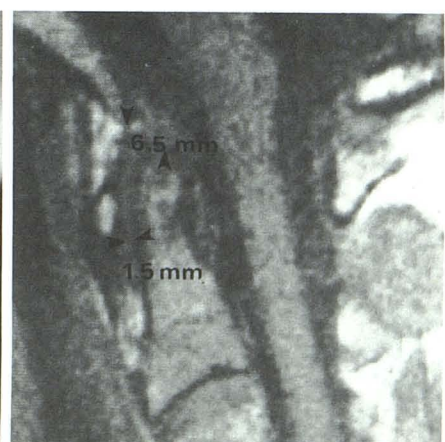
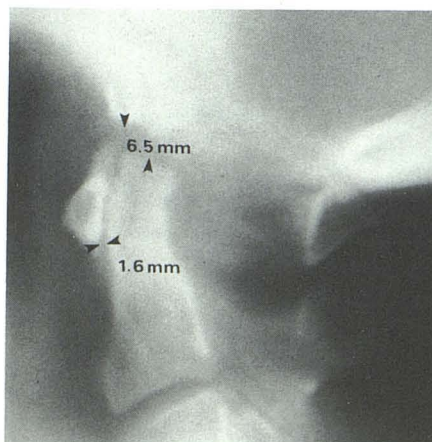


Fig. 3.—Case 5.

A, Midsagittal pluridirectional tomogram. Identified are atlantodental (1.6 mm) and basion-dental (6.5 mm) intervals.

B, Midsagittal T1-weighted MR image. Atlantodental and basion-dental intervals are again identified. Mildly prominent retrodental soft tissue represents thickened transverse ligament and/or pannus within synovial cavities posterior to dens. There is partial loss of fat, which caps dens.

mography. An additional patient had both anterior atlantoaxial subluxation and cranial settling. All subluxations were noted on MR. Of seven patients with subaxial subluxation, six were identified with MR imaging.

MR measurements of the atlantodental interval showed an agreement of $95\% \pm 1$ mm (range, 1–9.3 mm) in comparison with plain films and tomograms (Fig. 3). The MR measurements of the basion-dental interval were not as accurate, with an agreement of $77\% \pm 1.5$ mm (range, 3.2–11.9 mm). The MR odontoid configuration, including erosion, showed positive correlation with its plain-film or tomographic counterpart in 13 of 15 patients (Fig. 4). Nine of 15 patients demonstrated good agreement of (1) the degree and location of dental erosion with (2) the size and periodontoid position of pannus or thickened ligaments (Figs. 3 and 4). Of the two patients without radiographic evidence of odontoid erosion, moderate retrodental "pannus" was noted on MR in one. Pannus was seen in a retrodental location in 11 cases; in six cases pannus was predental and in five supradental. Laterodental pannus was the least common finding (two cases).

The degree and distribution of odontoid radiopacity were compared with the various odontoid intensities and their configurations in the 15 patients enrolled. Ten (67%) showed good agreement, with sclerotic areas appearing dark on MR images and osteopenic regions appearing bright (Fig. 5). Upper cervical ligamentous calcifications or osteophytes were well seen on MR. However, focal erosion or cystic changes in the occiput–C2 region were predicted with only a 50% accuracy (Fig. 6). Erosion of the posterior spinous process and subaxial articular changes were not reliably depicted by MR.

Measurements of the cervicomedullary angle in the 50 "normal" patients revealed a mean of 155.2° , a standard error of the mean of 8.7° , and a range of 135° – 175° (Fig. 7A). All rheumatoid arthritis patients with a cervicomedullary angle less than 135° had clinical evidence of myelopathy, brainstem compression, and/or C2 root pain (Fig. 7B). Conversely, as Table 2 reveals, three of the seven patients with neurologic

dysfunction had normal angles. Of these, one had mild and one had severe compression of the ventral cervicomedullary junction.

Discussion

Rheumatoid arthritis is a disease that leads to inflammation of the synovial lining of the bursae and articular capsules [4]. The resultant pannus formation is often followed by the destruction of cartilage and subchondral bone, characterized radiographically as erosion. Involvement of the synovial spaces may also lead to fibrosis or new bone formation. When the latter involves the peridental synovium, the term "shining odontoid" has been applied [11]. Rheumatoid disease can cause marked thickening and fibrosis of the dura and ligamentous structures [5, 12]. Alternatively, ligament laxity and eventual lysis can occur, which compounds the mechanical instability of a given region, as does decalcification and weakening of ligament insertions secondary to regional hyperemia [6, 13]. Steroids, administered to control the generally destructive inflammatory process, appear to exert their own deleterious effects, exacerbating instability, particularly in the occiput–C2 area. Obviously, this instability leads to subluxation.

Five subluxations are possible at the C1–C2 level, with the most common one occurring anteriorly. The incidence has been variously reported as ranging from 12–71% [6, 11, 14, 15], with the average probably closer to 30% [12, 16]. The 40% incidence of anterior atlantoaxial subluxation found in this study is in agreement with the previous findings. Cranial settling reportedly occurs in 3–22% of all rheumatoid arthritis patients [5, 6, 17]. The 27% incidence of cranial settling in our patient group may have been secondary to advanced disease. Lateral and rotary subluxations are believed to be less common than vertical subluxations, and this was true in our study. Posterior subluxations are rare.

All atlantoaxial subluxations appear to be related to disease duration, seropositivity, steroid treatment, and the presence

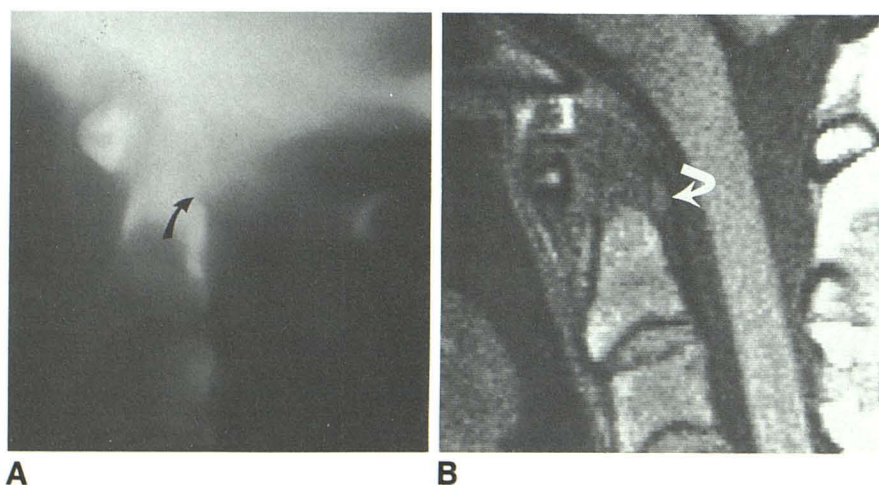


Fig. 4.—Case 8.

A, Midsagittal pluridirectional tomogram shows sclerosis of dens and upper portion of body of C2. Atlantodental interval is 6 mm. Note generalized erosion of posterior superior aspect of dens as well as focal erosion (arrow).

B, Midsagittal T1-weighted MR image shows mildly prominent transverse ligament and/or pannus at focal erosion site (arrow) as well as moderate predental pannus. Loss of supradental fat implies presence of pannus and/or thickened ligaments.

Fig. 5.—A and B, Case 11.

A, Midsagittal pluridirectional tomogram shows sclerosis of dens as well as osteophyte, which emanates from superior portion of anterior arch of C1.

B, Midsagittal T1-weighted MR image shows that sclerosis seen on tomography is nearly identical to distribution of hypointensity noted on MR. Cortical portion of anterior arch of C1 is well identified, as are calcifications extending superiorly toward basion.

C and D, Case 15.

C, Lateral plain film of cervical spine. Note posterior fusion with both bone and wire, anterior atlantoaxial subluxation (atlantodental interval = 8.4 mm), mild cranial settling, fusion of C4–C5 apophyseal joints, and diffuse osteopenia.

D, Midsagittal T1-weighted MR image shows marked predental pannus (arrow), which explains why anterior subluxation could not be reduced by posterior fusion. Displaced signal caused by metal fusion partially obscures cervicomedullary junction, which is severely compressed by ectopic dens, although cervicomedullary angle is normal. Cervical spine in general and dens in particular are quite hyperintense.

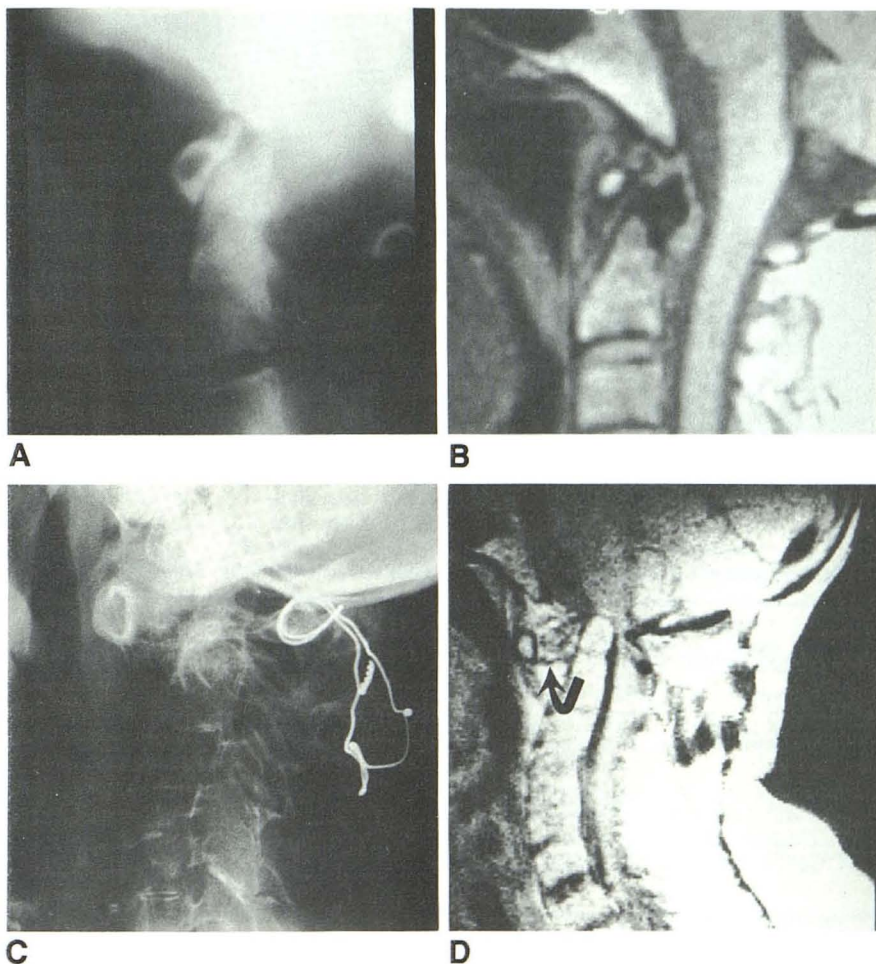
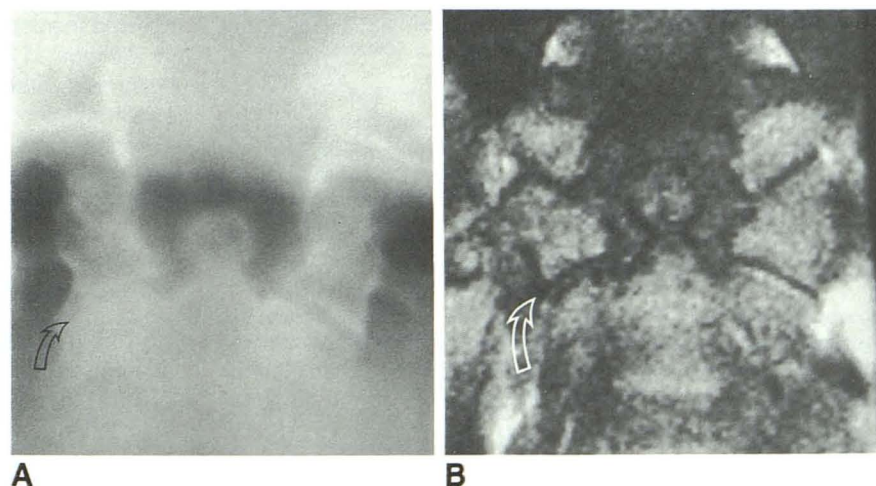


Fig. 6.—Case 5.

A, Coronal pluridirectional tomogram shows small erosions involving lateral aspect of dens inferiorly. There is narrowing of right C1–C2 articulation, and focal radiopacity (arrow) in inferolateral aspect of right lateral mass most likely represents a small cyst in a subchondral location.

B, Coronal T1-weighted MR image. Again identified are erosive changes of dens, narrowing of right C1–C2 articulation, and focal hypointensity (arrow) in region of cyst on A. Predictably, it is difficult to separate sclerosis from cyst formation on T1-weighted MR.



of rheumatoid nodules [6, 18]. On the other hand, one group of investigators believes that only subaxial subluxation correlates well with disease duration [15]. The development of subaxial subluxation and the progression of cranial settling

are regarded as ominous signs of impending neurologic catastrophe [18]. However, the patient may have no warning, since cervical subluxations can occur without symptoms referable to the neck [5, 6, 11]. Because an asymptomatic period

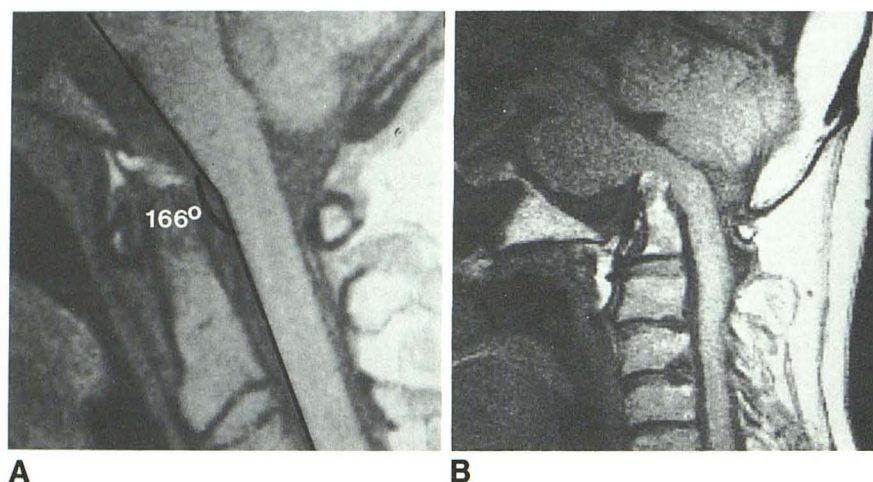


Fig. 7.—A, Volunteer. Midsagittal T1-weighted MR image. Lines parallel to anterior surface of medulla and upper cervical cord subtend cervicomedullary angle, 166°.

B, Case 2. Midsagittal T1-weighted MR image shows marked cranial settling with moderate compression of upper medulla. Prominent hypointensity representing calcification and/or ossification is seen ventrally. It is outlined by fat and extends toward basion. Prominent soft tissue is seen anterior to dens.

TABLE 2: Classic Rheumatoid Arthritis Patients with Myelopathy, Brainstem Compression, and/or C2 Root Pain

Case No.	Age	Gender	Disease Duration (years)	Sero-positivity	Subcutaneous Rheumatoid Nodules	Subluxation at C1–C2	Subaxial Subluxation	Cervicomedullary Angle °	Neuraxis Configuration	
									Mid and Lower Cervical	Craniovertebral Junction
2	58	M	24	+	—	Marked cranial settling	C3 on C4 (17%)	111	Normal	Moderate compression of pontomedullary junction
7	53	M	17	+	—	AAS (ADI, 6 mm)	None	150	Normal	Mild ventral compression of upper cervical cord
10	58	M	11	+	—	Mild cranial settling	C4 on C5 (20%)	131	Mild ventral defect	Mild ventral compression at cervicomedullary junction
12	59	M	2	+	+	None	C4 on C5 (10%)	162	Mild ventral defect	Normal
13	66	F	18	+	—	AAS (ADI, 8.7 mm)	C3 on C4 (16%)	133	Normal	Mild ventral compression of upper cervical cord
14	58	F	15	+	—	Marked cranial settling; R LAS (3 mm); RAS	None	98	Normal	Moderate anterior and posterior corticomedullary junction compression
15	68	F	20	+	—	AAS (ADI, 8.4); mild cranial settling	None	141	Normal	Severely compressed upper cervical cord and inferior medulla

Note.—+ = present; — = absent; AAS = anterior atlantoaxial subluxation; ADI = atlantodental interval; R = right; LAS = lateral atlantoaxial subluxation; RAS = rotatory atlantoaxial subluxation.

probably exists between onset of anatomic and clinical dysfunction, and because of the difficulty in inferring cord contour from bone alignment, there is disagreement about the ability of plain films to predict neurologic abnormalities [5, 13, 19, 20].

Significant axial and/or subaxial cervical cord deformities have been shown on CT metrizamide myelography to account for approximately 80% of the cases of myelopathy in rheumatoid arthritis patients [18]. Our study as well as work by others also suggest that the major cause of neurologic dysfunction in rheumatoid arthritis patients is mechanical compression [16]. This can lead to (1) microvascular compres-

sion from a sagittally directed force, as occurs in anterior atlantoaxial subluxation (e.g., compression of the distal sulcal branch of the anterior spinal artery) or (2) major vessel occlusion secondary to ectopic soft tissue or bone (e.g., compression of the anterior spinal, vertebral, or basilar artery). Other causes include primary arteritis, biochemical alterations in the cord, development of rheumatoid pachymeningitis, or constricting invasive epidural pannus [21]. There was no MR evidence of large-vessel occlusion in our patient population. The dura did not appear focally or diffusely thickened and the imaged cervical-cord intensity on sagittal T1-weighted images appeared unremarkable. T2-weighted acquisitions obtained

with a short, symmetric-echo technique [22] or with cardiac gating may have revealed cord-intensity abnormalities, but these were not obtained, primarily because of the length of the multiple plane T1-weighted examination.

The reported incidence of myelopathy in patients with atlantoaxial subluxation is 0–66% [11, 12, 23]. This wide range does not appear to correlate with the severity of the disease. We found that seven (47%) of 15 patients had evidence of neurologic dysfunction. All patients with a cervicomedullary angle less than 135° were neurologically abnormal; however, three of seven patients who had myelopathy, brainstem compression, and/or C2 root pain had a normal cervicomedullary angle. Two in this latter group had compression of the ventral cervicomedullary junction, and one had evidence of subcutaneous rheumatoid nodules. No patient in our study with cervicomedullary junction compression was neurologically normal. In addition, subcutaneous rheumatoid nodules occur more often in rheumatoid arthritis patients with myelopathy than in those without myelopathy (76.9% vs 55.1%) [5], although grossly abnormal dura was not demonstrated in this study. Therefore, a rheumatoid arthritis patient with an abnormal cervicomedullary angle and/or cervicomedullary junction compression should be evaluated carefully for the possibility of neurologic dysfunction.

The precise bony margins at the craniovertebral junction have been said to be indeterminate because cortical bone gives zero signal [3, 24]. We have found that MR measurements of the atlantodental interval are in excellent agreement and measurements of the basion-dental interval are in good agreement with their radiographic counterparts. The basion-dental measurements may not have been as accurate because they were made in the frequency-encoded direction; that is, the direction in which chemical-shift artifacts are seen. The radiographic and MR depictions of the odontoid configuration were nearly identical, with all but two cases showing evidence of erosion. We found fairly good agreement between the density of the dens on tomography and its intensity on MR. Presumably, when the predominantly fatty marrow of this study's age group is replaced by more compact bone, the signal intensity falls to near zero owing to lack of mobile protons. Conversely, a relative increase in fatty marrow (an osteopenic appearance on tomography) leads to a bright signal with T1-weighted MR.

We have shown that MR is as good as tomography for the evaluation of the atlantodental interval, dens erosion, ligamentous calcification or osteophytes of the upper cervical spine, subaxial subluxation, and the various subluxations that occur in the occiput–C2 region. MR was not as good in the evaluation of the basion-dental interval, erosion of the posterior spinous processes, apophyseal joint disease from C3 inferiorly, and cystic changes of the articular facets of C1–C2. Therefore, the most clinically important parameters are well seen with MR. MR is much better in the delineation of pannus formation, contour changes of the neuraxis, and evaluation of the cervicomedullary angle. In our opinion MR is the best single test for rheumatoid arthritis of the cervical spine.

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