Diagnostic Evaluation of Low Back Pain with Emphasis on Imaging

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Purpose: **To review evidence on the diagnostic accuracy of clinical information and imaging for patients with low back pain in primary care settings.**

Data Source: **MEDLINE search (January 1966 to September 2001) for articles and reviews relevant to the accuracy of the clinical and radiographic examination of patients with low back pain.**

Study Selection: **The authors reviewed abstracts and selected articles for review on the basis of a combined judgment. Data on the clinical examination were based primarily on recent systematic reviews; data on imaging tests were based primarily on original articles.**

Data Extraction: **Diagnostic results were extracted by one or the other author. Quality of methods was evaluated informally. Major potential biases were identified, but neither quantitative data extraction nor scoring was done.**

Data Synthesis: **Formal meta-analysis was not used because the diagnostic hardware and software, gold standards, and patient selection methods were heterogeneous and the number of studies was small. Sensitivity for cancer was highest for magnetic resonance imaging (0.83 to 0.93) and radionuclide scanning (0.74 to 0.98); specificity was highest for magnetic resonance imaging (0.9 to 0.97) and radiography (0.95 to 0.99). Magnetic resonance imaging was the most sensitive (0.96) and specific (0.92) test for infection. The sensitivity and specificity of magnetic resonance imaging for herniated discs were slightly higher than those for computed tomography but very similar for the diagnosis of spinal stenosis.**

Conclusions: **The data suggest a diagnostic strategy similar to the 1994 Agency for Health Care Policy and Research guidelines. For adults younger than 50 years of age with no signs or symptoms of systemic disease, symptomatic therapy without imaging is appropriate. For patients 50 years of age and older or those whose findings suggest systemic disease, plain radiography and simple laboratory tests can almost completely rule out underlying systemic diseases. Advanced imaging should be reserved for patients who are considering surgery or those in whom systemic disease is strongly suspected.**

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Low back pain is a pervasive problem that affects two thirds of adults at some time in their lives. It ranks among the top 10 reasons for visits to internists (1, 2) and is the most common and expensive reason for work disability in the United States (3).

Most often, back pain is benign and self-limited. However, it is occasionally the presenting symptom of such systemic diseases as cancer or infection. Some causes of back pain, especially those with neurologic symptoms, are surgically remediable. Thus, the major diagnostic task is to distinguish the 95% of patients with simple back pain from the 5% with serious underlying diseases or neurologic impairments.

Differential Diagnosis

The differential diagnosis of low back pain can be divided into mechanical causes (no primary inflammatory or neoplastic cause), visceral causes (no primary involvement of the spine), and all others (4) (**Table 1**). A definitive diagnosis cannot be made in as many as 85% of patients because symptoms and pathologic changes are not closely associated (9). Many cases of uncomplicated low back pain are assumed to result from muscle sprains and strains, ligamentous injuries, and spinal degenerative changes.

Disc herniation with nerve root compression or irritation is the most common cause of neurologic abnormalities. Spinal stenosis may also be associated with leg symptoms and neurologic abnormalities, often involving both sides of the body and multiple nerve roots.

Spinal "instability" (in the absence of fractures or spondylolisthesis) remains a controversial diagnosis. It is often identified by the finding of vertebral slippage on flexion radiographs (10). The prevalence of spinal instability in asymptomatic persons is unclear, as is the degree to which this condition causes pain.

The diagnosis of "internal disc disruption," identified by provocative discography (injection of contrast material into the disc with simultaneous assessment of pain), is even more controversial. Discography frequently generates pain in asymptomatic adults (11), and symptoms attributed to internal disc disruption often improve spontaneously (12). The true significance and appropriate management of this condition remain unclear.

When the precise anatomic sources of pain cannot be determined, early diagnostic evaluation that focuses on three basic questions is useful: 1) Is there underlying systemic disease? 2) Is there neurologic impairment that might require surgical evaluation? 3) Is social or psychological distress amplifying or prolonging the pain? (7). For most young or middle-aged adults, these questions can be answered on the basis of history and physical examination alone; diagnostic testing is infrequently required.

Pretest Probability of Disorders that Cause Back Pain

Systemic Diseases

In primary-care settings, about 0.7% of patients with back pain have metastatic cancer. About 0.01% have spinal

infections, and 4% have osteoporotic compression fractures. Only about 0.3% have ankylosing spondylitis (7).

Taking a history is more useful than physical examination in screening for underlying malignancy, at least in the early stages (**Table 2**) (7, 10). A history of cancer mandates further evaluation. The most common sources of metastatic cancer are the breast, lung, and prostate; these areas should be examined when cancer is suspected.

Spinal infections are usually acquired hematogenously from other sites. Common underlying infections are related to injection drug use, urinary tract infection, or skin infection.

Compression fractures in older adults usually result from osteoporosis. Only about 30% of such patients have identifiable trauma. The prevalence of this condition is substantially associated with race: African-American and Mexican-American women have 25% fewer compression fractures than white women (18).

Ankylosing spondylitis and other inflammatory spondyloarthropathies occur rarely, and the predictive value of positive findings is low (19). Tests of sacroiliac joint tenderness are poorly reproducible and inaccurate in distinguishing ankylosing spondylitis from mechanical spinal conditions (7).

Neurologic Impairment

The first clinical clue to neurologic impairment usually is a history of sciatica: sharp pain radiating down the posterior or lateral aspect of the leg, often associated with numbness or paresthesia. Pain radiating below the knee as opposed to pain limited to the buttocks or thigh is more likely to represent true radiculopathy. Pain is sometimes aggravated by coughing, sneezing, or the Valsalva maneuver.

The most common cause of sciatica is a herniated intervertebral disc, which occurs most often between the ages of 30 and 55 years. Imaging identifies herniated discs in many persons with low back pain (20–23); thus, only a minority of these discs are therapeutically important (14, 24). More than 95% of clinically important lumbar disc herniations occur at the two lowest discs and involve the L5 or S1 nerve roots. Thus, the most common neurologic syndromes are weakness of the ankle and great toe dorsiflexors and sensory loss along the medial foot (L5), or weakness of ankle plantar flexion, diminished ankle reflex, and sensory loss along the lateral aspect of the foot (S1) (**Table 2**). Combinations of findings have not been evaluated but are probably more useful than any single finding (7, 25).

Spinal stenosis may be caused by bone (for example, facet hypertrophy), soft tissue (for example, bulging disc or thickened ligamentum flavum), or both. Like other degenerative conditions, it is most common in older adults. As many as 20% of asymptomatic adults age 60 years or older have imaging evidence of spinal stenosis (20), but the prevalence of symptomatic stenosis is unknown.

The classic symptom of spinal stenosis is neurogenic

Table 1. **Differential Diagnosis of Low Back Pain***

Mechanical Low Back or Leg Pain (97%)†	Nonmechanical Spinal Conditions (~1%)	Visceral Disease (2%)
Lumbar strain or sprain (70%)‡	Neoplasia (0.7%)	Pelvic organ involvement
Degenerative processes of disc and facets (usually related to age) (10%)	Multiple myeloma	Prostatitis
Herniated disc (4%)	Metastatic carcinoma	Endometriosis
Spinal stenosis (3%)	Lymphoma and leukemia	Chronic pelvic inflammatory disease
Osteoporotic compression fracture (4%)	Spinal cord tumors	Renal involvement
Spondylolisthesis (2%)	Retroperitoneal tumors	Nephrolithiasis
Traumatic fractures (<1%)	Primary vertebral tumors	Pyelonephritis
Congenital disease (<1%)	Infection (0.01%)	Perinephric abscess
Severe kyphosis	Osteomyelitis	Aortic aneurysm
Severe scoliosis	Septic discitis	Gastrointestinal involvement
Transitional vertebrae	Paraspinous abscess	Pancreatitis
Spondylolysis§	Epidural abscess	Cholecystitis
Internal disc disruption or discogenic back pain‖	*Shingles*	Penetrating ulcer
Presumed instability**	Inflammatory arthritis (often HLA-B27 associated) (0.3%)	
	Ankylosing spondylitis	
	Psoriatic spondylitis	
	Reiter syndrome	
	Inflammatory bowel disease	
	Scheuermann disease (osteochondrosis)	
	Paget disease	

* Diagnoses in italics are often associated with neurogenic leg pain. Figures in parentheses indicate estimated percentage of patients with these conditions among all adult patients with signs and symptoms of low back pain. Percentages may vary substantially according to demographic characteristics or referral patterns in a practice. For example, spinal stenosis and osteoporosis will be more common in geriatrics practices and spinal infection will be more common in injection drug users. Data obtained from Deyo (4), Hart et al. (6), Deyo et al. (7), and Deyo et al. (8). Reproduced with permission from reference 5: Deyo RA, Weinstein JN. Low back pain. N Engl J Med 2001;344:363-70.

† The term *mechanical* is used here to designate an anatomic or functional abnormality without an underlying malignant, neoplastic, or inflammatory disease.

‡ *Strain* and *sprain* are nonspecific terms with no pathoanatomic confirmation. *Idiopathic low back pain* may be a preferable term.

§ Because spondylolysis is equally common in asymptomatic persons and those with low back pain, its etiologic role remains ambiguous.

‖ Internal disc disruption is diagnosed by provocative discography (injection of contrast material into a degenerative disc, with assessment of pain at the time of injection). However, discography often generates pain in asymptomatic adults, and many patients with positive discogram results improve spontaneously. Thus, the significance and appropriate management of this disorder remain unclear. Discogenic back pain is often used synonymously with internal disc disruption.

** Presumed instability is loosely defined as >10 degrees of angulation or 4 mm of vertebral displacement on lateral flexion and extension radiographs. However, diagnostic criteria, natural history, and surgical indications remain controversial.

claudication, which is leg pain that mimics arterial claudication (26). Compared with arterial claudication, neurogenic claudication is more likely to occur simply with standing. Numbness and tingling are common, and symptoms often worsen with coughing or sneezing. Perhaps the most useful finding is a history of no pain when the patient is seated with the spine flexed (**Table 2**) (16).

Another neurologic condition is the cauda equina syndrome, which may result from a massive midline disc hernia that causes compression of the cauda equina. It is a surgical emergency that requires immediate referral. The syndrome represents only 1% to 2% of lumbar disc herniations that require surgery. Prevalence among all patients with low back pain has been estimated at 0.0004 (7). The most consistent symptom is urinary retention. Unilateral or bilateral sciatica, sensory and motor deficits, and abnormal straight-leg raising are common. Sensory deficits over the buttocks, thighs, and perineal region ("saddle anesthesia") and reduced anal sphincter tone occur in about 75% of patients (7).

Diagnostic Test Description

To review the diagnostic imaging literature, we performed a MEDLINE search of articles published between January 1966 and September 2001. Methods used for the search strategy are available in the Appendix (available at www.annals.org). We sequentially reviewed all article titles ($n = 1468$). We then read the abstracts of 568 articles that seemed pertinent and the full text of 150 of these 568 articles. The authors and their affiliations were masked. Disagreements on whether particular articles should be in-

Table 2. **Estimated Accuracy of the History in the Diagnosis of Spinal Diseases That Cause Low Back Pain***

Disease or Condition	Reference	History	Sensitivity	Specificity	Positive Likelihood Ratio	Negative Likelihood Ratio
Cancer	8	Age >50 y	0.77	0.71	2.7	0.32
		Previous history of cancer	0.31	0.98	14.7	0.70
		Unexplained weight loss	0.15	0.94	2.7	0.90
		Failure to improve after 1 mo of therapy	0.31	0.90	3.0	0.77
		No relief with bed rest	>0.90	0.46	1.7	0.21
		Duration of pain > 1 mo	0.50	0.81	2.6	0.62
		Age > 50 y, history of cancer, unexplained weight loss, or failure of conservative therapy	1.00	0.60	2.5	0.0
Spinal osteomyelitis	13	Intravenous drug abuse, urinary tract infection, or skin infection	0.40	NA	—	—
		Spinal tenderness to percussion	0.86	0.60	2.1	0.23
Compression fracture†	Unpublished data	Age ≥ 50 y	0.84	0.61	2.2	0.26
		Age ≥ 70 y	0.22	0.96	5.5	0.81
		Trauma	0.30	0.85	2.0	0.82
		Corticosteroid use	0.06	0.995	12.0	0.94
Herniated disc	14, 15	Sciatica	0.95	0.88	7.9	0.06
		Ipsilateral straight-leg raising	0.80	0.40	1.3	0.50
		Crossed straight-leg raising	0.25	0.90	2.5	0.83
		Ankle dorsiflexion weakness	0.35	0.70	1.2	0.93
		Great toe extensor weakness	0.50	0.70	1.7	0.71
		Impaired ankle reflex	0.50	0.60	1.3	0.83
		Ankle plantar flexion weakness	0.06	0.95	1.2	0.99
Spinal stenosis	16	Age > 65	0.77	0.69	2.5	0.33
		Severe lower-extremity pain	0.65	0.67	2.0	0.52
		No pain when seated	0.46	0.93	6.6	0.58
		Symptoms improve when seated	0.52	0.83	3.1	0.58
		Symptoms worsen when walking	0.71	0.30	1.0	0.97
		Numbness	0.63	0.59	1.5	0.63
		Wide-based gait	0.43	0.97	14.3	0.59
		Abnormal Romberg test results	0.39	0.91	4.3	0.67
		Pinprick deficit	0.47	0.81	2.5	0.65
		Weakness	0.47	0.78	2.1	0.68
		Vibration deficit	0.53	0.81	2.8	0.58
		Absent Achilles reflex	0.46	0.78	2.1	0.69
Ankylosing spondylitis	17	Positive responses to 4 of 5 screening questions‡	0.23	0.82	1.3	0.94
		Age at onset ≤ 40 y	1.00	0.07	1.1	0.0
		Pain not relieved when in a supine position	0.80	0.49	1.6	0.41
		Morning back stiffness	0.64	0.59	1.6	0.61
		Pain duration ≥ 3 mo	0.71	0.54	1.5	0.54
		Chest expansion ≤ 2.5 cm	0.09	0.99	9.0	0.92

* NA = not available.
† From 833 patients with back pain at a walk-in clinic; all had plain lumbar radiography.
‡ Questions were: Did back discomfort begin before age 40 years? Did the discomfort begin slowly? Did the discomfort persist for at least 3 months? Was morning stiffness a problem? Did the discomfort improve with exercise?

Table 3. **Estimated Accuracy of Imaging Technique for Lumbar Spine Conditions***

Technique	Sensitivity	Specificity	Positive Likelihood Ratio	Negative Likelihood Ratio
Plain radiography				
Cancer	0.6	0.95–0.995	12–120	0.40–0.42
Infection	0.82	0.57	1.9	0.32
Ankylosing spondylitis	0.26–0.45	1	ND	0.55–0.74
Computed tomography				
Herniated disc	0.62–0.9	0.7–0.87	2.1–6.9	0.11–0.54
Stenosis	0.9	0.8–0.96	4.5–22	0.10–0.12
Magnetic resonance imaging				
Cancer	0.83–0.93	0.90–0.97	8.3–31	0.07–0.19
Infection	0.96	0.92	12	0.04
Ankylosing spondylitis	0.56			
Herniated disc	0.6–1.0	0.43–0.97	1.1–33	0–0.93
Stenosis	0.9	0.72–1.0	3.2–ND	0.10–0.14
Radionuclide scanning				
Cancer				
Planar imaging	0.74–0.98	0.64–0.81	3.9	0.32
SPECT	0.87–0.93	0.91–0.93	9.7	0.14
Infection	0.90	0.78	4.1	0.13
Ankylosing spondylitis	0.26	1.0	ND	0.74

* Estimated ranges are derived from multiple studies described in the text. ND = not defined; SPECT = single-photon emission computed tomography.

cluded (approximately 15% of total articles) were settled by consensus. The data for this article were collected only from articles in the MEDLINE search.

In primary care settings, the most common spine imaging tests are plain radiography, computed tomography (CT), magnetic resonance imaging (MRI), and bone scanning. Other tests (myelography, discography, and positron emission tomography) are usually ordered by specialists before surgical intervention and were not reviewed. The estimated diagnostic accuracy of these imaging techniques are given in **Table 3**.

Biases were common in the studies reviewed. The most common biases were failure to apply a single reference test to all patients, test review bias (study test was reviewed with knowledge of the final diagnosis), diagnosis review bias (determination of the final diagnosis was affected by the study test), and spectrum bias (only severe cases of disease were included). Most studies had several potential biases, and estimates of sensitivity and specificity must be considered imprecise.

Plain Radiography

Overview

Low cost and ready availability make plain radiography the most common spinal imaging test. Several investigators (27, 28) have recommended discontinuing use of routine oblique and spot lateral views because they do not provide adequate clinically relevant findings. This position was adopted in the Agency for Health Care Policy and Research (AHCPR) guidelines (29). The anteroposterior and lateral views demonstrate alignment, disc and vertebral body height, and gross assessment of bone density and architecture; however, soft tissue structures are not evaluated extensively by these views. Oblique views show the pars interarticularis in profile and are useful for diagnosing spondylolysis when clinical evidence exists. Other special views include flexion and extension views to assess instability and angled views of the sacrum to assess sacroiliac joints for ankylosing spondylitis.

Lumbar radiography may be harmful because it exposes the gonads to ionizing radiation, especially with oblique views or repeated exposures. This is a particular concern for younger female patients. The radiation exposure of oblique views is double the exposure of standard views, which alone are equivalent to the female gonadal radiation of daily chest radiography for several years (30–32).

Plain radiography identifies many abnormalities that are unrelated to back symptoms. This is known because the abnormalities are equally prevalent in persons with and without back pain. Examples include spondylolysis, facet joint abnormalities, some congenital anomalies, Schmorl nodes, and mild scoliosis (10).

Metastases

Although an uncommon cause of low back pain in the primary care setting, metastatic cancer remains a serious concern for primary care physicians. For vertebral metastatic lesions, plain radiographs are less sensitive than other imaging tests. Metastatic lesions may be lytic (radiolucent), blastic (radiodense), or mixed. Approximately 50% of trabecular bone must be lost before a lytic lesion is visible on radiographs (33, 34). Blastic lesions may be apparent earlier. The differential diagnosis for lytic and blastic lesions depends on their precise location (posterior elements, adjacent to endplate, or centered within the vertebral body), their margins, their internal matrix, and the degree to which they are expansile. In primary care patients, the presence of a lytic or blastic lesion on plain radiographs was 60% sensitive and 99.5% specific for cancer (8). Sensitivity improved to 70% when compression fractures were included in the analysis, but specificity declined to 95%.

Infection

With vertebral infections, similar to metastases, radiographic changes occur relatively late. In addition, changes are not specific. Infections are generally hematogenous in adults and start at the vertebral endplate; they secondarily involve adjacent discs, the epidural space, posterior elements, and paraspinal soft tissue. Over several weeks, there is loss of cortical definition, followed by bony lysis and rapid loss of disc height. Finally, the vertebral body on the other side of the disc becomes involved. In one study, radiography had a sensitivity of 82% for osteomyelitis and specificity of 57% (35).

Compression Fractures

Although many patients with osteoporotic compression fractures are asymptomatic (36, 37), new fractures are often associated with pain. The existence of one fracture raises the probability of subsequent fracture (38).

Most studies of plain radiography for compression fractures are flawed by diagnosis review bias, test review bias, and selective use of reference standards. Radiographs may be adequately sensitive, but their ability to distinguish acute from chronic compression fracture is poor. Osteophytes or vertebral body fusion indicate severity. Magnetic resonance imaging is more specific because it identifies marrow edema or an associated hematoma, which may indicate acuity (39).

Ankylosing Spondylitis

Sacroiliitis occurs early in ankylosing spondylitis and is readily detected by radiography. Erosions precede sclerosis, which is followed by bony ankylosis. Angled views of the sacroiliac joints provide greater sensitivity than routine anteroposterior views (27). Osteitis, syndesmophytosis (ossification within the annulus fibrosus), and erosions are the vertebral hallmarks of ankylosing spondylitis. In a study of 31 patients with spondyloarthropathy, Marc and colleagues (40) reported a sensitivity of 0.45 and a specificity of 1.0 for radiography (anteroposterior and lateral views only), although spectrum bias may have inflated both measurements.

Herniated Discs

Radiographs cannot directly visualize discs and are insensitive to herniations.

Spinal Stenosis

Radiographs only detect compromise of the vertebral canal by bone. Thus, myelography, CT, and MRI are more sensitive for central stenosis because they depict compromise by soft tissue as well.

Nerve Root Impingement

Radiographs cannot visualize nerve roots. Osteophytes from facets or severe spondylolisthesis may raise concern about nerve root impingement, but this must be confirmed by more sophisticated imaging.

Computed Tomography

Overview

Computed tomography continues to play a vital role in spinal imaging. Computed tomography uses x-rays to generate cross-sectional images of the spine. Although spine images can be obtained only in the axial or slightly off-axial plane, sagittal and coronal reformations can be made. Usually, the spine is imaged by 3- to 5-mm thick slices parallel to the disc spaces of L3/4, L4/5, and L5/S1. If clinical concern exists, higher levels can be imaged. Recently introduced multidetector CT scanners facilitate obtaining larger areas of coverage in less time. For evaluation of spinal stenosis, a single stack of parallel axial images is preferable to multiple angles, because they can be reformatted in the sagittal plane.

Herniated Discs

A study by Thornbury and colleagues (41) compared CT with MRI by establishing an expert panel to review all initial radiographic and clinical data and 6-month follow-up data. The panel served as a reference standard. Computed tomography had a sensitivity of 88% to 94% for herniated discs and a specificity of 57% to 64%, which was similar to the sensitivity and specificity of MRI. The area under the receiver-operating curve (ROC) for CT was 0.85 to 0.86. Radiologists were blinded to the final diagnosis, which was made with knowledge of the imaging tests being evaluated (diagnosis review bias). Jackson and colleagues (42) studied 59 patients who underwent surgical exploration. Although the study was limited by its selective use of the surgical reference standard, the authors found CT and MRI to be almost equal in accuracy; CT had a sensitivity of 0.6 and a specificity of 0.86, compared with a sensitivity of 0.64 and a specificity of 0.87 for magnetic resonance imaging.

As with other imaging tests, many abnormalities found with CT, including herniated discs, are also found in normal, asymptomatic persons (**Table 4**). Although probably true anatomic anomalies, they are irrelevant for clinical decision making and reduce test specificity.

Central Stenosis

A meta-analysis of imaging tests for the diagnosis of stenosis (51) reported sensitivity ranging from 0.7 to 1.0 and specificity ranging from 0.8 to 0.96. The authors could not pool data because the methods varied among studies and methodologic quality was generally poor. As with disc herniations, stenosis is common in asymptomatic persons (4% to 28%) (52, 53).

Nerve Root Impingement

Computed tomography can accurately depict the foraminal and extraforaminal nerve root because surrounding

Table 4. **Studies of Lumbar Spine Imaging in Asymptomatic Adults***

Test	Reference	Patients	Age	Prevalence of Anatomic Conditions				
				Herniated Disc	Bulging Disc	Degenerative Disc	Stenosis	Annular Tear
		n	*y*	← % →				
Plain radiography	43	143	14–25			20		
Myelography	44	300	Mean, 51	31				
CT	45	24	< 40 y	20			0	
		27	> 40 y	27			3	
			Mean, 40					
MRI	46	86	Mean, 28	9	44			
MRI	20	53	< 60	22	54	46	1	
		14	≥ 60	36	79	93	21	
MRI	21	98	Mean, 42	28†	52		7	14
MRI	22	46	Mean, 36	76‡	51	85		
MRI	47	41	Mean, 28					
MRI	48	36	Median, 42	33§	81	56		56
MRI	49	60	Mean, 35	56–60	20–28	72		19–20
MRI	50	54	Mean, 40					24
MRI	23	148	Mean, 54	38‖	64	91	10	38

* CT = computed tomography; MRI = magnetic resonance imaging.
† Sixty-four percent had disc bulge, protrusion, or extension; only 1% had extrusions.
‡ Four percent had nerve root compression; 22% had contact or nerve root displacement.
§ None had extrusions.
‖ Six percent had extrusions; 3% had nerve root compromise.

fat provides natural contrast. It allows direct visualization of nerve root displacement or compression. However, CT is less effective for evaluating the intrathecal nerve root (53). Neural foramina can be narrowed by osteophytes from facet joints or vertebral bodies and by bulging or herniated discs. With superior depiction of cortical bone, CT should be more reliable than MRI for detecting facet degenerative changes, but interpretations vary greatly (54).

Metastases, Osteomyelitis, Compression Fractures, and Ankylosing Spondylitis

We found no adequate data on the accuracy of CT for metastases, osteomyelitis, compression fractures, or ankylosing spondylitis.

Magnetic Resonance Imaging

Overview

Magnetic resonance imaging relies on mobile protons in tissues. In a strong static magnetic field, some protons align parallel to that field. Radio waves are then used to excite, or deposit energy within, those protons. When the protons relax to a lower energy state, they release energy—the signal used to create a magnetic resonance image. The amount of energy depends on several factors, including relaxation measures specific to tissues (called T1 and T2 relaxation). Image quality and, probably, test accuracy are improved by stronger magnetic fields, measured in Tesla.

Magnetic resonance imaging offers several advantages over CT for spinal imaging. Soft tissue contrast is better, which allows parts of the disc to be distinguished from one another (for example, the nucleus pulposus and annulus fibrosus) and visualization of the ligaments. Magnetic resonance imaging also offers better visualization of the vertebral marrow and contents of the spinal canal. It does not rely on reformatted axial images because it can obtain direct sagittal and coronal images. Finally, MRI uses no ionizing radiation.

A disadvantage of MRI is that it cannot directly visualize cortical bone, which does not have mobile protons and produces a black "signal void" on magnetic resonance images. When bony anatomy is critical, CT is preferable. In patients who have had acute trauma, for example, CT may better depict fractures, especially of the posterior elements.

A variant of MRI is MR-myelography (MRM). This imaging technique uses heavily weighted T2, three-dimensional images to produce a myelogram-like study, in which dark nerve roots are silhouetted against bright cerebrospinal fluid. In a study of 72 patients in which cervical, thoracic, and lumbar findings were combined, sensitivity of MRM for disc herniations and spinal stenosis at all levels was 82% to 89%. Specificity was not reported (55). Spectrum bias was a limitation because all patients underwent surgical confirmation as the gold standard.

Some authors advocate using gadolinium to identify nerve root enhancement and, thus, increase specificity; however, data on its value are conflicting (56–58). Evidence does not currently support use of contrast enhancement in patients who have not undergone surgery.

Metastases

Algra and colleagues (59) compared MRI with bone scintigraphy for detecting metastatic disease in 71 patients. Most patients in their study had breast cancer, and the reference standard was a combination of biopsy and follow-up imaging. Although sensitivity could not be calculated, MRI seemed to be more sensitive than bone scintigraphy. A similar study of 40 patients with known pri-

mary tumors and suspected metastases also suggested that MRI was more sensitive than bone scanning (60).

Carroll and colleagues (61) studied MRI for infiltrative marrow disease. Bone biopsy or 3-year clinical follow-up findings were the reference standards. However, the authors did not distinguish benign processes, such as osteomyelitis, fibrous dysplasia, and bone islands, from malignant processes. They estimated a sensitivity of 100% (95% CI, 90.3% to 100%) and specificity of 92% (CI, 85.1% to 99.5%). Several potential biases (selection, sampling, nonuniform application of reference standard, and diagnosis review) may have inflated apparent performance.

In a study of patients with known spinal metastases, sensitivity was 0.83, specificity was 0.92, and the area under the ROC was 0.91. The study was not influenced by test review bias, but other biases were present (62). Another smaller study of 22 patients with vertebral metastasis concluded that MRI was more sensitive overall than bone single-photon emission computed tomography (SPECT) (98% vs. 92%) but less sensitive for small metastatic lesions in the posterior elements (63).

Infection

Magnetic resonance imaging is probably the most useful imaging technique for characterizing spinal infections. In addition, MRI better delineates the extent of infection, which is critical in determining the need for surgery. In a well-designed study, MRI was shown to be more accurate than plain radiography or bone scanning; sensitivity was 96% and specificity was 92% (35).

The classic finding of pyogenic osteomyelitis is involvement of two vertebral bodies with their intervening disc. Early findings vary, with only one vertebral body sometimes involved (64). The disc may herniate through a softened vertebral body endplate. Tuberculous spondylitis has a more varied appearance than other infectious processes (65). Gadolinium may increase the specificity of MRI, with enhancement of an infected disc and endplates.

The epidural space may be infected hematogenously or by extension from pyogenic spondylitis. Because of greater soft tissue contrast, MRI characterizes the extent of an epidural process better than CT does and can identify frank abscesses. However, we did not find any studies that assessed the accuracy of MRI for epidural abscesses.

Ankylosing Spondylitis

In a study of 31 patients with spondyloarthropathies, MRI had a sensitivity of 55%. Specificity could not be determined (40).

Herniated Discs

A study of observer agreement for disc abnormalities defined three categories: normal, bulge, and herniation (protrusion and extrusion were subcategories of herniation) (66). A bulge was defined as circumferential and symmetrical extension of disc material beyond the interspace; herniation was defined as a focal or asymmetrical extension. Protrusions were broad-based. Extrusions had a "neck," such that the base was narrower than the extruded material itself. Interreader agreement with this classification was moderate (48–50). These distinctions are important because extrusions are rare in asymptomatic patients (1%), whereas bulges (52%) and protrusions (27%) are common.

In a study of 95 patients, Thornbury and colleagues (41) demonstrated a sensitivity of MRI for herniated discs of 0.89 to 1.0 but a specificity of only 0.43 to 0.57. The area under the ROC curve was 0.81 to 0.84. In a cohort of 180 patients, Janssen and colleagues (67) reported a sensitivity of 0.96 and specificity of 0.97. Although this study was not influenced by test review bias, diagnosis review bias was probably present and the surgical reference standard was applied selectively.

Central Stenosis

In a meta-analysis, the sensitivity of MRI for diagnosing stenosis was 0.81 to 0.97 and specificity ranged from 0.72 to 1.0. When stricter criteria for false-positive findings were used, specificity was 0.93 to 1.0 (51).

Nerve Root Impingement

As with CT, MRI can directly visualize nerve root impingement. Magnetic resonance imaging has the advantage of superior contrast and multiplanar imaging, which facilitates the visualization of both intrathecal and extrathecal nerve roots. Most studies have demonstrated a strong association between severe nerve root compression and pain distal to the knee (22, 68–70).

Annular Tears (High-Intensity Zones)

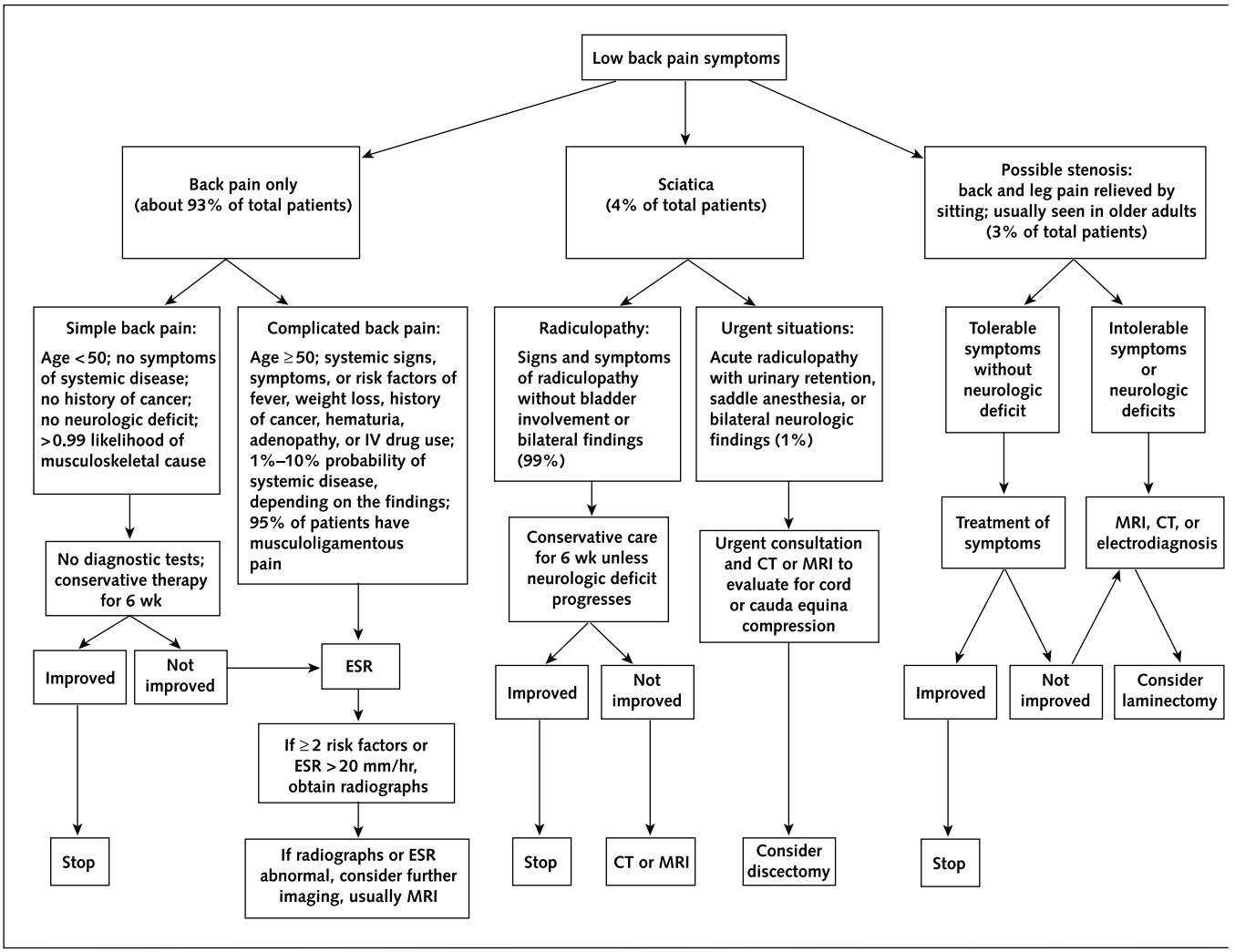
The term *high-intensity zone* has been proposed to describe the presence of focal high signal in the posterior annulus fibrosus, as seen on T2-weighted images (71). These high-intensity zones presumably represent tears in the annulus fibrosus of the disc. The clinical importance of identifying a high-intensity zone, however, remains controversial. Some authors report high concordance between the presence of a high-intensity zone and positive findings on discography (reproduction of a patient's usual back pain) (71, 72), but others find no relationship (50, 73, 74). The high prevalence of high-intensity zones in asymptomatic patients (as high as 38% of patients) limits its clinical value (23, 50).

Bone Scanning

Overview

Bone scanning involves intravenous injection of radioactive compounds that adhere to metabolically active bone. Since 1971, technetium-99m–labeled phosphate complexes have been the agents of choice (75). Imaging begins 2 to 4 hours after injection. For documentation of hyperemia or inflammation, dynamic blood flow and blood pool images are used in addition to standard delayed images.

Figure. **Suggested algorithm for the diagnostic evaluation of patients with low back pain.**



Patients are evaluated according to signs and symptoms of back pain only, sciatica, or possible stenosis. CT = computed tomography; ESR = erythrocyte sedimentation rate; IV = intravenous; MRI = magnetic resonance imaging.

This "triple-phase" bone scan is often used for diagnosing osteomyelitis. Single-photon emission CT produces cross-sectional slices through portions of the body. This imaging technique can increase sensitivity by improving visualization of subtle abnormalities and increase specificity by better localizing radionuclide uptake.

The primary objective of bone scanning is to detect occult fractures, infections, or bony metastases and to differentiate them from degenerative changes. Bone scanning has been used to detect stress fractures of the pars interarticularis (76), symptomatic spondylolysis (77), inflammatory sacroiliitis (78, 79), spinal infections (80), metastatic cancer (60, 81), and other systemic diseases.

Metastases

In a retrospective study, Han and colleagues (81) evaluated 174 patients with back pain who had planar imaging and SPECT. The reference standard was a combination of clinical follow-up and imaging studies. Spectrum bias, incorporation bias, test review bias, and diagnosis review bias limited interpretation. The unit of analysis was the lesion, not the patient, and disease prevalence was not stated. Other studies with similar and different limitations report estimates of sensitivity ranging from 0.74 to 0.98 (82–88).

Infection

Bone scanning is relatively sensitive (90%) but modestly specific (78%) for infection (80).

Compression Fractures

Bone scanning is most useful for determining the acuity of a suspected compression fracture rather than identifying the fracture. Old fractures should be metabolically inactive ("cold" on a bone scan); recent fractures should have high bone turnover and be "hot" (60).

Ankylosing Spondylitis

In a study of 31 patients with spondyloarthropathy and 14 control patients, 23 patients had bone scans. The bone scans were abnormal in 6 patients, indicating a sensitivity for detecting spondyloarthropathy of 26%. None of the control patients had increased uptake, indicating a specificity of 100% (40). In another study of 20 patients and 20 control patients, planar bone scintigraphy had a sensitivity of only 25% and a specificity of 95% (89). Single-photon electron computed tomography increased sensitivity to 85% but decreased specificity to 90%. Although recent studies of radionuclide scanning are methodologically stronger than earlier studies, most lack high-quality reference standards or independent interpretations.

Management Strategies

We advocate a diagnostic strategy similar to that recommended in the AHCPR guidelines on acute low back problems (29). These guidelines reflect a growing evidence-based consensus that plain radiography is unnecessary for every patient with back pain because of a low yield of useful findings, potentially misleading results, high dose of gonadal radiation, and interpretation disagreements. For persons younger than 50 years of age who do not have signs or symptoms of systemic disease, imaging tests are generally unnecessary (**Figure**). For persons older than 50 years or those with signs or symptoms suggesting systemic disease, plain radiography and laboratory tests, such as the erythrocyte sedimentation rate, can largely rule out underlying systemic diseases.

The most common systemic disease is malignancy. A cost-effectiveness analysis (90) suggested that a diagnostic strategy incorporating history taking, erythrocyte sedimentation rate, and plain radiography, with selective imaging based on the results of these tests, costs approximately $5300 per case of cancer detected. This compares with a cost of approximately $50 000 if MRI were performed on every patient. However, the incremental cost of routine use of MRI was $625 000 per additional case found. Because cancer that has metastasized is rarely curable, cost per year of life saved may be substantially greater. Disease prevalence was a critical determinant: Cost-effectiveness differed widely among strategies when the prevalence of cancer was less than 1% but converged substantially if prevalence was as high as 5% (90). An earlier cost-effectiveness analysis suggested that if radiography was done routinely at the initial visit in patients with acute back pain but no "red flags," the cost would be $2000 (in 1982 dollars) to avert 1 day of pain (91). The authors concluded that this was prohibitive and recommended radiography only if symptoms persisted for 8 weeks.

For patients with evidence of radiculopathy, conservative care for 6 weeks without imaging is usually appropriate. Most patients will improve during this time. If patients do not improve, MRI is usually indicated. If radicular symptoms are bilateral or associated with urinary retention, urgent imaging and consultation are appropriate to evaluate for possible cauda equina syndrome.

In an older patient with back and leg pain relieved by sitting, spinal stenosis should be considered. If symptoms are persistent or progressive and intolerable, imaging is appropriate. Magnetic resonance imaging is the technique of choice.

Table 5. **Key Summary Points***

The cause of back pain in most patients is benign, and neurologic impairment does not occur.
Careful history and physical examination can identify possible systemic disease involvement.
In the absence of findings suggestive of systemic disease, imaging is rarely necessary until after 6 weeks of conservative therapy.
For patients with findings suggestive of systemic disease or with back pain that does not improve after 6 weeks of conservative therapy, normal findings on plain radiography and a normal erythrocyte sedimentation rate can almost completely rule out systemic disease.
For patients with sciatica or symptoms of spinal stenosis that do not improve in 6 weeks, CT or MRI should be considered.
CT and MRI are equally accurate for diagnosing herniated discs or spinal stenosis.
MRI is probably more sensitive and specific than other imaging tests for detecting infections or malignancies causing back pain.
CT or MRI and surgical evaluation should be done immediately in patients with symptoms of the cauda equina syndrome.

* CT = computed tomography; MRI = magnetic resonance imaging.

Other Considerations in Test Selection

In a study of patients who underwent myelography, CT, and MRI, myelography was most often reported as painful and unpleasant (92, 93) because of the narrow caliber of the machine and the noise. For CT, immobilization was the main reason for discomfort. Approximately 10% of patients report claustrophobia in the traditional MRI machine and 1% in newer open-model machines. Other considerations include gonadal irradiation for plain radiography, myelography, and CT. Medicare reimbursements in Seattle in 2002 are as follows: plain radiography, $38; lumbar CT, $291; lumbar MRI, $562; whole-body bone scanning, $212; and SPECT, $285.

Limitations and Summary

Our search strategy may have been incomplete for the wide range of conditions relevant to low back pain. When a syndrome is involved and clinical relevance depends on more than the anatomic findings (for example, herniated discs and spinal stenosis), there is no widely accepted gold standard. Many of the original studies reviewed here were limited by several biases; thus, our estimates of diagnostic accuracy are likely to be inflated.

Nonetheless, this review suggests that imaging may not be needed for patients with acute back pain of less than 6 weeks' duration unless findings suggest systemic disease or progressive neurologic deficit (**Table 5**). The reasons for this conclusion are that imaging is unlikely to reveal a specific cause and irrelevant findings are common. Choice of imaging tests after acute pain has persisted for 6 weeks depends on clinical findings. However, for patients with systemic diseases, MRI probably offers the greatest sensitivity and specificity; for patients with degenerative conditions that produce neurologic compromise, MRI offers results comparable to those obtained with CT. The frequent finding of abnormalities in normal adults limits the specificity of all these tests.

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Appendix: Search Strategy Methods

We performed a MEDLINE search of articles published between January 1966 and September 2001. Sherry Dodson, a clinical medical librarian at the University of Washington, assisted in the design of the search. We used the following search statements: 1) back pain (major) OR intervertebral disc displacement (major) OR sciatica (major) OR spinal stenosis (major); 2) diagnostic imaging (major); 3) 2 AND 3; 4) 1 OR 4; 5) 5 AND eng (la). We applied the following subheadings to the first statement: diagnosis (di), or radiography (ra), or radionuclide imaging (ri). We excluded articles on experiments in animals and articles on pediatrics. We also excluded case reports, review articles, editorials, and articles written in foreign languages. We included only articles describing plain radiography, computed tomography, magnetic resonance imaging, and bone scanning. A total of 1468 citations were retrieved. Both authors reviewed all titles and, subsequently, the abstracts of 568 articles that seemed pertinent. Finally, we reviewed the full text of 150 articles. At each step, the authors of the articles and their institutional affiliations were masked. Disagreements on whether particular articles should be included (approximately 15%) were settled by consensus. Only those articles meeting our inclusion criteria were included and cited for this review.

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