Scintigraphy of spinal disorders in adolescents

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Abstract. Bone scintigraphy in adolescents is useful in helping to differentiate between developmental (atypical lumbar Scheuermann disease), infectious (discitis, osteomyelitis), neoplastic (osteoid osteoma, osteoblastoma), and traumatic (occult fractures, spondylolysis, pseudoarthrosis) disease of the spine. Double-phase (blood pool, delayed images) scintigraphy can characterize the pattern (i.e., linear in fracture, ovoid in nidus of osteoid osteoma). Single-photon emission computed tomography (SPECT) can be helpful in detecting the subtle presence of stress reaction (spondylolyses) not noted on routine planar scintigraphy and radiography. Bone scintigraphy is most beneficial when correlated with other imaging modalities in refining the diagnosis of spinal diseases.

Key words: Adolescent - Bone infarction - Neoplasm - Scintigraphy SPECT - Spine - Trauma

Methods of bone scintigraphy

The technique consists of the intravenous injection of a bolus of radionuclide, generally technetium-99m methylene diphosphonate, a bone-seeking radiopharmaceutical. Usually 200 μCi/kg is administered, the total dose being minimum 2 mCi and the maximum 20 mCi. Dual-phase bone scintigraphy is utilized with early 3- to 15-min high count, anterior and posterior blood pool images depicting the extracellular distribution of activity in the axial skeleton, and delayed 2- to 3-h images representing the patterns of osseous accumulation.

In addition to routine imaging procedures, high-resolution magnification imaging (pin-hole collimation or electronic/computer techniques) and single-photon emission computed tomography (SPECT) are available for more detailed and accurate definition of scintigraphic patterns in the adolescent spine. A pin-hole collimator with a small aperture allows better resolution with accurate localization of the abnormal focus of increased activity by defining the vertebral elements and the intervening disc spaces. SPECT is able to detect subtle accentuations of radioactive tracer deposition that cannot be identified on planar imaging. This method typically involves acquisition of counts at 64 positions in a 360° rotation around the region of interest. Tomographic reconstructions can then be obtained in the transaxial, coronal, and sagittal planes.

Discussion

The back pain syndrome may have various etiologies; developmental, infectious and inflammatory, tumor and tumor-like, and post-traumatic. The bone scan is very effective in identifying a region of osteoblastic activity, whether it relates to a primary bone-producing neoplasm (osteoid osteoma, osteoblastoma) or a secondary reactive response to an external stimulus such as infection, trauma, or neoplasm.

Developmental disease

Typical Scheuermann disease is a spinal dystrophy or osteochondrosis-like process originally described as a fixed juvenile thoracic kyphosis with radiographic changes of anterior vertebral wedging (> 5° each) of three or more contiguous vertebrae, sometimes associated with end-plate irregularity, elongation of vertebral...
bodies, narrowing of the intervertebral disc space, and intravertebral disc herniation [5]. The etiology of the condition is controversial; it is usually spontaneous in onset, often hereditary, and seldom painful. Histologic reportings have described either abnormal loose-appearing cartilage or absent cartilage in both the vertebral plate and the growth plate. Vertebral bone growth was reduced under the areas of abnormal growth plates [1, 20]. Typically, patients present with concerns about the appearance of a roundback deformity rather than back pain. Spondylolysis is increased in the classic Scheuermann disease [27].

Although less common (less than 5% of all cases), lumbar and distal dorsolumbar forms have been described with associated intravertebral anterior disc herniation (Schmorl node) causing “gouge or scoop” defects anteroinferiorly or anterosuperiorly, marginal sclerosis, endplate irregularities, and narrowing of associated disc spaces (Fig. 1A). This form of disease characteristically is associated with low back pain. The associated role of strenuous physical activity such as rowing, weight lifting, and gymnastics can increase intranuclear pressures, with fracturing of the endplate and the nuclear material rupturing into the vertebral body, resulting in a diminution of the intervening disc space [12]. Idiopathic scoliosis has a greater association with the lumbar form of Scheuermann disease (44%-70%) and less with the thoracic kyphotic type (33%). Two or more vertebral levels are involved most frequently (70% of the time; G.A. Mandell, unpublished data); single-level involvement can be confused with infection such as osteomyelitis or discitis.

Bone scintigraphy typically shows no abnormal activity in the classic thoracic form of Scheuermann disease [23]. If a scan displays increased activity in the area of the thoracic kyphosis, a different etiology such as trauma or infection has to be considered. The bone scan in the atypical form of lumbar Scheuermann disease may exhibit equivocal results with normal early blood-pool images and either slightly active or normal delayed planar images (Fig. 1B). SPECT usually shows areas of involvement with subtle increases in accumulation of the radiotracer (Fig. 1C). Pin-hole high resolution imaging may identify a slightly active end-plate. Magnetic resonance imaging (MRI) has confirmed that marginal sclerosis, intravertebral disc herniation, and narrowed disc spaces are more often associated with disc degeneration than just irregular or wedge-shaped vertebrae [28]. The marginal reactive sclerosis associated with anterior disc herniation involving the anterior ring apophyses in the lumbar region is probably the cause of the slightly increased uptake on bone scan in this form of Scheuermann disease. Schmorl nodes can occur as isolated phenomena in 76% of the normal population. A single reporting of this type of intervertebral herniation showing increased activity on bone scan has also been reported [22]. Acute or subacute trauma or infection usually evoke much more reaction with correspondingly increased radiotracer uptake. Acute posterior disc herniations at L4–5 and L5–S1 in adolescents usually show normal activity on bone scintigraphy including SPECT.

**Inflammatory and infectious conditions**

Spondylodiscitis is an inflammatory process that arises in the disc space. Intervertebral disc infection is usually an indolent process (benign osteomyelitis of the spine) and the patient is not particularly ill. A recent microangiographic investigation concludes that childhood discitis is a milder form of osteomyelitis because the anastomotic osseous arterial network in children prevents a large portion of the bone from being destroyed by infarction and subsequent infection [31]. Both discitis and osteomyelitis involve the disc space and adjacent vertebral bodies. In pyogenic vertebral osteomyelitis, the changes are usually more extensive and destructive.

Discitis has characteristically two peak age periods of incidence, occurring primarily in young children 6 months to 4 years of age, and in older children from 10 to 14 years of age. Although the erythrocyte sedimentation rate is usually elevated, the body temperature and leukocyte count are often normal. The etiology in most cases is uncertain, since positive cultures are usually not found [30]. Infection may hematogenously reach the disc [9] via subchondral vascular channels that arise in the marrow of the vertebral body and perforate the endplate.

Bacterial osteomyelitis appears predominantly in the first decade of life and is usually accompanied by systemic illness. Isolation of an organism (Staphylococcus aureus) occurs more frequently in osteomyelitis than in discitis. Osteomyelitis manifests frank bone destruction sometimes accompanied by soft-tissue abscesses (see Fig. 3 E, F).

Initial radiographs of the spine may be normal in both discitis and vertebral osteomyelitis. The earliest radiographic findings in discitis occur 2–4 weeks after the onset of symptoms, with narrowing of the disc space, marginal irregularity, and erosion or demineralization of the adjacent vertebral endplates (Fig. 2A). The earliest radiographic change noted in osteomyelitis is focal rarefaction in the superior or inferior region of the involved vertebra adjacent to the cartilaginous plate (Fig. 3A).

Bone scintigraphy can predate radiographic changes in both discitis and osteomyelitis by 3–6 weeks. Early detection of infection may occur as early as 7 days after the onset of the symptoms [38]. The usual scintigraphic pattern in discitis is increased uptake in the disc space and the contiguous ends of the adjoining vertebrae [10] (Fig. 2B, C). The increased tracer activity is noted on both the blood-pool and delayed images of the technetium phosphate scan. With vertebral osteomyelitis, bone scintigraphy usually shows diffuse uptake of the radiopharmaceutical within the involved vertebra in both blood-pool and delayed planar images [13] (Fig. 3B). SPECT imaging and pin-hole collimation are helpful in clarifying the distribution of the activity (Fig. 3C, D), either predominantly to one vertebral body and an adjacent disc (osteomyelitis plus disc space infection) or involving the disc space and endplates of the two contiguous vertebrae (spondylodiscitis).

When the bone scan is negative or equivocal and