Nuclear Orthopedics

With the development of bone scintigraphy using technetium-phosphate complexes, a higher degree of diagnostic sensitivity in osseous disorders has been obtainable than heretofore available roentgenographically. New applications have come so rapidly that standard orthopedic surgery texts have difficulty in keeping abreast of changing techniques. In the most recent (1980) edition of a leading orthopedics compendium there is only one reference to nuclear scintigraphy (in the detection of bone infection) (*1*). There are, nevertheless, many important areas of diagnostic collaboration with our orthopedic colleagues now being explored. The applications of nuclear medicine in non-neoplastic osseous disorders of interest to the orthopedist can be summarized as follows.

1. Aseptic bone inflammatory diseases or septic osteomyelitis and discitis present as scintigraphic abnormalities before the osseous reaction can be visualized roentgenographically (*2–4*).

2. Compromised blood supply leading to aseptic bone necrosis (of many etiologies, including fracture, Legg-Perthes disease, slipped capital femoral epiphysis, dislocation, sickle cell disease, steroid medication, frostbite, radiation, S.L.E., etc.) can also be detected much earlier by radionuclide imaging than by radiologic techniques, since the initial distribution of bone scanning agents depends on blood flow (*5–7*).

3. Metabolic bone diseases, such as osteomalacia, hypervitaminosis D, and hyperparathyroidism, will usually be manifest as diffuse bone uptake of the radionuclide, and associated "pseudofractures" may be diagnosed quite early in their course (*8–11*). Hypervitaminosis A, with multiple foci of uptake, is one of several other metabolic disorders in which early bone disease may be visualized (*12*).

4. Actively osteogenic areas of early Paget's disease have a characteristic pattern of uptake, which subsides as the disease enters a "burned out" phase (*13*).

5. In the differential diagnosis of pain that follows insertion of a prosthesis, loosening, formation of heterotopic bone, or development of osteomyelitis, all of these conditions may be detected prior to radiographic changes (*14*).

6. Arthritis not obvious on clinical examination, and confirmation of calcaneal periostitis (plantar fascitiis) can both be visualized when not seen radiographically (*15–18*).

7. The detection of areas of bone involvement by multifocal granulomatous disease, such as sarcoid and eosinophic granuloma, inapparent roentgenographically, is possible by radionuclide imaging (*19,20*).

8. Early detection by radiotracer imaging of fractures and areas of bone trauma, not always apparent on skeletal radiography, is now possible, e.g., stress and compression fractures in athletes and the "battered child syndrome" (*21*).

9. The assessment of bone-graft healing appears to be more sensitive by scintigraphic than radiographic techniques (*22,23*).

10. The diagnosis and prognosis of nonunion of fractures and the evaluation of therapies directed at effecting a union are now possible. This topic is the subject of a study by Desai et al. in this month's issue (*24*).

Some perspective on the problem of nonunion may be helpful. Nonunion has been defined as the failure of a fracture to heal by 6 (*25*) to 8 (*26*) months, although the distinction from delayed union can become a problem of semantics. In practice the orthopedist can usually identify a fracture that will not heal without intervention. The likelihood of nonunion is enhanced when the fracture is compound, comminuted, insecurely fixed, immobilized for an insufficient time, treated by an ill-advised open reduction, or distracted either by traction or plate and screw (*1*). Other important factors leading to an increased risk of nonunion include inadequate blood supply (*27*); existing metabolic disease, such as osteoporosis (*1*); hyperparathyroidism (*28*); poor nutritional status

(*29*); and, of major importance, infection (*25*). The incidence of nonunion also depends on the bone involved, being highest in the tibia and femur, and progressively decreasing when the humerus, radius, ulna, or clavicle are involved (*1*).

Some idea of the frequency of nonunion in our "high-speed society" has come from a study of 101 trauma patients (*30*). Of 39 surviving patients who were victims of automobile accidents, there were ten fractures with nonunion, and four of these were complicated by infection. Another 31 patients had been involved in motorcycle accidents; one required amputation and nonunion occurred in 11 others. In this series two of nine fractures that resulted from falls had nonunion, and in nine miscellaneous outdoor accidents (mostly crushing injuries) three had nonunion. Of an estimated 2 million fractures from all causes occurring yearly in the United States, 5% progress to nonunion (*31*). Because of the prolonged hospitalization required for these patients, the economic and psychological burdens of nonunion are enormous.

The pathogenesis of nonunion has been recently summarized (*32*). The final result is a fibrotic junction or a pseudoarthrosis, where one end of the fracture, usually the proximal, develops a concave surface articulating with the opposite convex surface, with a false joint cavity containing viscous fluid. Therapy involves treatment of infection, often with sequestrectomy, reduction and internal fixation, or closed methods (*30*).

At the two extremes of nonunion, the unlabeled fragments may be hypervascular, fully viable and show increased radiotracer uptake, or be avascular and physiologically inert with no Sr-85 uptake. It is this latter form of nonunion that often requires an autologous cancellous bone graft with decortication of the ends of the fragments (*1*). The pathophysiology of osteogenesis in healing fractures has been examined by several authors (*1,33–35*). In rats and rabbits technetium-99m phosphate uptake is seen peripheral to the fracture line in the first week after the trauma, followed by progressive uptake, including the fibrocartilaginous callus, within 2 wk (*34,35*). With nonunion the latter process does not occur.

A therapeutic modality of some promise in nonunion is electrical stimulation that has been evaluated by a group from the University of Pennsylvania both radiologically (*36*), and now scintigraphically by Desai et al. (*24*). In 1957 Fukado and Yasuda first noted the piezoelectric effect in mechanically stressed bone (*1*). Areas of compression were found to be electronegative and areas of tension, positive. This piezoelectric effect has been attributed to collagen rather than to mineral crystals of bone (*37*). Osteogenesis has been produced at negative electrodes either implanted in, or placed exterior to, fractures. The current may be AC or DC, with amperage ranging from nanoamperes to 20 microamperes over a period of weeks (*1*). Data are accumulating that in the treatment of nonunion this technique may be an important adjunct (*36*).

The radiographic appearance of the nonunion, either with osteoporosis or sclerosis, has no prognostic value in determining if the nonunion will heal with electrical stimulation (*36*). To provide this important information, however, Desai et al. have successfully applied nuclear medicine techniques (*24*), since the bone scan reflects both the vascular status of the fracture and the degree of osteogenesis (*38*). But as Desai et al. and Wahner have pointed out, scintigraphy alone does not always differentiate normal or delayed union from nonunion (*24,33*), despite a report to the contrary (*39*), since all three types of fracture may show intense focal radioisotope concentration (the Group 1 pattern of Desai et al.). Although the complicated nonunions (Group 2) that did not respond to electrical stimulation encompassed only five patients in this series, these important, but preliminary findings, deserve further inquiry for prompt confirmation.

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