Sports Nuclear Medicine: An Emerging Field

When hockey hall-of-famer Guy Le Fleur was winding down his career playing for the Montreal Canadians, he was not keeping pace with his record-setting 550-plus goals he had scored over the years. He complained about a throbbing pain on the pad of his foot, but an x-ray and MRI found nothing. His coaches thought his heart just was not in the game anymore. Then, Le Fleur's orthopedic surgeon suggested he have a bone scan. "We found he had numerous stress fractures in his metatarsal bones," said Leonard Rosenthall, MD, director of nuclear medicine at Montreal General Hospital and a professor of radiology at McGill University in Montreal, Canada. "It's no wonder he was in such agony."

For the past two decades, nuclear physicians have been performing bone scans on athletes to rule out minute stress fractures that frequently do not show up on x-rays for 3 to 10 weeks. Although the advent of MRI reduced the use of bone scans for many atheletic injuries, many nuclear physicians still find themselves performing bone scans for sports-related injuries.

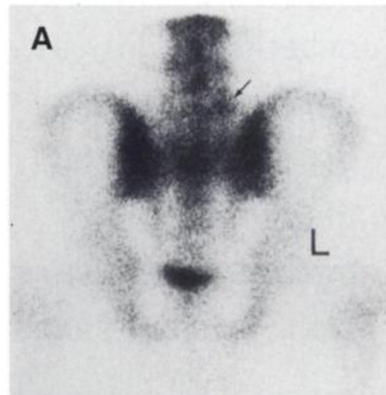
Like other areas of nuclear medicine, the use of bone scans in sports medicine varies considerably from institution to institution. In some hospitals, orthopedists only refer for bone scans after an MRI is performed and they suspect a stress fracture. In other places, bone scans may be the next test performed after an x-ray. Some nuclear physicians, if they see athletic injuries at all, may opt for three-phase scanning, while others also do whole-body imaging and SPECT. *Newsline* spoke with several nuclear physicians who practice "sports nuclear medicine" to learn how they became part of an orthopedic team.

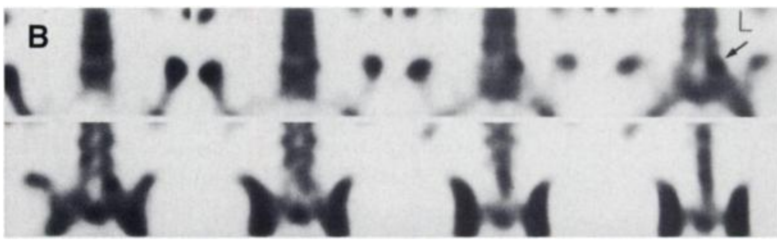
High-Tech Diagnosis

In a darkened room at the University of Maryland Medical Center in Baltimore, four computer monitors display skeletons of professional football players who tackle, block and pass for the Baltimore Ravens. With a click of a computer mouse, the soft-tissue outline of one athelete appears faintly around the skeleton; it spills off the screen. "This guy was too big to fit on the camera," proclaimed Lawrence E. Holder, MD, director of the nuclear medicine division at the hospital and a professor of radiology at the University of Maryland Medical School. He clicks into a new file and a rotating foot and ankle emerge in black and white. "This is a professional football player on the Ravens who came in recently with pain in his ankle and foot area. He had an x-ray which was 'normal' then had an MRI which appeared to suggest a little tendonitis," said Holder. "The orthopedic surgeon was still concerned about a stress fracture in the foot, so the player was referred for a bone scan." He pointed out an area of increased tracer localization on the screen. "This area along the lateral aspect of the foot had a little increased flow. During the blood-pool phase—in which the tracer has passively diffused from the vascular to the extravascular, extracellular spaces—the flow extended up into the ankle." On the third and final phase, however, the scan revealed a surprise. "We did spot views and found that there was no major increase in accumulation," said Holder. He concluded that the area was most likely caused by vascularity or inflammation in the soft tissues and not in the bone. "We agreed that there is tenosynovitis in the area but no underlying bone problem such as arthritic changes or a fracture." "If we hadn't done the blood pool, we wouldn't have appreciated the tenosynovitis," said Holder. "We confirmed a questionable MRI finding and ruled out a fracture. We determined the athelete could do his training accordingly."

In other instances, a bone scan will contradict MRI scan and x-ray results. Holder clicked on the file of another Raven football player with leg pain who was referred to the nuclear medicine department a few days before Holder spoke with *Newsline*. "The patient had a totally normal MRI, but a bone scan showed a marked increased flow in the lower leg. The hot area was in the patient's inner osseous membrane. It's the kind of trauma that occurs during a rotational injury of ankle," said Holder. "I don't know why the MRI didn't show this tear or oozing of blood in the membrane."

At Holder's institution, orthopedists generally order an MRI before a bone scan for atheletic





A 24-yr-old professional hockey player complaining of low back pain of 4 wk duration. Conventional radiographs of the lumbar spine and pelvis were normal. A radiophosphate bone scan (MDP) was requested. (A) Posterior planar scan showed low-grade, questionable focal uptake on the left in the L5-S1 region (arrow). (B) The SPECT images clearly demonstrated a focus in the inferior articular process of L5 (arrow).

injuries. For the most part, Holder does not find fault with this. "I'm the first one to say that if a clinician thinks there is a problem involving the soft tissues, then an MRI should be ordered," he said. "But if there's unexplained pain of potential osseous origin, we think orthopedists get more bang for the buck by ordering a nuclear scan." Holder said this is particularly the case when a patient gets the works: a blood-flow, blood-pool, whole-body scan to look for referred pain, high-resolution spot films and SPECT to anatomically localize any area of abnormal metabolism.

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Bone scans should be able to identify the cause of the pain or at the very least pinpoint the approximate location. "We're trying to provide physiologic information so the clinician can say, 'O.K. I don't know what it is, but the patient has some increased metabolism in this area where these two bones are coming together. Maybe it's related to the way he runs, and maybe I need to give him a heel pad or something else that will take the pressure off of that spot,' said Holder.

At Maryland, Holder and his colleagues do three-phase bone imaging (TPBI) routinely. In a chapter he wrote for the textbook *Diagnostic Nuclear Medicine, 3rd ed.*, vol. 1. Baltimore: Williams & Wilkins; 1996, Holder wrote: "TPBI in the sports medicine setting is important because usually there is clinical uncertainty as to the etiology of the symptoms. Information about blood flow, vascularity and metabolic activity allows for differential diagnosis as well as for the provision of physiologic information which, even without a specific diagnosis, can direct appropriate therapy."

Physician, Heal Thyself

David Brill, MD, a radiologist at the Geissinger Medical Center in Danville, PA, first experimented on using bone scans for sports injuries about 20 years ago. He was his own guinea pig. A die-hard runner, Brill had developed severe leg pain and thought he could find the cause on a bone scan. The scan showed some arthritic changes. "It was an acute thing," Brill said. "Once my legs got stronger from running, I corrected the minor joint problems."

Upon hearing of Brill's self-diagnosis, an orthopedic surgeon began sending high school track stars to Brill for bone scans. These runners were experiencing severe leg pain whose cause could not be determined on an x-ray. Brill did bone scans to check for hidden stress fractures and soon found his skills could be used for more than diagnosis. "I was finding that these younger atheletes didn't want to listen to their physicians. They didn't want to stop running to let their injury heal," he said. "I sat down with kids that I raced in com-

Uses for Bone Scans in Sports Medicine

• **Periostitis/Shin Splints:** Shin splits have been defined as the disruption/inflammation of the Sharpey fiber-periosteum interface and result from abnormal excursion of the musculotendon complex, with pathologic and scintigraphic changes representing a periostitis (not to be confused with a periosteal lesion that, say, results from a direct blow to the shin from a lacrosse stick).

• **Biomechanical Stress Lesions:** Sports medicine's equivalent of the repetitive stress syndromes, such as carpal tunnel syndrome, which affect the musculoskeletal system secondary to a wide range of activities.

• **Avulsion Fracture**: These fractures are caused by the pull of a muscle or tendon and usually occur in younger, skeletally immature patients whose apophyseal attachments are less strong than their tendon-bone interfaces. In the athletic setting, avulsion injuries also occur in the mature skeleton because of very strong concentrations of force associated with overstretched musculotendon complexes.

• **Avascular Necrosis:** Sudden disruption of the blood supply to areas of bone, which does not have the clinical or imaging findings associated with more established or accepted lesions or syndromes such as shin splints or stress fracture. The radionuclide bone scan is used to determine the physiologic significance of nonspecific anatomic findings seen with other imaging modalities, and to detect foci of abnormal metabolism when such anatomic imaging modalities do not show lesions.

• **Stress Fractures:** Stress fractures in the athletic setting are most often fatigue fractures, associated with cyclic loading of normal bone. Damage to a small number of osteonal units can occur acutely as the applied stress exceeds the bone's inherent strength or when loading initiates appropriate remodeling, but continues or increases before remodeling is complete, with fatigue fracture occurring during the process.

• **Tendonitis/Strains/Myositis/Bursitis:** Primary soft-tissue processes are occasionally demonstrated during three-phase bone imaging when they are associated with increased perfusion or vascularity, which can be seen on Phase I or Phase II images, but most often are detected because of secondary changes to associated or underlying bone that lead to focal areas of increased tracer uptake on delayed images. The exact etiology of such uptake is uncertain. Some authors suggest that more intense diffuse uptake about the lateral ligaments of the ankle is more related to more severe injury and might warrant more aggressive therapy.

—Excerpted from "Athletic Injuries" by Lawrence E. Holder, MD, from the textbook Diagnostic Nuclear Medicine, 3rd ed., vol. 1. Baltimore: Williams & Wilkins; 1996.

munity meets and may have thumped at the finish line. I emphathized with them, and they listened to me when I told them they needed to be shelved for a while."

Brill currently performs two to three bone scans per week during the high school track seasons in the rural town of Danville (population less than 6000). He uses three-phase bone imaging to diagnose mainly stress fractures and shin splits, which are caused by a tearing away of periosteum tissue surrounding the bone. After consulting with a runner's primary care physician, Brill often is the one to dispense the advice: Suspend activities for three to four weeks until the injury heals. Ice the shin splits after practice. Buy a new pair of running shoes. Many times, Brill has found, a bone scan is not needed if youngsters are willing to rest for a few weeks on their own.

MRI Versus Nuclear Bone Scanning

Nuclear physicians who diagnose sports injuries often find themselves in a bit of a push-and-pull relationship with radiologists who perform MRI. Usually, orthopedists or primary care physicians decide which test to order, but they may base their decision on their familiarity with the modality and previous experience. "Although bone scans are a lot cheaper for Montreal General Hospital to perform, they're usually not the first line of diagnosis," said Rosenthall. An MRI is often performed for joint injuries such as knee problems. In the cases of injuries away from the joint where a fracture is suspected, a bone scan will be performed following a negative x-ray.

Holder's institution follows a similar philosophy. "The reality is that nowadays for acute problems, the patient has an x-ray followed by MRI," Holder said. "We tend to see more subacute problems—prolonged pain or unexplained pain that isn't answered by MRI and x-ray." He admitted that "there is a little bit of tension" between the musculoskeletal radiologists and nuclear physicians. "But it really comes down to: Can your modality and your studies help the clinician and the patient? We all work together," said Holder.

In many instances, MRI holds an advantage. Most emergency rooms are equipped with MRI machines, which makes them more accessible to atheletes passing through with acute injuries. "You also can't assume that if a bone scan is negative, nothing is going on," Brill said. Soft-tissue injuries such as compartment syndrome can be quite severe but do not appear on bone scans.

Moreover, bone scans may be extremely sensitive, but they are also notoriously nonspecific, according to Brill. Other nuclear physicians who diagnose sports injuries agree that the bone scan's lack of resolution may be an obstacle to pinpointing a diagnosis. "However, by learning the pattern of the athletic injuries on bone scans—particularly in the joints—the bone scan can become more specific," said Conrad Nagle, MD, a nuclear physician at William Beaumont Hospital in Troy, MI, who diagnoses injuries in athletes. "Any finding should be correlated with x-rays and MRIs if they are available."

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Bone scans, however, hold some key advantages over MRI. One big plus is that bone scans can distinguish referred pain from the true source of pain—something that MRI cannot do. Referred pain is frequently a problem in back injuries where athletes may have pain in one side and actually have areas of increased uptake on the other. A whole-body bone scan can be quite helpful in distinguishing between referred pain and the area where the pain originated, according to Rosenthall. He recalled the case of a McGill University swimmer who had diffuse back pain. A whole-body scan discovered a benign osteoid osteoma. Moreover, SPECT with its three-dimensional views can be particularly useful in the spine to differentiate overlapping bones.

Nuclear bone scanning for atheletic injuries is not new. There is a dearth of recent studies on bone scanning in athletes and a dearth of novel radiopharmaceuticals used in three-phase bone imaging. (Most practitioners use one of the technetium-labeled diphosphonates.) But the technique has evolved considerably over the past several years. "Many of our studies are very individually tailored to the patient and are far more time consuming," said Holder. Bone imaging needed to become more advanced to keep up with the new kids on the block—CT, MRI and digital x-rays—that can show nearly flawless anatomic images. "In the past, nuclear physicians used to do whole-body bone scans and say simply, 'there's a hot spot in the foot,'" said Holder. "This is not acceptable anymore. You have to say which particular bone in the foot or at least pinpoint the area."

—Deborah Kotz

FYI You can obtain more information on the use of bone scans to diagnose sports injuries from a reference book called *Imaging of Athletic Injuries, A Multimodality Approach* by Joseph Martire, MD, and E. Mark Levinsohn, MD. New York: McGraw-Hill, 1992. It contains both MRI and nuclear scans with schematic diagrams and actual scans showing various athletic injuries. It explores pattern recognition in depth.