Comparison of Ultrasound Examination with Bone Scintiscan in the Diagnosis of Stress Fractures

CPT W. Derek Boam, MD, MC, USA; LTC William F. Miser, MD, MC, USA; MAJ Steven C. Yuill, MD, MC, USA; COL Calvin B. Delaplain, MD, MC, USA; MAJ Everett L. Gayle, MD, MC, USA; and MAJ(P) David C. MacDonald, DO, MC, USA

Background: **We wanted to compare an ultrasound examination with the bone scintiscan to diagnose stress fractures.**

Methods: **Using the bone scintiscan as the reference standard, we conducted a prospective, double-blind study of 78 patients (87 percent were men, mean age 24 years) referred for bone scintiscan to rule out tibial stress fractures. After the participants were injected with radionuclide, we examined each tibia once using ultrasound adjusted for an active intensity of 2.0 W/cm^2 and again with the wand turned off. The patient was blinded to the mode used. The patient's response to the ultrasound was considered positive if the patient reported pain as the wand passed over the tibia. A bone scintiscan was considered positive according to the criteria of Zwas. One sonography technician performed all examinations; both he and the nuclear medicine department were blinded to the other's findings. The final results were tabulated by a third, uninvolved party. A positive correlation between the scintiscan and ultrasound examination consisted of pain with active ultrasound and any degree of stress fracture in any part of the same tibia as found on the bone scintiscan.**

Results: **Thirty-five stress fractures were found on bone scintiscan, whereas only 15 were detected by ultrasound examination (sensitivity 43 percent). With ultrasound testing there were 22 false positives (specificity 49 percent) and 20 false negatives. These findings resulted in a positive predictive value of 41 percent and a negative predictive value of 51 percent.**

Conclusion: **Ultrasound is not reliable in the diagnosis of tibial stress fractures. Bone scintiscan remains the test of choice. (J Am Board Fam Pract 1996;9:414-7.)**

Overuse injuries of the lower extremities are commonly seen in primary care and sports medicine. Simple overuse injuries usually respond relatively quickly. True stress fractures require extended periods of abstinence from the offending activity if the natural healing and remodeling of the bone is to occur. Radiologic studies are often needed to distinguish stress fractures from the more-common stress reaction or shin splints.

The radiologic reference standard for the detection and diagnosis of stress fractures is the bone scintiscan. Able to detect fractures within a few days of their occurrence, a bone scintiscan offers a more rapid diagnosis than plain film radiographs, which require a number of weeks before diagnostic changes can be detected. Several authors have also suggested using ultrasound to distinguish stress fractures from stress changes that have not progressed to the point of fracture.[1-4] Ultrasound waves passing over the fracture site cause the patient to experience the sensation of pain. In a MEDLINE review of the English literature for the past 20 years, we found four studies using ultrasound in this manner. In 1980 Nitz and Scoville[1] reported 93 percent accuracy when comparing ultrasound examination with plain film radiographs in diagnosing medial tibial plateau stress fractures. Giladi et al[2] reported 71 percent accuracy with ultrasound compared with

Submitted, revised, 4 March 1996.

From the Keller Army Community Hospital, West Point, NY (WDB); the Department of Family Practice, Madigan Army Medical Center, Tacoma (WFM, DCM); and the Department of Radiology (SCY), and the Nuclear Medicine Service (CBD, ELG), Tripler Army Medical Center, Honolulu. Address reprint requests to W. Derek Boam, MD, Primary Care East, Keller Army Community Hospital, West Point, NY 10996.

The opinions and assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the United States Army, the Department of Defense, or the United States Government.

This study was completed while the authors were assigned to Tripler Army Medical Center, Honolulu.

This paper was presented at the 20th Annual Scientific Assembly of the Uniformed Services Academy of Family Physicians, April 1995, San Diego.

J Am Board Fam Pract: first published as 10.3122/jabfm.9.6.414 on 1 November 1996. Downloaded from http://www.jabfm.org/ on 23 April 2024 by guest. Protected by copyright.

bone scintiscan. Devereaux et al[3] found that ultrasonic evaluation correlated with bone scintiscan diagnosis of stress fractures 53 percent of the time. Moss and Mowat[4] reported 96 percent accuracy of ultrasound examination when compared with bone scintiscan in one small population and 75 percent correlation in another.

Because of this reported wide variation in accuracy, we conducted a prospective, double-blind study to compare ultrasound examination with bone scintiscan in the diagnosis of stress fractures. If ultrasound proved to be a reliable modality, it would represent a cheaper, faster, and more accessible diagnostic tool. Additionally, it would do away with the radiation exposure required with a bone scintiscan.

Methods

Our institutional review board approved this project. Patients referred to the nuclear medicine service for a bone scintiscan to rule out tibial stress fractures were invited to participate in this study. After we obtained informed consent, the patient was injected with 25 mCi of Tc 99m MDP intravenously. The patient was then sent for ultrasound examination. A single, dedicated sonography technician performed all examinations, and each examination evaluating the tibia was limited to 30 seconds, as this amount of time was allocated in the previous studies. With the patient lying supine, ultrasound transmission gel was spread on the anterior surface of the tibia. Ultrasound at an intensity of 2.0 W/cm^2 was then applied to the anterior surface of both tibias. The transducer was applied both with the power on (active) and with the power off (inactive). The technician did not inform the patient of the mode used, and the patient was unaware of whether the transducer was in the active or inactive mode. The technician moved the transducer slowly from the tibial plateau to the medial condyle, and the patient was instructed to report any discomfort or pain caused by the ultrasound examinations. Ultrasonic testing was considered positive if the patient reported pain as the wand was passed over the tibia. The location of any pain was recorded on a work sheet kept by the technician, and the patient then returned to complete the bone scintiscan.

Gamma camera planar imaging was performed approximately 3 hours after initial injection of the radionuclide. The first image was a 500,000-count anterior planar view of the knees. The rest of the images included views of the anterior tibiae, medial tibiae, anterior feet, and ankles. The presence, absence, and degree of stress fractures observed on the scintiscan was interpreted according to the criteria established by Zwas et al,[5] which consists of a grading system from I to IV based on the bony reaction as demonstrated by the scintiscan (Figure 1).

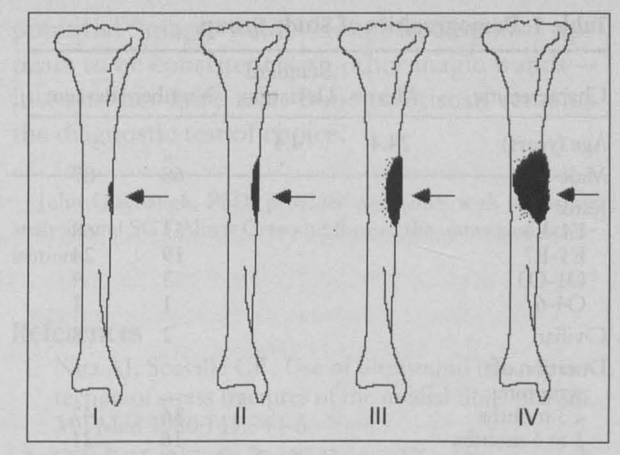

Figure 1. The four grades (I-IV) of stress fractures on bone scintiscan according to the criteria of Zwas et al.[5] Grade I is a small ill-defined cortical area of increased activity. Grade II is a larger, well-defined elongated cortical area of moderately increased activity. Grade III is a wide, fusiform, corticomedullary area of highly increased activity. Grade IV is an extensive transcortical area of intensely increased activity.

Both the sonography technician and the nuclear medicine department were blinded to each other's findings. The final results of both studies were tabulated by a third, uninvolved party. A positive correlation between the bone scintiscan and ultrasound testing consisted of pain with active ultrasound, no pain with inactive ultrasound, and any degree of stress fracture in any part of the same tibia as found on the bone scintiscan.

Statistical analysis was as follows: we did a power analysis using an alpha error of 0.05, setting the acceptable accuracy of ultrasound examination at 85 percent, which we then compared with the 50 percent success rate anticipated by chance alone. Using these parameters, the power was 0.83 as demonstrated by chi-square power analysis. We analyzed data using a binomial probability distribution and chi-square analysis.

J Am Board Fam Pract: first published as 10.3122/jabfm.9.6.414 on 1 November 1996. Downloaded from http://www.jabfm.org/ on 23 April 2024 by guest. Protected by copyright.

Table 1. Demographics of Study Group.

Characteristic	Mean	Standard Deviation	Number	Percent
Age (years)	24.4	4.4		
Male			68	87
Rank				
E1-E4			53	68
E5-E7			19	24
O1-O3			3	4
O4-6			1	1
Civilian			2	3
Duration of symptoms				
< 3 months			36	47
3 to 6 months			16	21
6 to 9 months			8	10
> 9 months			17	22
Nature of injury				
Running or other exercise			47	60
Road march			20	26
Local trauma			4	5
Unknown			7	9

Results

A total of 78 patients participated in the study (demographics are displayed in Table 1). The overwhelming majority of patients reported injury as a result of running or road marching, and two thirds had symptoms for less than 6 months before the bone scintiscan. A total of 35 stress fractures were found by bone scintiscan, whereas only 15 were detected by ultrasound examination, resulting in a sensitivity of 43 percent. Ultrasound examination had 22 false positives for a specificity of 49 percent. There were also 20 false negatives by ultrasound examination. These findings resulted in a positive predictive value of 41 percent and a negative predictive value of 51 percent (Table 2).

Table 2. Comparing Ultrasound Examination with Bone Scintiscan Results.

Ultrasound Result	Bone Scan Result: Positive	Bone Scan Result: Negative	Total
Active wand			
Positive	15	22	37
Negative	20	21	41
Inactive wand			
Positive	6	14	20
Negative	29	29	58
Total	35	43	78

Sensitivity of active wand = 15/35 = 43%.
Specificity of active wand = 21/43 = 49%.
Positive predictive value of active wand = 15/37 = 41%.
Negative predictive value of active wand = 21/41 = 51%.

Because one study[4] suggested that the usefulness of ultrasound in diagnosing stress fractures decreases with time since the onset of symptoms, we analyzed the 36 studies of patients who had symptoms for less than 3 months. In this group the sensitivity of ultrasound examination was 44 percent, the specificity was 50 percent, the positive predictive value was 41 percent, and the negative predictive value was 52 percent.

The data were analyzed by a binomial probability distribution and chi-square analysis using 35 of 78, or 44.87 percent, as the prevalence of the study population who had stress fractures found by bone scintiscan. Similarly, 43 of 78, or 55.13 percent, were found to have no stress fractures. The ultrasound method detected 15 of the 35 fractures and 21 of the 43 negative findings successfully. Both observations were significantly lower than the true occurrence rates at $P < 0.001$.

Another way to evaluate the data is to determine whether the ability of ultrasound examination to predict successfully the true occurrence of stress fractures is different from what would be expected by chance alone. Of the 35 positive results, 17.5 should have been correctly diagnosed by chance. Of the 43 negative results, 21.5 should have been correctly diagnosed by chance. Chi-square analysis failed to find a significant difference between the 15 stress fractures diagnosed by ultrasound examination and the 17.5 expected by chance. Similarly, there was no difference between the 21 correctly predicted negative studies by ultrasound examination and the 21.5 expected by chance.

Discussion

The strengths of this study included an adequate population sample that was fairly representative of a typical military population. The double-blind nature of the study, the use of both active and inactive ultrasound, the timing of the bone scintiscan and the ultrasound examination, and the use of the criterion standard when evaluating the accuracy of ultrasound results also contributed to a strong study design.

The limitations included no personal clinical evaluation of the participants before the radiologic studies by the authors and, therefore, no personal impression of whether the patient had a

J Am Board Fam Pract: first published as 10.3122/jabfm.9.6.414 on 1 November 1996. Downloaded from http://www.jabfm.org/ on 23 April 2024 by guest. Protected by copyright.

stress fracture. All participants were, however, referred by clinicians. In addition, no attempt was made to look for potential stress fractures in locations other than the tibiae. Finally, the sonography technician was not blinded to the mode used, although this bias was minimized because he was not allowed to talk to the patient about the activity of the wand.

We did not find the correlation between pain reported on ultrasound examinations and the presence of stress fractures previously reported. Reasons for this disagreement could be that one study comparison was between ultrasound examination and plain films.[1] Another study used both plain films as well as bone scintiscan as the reference standard.[4] In all studies where ultrasound examination was compared with bone scintiscan, the criteria used to establish a diagnosis of stress fracture on bone scintiscan were not specified and might have varied from study to study.

Based on our findings, we conclude that ultrasound is not reliable for detecting tibial stress fractures. Thus, for the practicing physician, the potential "magic wand" to aid in diagnosis appears to be consistent with other magic wands—just another fairy tale. Bone scintiscan remains the diagnostic test of choice.

John Claybaugh, PhD, provided assistance with statistical analysis, and SGT Albert Crews performed the ultrasound examinations.

References

1. Nitz AJ, Scoville CR. Use of ultrasound in early detection of stress fractures of the medial tibial plateau. Mil Med 1980;145:844-6.
2. Giladi M, Nili E, Ziv Y, Danon YL, Aharonson Z. Comparison between radiography, bone scan, and ultrasound in the diagnosis of stress fractures. Mil Med 1984;149:459-61.
3. Devereaux MD, Parr GR, Lachmann SM, Page-Thomas P, Hazleman BL. The diagnosis of stress fractures in athletes. JAMA 1984; 252:531-3.
4. Moss A, Mowat AG. Ultrasonic assessment of stress fractures. Br Med J Clin Res Ed 1983;286:1479-80.
5. Zwas ST, Elkanovitch R, Frank G. Interpretation and classification of bone scintigraphic findings in stress fractures. J Nucl Med 1987;28:452-57.

J Am Board Fam Pract: first published as 10.3122/jabfm.9.6.414 on 1 November 1996. Downloaded from http://www.jabfm.org/ on 23 April 2024 by guest. Protected by copyright.