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ARTICLE

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Magnetic resonance imaging: a cost-effective alternative to bone scintigraphy in the evaluation of patients with suspected hip fractures

Abstract *Objective.* To evaluate the cost-effectiveness of magnetic resonance imaging (MRI) compared with radionuclide bone scan in the evaluation of patients with clinically suspected hip fractures.
Design. The medical records of all patients who had been seen in the emergency room over a $4\frac{1}{2}$-year period with a clinically suspected hip fracture, negative or equivocal plain films, and either a subsequent bone scan or MRI examination were retrospectively reviewed. The time to diagnosis, admission rate, and time to surgery were determined. A two-sample *t*-test was used to assess the statistical significance of the results. A theoretical cost analysis was performed using current charges to estimate all expenses.
Patients. Forty patients (11 male, 29 female; age 28–99 years) satisfied our inclusion criteria.
Results and conclusions. Twenty-one patients had bone scans (six with fractures), and 19 had MRI (four with fractures). The time to diagnosis was 2.24±1.30 days for bone scanning and 0.368±0.597 days for MRI ($P<0.0001$). Twenty patients in the bone scan group were admitted compared with 13 in the MRI group. The time to surgery was at least 1 day longer in patients undergoing bone scanning. Bone scanning resulted in higher patient costs compared with MRI because of the delay in diagnosis. In the evaluation of patients with suspected hip fractures, early MRI is more cost-effective than delayed bone scanning. Further prospective studies comparing the cost-effectiveness of early MRI with early bone scanning are needed.

Key words Hip · MRI · Radionuclide studies · Fractures · Cost-effectiveness

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Introduction

Hip fractures are a major cost to health care [1–3] and are frequently a diagnostic dilemma. The history and physical examination are often unreliable and, in many cases, plain film examination is falsely negative or equivocal. Any delay in the diagnosis can lead to increased morbidity and prolonged hospitalization [4]. While previous studies have shown that radionuclide bone scintigraphy (RBS) and magnetic resonance imaging (MRI) are both relatively accurate in the early diagnosis of occult hip fractures [5–13], there is continuing debate over which of the two imaging modalities can be used in the most cost-effective manner. While Holder et al. [7] have shown that RBS performed within 24 h of injury is both accurate and useful, there is still a perception that it is not as accurate as MRI performed within the same time period and that a delay of up to 72 h is still necessary in older, osteoporotic patients for optimum results [8, 14].

In the current managed care environment, clinicians are under increasing pressure to justify the relative costs of the imaging modalities they order. At our institution, the cost of MRI of the hip is substantially higher than the cost of RBS. The purpose of our study was to evaluate the cost-effectiveness of RBS and MRI in the diagnosis of occult hip fractures at our institution.

Materials and methods

The radiology and orthopedic records of all patients seen in the emergency room with a suspected hip fracture between 16 September 1991 and 28 February 1996 were reviewed. All patients who fulfilled the following selection criteria were included in the study: (1) the initial standard radiographs were either negative or equivocal, and (2) the patient had a subsequent RBS or MRI study.

All RBS examinations were three-phase studies with the patient lying supine under a double-headed gamma camera (BIAD, Trionix, Twinsburg, Ohio). A bolus of 20 mCi of technetium-99m methylene diphosphonate was injected via an antecubital vein and sequential images of the pelvis and both hips were acquired using a low-energy all-purpose collimator at 4 s/frame for a minimum of 7 frames beginning with the appearance of activity in the early arterial phase. Immediate static images were obtained for 1 million counts. Delayed spot and whole-body images were obtained 2–3 h after the injection. The affected hip was imaged for 1 million counts and the opposite side was imaged for the same time period. When necessary, additional SPECT images were obtained and reconstructed in the axial, sagittal, and coronal planes. All RBS examinations were read by radiologists with special expertise in nuclear medicine.

All MRI studies were performed on a 1.5-T clinical unit (GE Signa, Milwaukee, Wis.) using a commercially available pelvic phased-array surface coil (GE, Milwaukee, Wis.) as a receiver. Axial images of the affected hip were obtained using a TR/TE of 400 ms/20 ms, 0.5 excitations, and a 256×128 matrix. T1-weighted (T1W) spin-echo images and either T2-weighted (T2W) fast spin-echo images with fat saturation or fast inversion recovery (IR) images were then acquired in the oblique coronal plane using a 16–20 cm field of view, 5 mm slice thickness, and a 1 mm interslice interval. A TR/TE of 600/20, 1 excitation, and 512×192 matrix were used for T1W images, TR/TE of 2000–4000/102, 2 excitations, 256×192 matrix, and echo train length of 8 for T2W fast spin-echo fat saturation images, and TR/TE of 4000/60, TI of 150, 2 excitations, 256×192 matrix, and echo train length of 8 for fast IR images. All MRI studies were read by radiologists with special expertise in musculoskeletal MRI.

The dates and times of the radiologic studies were obtained from our radiology computer database (IDX Systems, Burlington, Vt.). Each patient was placed into one of two groups on the basis of whether they had undergone RBS or MRI. Sensitivity, specificity, and accuracy of diagnosis were determined in the two groups from operative reports and clinical follow-up (3 months to 4 years). The following clinical parameters were evaluated and recorded from medical records: the time to diagnosis, the admission rate, and the time to surgery. The time to diagnosis was defined as the number of days between the initial radiographic examination and the subsequent MRI or RBS study. The admission rate was defined as the number of patients admitted divided by the total number of patients in each group. The time to surgery was defined as the number of days between the initial radiographic examination and surgery. All complications that occurred during the time waiting for MRI or RBS were also recorded.

The mean, standard deviation, and range for the time to diagnosis were calculated for each of the groups. A two-sample *t*-test was performed to measure the significance of the difference between the means. In addition, a 95% confidence interval was calculated to further assess any difference. A full statistical analysis was not possible on the sensitivity, specificity, accuracy, admission rate, or time to surgery data because of the limited sample size.

In our theoretical economic analysis, we estimated the cost of evaluating and treating a patient with a possible occult hip fracture using the following equation:

$$\text{Average cost per patient} = \frac{(\text{no of patients})(\text{cost of modality}) + (\text{no of admissions})(\text{LOS})(\text{CPD})}{(\text{no of patients})} \qquad (1)$$

where LOS it the length of stay in hospital and CPD is the cost per day in hospital.

The number of patients was those included in our study population. The number of admissions was estimated from the numbers of patients with and without fractures and was based on the following two hypothetical situations: (a) MRI is performed in all cases within 24 h of injury with 100% accuracy, and as a result all patients without fractures can be sent home without admission to the hospital; (b) RBS is performed in all cases between 24 and 72 h (which is the procedure at our institution) after the injury with 100% accuracy, and as a result all patients without fractures must be admitted to the hospital for observation while awaiting the RBS results.

If we then rewrite Equation (1) for each of these two situations, we get Equations (2) and (3):

$$\begin{aligned}\text{Average cost per MRI patient} &= \frac{(\text{no of patients})(\text{cost of MRI}) + (\text{no of fractures})(\text{LOS})(\text{CPD})}{(\text{no of patients})} \\ &= \text{cost of MRI} + (\text{fraction of patients with fractures}(\text{LOS})(\text{CPD})\end{aligned} \qquad (2)$$

$$\begin{aligned}\text{Average cost per RBS patient} &= \frac{(\text{no of patients})(\text{cost of RBS}) + (\text{no of patients})(\text{LOS})(\text{CPD})}{(\text{no of patients})} \\ &= \text{cost of RBS} + (\text{LOS})(\text{CPD})\end{aligned} \qquad (3)$$

Therefore, in these two situations, the costs of RBS and MRI are independent of the number of patients, and the cost of MRI depends on the prevalence of fractures in the patient population.

We used current charges to estimate all costs (i.e., MRI, RBS, and CPD). We used actual patient bills to calculate the CPD by dividing the total charge for the hospitalization by the length of stay for each patient. We used the median daily charge as a realistic estimate of the CPD, but also considered a range from the minimum price of the room itself to the maximum patient charge determined. We estimated the costs of the imaging studies from current charges including both the technical and professional components. The estimated cost of RBS used in our analysis was actually an average cost based on the number of cases in our study in which we used planar imaging alone versus SPECT.

We determined the lengths of stay for the patients in our study who were hospitalized, and used the median to estimate the LOS in Equations (2) and (3). We also used the range to determine a minimum and maximum LOS value. We used these minimum and maximum LOS values together with the minimum and maximum CPD values respectively in our analysis to cover a range of possible cost estimates.

Results

Forty patients (11 male, 29 female; age 28–99 years) satisfied our selection criteria (Table 1). Twenty-one were in the RBS group and 19 were in the MRI group. Ten of the 40 patients had fractures that required surgical intervention (i.e., 1/4 of the patients had surgery): six in the RBS group and four in the MRI group (Table 2). The sensitivities, specificities, and accuracies of the two imaging modalities for diagnosing hip fractures in our patient population were 100%, 100%, and 100% in the MRI group and 90.9%, 100%, and 95% in the RBS group. The accuracy of the bone scan alone for determining the site of the fracture was 90.5%. Examples of fractures diagnosed on RBS and MRI are illustrated in Figs. 1 and 2.

Table 1 Summary of patient data

	Bone Scan	MRI
No. of patients	21	19
No of fractures	6	4
Time to diagnosis (days)	2.24 ± 1.3	0.368 ± 0.597
“Overall” admission rate	20/21 = 95%	13/19 = 68%
Time to surgery (days)	2.33 (range 0–3)	1.25 (range 1–2)

The time-to-diagnosis was 2.24±1.30 days for the RBS group with a range of 0–6 days. The time to diagnosis was 0.368±0.597 days for the MRI group with a range of 0–2 days. The difference between the two groups was significant ($P<0.0001$). The 95% confidence interval for the difference between the means for the two groups was 1.22–2.52 days.

Within the RBS group 20 of 21 patients were admitted to the hospital, giving an admission rate of 95%. Eighteen patients had the bone scan as an inpatient. One patient was sent home from the emergency room and brought back for RBS as an outpatient. This patient had a negative bone scan. Another patient was admitted for 1 day of observation, was then sent home and brought back for RBS as an outpatient. This patient had pubic rami fractures that were treated on an outpatient basis. Neither of the patients who had RBS as an outpatient had a fracture requiring

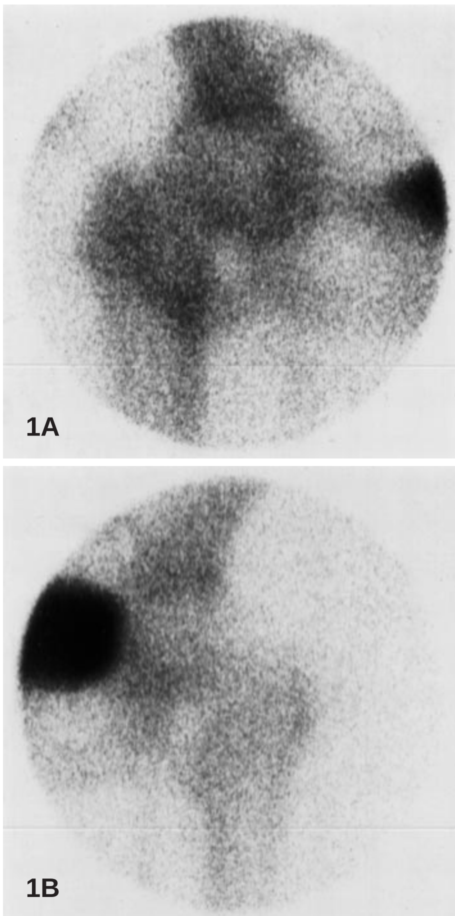

Fig. 1A, B An 83-year-old woman with a painful right hip after a fall. Initial radiographs were negative for a fracture. Delayed image from a ^{99m}Tc bone scan demonstrates an intertrochanteric fracture of the right proximal femur (**A**) with increased activity in the femoral head indicating adequate vascularity. The normal left hip (**B**) is shown for comparison

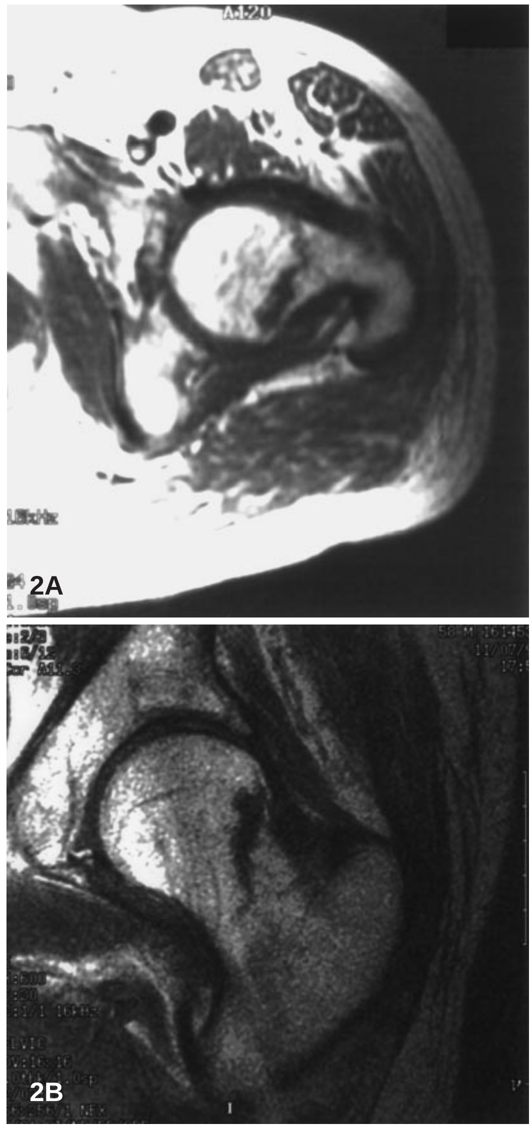

Fig. 2A, B A 58-year-old man with left hip pain after a fall and unremarkable radiographs. Axial T1-weighted MR image (**A**) and oblique coronal T1-weighted (600/20, TR/TE) image (**B**) illustrate a fracture of the femoral neck. The fracture has a vertical orientation

Table 2 Types of fractures and treatment

Bone scan group			MRI group		
No.	Type of fracture	Treatment	No.	Type of fracture	Treatment
6	Intertrochanteric	5 were pinned	1	Intertrochanteric	Pinning
4	Greater trochanteric	Conservative	2	Pubic rami	Conservative
1	Femoral neck	Hemiarthroplasty	2	Femoral stress fracture	Conservative
1	Pubic ramus	Conservative	3	Femoral neck	Pinning

Table 3 Estimated costs, in 1996 dollars (*CPD* cost per day of hospitalization)

	Cost	Total CPD
Bone scan (average cost)	460	
MRI	1280	
Median		787
Range		685–1337

surgery. One patient never had RBS because she fell on the second hospital day while waiting for her study and developed a displaced femoral neck fracture diagnosed on follow-up radiographic studies and requiring immediate surgical intervention with a hemiarthroplasty.

In the MRI group, 13 of 19 patients were admitted (an admission rate of 68%). Thirteen patients had the MRI examination as inpatients. Six patients were ruled out for a fracture and sent home directly from the emergency room. No complications occurred while patients were waiting for the MRI studies.

The average time to surgery was 2.33 days in the RBS group with a range of 0–3 days, while the time to surgery was 1.25 days in the MRI group with a range of 1–2 days. One patient had radiographs, RBS, and surgery all on the same day. This patient had fallen 5 days prior to coming into the emergency room, while the remainder of the patients in the study came to the emergency room well within 48 h (most well within 24 h) of the injury. The time to surgery was 2 days for the patient who fell in the hospital while waiting for RBS; therefore, it might have been longer had she not fallen. The time to surgery in each of the four remaining patients in the RBS group was 3 days.

The cost data used in our analysis are listed in Table 3. The average length of stay (LOS) for 31 of the 33 patients who were admitted (records of two patients were unavailable) was 17±30 days (range 1–161 days). The median LOS was 9 days. The data were heavily skewed by a few patients who stayed in the hospital much longer than the others. Therefore, we used the median value for LOS in the cost analysis.

When we plug all our data into Equations (2) and (3), including the median values for LOS and CPD, we find that the patient costs related to doing an MRI examination total $3050.75 compared with $7543 for a bone scan. When we repeat the calculations using the minimum values for LOS and CPD, we get a total cost of $1451.25 for MRI compared with $1145 for RBS. Finally, if we assume maximum values for LOS and CPD, we get a cost of $55094.25 for MRI and $215 717 for RBS.

Discussion

Surgery is the treatment of choice for the overwhelming majority of elderly patients with hip fractures [4]. Many of these patients need to recover their prior ability to lead their daily lives as soon as possible and are not able to endure the extended bed rest that is involved in conservative therapy. Perpetuated bed rest frequently results in complications, including pneumonia [15] and deep venous thrombosis [16, 17], which can be life-threatening. Conservative therapy also increases the chance of developing either a nonunited or malunited fracture [4].

The optimal timing of surgical intervention has been controversial for a long time. Although it is hard to prove that delaying surgery results in poor patient outcome, most orthopedists believe that urgent operative management is necessary in most cases [4]. Therefore, an imaging modality that accurately and quickly establishes the cause of the patient's hip pain would improve the quality of patient care.

The cost-effectiveness of using an imaging modality to make a diagnosis depends on both the cost of the study and the effect of the results on patient outcome. As reimbursement for medical practice continues to decrease, there is increasing pressure on doctors to justify the use of a more expensive modality such as MRI over a less expensive one (RBS).

Prior studies have questioned the accuracy of bone scanning in detecting occult fractures in elderly patients during the first 24 h after an injury [5, 12, 18–20]. Many studies have showed that the accuracy of early MRI is at least comparable to delayed bone scanning [6, 8–13]. Despite Holder et al.'s study [7], which showed that RBS has high accuracy even within 24 h of injury, there is still a concern that early RBS is not accurate enough to be reliable in ruling out fractures in elderly patients [8, 20].

Our study clearly demonstrates that there is a minimum delay of 1 day in diagnosis when a bone scan is used instead of MRI. Our data also suggest that by shortening the time-to-diagnosis, MRI prevents unnecessary hospitalizations and delays in definitive treatment. By preventing unnecessary admissions, MRI reduces the cost of care. By reducing the time-to-surgery, MRI might improve the quality of care and may shorten the length of the hospitalization. One of the patients in the bone scan group fell while hospitalized waiting for the bone scan, resulting in displacement of a femoral neck fracture; a prosthesis was required. Had the diagnosis been made sooner, the patient might have been more appropriately treated with pinning, which is cheaper than a prosthesis, and often has a better long-term prognosis.

Our cost analysis shows that the use of MRI compared with RBS to diagnose occult hip fractures results in a net reduction in the overall cost of care per patient for most estimates of LOS and CPD. More comparable total costs result when minimum estimates for LOS and CPD are used. The savings in our model resulted from preventing unnecessary admissions in fracture-negative patients. In our institution, where the practice is to delay bone scanning for 48 h, MRI is more cost-effective than RBS in diagnosing occult hip fractures. This is due to the inherent delay in performing an RBS resulting in unnecessary costly hospital admissions. This might not be the case in institutions performing early RBS.

The main limitation of our study was that it was retrospective. However, the selection criteria were clear-cut. There was some potential historical bias, since most of the bone scan patients were diagnosed and treated during the first half of the study while most of the MRI patients were seen during the second half. One cannot prove that some other unknown factor (e.g., increasing pressure from managed care companies to limit hospitalization) did not influence the results more than the choice of imaging modality, although the authors have no reason to believe this. Our study is also limited due to our small sample size. However, the numbers of patients in this study are sufficient to prove the most important finding: that using MRI instead of bone scanning shortens the time to diagnosis in patients with suspected hip fractures in institutions performing delayed RBS.

A main limitation of our cost analysis is that we used charges to estimate costs, and charges are usually higher than actual costs. We are partly justified in doing this since we used charges consistently in both patient groups, but a more accurate estimate of cost is desirable. In addition, there are many variables in our cost analysis, and care must be taken before extrapolating our results to another medical environment where the patient population, the percentage of patients having fractures requiring surgery, the costs of the imaging modalities, the cost of a day in the hospital, and the average length of stay may all be different. While our results may not be meaningful in communities that practice early RBS, they are relevant to those that practice delayed RBS and/or early MRI.

The major costs considered were the cost of the examinations and the costs associated with unnecessary hospitalization due to delayed diagnosis of fracture-negative patients. We did not attempt to calculate other patient costs related to co-morbidity due to other medical problems as these were quite variable in our patient sample and were independent of the modality.

The true value of early RBS compared with that of MRI is not known. MRI may have additional value over RBS in obtaining anatomical information about the extent and orientation of the fracture and may be more accurate in diagnosing femoral neck fractures in patients with advanced hip arthritis [11, 21]. A prospective study that compares the accuracies of RBS and MRI, the amount of information that each test provides the clinician, and the impact that this information has on patient outcome when both tests are done in the same patient within 24 h is necessary. The authors intend to perform this study in the future.

In summary, this study demonstrates that choosing MRI over RBS in the diagnosis of occult hip fractures shortens the time to diagnosis, decreases the admission rate, and shortens the time to surgery, and is therefore a cost-effective alternative at institutions performing RBS after a delay of 48 h or more.

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