Whole Body MRI for Detecting Metastatic Bone Tumor: Comparison with Bone Scintigrams

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(Received December 27, 2004; Accepted March 30, 2005)

Purpose: To compare the effectiveness of whole body MRI (WB-MRI [magnetic resonance imaging]) and bone scintigram (BS) at detecting bone metastasis.

Materials and Methods: WB-MRI was performed on 16 patients for detecting bone metastasis (6 breast carcinoma, 7 prostatic carcinoma, 1 renal cell carcinoma [RCC], 1 hepatocellular carcinoma [HCC], and 1 primary unknown). BS was also performed in all cases. Patients were placed on a table top extender (Philips Medical Systems). The maximal longitudinal field of view (FOV) was 200 cm. At first, the total spine was imaged in the sagittal plane with a three-station approach for two image sets (fast spin-echo [SE] T1-weighted images [T1WI] and short tau inversion recovery [STIR] images). The whole body was then imaged in the coronal plane with a seven-station approach for two image sets (fast field echo [FFE] T1WI and STIR). Total examination time, including patient positioning, was within 40 min. Three independent radiologists interpreted the imaging data.

Results: WB-MRI identified 5 cases of 24 lesions as bone metastasis, while BS identified 3 cases of 25 lesions. Concordance between WB-MRI and BS was seen in 3 cases of 22 lesions (81%). For two cases of 2 lesions, which were identified only with WB-MRI, the lesions were located in the sacrum and thoracic spine. For one case of 3 lesions, which was identified only with BS, the lesions were located in the skull and rib.

Conclusion: WB-MRI was an excellent method for screening bone metastasis, especially the vertebral body.

Keywords: magnetic resonance imaging, metastatic bone tumor, whole body imaging

Introduction

Since cellular bone marrow is the initial site of metastasis seeding to bone, MRI (magnetic resonance imaging) can detect metastatic lesions at an early stage, before the occurrence of changes in bone metabolism that render lesions detectable with bone scintigram (BS). BS has long been the standard for the detection of bony metastases. However, since the development of MR, several studies have compared the effectiveness of BS and MR imaging in tumor detection and characterization. Although most of these studies of localized areas conclude that MR imaging is both sensitive and more specific than BS, its use as an alternative to BS for whole body imaging has been limited by inconvenience and long acquisition times.

In recent years, some have reported on the use of whole body MRI (WB-MRI) for detecting bone metastasis. However, Hargaden et al. described that, prior to the development of a moving table top and table top extender, coronal scans of the head, neck, and thorax were acquired with the patient in the head-first position, whereas coronal scans of the abdomen, pelvis, and lower extremities...
were acquired with the patient in the feet-first position. Therefore, examination took a long time.

The use of some devices such as moving table tops, table top extenders and fast MR sequences have simplified the examination technique without requiring patient repositioning, thus reducing examination time. The purpose of this study is to assess WB-MRI as a new method for detecting bone metastasis and compare it to BS.

Materials and Methods

MR images

All MR studies were performed with a 1.5T whole body scanner (Master Philips Medical Systems, Best, The Netherlands).

Patients were placed in the feet-first position on a table top extender (prototype; Philips Medical Systems, Best, The Netherlands, Fig. 1).

The field of view (FOV), if used, is extended to 200 cm. The larger FOV enables head-to-toe scanning of most adult patients without repositioning of the patient.

At first, fast spin-echo (SE) T_{1}-weighted images (T_{1}WI; repetition time [TR]/echo time [TE], 400/13 ms; echo train length [ETL] 4, 4 min, 33 s) and short tau inversion recovery (STIR) sequence (TR/TE/inversion time [TI] 2500/70/170, ETL 15, 6 min, 15 s) of the total spine were imaged on the sagittal plane with a three-station approach. The FOV of each station was 30 cm of frequency direction × 24 cm of phase direction. The matrix size was 362 × 263 for T_{1}WI and 288 × 213 for the STIR sequence. A total of 5 total-spine sagittal images were acquired with a 7-mm slice thickness for each sequence.

Therefore, fast field echo (FFE) T_{1}WI (100/4.6, flip angle 70 degrees, 6 min, 24 s) and STIR sequences (1350/40/165, ETL 87, 5 min, 2 s) of the whole body were imaged on the coronal plane with a seven-station approach of 32 slices. The FOV of each station was 53 cm in the phase direction × 26.5 cm in the frequency direction. The matrix size was 178 × 112 for T_{1}WI and 144 × 96 for the STIR sequence. A total of 32 whole body coronal images of each sequence from anterior to posterior were acquired with a 7-mm slice thickness.

Total examination time, including patient positioning, was within 40 min.

Immediately after examination, the imaging data were transmitted to the provided workstation (ViewForum, Philips). The image realignment occurs at the workstation after acquisition and within minutes of imaging. To create true whole body images, the images of levels of the same slice at each station were aligned from cranial to caudal. The result was filmed.

Bone scintigram

A standard skeletal radionuclide scintigram was performed in the other hospitals with a planar one-phase technique. The examination was performed 3 h after injection of 550 Mbq of 99m Tc-labeled dicarboxypropane diphosphonate. Images were collected with a dual-head whole body scanner equipped with a high-resolution low-energy collimator. No single photon emission computed tomography (SPECT) was used in this analysis.

Patients

WB-MRI was performed on 16 patients to detect bone metastasis (6 breast carcinoma, 7 prostate carcinoma, 1 renal cell carcinoma [RCC], 1 hepatocellular carcinoma [HCC], and 1 primary unknown). In all cases, BS was also performed within 3 weeks. All patients provided informed consent.

The imaging data on the WB-MRI and BS films were interpreted by three independent radiologists who had neither clinical information nor information on other imaging modalities.

For image interpretation, the skeletal system was divided into 15 regions, as Lauenstein had done: skull, cervical spine, thoracic spine, lumbar spine, sacrum, coccyx, sternum, rib, clavicle, scapula, humerus, forearm, ilium, femur, and lower leg. The evaluation of both the WB-MRI and BS data was performed on a patient-by patient “per region” basis.

With WB-MRI, a lesion was considered malignant when a focal or diffuse hypointensity was evident in T_{1}WI and a corresponding intermediate-to-high signal intensity was evident in the STIR image. For the spine, additional criteria for malignant infiltration included bulging of the posterior margin of the vertebral body, signal intensity changes extending into pedicles, and paraosseous tumor extension. A lesion was considered benign process when it was located directly adjacent to degenerative changes of the vertebral endplates or near joint surfaces, or when the lesion displayed a high signal intensity in T_{1}WI.

With BS, the criteria for lesion characterization were distribution of tracer accumulation as well as localization, shape, and intensity of focal tracer uptake. A lesion was considered benign and of degenerative origin when focal tracer accumulation occurred adjacent to joint surfaces. Well-circumscribed linear tracer uptake involving the thoracic or lumbar spine or symmetrical tracer uptake of adjacent ribs was considered benign and caused by...
Fig. 1. Table top extender
A: Patients were placed in the feet-first position on table top extender (arrow).
B: The table top extender set to the most proximal position (arrow) on the moving table.
C: The table top extender, mounted on the moving table, set to the most distal position (arrow).
When used, the longitudinal FOV is extended to 200 cm.

Fig. 2. Comparison of bone metastasis detection by WB-MRI and BS

Results

In 16 cases where both WB-MRI and BS were performed, WB-MRI identified 5 cases of 24 lesions as bone metastasis, while BS identified 3 cases of 25 lesions (Fig. 2). Concordance between WB-MRI and BS was seen in 3 cases of 22 lesions (81%). In these cases, neither WB-MRI nor BS contributed to false positive findings.

In two cases of 2 lesions (Figs. 3 and 4), identified only by WB-MRI, the lesions were located in the sacrum due to metastasis of prostate carcinoma and in the thoracic spine from the metastasis of HCC. In one case of 3 lesions, identified only by
Fig. 3. A 66-year-old man with prostate carcinoma
A: The low-intensity area was detected in the lower sacrum (white arrow) in a T₁WI of the total spine.
B: The high-intensity area was detected in a whole body STIR image. It was diagnosed as bone metastasis (white arrow).
C: In the BS image, the uptake of this lesion was not clearly detected because the urine in the urinary bladder obscured the lower sacrum.

BS, the lesions were located in the skull and the rib due to metastasis of breast cancer (Fig. 5).

Discussion

MRI provides good contrast resolution of bone marrow and soft tissue. A number of studies have demonstrated the high sensitivity of MRI in the detection of bone marrow metastasis, and its advantages over BS. Although MRI has been found to be more accurate than BS in the detection of bone metastasis, its clinical role has remained limited. MRI is predominantly employed to assess individual lesions that could not be characterized by other modalities. Owing to the restricted FOV inherent with conventional MRI with surface coils, imaging has been limited to a single body region. Although the concept of WB-MRI is not new, its clinical impact has remained limited because of the long scanning times required, poor image quality, and complicated data realignment.

Recent developments in MR imaging—including fast MR sequences and devices such as moving tables—have simplified the examination technique and shortened the examination time.

The present study made use of an innovative table top extender that enabled us to keep the patients fixed in the feet-first position. Three stations of FOV in the total spine and seven stations in the whole body were moved automatically without the need to reposition the patients. This device shortened the examination time remarkably.

Total examination time, including table movement, did not exceed 40 min, which was comparable to previous reports. However, this was not excessive, considering the inclusion of two image sets of sagittal view of the total spine.

Moreover, after examination, the imaging data were immediately transmitted to the workstation. The image realignment occurred immediately after acquisition at the workstation, resulting in a true whole body scan within minutes of imaging. Currently, the movement of the table top facilitates image processing because the images at each station...
A 76-year-old man with HCC WB-MRI was performed because of suspected bone metastasis in a case of paralysis of bilateral lower extremities.

A: The low-intensity area was shown in a T1WI (white arrow) of the 9th thoracic spine.

B: The mild high-intensity area (white arrow) appearing in STIR images was diagnosed as bone metastasis.

C: In this BS image, subtle uptake was revealed on the 9th vertebra (arrow). However, this uptake could not be certified and other imaging modalities were recommended.

are acquired in exact matching slices. Therefore, one can predict numerically which images at each station should be aligned to create the whole body image.4 In our results, WB-MR was superior to BS for detecting lesions of the spine, while BS was superior to WB-MR for detecting lesions of the ribs. Although the number of cases was few, our results were similar to those of previous reports.1,3,5–12

In the case of lower sacral metastasis from prostate carcinoma identified only by WB-MRI (Fig. 3), the urine in the urinary bladder obscured the lower sacrum in the BS image because of hydronephrosis. However, this subtle lesion might have been difficult to depict even if the urine were not present.

We experienced metastasis from HCC in the thoracic spine (Fig. 4). In this case, WB-MRI depicted the lesion clearly, but BS did not. As described in the previous reports, some metastases are not associated with increased osteoclast/osteoblast activity and remain unrecognized in BS images.2,4 Therefore, the reactive osteoblastic change is rarely shown in metastasis from HCC and RCC and the skeletal involvement of malignant lymphoma, multiple myeloma. In these cases, BS is frequently insignificant and WB-MRI is considered a useful method for both detecting lesions and achieving a specific diagnosis.

In order to compensate for the disadvantage of rib metastasis, a respiratory-gating axial view of the STIR sequence may have to be added. However, adding the other sequences might lengthen examination time. Lauenstein et al.4 have demonstrated what can be accomplished with individual MR sequences. According to this paper, the STIR sequence had the highest sensitivity and T1-weighted GRE images had the highest specificity. In our preliminary study, we did not evaluate the performance of individual sequences. Therefore, we must attempt to evaluate such sequences in a future study and consider the possibility of omitting or
Fig. 5. A 55-year-old woman with breast carcinoma
A: High-intensity spots were shown in the 3rd and 5th left ribs in the coronal slice of WB-MRI at the level of the anterior rib (white arrows). The thoracic spine was also involved by metastasis (arrowhead) as revealed in STIR images.
B: The uptake was shown in the same lesions in the BS image of the anterior view (arrows).
C: The two metastatic lesions were detected on the posterior ribs in the WB-MRI coronal slice at the level of the posterior ribs (white arrows).
D: The two lesions of the upper posterior rib were depicted in BS images but not in MRI images (arrows).

One of the problems with our methods is the large amount of imaging data and films to be examined. It is more efficient and accurate to analyze the images on a workstation. Therefore, a filmless system would be the ideal method for transmitting imaging data to other departments.

As mentioned, WB-MRI is a preliminary method and the significance of this examination and pulse sequences have not yet been established. In the future, image resolution will improve and examination time will be shortened, and this approach will surely become an important option for whole body screening.

Conclusion

Whole-body MR is an excellent method for detecting bone metastasis, especially in the vertebral body. It can also detect other abnormalities. It has proved a useful method for screening whole body bone lesions.

Acknowledgments

The authors thank Akihiko Sada BS RT, Eiji Nakagaki RT, Kouji Ozaki RT, and Kenji Murakami RT, all of whom are technologists at the Osaka Seamen’s Insurance Hospital.

References

Whole Body MR May Replace Bone Scintigram

23:123–129.


Vol. 4 No. 1, 2005