Validity of bone scans to detect missed injury in patients with major trauma

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ABSTRACT

BACKGROUND: It is easy to miss injuries in patients with major trauma (MT). The authors hypothesized that bone scans (BSs) would reduce the number of missed injuries. However, there was not enough evidence on BS in patients with MT. The purpose of the present study was to identify the basic results of BS in patients with MT.

METHODS: The medical records of patients with MT between January 2013 and December 2013 were reviewed. Patients who underwent a BS were enrolled in the study. Hot-uptake lesions without previous evaluation were checked by X-ray. Hot-uptake lesions on BSs that differed from previous evaluations were checked by computed tomography (CT) scans. The results of BSs were analyzed along with the results of X-ray and CT scans. The sensitivity, specificity, positive predictive value, and negative predictive value (NPV) were calculated.

RESULTS: There were 115 patients with MT who received BS during the study period. The sensitivities were high on average (98.48–86.54). In addition, the NPVs were high (96.30–82.93). There were 16 cases of hidden fracture diagnosed after a BS.

CONCLUSION: BS showed high sensitivity and high NPV. Further large-scale studies might add more validity to the use of BS in patients with MT.

Keywords: Bone scan; missed injury; tertiary survey; trauma.
evaluate the whole body in one study. Therefore, the authors selected BS as screening tool to detect missed injury in patients with trauma initially.

However, evidence regarding the application of BS in cases of MT is insufficient. The present study analyzed the accuracy of BS in MT as a screening tool to detect missed injury.

**MATERIALS AND METHODS**

This was a retrospective study of patients with MT, defined as patients with an Injury Severity Score (ISS) of ≥16. The medical records of patients with trauma treated between January 2013 and December 2013 were reviewed. Patients who underwent a BS were included in the study. However, patients with other diseases, such as cancer or a history of osteomyelitis, were excluded from the study. This is because bone metastasis or osteomyelitis also results in hot uptake on a BS. Patients’ general information, such as sex, age, height, and weight, was collected. In addition, ISS and time between trauma and BS were recorded.

The basic treatment policy was as follows. The brain, chest, abdomen, and spine were routinely checked via CT in the emergency room. Every site that patients complained had pain or discomfort was checked by a simple X-ray after stabilization. BS was generally planned 7 days after trauma. Hot-uptake lesions without previous evaluation were checked by X-ray. Hot-uptake lesions in BS that differed from the results of a previous evaluation were checked by CT.

Any identified fracture seen on X-ray or CT was defined as a real fracture, and hot-uptake lesions seen on the BS were defined as positive findings. BS results were compared with X-ray or CT. Lesions with positive findings on BS and real fractures seen on X-ray or CT were regarded as true fractures. Lesions with positive findings on BS and without real fractures on X-ray or CT were regarded as false fractures. In addition, there were some real fractures that were not diagnosed at the initial evaluation and could be diagnosed through further evaluation after BS. These lesions were regarded as hidden fractures.

For analysis, the skeletal system was divided into four subgroups: chest, lower extremities (LEs), upper extremities (UEs), and spine. The ribs, sternum, and scapula were regarded as the chest. The pelvis to the toes was considered as the LE. The clavicle to the fingers was grouped into the UE. The skull and the face were also analyzed as the UE. The BS results were analyzed along with the results of X-ray and CT scans. The sensitivity, specificity, positive predictive value, and negative predictive value (NPV) were calculated. Our hospital’s Institutional Review Board approved the study. Informed consent was waived since this was a retrospective study.

**RESULTS**

A total of 304 patients with MT were found during the study period. BS was performed on 115 patients, and these patients were enrolled in the study. There were 76 (66.1%) male and 39 (33.9%) female patients. The mean age of the patients was 47.9 years. The mean ISS was 23.8, and the mean time from trauma to BS was 11.7 days.

Table 2 and Fig. 1 show the results of BS for detecting fracture. Sensitivity, an important point for a screening test, was high on average (>90%). The chest showed the highest sensitivity with 98.48%, followed by the LE with 97.44%. In addition, NPV was high on average. The NPV of the LE was 97.14%, and that of the chest was 96.30%. However, specificity was
By applying BS to MT, the authors analyzed the results of BS in MT as a tool to diagnose missed skeletal injuries. It is reported that BS is the best diagnostic study to diagnose clinically suspected fracture.\(^{[10]}\) By applying BS to MT, the authors identified 16 (5.3%) patients with hidden fractures that were missed in the fracture diagnosis process using simple X-rays. The authors believed that it could prevent further medical and legal problems. Delayed diagnosis and treatment of fracture have been reported to be associated with poorer outcomes including not only malunion and nonunion but also pulmonary complications and length of stay.\(^{[11–14]}\) By applying BS, physicians could properly detect the hidden fracture and reduce the related morbidities. Additionally, reducing hidden fracture is important at the time of legal action. The common etiology of MT in Korea is a blunt injury caused by traffic and industrial accidents that require suing for the damage caused. The missed injury could be disadvantageous for patients during the legal process. Especially, patients with traumatic brain injury, those under ventilator care, or those who could not complain about their symptoms could gain benefits from BS.

As a screening tool for detecting fractures in patients with MT, BS has some merits. First, BS displayed high sensitivity in the present study (mean, 94% [86.5%–98.5%]). High sensitivity is one of the main factors necessary for a screening tool. The sensitivity of a fecal occult blood test for colorectal cancer was reported to range from 73% to 92%, and that of mammography for breast cancer in high-risk women was reported to be 37.5% to 55.6%.\(^{[15,16]}\) Compared with these well-known screening methods, BS could yield strong results. Additionally, BS showed a high NPV. Therefore, negative results on a BS can be used as evidence to halt further unnecessary, repetitive evaluations. Thus, the use of BS may prevent increasing medical costs, prevent wasting patients’ time, and decrease patients’ radiation exposure.

The dose of radiation received during a BS is also low. The radiation dose received during a BS using Tc99 m bisphosphonate was reported to be 6.0 mSv.\(^{[6]}\) This is higher than the radiation dose associated with a chest X-ray (0.1 mSv) but is lower than those received during a pulmonary angiogram CT or abdominal and pelvic CT (13.7–15.0 mSv). One study examined the use of whole-body CT scan in patients with MT.\(^{[17]}\) A malignancy risk is present after radiation exposure.\(^{[18,19]}\) Considering that being less invasive is one of the main requirements of a screening tool, BS has an advantage as a screening method. MRI is an alternative method with no radiation exposure. However, it is the most expensive examination tool and requires a long time for single examination. Therefore, it has limitations as a screening tool.

On the other hand, the limitation of BS is its relatively low specificity. This is because BS detects not only fractures but also other causes of hot uptake in BS, such as bony contusions or chronic osteoarthritis, and such patients require further imaging studies for proper diagnosis. Therefore, BS cannot diagnose fracture alone, and other evaluations, such as X-ray or CT scans, are required. However, to reduce the incidence of missed injury and morbidity and mortality associated with delayed treatment, repetitive check-ups may be preferable in this situation. In addition, further study to develop the diagnostic modality that can distinguish acute fracture from old fracture, inflammation, or tumor is required. Additionally, further study to

**Table 3. Cases of hidden fracture**

<table>
<thead>
<tr>
<th>Lesion</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tibia</td>
<td>6</td>
<td>38</td>
</tr>
<tr>
<td>Fibula</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>Patella</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>100</td>
</tr>
</tbody>
</table>

**DISCUSSION**

Recently, by applying DCS and other advanced critical care methods, trauma surgery has advanced, and mortality has decreased.\(^{[7]}\) Patients requiring DCS are in emergency situations, and physicians usually focus on injuries to the brain, chest, and abdomen during initial resuscitation; therefore, it is easy to overlook skeletal injuries. It has been reported that 12% of patients with MT had missed injuries after the initial evaluation.\(^{[8]}\) However, further guidelines or specialized studies for evaluation after critical care are lacking.\(^{[9]}\) In the present study, the authors analyzed the results of BS in MT as a tool to diagnose missed skeletal injuries.

It is reported that BS is the best diagnostic study to diagnose clinically suspected fracture.\(^{[10]}\) By applying BS to MT, the authors identified 16 (5.3%) patients with hidden fractures that were missed in the fracture diagnosis process using simple X-rays. The authors believed that it could prevent further medical and legal problems. Delayed diagnosis and treatment of fracture have been reported to be associated with poorer outcomes including not only malunion and nonunion but also relative low. Specificity in the LE was only 53.13%, and that in the chest was 55.32%.

There were 16 cases of hidden fracture diagnosed after BS (Table 3). Almost all the hidden fractures were found in the LE. Tibia fracture was the most common hidden fracture (n=6, 38.8%), followed by fibula fracture (n=4, 25.0%).
check missed injury in pregnant patients or other patients who are vulnerable to radiation is required.

In addition, the medical cost might be a problem. With BS, the authors could identify 16 (5.3%) patients with hidden fractures that might have been missed in the fracture diagnosis process. However, in the case of patients with unidentified missed injury, BS might be an unnecessary examination that increases medical cost. In a reported study, the cost-effectiveness for CT and MRI has been evaluated; however, analysis about BS was lacking. The cost-effectiveness of BS for fracture screening in patients with MT is required.

Furthermore, the present study analyzed the sensitivity, specificity, and other statistical parameters of patients with MT and did not compare patients who did not undergo BS. To fully examine the validity of BS as a screening tool for missed injury in MT, further randomized controlled trials is essential. Other analyses of the results of BS and initial conditions following intubation, such as mental status, DCS, or further management or prognosis after BS, are currently lacking. However, even basic statistical results on BS were initially insufficient. The present study can serve as a pilot study that grants evidence in favor of further studies on BS in MT.

In conclusion, BS was associated with high sensitivity and other positive statistical parameters and has promise as a screening tool to detect missed injury in patients with MT. Furthermore, it has a high NPV, which is useful to confirm that no further evaluation for missed fractures is necessary. Further systemized studies will provide higher validity and feasibility to BS.

Conflict of interest: None declared.

REFERENCES

Majör travma hastalarında atlanmış yaralanmanın saptanmasında kemik taramalarının geçerliliği

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BULGULAR: Bu dönemde 115 majör travma hastası kemik taramalarından geçildi. Kemik taramalının duyarlık ve öngörüdürücü değerleri yüksek düzeylerdeydi (%98.48-%86.54 ve %96.30-%82.93), Kemik taramaları atlanmış 16 kırık olgusuna tanı konuldu.

TARTIŞMA: Kemik taramaların yüksek bir duyarlık ve negatif öngörüdürücü değere sahiptir. Daha fazla sayıda geniş çaplı çalışma majör travma hastalarında kemik taramalarının majör travma hastalarını kullanmasına daha fazla geçerlilik kazandırabilir.

Anahtar sözcükler: Atlanmış yaralanma; kemik taraması; travma; üçüncü araştırma.