



Available online at  
**ScienceDirect**  
[www.sciencedirect.com](http://www.sciencedirect.com)

Elsevier Masson France  
**EM|consulte**  
[www.em-consulte.com/en](http://www.em-consulte.com/en)



Original article

# Bone scan as a screening test for missed fractures in severely injured patients



K.-J. Lee, K. Jung, J. Kim, J. Kwon\*

Division of Trauma, Department of Surgery, Ajou University School of Medicine, San-5, Wonchon-dong, Yeoungtong-gu, Suwon 443-749, Republic of Korea

## ARTICLE INFO

*Article history:*  
 Accepted 11 September 2014

*Keywords:*  
 Bone scan  
 Trauma  
 Missed fracture  
 Diagnosis

## ABSTRACT

**Background:** In many cases, patients with severe blunt trauma have multiple fractures throughout the body. These fractures are not often detectable by history or physical examination, and their diagnosis can be delayed or even missed. Thus, screening test fractures of the whole body is required after initial management. We performed this study to evaluate the reliability of bone scans for detecting missed fractures in patients with multiple severe traumas and we analyzed the causes of missed fractures by using bone scan.

**Hypothesis:** A bone scan is useful as a screening test for fractures of the entire body of severe trauma patients who are passed the acute phase.

**Material and methods:** We reviewed the electronic medical records of severe trauma patients who underwent a bone scan from September 2009 to December 2010. Demographic and medical data were compared and statistically analyzed to determine whether missed fractures were detected after bone scan in the two groups.

**Results:** A total of 382 patients who had an injury severity score [ISS] greater than 16 points with multiple traumas visited the emergency room. One hundred and thirty-one patients underwent bone scan and 81 patients were identified with missed fractures by bone scan. The most frequent location for missed fractures was the rib area (55 cases, 41.98%), followed by the extremities (42 cases, 32.06%). The missed fractures that required surgery or splint were most common in extremities (11 cases). In univariate analysis, higher ISS scores and mechanism of injury were related with the probability that missed fractures would be found with a bone scan. The ISS score was statistically significant in multivariate analysis.

**Discussion:** Bone scan is an effective method of detecting missed fractures among patients with multiple severe traumas.

**Level of evidence:** Level IV, retrospective study.

© 2014 Elsevier Masson SAS. All rights reserved.

## 1. Introduction

Among trauma surgeons who care for patients with poly traumas, it is very important not to delay the life-saving procedures due to missed fractures. However, it is very difficult to diagnose initially all the non-fatal minor injuries in multiple trauma patients brought to the emergency room. It is undesirable to delay resuscitation due to performance of less urgent tests [1]. For musculoskeletal injury, particularly fractures of the extremities, a diagnosis can be made using X-ray, computer tomography (CT), magnetic resonance imaging (MRI) or ultrasound of the suspicious area after

vital signs become stabilized. These additional examinations are performed mostly on the areas with symptoms that relate from patients' complaints or on the areas that show abnormal findings on physical examination. In many cases, physicians may be unable to detect all the areas that have injury due to excessive patient pain, decreased awareness of the patient in the emergency room or during the early phases of the hospitalization. Even for mild injuries for which conservative treatment is sufficient, it is important to make accurate diagnosis and be able to determine the treatment period as this will help ensure correct legal and social handling as well as avoid ever-increasing malpractice cases. As such, we investigated the fractures that were detected by bone scan among severe trauma patients during their hospitalization after their treatment in the trauma center of this hospital. Bone scans were examined in terms of their effectiveness as a screening test for missed fractures.

\* Corresponding author. Tel.: +82 31 219 7767; fax: +82 31 219 7765.  
 E-mail addresses: [drkjlee@ajou.ac.kr](mailto:drkjlee@ajou.ac.kr) (K.-J. Lee), [jake98@daum.net](mailto:jake98@daum.net) (K. Jung), [trauma@ajou.ac.kr](mailto:trauma@ajou.ac.kr) (J. Kim), [aquaestel@gmail.com](mailto:aquaestel@gmail.com) (J. Kwon).

**Table 1**  
Relationship between missed injuries and the parameters analyzed.

	Diagnosis group	Missed group (treatment group)	P (treatment group)
Total number of patients	50	81 (40)	
Sex			
Male	40	65 (32)	NS (0.049) <sup>a</sup>
Female	10	16 (8)	
Age			
Mean ± SD	38.3 ± 20.4	42.5 ± 17.5 (41.1 ± 17.3)	NS (NS) <sup>b</sup>
ISS score (>15)			
Mean ± SD	18.8 ± 3.4	22.7 ± 6.2 (23.2 ± 7.0)	<0.001 (0.007) <sup>b,d</sup>
Conscious state <sup>c</sup>			
Good	40	62 (31)	NS (<0.001) <sup>a</sup>
Moderate	5	9 (5)	
Severe	5	10 (4)	
Mechanism of injury			
Traffic accidents	28	59 (31)	0.049 (<0.001) <sup>a</sup>
Falls	15	14 (7)	
Assaults	1	5 (2)	
Industrial accidents	6	3 (0)	

SD: standard deviation.

<sup>a</sup>  $\chi^2$ -test,  $P < 0.05$ .

<sup>b</sup> Independent sample  $t$ -test,  $P < 0.05$ .

<sup>c</sup> GCS score good, 13–15; moderate, 9–12; severe, ~8.

<sup>d</sup> Statistically significant in multivariate analysis.

## 2. Patients and methods

The 382 trauma patients who visited the emergency room between September 2009 and December 2010 had an ISS score of 16 or more. One hundred thirty-one patients who underwent bone scan were included in this study. The data were collected from the National Emergency Department Information System (NEDIS), medical records and the results of bone scan interpretation. The subjects' distribution by age and gender, mechanism of injury, time from admission to bone scan, ISS score and the Glasgow coma scale (GCS) score were assessed. For bone scan, intravenous injection of  $Tc^{99m}$  - DPD 20 mCi was performed. Urination was allowed four hours later and then an anteroposterior view of the whole body was taken using a gamma camera (dual head gamma, General Electric). In particular, for areas suspected to have a fracture due to increased uptake, magnified and oblique views were taken. Areas suspected of fracture in bone scan were finally diagnosed as a fracture after the performance of additional examinations such as CT and MRI. Among the patients who had been newly diagnosed with fractures, those who had required additional treatments such as splinting or surgery, in addition to conservative care, were identified and grouped into a separate patient group. The collected data were analyzed using SPSS 16.0 for Windows. Statistical analyses were performed using a  $t$ -test (independent sample  $t$ -test) and chi-square test;  $P < 0.05$  was considered statistically significant.

## 3. Results

The number of patients who had undergone bone scans and had an ISS score of 16 or more was 131 (105 were men, 26 were women; mean age was 41 years, range of 2–82). There are 6 children patients under 12 but no missed fracture was founded in these children. The mean ISS score was 21.2. For mechanism of injury, traffic accidents accounted for the highest proportion of entire cases, and other proportion was described in Table 1. Those with rib fractures (99 patients, 75.6%) accounted for the highest proportion of the entire fracture sites. The frequency of fracture by body area is presented in Table 2.

### 3.1. Bone scan

After the injury, bone scan was performed between 5 and 89 days (mean of 18 days) after the injury. New fractures were found among 81 patients (61.8%) and the most common area with newly found fractures was the rib area (55 patients, 42.0%). Forty patients (30.5%) required additional treatments such as splinting or surgery, in addition to conservative care or close observation. There was one patient who had a bone scan where three additional fractures were found requiring treatment. Among the 12 cases of spine fractures (thoracic vertebrae, 9; lumbosacral vertebrae, 3) that were found by bone scan, two cases required surgery like decompression and fusion. The immobilizations with braces were needed for 9 cases. And one case was needed only for observation. Of the sternum and rib fractures that were detected by bone scan, none required active treatments in addition to conservative care. All clavicle and scapula fractures that were found by bone scan required active treatments. Two cases of clavicle fracture required surgery like plate fixation and the other 6 cases were immobilized with figure of eight bandage. Four cases of scapula fracture required open reduction and/or internal implantation and the other 6 cases were needed braces. Of the fractures in the extremities that were found by bone scan, five required open reduction and/or internal fixation. And six required closed reduction and splinting without surgery. Conservative care with observation was performed for the other 31 cases (Table 2). There were three cases that fractures were not detected by bone scans. Two fractures were found in a 75-year-old female patient's T and L spine. The remaining fracture was found in the fibular of a 40-year-old male patient. Both patients had no other disease such as HTN and DM. The fracture was accidentally found in the outpatient follow up process after discharge.

### 3.2. Presence or absence of newly found fractures

Although there was no difference between men and women in terms of newly fractures found by bone scan, the frequency of these fractures that required active treatment was significantly higher among women than among men ( $P < 0.001$ ). For classification by mechanism of injury, the frequency of newly found fractures by bone scan was significantly high in vehicular accidents ( $P = 0.049$ ).

**Table 2**  
Number of fractures identified on bone scan and how was treated.

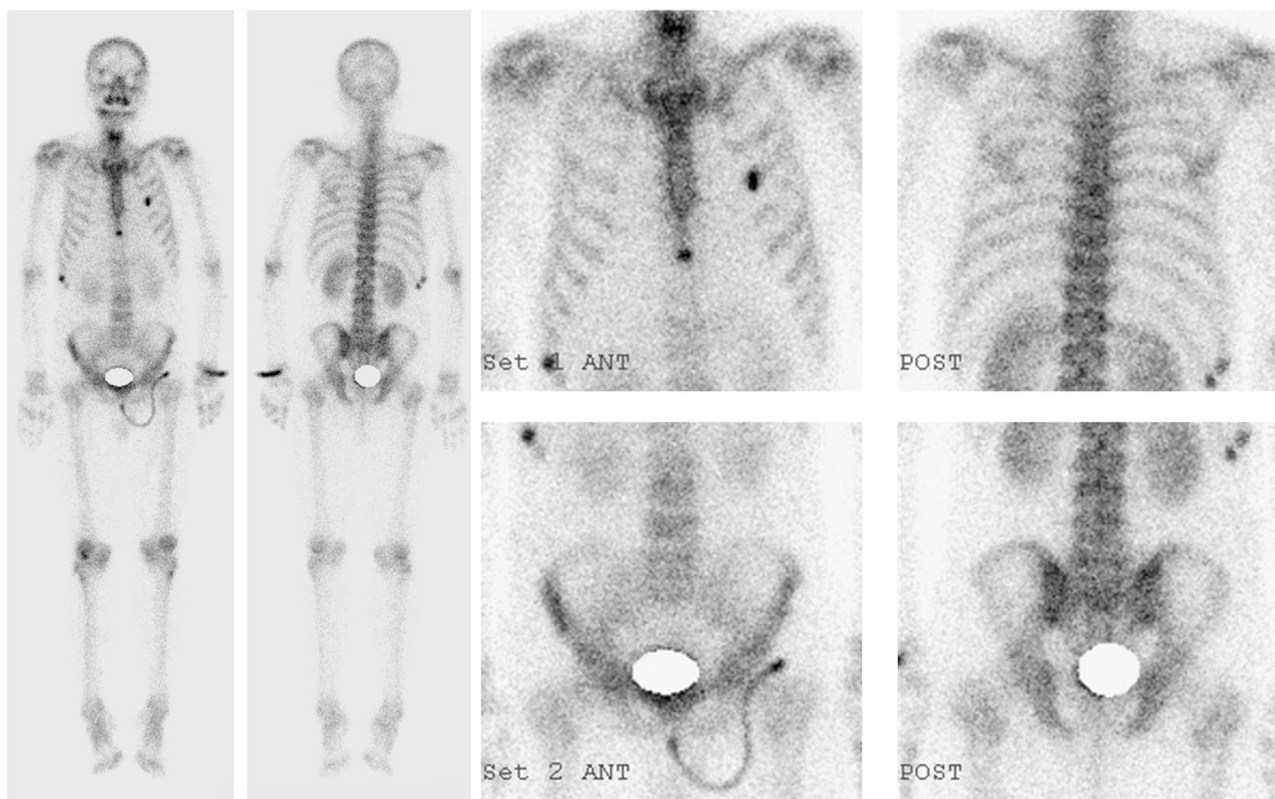
	Diagnosis	Missed	Operation	Immobilization	Conservative care only
Skull	33				
Spine					
Cervical	18				
Thoracic	20	9	1	7	1
Lumbosacral	25	3	1	2	
Sternum	5	11			11
Rib	45	55			55
Clavicle	13	8	2	6	
Scapular	6	10	4	6	
Extremity	35	42	5	6	31
Pelvis	24				

The frequency of newly found fractures by bone scan that required active treatment was also high after vehicular accidents ( $P < 0.001$ ). When the ISS score was higher, the frequency of newly found fractures was also higher ( $P < 0.001$ ). Likewise, the frequency of newly found fractures that required treatment was high ( $P = 0.007$ ). The higher the number of initially diagnosed fractures, the greater likelihood the patient had more newly found fractures by bone scan ( $P = 0.024$ ). The level of patient awareness was grouped into three classes based on GCS scores: the lower the level of awareness, the frequency of newly found fractures tended to be higher, though not significantly ( $P = 0.502$ ). The number of newly found fractures that had required treatment was significantly higher ( $P < 0.001$ ; Table 1). Multivariate analysis using variables such as ISS, GCS, age, sex and mechanism of injury was performed to identify the influence on the frequency of newly found fractures by bone scan. Only the ISS score was significant in relation with the newly found fractures ( $P < 0.001$ ).

#### 4. Discussion

Pfeifer et al. suggested that in order to reduce error in the diagnosis of fractures, additional tests are required for severe trauma patients whose ISS score is high, who are unconscious with low GCS or who are intubated [2]. Bone scan is more sensitive than radiography in detecting bone lesions as it uses physiologic changes of bone for imaging [3]. Bone scan is highly useful for diagnosing stress fractures or insufficiency fractures that are difficult to detect with radiologic examinations [4]. Abnormal bone uptake can be observed for as long as six months, even in fractures with a good prognosis. In about 90% of the cases, bone uptake becomes normalized within two years. For elderly people, the result of bone scans may appear normal even 10 days after the fracture. Bone scan in this study was performed an average of 18 days after the injury based on the rule that bone scans can be taken at least 5 days after the injury. The newly found fractures by bone scan were most common around the rib area. This is attributable to the fact that vehicle-related accidents (116 patients, 88.6%) as the mechanism of injury were most common [5]. In addition, there is a study reporting that rib fractures are easily overlooked in cases of blunt trauma [6]. The reason why rib fractures are easily overlooked in case of blunt trauma appears to be attributable to the fact that most of the newly found fractures in bone scan are in the form of hot uptake in costal cartilage or costochondrial junctions. The linear fractures in costal cartilage or costochondrial junctions are not easily diagnosed using plain chest radiography or CT [7] (Fig. 1). Excluding the case of flail chest, most of the traumatic fractures of rib and sternum are improved by conservative care including pain control [8]. In our study, there were no cases where active treatments including surgery were performed for newly found rib or sternum fractures. However, as severe trauma in many cases are accompanied with multiple rib and sternum fractures as well as

cardiopulmonary injury [9], the exact diagnosis of multiple rib and sternum fractures is helpful for detecting concomitant injury. In addition, as most of the causes of injury are attributed to traffic or industrial accidents (and thus closely related with insurance coverage and compensation), it is necessary to record even a simple rib fracture that does not require active treatment to avoid legal problems. No fractures were newly found in skull, cervical spine and pelvis by bone scan in this study. This is considered attributed to the fact that severe trauma patients who were transferred to this hospital underwent intensive trauma scans (e.g. brain, chest, cervical spine and abdominal-pelvic CT) even before bone scan, as situations would allow. In fact, very few patients had not undergone the aforementioned tests before bone scan. In spine (excluding the cervical spine), clavicle, scapula and extremities, a considerable number of fractures that required active treatment such as surgery were newly found by bone scan. Delay in the diagnosis of fractures in the aforementioned areas may result in persisting pain as well as functional loss unlike in the case of rib fractures. Moreover, such a delay may result in overcrowding of patients' rooms and increased medical costs due to prolongation of hospitalization. In addition, as missed diagnosis may cost the patient an opportunity for legal and financial compensation, it is very important to make a timely and accurate diagnosis of fractures in the aforementioned areas. The frequency of missed fractures was not significantly different by age. Pediatric patients, whose communication skills are less than adults, the frequency of missed fracture may be high. However, as most of the subjects in our study were adults, it appeared inappropriate to test the possible differences by age. Both the frequency of missed fractures and the frequency of missed fractures that required active treatments were higher in vehicle-related accidents than by other causes of injury. This is considered attributable to the fact that severe trauma caused by vehicle accidents commonly involves multiple fractures due to blunt trauma in multiple areas of the body. It is then difficult to make an early diagnosis of all the fractures. As described in the results section of this study, even in mechanisms of injury other than vehicle accidents, the higher the number of initially diagnosed fractures, the probability that missed fractures will also be likely detected as higher. Specifically, in vehicle-related accidents with an ISS score of 16 or more, rib fractures were generally found [10]. As described above, the frequency of newly found fractures was high in vehicle-related accidents possibly because multiple rib fractures are easily overlooked. Analysis showed that the lower level of the patient's consciousness was at the time of admission to the emergency room, the higher the number of newly found fractures that required treatments. The effect of a patient's level of consciousness at the time of admission to the emergency room with a delay in diagnosis of fractures has been continuously highlighted in numerous studies that addressed injury missed [11–13]. This is considered attributed to the fact that patients' complaints are easily overlooked because of the difficulty in performing history taking correctly. Further, physical examination is not extensively performed because of the poor



**Fig. 1.** Focal increased uptakes were seen at the right 10–11th, left 4th costochondral junctions and lower aspect of sternum and patella, right.

patient cooperation when their level of consciousness is decreased. In this study, the level of the patient's consciousness was compared based on the GCS score measured at the time of admission to the emergency room. Similarly, there is also a study that reported early sedation of the patient in the emergency room for intubation and mechanical ventilation might result in delayed diagnosis [11].

In more severe trauma based on the ISS score, the probability that patients will have missed injury was higher. This is considered attributed to the fact that the more severe the injury, the more likely a patient will have multiple injuries. Physicians pay more attention to diagnosis and treatments of injuries with high priority, thus fractures with mild symptoms or non-fatal fractures are not diagnosed correctly. Numerous studies investigated the relationship between the severity of trauma and delay in the diagnosis of fractures using ISS scores and frequency of detection of missed injury [14–16]. In this study, we investigated only severe trauma patients whose ISS score was 16 or more. We found a positive correlation between the ISS score and the frequency of detection of missed injury.

This study has several limitations. First, as this study was performed at a single trauma center, there may have been an imbalance in the types of traumas. Consequently, the scope of the study was limited, and for this reason, the results could not be generalized. Second, we did not consider the possibility that the diagnosis was incorrect because the diagnosis for trauma patients in the emergency room was performed in cooperation with multiple departments. Third, the initial radiographs and bone scans were interpreted by multiple radiologists. Thus, the possibility that there could be an actual fracture among the cases judged a symptom suspicious of fracture or trauma-related lesion could not be ruled out. Moreover, the possibility that an older lesion was diagnosed as the current fracture because of non-specificity of the bone scan and persistence of bone uptake findings cannot be excluded.

In this study, the delayed diagnosis of fractures in severe trauma patients based on the ISS score greater than 16 was investigated using bone scan results. The delayed diagnosis of fractures was most common around the rib area that did not require additional treatment. Some cases of delayed diagnosis of fractures in the clavicle, scapula, spine and extremities required additional treatments. The factors that caused delay in the diagnosis of fractures included vehicle-related accidents, ISS scores, levels of patient awareness and the total number of fractures of a patient. Among these factors, the ISS score was found to be significant in multivariate analysis. It is very difficult to find missed fractures in time after the initial assessment and treatment of patients with multiple trauma are finished. A bone scan is very useful in screening missed fractures and can be used reliably.

#### Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

**Funding:** this research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

#### References

- [1] Wei CJ, Tsai WC, Tiu CM, et al. Systematic analysis of missed extremity fractures in emergency radiology. *Acta Radiol* 2006;47:710–7.
- [2] Pfeifer R, Pape HC. Missed injuries in trauma patients: a literature review. *Patient Saf Surg* 2008;2:20.
- [3] Yang DC, Ratani RS, Mittal PK, et al. Radionuclide three-phase whole-body bone imaging. *Clin Nucl Med* 2002;27:419–26.
- [4] Kanstrup IL. Bone scintigraphy in sports medicine: a review. *Scand J Med Sci Sports* 1997;7:322–30.
- [5] Sirmali M, Turut H, Topcu S, et al. A comprehensive analysis of traumatic rib fractures: morbidity, mortality and management. *Eur J Cardiothorac Surg* 2003;24:133–8.
- [6] Davis S, Affatato A. Blunt chest trauma: utility of radiological evaluation and effect on treatment patterns. *Am J Emerg Med* 2006;24:482–6.

- [7] LaBan MM, Siegel CB, Schutz LK, et al. Occult radiographic fractures of the chest wall identified by nuclear scan imaging: report of seven cases. *Arch Phys Med Rehabil* 1994;75(3):353–4.
- [8] Liman ST, Kuzucu A, Tastepe AI, et al. Chest injury due to blunt trauma. *Eur J Cardiothorac Surg* 2003;23(3):374–8.
- [9] Borman JB, Aharonson-Daniel L, Savitsky B, et al. Unilateral flail chest is seldom a lethal injury. *Emerg Med J* 2006;23:903–5.
- [10] Pattimore D, Thomas P, Dave SH. Torso injury patterns and mechanisms in car crashes: an additional diagnostic tool. *Injury* 1992;23(2):123–6.
- [11] Buduhan G, Mc Ritchie DI. Missed injuries in patients with multiple trauma. *J Trauma* 2000;49:600–5.
- [12] Hallas P, Ellingsen T. Errors in fracture diagnoses in the emergency department – characteristics of patients and diurnal variation. *BMC Emerg Med* 2006;6:4.
- [13] Aaland MO, Smith K. Delayed diagnosis in a rural trauma center. *Surgery* 1996;120:774–8.
- [14] Janjua KJ, Sugrue M, Deane SA. Prospective evaluation of early missed injuries and the role of tertiary trauma survey. *J Trauma* 1998;44:1000–7.
- [15] Furnival RA, Woodward GA, Schunk JE. Delayed diagnosis in pediatric trauma. *Pediatrics* 1996;98:56–62.
- [16] Rizoli SB, Boulanger BR, McLellan BA, et al. Injuries missed during initial assessment of blunt trauma patients. *Accid Anal Prev* 1994;26:681–6.