

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

Maru Kim, M.D., Tae Hwa Hong, M.D., Hang Joo Cho, M.D.

Department of Trauma Surgery, Uijeongbu St. Mary's Hospital, The Catholic University of Korea, Cheonbo-ro Uijeongbu-si - South Korea

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.

INTRODUCTION

When managing patients with major trauma (MT), physicians often encounter several unexpected events, and missed injury is one of them. The incidence of missed injury might be as high as 38%.^[1] Airway maintenance, intubation, damage control surgery (DCS), and ventilator care are usually done prior to checking the extremities in initial management. It has been reported that patients with multiple traumas, traumatic brain injury, and decreased mental functioning were likely to have missed injuries.^[2,3] This may be associated with poorer outcomes, such as increased morbidity and mortality, and requires proper evaluation.^[4,5]

The brain, chest, and abdomen were routinely checked by computed tomography (CT) for stable patients with the

possibility of MT. Subsequent to initial resuscitation, the entire abnormal region was checked by X-ray according to the review of the system and physical examination. Painful regions without definite fracture or external wounds were regarded as contusion, sprain, or strain that could be managed conservatively. However, there were some patients with a complaint of continuous pain. In such cases, physicians can prescribe CT, magnetic resonance imaging (MRI), or bone scan (BS). Among these examinations, BS is the cheapest examination under the Korean National Health Insurance System (Table 1). It detects technetium-99 m-labeled bisphosphonates.^[6] It binds to sites of increased osteoblastic activity, such as physiological growth or turn-over. Thus, it is commonly used for the detection and follow-up of malignant lesions; however, it could also reveal injury or mechanical stress and can detect sites of fracture. In addition, it could

Cite this article as: Kim M, Hong TH, Cho HJ. Validity of bone scans to detect missed injury in patients with major trauma. *Ulus Travma Acil Cerrahi Derg* 2019;25:183-187.

Address for correspondence: Hang Joo Cho, M.D.

271, Cheonbo-ro Uijeongbu-si - South Korea.

Tel: 82-31-820-5378 E-mail: 10602800@cmcnu.or.kr



Ulus Travma Acil Cerrahi Derg 2019;25(2):183-187 DOI: 10.5505/tjtes.2018.55068 Submitted: 16.08.2017 Accepted: 26.07.2018 Online: 15.03.2019
Copyright 2019 Turkish Association of Trauma and Emergency Surgery

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

Table 1. Cost of CT, MRI, and bone scan in the Korean National Health Insurance System

Examination	Cost (US)
Bone scan	148.37
Knee computed tomography	206.39
Spine computed tomography	234.86
Knee magnetic resonance imaging	248.11
Spine magnetic resonance imaging	348.78

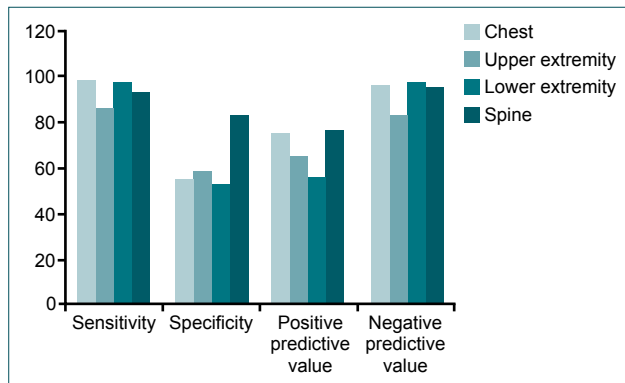
CT: Computed tomography, MRI: Magnetic resonance imaging.

Table 2. Results of bone scans used to detect fractures in patients with major trauma

Bone scan	Chest		Upper extremity		Lower extremity		Spine	
	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)
Fracture (+)	65	1	45	7	38	1	39	3
Fracture (-)	21	26	24	34	30	34	12	58
Sensitivity	98.48		86.54		97.44		92.86	
Specificity	55.32		58.62		53.13		82.86	
Positive predictive value	75.58		65.22		55.88		76.47	
Negative predictive value	96.30		82.93		97.14		95.08	

Table 3. Cases of hidden fracture

Lesion	n	%
Tibia	6	38
Fibula	4	25
Patella	3	19
Miscellaneous	3	19
Total	16	100

**Figure 1.** Sensitivity, specificity, positive predictive value, and negative predictive value of bone scan in patients with major trauma.

relatively 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%).

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

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, repetitious 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 every site with increased osteoblastic activity. Although patients with malignancies were excluded because of the possibility of bone metastasis, there exist 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

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.^[20] 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 are 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

1. Thomson CB, Greaves I. Missed injury and the tertiary trauma survey. *Injury* 2008;39:107–14. [\[CrossRef\]](#)
2. Giannakopoulos GF, Saltzherr TP, Beenen LE, Reitsma JB, Bloemers FW, Goslings JC, et al. Missed injuries during the initial assessment in a cohort of 1124 level-1 trauma patients. *Injury* 2012;43:1517–21. [\[CrossRef\]](#)
3. Buduhan G, McRitchie DI. Missed injuries in patients with multiple trauma. *J Trauma* 2000;49:600–5. [\[CrossRef\]](#)
4. Brooks A, Holroyd B, Riley B. Missed injury in major trauma patients. *Injury* 2004;35:407–10. [\[CrossRef\]](#)
5. Janjua KJ, Sugrue M, Deane SA. Prospective evaluation of early missed injuries and the role of tertiary trauma survey. *J Trauma* 1998;44:1000–6.
6. Lee JC, Hennessy AD, Khafagi FA. Bone scans. *Aust Fam Physician* 2012;41:689–92.
7. Ball CG. Damage control surgery. *Curr Opin Crit Care* 2015;21:538–43.
8. Ferree S, Houwert RM, van Laarhoven JJ, Smeeing DP, Leenen LP, Hietbrink F. Tertiary survey in polytrauma patients should be an ongoing process. *Injury* 2016;47:792–6. [\[CrossRef\]](#)
9. Aaland MO, Smith K. Delayed diagnosis in a rural trauma center. *Surgery* 1996;120:774–8. [\[CrossRef\]](#)
10. Mallee WH, Wang J, Poolman RW, Kloen P, Maas M, de Vet HC, et al. Computed tomography versus magnetic resonance imaging versus bone scintigraphy for clinically suspected scaphoid fractures in patients with negative plain radiographs. *Cochrane Database Syst Rev* 2015:Cd010023. [\[CrossRef\]](#)
11. Byrne JP, Nathens AB, Gomez D, Pincus D, Jenkinson RJ. Timing of femoral shaft fracture fixation following major trauma: A retrospective cohort study of United States trauma centers. *PLoS Med* 2017;14:e1002336. [\[CrossRef\]](#)
12. Nahm NJ, Vallier HA. Timing of definitive treatment of femoral shaft fractures in patients with multiple injuries: a systematic review of randomized and nonrandomized trials. *J Trauma Acute Care Surg* 2012;73:1046–63. [\[CrossRef\]](#)
13. Yu SY, Wang W, Liu S, Ruan HJ, Liu JJ, Li XJ, et al. Arthrolysis and delayed internal fixation combined with hinged external fixation for elbow stiffness associated with malunion or nonunion of capitellum fracture. *J Shoulder Elbow Surg* 2015;24:941–6. [\[CrossRef\]](#)
14. Jackson LC, Pacchiana PD. Common complications of fracture repair. *Clin Tech Small Anim Pract* 2004;19:168–79. [\[CrossRef\]](#)
15. Lin JS, Piper MA, Perdue LA, Rutter CM, Webber EM, O'Connor E, et al. Screening for Colorectal Cancer: Updated Evidence Report and Systematic Review for the US Preventive Services Task Force. *Jama* 2016;315:2576–94. [\[CrossRef\]](#)
16. Health Quality Ontario. Ultrasound as an adjunct to mammography for breast cancer screening: a health technology assessment. *Ont Health Technol Assess Ser* 2016;16:1–71.
17. Eurin M, Haddad N, Zappa M, Lenoir T, Dauzac C, Vilgrain V, et al. Incidence and predictors of missed injuries in trauma patients in the initial hot report of whole-body CT scan. *Injury* 2012;43:73–7. [\[CrossRef\]](#)
18. Kritsaneepeaboon S, Jutiyan A, Krisanachinda A. Cumulative radiation exposure and estimated lifetime cancer risk in multiple-injury adult patients undergoing repeated or multiple CTs. *Eur J Trauma Emerg Surg* 2018;44:19–27. [\[CrossRef\]](#)
19. Shah KH, Slovis BH, Runde D, Godbout B, Newman DH, Lee J. Radiation exposure among patients with the highest CT scan utilization in the emergency department. *Emerg Radiol* 2013;20:485–91. [\[CrossRef\]](#)
20. Yun BJ, Myriam Hunink MG, Prabhakar AM, Heng M, Liu SW, Qudsi R, et al. Diagnostic Imaging Strategies for Occult Hip Fractures: A Decision and Cost-Effectiveness Analysis. *Acad Emerg Med* 2016;23:1161–9. [\[CrossRef\]](#)

ORİJİNAL ÇALIŞMA - ÖZET

Majör travma hastalarında atlanmış yaralanmanın saptanmasında kemik taramalarının geçerliliği

Dr. Maru Kim, Dr. Tae Hwa Hong, Dr. Hang Joo Cho

Travma Cerrahisi Bölümü, Uijeongbu St. Mary's Hastanesi, Kore Katolik Üniversitesi, Cheonbo-ro Uijeongbu-si-Güney Kore

AMAÇ: Majör travma hastalarında yaralanmaları atlamak kolaydır. Yazarlar, kemik taramalarının atlanmış yaralanmaların sayısını azaltacağı varsayımında bulunmaktadır. Ancak majör travma hastalarında kemik taramalarına ait yeterli kanıt yoktur. Bu çalışmanın amacı kemik taramalarının başlıca sonuçlarını tanımlamaktır.

GEREÇ VE YÖNTEM: Ocak 2013 ila Aralık 2013 arasında majör travma hastalarının tıbbi kayıtları gözden geçirildi ve kemik taramaları yapılan hastaların kayıtları incelendi. Daha önce değerlendirilmemiş yoğun tutulum gösteren sıcak noktalar direkt radyografiyle kontrol edildi. Daha önceki değerlendirmelerden farklı olarak kemik taramalarında yoğun tutulum gösteren lezyonlar bilgisayarlı tomografi taramalarıyla kontrol edildi. Kemik taramalarının sonuçları direkt radyografi ve bilgisayarlı tomografi taramalarının sonuçlarıyla birlikte analiz edildi. Duyarlılık, özgüllük, pozitif ve negatif öngördürücü değerler hesaplandı.

BULGULAR: Bu dönem içinde 115 majör travma hastası kemik taramalarından geçirildi. Kemik taramalarının duyarlılık ve öngördürücü değerleri yüksek düzeylerdeydi (sırasıyla, %98.48–%86.54 ve %96.30–%82.93). Kemik taramaları atlanmış 16 kırık olgusuna tanı konuldu.

TARTIŞMA: Kemik taramaları yüksek bir duyarlılık ve negatif öngördücü değere sahiptir. Daha fazla sayıda geniş çaplı çalışma majör travma çalışmalarında kemik taramalarının majör travma hastalarında kullanımına daha fazla geçerlilik kazandırabilir.

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

Ulus Travma Acil Cerrahi Derg 2019;25(2):183-187 doi: 10.5505/tjtes.2018.55068