Patterns of isotope uptake in sequential postoperative bone scan in undisplaced femoral-neck fractures

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Abstract

Purpose We aimed to investigate the changing pattern of isotope uptake in the sequential bone scan test for the prediction of osteonecrosis of the femoral head in patients with an undisplaced femoral-neck fracture.

Methods Fifty-four cases of sequential bone scan for nondisplaced femoral-neck fracture treated by internal fixation with cannulated screws between 2000 and 2009 were retrospectively studied. The mean follow-up period was 4.2 years. The first postoperative bone scan was performed two weeks postoperatively in all patients. Second, third, and fourth follow-up bone scans were performed at one to six months, 12–18 months, and 18–24 months postoperatively.

Results Mean femoral-head ratio (FHR) in the first postoperative bone scan was 0.99. Although it was under 1.0 in 38 patients (70.4 % of the 54 patients), only one patient developed osteonecrosis of the femoral head. The others showed hot uptake in their second follow-up bone scan. Mean FHRs in the second, third, and fourth postoperative bone scans were 1.69, 1.29, and 1.05, respectively, and there were significant statistical differences in each follow-up period ($P=0.035$). In addition, there were unique patterns of isotope uptake with the passage of time, such as cold uptake in the early stage, hot uptake in a couple of months, and iso-uptake in the late stage.

Conclusions Early postoperative bone scan results should not be over interpreted when predicting osteonecrosis of the femoral head.

Introduction

Despite the advances in surgical techniques, femoral-neck fracture frequently results in complications such as nonunion and avascular necrosis (AVN), and osteonecrosis of the femoral head has been reported in about 5.8 % (from 1.6 % to 22.5 %) of nondisplaced fractures [1–4]. Osteonecrosis of the femoral head occurs when femoral-neck fracture results in rupture or kinking of the blood vessels running from the femoral neck to the femoral head and consequently, insufficient blood-flow [5]. A postoperative bone scan has been shown to correlate with eventual rates of nonunion and osteonecrosis in femoral-neck fractures [6]. We have encountered many cases in which the bone scan performed within two weeks postoperatively showed a cold isotope uptake, and the follow-up bone scans showed a hot isotope uptake and normal healing without osteonecrosis of the femoral head in patients with undisplaced femoral-neck fracture. Based on this finding, it was considered that isotope uptake in a bone scan would differ over time after femoral fracture and that this difference would be an important factor responsible for the difference in the accuracy of bone scans for the prediction of osteonecrosis of the femoral head. We therefore aimed to ascertain how isotope uptake changes over time after surgery by following up the result of the bone scan performed after internal fixation of undisplaced femoral-neck fracture.

Materials and methods

A total of 54 patients who had received internal fixation using cannulated screws for nondisplaced femoral-neck fracture from January 2000 to December 2009 and who

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underwent bone scans and follow up for three or more years were retrospectively investigated. The study was approved by the research ethics board. No patient had a history of surgery for femoral fracture or hip-joint arthritis; other patient characteristics were as follows: male patients, $n=26$; female patients, $n=28$; mean age at the time of surgery, 42.2 (range 17–69) years; mean follow-up, 4.2 (range three to seven) years.

All received internal fixation using three to four cannulated screws within 24 hours of injury (mean injury-to-surgery interval 12.1 hours; range four to 21 hours); for valgus-impacted fractures, closed reduction was carefully performed. From the day after the surgery, partial weight bearing was allowed as much as possible, and full weight bearing was allowed from at least eight weeks postoperatively. Three to four hours after the intravenous administration of technetium-99m-hydroxymethane diphosphonate (^{99m}Tc -HTD) 350 MBq, bone scans were obtained using a high-resolution gamma camera (IRIX 710 Philips). All patients underwent a first bone scan within two weeks postoperatively, and 47 patients underwent a second bone scan between one and six months postoperatively. Thirteen patients underwent a third bone scan between 12 and 18 months, and eight patients underwent a fourth bone scan between 18 and 24 months postoperatively.

The femoral-head ratio (FHR) obtained by dividing the intensity of the isotope uptake in the femoral head of the affected side by the intensity of the isotope uptake in the unaffected side was used as data for investigating the intensity of the isotope uptake over time. First, FHRs were plotted on a scatter diagram by time of bone scan (i.e. first, second, third, and fourth scans) to examine the overall distribution. FHRs at the first, second, third and fourth scans were compared to determine whether they were significantly different. As the number of samples from the third to the fourth scans

was small, the Kruskal–Wallis test was used to examine whether there was a significant difference. In addition, the pattern of change in FHRs over time was observed in each of the 13 patients who underwent third or fourth bone scans.

Results

The scatter diagram of the FHRs plotted by bone scan time showed that isotope uptake decreased in more than half of the patients in bone scans performed within two weeks postoperatively, whereas it increased in most patients in the second bone scans performed between one and six months postoperatively (Fig. 1).

In the 54 patients who underwent a first bone scan within two weeks postoperatively, mean FHR was 0.99 (range 0.42–3.26); in 38 (70.4 %) of patients, FHR in the first bone scan was under 1 (i.e. isotope uptake in the affected side was lower than that in the unaffected side). Of the 38 patients in whom isotope uptake decreased, however, only one developed osteonecrosis of the femoral head; in 37 of the 38 patients, isotope uptake increased in the second bone scan performed between one and six months postoperatively, and the fracture healed without osteonecrosis of the femoral head. In the 47 patients who underwent a bone scan between one and six months postoperatively, mean FHR was 1.69 (range 0.84–3.80); in the 13 patients who underwent a third bone scan between 12 and 18 months postoperatively, mean FHR was 1.29 (range 1.01–2.62); in the eight patients who underwent a fourth bone scan between 18 and 24 months postoperatively, mean FHR was 1.05 (range 1.03–1.16). In addition, FHRs were significantly different between the first, second, third and fourth bone scans ($P=0.035$) (Table 1).

Fig. 1 Distribution of the femoral-head ratios (FHRs) in follow-up bone scans. Most patients showed a decreased isotope uptake within 2 weeks postoperatively, but in most patients, uptake increased 1 month postoperatively

Table 1 Femoral-head ratio (FHR) in the follow-up bone scan postsurgery (Kruskal–Wallis test)

	Within 2 weeks postsurgery (54)	1–6 months postsurgery (47)	12–18 months postsurgery (13)	18–24 months postsurgery (8)	<i>P</i> value
Average FHR	0.99	1.69	1.29	1.05	0.035

The change in FHR between bone scan timings in individual patients who underwent a third or fourth scan was plotted on a scatter diagram: in 12 patients, isotope uptake immediately decreased postoperatively, remarkably increased between one and six months postoperatively and gradually decreased from 12 months postoperatively, reaching a level similar to that in the unaffected side (Fig. 2).

Discussion

Osteonecrosis of the femoral head occurs in about 10 % of cases of nondisplaced femoral-neck fracture [4]. Early diagnosis and prediction of osteonecrosis of the femoral head are highly important when determining the treatment plan in terms of the patient's best interest and medical cost [7]. The diagnostic value of plain radiography is low, as it can detect osteonecrosis of the femoral head only when the osteonecrosis has considerably advanced. Thus, bone scan is used for the early diagnosis of osteonecrosis of the femoral head [8–10]. Bone scan visualises the functional change of the bone rather than the anatomical change and is thus a sensitive test that can detect a bone lesion that cannot be detected well in an anatomical image. Bone scan, however, has the disadvantage of producing similar findings for all lesions, regardless of cause (e.g. tumour, inflammation, fracture) and thus lacks specificity. This is because the intensity

of isotope uptake depends on bone turnover and blood supply in the lesion [11].

Stromqvist et al. [12] reported that in 306 patients with femoral-neck fracture, the bone scan performed within two weeks postoperatively predicted osteonecrosis of the femoral head with 91 % accuracy regardless of the presence or absence of displacement. In contrast, Broeng et al. [13] reported that the bone scan performed between one and three weeks postoperatively in 103 patients with femoral-neck fracture correctly predicted osteonecrosis of the femoral head in only 50 % of patients. In these authors' hospital, early bone scan is performed within two weeks postoperatively to predict osteonecrosis of the femoral head in patients with femoral-neck fracture. In their study on patients with undisplaced femoral-neck fracture who underwent internal fixation, the bone scan performed within two weeks postoperatively predicted osteonecrosis of the femoral head only in 2.6 % of patients. As shown in the study by Broeng et al. [13], results of early bone scans are diverse, and thus, the value of early postoperative bone scan in predicting osteonecrosis of the femoral head needs to be re-evaluated.

Our study shows that the intensity of isotope uptake in bone scans after femoral-neck fracture differed over time, which can be explained in relation with the fracture healing process as follows: Vascular damage due to femoral-neck fracture blocked the blood flow to the femoral head for a certain time; active blood flow was recovered and maintained

Fig. 2 Femoral-head ratio (FHR) in the follow-up bone scan. Each FHR that was <1 immediately postoperatively became >1 at 1–6 months and went down to around 1 (red horizontal line) 12 months postoperatively

until completion of fracture healing due to revascularisation and reperfusion after the inflammatory phases; after completion of fracture healing, blood flow was maintained at the normal level. If we know exactly when revascularisation occurs after femoral-neck fracture, then bone scan at the time of revascularisation will be the best method for determining the success or failure of the revascularisation and will be most effective for predicting osteonecrosis of the femoral head. However, there has been no such study involving humans. Swiontkowski et al. [14], in a study using swine, which have numerous anatomical and histological similarities to humans, found that revascularisation occurred about four weeks after femoral-neck fracture and guessed that a similar occurrence would be observed in humans.

The low accuracy of early bone scan in predicting osteonecrosis of the femoral head in this and in the study conducted by Broeng et al. [13] was due to the pattern of change in isotope uptake that occurred in relation to the fracture-healing process. It is considered that the early bone scan performed before revascularisation was responsible for the high false positive rate and low accuracy. However, we could not explain the high accuracy of bone scans in predicting osteonecrosis of the femoral head conducted by Stromqvist et al. [12]. Factors related to osteonecrosis of the femoral head include the degree of displacement at the time of fracture, time to reduction, surgeon experience and the patient's systemic condition and lifestyle [15]. It is considered that various combinations of these many factors may result in a difference in the accuracy of bone scan in predicting osteonecrosis of the femoral head. In terms of time to surgery, conventionally, it is believed that shortening of injury-to-surgery interval can reduce fracture-induced osteonecrosis of the femoral head [16–18]. However, controversy still exists around the timing of such surgery in young patients. Barnes et al. [19] found that timing of surgery had no influence on the rates of AVN in patients treated by reduction and fixation up to seven days after injury. Haidukewych et al. [20] reported that in their series of 73 femoral-neck fractures in young patients, the rate of osteonecrosis was not statistically different between those treated within 24 hours from the time of diagnosis (24 %) and those treated over 24 hours from the time of diagnosis (20 %). In contrast to these findings, Jain et al. [21] compared early fixation (within 12 hours of injury) to delayed fixation (more than 12 hours) and recorded an incidence of AVN in 16 % of the delayed group compared with none in the early fixation group. Because the blood supply to the femoral head may be compromised by displacement or increased intracapsular pressure, early fixation should be recommended for better outcome after femoral-neck fractures.

A limitation to our study is that patients who had undisplaced femoral-neck fracture were included and those with displaced femoral-neck fracture were excluded. Therefore, direct comparison with other studies could not be

performed. Further studies are required to obtain comprehensive results by including a large number of patients with displaced femoral-neck fracture.

Conclusion

Early postoperative bone scan results should not be over interpreted when predicting osteonecrosis of the femoral head. It must be considered that there are unique patterns of isotope uptake with the passage of time, such as cold uptake in the early stage, hot uptake in a couple of months postoperatively and iso-uptake in the late stage.

Conflict of interest No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript. The authors declare that there are no conflicts of interest in this study.

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