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Limited Use for Bone Scintigraphy in the Follow-Up of Pediatric Femoral Neck Fractures

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Abstract

Purpose: Femoral neck fractures in children are rare injuries which are associated with a high incidence of osteonecrosis of the femoral head. We aimed to determine the predictive accuracy of bone scintigraphy for femoral head osteonecrosis after pediatric femoral neck fractures.

Materials and Methods: Thirteen scintigrams were performed in 10 children (6–15 years) at diverse moments after fixation of a femoral neck fracture. The results of the bone scintigrams were compared with the hip radiographs at final follow-up.

Results: Eight of the 10 femoral heads eventually developed osteonecrosis. Scintigrams performed within 2 weeks showed decreased uptake for these heads. However, four of the five scans that were performed more than 1 month after surgery showed normal uptake despite thesubsequent collapse of these femoral heads.

Conclusions: Bone scintigraphy has a very low accuracy in predicting compromised vascularity of the femoral head when performed more than 1 month after surgery of a femoral neck fracture in children. This finding questions the value of scintigraphy performed late in the follow-up of pediatric femoral neck fractures.

Level of Evidence: Level IV.

Keywords: Pediatric Hip Fracture; Bone Scan; Outcome

Introduction

Femoral neck fractures in children are rare injuries which are associated with a high incidence of osteonecrosis of the femoral head [1,2]. Given that these fractures account for <1% of all fractures in pediatric patients, familiarity with the post-operative concourse and imaging modalities to detect deviations from an uncomplicated healing process is often limited. Early detection of impaired revascularization of the femoral head is useful for its management since timely protective measures such as prolonged non-weight-bearing [3] and the administration of bisphosphonates [4] might prevent the imminent collapse of the femoral head. While several risk factors including fracture type and amount of dislocation, age of the patient, and interval between injury and reduction [1,2,5-8] have been identified, the determination of which individual patientis at highest risk remains challenging. Magnetic resonance imaging (MRI) is currently considered the gold standard for the detection and appreciation of the extent of osteonecrosis of the femoral head due to its high sensitivity and specificity for the earliest stages of osteonecrosis and its ability to assess focal capital femoral epiphyseal defects [9,10]. However, the prompt availability of MRI for children is often limited in some centers. In addition, MRI interpretation may be distorted as a result of metal implants used for internal fixation of the femoral neck fracture [5]. The use of bone scintigraphy to identify bone marrow infarction has been described since the early 1950s, and in the 1970s, technetium(99mTc) was introduced, showing good potential to predict osteonecrosis in adults [11,12]. Typically, bone scintigrams with a lower initial uptake and slower normalization up until several months after surgery have been associated with healing complications of the adult hip fracture [13-15]. In children, however, very minimal information is available on bone scintigraphy in the evaluation of femoral neck fractures [16,17]. The vascularity of the pediatric femoral head and the potential reversibility after avascular insults is different in children from adults [18]. It is, therefore, uncertain whether the same accuracy of predicting osteonecrosis with bone scintigraphy can be expected in pediatric femoral neck fractures. In this study, we reviewed a group of children with femoral neck fractures in which clinical concerns of possible osteonecrosis prompted the treating physician to evaluate epiphyseal vascularity with bone scintigraphy at some point during the follow-up period of the femoral neck fracture. The results of the bone scintigrams were compared with the hip radiographs at final follow-up.

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Materials and Methods

Patient selection

Institutional Review Board approval was obtained before initiation of this retrospective study. For this type of study, formal consent is not required. A single institution's database (Royal Children's Hospital Melbourne) was searched for all patients that were operated for a femoral neck fracture between 2001 and 2012, and an analysis of medical records and imaging was performed. 24 fractures were identified in 23 patients. Five patients were excluded due to follow-up of <6 months at our institute. One patient was excluded for being skeletally mature at the time of the injury. In 10 of the remaining 17 patients, bone scintigraphy was ordered postoperatively by the treating physician. It was standard clinical practice to perform bone scintigraphy if compromise of vascularity of the femoral head following femoral neck fractures was suspected because MRI was not readily available at our institute. In addition, fixation of pediatric femoral neck fractures occurred with stainless steel material which facilitates future removal of hardware compared to titanium screws but distorts post-operative MRI interpretation of potential osteonecrosis of the femoral head. The decision to perform bone scintigraphy in the included patients was based on clinical judgment by the treating physician (in the early post-operative course, this included concerns for impaired femoral head vascularity based on fracture type and displacement, and time to reduction; in the later follow-up, this included persistent pain related to the affected hip joint exacerbated with weight-bearing).A review of the clinical records and final radiographs of the excluded seven patients without bone scintigraphy in the post-operative follow-up period showed uneventful healing of all seven hips. The included patients with a post-operative bone scintigraphy were four males and six females (Table 1). The mean age of the patients was 11.3 years (range 6–15). The fracture type was Delbet Type-I in two patients (Fig. 1), Type-II in three patients, Type-III in four, and Type-IV in one patient. Fracture displacement was more than 5 mm in seven patients. Cannulated screws were used in the majority of patients (8 of 10 hips) and a dynamic hip screw (Synthes, Oberdorf, Switzerland) was used in the remaining two children. Two patients, both with a displacement of more than 5mm, required open reduction with internal fixation.

Imaging

In all patients, hip radiographs were taken at the time of admission, postoperatively, and at follow-up of minimum 6 months postoperatively (mean 30.2 months, range 8–77 months). The timing of post-operative bone scintigraphy in the 10 patients varied in accordance with the individual surgeon's preference and routine practice. 13 scintigrams were performed in total, with six of the scans performed within 2 weeks of surgery, three of these scans were repeated more than 1 month after surgery, and four additional scans were performed more than1 month after surgery (Table 1). 99mTc medronate in a weight adapted fractional adult dose was used. For hip viability studies, bilateral pinhole spot views of the hips were applied (5 min, 256 × 256 matrix static image, high energy pinhole collimator). The radiographs and bone scintigrams had been interpreted initially by a radiologist and the treating orthopedic surgeon. The subsequent development of secondary radiological changes in the hip joint in this study was determined on radiography by an independent orthopedic surgeon blinded to the bone scan results, using the Ficat classification [19]. The results of the bone scintigrams were compared with the hip radiographs at final follow-up.

Analysis

Descriptive statistics were used for the evaluation of the diagnostic test.

Results

In eight of the 10 patients, osteonecrosis of the femoral head was diagnosed on the final radiographs (Table 1). In the six bone scans that were performed within 2 weeks after surgery, decreased uptake suggesting impaired vascularity was seen in five femoral heads. These five femoral heads went onto collapse on final radiography. The radiograph of the remaining hip with normal uptake on bone scintigraphy was normal at final follow-up. Of the seven bone scintigrams that were taken more than 1 month after surgery, one scintigram demonstrated impaired vascularity of the femoral head. This patient indeed developed subsequent osteonecrosis. The vascularity of two hips was considered normal more than 1 month after surgery, and final radiographs did not show any signs of osteonecrosis. Vascularity of the femoral head on bone scintigraphy performed more than 1 month after surgery was considered normal in four patients, despite radiographic femoral head collapse on final radiograph.

Discussion

The principal finding of this study was that bone scintigraphy had a very low accuracy in predicting compromised vascularity of the femoral head when performed more than 1 month after surgery of a femoral neck fracture in children. The initial studies on bone scintigraphy in adults were very promising [20-22]. For example, Strömqvist et al. [23] found in study of 306 adults that the prognostic accuracy in predicting the outcome of healing of a femoral neck fracture was >90% when the scintigraphy was performed within 2 weeks from surgery. The high accuracy of early bone

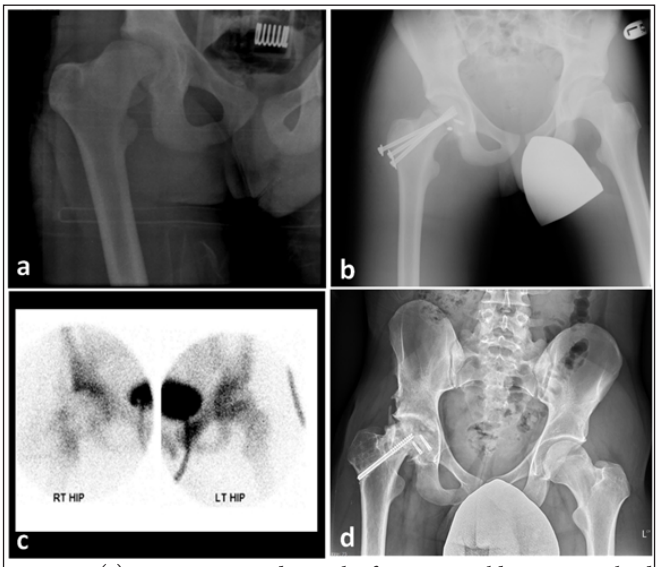

Figure 1: (a) Pre-operative radiograph of a 14-year-old patient involved in a bicycle versus truck accident resulting in a Delbet Type I fracture, (b) post-operative radiograph following open reduction and screw fixation, (c) early bone scan indicating an avascular femoral head, and (d) subsequent osteonecrosis with collapse of the femoral head.

scintigraphy was somewhat disputed in later studies. In a relatively smaller study of 46 patients, the decreased uptake that was seen on scintigraphy of patients with healing complications was only 50% specific [15]. A potential explanation in the variability in reported specificity of bone scintigraphy for healing complications following femoral neck fractures might be the unique patterns of isotope uptake that have been documented following femoral neck fractures which were not always necessarily related to subsequent collapse of the femoral head [24]. When analyzing femoral head viability, the physiological healing response with an increase and then decrease blood flow to baseline levels must be taken into account [13,25]. While bone scintigraphy has been shown to be susceptible for over interpretation of osteonecrosis of the femoral head in adults, the sensitivity of scintigraphy for the detection of osteonecrosis (i.e., a scan with normal uptake equals an uncomplicated healing process) has been consistently between 90 and 100%, in adult patients, even when performed several months after surgery of the fracture [15]. This is in stark contrast with the findings of the present study in children. Bone scintigraphy performed more than 1 month after surgery showed a normal uptake in four femoral heads even though the radiographs at final follow-up showed osteonecrosis of the femoral head. With one scintigram correctly showing impaired vascularity of the femoral head, the sensitivity of bone scintigraphy to predict osteonecrosis following femoral neck fracture in children was thus only 20% when performed more than a month after surgery. In the present study, it is tempting to conclude that the predictive accuracy of bone scintigraphy in children might be as high as 100% when performed within 2 weeks since the five femoral heads with deficient uptake on early bone scintigraphy indeed went on to collapse without any false-negative examinations. This diagnostic result would be substantially better than the accuracy of 50% of early bone scintigraphy documented by Juréus et al. in a recent study of eight children with femoral neck fractures [16]. However, the incidence of osteonecrosis in the later study was 25% compared to 80% in the present study. Due to the inherent selection bias, in the present study, i.e., inclusion of those patients in which bone scintigraphy was performed based on clinical suspicion of osteonecrosis; the predictive accuracy of bone scintigraphy is subsequently augmented by the higher a priori chance of osteonecrosis. A major limitation of the present study was the small number of patients. However, this limitation is inherent in studying a rare entity and is consistent with other reports on pediatric femoral neck fractures in the literature. Moreover, the unequivocal lack of accuracy in predicting compromised vascularity of the femoral head when performed more than 1 month after surgery in these 10 children might make a change, in conclusion, unlikely, if more children were to be included. A second limitation was the selection bias of our study. Due to the large radiation exposure, bone scintigraphy was only performed at our institute in the follow-up of pediatric femoral neck fractures when there was clinical suspicion of impaired vascularity of the femoral head. Such selection bias would affect the interpretation of the results if the goal of the present study was to determine the specificity of bone scintigraphy to predict osteonecrosis. However, these selection criteria did not interfere with the purpose of the present study which was to create a reasonable insight into the sensitivity of bone scintigraphy to predict osteonecrosis. Based on our findings, we would like to advise against bone scintigraphy in the follow-up of pediatric femoral neck fractures, certainly when performed more than 1 month after surgery. The high number of false-negative results does not justify the high radiation dosage associated with bone scintigraphy, especially if MRI with a well-documented high sensitivity and specificity for the detection and appreciation of the extent of osteonecrosis of the femoral

Table 1: 10 children with femoral neck fracture

Sex	Mechanism	Displacement >5 mm	Time to theater<24 h	Surgery	Time of early bone scan (days)	Result of early bone scan	Time of late bone scan (days)	Result of late bone scan	Radiographic osteonecrosis
M	MVA	Y	Y	CS (through ORIF)	3	avascular			yes
F	Fall	N	N	CS			231	normal	yes
F	Fall	Y	N	CS			40	normal	yes
M	MVA	Y	Y	DHS	11	avascular			yes
F	Direct impact	Y	Y	CS	7	avascular			yes
F	Fall	Y	N	CS	3	avascular	71	normal	yes
F	MVA	N	Y	CS	4	avascular	43	normal	yes
F	MVA	Y	Y	DHS			38	avascular	yes
M	Fall	Y	Y	CS (through ORIF)	3	normal	45	normal	no
M	MVA	N	N	CS			319	normal	No

MVA: Motor vehicle accidents, CS: Compression screws, DHS: Dynamic hip screw

head is available. It might be postulated that in the event that MRI is not available in a timely manner, the clinical suspicion of the orthopedic surgeon would suffice for the preliminary diagnosis of osteonecrosis since the final radiographs of eight of the 10 patients in which bone scintigraphy was ordered by the treating physician indeed showed osteonecrosis, while none of the patients in which no bone scintigraphy was ordered had post-operative impaired vascularity at final follow-up.

Conclusions

Bone scintigraphy has a very low accuracy in predicting compromised vascularity of the femoral head when performed more than 1 month after surgery of a femoral neck fracture in children.

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