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Diagnostic accuracy of ultrasonography for occult femoral neck fracture

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ABSTRACT

Background: A delay in the diagnosis and treatment of an occult femoral neck fracture (OFNF) can negatively affect the subsequent quality of life. We investigated the diagnostic accuracy of ultrasonography for OFNF in patients confirmed with this condition by magnetic resonance imaging (MRI), and compared these results with other clinical findings.

Methods: Ninety-four outpatients aged above 70 years with acute hip pain but without radiographic abnormal findings who were suspected of having an occult femoral neck fracture (11 men and 83 women with a mean age of 81.8 ± 6.0 years) were enrolled. Both ultrasonography and MRI were performed in all cases within 24 h. The ultrasonographic distance between the anterior aspect of the femoral neck and the anterior joint capsule (ultrasound joint swelling) was measured.

Results: By MRI findings, 27 patients were assigned to an occult femoral neck fracture (OFNF) group (1 man, 26 women) and 67 patients to a non-OFNF group (10 men, 57 women). The mean ultrasound joint swelling in both groups was 7.53 ± 1.52 mm and 3.45 ± 0.89 mm, respectively ($p = 0.006$, 95% CI, 3.58 −4.59). A cut-off value of 5.3 mm showed a sensitivity of 0.96 (0.89−0.96) and a specificity of 0.98 (0.92 −1.00).

Conclusions: Ultrasonography shows very high diagnostic accuracy for occult femoral neck fracture. This modality can thus contribute to initial bed-side examinations for this condition in patients over 70 years with acute hip pain.

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1. Introduction

Occult fractures can be diagnosed for the first time by magnetic resonance imaging (MRI) or bone scintigraphy because the fracture line is unclear on plain radiographs or computed tomography (CT) scans.[1] Occult femoral neck fractures (OFNF) account for 1.9−4.3% of all femoral neck fractures.[2–4]

In Japan, the current guidelines for femoral neck fractures recommend surgical treatment, even for occult fractures. Surgery is indicated for osteosynthesis as early as possible, and good clinical results have been reported from these interventions. MRI is a gold standard diagnostic modality for OFNF[5,6] with a reported sensitivity and specificity of 100%. However, an early diagnosis of OFNF will likely be difficult if no MRI equipment is available, if the patient has a pacemaker and an MRI would not be safe, if there is no history of falls, or if the patient is able to walk. Bone scintigraphy is one of the alternative modalities for detecting OFNF but is disadvantaged by a time lag of 72 h to obtain a positive signal, the invasiveness of using radiation, and a high cost.[7–9] When a diagnosis of a fracture is overlooked at the initial visit and proper treatment is not performed, the displacement caused at the fracture site can progress. An obvious femoral neck fracture requires a bipolar hip arthroplasty (BHA), which is highly invasive, and adversely affects postoperative outcomes.[10]

A fat pad sign is mostly used for the diagnosis of occult fractures

Abbreviations: MRI, magnetic resonance imaging; OFNF, occult femoral neck fracture; CT, computed tomography; BHA, bipolar hip arthroplasty; US, ultrasonography; UJS, ultrasonographic joint swelling; STIR, short TI inversion recovery; ROC, Receiver operating characteristic ROC; NPV, negative predictive value; PPV, positive predictive value.

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in other regions, which is indicated by joint swelling on plain radiographs. Chiang et al. reported previously that an elevation of a fat pad >1.5 mm (sensitivity 0.87, specificity 0.86) on an initial radiograph is a useful diagnostic indicator for OFNF.[2] Notably however, radiographic methods of imaging and evaluation are complicated procedures and are not suitable for routine clinical assessments.

Ultrasonography (US) has recently become a new diagnostic and therapeutic modality in the field of orthopedics.[11,12] The advantages of US are that it is non-invasive, involves no radiation exposure, is inexpensive, and is convenient. There are also no contraindications for its use. US of the hip joint is mainly used in the diagnosis of pediatric diseases.[13] One of the typical US findings in cases of hip arthritis is joint swelling with synovial fluid. Femoral neck fractures are an intra-articular fracture in which a subperiosteal hematoma enlarges the capsule. Therefore, UJS is a suspicious finding for OFNF. Prior studies have reported that the normal value for an ultrasonographic joint swelling (UJS), which is a measure of the ultrasonographic distance between the anterior aspect of the femoral neck and the anterior joint capsule, is approximately 6 mm.[13] The utility of UJS in the diagnosis of OFNF is not well known however.

The purpose of our present study was to investigate the diagnostic accuracy of ultrasonography for OFNF in patients confirmed with this condition by magnetic resonance imaging (MRI), and compare these results with other clinical findings.

2. Methods

2.1. Eligibility

A retrospective single-center study was performed on patients over 70 years old with acute hip pain who had been admitted to our hospital between April 2014 and March 2020. The clinical charts of these cases were reviewed and any patients with high energy trauma or fever were excluded. Patients with rheumatoid arthritis, pyogenic arthritis, excess alcohol consumption, and steroid use were also excluded. Symptoms of groin pain with the following 3 findings were judged as hip pain in this population: tenderness of the Scarpa triangle, groin pain during weight bearing, and groin pain when moving the hip joint. Any patients without abnormal findings on a plain hip joint radiograph underwent US scan at the initial visit, and MRI scans within 24 h of admission.

2.2. Definitive diagnosis of an occult femoral neck fracture

A definitive diagnosis of OFNF was made from an MRI scan of the femoral neck when a low intensity fracture line was evident on a T1-weighted image and a high intensity change was found on a T2-weighted or STIR (short TI inversion recovery) image (Fig. 1). Our included study patients were thereby stratified into OFNF and non-OFNF groups based on MRI.

2.3. Ultrasonography of the hip

All of the enrolled patients underwent ultrasonography conducted by an orthopedic surgeon who co-authored this study. A high-resolution linear probe from a Sonimage HS1 device (Konica Minolta, Inc., Tokyo, Japan) was used. The following examination procedures were applied: 1) the patients lay on a bed in the supine position; 2) the probe was placed in a longitudinal orientation along the femoral neck longitudinal axis so that the femoral head and neck aligned in a single plane; and 3) ultrasonographic joint swelling (UJS), i.e. the ultrasonographic distance between the anterior aspect of the femoral neck and the anterior joint capsule, was measured according to the method of Kallio et al (Fig. 2).[13]

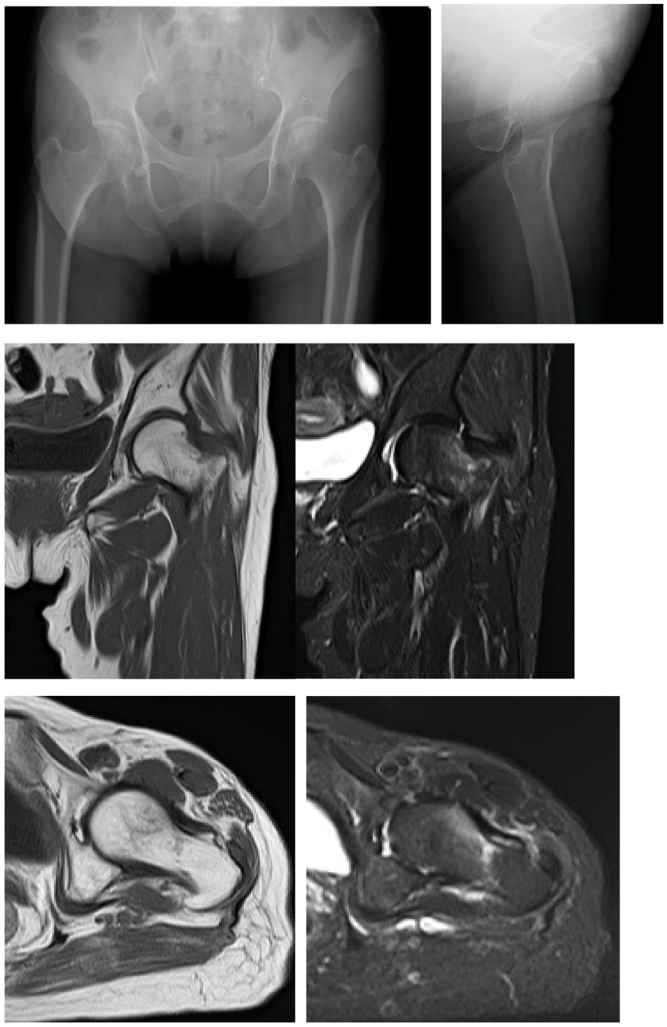

Fig. 1. Radiography and MRI in the femoral neck occult fracture.

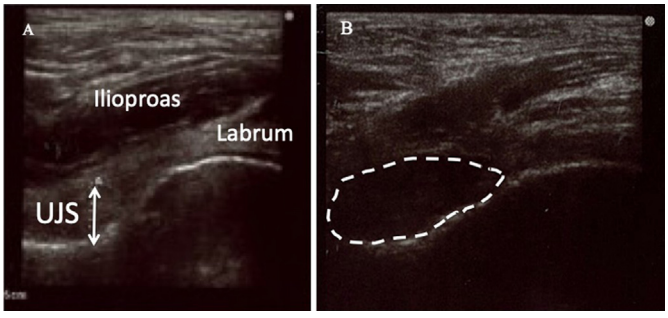

Fig. 2. Ultrasonography findings of femoral neck
Typical ultrasonographic findings (femoral neck longituidal view)
Ultrasonographic distance between the anterior aspect of the femoral neck and the internal aspect of the anterior joint capsule was measured (A). In case of a femoral neck occult fracture, echo free space (broken line) push forward the joint capsule (B).

2.4. Statistical analysis

All measurements were parametric. Statistical differences between the study groups were evaluated using a Student's *t*-test with a *P* value of 0.05 or less indicating significance. Receiver operating characteristic (ROC) curves were plotted for the UJS

Table 1
Characteristics and diagnosis of the enrolled patients.

Age, mean (SD)	81.8 (6.0)
Female, n (%)	83 (88.3)
Definitive diagnosis, n (%)	
femoral neck fracture	27 (28.7)
femoral trochanteric fracture	7 (7.4)
pubic and ischial fracture	18 (19.1)
acute hip arthritis (aseptic)	15 (16.0)
greater trochanteric bursitis	4 (4.3)
impairment of sacroiliac joint	13 (13.8)
adductor muscle injury	5 (5.3)
inguinal hernia	4 (4.3)
obturator hernia	1 (1.1)

Values are expressed as the number of the patients (percentage) or mean (SD).

measurements and their cut-off value for the diagnosis of OFNF was analyzed. The diagnostic accuracy of the UJS data and the patient's clinical symptoms were evaluated using two-way contingency table analysis and the Fisher's exact test. SPSS for Windows version 17.0 software (SPSS, Chicago, IL) was used for all statistical analyses. A post hoc power analysis was conducted using G*Power ver. 3.1.9.5 software (University of Kiel, Kiel, Germany). The statistical power was 0.97 (n1 = 26, n2 = 67, d = 0.8, sig. level = 0.05) indicating that this study was not underpowered.

2.5. Ethical standards

All patients provided written informed consent prior to their inclusion in this study. This research has been approved the IRB of the authors' affiliated institutions, and the analyses were performed in accordance with ethical standards set by this Committee.

3. Results

Ninety-four patients, 11 men and 83 women with a mean age of 81.8 ± 6.0 years, were enrolled in the current study cohort. 27 of these patients were assigned to the OFNF group (1 man, 26 women) and 67 cases to the non-OFNF group (10 men, 57 women). In the non- OFNF group, 18 patients were diagnosed with pubic and ischial fracture, 15 with acute hip arthritis (aseptic arthritis), 13 with impairment of the sacroiliac joint, 7 with trochanteric fracture, 5 with adductor muscle injury, 4 with inguinal hernia, 4 with greater trochanteric bursitis, and 1 patient with obturator hernia (Table 1).

The mean UJS was 7.53 ± 1.52 mm and 3.45 ± 0.89 mm in the OFNF and non-OFNF group, respectively (Table 2) which was a significant difference ($p = 0.006$, 95% CI, 3.58–4.59). A UJS cut-off value of 5.3 mm showed a sensitivity of 0.96 (0.89–0.96) and a specificity of 0.98 (0.92–1.00). The diagnostic accuracy of these clinical findings is presented in Table 3. The clinical findings made by an orthopedic surgeon showed predominantly false-positives Whereas the negative predictive value (NPV) was high for both US and clinical findings, the positive predictive value (PPV) was higher for the UJS than the clinical findings.

4. Discussion

The most important finding of this study was that the diagnosis accuracy of US for OFNF is equivalent to that of MRI. A delay in the diagnosis and treatment of OFNF may increase the risk of morbidity and mortality.[10] Thus, a rapid and accurate diagnosis is needed. In our current study series however, the clinical findings made by an orthopedic surgeon showed predominantly false-positives which may lead to unnecessary additional MRI scans. Not many hospitals in Japan can conduct an immediate MRI test however. It was thus desirable to find a way to minimize the number of required MRI scans.

US can quantitatively evaluate ultrasonographic joint swelling (UJS) as echo free space. Sada et al. have reported a UJS in Indian adults of 6.3 (SD 1.1) mm, which did not correlate with age, gender, height or weight.[14] Koski et al. have reported a mean US distance between the hip joint capsule and femur of 5.1 (SD 0.7) mm.[15] Various studies on the diagnostic accuracy of US examination for fractures have also been reported but the results have differed depending on the study design. Safran et al. reported a sensitivity and specificity of US for posttraumatic hip pain without initial radiographic findings of 1.00 and 0.65, respectively.[16] On the other hand, Akimoto and colleagues have described a sensitivity and specificity of a pocket-size US device for emergency outpatients with acute hip pain of 0.62 and 0.77, respectively.[17] However, their results were thought to be due to a patient selection bias. The former study targeted posttraumatic hip pain patients, the latter

Table 2
Demographics and ultrasonographic joint swelling measurements between the OFNF and non-OFNF groups.

	OFNF group (n = 27)	Non-OFNF group (n = 67)	*p*
Age, mean (SD)	82.2 (5.3)	80.9 (4.4)	0.876
Female, n (%)	26 (96.2)	57 (85.1)	0.132
Body weight, mean (SD)	53.2 (9.8)	56.4 (10.4)	0.533
Ultrasonographic joint swelling, mean (SD)	7.53 (1.53)	3.45 (0.89)	0.006

Values are expressed as number of the patients or as a mean ± SD. $p < 0.05$.
OFNF: occult femoral neck fracture.

Table 3
Diagnostic accuracy of ultrasonography for OFNF and clinical findings in the study patients with this condition.

US & clinical findings	Sn (95% CI)	Sp (95% CI)	PPV (95% CI)	NPV (95% CI)
UJS	0.96 (0.89–0.96)	0.98 (0.92–0.99)	0.97 (0.92–0.98)	0.99 (0.95–0.99)
tenderness on the Scarpa triangle	0.85 (0.70–0.94)	0.75 (0.69–0.78)	0.56 (0.46–0.62)	0.93 (0.86–0.97)
pain during active straight leg raising	0.85 (0.70–0.94)	0.79 (0.73–0.82)	0.62 (0.52–0.68)	0.93 (0.86–0.97)
axial loading pain	0.82 (0.69–0.89)	0.94 (0.89–0.97)	0.85 (0.71–0.93)	0.93 (0.88–0.96)
rotation pain	0.93 (0.79–0.98)	0.73 (0.68–0.75)	0.58 (0.50–0.62)	0.96 (0.89–0.99)
pain during weight bearing	0.89 (0.75–0.96)	0.84 (0.78–0.86)	0.69 (0.58–0.74)	0.94 (0.89–0.98)

US: ultrasonography, UJS: ultrasonographic joint swelling, Sn: Sensitivity, Sp: Specificity, PPV: positive predictive value, NPV: negative predictive value.

targeted hip pain patients with or without trauma. Moreover, the latter study investigated the diagnostic accuracy of US performed by physicians, and the differences in the pre-test probability yielded different results.

Our present findings indicated a higher diagnostic accuracy than the aforementioned studies. Notably in this regard however, we used a high resolution US device only and our patient selection was based on clinical diagnoses from an experienced orthopedic surgeon (HS). Proper medical interviews and clinical findings are effective in ruling out acute arthritis or osteonecrosis. Cases showing clear acute arthritis (e.g. pyogenic or pseudogout) with fever and an increased inflammatory response were excluded from our current analyses. The higher pre-test probability in our current investigation than in past reports led to a high PPV and NPV. It is difficult to distinguish between femoral proximal fractures and acute hip arthritis by US alone however. The utility and value of US is in providing diagnostic assistance in a suspected case of OFNF before deciding to conduct an MRI scan.

There were several limitations of our study of note. First, this was a retrospective study with a small number of subjects. It will be necessary to conduct prospective studies in the future. Second, there is a learning curve in relation to expertise with the US modality and it has a lower inter- and intra-rater reliability than MRI. Although the examiner in this study is well-trained in US, inter- and intra-rater reliability measurements should be included in future comparisons. Third, there is a possibility of a diagnostic suspicion bias and future examinations will need to be conducted in a blind manner.

5. Conclusion

US could contribute to an initial bed-side screening examination for OFNF in patients over 70 years with acute hip pain. This may reduce the number of MRI scans needed to diagnose this condition, resulting in an earlier diagnosis and treatment.

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Ethical standards

Approval was also obtained from the Omori Municipal Hospital Ethics Committee (No 2020−00001).

Declaration of competing interest

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors declare no competing interests in relation to this study.

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