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FULL PAPER

The validity of investigating occult hip fractures using multidetector CT

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Objective: 10% of all hip fractures are occult on plain radiography, requiring further investigation to ascertain the diagnosis. MRI is presently the gold standard investigation, but frequently has disadvantages of time delay, resulting in increased hospital stay and mortality. Our aim was to establish whether multidetector CT (MDCT) is an appropriate first-line investigation of occult femoral neck (NOF) fractures.

Methods: From 2013, we elected to use MDCT as the first-line investigation in patients believed to have an NOF fracture with negative plain films. These were reported by consultant musculoskeletal radiologists. We retrospectively analysed the data of consecutive patients presenting to the University Hospital of Wales, over 30 months with a clinical suspicion of a hip fracture.

Results: 1443 patients were admitted during the study period. 209 (14.5%) patients had negative plain films requiring further investigation to exclude an NOF fracture, of which 199 patients had a CT. 93 patients had no fracture and 20 patients had isolated greater trochanter fractures. None of these patients progressed to develop an intracapsular femoral neck fracture at 4-month follow-up, although one patient sustained an extracapsular fracture following a high-energy fall whilst admitted. 26 femoral neck fractures were diagnosed on CT, whilst the remaining 60 patients were diagnosed with other pelvic ring fractures.

Conclusion: When interpreted by experienced radiologists, MDCT has both sensitivity and specificity of 100%.

Advances in knowledge: We recommend the use of MDCT as a safe and appropriate first-line investigation for NOF fractures.

INTRODUCTION

There are currently 70–75,000 cases of proximal femoral (hip) fractures occurring annually within the UK, particularly in elderly patients (average age of females: 83 years and males: 84 years).¹ This costs the National Health Service £2 billion and 1.1 million inpatient bed days annually.¹ It is predicted the incidence will rise to 101,000 cases by 2020.²

Early surgical intervention (within 48 h of admission) in these patients has been shown to reduce hospital stay and mortality.^{3,4} First-line radiological investigation for hip fractures is plain film radiography (anteroposterior pelvis and lateral hip view), which has a sensitivity of 90–98%.⁵ Those which are not visible on initial radiographs but have a clinical suspicion of a hip fracture are termed occult hip fractures and require further imaging to determine the diagnosis.^{4,6–9}

MRI scan has been considered the “gold standard” investigation for occult hip fractures owing to 99% sensitivity.^{4,6–9} There has

been uncertainty about the role of CT with isolated reports of its lower sensitivity and high misdiagnosis rate (66%) compared with MRI.^{6,10}

MRI has disadvantages including time delay to diagnosis (mean time of 2.4 days), unavailability outside normal working hours and is contraindicated in patients with pacemakers and some metallic implants.¹¹ These delays result in increasing hospital stay and mortality.

The National Institute for Health and Care Excellence guidelines and the Guideline Development Group recommend MRI as the first line of investigation for occult hip fractures. Where this is contraindicated or unavailable within 24 h, a CT may be performed.¹ This is also reflective of the American College of Radiology appropriateness criteria.¹² The National Institute for Health and Care Excellence have recommended research into the clinical and cost-effectiveness of use of CT, as opposed to

Figure 1. Flow diagram: patients admitted with hip pain. GT, greater trochanter; IC, intracapsular; IT, intertrochanteric; NOF, femoral neck.

MRI, as this would have “considerable implications” on current practice.¹

With the development of technology and advancement of spiral and multidetector CT (MDCT), there have been reports of MDCT being a reasonable modality in the investigation of occult hip fractures.^{13,14}

At our institution, CT has been the first-choice investigation for occult hip fractures since January 2013.

MRI is used as a second-line investigation, if the clinical suspicion of a hip fracture remains, despite a negative CT scan.

The primary aim of this study was to establish whether CT is an appropriate first-line investigation for early diagnosis of occult femoral neck (NOF) fractures by establishing its sensitivity and specificity.

METHODS AND MATERIALS

In January 2013, we introduced a change of protocol, which made MDCT the first-line investigation for occult hip fractures with negative plain films. We analysed the data on all consecutive patients, aged 65 years and over, presenting to the University Hospital of Wales (Cardiff), over 30 months between 1 January 2013 and 30 June 2015, with a clinical suspicion of a hip fracture. We excluded patients who inadvertently had MRI as a first-line investigation.

Patients with hip pain following trauma who were unable to weight bear or straight leg raise underwent anteroposterior pelvis and lateral hip X-rays. Further imaging, MDCT, was requested if these initial radiographs were negative or inconclusive and there remained a clinical suspicion of a hip fracture. Patients with ongoing suspicion of occult fracture despite a negative CT could proceed to MRI if it was clinically indicated (Figure 1).

Patients found to have either no fracture or fractures managed conservatively were followed up for a minimum of 4 months, following presentation by review of their subsequent hospital and primary-care records.

CT examination was performed using a GE Lightspeed VCT 64-slice scanner, located within the emergency department (ED) and radiology department at the University Hospital of Wales.

Non-contrast pelvic CT scans were obtained with 0.625-mm contiguous slices with 40-mm collimation, and a pitch of 0.516:1. 2.5-mm-thick sagittal and coronal reformatted images with 2.5-mm interspacing were performed. The field of view included the whole bony pelvis from the iliac crest down to below the lesser trochanters.

Table 1. MRI parameters used

MRI parameter	T_1	STIR coronal
TE	Minimum	40
TR	400	3300
Inversion time	Not applicable	150
Echo train length	Not applicable	8
Bandwidth	31.25	15.63
Field of view	32	32
Slice thickness	5	5
Slice spacing	1	1
Frequency	256	256
Phase	192	160
NEX	2	2
Scan time (min)	5.20	6.56

NEX, number of excitations; STIR, short-tau inversion recovery; TE, echo time; TR, repetition time.

All images were reviewed on a GE Advantage workstation with proprietary software, allowing for interactive review of the data.

MRI examination was performed on a GE 1.5-T Echospeed MR. A three-plane localizer and T_1 and short-tau inversion recovery (STIR) coronal images of the whole pelvis were performed. The parameters are listed in [Table 1](#).

All examinations (CT and MRI) were reported by one of the consultant radiologists with a special interest in musculoskeletal (MSK) radiology. If the investigation was performed outside working hours, these were initially reported by the on-call radiology registrar before being reviewed in the morning by a MSK radiologist.

All imaging were reviewed by the senior author (KL), confirming the accuracy of diagnosis.

RESULTS

1443 patients presented with a clinical suspicion of fractured NOF over the 30-month period. 1234 patients had a definite hip fracture on their admission plain radiographs. 209 (14.5%) patients required a further investigation to exclude an occult NOF fracture.

199 of 209 patients fulfilled the study inclusion criteria, having a CT scan as their first-line investigation ([Table 2](#)). 10 patients who had MRI inadvertently as their first investigation were excluded from the study.

The cohort of 199 patients was comprised of 63 males and 136 females, with a median age of 85 years and a range of 65–100 years. CT diagnosed 26 (13.1%) NOF fractures (20 intracapsular and 6 extracapsular fractures), which were managed operatively. Of these CT diagnosed NOF fractures, one had an

MRI prior to surgery to confirm an atypical insufficiency intracapsular NOF fracture, which was also diagnosed on CT.

93 (46.7%) patients had no fracture on CT. 92 of these patients did not progress to develop a fractured NOF at the minimum 4-month follow-up. One patient did, however, have another separate high-energy fall two nights following the CT and in doing so, sustained a three-part intertrochanteric fracture on the same side that was previously investigated as a possible fracture. Three patients from this cohort had subsequent MRI as a second line of investigation. These three MRIs demonstrated no fractures ([Table 3](#)).

58 (29.1%) patients had various other pelvic ring fractures, as illustrated in [Table 1](#). None of these patients progressed to develop a fractured NOF.

22 (11.1%) patients had a greater trochanter fracture. Of these patients, two patients had complete intertrochanteric extension apparent on CT and were operated upon. The remaining 20 cases were isolated greater trochanter fractures and were treated conservatively. None of these 20 patients had progressed to develop a complete intertrochanteric NOF fracture at the time of follow-up.

From this study, the sensitivity and specificity of MDCT for occult hip fractures are 100% and 100%, respectively.

60 of the 199 CT scans were initially reported by the on-call radiology registrar. In one case, the registrar was uncertain about the significance of the findings and did not issue a definitive report. A review by the MSK radiologist the following day confirmed the findings of an impacted intracapsular NOF fracture. In all other cases, the reviewing MSK radiologists concurred with the preliminary report.

MRI was performed for 14 patients ([Table 3](#)). In 10 cases, MRI was performed inadvertently outside of protocol as first-line

Table 2. Breakdown of the results from CT scans

Diagnosis	Number	MRI following MDCT
No fracture	93	3
IC NOF fracture	20	1
EC NOF fracture	6	0
Isolated GT fracture	20	0
GT fracture with intertrochanteric extension	2	0
Pubic rami fracture	24	0
Acetabular fracture	7	0
Ilium fracture	1	0
Sacral fracture	5	0
Multiple diagnosis ^a	21	0
Total	199	4

EC, extracapsular; GT, greater trochanter; IC, intracapsular; MDCT, multidetector CT; NOF, occult femoral neck.

^aMultiple diagnosis: combinations of pubic rami, ilium, pubis, sacral and acetabular fractures only.

Table 3. Breakdown of the results from MRI scans

Diagnosis	Post-CT MRI	Primary investigation MRI (excluded from study)
No fracture	3	6
IC NOF fracture	1 ^a	0
EC NOF fracture	0	0
GT fracture	0	1
Acetabular fracture	0	1
Multiple diagnosis ^b	0	2
Total	4	10

EC, extracapsular; GT, greater trochanter; IC, intracapsular; NOF, occult femoral neck.

^aDenotes an insufficiency IC NOF fracture seen on CT.

^bMultiple diagnosis breakdown: one pubic rami, acetabulum and ilium fractures, one pubic rami and sacral fractures.

investigation instead of MDCT, resulting in their exclusion from the study.

One patient had a CT followed by a MRI, as he appeared to have unusual presentation of an insufficiency NOF fracture. The MRI was performed to confirm these CT findings along with excluding other pathological lesions. Three other patients underwent MRI following a negative CT owing to ongoing clinical concern about a possible fracture.

67.3% of the patients had their CT within 24 h of the time of the initial pelvic radiographs, whilst for 40.2% of all patients CT was performed within 12 h. This compares with only 30% of patients having MRI within 24 h of their plain radiographs (Table 4).

DISCUSSION

Elderly patients with undisplaced fractures of the hip may have negative or equivocal plain films at presentation and require further imaging for diagnosis. MRI has been accepted as the goal standard. Earlier surgery within 48 h is associated with lower overall morbidity and mortality, and if MRI is not available within 24 h or is contraindicated, CT should be considered.¹ In our hospital, as in many others, CT is more readily available than MRI and is tolerated better by patients.¹³ We therefore elected to prospectively use CT as the first-line investigation in elderly patients with plain-film negative, clinically suspected, femoral neck fractures using clinical outcome and follow-up to determine the sensitivity and specificity. MRI would be performed, if there was continued clinical concern or diagnostic uncertainty despite CT. In our study, the sensitivity and specificity of MDCT for occult hip fractures was 100% and 100%, respectively, which we believe is attributable to the improved accuracy of current MDCT, using thinner axial slices (0.625 mm *vs* 1.25–5 mm) and is reliable in ruling out a hip fracture requiring surgical intervention.¹⁴

The Guideline Development Group is currently overseeing the development of guidelines for the management of hip fractures in adults and recently recommended research into the clinical and cost-effectiveness of CT compared with MRI in confirming or excluding a fracture.¹ Their evidence update in March 2013 includes a systematic review by Chatha *et al*¹⁵ (2011). 15 prospective studies and 7 retrospective studies from 1989 to 2009 were included in this review.

One of these studies by Lubrovsky *et al*, which compared MRI with CT to investigate occult hip fractures, reported that CT has

a misdiagnosis rate of 66%.⁶ The small sample size from this study limits the validity of their results (only 13 cases were included, of which only six cases were investigated by CT). They found that 4/6 CT scans were wrongly reported and all were related to greater trochanter fractures, which after MRI upgraded to either a sub-capital fracture (one case) or “intertrochanteric” (three cases). The illustrated images they used to justify upgrading from greater trochanter to intertrochanteric fracture do not support this, and in our study, this case would have been managed conservatively. The sensitivity of MRI to marrow oedema has the potential to result in misinterpretation or overtreatment of the abnormalities identified. Incomplete intertrochanteric fractures are not part of the Association for Osteosynthesis/Association for the Study of Internal Fixation (AO/ASIF) classification and are a MRI-specific diagnosis.¹⁶ There is no historical evidence that these occult fractures progress to complete fractures and therefore can be treated conservatively.¹⁷ The literature shows that the management of these incomplete fractures should be conservative, as there is no difference in the length of hospital stay and mobility at discharge, suggesting that this is a stable fracture pattern.^{11,17,18} Conservative management also avoids unnecessarily exposing this elderly group of patients to the risks and potential complications of surgery and anaesthetic. This is supported in our study by the 20 isolated greater trochanter fractures identified on CT that were managed conservatively. None progressed to complete intertrochanteric fracture on mobilization or suffered adverse sequelae.

A study by Cabarrus *et al*¹⁰ which found that MRI was more sensitive than CT (99% *vs* 53%) in detecting insufficiency fractures. However, slice thickness in this study ranged from 1.25–7 mm, and in 39 of 64 cases, the slice thickness was >5 mm. Previous studies in the literature comparing CT with MRI have used variable axial thickness, ranging from 1.25 mm to 3 mm.^{5,6,14}

Hakkarinen *et al*⁵ also investigated the performance of CT and MRI for occult fractures. They found that CT missed 2% when compared with MRI. CT missed four fractures, of which three fractures were operated on (two femoral neck fractures and one intertrochanteric fracture), with the remaining case treated conservatively (acetabular fracture). However, this retrospective study relates to both hip and pelvis CT investigations undertaken between 2007 and 2009. They used variable axial slice thickness, 1.25-mm slices for hip CT and 2.5 mm for pelvis CT. By using these thicker slices, the fracture could potentially have been missed as opposed to being a truly occult NOF fracture on CT. In addition, the illustrated case demonstrates an incomplete intertrochanteric fracture, that we would manage conservatively, which is supported by the literature.¹⁷

A retrospective review by Dunker *et al*,¹⁴ published in 2012, compared the clinical utility of CT in evaluating occult hip fractures in the elderly after low-energy trauma. They had 95% sensitivity and no false-positive hip fracture diagnosis. In their review, the primary axial data had not been archived and were not available for review.

The study by Gill *et al*¹³ whereby CT was used, when MRI was either contraindicated or had an expected wait greater than 24 h, found that a modern MDCT did not miss femoral neck fractures.

Table 4. Waiting times for primary CT and MRI from time of pelvic radiographs

Waiting time (hours)	CT (%)	MRI (%)
0–12	80 (40.2)	1 (10)
12–24	54 (27.1)	2 (20)
24–48	19 (9.5)	1 (10)
>48	46 (23.1)	6 (60)

Henes et al compared the diagnostic accuracy of MDCT against MRI in patients with known pelvic ring fractures on plain radiographs. They found that MRI had a sensitivity of 98.6% compared with 66.1% for CT in detecting pelvic ring fractures, in particular sacral fractures.¹⁹ However, additional fracture findings on MR did not lead to any therapeutic operative consequence in these patients. The one unstable pelvic ring fracture was identified on both CT and MR. They did not identify any NOF fractures on MDCT or MRI. They concluded that in elderly patients with suspicion of a sacral fracture and negative MDCT, MRI may be considered as the next step in the diagnostic work-up if clinically indicated. This conclusion supports the use of MDCT as the first-line investigation in the evaluation of patients over the age of 65 years, with a clinical diagnosis of a possible occult NOF fracture.

CT does have the disadvantage of having to irradiate a patient; however, as this investigation is usually performed in the elderly, this risk can be weighed against its multiple advantages. It is a quick and safe investigation, which is easily accessible in most EDs, unlike MRI. Both total scan and actual scan times are shorter for CT than for MRI. A CT scan takes only a few minutes to perform. The majority of time is spent transferring an immobile patient, often in pain, who may also not be compliant, to and from the scanner. By limiting the number of sequences performed, the actual MRI scan time can be reduced to 15 min, but it still takes longer to perform.^{20,21} This still does not reduce the possibility of movement artefact in patients who are restless, anxious or in pain.

Patient compliance with the CT scan is greater, as the total scan time is considerably less than that for MRI, ensuring adequate comfort for the duration of the investigation and reducing the risk of motion artefact. A quicker diagnosis by means of CT results in less time confined in a bed waiting for an investigation. In turn, this results in quicker initiation of conservative or surgical treatment. This reduces hospital cost owing to shorter inpatient stay, with an associated lower mortality.^{3,4}

Further advancement in CT has been described with the advent of dual-energy CT scan that is able to detect bone-marrow oedema in patients, with a possible NOF fracture.²² We, however, feel that this method of CT investigation may result in misinterpretation of bone-marrow oedema to represent incomplete intertrochanteric fractures, as encountered with MRI. This would result in both overdiagnosis and overtreatment of these injuries, which this study and other studies have shown should be managed conservatively.¹⁷

Most importantly, we feel that our study demonstrates that CT is an appropriate first-line investigation for occult proximal femoral fractures. No patients were adversely affected by having CT instead of MRI, as nobody from the “no-fracture” group progressed to develop a NOF fracture at 4 months. The one fracture that did occur was due to separate independent, high-energy trauma that occurred post CT, resulting in a three-part intertrochanteric femoral neck fracture.

This study also includes a subcohort of 20 patients with a CT diagnosis of isolated greater trochanter or incomplete intertrochanteric fractures, none of which progressed to a complete fracture, confirming what other studies have concluded that these fractures have a stable configuration and can be managed conservatively.^{17,18}

Patients found to have either no fracture or fractures managed conservatively were followed up for a minimum of 4 months following presentation, by review of their subsequent hospital and primary-care records to confirm the sensitivity of the examination.

The waiting times of CT were considerably less than those of MRI, with 67.3% of patients undergoing CT within 24 h compared with 30.0% of patients having MRI within 24 h of their previous plain radiograph. This facilitates the desired early surgical intervention within 48 h, when required.

In addition, this protocol does not have to be serviced by specialist MSK radiologists, as proven by the on-call radiology registrars (generalists), who issued preliminary reports on 60 CT performed out of hours. In 59 cases, the reviewing MSK radiologist agreed with the registrar report. In one case, there was uncertainty about the significance of the findings and a definitive report stating a fracture was not issued until it was reviewed by the MSK radiologist.

In our tertiary hospital, MRI services are in great demand and our prolonged waiting time is similar to that reported by Sankey et al.¹¹ We do, however, recognize that in some other centres, investigating occult femoral fractures by MRI may be prioritized urgently and that waiting times may be considerably less.

With MDCT of 0.625-mm axial slice thickness, as used in this study, located in the ED, it is feasible to incorporate a CT pelvis into the algorithm of the investigation of patients with clinical suspicion of NOF fracture with negative plain films, again improving the time to diagnosis, so that management and rehabilitation can begin as quickly as possible.

The aim of this study was to assess the safety, efficacy and clinical outcomes of using MDCT as the first-line investigation in patients with negative plain films with the end point being either a diagnosis or exclusion of a proximal femur fracture. It was not the intention to directly compare the sensitivity of both modalities against each other. Ultimately, no patient represented with a femoral neck or pelvic ring fracture, who had been cleared with a CT scan.

CONCLUSION

From our experiences, over a 30-month period at a busy university tertiary hospital, MDCT with slice thickness of 0.625 mm, can be recommended as an appropriate first-line investigation for occult NOF fractures. It is a practical, quick, cost-effective and patient-friendly investigation, which is easily accessible in most hospitals. In the diagnosis of proximal femoral fractures and pelvic fractures, the findings of MDCT are reliable with both sensitivity and specificity of 100%.

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