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Justifying CT prior to MRI in cases of suspected occult hip fracture. A proposed diagnostic protocol

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ABSTRACT

Introduction: Patients with clinical suspicion of hip fracture, but negative radiographs are suspected of having an occult hip fracture (OHF). Different diagnostic modalities are available for investigating OHF and various protocols have been suggested. MRI has the highest sensitivity and specificity, however availability is limited in many institutes. CT is readily accessible in the large majority of hospitals throughout the world but has lower sensitivity and may miss some fractures. In this article we investigate a protocol that balances these issues providing a practical and cost-effective solution.

Methods: During a four-year period between 2012 and 2016 a strict diagnostic protocol was followed at our Medical Center for patients suspected of OHF. This MRI selective protocol consisted of CT initially being performed and only when negative for fracture, followed by an MRI. Retrospective analysis of all patients who followed the protocol was performed. The patients were divided into two groups: those diagnosed by CT alone and those diagnosed by MRI after having a negative CT scan. Diagnostic performance, time to diagnosis and the cost of this protocol were evaluated.

Results: 103 patients were treated under the protocol. In 50 patients (49%) hip fracture was diagnosed by CT alone. In the remaining 53 patients (51%) no definitive diagnosis was reached by CT and MRI was subsequently performed. 12 of these 53 patients (23%) were diagnosed with hip fracture necessitating surgery. In the CT only group mean time from admission to diagnosis was 3 hours, in the CT + MRI group this rose to 40 hours. Cost analysis showed that this protocol was more cost-effective than performing MRI in all patients, saving an estimated 66,805 Euro during the study period.

Conclusion: The clinical challenge of diagnosing OHF can be minimised by implementing a diagnostic protocol. The protocol should take into consideration the diagnostic sensitivity, availability and cost of different imaging modalities. An MRI selective strategy with initial CT scanning is recommended, as it reduces time to diagnosis and lowers overall costs.

Introduction

A patient with a clinical suspicion of hip fracture and negative radiograph is a common challenge that the orthopaedic surgeon and the emergency physician face. These fractures are referred to as occult hip fractures (OHF). The incidence of hip fractures is increasing partly due to a larger geriatric population, OHF accounts for 2-10 % [1–5] out of all hip fractures, making this diagnostic challenge a common one. A missed OHF may have a devastating outcome, especially in cases where a non-displaced intracapsular fracture of the neck of femur (NOF) becomes displaced, necessitating a larger surgery than otherwise (partial or total hip replacement instead of in situ fixation) with higher mortality rates [6,7]. Therefore, timely diagnosis of these fractures is vital.

Whilst the superiority of magnetic resonance imaging (MRI), is well established in diagnosing OHF due to its high sensitivity and specificity [1,8–11] the relatively high cost and low availability dictate that other imaging modalities are utilized including ultrasound (US), computed tomography (CT) and skeletal scintigraphy (bone scan). US and bone scan are of low sensitivity, with US requiring a

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skilled operator [12], and bone scan is only diagnostic after several days [13]. Due to these factors MRI is the recommended diagnostic modality according to most guidelines and protocols [14–17]. However, in many health care systems, due to lower availability, MRI is still not the first-line examination [18]. We retrospectively investigated a diagnostic protocol for diagnosing OHF at our institution, whereby a CT scan was conducted initially and only if negative for fracture, would an MRI be performed. The justification for conducting a CT prior to MRI was examined in terms of; time to diagnosis, costs involved and the impact on treatment modality.

Patients and Methods

Between January 2012 and July 2016, a strict diagnostic protocol was followed in our medical centre for patients with suspicion of OHF. In this study we retrospectively analysed medical records of 103 patients who, due to a suspected OHF, underwent either CT only (CT study group) or CT+MRI (CT+MRI study group). Ethical approval for this study was obtained from institutional review board. All the patients had an initial, diagnostically negative radiograph. Inclusion criteria were 1. any patient undergoing surgery for hip fracture where no clear fracture had been identified on radiograph, but were instead diagnosed by CT or MRI; 2. any patient who underwent both CT and MRI examinations due to suspicion of OHF, but received an alternate or no diagnosis. Excluded from our analysis were patients for whom CT or MRI were contraindicated or not recommended like pregnant women, patients with specific cardiac pacemaker or metal implants. Patients under 18 years of age were excluded, as CT was felt to be inappropriate due to ionizing radiation. Patients who complained of having chronic pain or those who had no history of trauma were also excluded. Data regarding demographics, diagnosis, time from admission to diagnosis, and cost of the work-up were recorded. Comparison of these factors was performed for patients with positive CT versus those who required CT+ MRI to establish their diagnosis.

Diagnostic Protocol

All patients were examined by an orthopaedic resident or a senior orthopaedic surgeon. Suspicion for fracture was defined as persistent hip pain following trauma with inability to fully weight bear. Additionally pain on attempted straight leg raise, passive rotation, or axial loading raised suspicion of fracture. Patients underwent antero-posterior pelvis and lateral hip radiographs which were interpreted by the initial examiner as negative or inconclusive. Where the initial radiographs were of inadequate quality, additional plain films were performed with the leg in internal rotation and centred on the femoral head. In cases where no diagnosis consistent with the clinical symptoms could be made based on the initial radiograph, a CT scan was then performed and evaluated together with a senior orthopaedic surgeon. In cases where no diagnosis could be made based on the CT scan, an MRI was conducted. Images were reviewed on PACS (picture archiving and communication system) by a senior orthopaedic surgeon and the MRI examinations were evaluated by both a senior musculoskeletal radiologist and a senior orthopaedic surgeon. The CT examinations were conducted using one of two multi-slice helical scanners (Siemens SOMATOM Definition Flash, Force Siemens Healthcare, Erlangen, Germany). A CT protocol was developed for these pelvic examinations in order to reduce radiation exposure. The protocol included a tube voltage of 120kV and 100-190 effective mAs. Data reconstruction was performed by bone filter in axial, sagittal and coronal plane of 1 mm thickness with soft tissue filter of 2 mm thickness. CT dose index (CTDIvol) in mGy was estimated for each CT examination automatically by the scanner. Data regarding CTDIvol was randomly collected from ten cohort patients and the mean and standard deviation (SD) was calculated. The MRI examinations were conducted by using T1 weighted spin echo + STIR (Short Tau Inversion Recovery) axial and coronal scans, using a 3T or 1.5T scanner (Siemnes MAGNETOM Aera or Skyra, Siemens Healthcare, Erlangen, Germany)

Compared parameters and statistical analysis

Analysis of the CT versus the CT+MRI study groups was conducted with regards to demographic data, diagnosis, time from admission to diagnosis and the cost of work-up. The time to diagnosis was defined as the time from admission to the time the diagnostic tests were performed. Two factors were considered when calculating the cost of work-up: the cost of the relevant diagnostic modalities and the length of admission. This cost evaluation was analysed by the financial department of our hospital. The Statistical Package for the Social Science SPSS v20 (SPSS Inc., Chicago, IL, USA) was used to analyze the study's data. The Chi-square test or Fisher's exact test (two tailed version) were used to analyze the categorical variables. The Student T-test or Non-parametric tests, where applicable, were used for continuous variables.

Results

Between January 2012 and July 2016, 1,498 patients were operated on in our medical centre due to hip fractures. 1436/1498 (96%) of these patients were diagnosed by radiograph. During this period 103 patients were suspected of having hip fractures, without confirmed fractures on radiograph. 36 patients were male and 67 were female with a mean age of 78.4 years (range 22-103). Of these patients, 50/103 (49%) were diagnosed with hip fracture by CT scan and were subsequently operated on. In 53/103 (51%) no diagnosis could be determined by CT, therefore an MRI was performed. Out of the 53 patients who underwent both CT and MRI, 12/53 (23%) were diagnosed with hip fracture which required surgical treatment; the other 41/53 (67%) patients had non-surgical diagnoses. A comparison regarding age, gender and fracture type between the two study groups (CT versus CT+MRI) is shown in Table 1. Subgroups comparison of gender and age between CT and CT+ MRI is shown in Table 2a and 2b. A flow chart of the diagnostic protocol and results are shown in Fig. 1.

The patients who required an MRI scan to reach a conclusive diagnosis were significantly younger ($P=0.01$). 74% (46/62) of diagnosed fractures were intracapsular fractures. All patients diagnosed with intracapsular fracture were treated by fixation with cannulated screws, except for 5 patients from the CT group which were treated by hip hemiarthroplasty. These patients had inconclusive radiographs due to morbid obesity or dysmorphic femoral head and CT scan demonstrated a displaced fracture in these cases. There was no statistical difference in the distribution of fracture types (intracapsular vs pertrochanteric) between the two study groups (see Table 1).

Incomplete pertrochanteric fractures were identified in 6/53 (11%) of the patients in the CT+MRI group. In these fractures the fracture line did not reach the medial cortex and non-operative treatment was recommended. At 6 months follow up no displacement was noted. Other fractures and soft tissue injuries diagnosed in 50/53 (94%) of the CT+MRI group are shown in Table 3. Three patients had no diagnostic explanation on CT or MRI for their symptoms and were treated by physiotherapy. No diagnosis was identified in these patients throughout their hospitalization. Time from admission to diagnosis was median of 3 hours for the CT group and 40 hours in CT+MRI group (see Table 4).

For the cost analysis our financial department estimated the real costs sustained by the hospital. The estimated cost of a CT scan was 150 EUR and 450 EUR for an MRI exam. The use of this

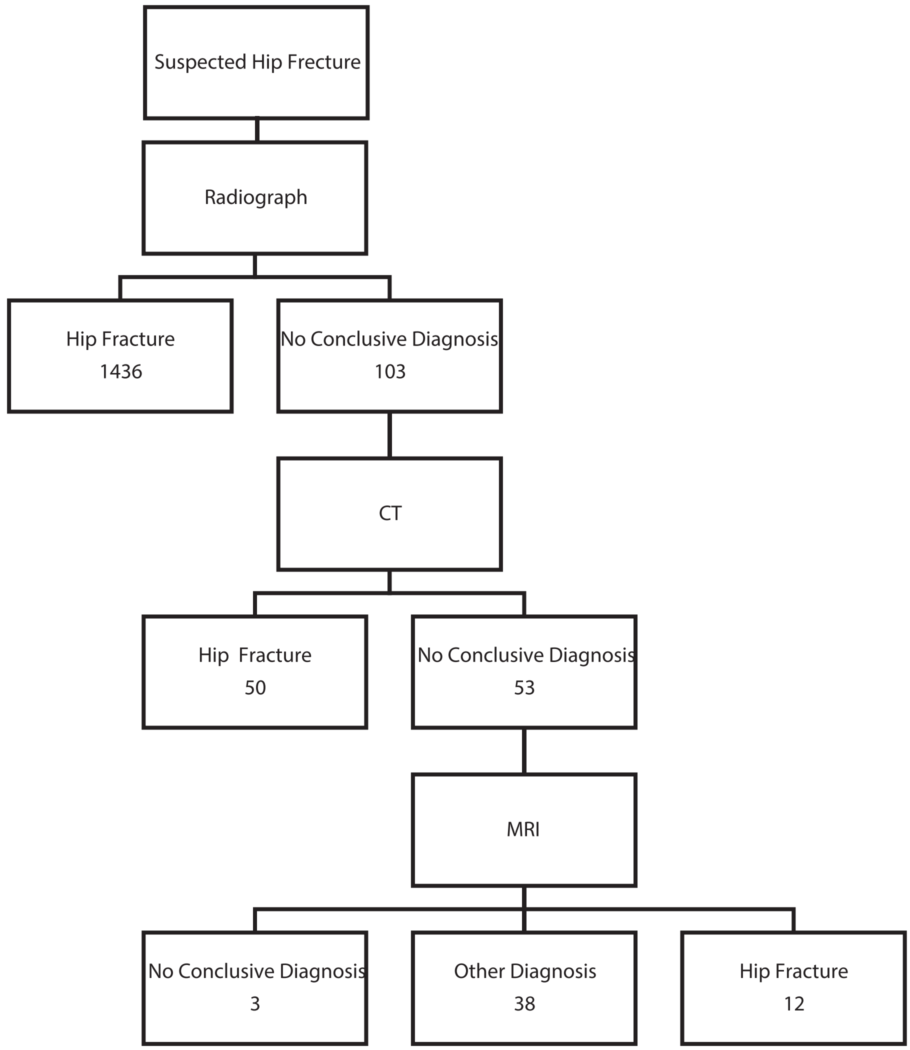

Fig. 1. A flow chart and summary of our study's protocol.

Table 1
Demographic distribution and type of hip fractures.

		CT	CT+MRI	Overall/Sum	P -Value
Age, Years, Median (IQR)		81.7 (77-90)	75.2 (68-84)		<0.01
Gender number of patients (%)	Male	15 (30%)	21 (40%)	36 (35%)	NS (0.31)
	Female	35 (70%)	32 (60%)	67 (65%)	
Type of Hip Fracture number of patients/ patients in the group (%)	Pertrochanteric fracture	11/50 (22%)	5/12 (42%)	16/62 (26%)	NS (0.27)
	Intra- capsular fracture	39/50 (78%)	7/12 (58%)	46/62 (74%)	

Table 2a
Age and Gender in the different diagnostic modalities subgroups- Female.

	Female CT	Female CT+MRI	P- value
Number of Patients	35	32	
Age in years, Median (IQR)	87 (78-90)	79 (50-83)	0.045

Table 2b
Age and Gender in the different diagnostic modalities subgroups- Male.

	Male CT	Male CT+MRI	P- value
Number of Patients	35	32	
Age in years, Median (IQR)	87 (78-90)	79 (50-83)	1

diagnostic protocol during the study period avoided the use of MRI scans on 50 patients with suspected OHF, thus saving the hospital a total of 7,050 EUR. This calculation included deducting the cost of CT scans, which were performed in both the CT and CT+ MRI study groups. When calculating hospitalization time costs in the two groups, we calculated 40 hours median to perform MRI and 3 hours for CT. The additional time to diagnosis in the CT+MRI group was therefore 37 hours. The estimated cost of admission in our hospital is 775 EUR per day (32.3 EUR per hour). This meant that by reducing hospitalization time by 37 hours in the CT group an additional saving of 59,755 EUR was achieved. The total saving during the study period was 66,805 EUR.

Table 3
Fractures and soft tissue injuries diagnosed in the CT+MRI group.

Hip fracture	12
Pubic rami fracture	8
Incomplete Hip fracture	6
Non-specific edema	6
Greater trochanter fracture	4
Iliopsoas muscle contusion	4
Gluteal muscle contusion	3
Normal exam	3
Increased intra-articular fluid	2
Tensor fascia lata muscle contusion	2
Rectus femoris muscle contusion	2
Adductor muscle contusion	1
Obturator internus muscle contusion	1
Acetabular fracture	1

Table 4
Time from admission to diagnosis (in hours).

	Patients	Median (IQR) time in hours
CT+MRI	50	40 (22-51)
CT	53	3 (2-5)

Evaluation of radiation exposure (CTDIvol) was estimated for each CT examination automatically by the scanner, mean radiation dose estimation of random ten cohort patients was 7.51 mGy (SD 1.77).

Discussion

Most protocols advise using MRI as a first line modality for diagnosis of OHF [14,16,17] due to its superior sensitivity and specificity. CT however is recommended where there is contraindication to MRI, or where MRI is not available. Protocols exist that advise CT in place of MRI, for example in cases of high energy truma and low risk of osteoporosis [19], but there is no evidence base for such recommendations - no retrospective or other analysis of these protocols was found in our literature search. Indeed both the NCGC (National Clinical Guidelines Centre) [20] and AAOS (American Association of Orthopaedic Surgery) [14] recommend further investigation in their latest guidelines.

In our study, the time from admission to diagnosis in the CT group was found to be 3 hours, compared to 40 hours in the CT+MRI group. The availability of MRI and CT differs widely around the world, but in most hospitals, especially within the Emergency Room setting, CT is much more accessible than MRI [14,21]. A faster diagnosis relieves the psychological stress that uncertainty places upon patients and their carers. More importantly reduced time to surgery is clinically advantageous [22,23]. Quicker diagnosis normally leads to a shorter admission and potentially lower complication rates [24], both of which affect the financial impact of fracture.

The majority of the patients (41 out of 62) who were operated on had non-displaced intracapsular NOF fractures and were treated by fixation with cannulated screws. As already mentioned, these fractures can have a devastating outcome if undiagnosed, due to the likelihood of becoming displaced and requiring arthroplasty, a surgical procedure with higher mortality and morbidity rates as compared to fixation with cannulated screws [7]. This finding emphasizes the importance of having a strict diagnostic protocol in order to avoid the misdiagnosis of these patients.

Hip fracture was the most common diagnosis made by MRI, followed by soft tissue trauma, especially muscle contusion (see Table 3). The non-surgical diagnoses have clinical importance, as decisions regarding weight bearing and treatment strategy could be taken. Only three of the 103 patients (2.9%) who were suspected of having an OHF remained without a diagnosis that could explain their clinical signs.

The quality of CT imaging continues to improve and new technologies, such as dual energy bone marrow enhancing protocol, promise further advances in the near future [32,33]. Some authors claim no significant clinical difference between MRI and CT in OHF due to these factors [25]. Despite this, in our study MRI detected 12 hip fractures requiring surgical intervention that were not detected by CT. This demonstrates the need to perform additional imaging where CT is negative in cases of suspected OHF.

The patients in the CT group were found to be older than those in the CT+MRI Group (81.7 vs 75.2) (see Table 1). Analysis of the CT and CT+MRI groups included gender and age subgroups as listed in Table 2. Comparison of these subgroups revealed that older female patients were most likely to be diagnosed by CT (see Table 2a). There were no other significant findings.

Evaluating cost benefit remains challenging due to its multifactorial nature. Cost analysis was limited to the cost of diagnostic tests and their corresponding length of admission. We showed that this diagnostic protocol was more economical than MRI as a first line examination in all patients. Taking into consideration other factors such as a shorter stay in the emergency room, faster diagnosis and likely reduced complication rates [23], the financial benefits become more evident.

Yun et al. [26] reached a different conclusion when addressing the financial aspects of diagnostic modalities in OHF. They conducted a decision analytical model and compared different theoretical diagnostic strategies, concluding that MRI was more cost effective that CT+MRI or plain radiograph alone. Several factors can account for the different conclusions reached in their paper. Their calculation was performed by calculating the theoretical cost benefit for only one patient. Additionally the costs included in their calculation were Medicare reimbursement rates rather than actual costs incurred by the hospital. The prolonged hospital stay due to lower availability of MRI was not addressed and MRI to CT cost ratio was less than 50 per cent, whereas in our hospital MRI was three times more expensive than CT.

To our knowledge this is the first retrospective cost analysis performed. The results validate the protocol utilised during the study period within the context specific to our healthcare system. Differences in cost and availability of MRI exist between different institutions and countries [21] and must be taken into account when considering the results of this study. This constitutes one of the limitations of our study.

It must be stressed that obtaining high quality radiographs is the first step in the diagnostic imaging pathway and efforts should be made to ensure this prior to more advanced imaging studies. In our protocol standard AP and lateral radiographs of the hip were initially obtained. In cases where the initial radiographs were of inadequate quality, additional plain films were performed with the leg in internal rotation and centred on the femoral head. This was not however performed routinely prior to CT if the initial radiographs were felt to be of adequate quality. This may constitute a limitation of this study.

An additional limitation of this study is that patients were examined by several different clinicians, although we feel that defined and consistent parameters for diagnosis of OHF mitigated this.

An obvious disadvantage of all patients with suspected OHF undergoing CT is the radiation exposure. We utilized a low radiation protocol as described and the mean CTDIvol for ten random cohort patients was only 7.51 $\pm$1.77 mGy - lower than previously reported (CTDIvol 23.34 $\pm$ 9.83) [27]. This emphasizes the importance of implementing a low dose CT protocol. OHF is an emergent situation and rapid diagnosis is important. We believe that the benefit of early diagnosis justifies the radiation exposure that CT necessitates, in institutes were MRI is not as accessible as CT. This justification cannot be extended to pregnant and skeletally immature patients, therefore they were excluded from our imaging protocol.

This study contributes to the dilemma of choosing a diagnostic modality in suspected OHF. Our recommendations of MRI selective strategy with initial CT scanning supports other publications with similar recommendations [28-31]. Although our study investigated one of the largest groups of patients with suspected OHF that has been analysed to date, it is still a relatively small group, especially when the patients were divided into subgroups for statistical analysis. Prospective multicentre studies are still needed to confirm our finding.

Conclusion

The clinical challenge of diagnosing OHF can be minimised by following a diagnostic protocol. The protocol should take into consideration the diagnostic sensitivity, availability and cost of different imaging modalities. An MRI selective strategy with initial CT scanning is recommended, as it reduces time to diagnosis and lowers overall costs.

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