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Significance of Lumbar MRI in Diagnosis of Sacral Insufficiency Fracture

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Abstract

Study Design: Retrospective observational study.

Objective: The aim of the present study was to evaluate the role of lumbar magnetic resonance imaging (MRI) in the diagnostic algorithm of sacral insufficiency fractures (SIF). The primary objective was to compare the sensitivity in fracture detection and correct fracture classification according to MRI and computed tomography (CT). The secondary objective was to identify differences of additional pathologies found in MRI of the lumbar spine and the pelvis and their rates.

Methods: A total of 943 patients (from 2010 to 2017) with fracture of the pelvic ring were screened. All patients without high-energy trauma and radiologic diagnostics consisting of X-ray, CT, and MRI of the pelvis or the lumbar spine including the sacrum were included. Differences in fracture detection and description in the various radiologic procedures were evaluated. Detection rates of additional pathologies in MRI of the pelvis and lumbar spine were recorded.

Results: A total of 77 subjects were included. The sensitivities for SIF were 14% in X-ray and 88% in CT, and all fractures were detected in MRI. MRI showed a more complex fracture pattern compared with CT in 65% of the cases. Additional pathologies were seen in MRI of the lumbar spine (51%) and that of the pelvis (18%).

Conclusions: We suggest performing MRI of the lumbar spine including the sacrum with coronal STIR (short tau inversion recovery) sequence for elderly patients with suddenly increasing low back pain at an early stage. This procedure might improve fracture detection, classification, and recognition of concomitant pathologies.

Keywords

sacrum, insufficiency fracture, MRI, CT

Introduction

Per definition, insufficiency fractures occur as a result of physiological stress on a weakened bony structure. The most common underlying reason is osteoporosis.[1] The typical patient for a sacral insufficiency fracture (SIF) is an elderly female patient without an individual history of trauma.[2] Patient-reported symptoms can range from mild nonspecific lower back pain to immobilizing pain. There are no specific symptoms for insufficiency fracture of the sacrum, and the symptoms can mimic those of other lumbar spine pathologies,[3] often leading to late or missed diagnosis.[4] Appropriate treatment should aim at reducing pain, enabling early mobilization of the patient, and avoiding secondary morbidity. Delayed diagnosis can lead to further immobilization and results in complications such as deep vein thrombosis, pulmonary or cardiac complications, depression, and increased bone resorption.[5] Therefore, early diagnosis helps optimize the treatment outcome.[6] In acute traumatic fractures of the pelvis, a clear diagnostic algorithm with computed tomography (CT) as a gold standard exists. However, for SIF, there is no such standard defined.

Sacral insufficiency fractures are often occult in X-ray, with a sensitivity of only 5% to 35%.[7] However, even CT can fail in fracture detection if overlying cortical bone is intact or if microfractures cannot be sufficiently visualized.[8] In recent

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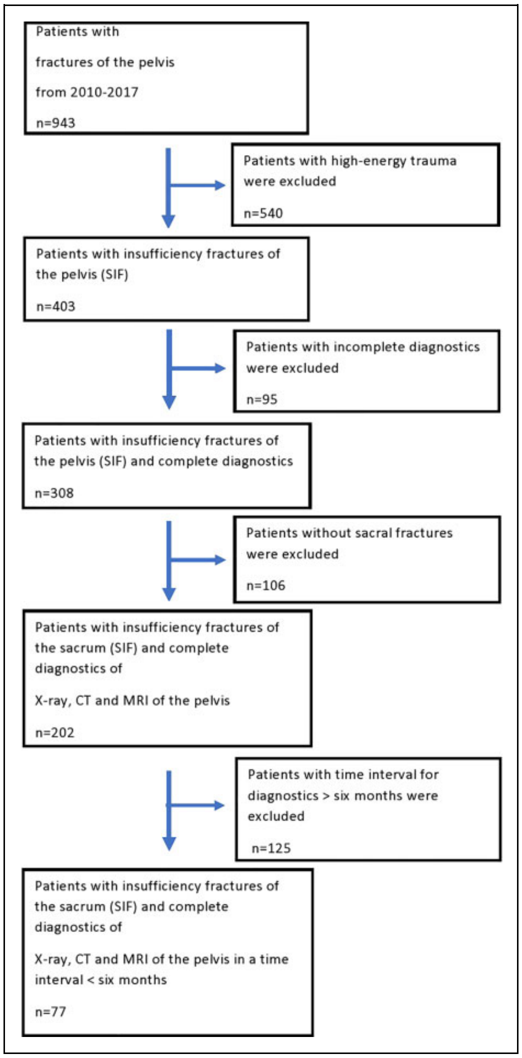

Figure 1. STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) flowchart of the patient selection process.

studies of Henes et al[8] and Cabarrus et al,[9] magnetic resonance imaging (MRI) was the superior diagnostic tool for occult SIF. Therefore, especially in patients with clinical symptoms of an SIF but with negative findings in X-ray and CT, an additional MRI may be beneficial. Additionally, MRI may be more specific for the detection of sacral insufficiency fractures, but it is not yet clear which MRI sequences/planes (eg, coronal vs sagittal short tau inversion recovery [STIR] sequences) and focus (pelvis or lumbar spine) are the best for correct identification and classification of SIF as well as for recognition of secondary pathologies.[10]

Therefore, the primary objective of this study was to compare sensitivity in fracture detection and correct fracture classification according to MRI and CT. The secondary objective was to identify the rate of additional pathologies found in MRI of the pelvis and MRI of the lumbar spine that might have an influence on the treatment strategy and that are possibly missed by employing CT diagnostics only.

Methods

The study was approved by the local ethics committee.

All patients who were admitted with pelvic fracture to the Trauma or Orthopedics Department of the University Hospital between January 2010 and December 2017 were screened for insufficiency fractures of the sacrum. Therefore, all medical charts were screened for the diagnosis “fracture of the pelvis” by International Classification of Diseases Version 10–German Version (ICD-10 S32.1-5, S32.7, S32.81-83, S32.89, S33.2-4). Out of these patients, those were selected with a fracture of the sacrum by screening the discharge letters. Furthermore, patients with sacrum fracture because of an adequate trauma (high-energy trauma), suspected bone metastasis, osteomyelitis, and myelodysplastic syndrome were excluded. Patients with a documented low-energy trauma, such as falling from a sitting position, or no trauma history were included. Finally, all 3 radiological diagnostic modalities, X-ray, CT of the pelvis, and MRI of the pelvis or MRI of the lumbar spine with sacrum instead of that of the pelvis, had to be performed for inclusion. The radiologic workup had to be done within 6 months after the beginning of symptoms (Figure 1).

X-ray, CT, and MRI were reanalyzed by an experienced spine surgeon and a radiologist trained in musculoskeletal radiology. Image analysis was performed blinded and independently by both observers and separately regarding the modality to avoid an intermodality and interobserver bias. In cases of conflicting results, judgment was made following a conference of both observers. The following quality criteria had to be present in the radiological images, and the following data was registered.

Standard X-ray of the pelvis had to be performed in anteroposterior projection. Iliac crest and both femoral heads had to be visible. X-rays were assessed regarding signs of fracture and other pathologies such as degenerative changes, former fractures or total hip arthroplasty (THA).

CT of the pelvis had to be performed with 120 kVp and a slice thickness of 2 to 5 mm. Images were assessed regarding signs of fracture.

MRIs had to include T2 turbo spin echo (TSE) sagittal, T1 TSE sagittal, T2 TSE STIR, and T2 TSE transversal protocols (Gyroview Philips 1.0 tesla). Images were assessed regarding signs of fracture, such as a linear structure in either STIR, T1-weighted, or fat-saturated T2-weighted sequences and edema in the STIR sequence. In addition, further pathologies, such as vertebral body fractures or narrowing of the neuroforamina or spinal canal, were noted.

All fractures were analyzed regarding their fracture pattern by means of the presence of different components: (1) vertical unilateral fractures, (2) vertical bilateral fractures, and (3) horizontal fractures. Detection rates for each fracture component were compared between MRI and CT. Additionally, the fractures were classified according to the FFP (fragility fracture of the pelvis) classification published by Rommens et al.[11] Fractures of the iliac wing were not considered in this study.

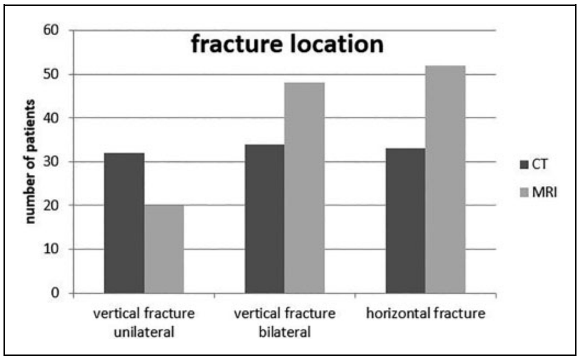

Figure 2. Distribution of the fracture location findings comparing computed tomography (CT) with magnetic resonance imaging (MRI): from left to right: vertical unilateral fractures (32 vs 20 patients; $P = .027$), vertical bilateral fractures (34 vs 48 patients; $P = .007$), and horizontal fractures (33 vs 52 patients; $P < .001$).

Differences in fracture detection rate and location between the various radiologic procedures were compared. For a more detailed comparison of the difference in fracture detection, the number or fracture components detected were compared between CT and MRI. Additionally, FFP classification was compared between MRI and CT.

To compare the results between MRI of the pelvis and that of the lumbar spine, 2 subgroups were created: the first with MRI of the pelvis and the second with MRI of the lumbar spine including the sacrum.

A positive fracture detection in at least one of the available imaging modalities (X-ray, CT, and MRI) was used to define a reference for the calculation of the detection rates of each modality.[9]

Statistical analysis was performed using SPSS V24.0 (IBM Corp). Basic descriptive statistics were used. Means and standard deviations (SDs) were calculated for continuous variables. Sensitivities were calculated as the percentage of patients correctly identified as having a fracture by at least 1 of the 3 techniques. For comparison between the groups, the 2-tailed, 2-sided Student's t test for continuous variables and the chi-square test and Fisher's exact test for categoric variables were used. The significance level was set to $P < .05$. The sensitivities of CT and MRI were compared using a paired proportion test (McNemar test).

The study was approved by the local ethics committee.

Results

A total of 943 patients with a pelvic fracture were admitted to our hospital between January 2010 and December 2017. Based on the exclusion criteria, 77 (63 females, 14 males; 8% of all patients with pelvic fracture) subjects could be included in the analysis. The average age was 76.2 years (range 46-90 years). Six of the patients had a history of posterior instrumentation of the lumbar spine.

Sensitivity

The sensitivities to detect insufficiency fractures of the sacrum were 14% (11/77) in X-ray, 88% (68/77) in CT, and 100% in MRI using a positive fracture screening in at least one of the imaging modalities (X-ray, CT, and MRI) as a reference. In 9 patients (12%), there were no fracture signs in CT, but MRI showed an edema in the sacral ala. Five fractures (3%) detected in CT could be classified as not acute by missing fracture edema in MRI.

Fracture Pattern Detection Rates

A total of 182 fracture components were detected in the 77 cases (2.4 fractures per patient, range 1-3) and could be compared between CT and MRI. Overall, 74% (134/182) of the single fracture components were detected in CT, and 92% (167/182) of the single fracture components were detected in MRI. The MRIs in which the 15 fracture components (8%) were missed were performed without coronal STIR sequence of the lumbar spine. MRI (McNemar test $P < .01$) showed a significantly increased sensitivity of the MRI for fracture detection compared with CT. MRI showed higher detection rates in both vertical and horizontal fracture components. Comparing the different fracture localizations and presentations in CT and MRI, the following distribution was seen: 48 fracture components (26%) were missed in CT but could be detected in MRI. (1) Vertical unilateral fractures were seen in 41% (32 patients) in CT and 26% (20 patients) in MRI ($P = .027$) and (2) vertical bilateral fractures were seen in 44% (34 patients) versus 62% (48 patients) ($P = .007$), respectively. A horizontal fracture (3) was seen in 43% (33 patients) using CT versus 68% (52 patients) using MRI ($P < .001$) (Figure 2).

Classification of Fractures

According to the classification of Rommens, 42% (32/77) were FFP II, 4% (3/77) FFP III, and 38% (29/77) FFP IV in CT imaging and 38% (29/77) were FFP II, 7% (5/77) FFP III, and 56% (43/77) FFP IV in MRI imaging. While FFP II was more frequently detected in CT, FFP III and FFP IV were found more frequently in MRI. A shift from unilateral vertical fractures or missed fractures in CT to bilateral vertical fractures or H-type fractures in MRI could be observed. Only considering the fractures FFP II-III in CT, a more complex fracture pattern was seen in 65% of MRIs ($P = .11$) (Figure 3).

Additional Pathologies

An MRI of the lumbar spine was performed in 39 cases, and an MRI of the pelvis was performed in 38 cases. Additional pathologies in MRI were found in 35% (27/77). By MRI, spinal stenosis was found in 17% of the cases (13/77; 9 in lumbar MRI), and neuroforaminal stenosis was found in 14% of the cases (11/77; 8 in lumbar MRI). In 8% (3/39), an additional fracture of a vertebra (1× L1, 1× L4, and 1× L5) could be found in lumbar MRI. Additional pathological findings were more frequently seen in MRI of the lumbar spine, 51% (20/39), compared with MRI of the pelvis, 18% (7/38) ($P = .003$).

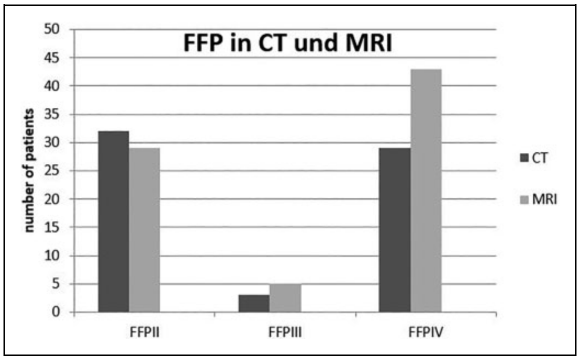

Figure 3. Distribution the number of patients according to the fragility fracture of the pelvis (FFP) classification according to Rommens comparing computed tomography (CT) and magnetic resonance imaging (MRI): FFP II (32 vs 29 patients), FFP III (3 vs 5 patients), and FFP IV (29 vs 43 patients).

Discussion

The objectives of the present study were to compare the sensitivity in fracture detection rate and the ability to correctly classify the fracture pattern between MRI and CT. In addition, the aim of the study was to identify the rates of additional pathologies in MRI of the pelvis and in MRI of the lumbar spine, which might have an influence on the treatment strategy, and which possibly is missed by employing CT diagnostics only. We found a significantly higher sensitivity (100%) in detection of SIF by MRI compared with that by CT (88%). Because of the higher sensitivity, more fracture components were detected in MRI, with 92% (167/182), compared with CT, with 74% (134/182). In 49% (29/77) of the cases, fracture classification had to be upgraded after additional MRI analysis.

The finding of superior sensitivity of MRI compared with CT and X-ray is consistent with the current literature. Cabarrus et al[9] reported in a retrospective study of 67 patients that 75% (50/67) of sacral fractures were detected by CT and 100% (67/67) by MRI. Henes et al[8] showed in a prospective study with a sample size of 38 patients that 58-77% of sacral fractures were detected by CT and 97% to 100% by MRI. The results even remained consistent if the time between symptoms and diagnostics increased since the radiological diagnostics had to be completed within 6 months in the present study, whereas CT and MRI had to be performed within 3 months or 7 days in the previous studies. We chose a 6-month cutoff because of the delayed fracture healing process in patients with insufficiency fractures and the prolonged healing period of SIF of at least several months.[12,13]

Although the MRI clearly has the highest sensitivity for detecting a SIF, in many centers, the diagnostic algorithm for acute and insufficiency fractures of the pelvis usually begins with CT instead of MRI. The diagnostic priorities have been demonstrated to be less clear in insufficiency fractures compared with those in traumatic fractures in a group of 25 experienced pelvic surgeons.[14]

The main reason for this is that CT can be performed quickly, almost nationwide and 24 hours a day, 7 days a week. In CT, the fracture lines are better depicted, it is mandatory for planning surgery, and it is needed for some intraoperative navigation systems. MRI is not always available, and it is associated with higher costs. Moreover, elderly patients have to lie motionless in an uncomfortable position for several minutes.

In addition, the present study demonstrated that MRI not only has higher sensitivity in the detection of sacral fractures but can also lead to an upgrade in fracture classification because of the higher sensitivity for detecting fracture components in fracture pattern analysis. In MRI, a bilateral insufficiency fracture was detected more often than in CT (62% vs 44%), and the horizontal fracture component was more often seen in MRI (68% vs 43%). This is important for planning the surgical treatment because the horizontal fracture component in particular can be a sign of instability. Furthermore, the differentiation between acute and chronic lesions is possible with MRI, and further pathologies can be seen, for example, in the lumbar spine.[10] The (preoperative/pretreatment) knowledge about accompanying pathologies can modify surgical decision making and surgical treatment strategy, such as in cases with additional lumbar fractures. Therefore, an additional preoperative MRI could possibly improve the outcome of the patients. However, in the present study, the outcome of such therapeutic consequences was not examined and has to be part of ongoing studies.[6] Therefore, we strongly recommend performing MRI of the lumbar spine with inclusion of the sacrum and with STIR sequence in a coronal instead of a sagittal plane. Regarding this, fracture components had only not been found in MRI (8%) if the STIR sequence was not performed in a coronal plane. In a further 8% of the patients, an additional vertebral body fracture could be identified by lumbar MRI. These findings are in agreement with those of Hatgis et al,[15] who found that 13% of patients with vertebral body fractures had concomitant sacral fractures. Patients suffering from a non-traumatic vertebral compression fracture have the same risk pattern as those with SIF: osteoporosis, advanced age, history of carcinoma, previous radiation therapy, or corticosteroid use.[12,16-18] Therefore, concomitant lumbar fractures will be missed when performing MRI and CT of the pelvis only. In addition to fractures, further pathologies such as spinal stenosis and neuroforaminal stenosis can also remain unrecognized but can affect the surgical strategy. In the present study, as many as 51% (20/39) of the patients showed such changes. At which level this also changed the treatment decision or strategy remains unclear (such as extension of the stabilization to the lumbar spine, other surgical procedures such as kyphoplasty, or surgery decision making). Our recommendation to perform lumbar MRI goes along with the recent literature that favors MRI as the modality of choice for early diagnostics of sacral insufficiency fractures.[10,19] Nevertheless, preoperative CT is strongly recommended for planning surgery, especially defining fracture lines, and it is frequently necessary for intraoperative navigation systems. In our opinion, we prefer the lumbar MRI as a first-line diagnostic. However, due to its availability and costs, CT can still be a possible first-line diagnostic modality, but because of its low sensitivity and the issues discussed, a lumbar MRI should at least be performed if the CT is negative.

Additionally, CT was only performed of the pelvis. Therefore, additional pathologies of the lumbar spine could not be detected with CT. This must not be interpreted as a weakness of the modality itself but as a problem of choosing the optimal region of interest for diagnostics in patients with pelvic pain.

In conclusion and according to the results of the present study, we suggest performing an MRI of the lumbar spine including the sacrum with coronal STIR-sequence for elderly patients with suspected SIF at an early stage. Furthermore, if an insufficiency fracture of the sacrum is diagnosed and surgery is planned, further evaluation by CT of the pelvis is recommended. Following this, SIF will be diagnosed early and correctly classified, and an adequate treatment can be started immediately, with regard for concomitant pathologies.

Author Contributions

All authors contributed toward data analysis, drafting, and revising the paper and all agree to be responsible for all aspects of the work.

Declaration of Conflicting Interests

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