Modified Therapy Concepts for Fragility Fractures of the Pelvis after additional MRI

Isabel Graul (isabel.graul@med.uni-jena.de)
Universitatsklinikum Jena https://orcid.org/0000-0002-8508-1174

Ivan Marintschev
Universitatsklinikum Jena

Carsten Hackenbroch
Universitatsklinikum Ulm

Hans-Georg Palm
Universitatsklinikum Ulm

Benedikt Friemert
Universitatsklinikum Ulm

Patricia Lang
Universitatsklinikum Ulm

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Abstract

Background Fractures of the pelvic ring in elderly patients have increased in frequency over time. These injuries are associated with a high morbidity and have a socio-economic impact. The diagnostic procedures and their influence of therapy decisions are still controversial.

Methods In a retrospective study, we investigate the value of additional MRI examination on therapy decision of fragility fractures of the pelvis. The evaluation of all patients with pelvic fractures without adequate trauma and with performed CT and MRI from 2010 to 2017 was conducted at three large German hospitals. The imaging procedure took place within a maximum interval of 4 weeks. After evaluation of the imaging, the resulting therapeutic consequences either based on CT alone or on CT and MRI were reviewed by experienced pelvic surgeons. Furthermore, a measurement of Hounsfield units as an indicator of reduced bone density was recorded in the L5 vertebra.

Results Of 754 patients with pelvic injuries, 67 (age 80 +/- 9.7 years, f: m 54:13) could be included in the study. The detection of vertical fractures in CT (n = 40 unilateral, n = 11 bilateral) could be increased by the additional MRI (n = 44 unilateral, n = 23 bilateral). A horizontal fracture component was identified in CT in 9.0% (n = 6) vs. MRI in 25.4% (n = 17) of the cases. An anterior pelvic ring injury was detected in 71.6% (n = 44; 4x bilateral) in CT, in 80.6% in MRI (n = 50, 4 bilateral). Additive MRI imaging increased the decision rate for surgical therapy from 20.9% (n = 14) to 31.3% (n = 21). In 90.0% of the patients (n = 60) a reduced bone density in the L5 vertebra was measured.

Conclusions The results of this study further support the value of bone marrow detection by MRI diagnostics (or dual source CT which showed promising initial results) for the detection of pelvic ring fractures. For the first time, the study identifies an additional therapeutic consequence by an increased rate of surgical procedures.

Background

Due to the demographic development of an ageing population, the number of pelvic fractures in the elderly is increasing[1–3]. Through improved diagnostic possibilities, so-called insufficiency fractures of the pelvic ring (Fragility Fractures of the Pelvis, FFP) are diagnosed in patients without adequate or memorable trauma. The Availability of different diagnostic decision algorithms and associated therapies are often a challenge for the treating physician.

Risk factors for insufficiency fractures of the pelvic ring

The cause of an insufficiency fracture of the pelvis is usually a disturbed bone strength and biology in the sense of osteoporosis[4–6].Physiological bone resorption occurs in the course of aging. Main risk factors are age[1–3] and female gender[1–3], in addition to rheumatoid arthritis with corticosteroid therapy[7], condition after radiotherapy[8], bone metabolic diseases, long-term immobilization, vitamin D deficiency[9], nicotine abuse, organ transplantation and diabetes mellitus type 1[9].

Epidemiology

A large Finnish cohort study showed an incidence of osteoporotic pelvic fractures of 25 per 100,0000 inhabitants per year. 94% of all pelvic fractures occured in patients over 60 years of age and were due to osteoporosis[3]. The average cumulative risk of suffering FFP at 65 to 90 years of age was twice as high in women (6.9%) as in men (2.8%)[10]. Predictions for the year 2030 suggested an increase by 200%[11]. In the evaluations of the Pelvic Injury Register of the German Trauma Society with 13,300 pelvic fractures, a shift in the average age of onset of the disease from 52 years in 2004 to 67 years in 2016 could be seen[12]. In the USA, 7% of osteoporosis-associated fractures were insufficiency fractures of the pelvis over the age of 50; with a share of 5% of the total treatment costs, they have a high socio-economic relevance[13].

Marrinan et al. evaluated 110 conservatively treated patients with FFP and found a 9% mortality rate during inpatient stay[3]. Morris et al. were able to show that 1-year mortality rate was 10% and 5-year mortality rate 50%. This is comparable to the lethality rate of fractures near the hip joint[14]. Similar results could also be shown by Hill et al. with a lethality rate of 7% in hospital and 13.3% after 13 months[4]. 66% of the patients needed FFP aids[15] and 25% lost their independence[3].

Pathophysiology

Pathophysiologically, FFP can be distinguished from pelvic ring fractures of the younger person in adequate trauma (e.g. traffic accident or fall from high altitude) and fatigue fractures ("marching fractures") after unphysiological, repetitive stress[16]. FFP occur in reduced bone quality with reduced elastic resistance to physiological forces; the strong pelvic ligament structures usually remain intact. As a result, Rommens et al. introduced their own classification of these lesions in 2012. It takes the specific morphology of geriatric fractures (FFP types I-IV) [17] (Table 1) into account by means of CT diagnostics. From this, a therapeutic regime can be derived that enables rapid and painless remobilization and reduces immobilization-associated risks (e.g. pneumonia, thromboembolism, skin ulcerations)[18].

Diagnosis

Older patients usually present with a minor trauma that is not remembered or that often occurred weeks ago. The leading symptoms are lumbosacral pain and immobility, but not neurological deficits or concomitant injuries. This requires a certain amount of experience in clinical and radiological diagnostics in order to attach adequate importance to the unspecific clinical picture and to initiate further diagnostics. Conventional x-rays often show no pathological findings or only a fracture of the pubic bone. The sensitivity of X-rays for the detection of a posterior pelvic ring injury is only 15–35%[19]. The need for further imaging (CT, MRT, bone scintigraphy, 18F fluorodeoxyglucose (FDP) positron emission tomography (PET/CT) and, as a new option, dual-energy CT using the so-called virtual non-calcium technique) is derived from this. Possible methods for the representation of FFP are presented in Table 2.

According to WHO, the measurement of bone mineral density (BMD) using Dual Energy X-ray Absorptiometry (DEXA) is the method of choice[20]. Quantitative computed tomography (QTC) is another option, but has lost importance due to radiation exposure. There are already studies that have dealt with the screening of osteoporosis by determining bone density using conventional CT examination ("opportunistic osteoporosis diagnosis")[21].This involves ROI measurement of the Hounsfield Units (HU), within the vertebral spongiosa in a normally configured WK, preferably lumbar. There are already initial results showing a statistically significant correlation between the T-score from the DEXA measurement and the bone density measurement using CT[21]. It is not yet clear whether the HUs recorded in LWK 5, for example, correlate with the severity of the insufficiency fracture.

Study situation on diagnostic recommendations and research questions

In severely injured patients with adequate pelvic trauma, diagnosis is clearly defined by the S3 guideline polytrauma[22]. In contrast, the diagnostic procedure for insufficiency fractures has not yet been conclusively clarified: An equivalent priority of MRT and Dual Energy CT (DECT) is described[12, 23]. In a current study, 25 experts of the Pelvic Injury Register of the German Trauma Society were asked about the significance of the above-mentioned diagnostic procedures for the detection of FFP: On a scale of 1 (= most useful) to 7 (= least useful), the MRT was rated on average 3.0 for suspected insufficiency fractures and 4.0 for follow-up, the DECT came to 2.6 as the initial diagnostic method and 3.6 as the follow-up. The classic CT received the best evaluation with an average of 2.1 in the initial phase and the X-ray with 1.1 as follow-up. It should be mentioned that only 8 of the 25 interviewed experts had the possibility of a DECT examination in their respective institution. MRI, on the other hand, is held in all hospitals, but 40% of it was only available during regular working hours[12].

Nüchtern et al. described in a patient collective (n = 60) a detection rate of the posterior pelvic ring fracture in CT of 71%. This was 99% in the MRI. In the CT examination the posterior pelvic ring fracture was overlooked in 17% (n = 8)[24]. Similar results were shown in the study by Henes et al. (n = 38) with a detection rate of sacral fractures in CT of 66% and in MRI of 99%. These studies included patients with trauma who had an anterior pelvic ring fracture in x-ray[25]. Insufficiency fractures, however, were not included. The study by Pulley et al. retrospectively investigated the frequency of pelvic fractures in patients older than 50 years and low-energy traumas. He found a frequency of 16.7% (n = 19/114). Pulley diagnosed the fractures in CT and an MRI was supplemented only in some cases[26]. Insufficiency fractures were not detected.

As far as the detection of FFP is concerned, there is only one study with two-digit case numbers by Cabarrus et al. which directly compares MRI and CT. Insufficiency fractures of the sacrum were detected in MRI in 100% (n = 67) and in CT in 75% of the cases. In the area of the anterior pelvic ring he showed a detection rate of 100% in MRI and 65.5% in CT. As a result, he recommends MRI as the diagnostic standard[27]. However, a common consensus has not yet been reached.

It is also unclear which diagnostic workflow shall be applied in case of suspicion of an insufficiency fracture of the pelvis.

The aim of our retrospective multicenter study with 67 patients included is therefore to analyse the sequence of the diagnostics performed on patients with suspected FFP and to derive a workflow from this. The main objective is on the one hand to determine whether the additional MRI examination leads to a change in the CT-based FFP classification according to Rommens and on the other hand whether the additional MRI examination entails a modification of the therapy (conservative vs. surgical or change in the surgical procedure).

The Hounsfield units in LWK 5 as an indicator of reduced bone density were recorded as a secondary target.

Patients And Methods

Patients

Three German hospitals participated in the retrospective multicenter study.

Included were 67 patients (80+/-9.7 years, f:m 54:13) of the years 2010 to 2017 who were treated with unremarkable or inadequate trauma and resulting FFP and received both MRI and conventional CT with a maximum interval of 4 weeks to analyze fracture morphology in both imaging techniques (Figure 1). Since bone marrow edema changes persist for a very long time (over weeks) source, a period of 4 weeks was tolerated, whereby we ultimately had an average of 4 days. Ultimately, in the case of insufficiency fractures, newly occurring edema can never be completely ruled out, but this seemed rather unlikely in our patient group (clinical correlation). All patients with FFP and incomplete diagnosis or extended period (>4 weeks) until diagnosis from CT and MRT or with adequate trauma anamnesis such as high energy injury were excluded.

Implementation

Patients with FFP fractures were recorded for a period of seven years via internal clinical databases. In addition, all patients who did not meet the inclusion criteria were excluded. The fractures were classified in CT diagnostics according to the FFP classification of Rommens and Hofmann[18]. In the MRI diagnostics, the bone marrow edema was documented in regions defined by us (Ala, S1 vertebral body, S2 vertebral body, anterior pelvic ring). While CT detects well cortical interruption lines, especially when these are dislocated, cancellous fractures are sometimes very difficult to detect and show up as compression zones. MRI as the best diagnostic tool for the detection of bone marrow edema changes, on the other hand, shows edematous changes at an early stage. The additional detection of compression lines in T1w or T2w sequences also contributes to the detection of fractures in MRI. Especially with insufficiency fractures of the pelvis, extensive bone marrow edema alterations of the os sacrum can be the only image morphological correlate, so that in this study a bone marrow edema in conjunction with the clinic was evaluated as a fracture. Furthermore, a measurement of the Hounsfield units was recorded in LWK 5 as an indicator of reduced bone density[21,28]. Subsequently, the respective data sets were presented to experienced pelvic surgeons (at least 10 years of professional experience with a focus on pelvic fractures) with the question whether and how they would classify the fracture according to FFP and how they would change the therapy decision by the additional information from the MRI examination. The change in therapy was defined as a change from conservative to surgical or in the type of surgical procedure. In addition, patient-specific data such as "age", "sex", "underlying diseases", trauma history and "concomitant injuries" as well as inpatient treatment data such as length of stay and interval between CT and MRI are to be recorded and analysed. The parameters for each patient were listed using the Excel program (Microsoft Office 2016).

CT diagnosis was used as native CT of the pelvis in case of insufficiency fractures. Reconstruction was performed in the bone and soft tissue windows with sagittal and coronary reformations (multiplanar reconstructions (MPR)). Since each clinic uses different CT devices, there is no uniformity, the layer thickness was 1-5 mm. Different scanners were also used for MRI diagnostics, so that there is no uniform standard protocol. Edema expansion was assessed using fluid-sensitive fat-saturated sequences T2w or PDw sequences (Short-Tau Inversion Recovery (STIR)/ Turbo-Inversion Recovery-Magnitude (TIRM), Protone Densitiy weighted (PDw), Fat Saturation (fatsat)) and partially complementary T1w and T2w sequences.

In retrospective data evaluation, patients received an MRI if they complained of pain in the pelvic region, which could not be appropriately explained by CT imaging (no fracture detection and persistent pain). In patients who were seen to have a fracture in CT, MRI diagnosis was only performed if the fracture did not correspond to the symptoms. There are no internal clinical guidelines for the decision on MRI imaging. The procedure depends on the criteria mentioned above.

Statistics

The number of cases resulted from the patients admitted and treated during the period with an insufficiency fracture of the pelvis.

Statistical analysis was performed with SPSS V24.0 (IBM, Armonk, USA). Descriptive statistics were used for the basic variables. For continuous variables mean values and standard deviations (SD) were calculated. Fracture capture rates for CT and MRI were calculated using the previously described reference standard [44]. Sensitivities were computed as a percentage of patients in whom at least one of the three techniques detected a fracture. To compare the groups, the two-sided student t-test for continuous variables and the Chi-square test and Fisher's exact test for categorical variables were used. Results were considered statistically significant if at the corresponding p-value was < 0.05. The significance tests of CT and MRI sensitivities were calculated using the McNemar test.

The study obtained approval by the Ethics Commission of the University of Jena (application number 2019-1380) and Ulm (application number 250/19) as well as registration in the German Register of

Clinical Trials (DRKS; number DRKS00012440). Advice on data protection law has taken place.

Results

A total of 67 out of a total of 754 patients (88.9%) (80+/-9.7 years, f:m 54:13) could be included. The time interval between CT and MRI of the pelvis was on average 4 days (range 1-21). The total hospital stay was 13 +/ -7.4 days. 31.3% (21/67) of the patients underwent surgical treatment. The hospital stay of the surgical group was significantly longer: 18 (+/-6.4) days vs. 10 (+/-6.4) days (p<0.01).

Dividing the underlying diseases into large groups with diseases of the blood vessels, heart, lungs, kidneys, musculoskeletal system (rheumatoid arthritis, chronic lumbar syndrome, etc.), malignancies, osteoporosis and endocrine diseases, resulted in 13% showing no relevant underlying diseases. On average, the patient suffered from 1.8 diseases (range 0-6) (Figure 2). In 31.3% (21/67) of the patients no trauma anamnesis could be recorded, in 698.7% (46/67) a low-energy trauma usually consisted of a trip or fall from a sitting position. In 82.1% (55/67) the pelvic insufficiency fracture was a mono injury. Eleven patients had multiple injuries and showed 13 fractures, 1.2 fractures per patient (range 1-2) sorted by frequency: 6.0% (4/67) vertebral body fractures (1x L2, 1x L2 and L3, 1x T10, L1 and L2 and 1x L3), 4.5% (3/67) rib fractures, 3.0% (2/67) radius fractures, 3.0% (2/67) humeral fractures, 3.0% (2/67) acetabular fractures.

Of the 67 patients, 4.5% (n=3) showed no fracture, 19.4% (n=13) FFP I, 50.7% (n=34) FFP II, 9.0% (n=6) FFP III, and 16.4% (n=11) an FFP IV and in MRI 7.5% (n=5) an FFP I, 52.2% (n=35) an FFP II, 3.0% (n=2) an FFP III and 37.3% (n=25) an FFP IV.

In the CT of the sacrum, 62 vertical fractures have been detected in 67 patients, of which 11 were bilateral fractures. The MRI of the sacrum revealed 90 vertical fractures, 23 of which were bilateral fractures. One transverse component was demarcated in CT in 9.0% (n=6) vs. MRI in 25.4% (n=17) of cases.

The anterior pelvic ring was fractured in CT 71.6% (n=44; 4x bilateral), in MRT 80.6% (n=50, 4x bilateral).

A fracture of the transverse process of LWK 5 was shown in 9.0% (n=6/67) in the radiological images.

In summary, 72.7% (n=120/165) of the pelvic ring fracture components could be detected in the CT of the pelvis compared to the MRI of the pelvis, and all fractures could be detected in the MRI.

19.4% (n=13) of the patients with posterior pelvic ring fractures showed no simultaneous involvement of the anterior pelvic ring in CT or MRI. 36.4% of the sacral fractures showed an additional fracture component (vertical or horizontal fracture) in the MRI compared to the CT examination. (Figure 3).

Based on the classification of Rommens and Hofmann[18], the CT-based distribution shown in Figure 4 was obtained.

The evaluation of the imaging diagnostics by an experienced pelvic surgeon without consideration of the clinical aspects was divided into the decision categories: Operative therapy with stabilization of the sacrum, operative therapy with lumbopelvic stabilization and conservative therapy.

Based on the isolated CT findings, 79.1% (n=53/67) would have been treated with conservative therapy, 20.9% (n=14/67) with surgical stabilization. Surgical stabilization (n=14) was followed in 42.9% (n=6/14) by isolated stabilization of the sacrum and in 57.1% (n=8/14) by lumbopelvic stabilization.

Because of the combined CT and MRT findings 68.7% (n=46/67) were subjected to conservative therapy, 31.3% (n=21) to surgical stabilization. Surgical stabilization consisted of 42.9% (n=9/21) sacral stabilization and 57.1% (n=12/21) lumbopelvic stabilization. (Figure 5)

This increase in knowledge through MRI led to a change in the treatment decision in 10% (n=7/67): In 6 cases, a change was made from conservative to surgical treatment and in one case from isolated stabilization of the sacrum to lumbopelvic stabilization.

The Hounsfield units in LWK 5 were 62.7 +/- 33.7 HU. 10% of the patients showed values > 100 HU and therefore no clear bone density reduction in LWK 5.

A correlation of the Hounsfield units to the individual fracture classes FFP I-IV after Rommens could not be established. FFP IV fractures showed no lower bone density than FFP I, II or III. (Figure 6)

An antiosteoporotic therapy was already taken at least as a basic therapy with calcium and vitamin D in 35.8% (n=24/67). 64.2% (n=43/67) did not receive antiosteoporotic therapy.

Discussion

The aim of the present study was to analyze the diagnostic procedure for 67 insufficiency fractures of the pelvis in a retrospective multicenter design and to derive a possible algorithm for diagnosis and therapy. Furthermore, a possible change of the FFP classification by the MRT diagnosis as well as a resulting change of the therapy should be recorded. The recording of the Hounsfield units in LWK 5 for the assessment of bone density was a secondary objective.

Fracture detection rates were statistically significant superior for MRI as compared to CT (100% MRI; 72.7% CT; p-value <0.05). This led to an appreciation of the fracture classification to more severe injuries and thus to a more frequent decision on the surgical procedure. The surgical procedure was also partially influenced: Based on the therapy recommendations of Rommens et al. [17], lumbopelvic stabilization should be considered for additional transverse fracture components.

The present imaging diagnosis was examined for fracture signs. CT and MRI data were evaluated because of the FFP classification according to Rommens et al. [18].

In the present study, edema in MRI without adequate trauma was evaluated as fracture-associated bone bruise; this represents the histopathological correlate of microfractures of the cancellous bone with bleeding into the fatty bone marrow[29,30]. In the absence of regeneration processes, the fracture becomes radiologically visible after 2-3 weeks in CT[31]. If the overload and the pathological bone metabolism can be eliminated, the development of a fracture can be avoided[32].

The question of the relevance of the additional MRI examination was assessed by investigating a change the therapy (conservative vs. surgical, or changing the surgical procedure) on the basis of findings from imaging diagnostics.

Patients with pain in a region of the pelvis without corresponding fracture detection in CT should be diagnosed by MRI or DECT. The indirect fracture signs of oedema with or without a delimitable fracture line are often visible here. Cabarrus et al. describes this in 7% of their patients[27]. With continued immobility and fracture signs visible in MRI, it remains controversial whether surgical intervention is indicated to avoid immobilization-associated complications[33,34]. The question of a bilateral stabilization of sacrum fractures with only unilateral fractures in CT and additional contralateral edema in MRT to avoid subsequent operations by a contralateral follow-up fracture is also controversial. Based on the therapy recommendations of Rommens et al. [18], vertebropelvine stabilization must be considered for additional transverse fracture components.

Only 10% of the patients showed no clear bone density reduction based on the Hounsfield units in LWK 5. In 90% (n=60/67) a reduced bone density could be measured in LWK 5. Additive bone density measurements (DEXA or QCT) were not available. However, existing studies showed a correlation between reduced Hounsfield units and reduced bone density[24,35]. A correlation of the Hounsfield units with more complex fracture patterns in the sense of a higher classification according to Rommens and Hofmann could not be demonstrated. An osteological diagnosis and possibly antiosteoporotic therapy is indicated in surgical and conservative procedures.

The question of a quantitative regression of oedema without fracture line in MRI with isolated anti-osteoporotic therapy cannot be answered on the basis of the data available.

Limitations

In our multicenter study, FFP fractures were evaluated with CT and MRT. Out of the 754 only 67 have been included. Hence the sample considered by not be representative of the underlying overall population in a clinical practice setting. Different devices were used, so that there was no uniform protocol for retrospective analysis.

The FFP classification is defined by the CT and the presence of edema in the MRT has not yet been taken into account. However, our interpretation of the classification in MRI is based on the proof of edema, so that it is necessary to critically question the disease value of the edema. However, we would like to encourage discussion as to whether it would not make sense to supplement the FFP classification in the sense of modifiers with additional edema detection. This aspect would require further research.

Whether the results of the MRI really only resulted in a change of the therapy regime in 10% (n=7/67) cannot be answered retrospectively, since no documentation was available as to which operative planning was previously available.

In the case of a one-sided fracture of the sacrum, prophylactically stabilizing the opposite side with, for example, transiliosacral fixator internal, "sacral bar" or transiliosacral screw osteosynthesis remains controversial within the participating clinics. An evaluation of the therapy change from one-sided to bilateral stabilization of the sacrum is not possible in this study, but would be desirable for future studies.

Summary And Conclusion

Study results suggest that MRI can detect a significantly higher number of FFPs as compared to conventional CT. In addition, fractures were classified into more severe injuries, which led to a more frequent surgical procedure. The evaluation of bone marrow changes by MRI or Dual Source CT is therefore recommended for early treatment decisions and operative planning.

Declarations

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Statement of Ethics
Ethical approval in accordance with the World Medical Association Declaration of Helsinki was not obtained.

Disclosure Statement

The authors have no conflicts of interest to declare.

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Author Contributions

All authors have taken part in the performing of the study and approved the manuscript and agree with submission

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Tables

Due to technical limitations, tables only available as a download in the supplemental files section

Figures

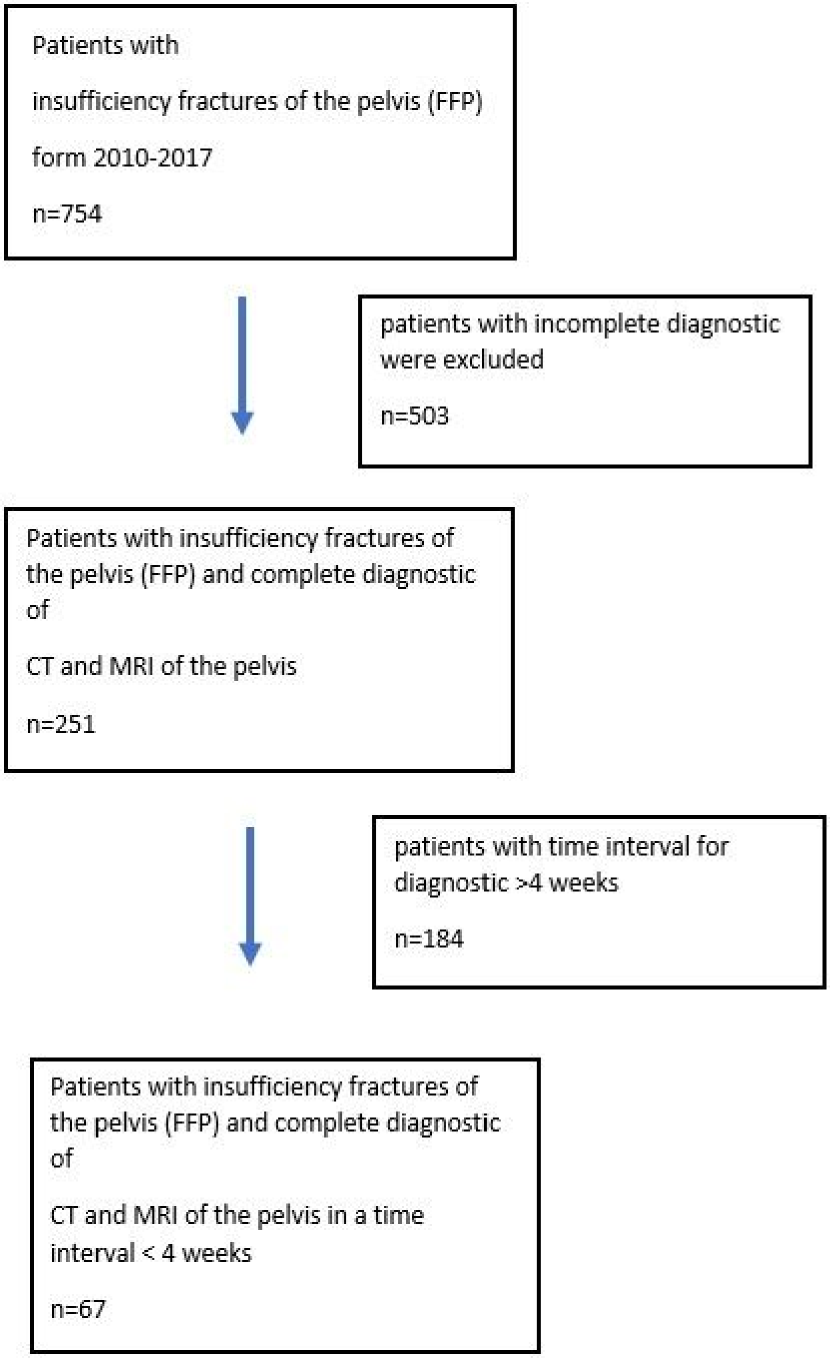

Figure 1

morphology in both imaging techniques

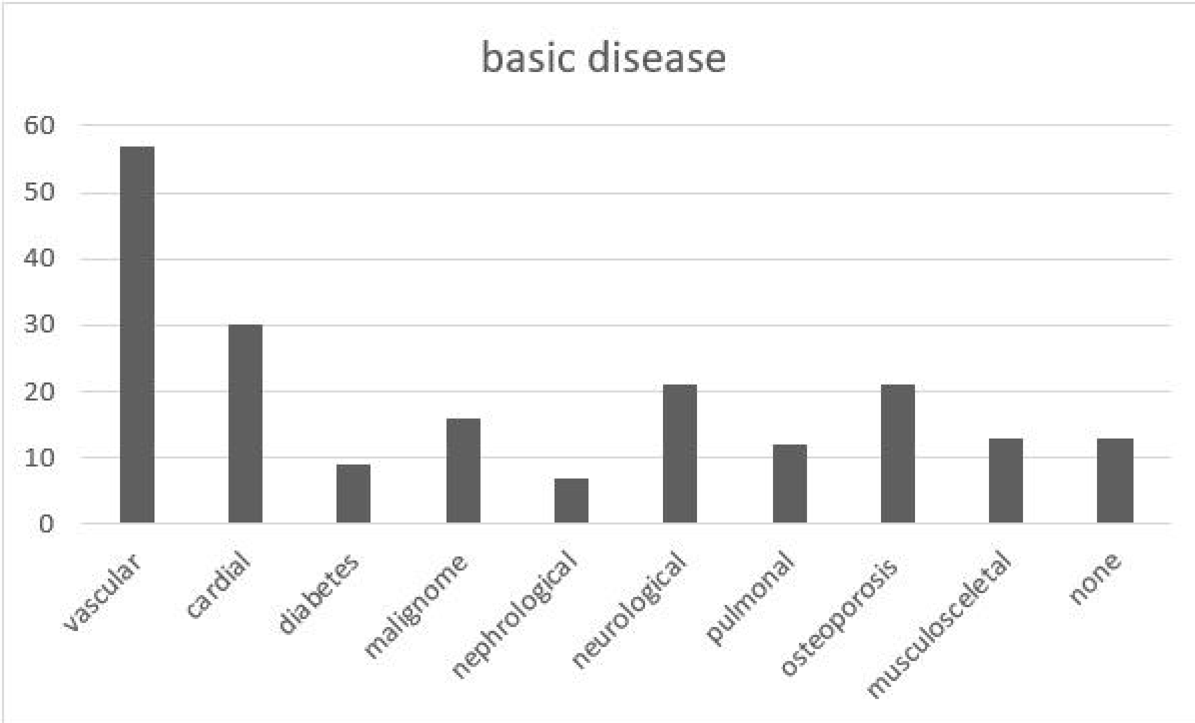

Figure 2

On average, the patient suffered from 1.8 diseases (range 0-6)

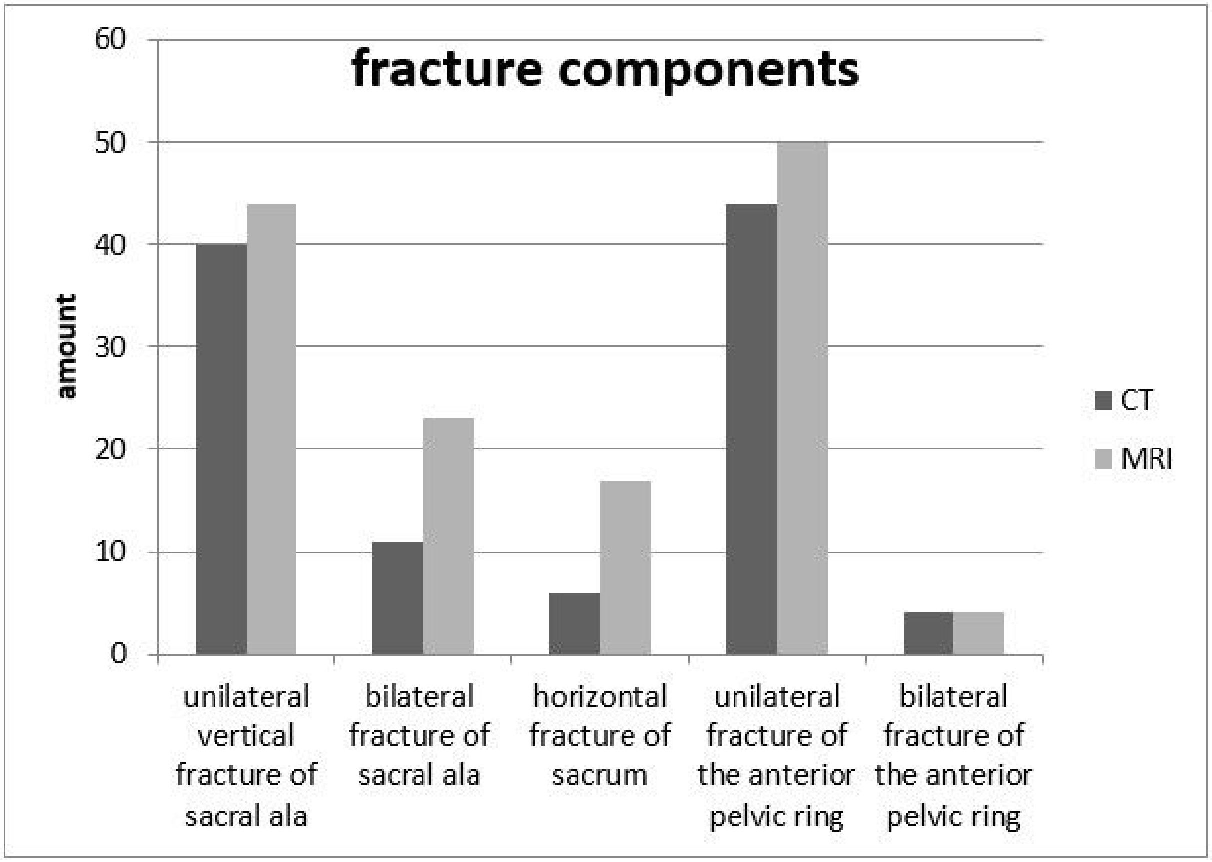

Figure 3

MRI compared to the CT examination

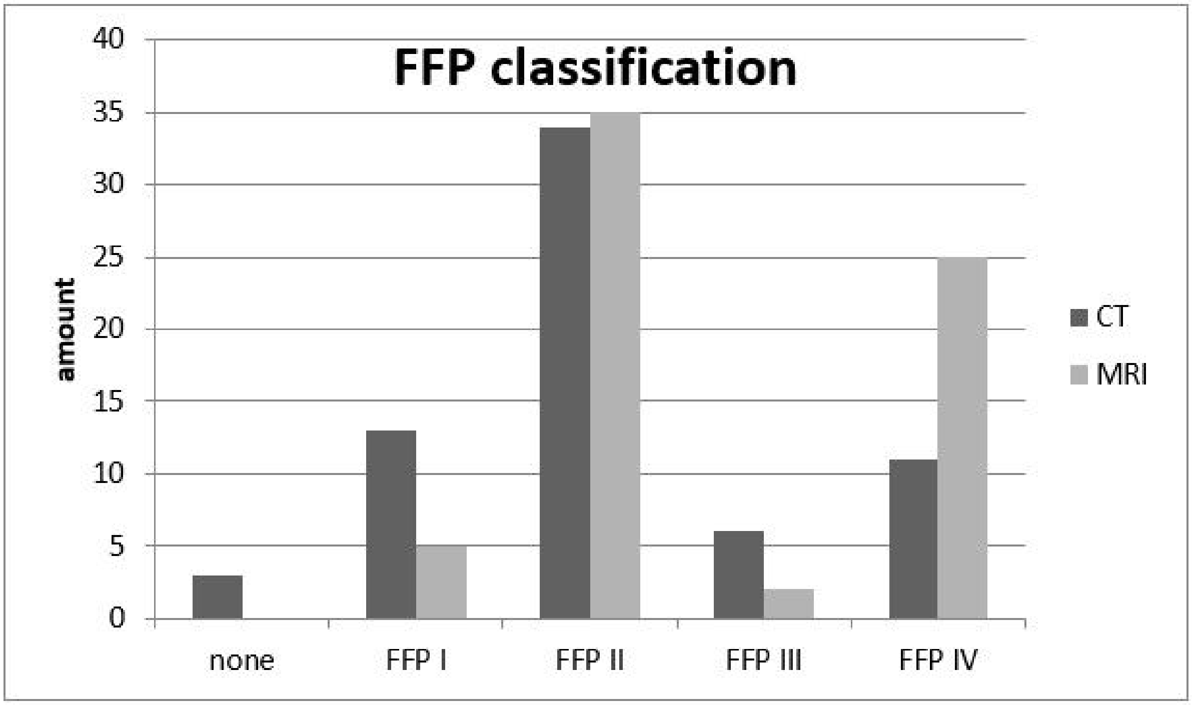

Figure 4

Based on the classification of Rommens and Hofmann[18], the CT-based distribution shown in Figure 4 was obtained.

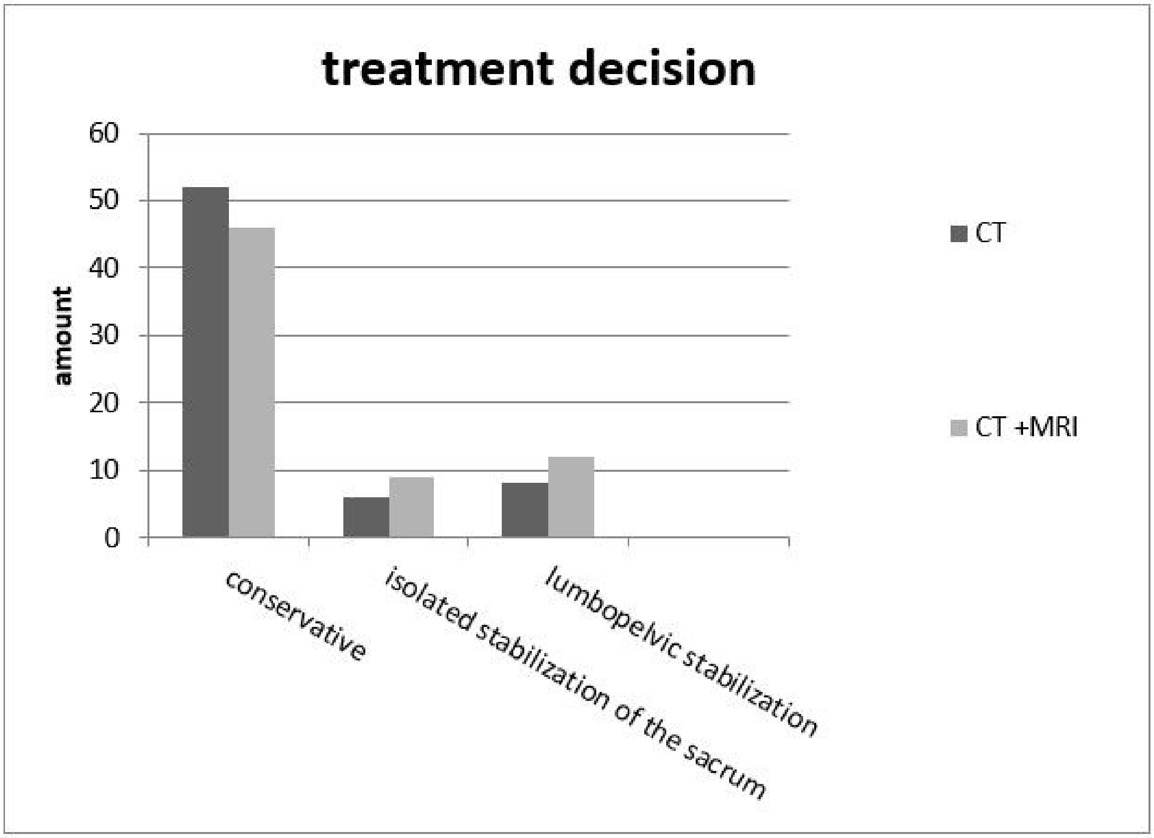

Figure 5

Surgical stabilization consisted of 42.9% (n=9/21) sacral stabilization and 57.1% (n=12/21) lumbopelvic stabilization. (Figure 5)

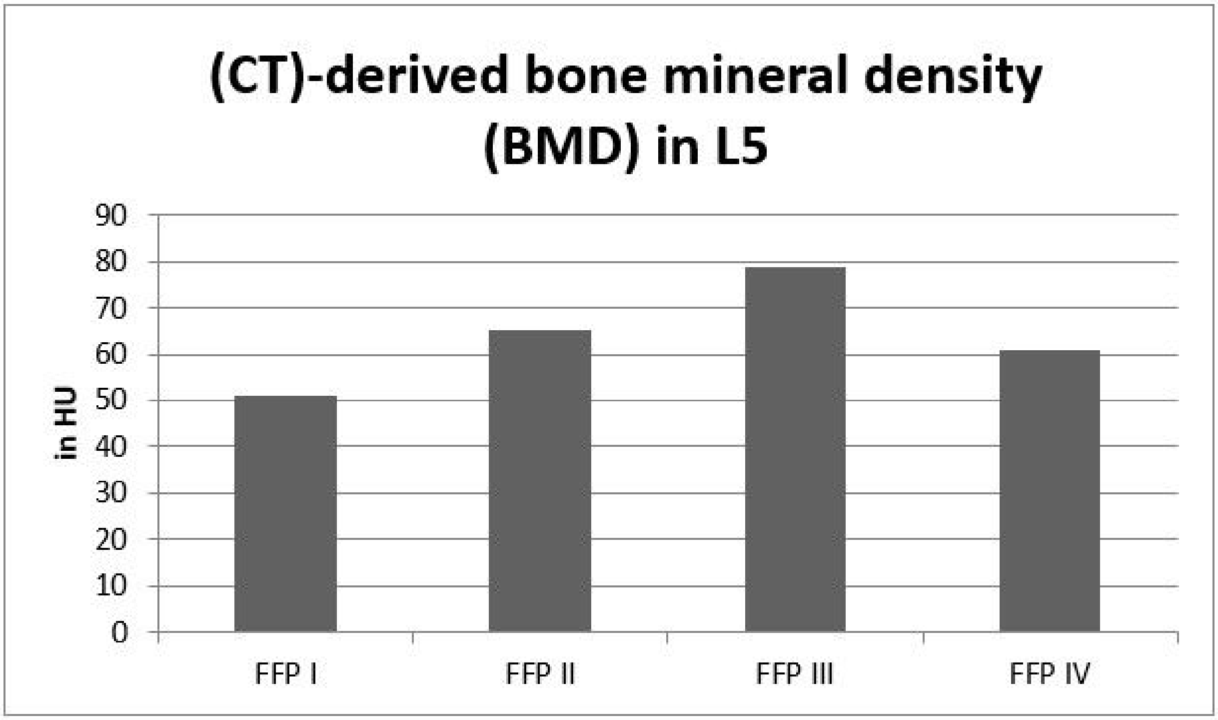

Figure 6

A correlation of the Hounsfield units to the individual fracture classes FFP I-IV after Rommens could not be established. FFP IV fractures showed no lower bone density than FFP I, II or III. (Figure 6)