Determination of bone density in patients with sacral fractures via CT scan

Josephine Berger-Groch a,⁎, Darius M. Thiesen a, Dimitris Ntalos a, Lars G. Grossterlinden b, Eric Hesse a, Florian Fensky a,1, Maximilian J. Hartel a,1

a Department of Trauma, Hand, and Reconstructive Surgery, University Medical Center Hamburg-Eppendorf, Martinistraße 52, 20246 Hamburg, Germany
b Department of Orthopaedics, Trauma- and Spine Surgery, Asklepios Hospital Hamburg-Altona, Paul-Ehrlich-Straße 1, 22763 Hamburg, Germany

Abstract

Background: Gold standard to diagnose osteoporosis is standard dual-energy X-ray absorptiometry (DXA). CT is a standard diagnostic tool to detect injuries to the pelvic ring. The aim of the study was to collect information on bone density without DXA by determination of Hounsfield units (HU) in CT scans of patients with sacral fractures, to draw conclusions on the prevalence of osteoporosis in patients admitted to the investigating institution.

Hypothesis: Is the determination of HU in CT scans a useful method to gain more information about bone density in patients with sacral fractures?

Patients and methods: We performed a retrospective analysis of all patients treated from 2004–2014 with sacral fractures confirmed with a CT scan. A total of 531 patients (398 female, 133 male) were included in the study. Bone density was measured with CT scans in Hounsfield units in vertebral body L5. The assessment was performed by placing a single oval over the trabecular bone in the axial view. In the sagittal plane, the correct position in the middle of the vertebral body was checked. As in previously published studies, we defined bone of less than 100 HU as osteoporotic, 100–150 HU as osteopenic and above 150 HU as normal.

Results: In 71.6% of the patients, bone density was reduced. Seventy-five percent of patients aged 65 or more exhibited manifest osteoporosis. With each additional year of age, bone density decreased by 2.7 Hounsfield units (p < 0.001). Female patients were predominant in the patient group with osteoporotic bone (p < 0.001).

Conclusions: There is significant prevalence of reduced bone density in the investigated patient group. The methodology used in this study is an uncomplicated procedure to further assess bone quality in patients with fractures of the pelvic ring. Fractures of the posterior pelvic ring in women over 65 years with low-energy trauma are most probably osteoporotic.

Level of evidence: III.

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1. Introduction

Typical osteoporotic fractures are in the proximal femur, proximal humerus, distal forearm or the vertebral column [1]. In general, fractures of the sacrum are not suspected of being osteoporotic. This is because pelvic fractures are often associated with high-energy trauma. But pelvic fractures occur in two age groups. While in younger patients, high-energy trauma is required to provoke fractures to the pelvic ring, low-energy trauma can cause fractures in the elderly, as their bone quality is impaired [2]. Due to demographic changes, this second group is rapidly growing. While extensive research has been carried out on the nature, epidemiology and treatment of pelvic fractures, there is still inadequate information on the occurrence of osteoporosis in patients with pelvic fractures.

Computed tomography is established as a standard diagnostic tool to detect injuries to the posterior pelvic ring [3,4]. Dual-energy X-ray absorptiometry (DXA) is commonly used, but is not available in every hospital. In addition, Pickhardt et al. have described a CT scan-based method to analyse bone quality. A DXA T-score of 2.5 or less was taken to indicate osteoporotic bone; a score between –1.0

⁎ Corresponding author.
E-mail address: j.berger@uke.de (J. Berger-Groch).
1 Authors contributed equally and therefore share last authorship.

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and −2.4 indicated osteopenic bone. They determined Hounsfield units (HU) in CT scans of the spine and correlated the results with standard dual-energy X-ray absorptiometry (DXA) [5,6].

In order to obtain additional information on bone density in patients with sacral fractures, we measured the HU in vertebral body L5 via a CT scan, as in Pickhardt et al., in every patient admitted to our hospital in a 10-year period. This is, to our knowledge, the first study that examines bone density via CT scan in such a large cohort of patients with sacral fractures.

2. Materials and methods

2.1. Patients

We studied all patients admitted to our hospital between 2004 and 2014 with posterior pelvic ring fracture. A total of 531 patients (398 female, 133 male) were included in this retrospective study. To be included in the final analysis, the diagnosis of a sacrum fracture needed to be confirmed in a CT scan and lumbar vertebral body 5 had to be intact to ensure valid bone quality assessment. CT attenuation in a pre-defined region of interest (ROI) through trabecular bone in the L5 vertebral body was recorded in Hounsfield units (HU) for each patient. The cohort was analysed by gender and age. Three age groups (under 45, between 46–65 and over 65) were defined.

2.2. Radiological assessment

All CT scans were carried out with a 256-detector row scanner (ICT 256, Philips Healthcare, Best, The Netherlands). The following scan parameters were used: 64 mm × 0.625 mm collimation by both scanners, rotation time of 0.75 s and 1.0 s and pitch of 0.98 and 0.61, respectively. The field of view was adapted to the individual anatomy. In every case, the entire bony pelvis and the vertebral body of L5 were included in the studies. A bone and soft-tissue kernel was constructed with slices 3 mm thick slices for all scans. All fractures of the pelvis were classified via the CT scan using the OTA [7], Tile [8] and Denis [9] classification.

As described previously, the assessment was performed by placing a single oval over the trabecular bone in the axial view. The correct position in the middle of the vertebral body was double-checked in the sagittal plane (see Fig. 1).

Patients with HU values lower than 100 HU were diagnosed as having osteoporosis. Patients with 100–150 HU were considered to exhibit osteopenic bone status. Patients with 150 HU and over exhibited normal bone density [10].

2.3. Statistics

All statistical analyses were performed with SPSS statistical software version 22.0 (SPSS, Chicago, IL). p-values < 0.05 (2-tailed) were considered statistically significant. Whenever the expected numbers in cell entries were smaller than 5, Fisher’s exact test was applied to calculate p-values. To address the comparability of two groups, descriptive statistics were presented as proportions for categorical variables and means plus standard deviations for continuous variables.

3. Results

The mean age in this study was 67.33 years (±20.86; range: 18–101). In the female subgroup, the mean age was 72.13 years (±19.10; range: 18–101) and in the male subgroup, 52.97 years (±19.32; range: 18–89).

The three defined groups of different bone status are composed as follows:

• 279 patients with osteoporotic bone status (HU < 99);
• 101 patients with osteopenic bone (HU 100–150);
• 151 patients with normal bone (150 HU).

In total, 52.5% of all patients had obvious reduced Hounsfield units, with HU < 99, — corresponding to osteoporotic bone status. The results are shown in Fig. 2.

There were significantly more females in the subgroup with osteoporotic bone status (89.2%, n = 249, p < 0.001) (see also Table 1).

By age group (under 45, between 46–65 and over 65), patients over 65 had the greatest risk of having osteoporotic bone. Two-thirds (75.1%) were affected (see Fig. 3).

Patients in our study population with normal bone status had a mean age of 42.68 (±17.79) years. These patients can be considered as a control group. Patients with 100–150 HU (osteopenia) had a mean age of 68.90 (±14.02) years and those with HU < 99 (osteoporosis) a mean age of 80.11 (±9.66) years. With each additional year of age, bone density decreased by 2.7 Hounsfield units (95% CI [2.5–2.9], p < 0.001). A particular striking loss of HU was seen between ages 50 and 70 (see Fig. 4).

Significantly higher bone density was seen in patients with high-energy trauma (HET) than with low-energy trauma (LET): patients with a high-energy trauma had a mean of 104.9 Hounsfield units more than patients with low-energy trauma (95% CI [93.64–116.18], p < 0.001. HET included 9.3% of all patients with HU < 99, 15.0% with 100–150 HU and 75.7% with HU < 150. While patients with LET included 69.8% HU < 99, 19.8% 100–150 HU and only 10.3% HU ≥ 150.

Most fractures (59.1%) were located in Zone 1 by the Denis classification. In contrast to Zones 2 and 3, 58.6% of patients with fractures in Zone 1 exhibited HU < 99 and were thus the greatest fraction in this group (see Table 2).

Fig. 1. A and B. CT scan of the pelvis. Demonstration of HU measurement in the axial and sagittal planes in vertebral body L5.
4. Discussion

In this study, the incidence of impaired bone density was identified in a large cohort. A method originally described by Pickhard et al. was used [5]. The methodology has already proven its applicability in patients with pelvic trauma [6]. Fractures of the pelvis were traditionally associated with high-energy trauma [11]. This study showed that sacral fractures mainly occur in female patients over 65 years after low-energy trauma. We were able to show an impressive age-related decrease in bone density in the sacrum. Osteoporosis influenced sacral fractures, particularly in low-energy trauma. Therefore, a significant increase in this fracture entity is probably linked to decreasing bone density. As with other osteoporotic fractures, female gender can be defined as a risk factor [12].

Reduced bone mass and disruption of bone architecture define osteoporosis, leading to an increased risk of fragility fractures [13]. Recognition of the high incidence of osteoporosis in this special patient group has additional implications. One question is whether the decrease in bone mass follows a regular pattern. Type B fractures were mainly encountered in this study. A cadaver study analysing bone density and cortical thickness of different sacra...
showed that there was significantly lower cancellous bone density in the osteoporotic group, especially lateral to the neural foramina, with a uniform decrease in cortical thickness [14]. This is consistent with our findings on fracture location using the Denis classification [9]. Most fractures were found in Denis zone 1. Likewise, a CT based study with 91 scans of different pelvises showed that the lowest Hounsfield unit value was in the paraforaminral lateral region in the sacral ala [15]. The reduced bone mass in this area may explain the specific paraforaminral fracture pattern in osteoporotic fractures of the sacrum [16].

The current standard technique for the detection of a posterior pelvic ring fracture is computed tomography of the pelvis [6]. This is used to describe the fracture, assess its stability, and to identify anomalies in sacral morphology [17]. The methodology used in this study is an uncomplicated procedure to further assess bone quality in patients with and without fractures of the pelvic ring. This additional information may be used for further individual conservative or surgical interventions.

One limitation of our study was the measurement of the Hounsfield units in L5 and not directly in the os sacrum. However, measurement in fractured bone areas would probably have given flawed results. In addition, no t-value determination via DXA was performed for further comparison. Furthermore, the retrospective design is a limitation of the study. Differentiation between osteoporotic and osteomalatic fracture was not possible, as there were no laboratory values for comparison.

In conclusion, determination of the Hounsfield units is a rapid and easy approach to obtain additional information on bone status in CT-scans of the pelvis. Women aged 65 or more most often exhibit osteoporotic bone status. Fractures typically follow a low-energy trauma and are localised in Denis Zone 1. Patients meeting these criteria (age, trauma mechanism and fracture classification) should be further treated for impaired bone status.

Ethical approval

All procedures involving human participants were in accordance with the ethical standards of the institutional and national research committee (reference number: WF-009/18) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Disclosure of interest

The authors declare that they have no competing interest.

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Authors’ contribution

J. Berger-Groch and D.M. Thiesen data collection.
E. Hesse and F. Fensky writing.
M.J. Hartel critical review.
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