How much intravenous contrast media affect bone mineral density (BMD) assessed by routine computed tomography (CT)

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Received 30 September 2015; accepted 20 March 2016
Available online 11 April 2016

KEYWORDS
Bone mineral density; Computed tomography; Osteoporosis; Contrast media; Hounsfield unit

Abstract Purpose: The data from routine abdominal multi-detector CT (MDCT) examinations provide information to diagnosis of the bone mineral density (BMD). The aim of this study was to measure the effect of intravenous contrast media on the BMD measuring of lumbar spine vertebrae (L1–L3) with CT densitometric data, Hounsfield unit (HU), obtained by routine abdominal examinations.

Patients and methods: The data on abdominal CT scans of 261 adults (150 females and 111 males) with a mean age of 59.6 years who underwent both unenhanced and enhanced abdominal CT examinations, with a 16-slice CT system (Toshiba Alexion Advance Edition 16, Japan), were evaluated for measuring the bone mineral density.

Results: Using trabecular region of interest (ROI), CT attenuation considerably differed between the unenhanced and enhanced abdominal scans for each imaging.

Conclusions: BMD values derived from the routine abdominal MDCT can be affected by intravenous contrast media in enhanced abdominal CT scanning. The impact of contrast media on the BMD decreases with increasing age of patients.

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1. Introduction

Osteoporosis is a systemic skeletal disease, which is characterized by bone fragility and fracture sensitiveness (1). Patients with decreased BMD have an increased risk of fracture, the incidence of which particularly at the hip and spine increases
with age in both women and men. Bone mineral density can be measured in a variety of sites with several techniques.

For BMD assessment of the lumbar vertebrae and proximal femur, Quantitative computed tomography (QCT) is one of the standard techniques (2). QCT has grown from its initial introduction in the 1970s to become an established technique for evaluating both skeletal condition and response to treatment for osteoporosis and other metabolic bone disease. It is accepted that QCT is the most sensitive method available to detect osteoporosis (2–5). While QCT technology delivers a higher dose than DXA, DXA still represents the “gold standard” for diagnosis of osteoporosis and as a technique of choice. QCT is inimitable between modern noninvasive measurements of bone mineral as that measures true three-dimensional BMD as opposed to the area (two-dimensional) density measures obtained from some protection techniques. QCT has the ability to measure cortical, trabecular or integral (cortical plus trabecular) bone at any site of body (6,3).

During the non-contrast abdominal CT examination when the lumbar vertebrae are in view, the real-time BMD measurement of the lumbar vertebrae by QCT analysis without being subjected to additional radiation exposure and additional radiologic examination is defined in the medical literature as potentially beneficial and superior to Dual-energy X-ray absorptiometry (DXA) (7,8,9).

Because osteoporosis is prevalent and treatable and conveys a considerable lifetime fracture risk, yet it remains substantially under diagnosed and undertreated (10–13). Safe and cost-effective alternatives to increase detection of this condition are needed.

Abdominal CT is the most frequent radiologic studies, which are used to assess mass lesions in CT centers. In a research conducted by Pickhardt et al. (5), it is reported that the abdominal CT images can be used to Screen patients with osteoporosis or normal Bone mineral density (5).

Retrieval of BMD data available on body CT examinations ordered for other indications requires no additional expense, software package, patient time, medical equipment, or radiation dose, and these data can be retrospectively achieved. Therefore, it could expand population screening efforts for osteoporosis.

2. Aims and objective

The purpose of our study was to evaluate the influence of intravenous contrast media on the BMD of lumbar spine (L1–L3) vertebrae by generating CT densitometric data (HU) based on routine abdominal with and without contrast examinations and to investigate whether these data can be affected on bone density condition.

3. Patients and methods

This retrospective single-institute study, approved by the institutional review board, was conducted in accordance with the ethical standards of the Declaration of Helsinki. All CT studies were accomplished with a 16-slice CT system (Toshiba Alexion Advance Edition 16, Japan). A routine MDCT protocol of abdominal examination was used for the study of all patients. CT parameters were including the following: 120 kVp, 160 mA s, 16 × 1 mm, 0.938 mm respectively for tube voltage, tube current, beam collimation and pitch factor. Two dimensional reconstructions (image slice 5 mm, window width 1500 and window level 300) were obtained in the axial planes. Elliptical ROI (20* 10 mm) located in the middle trabecular portion of each vertebral body before and after IV contrast injection and the mean CT attenuation were measured in HU. All ROIs were placed by a radiologist. Two hundred and sixty-one adults (150 females and 111 males) with a mean age of 59.6 years who underwent both the unenhanced and enhanced abdominal CT examinations were evaluated for measuring the bone mineral density. All patients received VISIPAQUE with an iodine concentration of 320 mg/ml (iodixanol; GE Healthcare Ireland, Ireland). The rate of intravenous injection of contrast material was set

<table>
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<tr>
<th>Table 1</th>
<th>The data of HU values in abdominal examinations before and after IV contrast administration (portal phase) in females. ROI at L1–L3 vertebrae.</th>
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<tbody>
<tr>
<td>Age</td>
<td>Unenhanced</td>
</tr>
<tr>
<td>40–49</td>
<td>190 ± 42</td>
</tr>
<tr>
<td>50–59</td>
<td>169 ± 40</td>
</tr>
<tr>
<td>60–69</td>
<td>127 ± 43</td>
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<tr>
<td>70–79</td>
<td>100 ± 47</td>
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<tr>
<th>Table 2</th>
<th>The data of HU values in abdominal examinations before and after IV contrast administration (portal phase) in males. ROI at L1–L3 vertebrae.</th>
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</thead>
<tbody>
<tr>
<td>Age</td>
<td>Unenhanced</td>
</tr>
<tr>
<td>40–49</td>
<td>191 ± 40</td>
</tr>
<tr>
<td>50–59</td>
<td>169 ± 41</td>
</tr>
<tr>
<td>60–69</td>
<td>163 ± 43</td>
</tr>
<tr>
<td>70–79</td>
<td>114 ± 56</td>
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</table>
Fig. 1  Computed tomography scans illustrating the calculating vertebral BMD pre- and post-contrast with Hus (a 56 year female). Corresponding lateral (A) and (B) scout images of the spine. (C) Axial images showing HUvalues (yellow ROI placed in vertebra) generated in pre-contrast. (D) Axial images showing HU values (yellow ROI placed in vertebra) generated in post-contrast.
at 4.0 ml/s with an automatic power injector for all examinations. Patients received 1.5 ml of contrast media per kilogram of body weight. For post-contrast assessment of the BMD of L1–L3 vertebral body, all measurements were made at the portal phases.

In our study we excluded patients with a malignancy and patients with apparent lumbar spine deformity and history of damaged trauma in the lumbar spine, because malignancy and damaged spine could influence on the bone mineral density (14–16). Also patients less than 40 years of age were excluded. Patients were grouped by sex and decade of life.

4. Statistical analysis

The statistical analysis was carried out using Statistical Package for Social Sciences (SPSS) Version 21.0 software for Windows. Mean HU values and SDs were calculated for L1–L3 vertebral; Student's t-tests were used to examine the significance of the differences. All statistical tests were two-sided. A p-value of < 0.05 was considered statistically significant.

5. Results

Using trabecular ROI, CT attenuation was considerably different between the unenhanced and enhanced patients for each modality imaging. The data of trabecular ROI mean ± SD HU values, in routine abdominal examinations with and without contrast media, in the portal phase from the L1 to L3 vertebral body are shown in Tables 1 and 2.

The HU values were linearly decreased by increasing the decades of life. Also amplification of mean HU at the enhanced images in both female and male was decreased with increasing the age. However, there were no significant differences for incrementing of HU in the enhanced images between the sexes, although there was a decrement of mean HU value in females with an age range of 60–69 years.

6. Discussion

Early diagnosis of osteoporosis has a very important impress in determining the risk of bone fracture. The purpose of this research was to determine the difference in HU-values of vertebrae from unenhanced and contrast-enhanced abdominal MDCT and to evaluate the impact of contrast media in CT as a screening tool for identifying patients with osteoporosis or normal BMD.

In a research conducted by Pickhardt et al. (5), it was reported that the abdominal CT images can be used to recognize osteoporosis or normal BMD. In another study by Pickhardt et al., on 252 patients (17), for comparing corpus vertebrae densities with DXA and QCT, it was found that when the threshold values were taken at 160 HU in L1 vertebra level, at 130 HU at L3 vertebra level and an average of 145 HU between T12-L5 vertebra, the diagnosis of osteoporosis showed a sensitivity of about 100% (see Fig. 1).

The effects of contrast media as an important factor in the attenuation value of L1 and on the diagnostic value of CT as a screening tool for osteoporosis were reported by Acu et al. (18). The image calculated BMD data from 198 patients who underwent standardized biphasic MDCT, and demonstrated that IV contrast agent leads to about 8.6% increase in overall density of L1–L3 from the phase I to phase II (p < 0.0001). Moreover, comparison of BMD values between phases I and II reveals a change from osteoporotic to osteopenic condition in 4.5% of the population and from osteopenic to normal for 11.1% of the subjects. Bauer et al. (19) have shown a higher attenuation values, 31%, in the spine on contrast-enhanced CT scans. Also, according to the findings of Toelly et al. (20) there was a direct relation between the measured BMD values from unenhanced and arterial phase scans, while the values from venous phase were consistently higher. We could also demonstrate that the application of intravenous contrast agent has a significant influence on the BMD measurement in the lumbar vertebrae. Our study showed that HU values were linearly decreased by increasing the decades of life, and thus confirmed previous study on significant correlation between age and HU (21). In the current study, CT attenuation (in HUs) increased considerably in the enhanced CT examinations. For example, at the age group of 40–49, in L1 level, a mean difference of 30 HU was found between the unenhanced and the enhanced CT scans; however, in a small-cohort QCT survey was not detected a noticeable difference (22). In a study by Pompe et al., (23) BMD was overestimated on the three examinations as shown by CT-attenuation values (in HUs) only in the first lumbar vertebra (L1), and also, it was determined that CT-attenuation values were significantly higher in contrast-enhanced phases compared to the unenhanced phase. For individual risk assessment, it is preferable to measure multiple vertebrae. According to the thresholds defined by Pickhardt et al., the contrast media in routine abdominal examinations influence the HU values and so higher ROI threshold values were needed for diagnosis of osteoporosis.

In the present study, the age groups were classified to observe the correlation of age with contrast media on the BMD. A significant correlation was observed between the age and HUs. The mean HU in females ranged from 30 in adults to less than 12 in those in their 8th decade. Also the mean HU in males differs from 34 in full-grown to 14 in those in their 8th decade.

This study has some limitations which have to be pointed out. Our study as a retrospective evaluation needed some larger number of subjects and also included an extended age ranges to an absolute conclusion. Meanwhile, for an accurate measures, an obvious or known bone abnormalities such as fractures, deformities, and metastases should not be included, as well as, regularly calibrating of the imaging system is necessary to avoid drifting of the CT numbers, proper selection of vertebrae, and necessity of future prospective studies, bringing up a need for some more extended studies to generalize the approach for BMD.

7. Conclusion

Bone mineral density values derived from the routine abdominal multi-detector CT may be affected by intravenous contrast media in enhanced abdominal CT and the effect decreases with patient age.

Conflict of interest

We have no conflict of interest to declare.
Acknowledgment

This research is financially supported by a research Grant by the Immunology Research Center in Tabriz University of Medical Sciences (Grant 5/47/2318), Tabriz, Iran. The authors wish to greatly thank the staff and also the head of Private Medical Imaging Centre of Nova, Maragheh, Iran.

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