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Original Article

Effect of Intravenous Contrast on Volumetric Bone Mineral Density in Patients with Chronic Kidney Disease

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Abstract

Volumetric bone mineral density (vBMD) can be measured from clinical computed tomography (CT) scans, facilitating screening for osteoporosis. However, use of X-ray contrast media may influence vBMD analyses, and previous studies reported as much as a 30% increase in lumbar spine (LS) vBMD after contrast administration. At the total hip (TH), an increase of only 4.1% was reported, indicating less sensitivity to contrast enhancement at this site. This study aimed to investigate the changes in vBMD after intravenous contrast media administration at both the LS and proximal femur in patients with chronic kidney disease. Seventy-one patients underwent CT angiography of the chest, abdomen, and pelvis as part of the cardiac workup before kidney transplantation. vBMD of the LS and proximal femur were calculated before and after administration of 95 mL ioversol intravenously. *XY*- and Bland–Altman plots and paired Student's *t*-test were used to evaluate changes in vBMD. After contrast media administration vBMD increased both at the LS and proximal femur. Although the absolute difference was comparable, the relative difference was almost twice as high at the LS (10.2% [6.1–14.1]) compared to the TH (5.9% [2.4–9.3], $p < 0.001$) and femoral neck (FN) (5.3% [0.5–9.9], $p < 0.001$). Women had a greater increase in LS-vBMD than men (13.4 ± 8.0 vs 9.8 ± 4.8 mg/cc, $p = 0.02$). Based on FN *T*-scores, 11 patients (16%) changed osteoporotic status after contrast enhancement. In conclusion vBMD of the spine and hip increased after contrast media administration in a cohort of patients with chronic kidney disease. FN *T*-scores from contrast-enhanced clinical CT scans should therefore be interpreted with caution. The proximal femur may be the preferred region for vBMD analysis from clinical CT scans, as sensitivity to contrast enhancement seem less at this site. These results may not be applicable to other patient populations.

Key Words: Bone density; chronic kidney disease; computed tomography; contrast media; osteoporosis.

Introduction

Computed tomography (CT) scans are increasingly used for diagnostic purposes and as spine and hips are often included in the scanned region, concomitant measurement of volumetric bone mineral density (vBMD) is possible *(1)*. Previous studies have shown that clinical CT scans can provide accurate and clinically relevant bone density data *(2–4)*.

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Patients with chronic kidney disease (CKD) suffer from bone disease with an increased risk of fractures. Diagnostic use of areal bone mineral density (aBMD) is controversial in CKD, and screening for osteoporosis using dual-energy X-ray absorptiometry (DXA) scan is not recommended *(5)*. As DXA scans yield 2-dimensional images, calcifications in surrounding tissues may be included in aBMD analyses *(6)*, and particularly the widespread aortic calcification seen in CKD could lead to an overestimation of lumbar spine (LS)-aBMD *(7)*. Dialytic fluid in the abdomen *(8)* and mineral-containing phosphate binders in the intestine *(9,10)* have also been shown to influence aBMD by DXA in patients with CKD. Although lateral DXA measurements of the LS could potentially minimize these effects, to our knowledge, there are no studies published using this approach for patients with CKD. The 3-dimensional images of CT scans enable precise placement of regions of interest in the bone compartment, and this technique may therefore be particularly suitable for these patients.

Clinical CT scans frequently use intravenous (iv) X-ray contrast media, which may influence vBMD analyses, and previous studies reported as much as a 30% increase in vBMD after iv contrast administration *(11–13)*. Most studies investigated changes in LS-vBMD, reporting relative increases of 8.6%-30% in bone density or bone attenuation *(11–16)*. Only a single study investigated vBMD changes at the proximal femur and reported an increase of only 4.1% of total hip (TH)-vBMD *(11)*. Thus, the effect of iv contrast media enhancement on vBMD analyses may be less pronounced at this site. The aim of the present study was to investigate the changes in vBMD after iv contrast media administration both at the spine and hip, in a group of patients with severe CKD.

Materials and Methods

Patients

From February 2011 to February 2013, patients with CKD referred for cardiovascular evaluation before kidney transplantation from 9 hospitals in the North and Central Regions of Denmark were consecutively enrolled and scheduled for a CT angiography. Details of inclusion have been described elsewhere *(17)*, but briefly, inclusion criteria were an indication for kidney transplantation and need of cardiovascular screening by at least one of the following characteristics: age > 40 yr, diabetes mellitus, renal replacement therapy > 5 yr, being on kidney transplant waiting list > 3 yr, or symptoms of cardiovascular disease. Exclusion criteria were age < 18 yr or acute coronary syndrome. Of 77 scheduled patients, six were excluded due to inability to establish iv access, and a total of 71 patients were thus included in the present analysis.

All patients provided written informed consent before study participation. The study was approved by the Central Denmark Regional Committee on Health Research Ethics and The Danish Data Protection Agency and followed the principles in the declaration of Helsinki. The study was registered at ClinicalTrials.gov (NCT01344434).

Image Acquisition and Analysis

CT angiography of the chest, abdomen, and pelvis was performed on a dual-source scanner (SOMATOM Definition Flash; Siemens Healthcare, Erlangen, Germany) with both a nonenhanced and a contrast media-enhanced scan performed during the same session. Before the enhanced scan, a fixed contrast dose of 95 mL ioversol (Optiray 350 mg/mL; Mallinckrodt, Hennef, Germany) was administered intravenously at a continuous flow of 6 mL/s. Mean contrast dose per body weight was 1.25 ± 0.21 mL/kg. The delay between contrast media administration and image acquisition was 30 ± 5 s. Both scans were high-pitch, low-dose flash scans. Gantry rotation speed was 0.28 s, the pitch was 3.4, and detector collimation was 2 × 64 × 0.6 mm. Tube X-ray energy was set at 100 or 120 kVp dependent on patient size, and the majority of patients had a tube energy of 100 kVp at both scans (n = 51). Nine patients had a setting of 120 kVp at both scans and 11 patients had different tube energies at the 2 scans. Tube current was dose modulated and set at 100 (93.9 ± 19.6) mAs for the nonenhanced scan and 250 (261.1 ± 58.0) mAs for the contrast-enhanced scan. The field of view was 332.0 mm and images were reconstructed to a slice thickness of 3 mm using a standard soft tissue kernel B30f (Syngo.via; Siemens Healthcare, Erlangen, Germany).

vBMD was determined using the commercially available software QCT Pro (Mindways Software Inc., Austin, TX), together with the quality assurance calibration phantom Mindways Solid (Mindways Software Inc.). The phantom was scanned at regular intervals with a CT protocol matched to patients' scans to provide calibration data for asynchronous analysis *(18)*.

Analysis of LS-vBMD was performed on 3 consecutive vertebral bodies from L1 to L4. L1–L3 were preferred, although in 10 patients L2–L4 were analyzed due to fractures or other visible deformities in L1. A circular region of interest was placed in the anterior part of the vertebral body, excluding the posterior venous plexus, focal heterogeneity, or lesions and imaging-related artifacts. Analysis of the proximal femur was performed using the semiautomatic functions provided by the software, yielding both a 2- and a 3-dimensional projection of TH and subcompartments. Left hip was preferred, although the right hip was analyzed in 7 cases due to previous fracture, metallic prosthesis, or incomplete image of the left hip. *T*- and *Z*-scores at the femoral neck (FN) were determined based on reference data supplied by the software manufacturer *(18)*.

Fractures

Fragility fractures were defined as (1) previous fractures resulting from trauma equal to a fall from standing height or less or (2) 1 or more prevalent vertebral fractures (VFx) not caused by high-energy trauma. Previous