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Original Article

Precision of Second-Generation High-Resolution Peripheral Quantitative Computed Tomography: Intra- and Intertester Reproducibilities and Factors Involved in the Reproducibility of Cortical Porosity

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Abstract

High-resolution peripheral quantitative computed tomography (HR-pQCT) was upgraded to a second generation in 2014 with higher spatial resolution, faster scan time, and a different measurement algorithm. The purpose of this study was to investigate the precision of the second-generation HR-pQCT. The distal radius and tibia of 15 healthy men and women (age range of 20–74 yr, 8 men and 7 women) were scanned by second-generation HR-pQCT, and their geometry, bone mineral density (BMD), and the microstructure of trabecular and cortical bones were evaluated. Scans and measurements were performed by tester 1 at baseline and at 1 and 4 wk to evaluate intratester reproducibility, and by testers 2 and 3 one time each to evaluate intertester reproducibility. Reproducibility was evaluated by root mean square percent coefficient of variance (RMS%CV). Factors involved in the reproducibility of cortical porosity (Ct.Po) were also investigated. The ranges of RMS%CV were 0.2%–2.5% for geometry, 0.6%–1.7% for BMD, 0.7%–2.4% for trabecular bone, and 1.1%–1.3% for cortical thickness, showing excellent reproducibility. The range of RMS%CV for Ct.Po was 11.0%–13.3%, relatively higher than those for the other parameters. There was no apparent difference between intra- and intertester reproducibilities. There was no clear correlation between the percent coefficient of variance of Ct.Po and the subjects' background characteristics, motion artifact, and cortical bone structure. The reproducibility of the second-generation HR-pQCT was excellent in geometry, BMD, trabecular bone, and cortical thickness, with no apparent difference between intra- and intertester reproducibilities. Compared with the first-generation HR-pQCT, the reproducibility of trabecular bone was improved. The reproducibility of Ct.Po was insufficient and needed to be improved, and factors that influence its reproducibility were not clear.

Key Words: Cortical porosity; HR-pQCT; reproducibility; second-generation.

Introduction

High-resolution peripheral quantitative computed tomography (HR-pQCT) enables us to investigate patients' bone microarchitecture in vivo and now plays an important part in osteoporosis studies *(1–3)*. HR-pQCT was developed in 2004 in Switzerland and improved in 2014 as a second-generation HR-pQCT with higher spatial resolution and faster scan time (voxel size: from 82 to 61 μm,

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scanning time: from 3 to 2 min), using a different measurement algorithm for trabecular bone structure as a result (direct measurement) *(4,5)*.

The precision of first-generation HR-pQCT had been investigated previously, reporting good reproducibility in density parameters (coefficient of variance 0.5%–2%) *(6–14)*, but there have been no reports of second-generation HR-pQCT.

It is generally recommended that the scan and measurement of HR-pQCT be done by a single tester to ensure good reproducibility, but in actual research projects, testers sometimes change due to their employment or career path. However, most previous publications investigated reproducibility by a single tester. Furthermore, previous reports said that reproducibility of cortical porosity (Ct.Po) is not good (5%–20% coefficient of variance [%CV]) compared with other parameters, but the definite cause for this finding was unknown *(9–11,13,14)*.

The purpose of the present study was to investigate the precision of second-generation HR-pQCT, looking at both intra- and intertester reproducibilities (3 testers). Factors that influence the reproducibility of Ct.Po were also investigated.

Methods

Subjects

Based on a previous report, a study of bone densitometer precision requires at least 14 subjects when scans are performed 3 times *(15)*. In the present study, scans were conducted 3 times in 15 healthy men and women (Table 1). Studies using HR-pQCT can target both men and women, and both young and old subjects. Therefore, 5 men and women were selected from each of 3 age groups (20–39, 40–59, and 60–79 yr), with the final analysis set consisting of 8 men and 7 women with an age range of 20–74 yr.

The study protocol was approved by the institutional review board of Nagasaki University Hospital and complied with the Declaration of Helsinki of 1975, revised in 2000, and written informed consent was obtained from the subjects before participation.

Testers

Tester 1, an orthopedic surgeon with 2 yr of experience with HR-pQCT, scanned and analyzed the 15 subjects at baseline and at 1 and 4 wk after baseline to investigate intratester reproducibility. Tester 2 was also an orthopedic surgeon with 2 yr of experience. Tester 3 was an orthopedic surgeon with 1 mo of experience. Testers 2 and 3 also scanned and analyzed the 15 subjects to assess intertester reproducibility. Therefore, the subjects underwent a total of 5 scans within a month.

Table 1
Data on Subjects

N	15
Age (yr)	48 ± 15 (20–74)
Gender	M = 8, F = 7
Height (cm)	164.5 ± 7.6 (148.5–176)
Weight (kg)	60.1 ± 10.2 (46–80)
BMI (kg/m^2)	22.1 ± 2.5 (18.9–27.7)

Abbr: BMI, body mass index; F, female; M, male.

Scan

Based on the manufacturer's standard scan protocol, the ultradistal radius and tibia were scanned by a second-generation HR-pQCT (XtremeCT II; Scanco Medical, Brüttisellen, Switzerland). The subjects' nondominant forearm and lower leg were fixed by dedicated casts (the design of the forearm cast for second-generation HR-pQCT was improved to reduce motion artifact). The scan region was 10.2 mm in width at the distal radius, 9.0 mm proximal from the wrist joint (the prominence between the lunate and scaphoid facets), and 10.2 mm in width at the distal tibia, 22.0 mm proximal from the subchondral endplate of the ankle joint.

The scan settings were as follows: voltage, 68 kVp; current, 1470 μA, 100 W; integration time, 43 ms; number of projections, 900; field of view, 140 mm; matrix, 2304 × 2304; voxel size, 60.7 μm; and total number of slices, 168. The scan time was 2.0 min, and the radiation doses were 10.8-mGy volume computed tomography dose index and 11.0-mGycm dose length product.

Measurement

Based on the manufacturer's standard measurement program for XtremeCT II, bone geometry, mineral density, and microstructure were evaluated.

Registrations of cortical and cancellous bones were performed semiautomatically. First, the periosteal line was contoured automatically, usually without any correction. Then, the endocortical line was also contoured automatically, often requiring manual correction. The correction is not performed per slice but every 10 slices using an interpolating method.

To match measurement regions of 3 scans, the common region registration method was used. This method is provided by the manufacturer as standard procedure, finding a common region of multiscans based on cross-sectional area.

Measurement parameters were (1) geometry: total area (Tot.Ar, mm^2), trabecular area (Tb.Ar, mm^2), cortical area (Ct.Ar, mm^2), and cortical perimeter (Ct.Pm, mm); (2) bone mineral density (BMD): total volumetric BMD (Tot.vBMD, mg/cm^3), trabecular volumetric BMD (Tb.vBMD, mg/cm^3), and cortical volumetric BMD (Ct.vBMD, mg/cm^3); and (3) microstructure: (3-1) trabecular bone: bone volume fraction (BV/TV, %), trabecular number (Tb.N, 1/mm), trabecular thickness (Tb.Th, mm), and trabecular separation (Tb.Sp, mm), and (3-2) cortical bone: cortical thickness (Ct.Th, mm), Ct.Po (%), and cortical porosity diameter (Ct.Po.Dm, mm).

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