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Original Article

A Critical Comparison Between Two Scanning Protocols of High-Resolution Peripheral Quantitative Computed Tomography at the Distal Radius in Adolescents

Ka-Yee Cheuk,[1,2,3] Elisa Man-Shan Tam,[1,2,3] Fiona Wai-Ping Yu,[1,2,3,4] Benjamin Hon-Kei Yip,[1,2,5] Vivian Wing-Yin Hung,[1,2,3,4] Xiaofang Wang,[6] Ali Ghasem-Zadeh,[6] Tracy Y. Zhu,[1,2,4] Ling Qin,[1,2,4] Jack Chun-Yiu Cheng,[1,2,3,4] and Tsz-Ping Lam[*,1,2,3,4]*

[1]Department of Orthopaedics and Traumatology, The Chinese University of Hong Kong, Hong Kong SAR; [2]SH Ho Scoliosis Research Laboratory, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong SAR; [3]Joint Scoliosis Research Center of the Chinese University of Hong Kong and Nanjing University, The Chinese University of Hong Kong, Hong Kong SAR; [4]Bone Quality and Health Centre, Department of Orthopaedics and Traumatology, The Chinese University of Hong Kong, Hong Kong SAR; [5]School of Public Health and Primary Care, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong SAR; and [6]Departments of Endocrinology and Medicine, Austin Health, University of Melbourne, Australia

Abstract

High-resolution peripheral quantitative computed tomography (HR-pQCT) is a unique technology for assessing bone mineral density and bone microarchitecture. Currently, no universally accepted protocol for selecting the region of interest (ROI) at the distal radius has been established for growing subjects. This study aimed (1) to investigate the differences in HR-pQCT measurements of 2 different ROI protocols applied to the distal radius of healthy adolescents and (2) to identify the least common area of ROI (the least common ROI) between the protocols. Twenty-six boys and 26 girls aged between 13 and 16 yr old were recruited. Nondominant distal radius was scanned by 2 HR-pQCT protocols, namely, the "5-mm protocol," where the distal end of ROI started at 5 mm proximal to a reference line, and the "4% protocol," where the ROI started at 4% of the ulnar length proximal to another reference line. The least common ROI between the 2 protocols was identified and the slice numbering within the common ROI was determined. Bland–Altman plots were used to check the agreement of the least common ROIs between the 2 protocols. Paired *t*-test and Wilcoxon signed-rank test were used for analysis. In boys, significant differences between protocols were found in most parameters with the maximum difference observed in the cortical area (25.0%, $p < 0.001$). In girls, differences were observed only for total volumetric bone mineral density (3.6%, $p = 0.032$). The number of slices in the least common ROI was 66 (60.0%) and 57 (51.8%) in boys and girls, respectively. Good agreements on all HR-pQCT parameters from the least common ROI between the 2 protocols were found. Significant differences in bone parameters were noted between the 2 protocols. When comparing the 2 protocols, observed gender differences could reflect the differences in skeletal growth at the peripubertal period between genders. Least common ROI could be useful for cross-center comparisons and when merging datasets from different centers.

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*Address correspondence to: Tsz-Ping Lam, MBBS (HK), FHKAM (Orthopaedic Surgery), FRCS (Edin), Department of Orthopaedics and Traumatology, 5/F, Clinical Science Building, Prince of Wales Hospital, Shatin, NT, Hong Kong SAR, China. E-mail: tplam@ort.cuhk.edu.hk

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Introduction

High-resolution peripheral quantitative computed tomography (HR-pQCT) is an advanced noninvasive 3-dimensional (3D) imaging technique measuring bone morphometry, trabecular bone microarchitecture, and volumetric bone mineral density (vBMD) of the cortical and trabecular compartments at the distal radius and tibia both for bedside clinical assessment and research including therapeutic clinical studies *(1–4)*.

HR-pQCT is performed by scanning a region of interest (ROI) defined by the manufacturer for adults with the distal border starting at 9.5 and 22.5 mm proximal to the reference line for the distal radius and distal tibia, respectively *(5)*. *Official Positions 2013 – Pediatric*, published by the International Society for Clinical Densitometry, stated that "QCT, pQCT and HR-pQCT can be used clinically in children where appropriate reference data and expertise are available" *(6)*. Currently, there is no consensus on the scanning protocol for young subjects with open growth plates, which are radiation-sensitive regions and should be avoided during scanning *(7)*. In general, there exist 2 types of scanning protocols, namely, those with ROI starting at a fixed distance (1, 2, 5, or 9.5 mm) or a relative offset (4% or 7%) of the ulnar length proximal to different reference lines *(7–13)*. Due to the diversity of existing protocols, it is difficult to perform cross-study comparisons and to merge datasets from different centers for analysis.

To the best of our knowledge, there is by far no study investigating how different ROIs affect the measurements obtained from HR-pQCT in young subjects with visible growth plates. In the present study, we compared the "5-mm protocol," where the distal end of the ROI started at 5 mm proximal to a well-defined reference line, and the "4% protocol," where the ROI started at 4% of the ulnar length proximal to a different well-defined reference line. The aims of this study were (1) to investigate the differences in HR-pQCT measurements at the distal radius of healthy adolescents between the 2 different protocols and (2) to identify the least common area of ROI (the least common ROI) between the protocols.

Subjects and Methods

Subjects

Twenty-six boys and 26 girls aged between 13 and 16 yr old were recruited from local secondary schools. All subjects had open growth plates at the distal radius. The exclusion criteria were as follows: congenital deformities, neuromuscular diseases, genetic diseases, chromosomal defects, autoimmune disorders, endocrine disturbances, any disorders, or any medication affecting bone metabolism. Written informed consents were obtained from all subjects and guardians. The present study was carried out according to the Declaration of Helsinki and was approved by our Institutional Review Board (http://www.crec.cuhk.edu.hk/, CREC-2011.025).

Anthropometric and Maturity Assessment

Anthropometric parameters on body weight, body height, sitting height, and arm span were measured. Accurate measurement of the length of the radius can be difficult; hence, the ulnar length (at the nondominant side) from the tip of the styloid process distally to the tip of the olecranon process with elbow flexed at 90° was measured instead *(13)*. The percentage of coefficient of variation for ulnar length measurement was 1.04%. Body mass index was calculated as body weight/body height^2 (kilogram per square meter). Pubertal maturity was assessed with self-reported Tanner staging administered under close supervision of an experienced research worker. The physical activity level of the subjects for the past 12 mo was assessed with the Chinese version of the Modified Baecke Questionnaire adopted by Pols et al *(14)*. Overall physical activity level (total score) was calculated from work, sport, and leisure indices.

HR-pQCT Assessment and Image Analysis

The nondominant forearm was scanned with HR-pQCT (XtremeCT I; Scanco Medical, Brüttisellen, Switzerland) using 2 different protocols consecutively without repositioning. The X-ray tube potential was 60 kVp and the size of matrix was 1536 × 1536. The voxel size was 82 μm^3. A scout view was obtained to define the ROI.

For the fixed offset method, the 5-mm protocol adopted by our research group taking reference to an early report by Kirmani et al *(8)* on HR-pQCT investigation for adolescents was evaluated. In the 5-mm protocol, the distal border of the ROI started at 5 mm proximal to the most proximal limit of the inner aspect of the epiphyseal plate as shown by lime green lines in Fig. 1 *(10)*. Regarding the relative offset method, studies conducted with protocols using various "percentages" were noted. We took reference of the report by Wang et al who used the 4% protocol *(13)*. Jamal et al, Neu et al, and Burt et al also used the 4% protocol when investigating with pQCT *(15–17)*. The ROI started at 4% of the ulnar length proximal to the radial joint surface of the wrist as shown by the magenta lines in Fig. 1 *(13)*. As the ROIs for both the 5-mm and 4% protocols similarly occupied the distal region of the radius, they were included for comparison in this investigation. For both protocols, the ROI spanned proximally for 9.02 mm, equivalent to 110 slices of scanning.

Image processing and analysis were conducted with the same algorithm for the 2 scanning protocols. The periosteal surface of the radius was contoured semiautomatically by a single technician. A Gaussian filter was employed to remove the noise signal and an automated