Standardized Training For HR-pQCT Scan Positioning Reduces Inter-Operator Precision Errors: The MrOS Multicenter Study Experience

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The role of high-resolution peripheral quantitative tomography (HR-pQCT) in musculoskeletal research is rapidly expanding through its inclusion into multicenter clinical trials and observational cohort studies, such as the Osteoporotic Fractures in Men Study (MrOS, an observational study being conducted at 6 clinical sites). Previously[1], we found that positioning variability is an important source of imprecision. In this study, we aimed to reduce inter-operator positioning precision errors through standardized training.

The training procedure included theoretical and practical demonstrations led by a vendor representative and MrOS investigator, followed by simulated scan positioning exercises using software developed at UCSF. The software reproduced the graphical user interface of the XtremeCT (Scanco Medical AG) and provided the user with a series of scout images of the radius and tibia to perform simulated scan positioning. In this study, we enrolled 6 new operators with various background and no previous HR-pQCT experience, who required certification to perform HR-pQCT exams for MrOS. After successful completion of the software training and evaluation, operators performed a blinded positioning exercise to test intra- and inter-operator reproducibility. In these exercises, we measured positioning precision and the corresponding precision error in cortical and trabecular bone measurements. Results from the MrOS trainees were compared to previously acquired data from experienced operators with a heterogeneous training history[1].

Intra-operator precision errors of the trainees were not significantly different compared to the experienced operators (e.g. Ct.Th: 3.2% vs. 3.5%), indicating that new operators achieved equivalent reliability to experienced operators (Table 1). Inter-operator precision errors of trainees in this study were half than errors of the experienced operators (e.g. Ct.Th: 4.9% vs. 8.4%, $p<0.001$) and approached the level of intra-operator precision. Thus the training regimen led to the new operators achieving a superior level of multicenter reproducibility.

In conclusion, we found that inter-operator variability in scan positioning can be significantly reduced with standardized training procedures in a controlled environment. With the purpose of making our training platform available to the community, we are developing a version of the training and evaluation tool that will be openly disseminated as a web application.

[1]Bonaretti S. et al. ASBMR 2014

Table 1. Precision errors of reference line positioning and corresponding errors in bone and mechanical parameter measurements for radius and tibia for intra- and inter-operator reproducibility. "Experienced" refers to the operators involved in our previous study[1], who participated in the experiments without common training. "New" refers to MrOS operators enrolled in the present study, who participated in the experiments after common training. Details of the precision experiment were described in our previous study[1].

RADIUS	**Positioning Precision** SD_{RMS} [mm]	**BMD** CV_{RMS} [%]	**Ct.Th** CV_{RMS} [%]	**Tb.N** CV_{RMS} [%]	**$L_{failure}$** CV_{RMS} [%]
*Intra-operator**					
Experienced	0.24 ± 0.05[a]	1.39 ± 0.32[a,c]	3.17 ± 0.65[a,c]	0.47 ± 0.14[a]	0.42 ± 0.12[a,c]
New	0.28 ± 0.08[c]	1.50 ± 0.25[a,c]	3.46 ± 1.24[a,c]	0.69 ± 0.56	0.41 ± 0.11[c]
Inter-operator					
Experienced	0.68[a,b,c]	3.69[a,b,c]	8.40[a,b,c]	2.12[a,b]	1.17[a,b,c]
New	0.34[b,c]	2.09[a,b,c]	4.90[a,b,c]	1.32[b]	0.72[a,b,c]

(a)

TIBIA	**Positioning Precision** SD_{RMS} [mm]	**BMD** CV_{RMS} [%]	**Ct.Th** CV_{RMS} [%]	**Tb.N** CV_{RMS} [%]	**$L_{failure}$** CV_{RMS} [%]
*Intra-operator**					
Experienced	0.13 ± 0.07[a]	0.26 ± 0.15[a,c]	0.94 ± 0.50[a,c]	0.31 ± 0.18[a]	0.07 ± 0.03[a,c]
New	0.11 ± 0.03[a,c]	0.31 ± 0.06[c]	0.52 ± 0.29[a,c]	0.31 ± 0.05	0.06 ± 0.01[a,c]
Inter-operator					
Experienced	0.30[a,b,c]	0.61[a,b,c]	1.97[a,b,c]	0.85[a,b]	0.20[a,b,c]
New	0.16[a,b,c]	0.30[b,c]	1.02[a,b,c]	0.41[b]	0.08[a,b,c]

(b)

[a] Intra-operator vs. inter-operator comparison; p<0.001.
[b] Experienced vs. new operator comparison; p<0.001.
[c] Radius vs. tibia; p<0.001.
* For intra-operator precision and corresponding bone parameters, values refer to mean ± standard deviation.
SD_{RMS} [mm] = Root mean square of standard deviations.
CV_{RMS} [%] = Root mean square of percentage coefficient of variations.
BMD = bone mineral density; Ct.Th = cortical thickness; Tb.N = trabecular number; $L_{failure}$ = failure load.