# The Role of Intra- and Inter-Operator Variability in HR-pQCT Precision

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The role of the operator on HR-pQCT precision has not been systematically investigated, though likely contributes significant measurement variability, especially in multicenter cross-sectional studies. At scan time, the operator acquires a 2D projection (scout view) of the limb, then visually identifies a reference anatomic landmark, which defines the scan region. Variability of region localization greatly affects bone quality measures, especially where large spatial variations in morphology occur, such as in the ultradistal radius. We evaluated short- and long-term intra-operator and inter-operator precision in scan localization, and the corresponding effect on bone parameters. For reference we compared this to scan-rescan precision.

To simulate the scan localization process, we recreated the graphical user interface (GUI) of the HR-pQCT acquisition software (XtremeCT, Scanco Medical AG), specifically the scout view visualization and reference line positioning components. Eight operators, from eight centers performed the landmarking procedure in a set of 56 scout images of the radius and tibia. The scouts corresponded to in vivo exams with double-stack (220 slice) acquisitions. Based on the position of each operator's reference line, standard-size acquisition subvolumes (110 slices) were extracted for analysis to determine the impact on bone parameters. Specifically, we evaluated: 1) Intra-operator short-term precision for 8 operators on a set of 15 scout images, repeated thrice; 2) Intra-operator long-term precision (6-24 months) for 2 operators; and 3) Inter-operator variability for 8 operators on 56 scout images. Landmark location precision was calculated in millimeters as the RMS of the SDs for each scout ($SD_{RMS}$) and the effect on bone parameters as the coefficient of variation ($CV_{RMS}$). Scan–rescan precision was calculated on 57 radii and 63 tibiae reproducibility scans.

Positioning the tibia was highly reproducible, even across multiple operators ($SD_{RMS}$=0.30mm, $CV_{RMS}$<1.96%). Errors for the radius were significantly greater ($p<0.05$), and particularly high across operators ($SD_{RMS}$=0.61mm, $CV_{RMS}$=8.48% for Ct.Th). Ct.Th was considerably more sensitive to position variability than density and structure measures. Compared to scan-rescan precision, operator precision

errors were generally greater for density and Ct.Th, and less for structural parameters.

In conclusion, HR-pQCT operator precision errors were moderately high for the radius over time, within and across operators. Positioning variability contributes greater overall measurement error than patient motion. More rigorous operator training using standard tools, such as the presented GUI, would greatly benefit future multicenter studies. Alternatively a more reproducible anatomic landmark for positioning should be considered, as well as the development of automatic landmark detection techniques.