Intra- and Inter-Operator Variability in HR-pQCT Scan Positioning

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BACKGROUND

- The role of the operator is critical for comparability of data in cross-sectional studies, in particular multicenter studies
- The operator acquires a projection of the limb (scout view), and s/he visually identifies an anatomical landmark that determines the region to be scanned
- Variability in landmark identification impacts bone measurements, especially in the radius

AIM

- To quantify long-term and short-term intra-operator, and inter-operator precision
- To quantify effects of operator precision on bone parameters

REFERENCE LINE POSITIONING

- We reproduced the acquisition interface of the HR-pQCT system (XtremeCT, Scanco)
- We used scout-view images corresponding to double-stack (220 slices) HR-pQCT scans
- We virtually localized standard 110-slice volume based on each operator's positioning

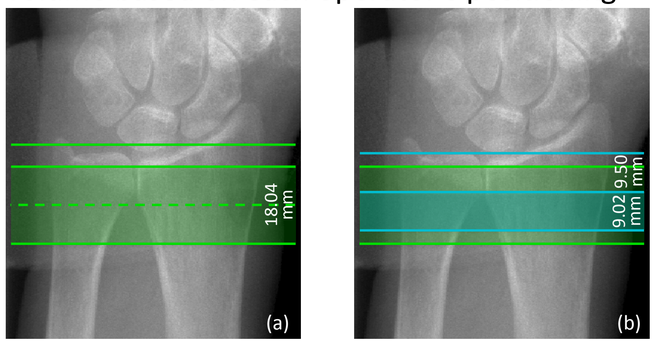

Figure 1. Scout view of double-stack volume images (a). Reference line and corresponding single-stack volume (cyan) (b).

EXPERIMENTS

- A total of 6 operators from multiple imaging positioned reference lines at anatomical landmarks on 56 scout view images
- We measured positioning precision (SD_{RMS}) and impact on bone parameters (CV_{RMS}) for:
  - Short-term intra-operator reproducibility
  - Long-term (6-24 months) intra-operator reproducibility
  - Inter-operator reproducibility

POSITIONING PRECISION AND IMPACT ON BONE PARAMETER MEASUREMENTS

- Positioning for the tibia was highly reproducible
- Errors were greater for the radius and for inter-operator reproducibility
- Ct.Th was the most sensitive bone measurement to precision variation

Table 1. Long-term and short-term intra-operator and inter-operator precision and impact of precision on bone parameter measurements for radius and tibia

RADIUS	Precision SD_{RMS} [mm]	Impact on Bone Parameter Measurements CV_{RMS} [%]					
		BMD	Ct.BMD	Tb.BMD	Ct.Th	Tb.N	Tb.Sp.SD
Short-term intra-op (O: 8; I: 15x3)	0.25	1.39	0.93	0.40	3.17	0.47	0.83
Long-term intra-op (O: 2; I: 27)	0.35	2.09	1.41	0.70	4.76	1.05	1.77
Inter-op (O: 8. I: 53)	0.68	3.69	2.56	1.46	8.40	2.12	3.11
Scan/rescan	-	0.89	0.76	0.72	2.10	4.23	5.71

TIBIA	Precision SD_{RMS} [mm]	Impact on Bone Parameter Measurements CV_{RMS} [%]					
		BMD	Ct.BMD	Tb.BMD	Ct.Th	Tb.N	Tb.Sp.SD
Short-term intra-op (O: 8; I: 15x3)	0.13	0.26	0.19	0.26	0.94	0.31	0.48
Long-term intra-op (O: 2; I: 28)	0.36	0.72	0.58	0.75	3.01	0.93	1.59
Inter-op (O: 8.I: 56)	0.30	0.61	0.42	0.65	1.97	0.85	1.43
Scan/rescan	-	0.43	1.38	0.70	1.25	5.64	6.10

O = Number of Operators. I = Number of Images.

DISCUSSION

- HR-pQCT positioning for the tibia is highly reproducible over time and across operators
- Greater position variability is observed for the radius, leading to high precision errors which exceed errors related to patient motion.
- There is a need for more reproducible landmarks, fully automatic scan positioning, and standardized training for operators

NEXT STEP: TRAINING AND EVALUATION

- We adapted the simulation user interface into a platform to train and evaluate HR-pQCT operators
- Operators position reference lines on scout view images grouped by bone laterality and landmark visibility, and receive feedbacks on their performances

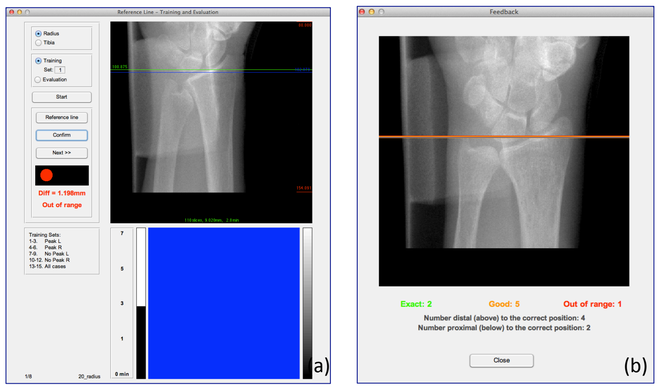

Figure 2. Training and evaluation software for reference line position (a). Feedback to operators after training (b).

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