Development of a Subchondral Knee Bone-Muscle Imaging Protocol on pQCT

Rachel D.A. Whyte[1,2], Jonathan D Adachi[3], Andy Kin On Wong[1,2*]

[1]Joint Department of Medical Imaging, [2]Centre of Excellence in Skeletal Health Assessment, University Health Network, Toronto, ON; [3]Division of Rheumatology, Department of Medicine, McMaster University, Hamilton, ON

* = Corresponding author contact:
andy.wong@uhnresearch.ca
Tel: 905-399-0329, Fax: 416-340-3215

Background

•Pain is better related to subchondral bone than cartilage in women with osteoporosis (OAI data)

•Peripheral quantitative CT (pQCT) has been used to image bone and muscle at the 66% tibia site

•Possible to use pQCT to study the knee subchondral bone in thinner individuals

Objective

•Develop a pQCT knee imaging protocol to quantify subchondral bone and peri-articular muscle

The Approach

pQCT knee imaging protocol was refined by step-wise modification based on volunteer participant feedback, resultant image quality, fidelity to subchondral bone, consistency of landmark placement, and consideration for resilience against knee OA-related joint abnormalities

Information measured using pQCT

•Subchondral bone microarchitecture
- Trabecular separation (Tb.Sp)
- Trabecular thickness (Tb.Th)
- Trabecular number (Tb.N)
- Cortical thickness (Ct.Th)
- Bone volume fraction (BV/TV)

•Volumetric bone mineral density (vBMD)
- Trabecular (vBMDtr)
- Cortical (vBMDc)
- Integral (vBMDi)

•Bone marrow fraction
•Bone marrow density
•Peri-articular muscle

Information of Interest

•Structural and density measures as well as measuring any bone marrow lesions and cysts

Where are we now?

- Scanned 10 healthy volunteers in order to determine reproducibility of protocol and scans

- Utilizing feedback with regards to positioning from volunteers to improve pQCT imaging protocol 3 for the knee before recruitment
  - Higher chair
  - Pillow to sit on
  - Chair against the wall to assist with positioning
  - Extra padding under the knee to rest on holder

Acknowledgment

This project was funded by a CIHR Project Grant (PJT-156274). Rachel Whyte received a Yonug Investigators' Award to attend the QMSKI meeting. Investigators have no conflicts of interests to declare.

Protocol 1: Technical Details

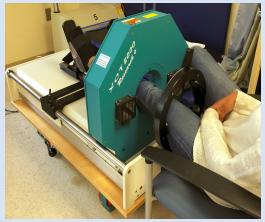
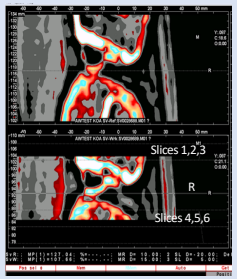
Tibial Length
•Distance from proximal aspect of the medial tibial plateau to tip of medial malleolus

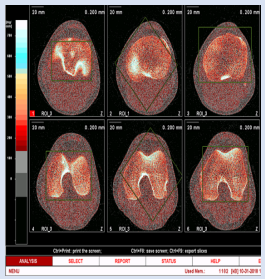
Acquisition
•**pQCT model:** XCT2000
•**CT speed:** 10 mm/s, 38 kVp, 0.3 mA
•**In-plane pixel size:** 200 µm
•**Thickness:** 2.3 ± 0.5mm
•**Effective dose:** 2.66 µSv/slice

Positioning
- **Leg position:** parallel to cart at minimum height
  - 10 cm clearance between gantry and knee
- **Laser position:** distal to patella

Scout Scan
- Sagittal view of knee
- 90 degrees
- **Speed:** 50 mm/s

Scan Prescription
- **Reference Line:** centered within joint space
- **Number of reference lines:** 1
- **Number of slices:** 6
  - Subchondral tibia: 3
  - Subchondral femur: 3
- **Distance between slices:** 2.5mm
- **Slice position:** 15mm distal to reference line, 10mm proximal to the reference line



Rationale for Change: Challenges, Limitations & Solutions

- Joint space narrowing and subchondral bone attrition commonly develop in those with knee osteoarthritis
- Using the middle of the joint to place reference lines has limitations due to the fact that structures such as the tibial plateau and in the joint are likely to change
- Changes in structures will likely lead to misplacement of reference lines for scans taken during long term follow ups

Solutions
•Modified imaging protocol 1 for correct reference line placements and landmarks used
•Attempt to use two reference lines to measure a relative site for subchondral tibia and femur
•Adapted relative slice prescription and landmark selection from study by Bennell et al. 2008

Protocol 2: Technical Details

Tibial Length
•Distance from proximal aspect of the medial tibial plateau to tip of medial malleolus

Acquisition
•**pQCT model:** XCT2000
•**CT speed:** 10 mm/s, 38 kVp, 0.3 mA
•**In-plane pixel size:** 200 µm
•**Thickness:** 2.3 ± 0.5mm
•**Effective dose:** 2.66 µSv/slice

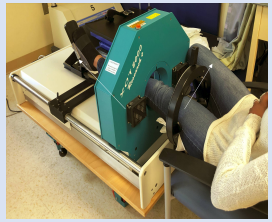
Positioning
•**Leg position:** parallel to cart at minimum height with thin padding
- 10 cm clearance between gantry and knee
- **Laser position:** distal to patella

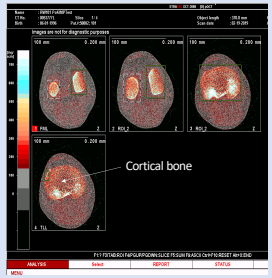
Scout Scan
- Sagittal view of knee
- 90 degrees
- **Speed:** 50 mm/s

Scan Prescription
•**Reference Line:** centered across compartments
•**Number of reference lines:** 2
- 1 at highest point of tibial plateau
- 1 at highest point of femoral condyle

•**Number of slices: 4**
- 1% of tibial length distal to tibial plateau: 2
- 1% of femur length proximal from femoral condyles: 2

•**Distance between slices:** 2.5mm
•**Slice position:** 1% distal to reference line, 1% proximal to the reference line





Rationale for Change: Challenges, Limitations & Solutions

- Measuring at the 1% site of the subchondral tibia and femur using two reference lines was unsuccessful since the knee is often angled in the scanner – tibial plateau/femoral condyles at an oblique
  - Resulted in slices capturing one compartment but missing a significant portion of the other
  - Failed to capture more pertinent subchondral region (just beneath cortex) at the tibia and 1% slices were too distal regarding the femoral condyles
- Individuals found gantry holder uncomfortable

Solutions
•To ensure full view of the subchondral bone in both femur and tibia, 4 reference lines were placed on the scout scan- one at each of the 4 compartments
•Added thin sheet between knee and leg holder for comfort

Protocol 3: Technical Details

Tibial Length
•Distance from proximal aspect of the medial tibial plateau to tip of the medial malleolus

Acquisition
•**pQCT model:** XCT2000
•**CT speed:** 10 mm/s, 38 kVp, 0.3 mA
•**In-plane pixel size:** 200 µm
•**Thickness:** 2.3 ± 0.5mm
•**Effective dose:** 2.66 µSv/slice

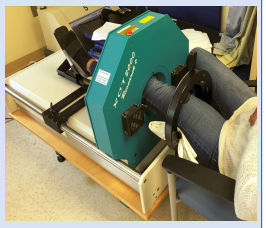
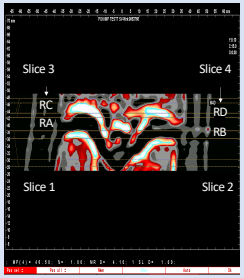
Positioning
•**Leg position:** parallel to cart at minimum height with thin padding
- 10 cm clearance between gantry and knee
- **Laser position:** distal to patella

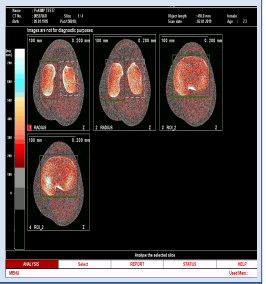
Scout Scan
- Sagittal view of knee
- 90 degrees
- **Speed:** 50 mm/s

Scan Prescription
•**Reference Line:** Placed at joint interface ie. edge of cortex next to joint space
•**Number of reference lines:** 4
- 1 Medial tibial plateau 1 and 1 femoral condyle
- Lateral tibial plateau (1) and femoral condyle (1)

•**Number of slices: 4**
- 1 slice at each compartment

•**Distance between slices:** 2.3mm
•**Slice position:** 1% distal to medial/lateral tibial plateaus, 2% proximal from medial/lateral femoral condyles



Rationale for Change: Challenges, Limitations & Solutions

- During scout scan knee was still angled-resulting in some slices being at an oblique and reference lines were a challenge to place – landmarks not always clear
  - Resulted in some missing data
- When only relying on relative slice positioning, you end up with cortex captured within slices

Solutions
•Positioned patient with thick sheet in gantry holder, assisting with angulation and comfort
•Place reference lines based on what information the scan slice will take instead of using anatomical references such as the tibial plateau and femoral condyles
- Possible place line in the internal border of the cortex