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The reproducibility of measuring trabecular bone parameters using a commercially available high-resolution magnetic resonance imaging approach: A pilot study

Sarah L. West[a,b,*], Chamith S. Rajapakse[c,d], Tammy Rayner[e], Rhiannon Miller[c,d], Michelle A. Slinger[c,d], Greg D. Wells[b,f]

[a] Department of Biology, Trent/Fleming School of Nursing, Trent University, Peterborough, Ontario, Canada
[b] Translational Medicine, The Hospital for Sick Children, Toronto, Ontario, Canada
[c] Department of Radiology, University of Pennsylvania School of Medicine, Philadelphia, PA, USA
[d] Department of Orthopaedic Surgery, University of Pennsylvania School of Medicine, Philadelphia, PA, USA
[e] Radiology, The Hospital for Sick Children, Toronto, Ontario, Canada
[f] Faculty of Kinesiology and Physical Education, University of Toronto, Toronto, Ontario, Canada

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ABSTRACT

Bone imaging is currently the best non-invasive way to assess changes to bone associated with aging or chronic disease. However, common imaging techniques such as dual energy x-ray absorptiometry are associated with limitations. Magnetic resonance imaging (MRI) is a radiation-free technique that can measure bone microarchitecture. However, published MRI bone assessment protocols use specialized MRI coils and sequences and therefore have limited transferability across institutions. We developed a protocol on a Siemens 3 Tesla MRI machine, using a commercially available coil (Siemens 15 CH knee coil), and manufacturer supplied sequences to acquire images at the tibia. We tested the reproducibility of the FSE and the GE Axial sequences and hypothesized that both would generate reproducible trabecular bone parameters. Eight healthy adults (age 25.5 ± 5.4 years) completed three measurements of each MRI sequence at the tibia. Each of the images was processed for 8 different bone parameters (such as volumetric bone volume fraction). We computed the coefficient of variation (CV) and intraclass correlation coefficients (ICC) to assess reproducibility and reliability. Both sequences resulted in trabecular parameters that were reproducible (CV < 5% for most) and reliable (ICC > 80% for all). Our study is one of the first to report that a commercially available MRI protocol can result in reproducible data, and is significant as MRI may be an accessible method to measure bone microarchitecture in clinical or research environments. This technique requires further testing, including validation and evaluation in other populations.

1. Introduction

Bone loss that is characterized by a decrease in bone mass and a disruption in bone microarchitecture is prevalent in the aging population and in both pediatric and adult cohorts with chronic disease (Cummings et al., 2002; Rodd et al., 2012; Bates et al., 2002; Bouxsein and Seeman, 2009; Legrand et al., 2000; Nickolas et al., 2010; Leonard, 2009; Shanbhogue et al., 2016; Alsufyani et al., 2005; Bhudhikanok et al., 1998; Mostoufi-Moab et al., 2012). Bone imaging techniques are currently the best non-invasive way to assess changes to bone and determine the need for treatment. Bone mineral density (BMD) measured by dual energy X-ray absorptiometry (DXA) is the current standard of care used to evaluate fracture risk (Stone et al., 2003; Miller et al., 1999). However, BMD by DXA has limitations; for example, it produces a 2-dimenstional image of a 3-dimensional structure and it cannot differentiate between cortical and trabecular bone (Bouxsein and Seeman, 2009). This is problematic because areal BMD by DXA does not reflect alterations in bone microarchitecture, which has been shown to independently influence fracture risk (Boutroy et al., 2008; Boutroy et al., 2016).

High-resolution peripheral quantitative computed tomography (HR-pQCT) is an imaging technique that can differentiate between cortical and trabecular bone and can offer insight into structural bone changes including bone microarchitecture and strength. However, HR-pQCT has

* Corresponding author at: Trent University, LHS, D231, 1600 West Bank Drive, Peterborough, Ontario K9L 0G2, Canada.
E-mail addresses: sarahwest@trentu.ca, sarahwest@sickkids.ca (S.L. West).

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Table 1
MRI derived trabecular structural and mechanical bone parameters at the tibia.

	Sequence 1 (FSE)					Sequence 2 (GE)				
	Range	Mean	Median CV (%)	IQR of CV	ICC	Range	Mean	Median CV (%)	IQR of CV	ICC
BV/TV (%)	9.03;12.62	10.73	3	4.3	0.88	13.60;17.79	15.53	3.6	2.6	0.84
TbTh (mm)	0.147;0.181	0.156	0.9	2.1	0.85	0.201;0.214	0.206	0.7	0.6	0.95
TbN (mm-1)	0.6;0.77	0.69	2.2	3.2	0.9	0.68;0.83	0.75	3	1.9	0.8
TbS (mm)	1.15;1.52	1.30	2.5	3.4	0.89	0.99;1.28	1.13	3.6	2.3	0.81
TbA (mm^2)	13.65;25.21	17.67	1.5	2.2	0.99	21.18;39.85	27.26	2.1	1.3	0.99
S/C	4.01;7.9	5.78	5.5	6.8	0.94	5.83;12.18	8.90	5.7	4.9	0.93
EI	0.56;1.17	0.8	4.0	5.5	0.98	0.39;0.83	0.6	5.6	4.4	0.92
Stiffness (GPa)	1.61;3.03	2.43	4.4	5.7	0.98	2.26;3.25	2.87	1.8	3.3	0.95

BV/TV: bone volume/total volume; TbTh: trabecular thickness; TbN: trabecular number; TbS: average trabecular spacing; TbA: trabecular area; S/C: surface to curve ratio; EI: erosion index; CV: coefficient of variation; IQR: Interquartile range; ICC: intraclass correlation coefficient.

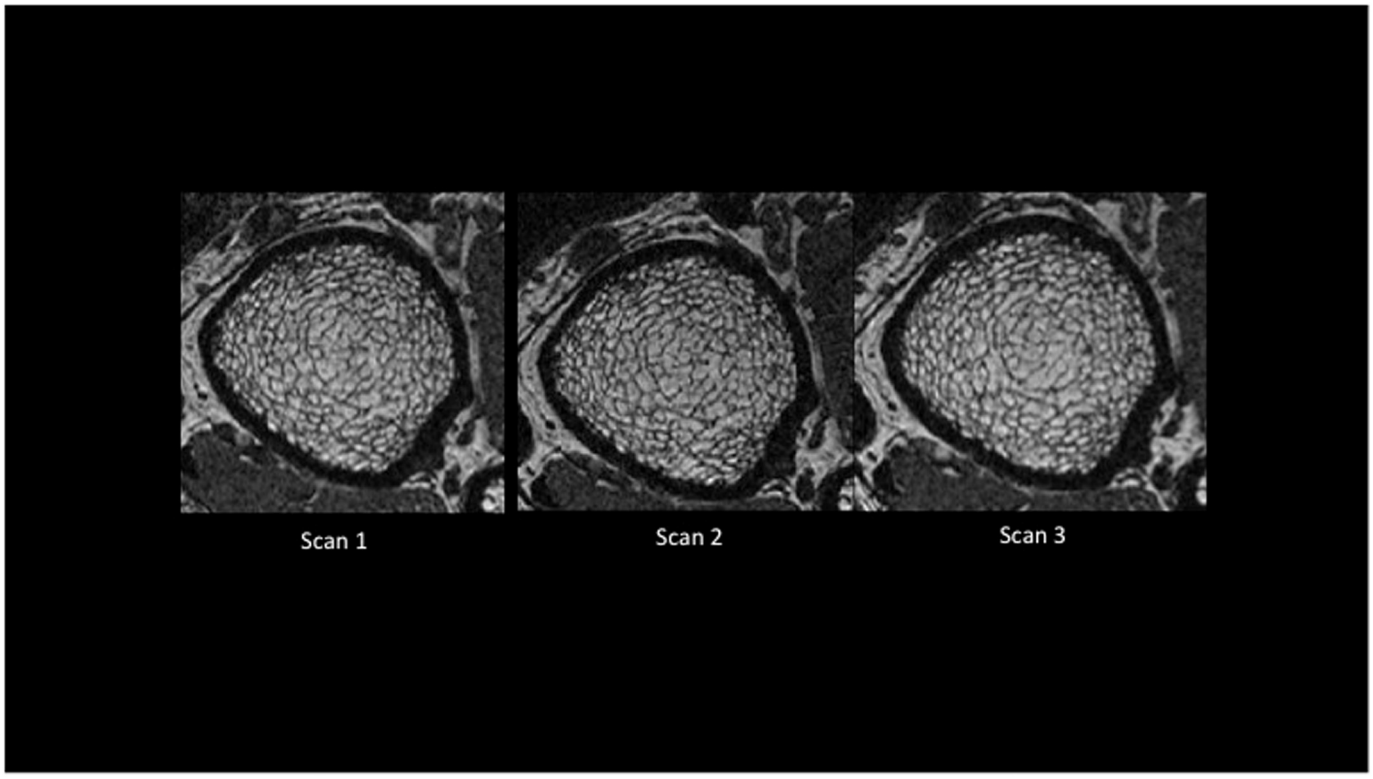

Fig. 1. Repeat images from one participant. Note the visual similarities among all three MRI scans.

limitations. For example, there are a small number of machines currently in use (~20 across Canada and the United States) and this technique is not widely available for clinical or research related evaluations. Furthermore, HR-pQCT measurements are limited to measuring peripheral sites. Recently, modern multidetector row CT (MDCT) has been identified as a reproducible and potentially transferrable trabecular bone imaging technique (Saha et al., 2015; Chen et al., 2017). However, the validity of this technique is unclear (for example, some measures such as trabecular thickness and separation were weakly correlated with gold standard micro-CT-derived values), and although lower than other CT imaging techniques, MDCT exposes individuals to radiation (Chen et al., 2017).

Magnetic resonance imaging (MRI) is associated with many advantages over other bone imaging techniques: 1) it can produce high resolution images that differentiate between cortical and trabecular bone at peripheral skeletal sites (Lam et al., 2011; Wald et al., 2010) and at the hip (Hotca et al., 2015; Chang et al., 2015a); 2) it does not involve ionizing radiation; and 3) machines are available at most major medical institutions. MRI has recently been successful in measuring bone microarchitecture (Lam et al., 2011; Wald et al., 2010; Chang et al., 2015b). However, laboratories that measure bone with MRI often use in-house built MRI coils vs. commercially available coils and in-house developed MRI sequences vs. manufacturer supplied sequences (Lam et al., 2011; Wald et al., 2010). Protocols are therefore not easily transferrable across institutions.

As a first step in addressing this issue, we developed a protocol that uses a commercially available MRI coil and manufacturer supplied sequences to acquire high-resolution images at the tibia. We tested the reproducibility of images produced with two MRI sequences (fast spin echo (FSE) Axial and gradient echo (GE) Axial) by quantifying and comparing trabecular bone parameters. We hypothesized that both MRI sequences would produce images that would generate reproducible trabecular bone microarchitecture outcomes.