

Introduction:

- Cartilage analysis from fused MRI data sets is a very promising technique for the evaluation of OA progression.
- The morphological cartilage quantification has been validated on 1.5T magnets using the FLASH sequences [1].
- Due to its ability to separate the cartilage tissue from adjacent tissue, musculoskeletal radiologists prefer the 3D GRE T2* weighted for the OA clinical evaluation.
- Recent advances in image processing have allowed the combination of FLASH and 3D GRE sequences into a single fused MR image data set.

Scope:

- This work cross validates the quantitative analysis of cartilage tissue from fused SPGR-GRE T2* weighted MRI sequences via the direct comparison to the validated FLASH MRI sequences on a 1.5T magnet. Furthermore, the fused sequence is also validated at 3.0T, by cross validating the 3.0T quantification versus the 1.5T magnet results.

Materials and Methods:

- Thirty female subjects (age 45 ± 5 years), 15 with mild/moderate OA and 15 control, were recruited at one clinical center.
- The subjects were scanned with a Siemens Symphony 1.5T MRI scanner using the following sequences:
 - 3D FLASH protocol.
 - A coronal T1 weighted 3D SPGR sequence (TE=9.15ms, TR=23ms, Flip angle=25, Nex=1, FOV=15x15cm, Slice thickness=1.5mm).
 - A coronal 3D GRE T2* weighted sequence (TE=14ms, TR=23ms, flip angle=50, Nex=1, FOV=15x15cm, Slice thickness=1.5mm).
- The same subjects were scanned in a 3.0T magnet using the equivalent 1.5T sequences.
- The 3D SPGR and 3D GRE T2* were registered and fused for both 1.5T and 3.0T sets (Figure 1 (b) and (d)).
- The FLASH, 1.5T, and 3.0T fused images were analyzed using proprietary software[2].
- The volume, average thickness, and bone-cartilage-interface (BCI) area were calculated for the tibia medial and tibia lateral cartilage (Figure 2).

Statistical Analysis:

- All tibia cartilage regions (30 medial and 30 lateral) were pooled and analyzed for the FLASH fused sequences and the fused sequences of the 1.5T magnet.

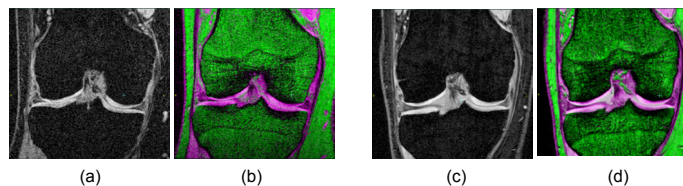


Figure 1: 1.5T 3D FLASH coronal image (a) and 1.5T registered and fused 3D GRE-SPGR image (b). 3.0T 3D FLASH coronal image (c) and 3.0T registered and fused 3D GRE-SPGR image (d).

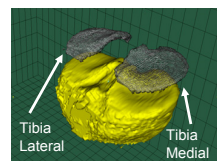


Figure 2: 3D reconstruction of the tibia lateral and tibia medial cartilage regions.

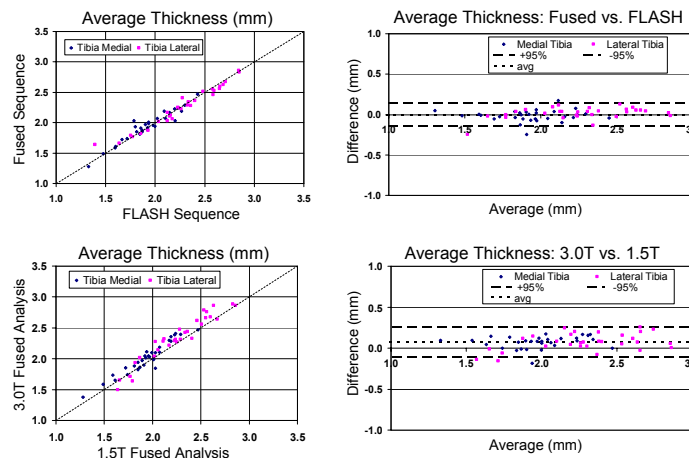


Figure 3: Scatter plots of the thickness measurements and the corresponding Bland-Altman plots.

Biomarker	Mean	Std	Bias	P value	95% LLA	95% ULA	Correlation	CV
Volume (VC) 1.5T	1966.64	393.58	29.06	0.02	-157.54	215.65	0.97	1.5%
BCI (AC) 1.5T	922.24	104.89	5.45	0.19	-57.95	68.85	0.95	1.3%
Thickness (ThCc) 1.5T	2.10	0.35	0.00	0.99	-0.15	0.15	0.98	1.5%

Table 1: Summary statistics for the fused GRE-SPGR image set versus the FLASH sequence acquired with the 1.5T scanner.

Biomarker	Mean	Std	Bias	P value	95% LLA	95% ULA	Correlation	CV
Volume (VC) 3.0T	1937.58	369.49	97.13	0.00	-135.43	329.68	0.96	1.7%
BCI (AC) 3.0T	916.79	103.50	3.37	0.51	-87.97	94.70	0.93	1.4%
Thickness (ThCc) 3.0T	2.10	0.33	0.07	0.00	-0.11	0.26	0.97	1.7%

Table 2: Summary statistics for the fused GRE-SPGR 1.5T image set versus the equivalent sequence acquired with the 3.0T scanner.

- The volume, the BCI, and the average thickness were plotted, Bland-Altman plots were generated, and the limits of agreement were computed (Figure 3).
- A paired analysis was done to compare the results and the correlation coefficient was computed.
- Reproducibility was computed using the scan-rescan data for the FLASH sequence.
- The scan-rescan data of the 3.0T magnet was analyzed and the volume, BCI, and average thickness were plotted against the 1.5T magnet results. Bland-Altman plots were generated along with the computation of the limits of agreement (Figure 3).
- To compute the bias, a paired analysis was performed. The reproducibility of the 3.0T analysis was computed.

Results:

- Summary statistics were obtained for the pooled cartilage measurements and the results from 1.5T fused images were compared to the results from the validated 1.5T FLASH images as well as the 3.0T fused image sets. Figure 3 shows the scatter plots of the thickness measurements.
- Table 1 summarizes the analysis results for the fused 1.5T vs. 1.5T FLASH sequences.
- Table 2 summarizes the analysis results for the fused 1.5T vs. 3.0T sequences.
- Both tables report the following biomarkers for the reference pulse sequence: average tibia plate cartilage (VC), thickness (ThCc), and bone-cartilage-interface-area (BCI (AC)).
- Both tables also report the standard deviation (Std), the difference between the sequences (Bias), the P value associated with a paired comparison between all the measurements, the 95% lower limit of agreement (95% LLA), the 95% upper limit of agreement (95% ULA), the correlation, and the reproducibility of the FLASH technique expressed by the coefficient of variation (CV).

Conclusion:

- This work demonstrates that cartilage quantification using the fused GRE-SPGR MRI sequences on 1.5T and 3.0T magnets are equivalent to the 1.5T quantification using the FLASH sequences.
- The small bias observed in the 1.5T cartilage volume (1.5%) and the slight difference between the 1.5T and 3.0T measurements are not large enough to be of concern in clinical research.
- The fused data sets offer higher contrast between the cartilage and soft tissue such as the meniscus and the fluid. This enhanced view opens the opportunity for a more accurate assessment of the OA stage.

References:

- 1) Glaser C., et al. *Magnetic Resonance in Medicine* 50 (2003): 1229-1236.
- 2) Tamez-Pena J. et al. *SPIE Medical Imaging* 5370 (2004): 1774-1784.