SPATIAL AND TEMPORAL PATTERN OF SPORADIC SIGNAL VOIDS IN INCOHERENT MOTION SENSITIVE EXAMINATIONS OF MUSCULATURE IN THE LOWER LEG

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Purpose

Resting skeletal musculature is usually considered to be not mechanically active[1,2], since electromyography shows only minor baseline activity which is attributed to small depolarization effects from acetylcholine releases at the motor endplates not leading to muscular contraction[3]. On the other hand, intra-voxel incoherent motion (IVIM) sensitive MR images from single acquisitions recorded in resting calf musculature in healthy volunteers often display irregularly shaped areas with clear signal voids. The reason for these signal voids is focal mechanical contraction at rest leading to intra-voxel distortions of the tissue which in turn leads to pronounced dephasing of transverse magnetization. This work reports for the first time on systematic magnetic resonance studies on the spatial and temporal pattern of such signal voids in calf musculature of 10 healthy subjects indicating unconscious muscular activity at rest.

Methods

Measurements of skeletal muscle tissue of the lower leg of 10 healthy volunteers were performed on a 3 T whole-body MR scanner (Magnetom Trio, Siemens Healthcare, Erlangen, Germany) in supine and comfortable position. For signal detection the eight channel knee coil of the manufacturer was employed. Incoherent motion sensitive transverse images (at the level of maximum cross-sectional area) were acquired with an EPI sequence using a stimulated echo for signal refocusing[4]. Sequence parameters were matrix size 64 x 64, receiver bandwidth 2004 Hz/pixel, FoV 200 mm x 200 mm, TE 31 ms, TM 145 ms and b-value 100 s/mm². Repetitive measurements using 1000 scans with a repetition time of 500 ms were executed with motion sensitizing along the z-axis. Additionally, for some volunteers the spatial pattern of the signal voids was also assessed for other slice orientations and other directions of motion sensitizing gradients. Possible effects or interactions with arterial blood pulsation were tested by repetitive ECG-triggered measurements performed at different time points in the cardiac cycle. The number of images (out of the series of 1000 images recorded in a row) with clearly visible signal voids in specific muscle groups was counted and compared for different muscle groups and individuals. Recorded images were further analyzed offline on a PC using home-made routines written with Matlab® (The Mathworks, Inc., Natick, MA, USA).

Results

Appearance and size of the signal voids were evaluated for all 10 volunteers for the muscle groups tibialis anterior (TA), tibialis posterior (TP), extensor digitorum longus (EDL), peroneus longus and brevis (PLB), soleus (SOL), gastrocnemius lateralis (GL) and gastrocnemius medialis (GM). Table 1 shows the results for transverse images with incoherent motion sensitizing in z-direction. Typical examples for size and appearance of signal losses can be seen in Figure 1 for one volunteer. Comparison of all muscle groups showed clearly more frequent activity in gastrocnemius and soleus muscles (containing a high fraction of type I fibers) compared to tibialis muscles (mainly type II fibers), which shows practically no signal voids (Figure 2). Evaluation of the size of the signal holes in the different muscle groups of all 10 volunteers led to typical sizes of the affected muscular areas from 0.5 to 2.5 cm in transverse and from 1.5 to 7 cm in longitudinal direction.

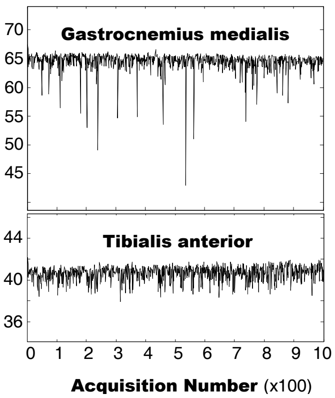

Figure 2: *Example for the temporal course of the signal intensity in ROIs positioned in the m. gastrocnemius med. and m. tibialis anterior, respectively.*

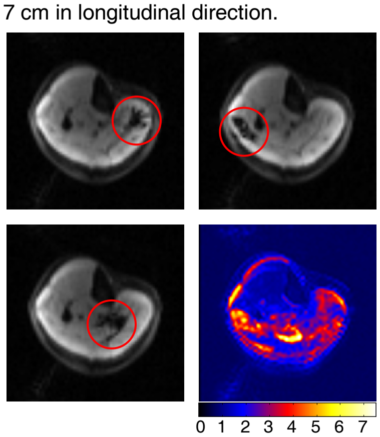

Figure 1: *Examples for signal voids in incoherent motion sensitized images in transverse orientation. Signal voids especially appear in m. gastrocnemius and m. soleus (a,b,c).*

Pixelwisely calculated standard deviation (SD) of the signal values. Appearance of larger SD values corresponds with more frequently occurring signal losses (d).

Vol.	TA	TP	EDL	PLB	GL	SOL	GM
#1	0	12	1	7	27	344	58
#2	2	2	2	4	12	36	12
#3	0	4	0	0	4	27	14
#4	0	1	5	15	6	87	14
#5	0	5	4	5	5	129	9
#6	0	0	0	0	13	45	15
#7	4	1	15	0	14	31	32
#8	1	5	1	12	27	102	55
#9	0	0	4	12	4	116	40
#10	0	0	2	24	26	356	404

Table 1: *Number of signal voids in different muscle groups for all ten volunteers for motion sensitizing in z-direction.*

Discussion and Conclusion

Spontaneous focal mechanical activity of resting calf musculature causes pronounced dephasing of transverse magnetization in incoherent motion sensitive images with an irregular temporal and spatial pattern. Possible effects or interactions of arterial blood pulsations as main reason for the signal voids could be ruled out by repetitive ECG-triggered measurements performed at different time points in the cardiac cycle. Comparison of the results with measurements with motion sensitizing in x- or y-direction showed no distinct differences concerning frequency and spatial distribution of the signal voids. As a consequence, common diffusion or diffusion tensor measurements in the skeletal musculature of the lower leg are hampered by those sporadic activity-related signal voids, when mean signals of series of measurements are used for the calculations. Those sporadic events have to be considered for quantitative DWI or DTI of musculature. Furthermore, spontaneous muscular activity might play an important role in assessment of neuromuscular diseases and resting metabolic rate, which plays an important role in pathogenesis of obesity and diabetes.

References

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