# Characterization of muscular microstructure by diffusion magnetic resonance

Laure Gauthé, Sylvie Clerjon, Denis S Grebenkov, J.-M. Bonny

# CHARACTERIZATION OF MUSCULAR MICROSTRUCTURE BY DIFFUSION MAGNETIC RESONANCE

Gauthé, Laure[1,2], Clerjon, Sylvie[1,2], Grebenkov, Denis[3], Bonny, Jean-Marie[1,2]

laure.gauthe@inrae.fr, sylvie.clerjon@inrae.fr, denis.grebenkov@polytechnique.edu, jean-marie.bonny@inrae.fr

[1]INRAE, QuaPA, F-63122 Saint-Genes-Champanelle, France

[2]INRAE, PROBE research infrastructure, AgroResonance facility, F-63122 Saint-Genes-Champanelle, France

[3]PMC, CNRS -- Ecole Polytechnique, Institut Polytechnique de Paris, F-91120 Palaiseau France

Diffusion-weighted nuclear magnetic resonance (DW-NMR) is a non-destructive technique that allows an indirect characterization of tissue microstructure through the analysis of the signal decay as a function of the diffusion weighting (b-value). For example, DW-NMR has already proven to be efficient for sizing and counting intramyocellular lipid droplets [1]. In muscle samples, our experiments revealed in particular a residual water signal at high b-values (i.e. ranging 5000 to 20 000 s/mm²) irrespective of the measurement direction. Quantifying this slowly diffusing fraction allowed estimating the organelle typical size and then inferring that it could correspond to the water fraction trapped in mitochondria [2,3]. In order to further investigate this hypothesis, we applied the same DW measurement protocol to muscles with contrasted mitochondrial contents, starting between 20 to 50 min *post mortem*. The muscles, in ascending order of mitochondrial volume fraction, were: glycolytic (*extensor digitorum longus*), and oxidative (*soleus*) skeletal muscles as well as cardiac muscles (interventricular septum and left ventricle). We mainly observed significant differences of the residual signal between skeletal and cardiac muscles (Fig. 1). This finding was in line with the expected contrast of mitochondria content, which is consistent with our hypothesis. In addition, these differences were emphasized with the increase of *post mortem* delay, which is compatible with a supposed mitochondrial swelling. All these interpretations will be confronted later to electron microscopy analysis. These results suggest that DW-NMR would be the first non-destructive technique to obtain morphometric data on mitochondria and could offer a new perspective on muscle pathologies and adaptation to exercise.
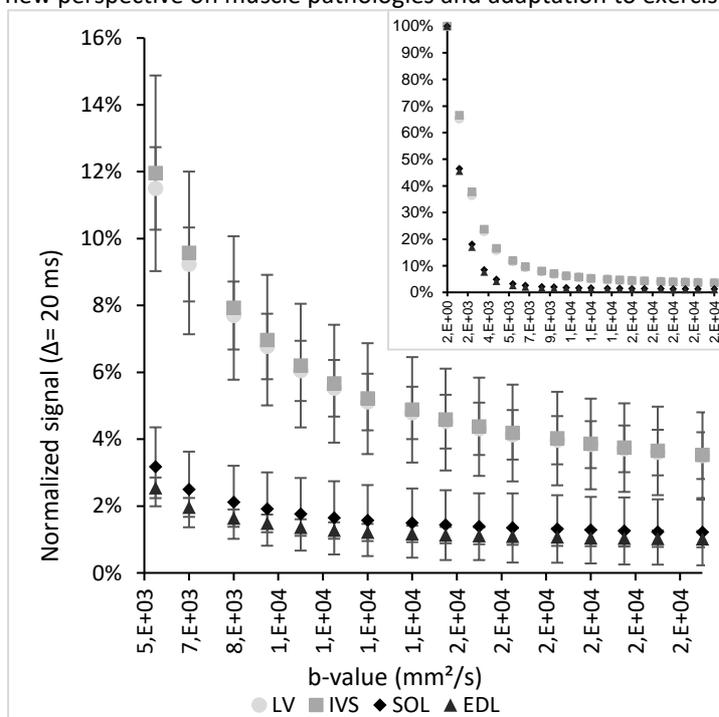


Figure 1 : Mean signal diffusion decays ± standard deviation from 4 fresh swines heart muscles (4 left ventricles: LV, 4 interventricular septums: IVS) and 4 rats skeletal muscles (4 soleus: SOL, 4 extensor digitorum longus: EDL) measured at 9.4T (Avance 400, Bruker) for δ = 3.2 ms, Δ = 20 ms and b-values up to 20 000 s/mm². The signal is averaged on six non-collinear gradient directions then normalized by the signal at the first b-value = 252 s/mm² and interpolated so that all samples are compared at a *post mortem* delay of 71 min. The inset represents the complete data and the main graph represents the same data zoomed in on high b-values.

[1] Cao, P., Fan, S.-J. et al., 2015, Magnetic Resonance in Medicine 73 (1) 59–69., doi: 10.1002/mrm.25116.
[2] Moutal, N., 2020, Institut Polytechnique de Paris, Study of the Bloch-Torrey equation associated to diffusion magnetic resonance imaging (PhD).
[3] Moutal, N., et al., 2019, ICMRM Quantifying the mitochondrial content with diffusion MRI