KWIC-Filtered Cardiac T_2 Mapping for Improved Precision and Faster Acquisition

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Target audience Basic and clinical scientists interested in cardiac tissue characterization.

Purpose In recent years, several successful variations of cardiac T_2 mapping with a varying T_2 preparation module (T_2Prep) have been described for the quantification of cardiac edema [1-3]. Radial high-resolution T_2 mapping [3] has the advantage of reduced motion sensitivity, but suffers from a lower signal-to-noise ratio (SNR) in its source images when compared to Cartesian imaging. This is due to the undersampling of k-space periphery, and due to its density compensation function (DCF), which increases the weight of this relatively "noisy" k-space periphery (Fig.1a). Since the radial source images of a single T_2 map have the same geometry, and since their differing contrast is mainly defined by the center of k-space, their peripheral k-space can be shared for noise reduction (k-space weighted image contrast KWIC [4]). This k-space sharing filter in combination with a golden-angle acquisition scheme furthermore allows the addition of several k-spaces without duplicates (Fig.1b). Moreover, when undersampling is used to acquire more images per time unit and per T_2 map (resulting in more k-space peripheries that can be shared), KWIC filtering further reduces the noise-like undersampling artifacts (Fig.1c). The goal of this study was therefore to test whether the use of the KWIC filter and undersampling leads to a higher precision in radial T_2 maps for a given acquisition time.

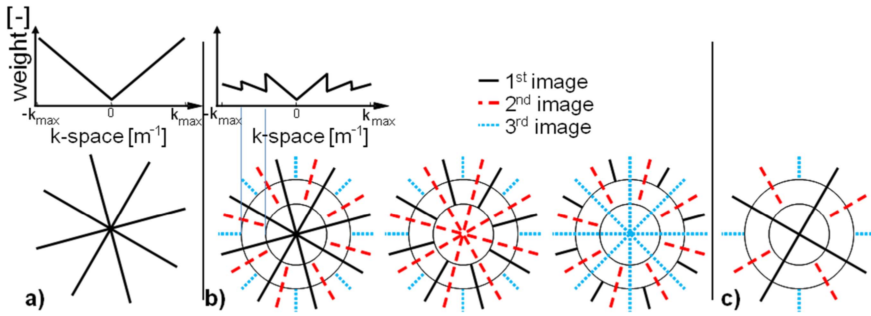

Figure 1. Schematic overview of the KWIC filter. **a)** A conventional radial k-space sampling pattern shown below its DCF along one radial line. The DCF is used to weigh the k-space points when regridding before the Fourier transform. Because of their high density, data from the center of k-space have a much lower weight than data from the periphery. **b)** Three similar k-spaces that share their periphery through the KWIC filter, thus increasing the local sampling density and decreasing the local DCF (which in turn prevents noise amplification). The circles (determined with the Nyquist criterion) indicate the radii outside of which an extra k-space is added. **c)** An undersampled KWIC-filtered k-space. While the number of lines has decreased, the periphery of k-space still has a higher sampling density than the single radial k-space in a).

Methods Baseline navigator-gated radial T_2 maps were acquired at 3T (Magnetom Skyra, Siemens Healthcare) with 3 T_2Prep durations (0, 30, and 60ms), 308 radial lines per image, matrix 256^2, and spatial resolution $(1.17mm)^2$ [3] in an agar-$NiCl_2$ phantom with relaxation times that approximated myocardium and blood. Subsequently, T_2 maps with a continuously increasing golden-angle acquisition were acquired at the same location with 6 T_2Prep durations (0, 30, 45, 60, 75 and 90ms), with 308 and 110 lines per image. T_2 maps were reconstructed both with and without the KWIC filter. The Nyquist criterion was used to define the k-space radii for application of the KWIC filter. The average T_2 value (μ_{T2}), the T_2 standard deviation (σ_{T2}, which corresponds to the precision) and the relative T_2 standard deviation ($\sigma_R=\sigma_{T2}/\mu_{T2}$; in order to account for different T_2 values) of the myocardial compartment in the resulting T_2 maps were then compared. Finally, the control T_2 map and an undersampled KWIC-filtered T_2 map (110 lines per image) were acquired in midventricular short-axis orientation in 4 healthy adult volunteers. The T_2 maps were segmented according to the AHA guidelines [5], and a paired Student's t-test was applied to test for significant differences in σ_R between the segments of the control T_2 map and the undersampled KWIC-filtered T_2 map.

Results All phantom T_2 maps demonstrated a homogenous myocardial compartment (Fig.2a). The undersampled KWIC-filtered T_2 map was acquired in 72% of the time needed for the baseline acquisition, and resulted in a σ_{T2} decrease from 2.1 to 1.2ms, or a σ_R decrease from 5.7% to 3.4% (Fig.2b). The T_2 maps in the volunteers resulted in a similarly homogenous myocardium (Fig.2c,d). In the myocardial segments, σ_R significantly decreased from 9±2% for the standard T_2 maps to 7±2% for the undersampled KWIC-filtered T_2 maps ($p = 0.002$).

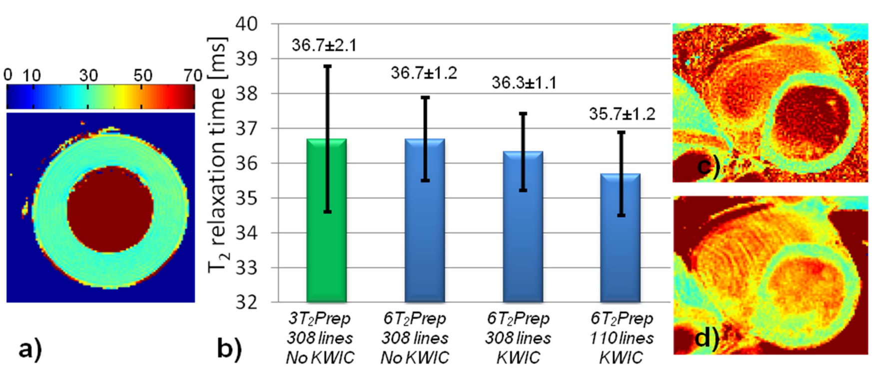

Figure 2. Radial T_2 mapping with the KWIC filter. a) Example of a T_2 map of the phantom, with homogenous T_2 in the blue-green circular compartment that has relaxation times similar to those of the myocardium. **b)** Results of the different T_2 mapping techniques in the phantoms. The undersampled KWIC-filtered image uses ~36% of the radial lines per source image of the standard T_2 map (and thus ~72% of its acquisition time), and has a significantly lower T_2 standard deviation. **c)** Standard short-axis cardiac T_2 map in a volunteer, (overall T_2=35.1±3.0ms) and **d)** KWIC filtered undersampled T_2 map (overall T_2=36.3±2.4ms).

Conclusion This study successfully demonstrated that the application of the KWIC filter to undersampled radial T_2 mapping enables a shortening of the acquisition time together with an increase in the number of points available for the fitting of the T_2 values, and therefore an increase in precision, both in phantoms and in vivo.

References **[1]** Foltz et al., Magn Reson Med 2003, 49(6):1089-97. **[2]** Giri et al., J Cardiovasc Magn Reson, 2009, 30;11:56. **[3]** van Heeswijk et al.,JACC Cardiovasc Imaging, 2012, 5(12):1231-9. **[4]** Song et al., Magn Reson Med, 2000, 44(6):825-32. **[5]** Cerqueira et al., Circulation 2002, 105(4):539-42.