

# Demonstration of a Novel Edge Analysis Technique Using a Purpose Built MR Phantom

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## Introduction

In many diseases, the interface between diseased and healthy tissue contains a great deal of information. One example of this is the brain tumor oligodendroglioma. Tumors harbouring a specific genetic abnormality, 1p/19q co-deletion, have markedly different prognoses and responses to treatment than those that do not. Several magnetic resonance (MR) image features that are significantly associated with 1p/19q deletion, but one of the best predictors is the “sharpness” of the tumor border, with poorly defined edges being associated with 1p/19q co-deletion and good response to chemotherapy and radiation treatment.<sup>1</sup>

Quantifying the properties of tissue borders in MR imaging requires an edge analysis technique. To compare edge characterization methods under controlled circumstances, we created an MR phantom in which a contrast agent diffuses across an interface. Through this process, images of the interface show a progressively less well-defined edge. Images from this phantom were then analyzed with a novel edge analysis technique based on the general Fourier family transform (GFT). The GFT is similar to the S-transform<sup>2</sup> in that it provides localized frequency measurements, but there are efficient algorithms that allow the GFT to be calculated more quickly.<sup>3</sup>

## Methods

A 2%-agar phantom as constructed. While the agar was setting, a sealed, cylindrical tube was suspended vertically in the agar. After the agar hardened, this tube was removed, leaving a cylindrical well. Immediately before imaging the well was filled with a 4% MR contrast agent (Magnevist; Bayer, Wayne, NJ) saline-solution. The phantom was imaged at 3 T (Signa; General Electric). T2-weighted (fast spin echo, TR/TE = 4500/100 ms, ETL = 16, 20 cm × 20 cm FOV, 512 × 512 acquisition matrix, 10 mm slices) and T1-weighted (gradient recalled echo, TR/TE = 4.9/1.3 ms, ETL = 1, 20 cm × 20 cm FOV, 256 × 256 acquisition matrix, 5 mm slices) imaging was repeated four times at each of 0, 6, 9, 12, 25 and 50 hours, with the phantom removed and replaced in the scanner between each repetition. The circular well simulates a lesion, such as a tumor, while diffusion of contrast material produces a progressively less defined interface, simulating invasive mixing of abnormal and normal tissue at the lesion margin.

GFT edge analysis was performed on each image at each time-point. For each image, a region of interest (ROI) was hand drawn, with the perimeter corresponding to the visually determined centre of the transition region between the contrast filled well and agar containing no contrast material. Computer software<sup>4</sup> extracted one-dimensional pixel intensity profiles perpendicular to the ROI perimeter. These profiles were transformed with the GFT and averaged to provide a mean space-frequency spectrum describing the edge. These spectra were statistically analyzed using repeated-measures ANOVA.

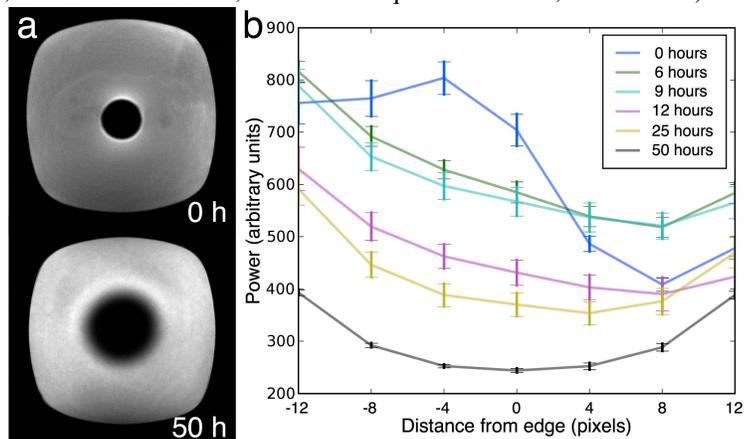


Figure 1: T2-weighted images from 0 h and 50 h (a) and the high frequency band (0.64 mm<sup>-1</sup> to 1.28 mm<sup>-1</sup>) of the GFT spectra (b). Error bars indicate standard deviation.

## Results

Between each imaging time-point, contrast agent diffused from the well into the surrounding agar, resulting in a gradual transition between an initially sharp, well-defined edge to a gentle, poorly defined edge at 50 h (Figure 1a).

The GFT edge analysis procedure detected significant changes between time-points on both contrasts (T1:  $p < 0.0007$ , T2:  $p < 0.0005$ ; Greenhouse-Geisser correction). The GFT spectra show a decrease in power over time in the mid and high frequency bands at locations within the transition region (Figure 1b).

## Conclusions

The phantom design provided MR images with edges ranging from hard to soft depending on the amount of time allowed for diffusion of the contrast agent into the agar. The GFT edge analysis technique successfully detected and quantified these differences. The GFT spectra all have similar shapes, except for the 0 h spectrum (Figure 1b). This difference is due to the transition region on the initial scan being very narrow, so a great deal of spatial variation is observed. By taking advantage of the spatial information provided by the GFT, extrema in the spectrum could potentially be used to fine-tune hand-drawn ROIs. This proof-of-principle study shows the potential utility of the GFT to differentiate lesion edge characteristics, which can assist in the diagnosis and treatment of different pathologies, such as with oligodendrogliomas.

## References

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