Impact of motion correction on quantitative analysis of dynamic contrast enhanced MRI of kidney tumors

H. von Tengg-Kobligk[1], G. Jia[1], M. J. McAuliffe[2], P. L. Choyke[2], M. V. Knopp[1]

[1]The Ohio State University, Columbus, OH, United States, [2]National Institutes of Health, Bethesda, MD, United States

Synopsis

Motion of organs is an undesirable occurrence during dynamic contrast enhanced MR imaging especially relevant for pixel based quantitative analytical methods. Targeted region-of-interest analysis is susceptible to motion related errors in unregistered time-series datasets. We evaluated the capabilities of an automated registration algorithm using a pixel-based similarity cost function to register the time-series datasets of patient's kidneys. Subsequently; we analyzed the effect of motion correction an quantitative ROI based analysis. We found that the methodology is robust and reproducible and, as expected, substantial effects on quantitative parameters we noticed. Motion correction does improve classification of tissue enhancement patterns.

Introduction

Quantitative analysis of dynamic contrast enhancement in tumors has been implemented by various groups using different models (1,5). The key to diagnosis is the ability to characterize the rise in the MR signal level as the contrast agent passes through the tissue. Based on targeted region-of-interest (ROI) analysis, time signal intensity curves are derived and pharmacokinetic parameters can be calculated. The pattern of the curve, as well as the specific model parameters (amplitude, k_{ep}, etc.) is important for diagnostic classification. In abdominal organs like the kidney, however, there is an additional challenge of physiological motion; breathing in addition to general patient motion. Different approaches have been reported to correct motion (2-7). In this study, time intensity curves, as well as individual pharmacokinetic parameters, were intra-individually compared prior and after motion correction to evaluate if registration improves differentiation of healthy parenchyma versus malignant tissue (tumor).

Materials and Methods

30 patients with renal tumors were included in the study protocol. Dynamic coronal datasets were acquired on a clinical 1.5-T MR system (GE SIGNA) using a fast gradient-echo sequence (3D-FSPGR): repetition time = 7.5 msec, echo time = 2.9 msec, flip angle = 40º, FOV = 320, matrix size = 256 x 256, slice thickness = 7.0 mm, number of excitations = 0.5 using a standard phased array body coil. Total scan time was about 8 minutes. After the third phase a small molecular weight paramagnetic contrast agent (e.g. Gd-DTPA, Magnevist®) was injected using a power injector at a constant infusion rate of 0.3 cc/s; dose 0.1 mmol/kg bodyweight for approximately one minute. Image registration was performed using MIPAV (Medical Image Processing Analysis and Visualization, CIT, NIH) software (8). Different algorithms for motion correction were investigated (AIR linear, optimized automatic registration (OAR) 2D + time and manual 2D series registration) and an algorithm using a pixel-based similarity cost function was used. For quantification, we applied a two-compartment pharmacokinetic model and evaluated the effects on Amplitude, exchange rate and elimination rate. Region of interest (ROI) analysis was standardized by saving the ROI size and coordinates.

Results

After motion correction, the number of assessable voxels within a targeted ROI increased for tumor lesions from a median of 86% assessable voxels to 97% and for normal renal parenchyma from 96% to vs. post 99%) (Tab. 1, Fig. 1). The median k_{ep} of the tumor ROI increased by 25% whereas the parenchyma value slightly decreased by 5%. (Tab. 1). In addition, the time intensity curves showed smaller variance after registration.

Conclusions

Automated, software based motion correction can substantially improve quantitative analysis of dynamic contrast enhancement in abdominal organs. We found that motion artificially reduces malignant enhancement patterns and increases time intensity patterns of benign tissue areas. The effect for contrasting differences in the enhancement pattern for quantitative evaluation was pronounced. This pilot data, warrant further validation of this approach and suggest, that motion correction should be seriously considered in organs that are prone to physiologic or involuntary motion.

References

1. Taylor JS et al, JMRI, 1999, 10:903-7.
2. Gerig G et al, JCAT, 1991, 15:725-32.
3. Bidaut LM et al, JMRI, 2001, 13:648-55.
4. Bruckner T et al, Med Phys, 2000, 27:2456-61.
5. Hayton P et al, Med Image Anal, 1997, 1:207-24.
6. Welch EB et al, MRM, 2002, 48:147-56.
7. Zuo CS et al, Radiology, 1996, 198:903-6.
8. McAuliffe MJ et al, IEEE CBMS, 2001:381-386.

Table 1: Comparison of the median for total counts (pixel) in ROI of tumor and parenchyma. k_{ep}=exchange rate, Diff.=difference

	Tumor			Parenchyma		
	Pre	Post	Diff.	Pre	post	Diff.
Total counts	216	245	29	1117	1152	35
Maximum counts	252	252	0	1161	1161	0
kep<=5	51%	38%	-13%	49%	49%	0%
kep>5	49%	62%	+13%	51%	51%	0%
kep>8	41%	51%	+10%	41%	39%	-2%

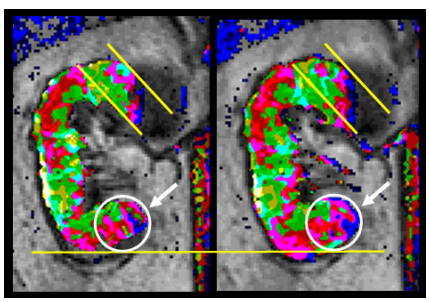

Figure 1

Fig 1: Intra-individual comparison of color coded maps of right kidney with tumor at the lower pole (circle) pre (left) and post (right) automated registration. Note that the number of colored pixels increased after registration covering the whole kidney and tumor (yellow lines are used for reference).

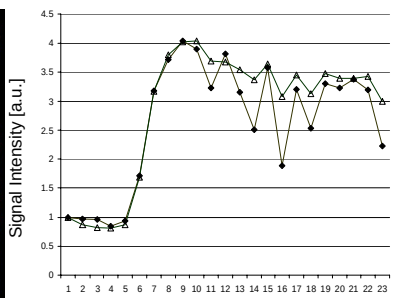

Figure 2

Fig 2: Time intensity curve of a tumor ROI. Filled diamond = pre-registration, open triangle = post-registration