Importance of T1-Correction in T1-Weighted MR Renal Perfusion Measurements

C. Kremser[1], M. Abd Ellah[1], L. Pallwein-Prettner[1], C. Wolf[1], F. Frauscher[1], G. Bartsch[2], W. Jaschke[1], and M. Schocke[1]

[1]Dept. of Radiology, Innsbruck Medical University, Innsbruck, Tyrol, Austria, [2]Dept. of Urology, Innsbruck Medical University, Innsbruck, Tyrol, Austria

Introduction

There is a steady interest in renal perfusion measurements because they offer a non-invasive way to determine renal function of the individual kidneys. Thereby usually T1-weighted measurement sequences are used to obtain the time course of a contrast agent (CA) after bolus injection. However, CA concentration-time curves obtained in this way are prone to errors due to non-linear signal behavior or tissue-specific influences (1) as long as no signal calibration is performed (2). In this study we demonstrate how the omission of signal calibration may influence the results and conclusions of clinical studies.

Matrials and Methods

For this study dynamic contrast enhanced (DCE) MRI was performed on patients before and after extracorporeal shockwave lithotripsy (ESWL) to remove renal stones. MR Imaging was performed on a 1.5T Magnetom VISION plus whole body scanner (Siemens, Erlangen, Germany). Each patient was examined before and 6 hours after ESWL. Typically the time between both examinations was about 24h. DCE perfusion imaging was performed using a saturation recovery snapshot FLASH sequence. The saturation preparation period was followed by a snap shot FLASH imaging sequence which allowed an interleaved acquisition of multiple slices (16 slices, TR=71ms, TE=2.1ms, TI=1000ms, flip angle=8°, slice thickness: 6mm, slice gap: 1.8mm, acquisition matrix: 64x128). For dynamic imaging the sequence was repeated 30 times and every acquisition was performed in a breath-hold state. To allow the patient sufficient recovery after each breath-hold the time-interval of successive acquisitions was chosen to be 20sec. The contrast agent was injected for all patients intravenously using a MR compatible injector (Medrad, Indianola, PA, USA) at the slowest available rate of 0.1 ml/s using a fixed dose of 7ml of a Gd-DTPA (Magnevist, Bayer-Schering, Germany). Injection was started after two initial pre-contrast acquisitions. To be able to calculate changes of relaxation rate, pre-contrast tissue T1-values were acquired using a fast T1-mapping sequence based on an inversion recovery snapshot FLASH sequence as originally described by Haase et al (3). Details of sequence implementation and T1-calculation have been published elsewhere (4). The obtained native T1 values were used to calculate CA concentration time curves from the saturation recovery data assuming a linear relationship between the bulk tissue relaxation rate, R1=1/T1, and the CA concentration. To obtain a measure of tissue blood flow from the obtained concentration time curves the maximum slope of the initial CA uptake was determined.

Results

Figure 1 shows the slope values obtained from uncalibrated T1-weighted signal intensities for treated and untreated kidney regions (cortex and medulla) before and after ESWL. Significant changes are observed between measurements before and after treatment even for the untreated kidneys. Figure 2 shows slope values obtained for the same kidney regions, however, this time after calibration with the acquired native T1 values. After calibration no significant differences are seen before and after treatment in both kidneys. Comparing T1 values for the pre and post treatment examinations (figure 3) it turns out that after 24h there is still a significant T1 reduction seen which is due to residual CA. Since the initial slope of CA uptake correlates with tissue blood flow the above observation on uncalibrated data would lead to the conclusion that ESWL leads to a significant decrease of blood flow in treated and untreated kidneys. With signal calibration the results lead to a different conclusion, that perfusion is not changed as a result of ESWL. From ultrasound examination it is known that the renal vascular resistance increases as a result of ESWL, which can be explained by post ESWL trauma resulting in vasoconstrictive agents release and tissue edema. This points at some auto-regulatory mechanism which keeps kidney tissue perfusion constant despite increased vascular resistance.

Conclusions

The presented results show that the omission of signal calibration in T1 weighted DCE perfusion studies may significantly change observed results and their clinical interpretation. This is especially true for the repetition of perfusion studies in the kidneys on two consecutive days. It was observed that residual CA in the kidney after 24h leads to visible changes in kidney T1-values which in turn affects relative signal changes of T1-weighted sequences and thus the outcome of perfusion measurements.

References

[1] Hittmair, K., et al., Magn Reson.Med. 1994;31(5):567-71. [2] Vallee, J. P., et al. Eur Radiol 2000;10(8):1245-52. [3] Haase A, et al., JCAT 13(6): 1036-40 (1989) ; [4] Kremser C, et al. JMRI 2007; 26(3):662-71. [5] Knapp R, et al. J Urol 1995;154(3):955-8.

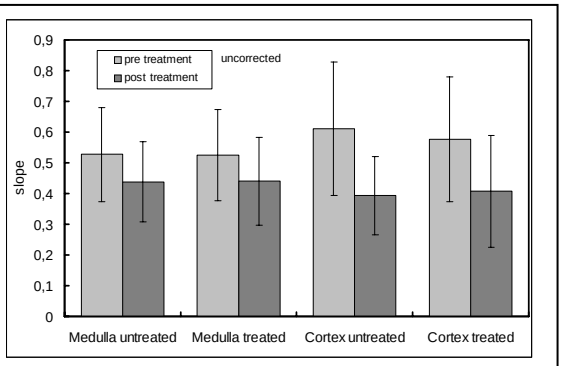

Figure 1: slope values obtained from uncalibrated T1-weighted signal intensities for different kidney regions

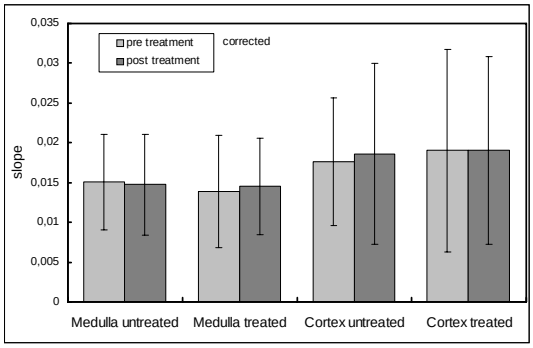

Figure 2: slope values obtained after calibration with the acquired native T1 values

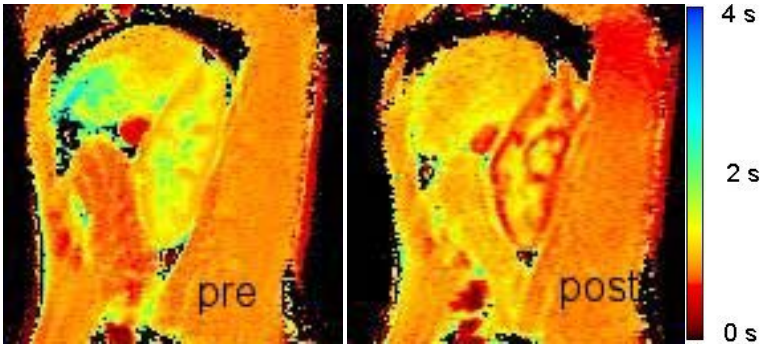

Figure 3: Kidney T1 maps before and after ESWL treatment