Quantitative magnetization transfer imaging in postmortem brain at 3T using bSSFP

M. Soellinger[1], C. Langkammer[1,2], T. Seifert-Held[1], N. Krebs[2], M. Gloor[3], E. Scheurer[2], K. Scheffler[3], F. Fazekas[1], and S. Ropele[1]
[1]Department of Neurology, Medical University of Graz, Graz, Austria, [2]Ludwig Boltzmann Institute for Clinical-Forensic Imaging, Graz, Austria, [3]Department of Radiology, University Hospital Basel, Basel, Switzerland

Introduction

Balanced steady state free precession (bSSFP) has been proposed recently for quantitative magnetization transfer (qMT) imaging [1]. Basically, bSSFP allows the determination of fundamental parameters of the two pool model [2], provided that T_1 and B_1 data are available. A critical point is the estimation of G0, which is the on-resonant singularity of the superlorentzian absorption line shape [3] and closely linked to the transverse relaxation time of the bound pool $T_{2,restricted}$. G0 has a strong influence on the resulting qMT parameters, but can vary significantly according to the estimation procedure. For in-vivo studies reference data from other qMT techniques can be used to calibrate G0. To our knowledge there are no such reference qMT data for postmortem studies on healthy brains available. Therefore, we present an empirical calibration method for G0 which is based on cross-linked BSA (bovine serum albumin) probes of different concentrations, mimicking brain tissue with different bound pool fractions. First results of postmortem in-situ brain-scans are shown.

Methods

All measurements were performed on a 3T Tim Trio (Siemens Healthcare, Erlangen, Germany) transversally covering the whole brain. The protocol consisted of i) standard multislice inversion recovery T_1 measurements with six different inversion times (6-12°C: TI=100-1200ms, 12-20°C: TI=100-3200ms) (1x1x4mm³) ii) multi-slice B_1 mapping using a stimulated echo approach (2x2x5mm³) iii) eight bSSFP sequences with TR/T_{RF} of 5.8 and varying flip angles from 4 to 35° as well as ten bSSFP sequences with a fixed flip angle of 30° and varying TR/T_{RF} ranging from 2.4 to 8.2 (1.3x1.3x1.3mm³). Further postprocessing and fitting of the MT model were performed as described in [1]. For empirical calibration six cross-linked BSA samples with concentrations from 0.1-3.0 BSA/water per weight were measured at several temperatures ranging from 6-20°C. Temperature was monitored in the phantom with a fluoroptic thermometer (Luxtron 790) and cooling was performed with ice cubes in a separate compartment. G0 was calculated [3] with a pulse duration of 600µs, time-bandwidth product of 2.7 and $T_{2,restricted}$ of 9.6µs, representing the average of white and grey matter at 3T [4]. Additionally, bound pool fractions (BPF=bound proton pool / (free proton pool + bound proton pool)) were estimated for all probes with different G0 ranging from 1.4E-5 to 2.1E-5. Linearity between the six BSA concentrations and the calculated BPFs was used as a selection criterion for the optimal G0. Three deceased subjects without known neurological deficits aged 48, 59 and 81 years were measured within 72 hours after death. Body temperatures before scanning ranged from 4.5-6.5 °C. Additionally, two healthy volunteers aged 33 and 41 years were measured with the same parameters.

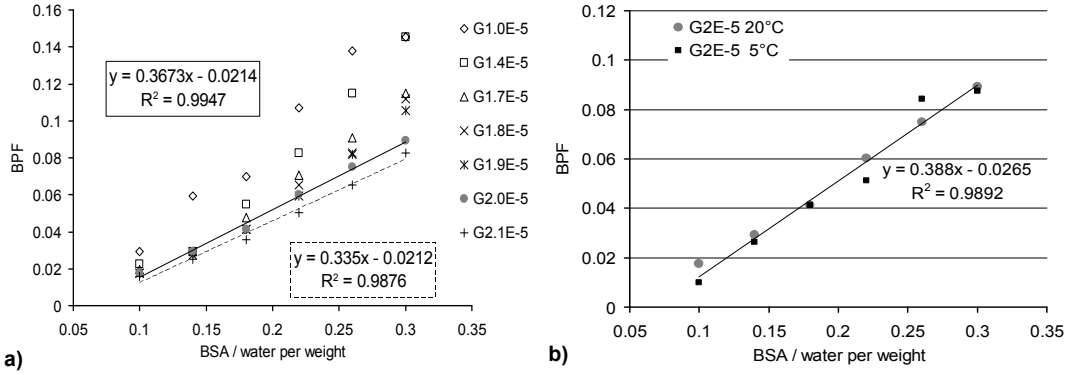

Figure 1:
a) Bound pool fractions (BPF= bound proton pool / (free proton pool + bound proton pool)) calculated with different G0s from qMT bSSFP measurements at 20°C. **b)** BPF at 20°C and 6°C for a G0 factor of 2.0E-5 for different concentrations of cross-linked BSA.

Results

Conventional calculation of G0 for 3T resulted in G0 = 1.4E-5. BPF results with the highest linearity for the BSA concentration range investigated were obtained for G0 = 2.0E-5. This result was found to be independent from temperature in the investigated range of 5 to 20°C (Figure 1) and used for all further calculations. Means from the ROI analysis are presented in Table 1 for the pool size ratio f. Figure 2 shows representative qMT maps of two postmortem scanned subjects (#1 and #2 in Table 1), deceased at the age of 48y and 81y. In vivo datasets revealed average values of f=0.17/0.15 in frontal white matter and f =0.086/0.073 in the putamen for volunteer 1/2.

Table 1: Pool size ratio f (bound proton pool / free proton pool) is presented for G0=2.0E-5 in three deceased subjects for three regions.

In situ f	Age	Time after death	Frontal WM	Occipital WM	Putamen
# 1	81y	61h	0.098	0.076	0.069
# 2	48y	64h	0.106	0.097	0.084
# 3	59y	50h	0.128	0.098	0.076
Mean	62y	58 h	0.111	0.091	0.076

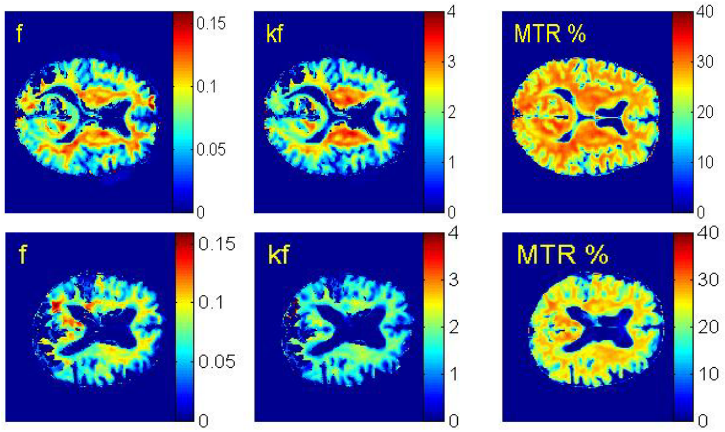

Figure 2: Exemplary slices of two in situ datasets. Upper row: about 64 hours after death, 48y. Lower row: about 61 hours after death, 81y. The pool size ratio f (bound proton pool/ free proton pool), forward transfer rate kf and magnetization transfer ratio MTR were calculated with G0=2.0E-5.

Discussion

Using an experimental setup with cross-linked BSA phantoms, we extended the theoretical calculations to optimize G0 in post-mortem qMT. G0 proposed for fitting the bSSFP data acquired with the above settings at 3T is higher than G0 calculated according to [3]. Additionally, the experimental setup showed that the sensitivity of G0 on BPFs is augmented with the increase of BSA concentration. The offset in the linear equation in Figure 1b) indicates slightly underestimated BPFs with the proposed G0. In-vivo measurements using G0 = 2.0E-5 were in good agreement with [5]. All postmortem data showed decreased pool size ratio f in white matter compared to healthy volunteers, whereas Figure 2 suggests an additional age dependent decrease, which is to be verified in an ongoing study.

References *[1] Gloor et al MRM 60:691–700 (2008) [2] Henkelman et al MRM 29:759–766 (1993) [3] Bieri et al MRM 56:1067–1074 (2006) [4] Stanisz et al MRM 54:507-12 (2005) [5] Sled et al MRM 46:923–932 (2001)*