MRI of an Egyptian Mummy on Clinical 1.5 and 3 T Whole Body Imagers

M. Bock[1], P. Speier[2], S. Nielles-Vallespin[2], M. Szimtenings[2], K. Leotta[1], and F. Rühli[3]

[1]Medical Physics in Radiology, Deutsches Krebsforschungszentrum (dkfz), Heidelberg, Germany, [2]Siemens Medical Solutions, Erlangen, Germany, [3]Institute of Anatomy, University of Zurich, Zürich, Switzerland

Introduction

Nondestructive diagnostic imaging of ancient mummies has a long tradition, and high-resolution images of the morphology of these remains have been acquired with computed tomography (CT since the 1970's. Due to the low water content, MRI of ancient mummies has initially only been reported on artificially re-hydrated mummified tissue [1], a process which could hardly be regarded as nondestructive. Recently, proton and sodium MRI of a ancient mummified finger have been demonstrated in a high-field small animal MRI system [2]. Due to the short T2 of about 300 µs and the relatively long echo times (TE > 800 µs) used in this study, a sufficient SNR could be achieved at long scan times. In this work, we investigated whether proton MRI of a mummified Egyptian human head is feasible within short measurement times on clinical MRI systems.

Fig 1: Head of an Egyptian mummy in a transmit-receive coil.

Materials and Methods

The isolated head of an Egyptian mummy (1000 B.C., former collection of Musée d'Orbe, Switzerland) was imaged with three different pulse sequences offering an ultra-short TE below 1 ms (Fig. 1). The sequences were implemented on a clinical 1.5 T (Avanto) and 3 T (Tim Trio, Siemens, Erlangen, Germany) system, which both provided a G_{max} = 40 mT/m:

1. 3D radial pulse sequence with ultra-short TE (UTE): minimum echo time TE_{min} = 70 µs, TR = 2.2 ms, BW = 2440 Hz/pixel, matrix = 256^3, TA = 4 min
2. Single Point Imaging (SPI) pulse sequence: TE = 150 µs, TR = 1.1 ms, matrix = 256^3, TA = 9 h, 2 averages
3. 3D FLASH pulse sequence: highly asymmetric readout (10%), TE_{min} = 450 µs, TR = 1.5 ms, BW = 1300 Hz/pixel, matrix = 192^3, TA = 33 min

On both systems volume transmit-receive coils were used to reduce the peak voltages for the non-selective rf excitation pulses. Additionally, the relaxation times T1 and T2* were measured with the radial pulse sequence by varying the flip angle (α = 5°-85°) and the echo time (TE = 70-500 µs), respectively. For co-localization high-resolution CT data sets of the head were acquired with a prototype flat panel volume CT system (Siemens, spatial resolution: 100 µm).

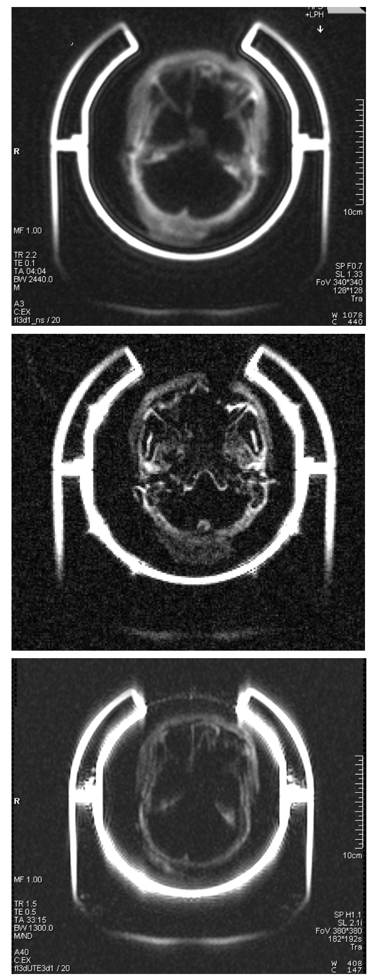

Fig 2: (top) 3D radial, (center) SPI, and (bottom) 3D FLASH image of the head at B_0 = 1.5 T. In all images the Tx/Rx rf coil is visible as a bright ring structure.

Results and Discussion

The relaxation times of the mummy tissue were T1 = 12.7 / 58.9 ms and T2* = 135 /145 µs at 1.5 / 3T. All three pulse sequences were able to visualize mummified tissue (e.g., the tongue), embalming material in the skull, and even bandages (Fig. 2). As expected, the SPI sequence offered the highest spatial resolution due to the absence of signal decay during data reception, however, at the cost of a very long measurement time (9h). The radial sequence had the highest SNR per unit time, but minor blurring of the edge structures was detectable. In the FLASH images details of the anatomy were also visible with a highly pronounced T2* contrast due to the relatively long echo time. The morphological comparison with CT (Fig. 3) showed the excellent agreement and the complementary nature of the data sets. This study demonstrates that MRI of ancient mummies can be performed without re-hydration in less than an hour on conventional clinical MRI systems.

References

[1] Piepenbrink H, et al. Am J Phys Anthropol 1986; 70:27-28.
[2] Münnemann K, et al. Magn Reson Imaging 2007; 25(9): 1341-5.

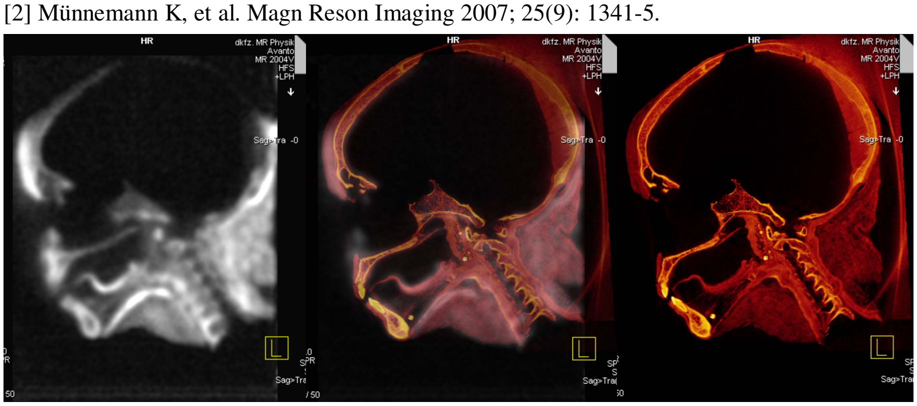

Fig.3: (Left) 3D radial MRI, (right) volume CT, and (center) merged images. With both modalities, fine anatomical structures as the tongue are visible in this mid-sagittal image.