ZTE MRI ENABLES IMAGING OF EGYPTIAN MUMMY: A COMPARISON TO CT AND THZ IMAGING

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Introduction

Non-invasive imaging of ancient mummified tissues is of increasing interest in paleoanthropology and paleopathology [1]. The imaging modality of choice for these objects is still conventional radiography or computed tomography (CT). However, the ability to differentiate soft tissues by CT in mummies is limited. Magnetic Resonance Imaging (MRI) has already been applied to ancient remains using 3D radial pulse sequences with ultra-short TE (UTE) with long scan times of several hours [2-4]. Zero echo time (ZTE) imaging further increases the ability to image short T2 samples with MR, but has not been applied to mummified remains so far. In this study we demonstrate ZTE MRI of dehydrated tissue by the examination of an ancient Egyptian mummified fish. We compare the results to the gold standard of paleoradiology, CT, and a promising emerging technique, Terahertz (THz) imaging [5].

Methods

An embalmed ancient Egyptian fish (*tilapia*, private collection, undated, ancient Egyptian time period; see Fig. 1) was imaged with a 3D ZTE sequence on a preclinical 9.4 T MR system (BioSpec 94/20, Bruker, Ettlingen, Germany) with a maximum gradient strength of 680 mT/m. For RF excitation and signal detection a Tx/Rx whole-body mouse quadrature birdcage coil (BGA12S, Bruker, Ettlingen, Germany, ∅ = 36 mm) was used along with the following imaging parameters: interval between excitation pulse and acquisition D = 10.9 µs at TE = 0, TR = 5 ms, FOV = 9 cm, BW = 625 kHz/px, matrix = 256^3, voxel size $(350\ \mu m)^3$, 10 averages. CT images (Philips Brilliance CT 40, Hamburg, Germany) were performed with slice-thickness 0,67 mm, matrix size: 512 x 512, tube voltage 120 kVp, tube current 87 mA, pixel spacing 172 µm. In addition, Terahertz transmission images were recorded by spatially raster-scanning the samples through the focus of a standard THz time-domain spectroscopy system. Fourier-transformation of the waveforms at each spatial pixel yields the corresponding amplitude spectra enabling the extraction of THz amplitude transmission images at different frequencies within the useable bandwidth of the experiment (10 GHz–3 THz) [5].

Results

Figure 1 shows a comparison of the ZTE MR images with CT and THz data. With all imaging modalities the vertebral column of the *tilapia* could be delineated (Fig. 1, arrow). The orbital region could be identified in CT and MRI but not in THz in this case. However, reconstruction at a different frequency enables also visualization of the orbita [5]. ZTE MR images appear significantly more blurred than the CT images. A comparison of the signal-to-noise ratio (SNR) of some anatomical structures is listed in Table 1.

***Table 1**: SNR values of selected anatomical regions (MR measurement).*

	Vertebral column	Abdominal hypointensity	Orbital region
SNR	83	22	32

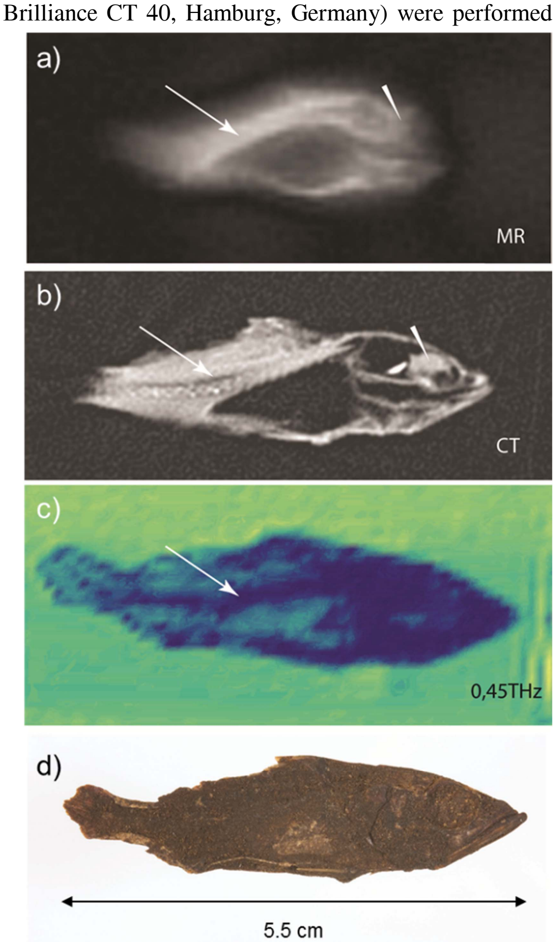

***Figure 1:** Embalmed ancient Egyptian mummified fish (undated): coronal images acquired with a) MR, b) CT, c) THz imaging at 0.45 THz. Note that THz imaging is a projection technique. d) Photograph. Arrow indicates the vertebral column, wedge shows orbit region.*

Discussion & Conclusion

With ZTE MRI, the main anatomical structures of the mummified fish could be clearly distinguished. The strong blurring artifacts in the ZTE images are caused by the rapid T2* signal decay in the order of 0.2ms during data readout. To overcome the blurring, alternative acquisition strategies such as single point imaging (SPI) might be used and combined with ZTE. Currently, ZTE is routinely available only on small animal systems [6]; however, an implementation on a whole-body MR system was shown recently [7].

In this preliminary work, ZTE MRI mummified tissue was presented for the first time. While CT remains the gold standard for imaging of mummified ancient remains, ZTE MRI could potentially deliver complementary information about these highly valuable objects. In combination with projection techniques such as THz imaging, the combination of various imaging modalities might help to visualize anatomical structures that remain unidentified in CT imaging alone. Improvements in ZTE MRI could eventually also lead to novel clinical MR applications for the visualization of structures such as teeth, tendons, and bones.

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Acknowledgements

We thank the Academy of Excellence of the German Research Foundation and the Mäxi foundation, Zürich, for financial support.