Zero TE based PET attenuation correction in the head

Florian Wiesinger[1], Anne Menini[1], Sangtae Ahn[2], Lishui Cheng[2], Gaspar Delso[3], Sandeep Kaushik[4], Ravindra Manjeshwar[2], and Dattesh Shanbhag[4]
[1]*GE Global Research, Munich, Germany,* [2]*GE Global Research, Niskayuna, NY, United States,* [3]*GE Healthcare, Zurich, Switzerland,* [4]*GE Global Research, Bangalore, India*

Target Audience: MR and PET/MR physicists

Introduction: PET/MR is a novel hybrid imaging modality which promises to influence radiology in the near and long-term future. Despite dedicated and focused research efforts, MR-based PET attenuation correction (MR-AC) as required for quantitative PET is still considered challenging; especially when compared to PET/CT[1,2]. A particular challenge is the correct characterization of bone; i.e. the tissue with the highest PET attenuation value but which appears invisible (and indistinguishable from background air) using standard MR methods. Recently zero TE (ZT) has been demonstrated to perform fast and reliable bone depiction and segmentation[3]. Here we investigate its feasibility for ZT-based PET attenuation correction (ZT-AC) in the head.

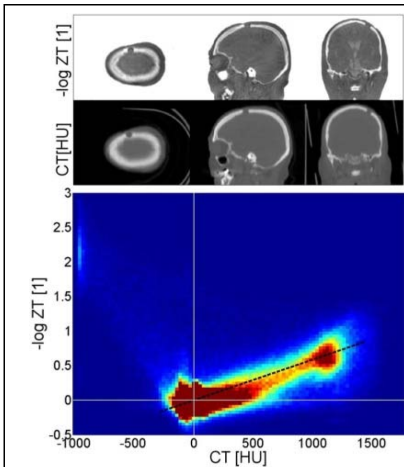

Fig. 1: Co-registered ZT and CT patient head acquired on a tri-modality PET/CT+MR system. The 2D histogram distribution indicates an approximate linear correlation between CT and ZT for Hounsfield units corresponding to soft tissue and bone.

Methods: Patients were scanned on a sequential PET/CT+MR tri-modality system[4] consisting of a time-of-flight (TOF) Discovery PET/CT 690 scanner, a Discovery MR750w 3.0T scanner, and a dedicated patient transporter system (GE Healthcare, Waukesha, WI, USA). Zero TE images were acquired using proton density (PD) weighted parameter settings (FA=1°, BW=±62.5kHz, 147456 radial spokes) with isotropic 3D head coverage (FOV=260mm, res=1.2mm) acquired in 2min53s scan time. A low-dose CT scan was performed for standard CT-based PET AC (CT-AC).

Zero TE data acquisition, reconstruction, bias correction and normalization (with soft-tissue signal = 1) was performed as described in reference[3]. The method takes advantage of 1) PD differences between soft-tissue (~80%), bone (~20%) and air (~0%) and 2) efficient capture of short-lived bone signals (T2~400μs). An inverse-logarithmic scaling (i.e. –log(image)) was used to obtain CT-like image appearance (with soft tissue dark and bone gray). The bright background/air was artificially set to zero via automatic thresholding (with the exact threshold value derived from the noise peak in the histogram distribution). Another linear scaling operation was used to match ZT signal intensities to Hounsfield units (HU) and to generate a ZT-derived, continuous-valued pseudo CT.

PET emission images were reconstructed using a time-of-flight (TOF), ordered subset expectation maximization (OSEM) algorithm (2 iterations, 24 subsets) comparing different attenuation correction schemes. For ZT-based AC, the pseudo CT of the head was registered and pasted into the real CT. For comparison also standard CT-AC and segmented CT-AC (segCT-AC) were evaluated. For the latter, the CT was segmented into air (CT<-300HU with μ_{air}=0) and tissue (CT>-300HU with μ_{tissue}=0.098cm^{-1}).

Results: Figure 1 illustrates co-registered ZT and low-dose CT patient images acquired on the PET/CT+MR tri-modality system. The inverse log-scaled images appear CT like with most of the anatomy equally well depicted in both cases (cf. the cranial hole originating from a brain surgery). Notably, the 2D histogram distribution indicates an approximate linear relationship between the inverse log-scaled ZT (vertical axis) and the CT signals (horizontal axis) for Hounsfield units between -300HU and 1500HU (corresponding to soft tissue and bone).

Figure 2 illustrates the PET attenuation maps (top), PET emission images (middle) and relative error maps (bottom) for gold standard CT-AC (left), segCT-AC (middle), and continuous valued ZT-AC (right). The relative error was calculated as 100*(PET_X-$PET_{CT\text{-}AC}$)/$PET_{CT\text{-}AC}$ with X either segCT-AC, or ZT-AC and was evaluated in high uptake regions only. The average relative error is significantly lower for ZT-AC (+0.59%) compared to segCT-AC (-7.91%).

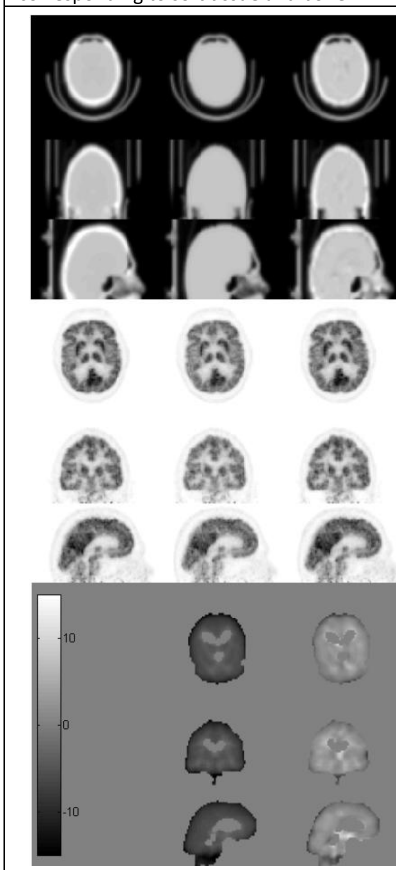

Fig. 2: PET attenuation maps (top), PET emission images (middle), relative error maps (bottom) for CT-AC (left), segCT-AC (middle) and ZT-AC (right).

Discussion: Zero TE is an efficient and robust pulse sequence that provides reliable air/tissue/bone separation based on PD differences (which is fundamentally different from known UTE methods exploring T2* relaxation differences[5,6]). Using a logarithmic image scaling the bias corrected ZT image can be translated into a pseudo CT with continuous attenuation value assignment for Hounsfield units between -300HU and +1500HU. Next, the quantitative performance of ZT-AC needs to be assessed in dedicated clinical studies.

References: [1] Keereman et al, MagnResonMaterPhysBiol 26: 81-98 (2013), [2] Bezrukov et al, SemNuclMed 42: 45-59 (2013), [3] Wiesinger et al, ISMRM p4261 (2014), [4] Veit-Haibach et al, MagnResonMaterPhysBiol 26:25-35 (2013), [5] Keereman et al, JNuclMed 51:812-818 (2010), [6] Catana et al, JNuclMed 51:1431-1438 (2010).