Wireless MR active marker based PET motion correction in simultaneous brain MR-PET

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Target Audience: Scientists and clinicians interested in motion correction in brain imaging and/or simultaneous MR-PET scanning.

Purpose: MR active markers have been used for position tracking since the method was developed in 1986[1]. Investigators have used it to track and correct head motion during brain MRI[2]. Recently, wireless active markers have begun to attract interest in head motion tracking/correction in brain MRI due to improved patient safety, ease-of-use and simpler manufacturing[3,4].

Brain PET scan also plays an important role in the diagnosis, prognostication and monitoring of brain diseases; as well as in animal neuroimaging including non-human primates. Head motion is even more of a problem in brain PET since dynamic brain PET scans can last more than an hour. Voluntary and involuntary head motions are almost inevitable. Furthermore, anesthesia is often used to keep animals still during brain PET acquisitions, but many studies showed that anesthesia can also perturb the neurological process under study.

Figure 1. a) Components of the wireless active marker compard to a US penny .b) The assembled marker in a protective plastic tube.

Simultaneous MR-PET is a novel hybrid modality generating substantial interest in recent years. Complementary information on the brain from PET and MR can be simultaneously obtained. This new modality also opens the possibility to use MR active marker derived motion information for PET motion correction.

In this work, we demonstrate in phantom and non-human primate studies the use of wireless active markers to track head motion and incorporating the measure motion information in the list-mode PET reconstruction to obtain PET images without motion artifacts in simultaneous MR-PET.

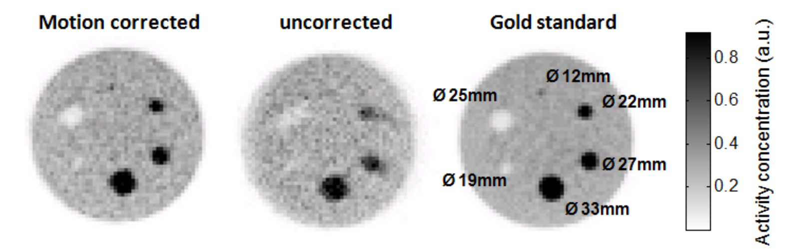

Figure 2. PET images reconstructed from the same PET dataset with and without motion correction based on the motion data measured by wireless active markers. Gold standard image was reconstructed from data acquired without motion with 10 times more PET data.

Methods: Experiments were performed on a Siemens Biograph mMR. One wireless active marker used in this work is shown in Figure 1. The wireless markers were built by installing a spherical NMR microsample cell filled with doped water into a solenoidal wireless MR miniature coil. The locations of the active markers were measured using a pulse sequence consisting of a non-selective RF pulse (flip angle = 1°) and gradient echoes in the X, Y and Z direction[2-4]. Tracking sequence parameters are: projection pixel size = 1.15ms, 256 samples per projection, bandwidth = 1149 Hz/pixel. The tracking sequence was performed every 42 (phantom) or 50ms (monkey).

Table 1. % errors of the contrast biases of the spheres shown in Figure 2.

OD	12mm	22mm	27mm	33mm	19mm	25mm
corrected	-10.7	-6.3	1.2	-1.6	3.4	2.7
uncorrected	-75.0	-62.7	-51.9	-27.2	27.9	19.6

In the phantom experiment, four hollow spheres and two solid spheres were placed into an ACR Flangeless phantom filled with ^{18}F activity. The hollow spheres were filled with activity concentration approximately 4 times that of the phantom. The activity within the entire phantom was about 1.6 mCi at the beginning of the MR-PET acquisition. Three wireless markers were fixed onto the phantom surface. Pseudo-periodic motion was introduced by a ventilator driven balloon (approximately 3 cm translation and 15° rotation). The rate of the motion was 65 cycles/min.

In vivo experiments were performed on a rhesus macaque anesthetized with isoflurane. Two hours prior to the MR-PET acquisition, 4.85 mCi of ^{18}F-FDG was administered by intravenous injection. Three wireless active markers (which passed our institutional coil safety test) were attached to a cranial post rigidly fixed to the skull during the uptake period. The post was installed for head immobilization in other studies. Motion was introduced by gently removing a small pillow on which the monkey's head rested on using a cord attached to the pillow.

The motion PET data in both studies were reconstructed with and without wireless MR active marker derived motion information. The PET motion correction was achieved by incorporating the measured motion data into the system matrix[4].

Results and Discussion: Figure 2 shows the PET images reconstructed from the same phantom data with and without motion correction based on the motion measured by wireless active markers. The gold standard image reconstructed from data acquired while the phantom was static with 10 times more PET event counts is also shown for reference. It can be seen that the motion blurring which is prominent in the uncorrected image was almost completely removed by the MR wireless active marker based motion correction. And the corrected image agrees well with the static gold standard. Quantitative contrast bias analysis was performed on the 6 spheres using the gold standard image as the reference with 24 noise realizations (56-min MR-PET data divided into 24 sessions), and the result is shown in Table 1. This table shows the motion corrected images yield more accurate PET contrasts (similarly more accurate PET uptake values).

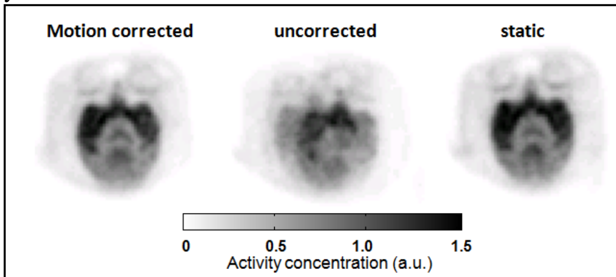

Figure 3. The same transverse slices of the monkey image volumes reconstructed with and without wireless MR active marker based motion correction from the same PET data set, compared to a static reference reconstructed from data acquired with the same acquisition duration while the head was static.

Figure 3 shows the image reconstructed from *in vivo* data. It can also be seen that motion artifacts were removed by the active marker based motion correction.

Conclusion: In this work, PET motion correction in brain imaging based on wireless MR active marker was demonstrated using phantom and *in vivo* data acquired on a simultaneous MR-PET scanner. Combining this with prospective motion correction in MRI[2,3], it also enables further harnessing the synergy of simultaneous MR and PET in brain imaging.

References:1.Ackerman J, et al. Proc. 5th ISMRM 1986;1131 2. Ooi MB, et al. MRM 2009, 62; 943 3. Ooi MB, et al. MRM 2013, 70;639 4. Sengupta S, et al. Proc. 21st ISMRM 2013; 2578

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