Precise co-registration of SPECT and MRI for small animal imaging using a common animal bed with external references: A feasibility study

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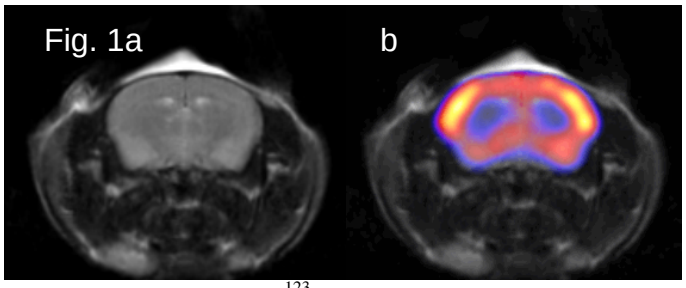
Introduction: Nuclear medicine (NM) can provide unique information about the distribution of receptors or sentinel lymph nodes (SLNs), although it shows poor anatomical information; therefore, the superimposition of NM images on MR images would enhance the excellent features of MRI in spatial resolution and tissue contrast. A high magnetic field, however, makes it difficult to develop a combined scanner [1, 2], especially in combination with a single photon emission computed tomography (SPECT) scanner that requires metallic collimators. The software-based post-processing precise fusion of images obtained by separate scanners would therefore be practical. In this study, we conducted a feasibility test of a post-processing method of high resolution SPECT (up to 1mm in spatial resolution) and MRI (up to 117μm in-plane resolution) co-registration in animal experiments. Since it is vulnerable to voluntary and involuntary animal motion during SPECT and MRI scans as well as in the interval between these scans, an in-house built animal bed for both scans (a common animal bed) was constructed to immobilize animals during experiments.

Materials and methods: All MR images were acquired with a 3 T whole body scanner (Signa HDx, GE, Milwaukee, WI) equipped with a dedicated receiver coil for small animal use. SPECT images were acquired with a small animal scanner equipped with 4 detectors each of which has 9 multi-pinhole collimators (MPCs) (NanoSPECT CT; Bioscan, Washington DC). A common animal bed was constructed with an acrylic tube which has 3 small containers filled with radioisotope fluid used as external references in image co-registration. SPECT and MRI data were acquired separately and both image data sets with DICOM format were merged using commercially available software (In Vivo Scope ver1.37, BioScan, Washington, D.C.). A pilot study was conducted using a tubular water phantom in which 2 syringes containing ^{99m}Tc and $CuSO_4$ solution, respectively, were placed in parallel. Signal profiles with respect to the location of the transverse axis were compared among SPECT, T_1- and T_2-weighted MRI (T_2WI), and merged images to verify that the co-registration procedure worked appropriately. Four male ddY mice then underwent SPECT-MRI fusion experiments, in which ^{123}I iomazenil (IMZ) SPECT (45-66MBq i.v., acquisition counts of 110-165 x10^3, 24 projections, 300 sec/projection, OSEM reconstruction algorithm) and fast-spin echo T_2WI (TR/effTE = 4000/80 ms) of the brain were merged in 2 mice, and in the other 2 mice ^{99m}Tc phytate interstitial SPECT lymphography (0.05ml of 74MBq/mL ^{99m}Tc phytate administered to the right foot pad) and T_2WI (4000/60 ms) were merged to detect SLNs of the lower extremities.

Results and discussion: Signal profiles of two syringe phantoms could be precisely matched on SPECT-MRI fusion images. MRI and ^{123}I IMZ SPECT of the mouse brain were successfully merged and areas of strong uptake of ^{123}I IMZ were comparable to those of high intensity on T_2WI, showing that ^{123}I IMZ accumulated in the cerebral cortex (Fig. 1). ^{99m}Tc phytate SPECT and MR images were also completely co-registered. As a result, SLNs of the lower extremities less than 2mm in diameter could be clearly demonstrated in the popliteal region on a merged image (Fig. 2). Errors in the co-registration procedure were within 0.6 mm. Our in-house-built common animal bed with external markers avoided spatial mismatch, leading to accurate MRI-SPECT fusion images even for small animals. The combination of a high static magnetic field of 3 T with a highly sensitive receiver coil and a MPC SPECT facilitated *in vivo* observation of small animal organs such as tiny SLNs. The post-processing merge technique of MR images and SPECT ones may be a practical approach.

Conclusion: A post-processing fusion technique of SPECT and MRI is feasible for simultaneous evaluation of functional and anatomical aspects *in vivo* of small animal organs, providing unique information.

References [1] Nalcloglu O, et al. Proc. ISMRM 2007; 15: 920 [2] Goto T, et al. Proc. ISMRM 2008; 16: 1174



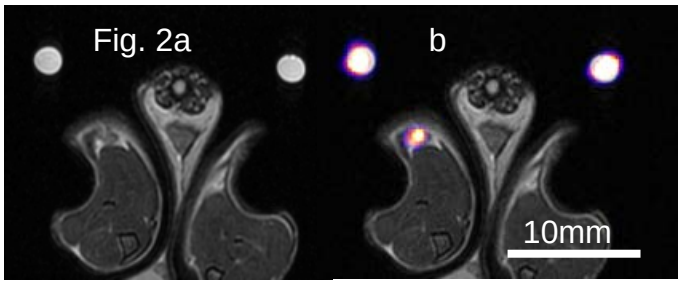


Figure 1 shows T_2W MRI (a) and ^{123}I IMZ SPECT-MRI fusion image (b) of the mouse brain. On T_2WI, cerebral cortex is demonstrated as high intensity area, where strong uptake of ^{123}I IMZ (red and yellow) is seen on SPECT (b). Figure 2 shows T_2WI (a) and ^{99m}Tc phytate interstitial SPECT lymphography (b) of the lower extremities. A small lymph node is seen as a nodule with intermediate signal on T_2WI (a) and as an area of strong uptake (red and white) on ^{99m}Tc SPECT (b). Note that two external markers, which were used for co-registration of the two transverse images, are completely matched on the SPECT-MRI fusion image (b). Another external marker (not shown) perpendicular to these two was used to identify the location in the cranio-caudal direction.