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 1 mm in spatial resolution) and MRI (up to 117 μm 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 CuSO4 solution, respectively, were placed in parallel. Signal profiles with respect to the location of the transverse axis were compared among SPECT, T1- and T2-weighted MRI (T1WI), and merged images to verify that the co-registration procedure worked appropriately. Four male ddY mice then underwent SPECT-MRI fusion experiments, in which 123I iomazenil (IMZ) SPECT (45-66 MBq i.v., acquisition counts of 110-165 x10^4, 24 projections, 300 sec/projection, OSEM reconstruction algorithm) and fast-spin echo T2WI (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 (0.05 ml of 74 MBq/ml 99m-Tc phytate administered to the right foot pad) and T2WI (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 123I IMZ SPECT of the mouse brain were successfully merged and areas of strong uptake of 123I IMZ were comparable to those of high intensity on T2WI, showing that 123I 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 2 mm 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.


Figure 1 shows T2W MRI (a) and 123I IMZ SPECT-MRI fusion image (b) of the mouse brain. On T2WI, cerebral cortex is demonstrated as high intensity area, where strong uptake of 123I IMZ (red and yellow) is seen on SPECT (b). Figure 2 shows T2WI (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 T2WI (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.