Simultaneous in vivo $^{1}H/^{23}Na$-imaging of superficial lymph nodes using 7 Tesla-MRI

Martin T. Freitag[1], Nadia Benkhedah[2], Pedram Yazdanbakhsh[3], Titus Lanz[3], Moritz Berger[2], Mathies Breithaupt[2], Jessica Hassel[4], Heinz-Peter Schlemmer[1], Mark E Ladd[2], and Armin M. Nagel[2]

[1]Department of Radiology, German Cancer Research Center, Heidelberg, Baden-Wuerttemberg, Germany, [2]Medical Physics in Radiology, German Cancer Research Center, Heidelberg, Baden-Wuerttemberg, Germany, [3]Rapid Biomedical, Rimpar, Bayern, Germany, [4]Department of Dermatology, National Center for Tumor Diseases, Heidelberg, Baden-Wuerttemberg, Germany

Introduction

Lymph node (LN) classification in computed tomography or conventional magnetic resonance imaging is mainly relying on simple size criteria and therefore limited. Thus, there is substantial interest to develop diagnostic procedures for LN staging that feature a high spatial resolution combined with functional imaging techniques. Recently, a setup was reported where the feasibility of high-resolution ^{1}H-based examinations at 7 Tesla of LNs was described showing that mesoscopic details of metastatic and healthy nodes are depictable *in vivo*[1]. ^{23}Na imaging could be of interest for LN staging, because Na^{+}-ions are osmolar, being present at high concentration in vessels and blood and thus potentially accumulated in hypervascularized LN metastases. Additionally, tumor malignancy is often associated with increased intracellular sodium content[2]. As the value of ^{23}Na for LN imaging is largely unexplored, we investigate, whether simultaneous $^{1}H/^{23}Na$-acquisitions are feasible in patients using a double-resonant flexible loop coil and whether potential ^{23}Na signal intensity differences between healthy and pathological LNs are observed.

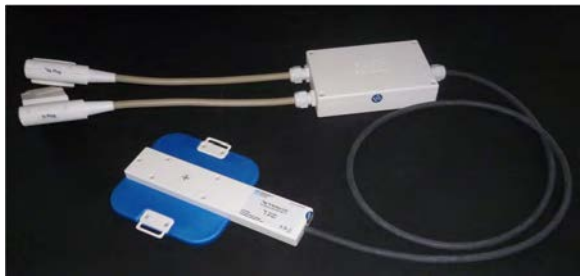

Figure 1: Double-resonant $^{1}H/^{23}Na$-Coil (Rapid Biomedical) with a flexible element which facilitates the imaging of uneven body surfaces such as the cervical region or the groin.

Materials and Methods

The study was conducted in accordance with the Declaration of Helsinki including approval from the ethics committee. Four patients with a history of malignant melanoma and one patient with malignant T-cell lymphoma of the nasal cavity were included. Image acquisition was conducted using a double-resonant, flexible $^{1}H/^{23}Na$ coil (Rapid Biomedical, Rimpar, Germany) (Figure 1). The examination was performed as previously described where the coil was placed in correlation to the location of the suspicious LN which was determined by ultrasound[1]. In 4 patients with malignant melanoma, 7-Tesla MRI examinations were conducted prior to surgical treatment where the suspected LNs were confirmed by histopathology. The fifth patient suffering of lymphoma directly underwent chemotherapy due to clearly enlarged LN bulks in the right cervical region. All pathological LNs were confirmed to be hypervascularized in duplex sonography by two radiologists. The scan protocol included localizer and a T1w Dixon VIBE (0.5 x 0.5 x 0.5 mm^3, FOV 192 x 192, TR/TE 10/2.7ms, flip angle 13°, 1 average, acquisition time 7 min.). For ^{23}Na imaging, a 3D density-adapted radial imaging technique with a nominal spatial resolution of 3 x 3 x 3 mm^3 was used[3]. Isotropic ^{23}Na-Data was co-registered to the isotropic T1w-Dixon in axial orientation using Osirix Software[4]. The visible target depth for both ^{1}H- and ^{23}Na-acquisitions was quantified where a radiologist was evaluating until which distance from skin surface to depth, sufficient signal was visible to reliably delineate the anatomy. The relative ^{23}Na-signal was calculated by dividing the measured signal from the ROI through the signal of muscle. The muscle ROI for normalization was placed at height of the quantified LN.

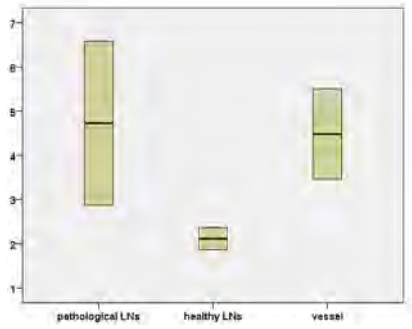

Figure 2: Relative sodium signal (normalized to muscle). Data distribution in 5 pathological and 7 healthy LNs demonstrates that pathological LNs reveal higher ^{23}Na signal compared to healthy nodes.

Results

The examinations succeeded in all patients (4 in the groin, 1 cervical). Five pathological and 7 healthy LNs were analyzed. As given in Figure 2, the semi-quantitative analysis of the relative sodium signal revealed higher signal intensities in pathological LNs (Figure 3 and 4). Visual target depth of 1H-acquisitions was reliable for 4.62±0.51 cm. For ^{23}Na-acquisitions, the reliable target depth was 4.30±0.47 cm.

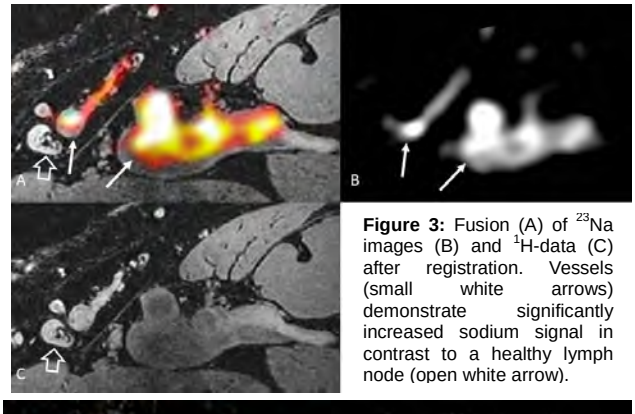

Figure 3: Fusion (A) of ^{23}Na images (B) and ^{1}H-data (C) after registration. Vessels (small white arrows) demonstrate significantly increased sodium signal in contrast to a healthy lymph node (open white arrow).

Discussion

We have demonstrated the feasibility of simultaneous *in vivo* $^{1}H/^{23}Na$-acquisitions of superficial LNs at 7-Tesla. Because the signal intensities of malignant LNs were similar to that of the femoral vein, this patient series raises the question whether the observed higher sodium signal in pathological LNs results from the feature of hypervascularization, confirmed in all LNs by duplex sonography, or from intra- or extra-cellular sodium. The given differences in signal intensity might be influenced by B1-inhomogeneity. To minimize this effect, the quantification was performed at similar height 1-4 cm below the skin surface. Differences in sodium concentration between healthy and pathological LNs could be useful for nodal staging, if this preliminary finding is confirmed in a larger patient cohort.

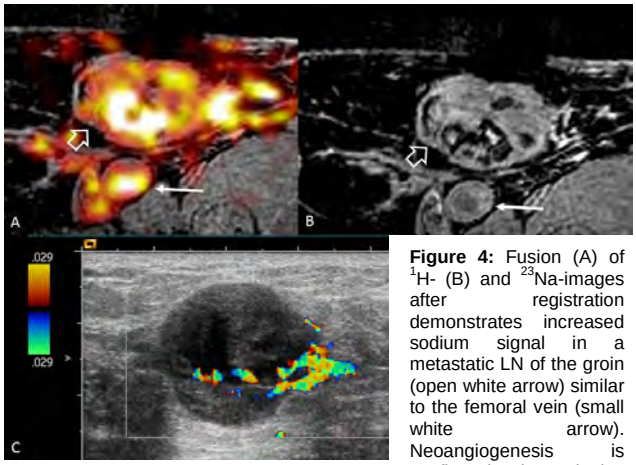

Figure 4: Fusion (A) of ^{1}H- (B) and ^{23}Na-images after registration demonstrates increased sodium signal in a metastatic LN of the groin (open white arrow) similar to the femoral vein (small white arrow). Neoangiogenesis is confirmed by duplex sonography (colored vessels).

References: [1]Freitag et al., 2014, JMRI; [2]Cameron et al., 1980, Cancer Res; [3]Nagel et al., 2009, Magn Med Reson; [4]Rosset et al, 2004, J Digit imaging