Quantitative ^{23}Na-MRI: From Pre-Clinical to Clinical Practice

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Introduction

Quantitative ^{23}Na-MRI (qNa-MRI) is a non-invasive technique which allows for measuring subtle changes in the Tissue Sodium Concentration (TSC) after ischaemic stroke. Although, an increase in TSC after stroke has been reported many times in the literature [1-5] the underlying mechanisms related to the regionally TSC changes have only recently been investigated in an animal stroke model. The *in vivo* TSC time-course data revealed that the time point at which the TSC started to increase varied significantly in still viable (penumbra) and permanently damaged (core) tissue [6]. A threshold at normal TSC level could consequently serve to differentiate between penumbra and core tissue after stroke. However, the TSC has never been studied during the acute stroke phase in humans (<6h after Onset) due to the challenges involved in adding qNa-MRI to the standard ^{1}H-MRI protocol. The aim of this study was to develop a comprehensive stroke protocol for ^{1}H and ^{23}Na MRI of acute stroke patients at 3T.

Methods

A double-tuned ^{1}H/^{23}Na birdcage coil was used for ^{23}Na and ^{1}H MRI of three stroke patients. A 3D density adapted radial sequence [7] was used to achieve a short TE (300 µs), with voxel resolution 4 x 4 x 4 mm^3, TR = 15 ms and 10 min acquisition time. ^{1}H-diffusion weighted, T2-weighted, and angiography imaging was performed using standard 3T imaging parameters. The total protocol length was below 30 minutes without the need to change coil system during the measurement procedure. During a pilot study of the developed stroke protocol, two untreated patients were examined at 24h and 5d after stroke, respectively. A further rt-Pa treated patient was examined at 22h after stroke.

Results

The ^{1}H image quality of the T2-weighted and angiography images was found to be excellent compared to ^{1}H MR images acquired at 1.5T. The ^{23}Na signal was found to be increased by 30% and 80% in the two untreated patients at 24h and 5d after stroke, respectively. Surprisingly, the ^{23}Na signal measured in the stroke lesion defined by low ADC value in the treated patient was found to be 15% below the normal ^{23}Na signal intensity on the contralateral normal side. The ADC values on the other hand were measured lower than 50% of the normal ADC on the contralateral side in the treated and untreated patient at measurement times below 24h after stroke, whereas the ADC was measured to be 80% higher at 5d after stroke. T2-weighted ^{1}H signal intensity was increased in all three patients, but the greatest change in T_2-weighted signal intensity of 80% was determined for the untreated patient at 5d after stroke.

Discussion

^{23}Na-MRI was successfully incorporated as part of a 30min long clinical stroke protocol at 3T, without the need to change coil systems during the measurement procedure. A protocol for ^{23}Na-MRI of stroke had been previously implemented with the need to change coils resulting in a total acquisition time of 45 minutes [5]. A recent study required patients to be scanned at 1.5T for the ^{1}H protocol and later at 4.7T for the ^{23}Na-protocol, which limited the amount of patients to be scanned during the acute stroke phase. In this study the ^{1}H ADC reversed at 5d after stroke and therefore proves difficult to be used as a marker for infarcted tissue after stroke. For the first time a decrease in ^{23}Na-signal intensity was measured in human stroke, despite a measured ADC decrease and ^{1}H T2-weighted signal increase in the very same brain region. The decrease in ^{23}Na-signal intensity could potentially indicate still viable stroke tissue before and after rt-PA-treatment. A decrease in TSC has recently been measured in still viable stroke tissue during an *in vivo* study [6]. Nevertheless more human qNa-MRI studies are required in order to confirm that TSC decreases in still viable stroke tissue during the acute phase.

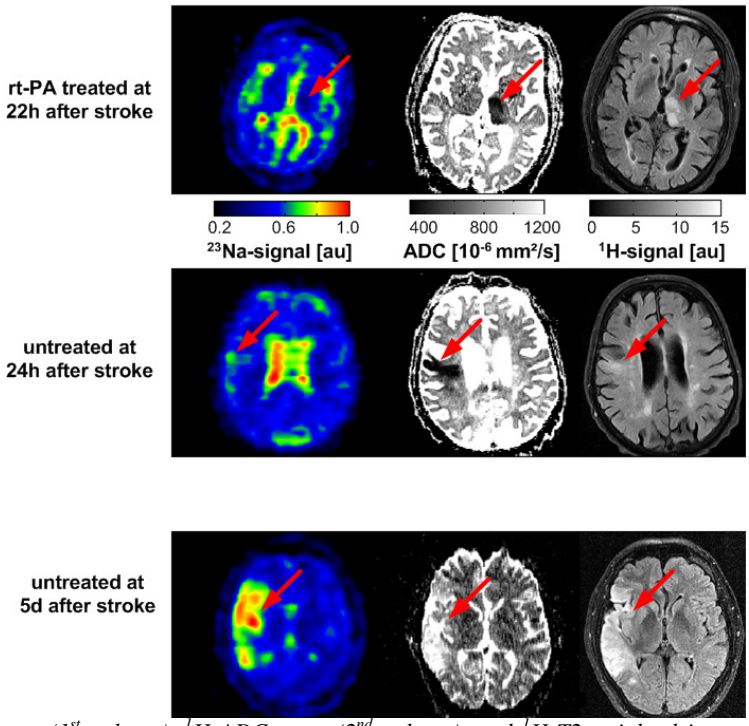

Figure 1: ^{23}Na-MR images (1st column), ^{1}H ADC maps (2nd column), and ^{1}H T2-weighted images (3rd column) for three patients at different times after ischaemic stroke. Note the decrease in ^{23}Na signal intensity in the treated patient at 22h after stroke.

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