

# Tissue sodium concentration in ischemic stroke patients

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## Target Audience

Scientists and clinicians interested in quantitative clinical sodium MRI studies for brain acquisitions, e.g. stroke

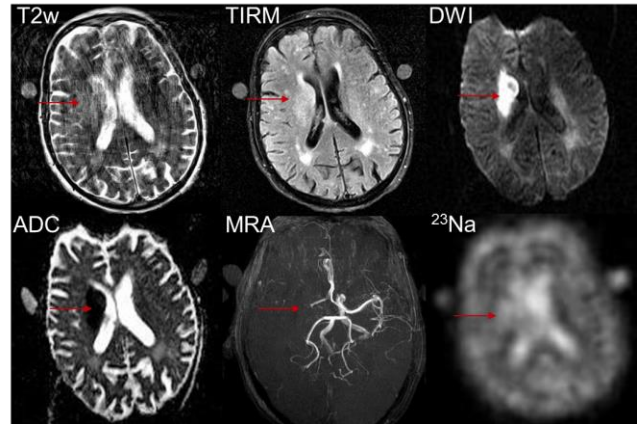
## Purpose

Sodium is one of the essential ions present in the human body. It is involved in a variety of processes in health and disease. Quantitative <sup>23</sup>Na MRI offers the opportunity of non-invasive tissue sodium concentration (TSC) determination, which may serve as cellular biomarker. Previous clinical studies confirmed that quantitative <sup>23</sup>Na MRI is a promising imaging modality in ischemic stroke (1-4).

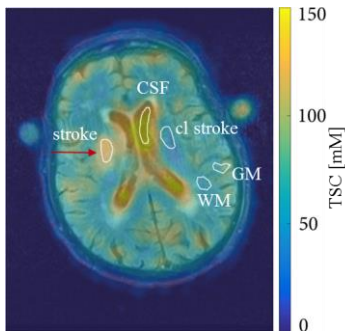
## Methods

A total number of 11 patients, of these six females, with a mean ± SD age of 76.4 ± 10.5 years were scanned by a clinical stroke <sup>23</sup>Na/<sup>1</sup>H MR protocol presented before (1), which was extended by a sodium flip angle mapping sequence. Flip angle mapping was conducted by the phase sensitive method (5). The pulse pattern was included in a density adapted 3D ultra-short echo time (UTE) sequence (6) with the following parameters: TR = 100 ms, TE = 0.4 ms, FA = 90°, spokes = 670, points on spoke = 384, undersampling factor = 0.83, nominal isotropic spatial resolution = (15 × 15 × 15) mm<sup>3</sup>, FOV = (241 × 241 × 241) mm<sup>3</sup>, acquisition time = 2 min 2 s.

The measurements were approved by the local ethical review committee. The inclusion criterion was a clinically suspected obstruction of the middle cerebral artery with an onset of less than 12 hours. All patients received a standard diagnostic and therapeutic care in the local stroke unit, following the latest guidelines, including an initial cerebral imaging and reperfusion therapy, if clinically indicated. TSC was calculated by a linear fit between reference vials (50 mM and 100 mM NaCl with 2 % agarose each) placed inside the FOV. Stroke regions of interest (ROI) were drawn manually under a neuroradiologist's supervision to ensure an unambiguous assignment. Additional ROIs were determined in unimpaired regions to allow comparisons with literature values (7). We assessed white matter (WM), grey matter (GM), cerebrospinal fluid (CSF) and the stroke contralateral area (cl stroke). Two sided t-tests were performed between TSC in stroke and cl stroke areas as well as between WM and GM regions.



**Figure 1** <sup>1</sup>H and <sup>23</sup>Na MRI in stroke patients. T2 weighted (T2w) images, turbo inversion recovery magnitude (TIRM), diffusion weighted images (DWI), apparent diffusion coefficient (ADC) map, magnetic resonance angiography (MRA), and sodium signal intensity (<sup>23</sup>Na) images of stroke patient. The stroke area (red arrows) presents as hyperintensity in T2w, TIRM, DWI, and <sup>23</sup>Na images and as hypointensity in the ADC map. In the MRA an occlusion of the internal carotid and the middle cerebral artery is visible (red arrow).



**Figure 2** TSC map and <sup>23</sup>Na/<sup>1</sup>H overlay with ROIs in stroke patients. Color bar indicates TSC in mM.

**Table 1** Comparison of tissue sodium concentrations (TSC) in stroke patients.

Patient	TSC stroke (mM)		TSC cl stroke (mM)		TSC WM (mM)		TSC GM (mM)		TSC CSF (mM)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	117.1	11.7	52.2	11.2	55.6	4.3	73.6	11.5	148.7	12.7
2	107.7	5.6	53.5	6.7	49.3	3.5	59.0	5.1	137.3	4.5
3	88.4	4.9	74.2	4.4	56.2	3.5	64.1	9.6	145.5	12.9
4	73.7	3.2	60.6	3.0	56.5	4.4	72.8	3.4	139.0	11.5
5	89.0	6.5	39.2	2.8	59.6	3.2	70.6	7.6	150.4	5.2
6	112.8	6.0	67.4	6.5	49.8	4.0	67.1	10.2	158.3	6.3
7	77.5	3.6	76.3	7.2	63.7	5.9	76.6	6.2	149.3	11.2
8	125.5	7.1	69.2	5.4	62.7	3.5	68.0	6.7	130.5	5.7
9	82.4	3.4	58.7	4.0	54.1	4.0	68.2	2.7	143.9	13.0
10	127.9	15.6	50.0	7.3	48.8	4.6	69.8	7.8	141.1	15.4
11	141.6	7.2	84.6	12.3	72.6	5.5	81.0	5.2	155.5	26.2
all	104.0	22.9	62.4	13.4	57.2	7.2	70.1	6.0	145.4	8.2
literature (7)					20 mM - 60 mM		30 mM - 70 mM		140 mM - 150 mM	

## Results

Stroke regions were in all cases well definable from the surrounding tissue observing the TSC maps (Figure 1) and coincided well with the impaired area identified in diffusion weighted images (DWI) and apparent diffusion coefficient (ADC) images (Figure 2). Measured TSC values correspond to the literature (Table 1). TSC values in stroke regions compared to TSC values in unimpaired control areas located on the contralateral hemisphere were significantly different over all subjects ( $p < 0.001$ ). In addition, the average TSC values of gray and white matters were significantly different ( $p < 0.001$ ).

## Discussion and Conclusion

We successfully evaluated TSC in eleven stroke patients. TSC values seem to be able to aid distinguish tissues impaired by the stroke from its surrounding tissue. TSC is enlarged in the infarct but not in penumbral tissue. Hence, <sup>23</sup>Na MRI could be considered as supplement in the diagnostic process in stroke patients.

## References

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