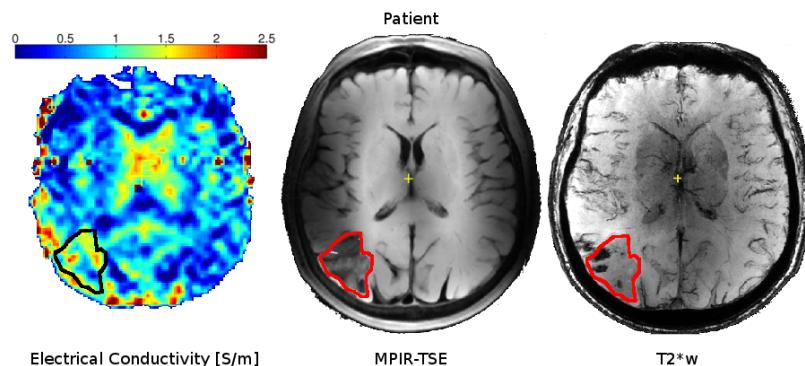


## Electrical conductivity in ischemic stroke at 7.0 Tesla: A Case Study

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**Introduction:** In ischemic stroke, ATP depletion and subsequent disturbance of ion homeostasis can be visualized using sodium (<sup>23</sup>Na)-MRI<sup>[1]</sup>. Recently, electrical properties tomography (EPT)<sup>[2]</sup> was introduced as a new contrast in MRI. This contrast enables us to visualize the local electrical properties of tissue, being the conductivity (example in Fig.1) and permittivity; the electrical conductivity is related to  $[\text{Na}^+]$ . In contrary to <sup>23</sup>Na imaging, EPT is measured at the proton Larmor frequency, not requiring dedicated equipment (e.g. coils) and sophisticated sequences to realize sufficient SNR to compensate for the low abundance and relative short  $T_2$  of <sup>23</sup>Na. The EPT technique is based on the local fluctuations in the RF magnetic field ( $B_1^+$  field). Already several applications for EPT were shown, such as mapping of glioma<sup>[3, 4]</sup> and stomach contents<sup>[5]</sup>. In this study, it is investigated if a change in local conductivity can also be observed in stroke patients.

**Methods:** This study was approved by our institutional review board; the included patient gave written informed consent. A 65-year-old woman presented with ischemic stroke of the left middle cerebral artery territory, and was scanned two months after the infarction on a 7.0 Tesla whole body system (Philips Healthcare, Cleveland, OH, USA) with a 32-channel receive coil and volume transmit/receive coil for transmission (Nova Medical, Wilmington, MA, USA). For EPT, two measurements are required to map the complex  $B_1^+$  field. The  $B_1^+$  amplitude map was acquired using a Bloch-Siegert shift ( $\omega_{\text{off,res.}} = 1.5\text{kHz}$ , 8ms Fermi pulse)<sup>[6]</sup>. For the  $B_1^+$  phase, two interleaved GRE measurements with different echo times ( $TE_1 = 1.41\text{ms}$ ,  $TE_2 = 2.41\text{ms}$ ) were performed, this scan was repeated with opposed gradient polarity to obtain the eddy current corrected phase<sup>[7]</sup>. All scans had a  $2.5 \times 2.5 \times 5\text{mm}$  resolution. The conductivity was calculated from the complex  $B_1^+$  using the method described in<sup>[3]</sup>. Along with the electrical conductivity map, a MPIR-TSE scan<sup>[8]</sup> and a  $T_2^*$ -weighted sequence<sup>[9]</sup> were used for clinical diagnosis and anatomical characterization.

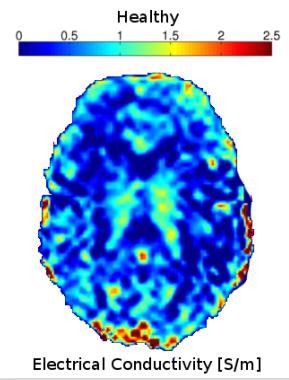


**Figure 2:** Electrical conductivity, MPIR-TSE and  $T_2^*$  weighted scan of stroke patient at 2 months. The affected region was delineated based on the MPIR-TSE scan.

**Conclusion and discussion:** In this case study, it was shown that the electrical conductivity was locally altered in the tissue affected by the infarction. This conductivity elevation corresponded at least in part to seemingly viable brain parenchyma, although it can also partly be explained by increased CSF in the ischemic area, due to tissue loss. Further studies are needed to further investigate these findings. In such studies conductivity mapping during the acute phase of the infarction is of special interest, as it was suggested that a high  $[\text{Na}^+]$  can be indicative of a nonviable infarction<sup>[1]</sup>.

### References:

1. K. R. Thulborn, et al. Radiology 1999 213:156-66
2. U. Katscher, et al. IEEE Trans Med Imaging 2009 28:1365-74
3. A. L. van Lier, et al. In: Proceedings of the 19th Annual Meeting of ISMRM Montreal, Quebec, Canada 2011:4464
4. T. Voigt, et al. In: Proceedings of the 19th Annual Meeting of ISMRM Montreal, Quebec, Canada 2011:127
5. C. Stehning, et al. In: Proceedings of the 19th Annual Meeting of ISMRM Montreal, Quebec, Canada 2011:128
6. L. I. Sacolick, et al. Magn Reson Med 2010 63:1315-22
7. A. L. van Lier, et al. Magn Reson Med 2011 in press
8. A. G. van der Kolk, et al. Stroke 2011 42:2478-84
9. M. M. Conijn, et al. J Magn Reson Imaging 2010 32:52-9



**Figure 1:** Electrical conductivity map of a healthy volunteer.

**Results:** The MPIR-TSE scan showed demarcation of an ischemic infarct on the posterior border of the middle cerebral artery territory, with corresponding tissue loss, seen as hypointense areas due to the prolonged  $T_1$  (Fig. 2). The  $T_2^*$ -weighted image shows hypointense cortical areas, possibly corresponding to residual hemorrhagic components. To compare with the conductivity map, the infarction was delineated on the anatomical scans. In the delineated region an elevation of conductivity was observed; compared to the healthy contra-lateral side the conductivity was more than 2 times higher (lesion:  $1.21 \pm 0.35 \text{ S/m}$ , contra-lateral side:  $0.52 \pm 0.27 \text{ S/m}$ ).