Clinical Applications of Navigated TMS in Acute Neurological Injury

Phiroz E. Tarapore, MD FAANS

Associate Professor
Department of Neurological Surgery
University of California, San Francisco

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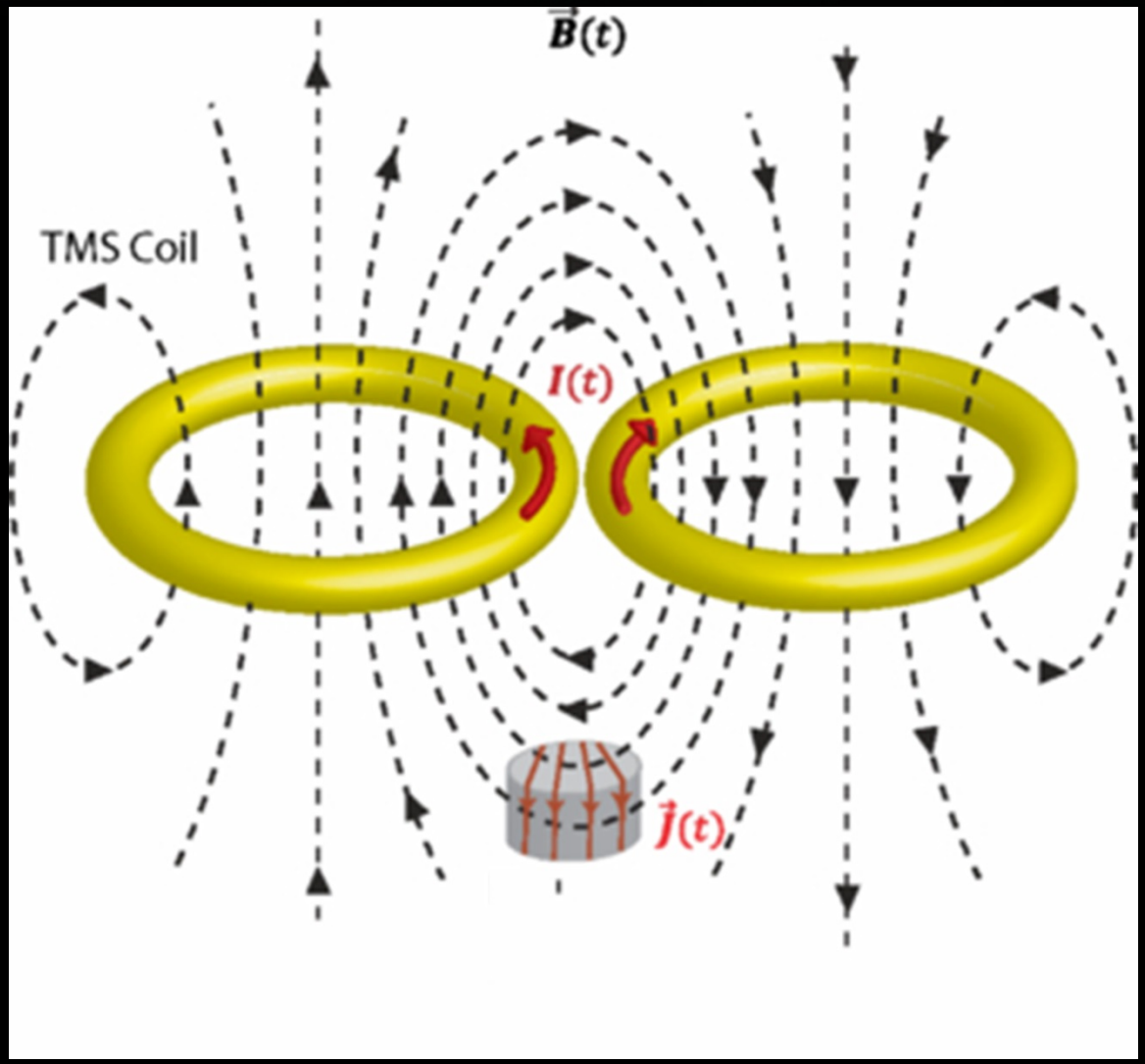
Induction



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Transcranial Induction

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Where it all began…

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A novel approach for documenting naming errors induced by navigated transcranial magnetic stimulation

Pantelis Lioumis[a,*], Andrey Zhdanov[a], Niko Mäkelä[a], Henri Lehtinen[b], Juha Wilenius[a], Tuomas Neuvonen[c], Henri Hannula[c], Vedran Deletis[d,e], Thomas Picht[f], Jyrki Mäkelä[a]

[a] BioMag Laboratory, HUSLAB, Hospital District of Helsinki and Uusimaa, P.O. Box 340, FI-00029 HUS, Helsinki, Finland
[b] Epilepsy Unit, Department of Pediatric Neurology, Helsinki University Central Hospital, Helsinki, Finland
[c] Nexstim Ltd., Helsinki, Finland and Neuroscience Unit, Institute of Biomedicine/Physiology, University of Helsinki, Helsinki, Finland
[d] Department for Intraoperative Neurophysiology, St Luke's Roosevelt Hospital, New York, NY, United States
[e] Laboratory for Human and Experimental Neurophysiology, School of Medicine, University of Split, Croatia
[f] Department of Neurosurgery, Charité University Hospital, Berlin, Germany

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ABSTRACT

Transcranial magnetic stimulation (TMS) is widely used both in basic research and in clinical practice. TMS has been utilized in studies of functional organization of speech in healthy volunteers. Navigated TMS (nTMS) allows preoperative mapping of the motor cortex for surgical planning. Recording behavioral responses to nTMS in the speech-related cortical network in a manner that allows off-line review of performance might increase utility of nTMS both for scientific and clinical purposes, e.g., for a careful preoperative planning.

Four subjects participated in the study. The subjects named pictures of objects presented every 2.5 s on a computer screen. One-second trains of 5 pulses were applied by nTMS 300 ms after the presentation of pictures. The nTMS and stimulus presentation screens were cloned. A commercial digital camera was utilized to record the subject's performance and the screen clones. Delays between presentation, audio and video signals were eliminated by carefully tested combination of displays and camera. An experienced neuropsychologist studied the videos and classified the errors evoked by nTMS during the object naming.

Complete anomias, semantic, phonological and performance errors were observed during nTMS of left fronto-parieto-temporal cortical regions. Several errors were detected only in the video classification.

nTMS combined with synchronized video recording provides an accurate monitoring tool of behavioral TMS experiments. This experimental setup can be particularly useful for high-quality cognitive paradigms and for clinical purposes.

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nTMS Language Mapping

RESEARCH—HUMAN—CLINICAL STUDIES

A Comparison of Language Mapping by Preoperative Navigated Transcranial Magnetic Stimulation and Direct Cortical Stimulation During Awake Surgery

Thomas Picht, MD*‡
Sandro M. Krieg, MD*§
Nico Sollmann§
Judith Rösler‡
Birat Niraula‡
Tuomas Neuvonen, MS¶
Petri Savolainen, MS¶
Pantelis Lioumis, PhD||
Jyrki P. Mäkelä, MD, PhD||
Vedran Deletis, MD, PhD#**
Bernhard Meyer, MD§
Peter Vajkoczy, MD*‡
Florian Ringel, MD*§

‡Department of Neurosurgery, Charité Universitätsmedizin, Berlin, Germany; §Department of Neurosurgery, Klinikum rechts der Isar, Technische Universität München, Germany; ¶Nexstim Ltd., Helsinki, Finland and Neuroscience Unit, Institute of Biomedicine/Physiology, University of Helsinki, Finland; ||BioMag Laboratory, HUS Medical Imaging, Hospital District of Helsinki and Uusimaa, Helsinki, Finland; #Department of Intraoperative Neurophysiology, St. Luke's-Roosevelt Hospital, New York, New York; **Laboratory for Human and Experimental Neurophysiology, School of Medicine, University of Split, Split, Croatia

BACKGROUND: Navigated transcranial magnetic stimulation (nTMS) is increasingly used in presurgical brain mapping. Preoperative nTMS results correlate well with direct cortical stimulation (DCS) data in the identification of the primary motor cortex. Repetitive nTMS can also be used for mapping of speech-sensitive cortical areas.

OBJECTIVE: The current cohort study compares the safety and effectiveness of preoperative nTMS with DCS mapping during awake surgery for the identification of language areas in patients with left-sided cerebral lesions.

METHODS: Twenty patients with tumors in or close to left-sided language eloquent regions were examined by repetitive nTMS before surgery. During awake surgery, language-eloquent cortex was identified by DCS. nTMS results were compared for accuracy and reliability with regard to DCS by projecting both results into the cortical parcellation system.

RESULTS: Presurgical nTMS maps showed an overall sensitivity of 90.2%, specificity of 23.8%, positive predictive value of 35.6%, and negative predictive value of 83.9% compared with DCS. For the anatomic Broca's area, the corresponding values were a sensitivity of 100%, specificity of 13.0%, positive predictive value of 56.5%, and negative predictive value of 100%, respectively.

CONCLUSION: Good overall correlation between repetitive nTMS and DCS was observed, particularly with regard to negatively mapped regions. Noninvasive inhibition mapping with nTMS is evolving as a valuable tool for preoperative mapping of language areas. Yet its low specificity in posterior language areas in the current study necessitates further research to refine the methodology.

KEY WORDS: Awake surgery, Language, Preoperative mapping, Transcranial magnetic stimulation, Tumor

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A Comparison of Language Mapping by

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NeuroImage

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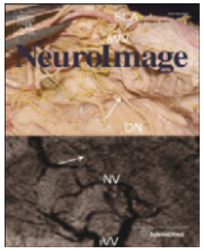

Language mapping with navigated repetitive TMS: Proof of technique and validation

Phiroz E. Tarapore [a,*], Anne M. Findlay [b], Susanne M. Honma [b], Danielle Mizuiri [b], John F. Houde [c], Mitchel S. Berger [a], Srikantan S. Nagarajan [b]

[a] Department of Neurological Surgery, University of California, San Francisco, 505 Parnassus Ave., San Francisco, CA 94143, USA
[b] Department of Radiology and Biomedical Imaging, University of California, San Francisco, 505 Parnassus Ave., San Francisco, CA 94143, USA
[c] Department of Otolaryngology, Head and Neck Surgery, University of California, San Francisco, 505 Parnassus Ave., San Francisco, CA 94143, USA

Intraoperative Neurophysiology, St. Luke's-Roosevelt Hospital, New York, New York; **Laboratory for Human and Experimental Neurophysiology, School of Medicine, University of Split, Split, Croatia

KEY WORDS: Awake surgery, Language, Preoperative mapping, Transcranial magnetic stimulation, Tumor

Neurosurgery 72:808–819, 2013 DOI: 10.1227/NEU.0b013e3182889e01 www.neurosurgery-online.com

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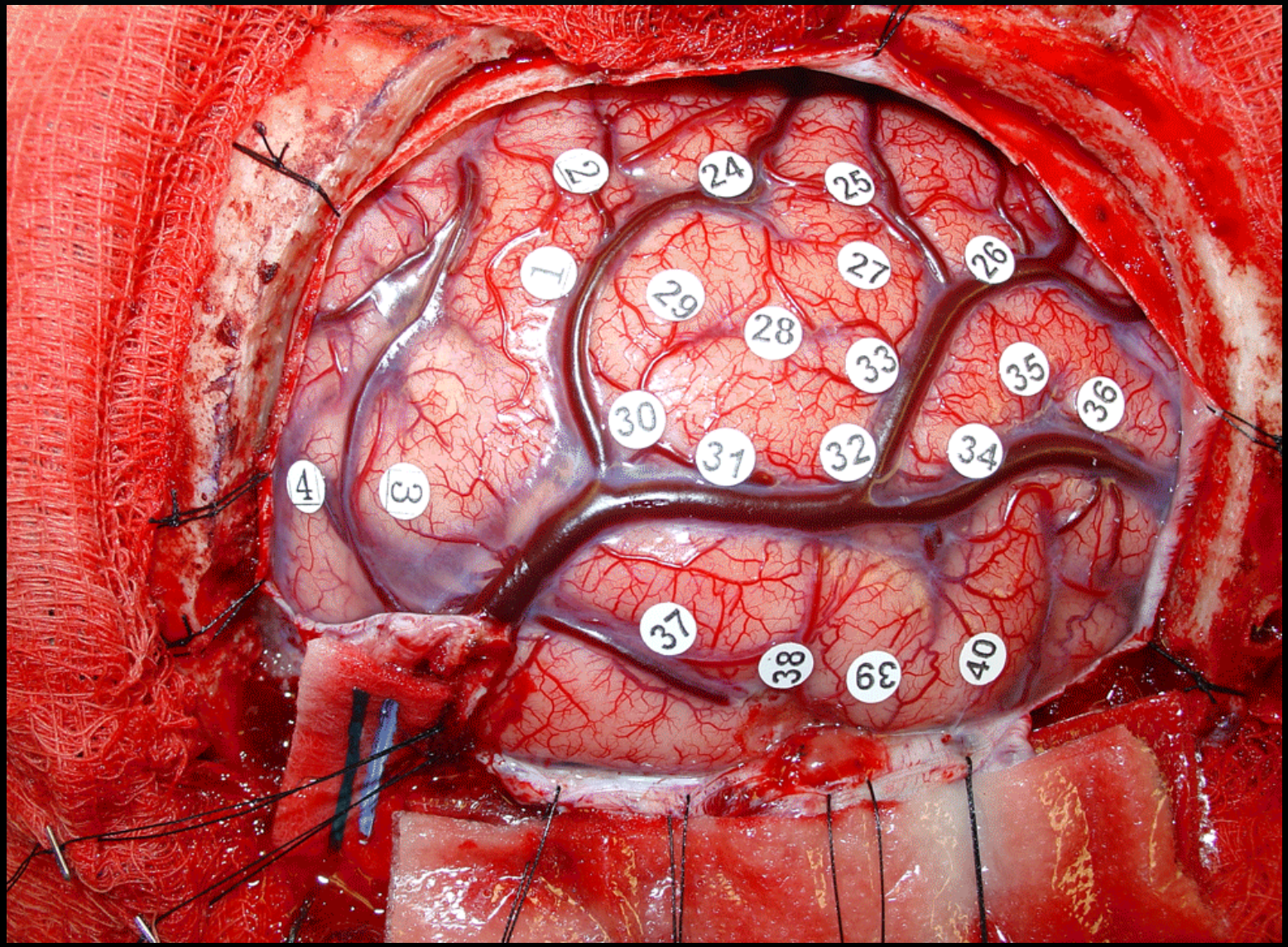
Motor



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Motor Mapping with TMS

Reference	Number of patients	Mean distance nTMS to DCS	Mean distance fMRI/MEG to DCS
Krings, 1997	2	<10 mm	-
Picht, 2009	10	3 mm	-
Kantelhardt , 2010	1	<5 mm	-
Picht, 2011	23	8 mm	14 mm (fMRI)
Forster, 2011	10	13 mm	21 mm (fMRI)
Krieg, 2012	14	4 mm	10 mm (fMRI)
Paiva, 2012	6	4 mm	-
Tarapore, 2012	8	2 mm	5 mm (MEG)
Coburger, 2012	30	-	23% fMRI not feasible
Krieg, 2013	24	5 mm	9 mm (fMRI)
Vitikainen, 2013	13	11 mm	-
Mangraviti, 2013	8	8 mm	13 mm (fMRI)
Frey, 2014	82	6 mm	-

Takahashi et al, Neurosurg. Focus, 2013

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Facial Recognition

Non-invasive Mapping of Face Processing by Navigated Transcranial Magnetic Stimulation

Stefanie Maurer[1], Katrin Giglhuber[1], Nico Sollmann[1], Anna Kelm[1], Sebastian Ille[1], Theresa Hauck[1], Noriko Tanigawa[2], Florian Ringel[1], Tobias Boeckh-Behrens[3], Bernhard Meyer[1] and Sandro M. Krieg[1]

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nTMS Mapping Consensus

Acta Neurochir (2017) 159:1187–1195
DOI 10.1007/s00701-017-3187-z

CrossMark

REVIEW ARTICLE - NEUROSURGICAL TECHNIQUES

Protocol for motor and language mapping by navigated TMS in patients and healthy volunteers; workshop report

Sandro M. Krieg[1] · Pantelis Lioumis[2] · Jyrki P. Mäkelä[2] · Juha Wilenius[3] · Jari Karhu[4] · Henri Hannula[4,5] · Petri Savolainen[4] · Carolin Weiss Lucas[6] · Kathleen Seidel[7] · Aki Laakso[8] · Mominul Islam[9] · Selja Vaalto[3] · Henri Lehtinen[10] · Anne-Mari Vitikainen[2] · Phiroz E. Tarapore[11] · Thomas Picht[12]

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Abstract
Introduction Navigated transcranial magnetic stimulation (nTMS) is increasingly used for preoperative mapping of motor function, and clinical evidence for its benefit for brain tumor patients is accumulating. In respect to language mapping with repetitive nTMS, literature reports have yielded variable results, and it is currently not routinely performed for presurgical language localization. The aim of this project is to define a common protocol for nTMS motor and language mapping to standardize its neurosurgical application and increase its clinical value.

All authors contributed equally to this work

The navigated TMS workshop group; Helsinki Meeting 2016

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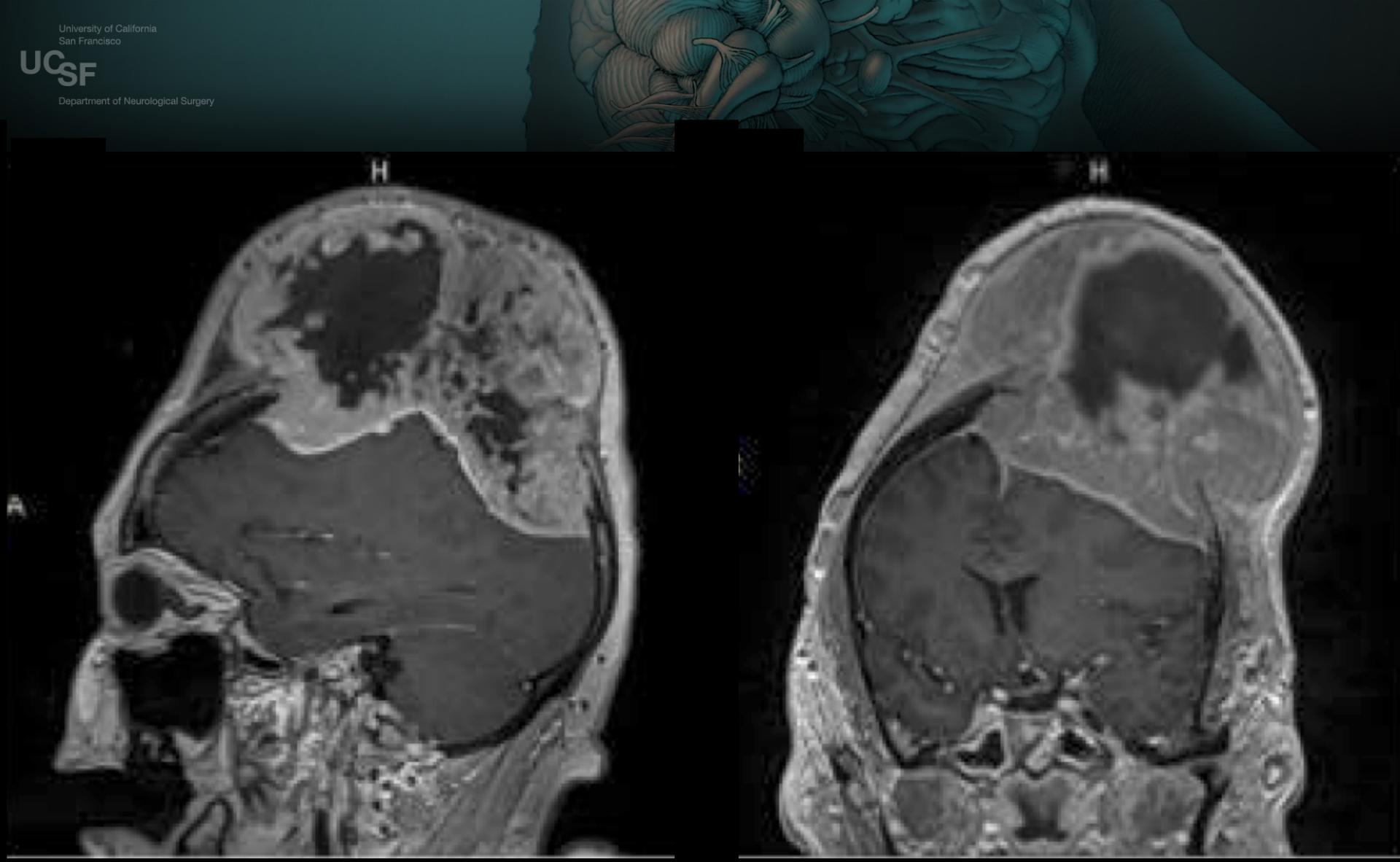

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Broadening the Indications for nTMS

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New Frontiers…

nTMS – An Adjunct Neuro Exam

- Quantitative (MEPs)
- Repeatable
- Reproducible
- Highly sensitive and specific
- Does not require patient participation

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Acute Traumatic Brain Injury

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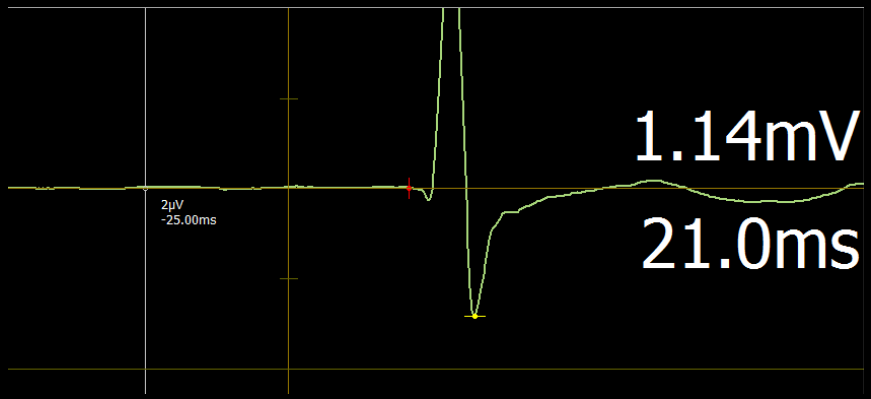
Post-operative Day 1

- RMT APB– Left 45% / Right 47%
- Latency 21-24ms



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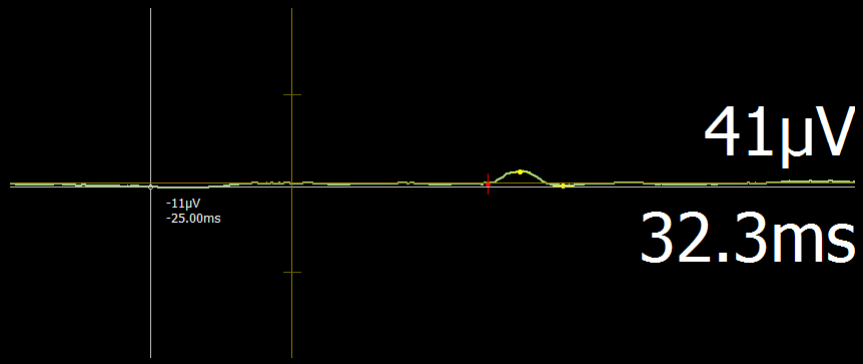
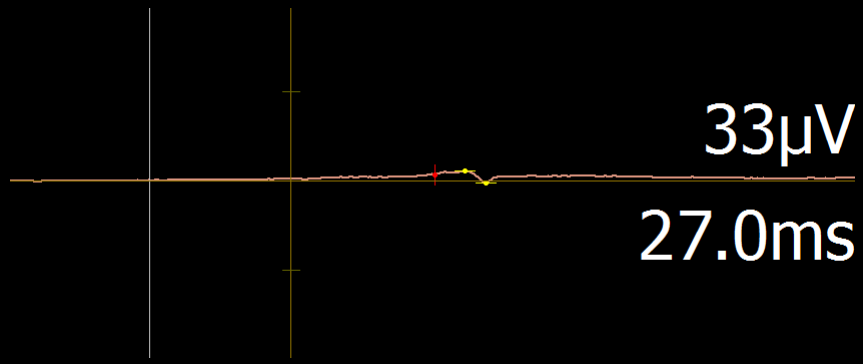
Post-operative Day 4

- Intermittently elevated ICP (20-26)





- Decrease in amplitude
- Monophasic morphology
- longer (and asymmetric) latency

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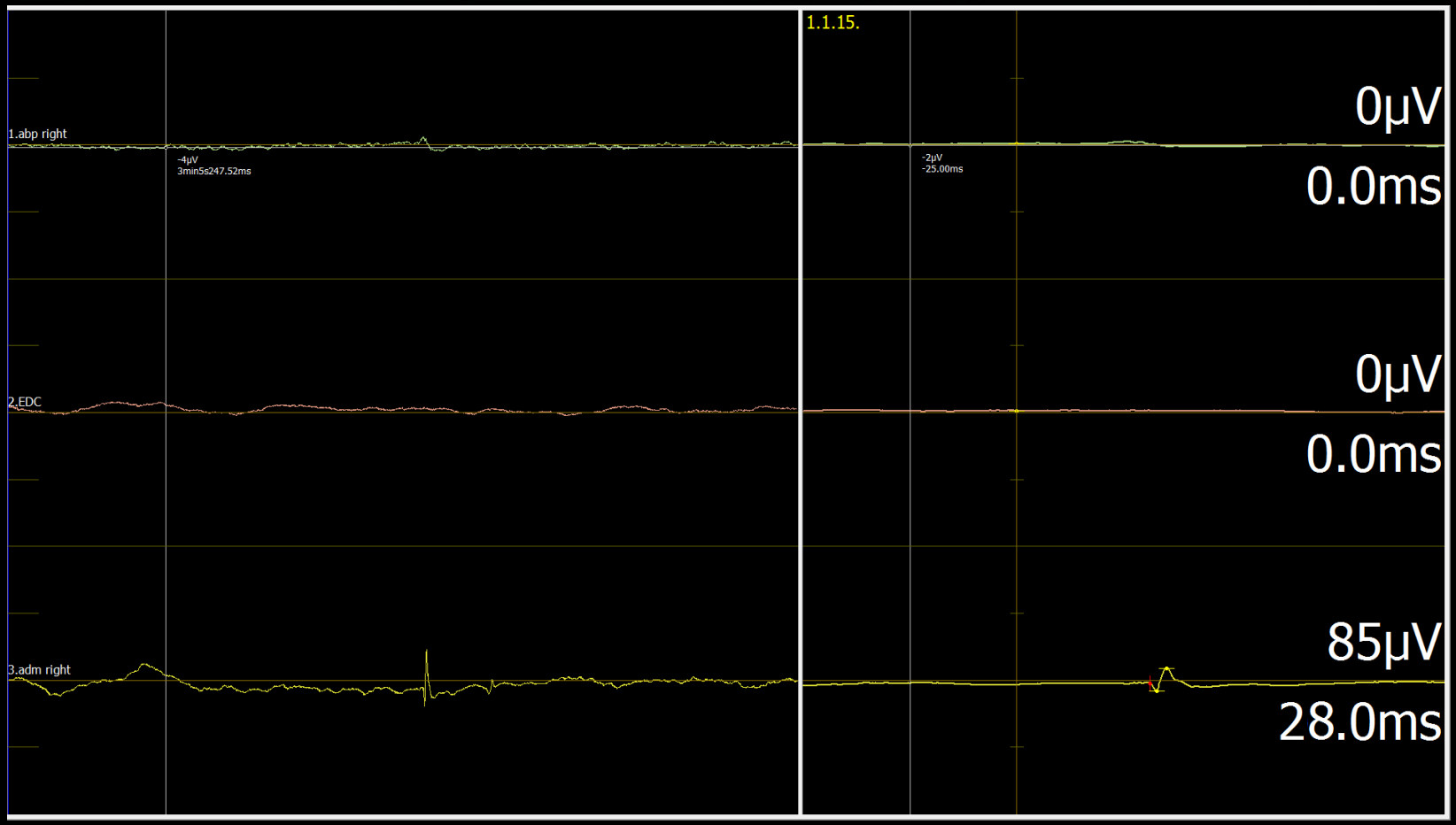
Post-operative Day 4 (Late)



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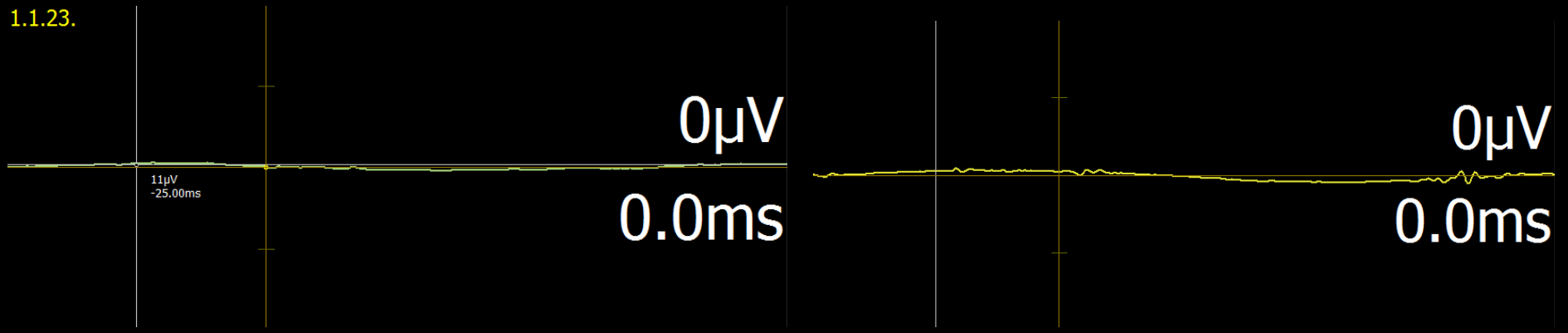
Post-operative Day 5

- Persistently elevated ICP (25-35)



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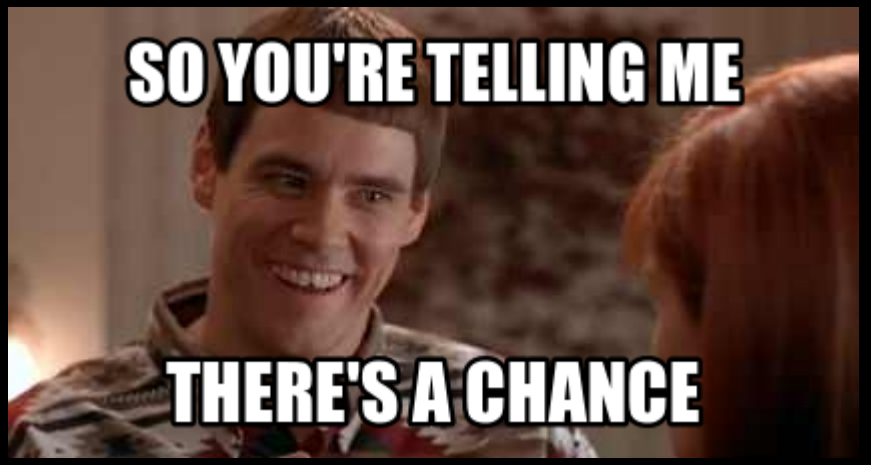
Lessons Learned

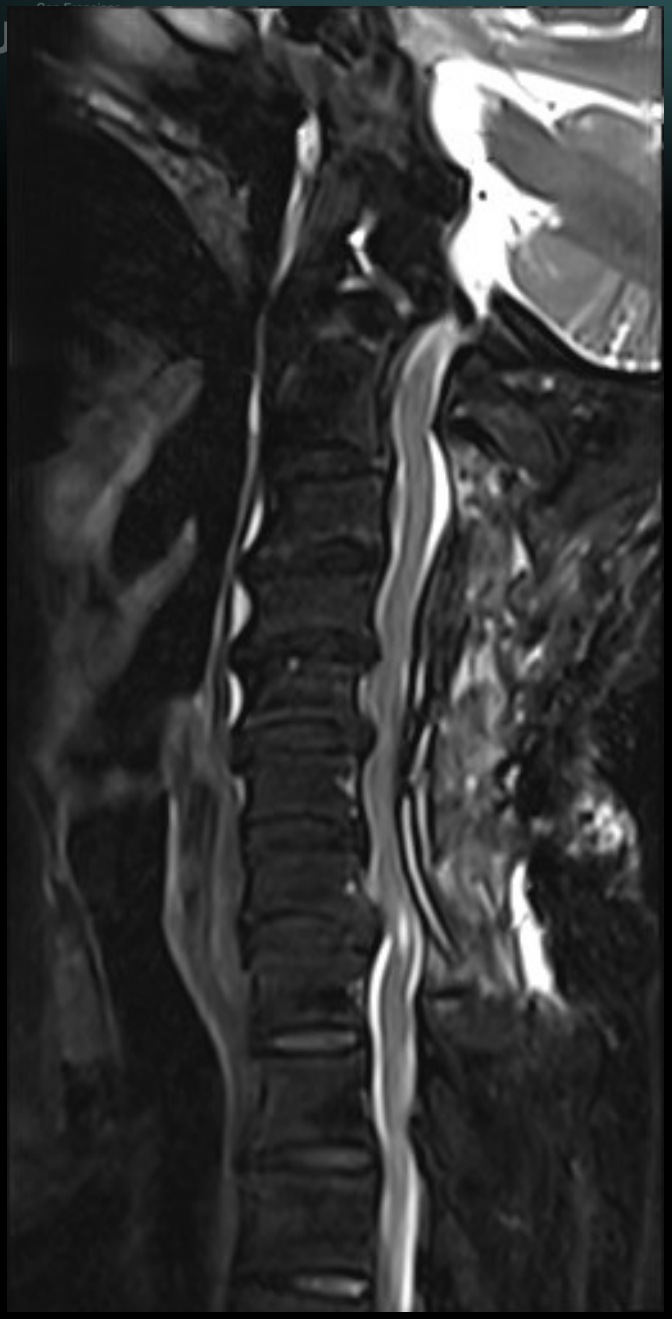
- nTMS can be used in an acute inpatient setting, in a critically ill patient
- MEPs may change with the neurophysiology
  - Amplitude
  - Morphology
  - Latency

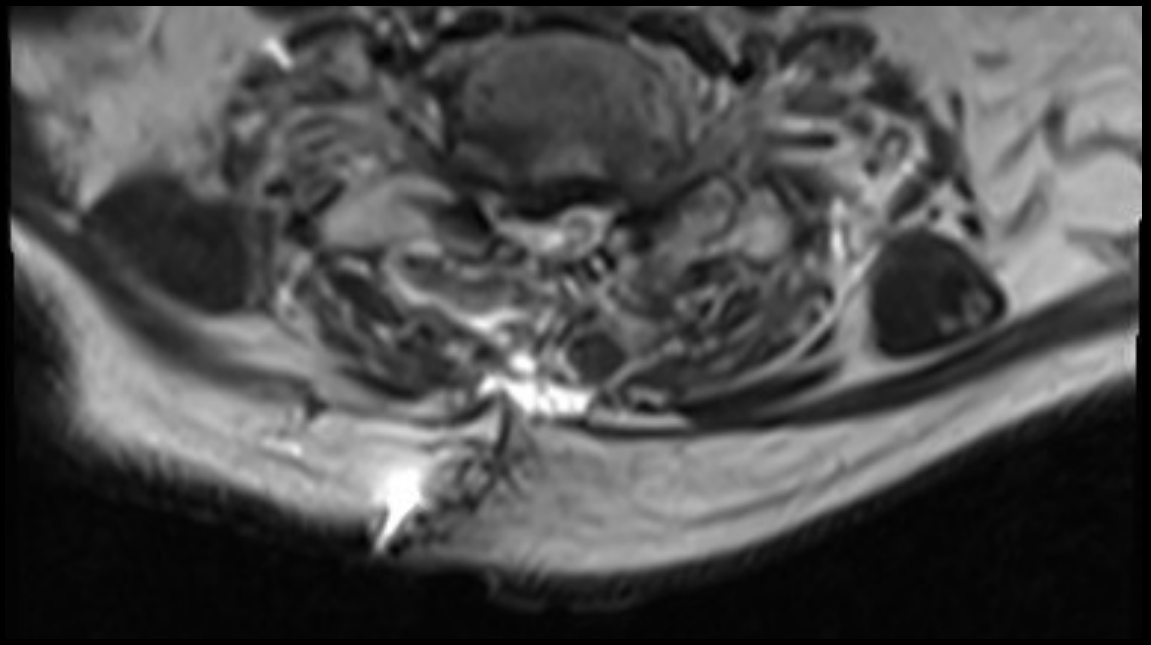
so…

- It's possible!



Acute Cervical Spinal Cord Injury





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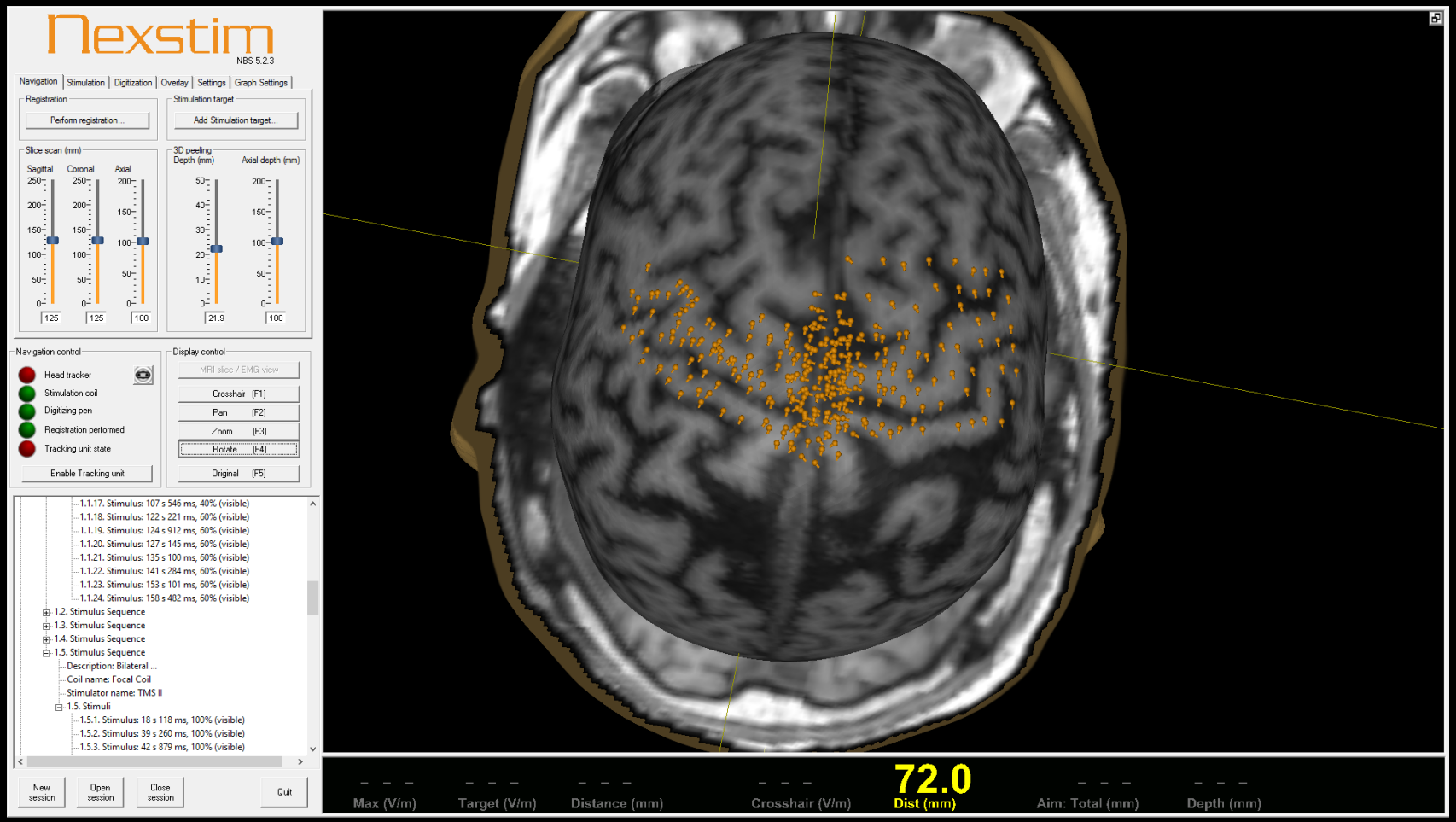
Post-operative Day 1



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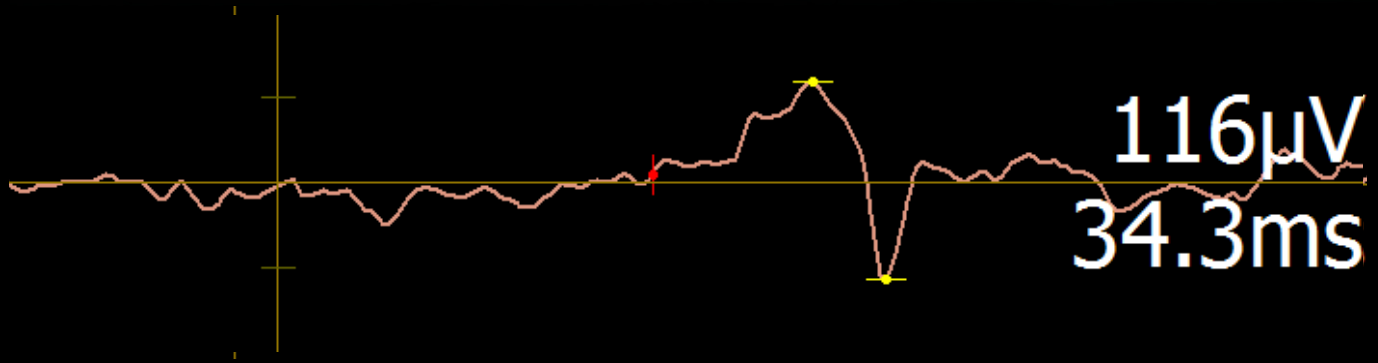
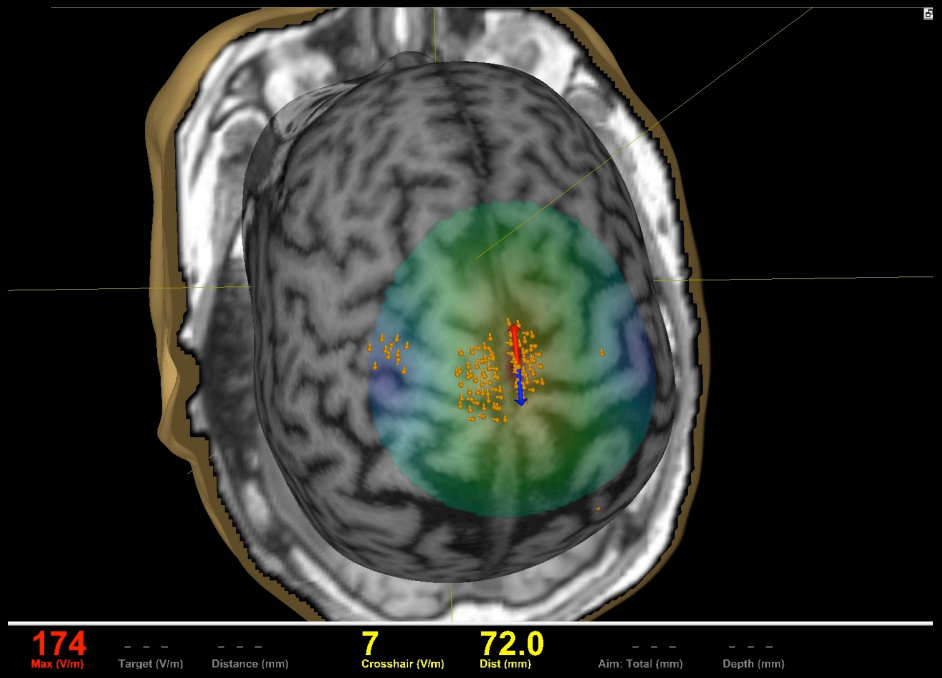
Post-operative Days 1-2





Day 2 (delirious)

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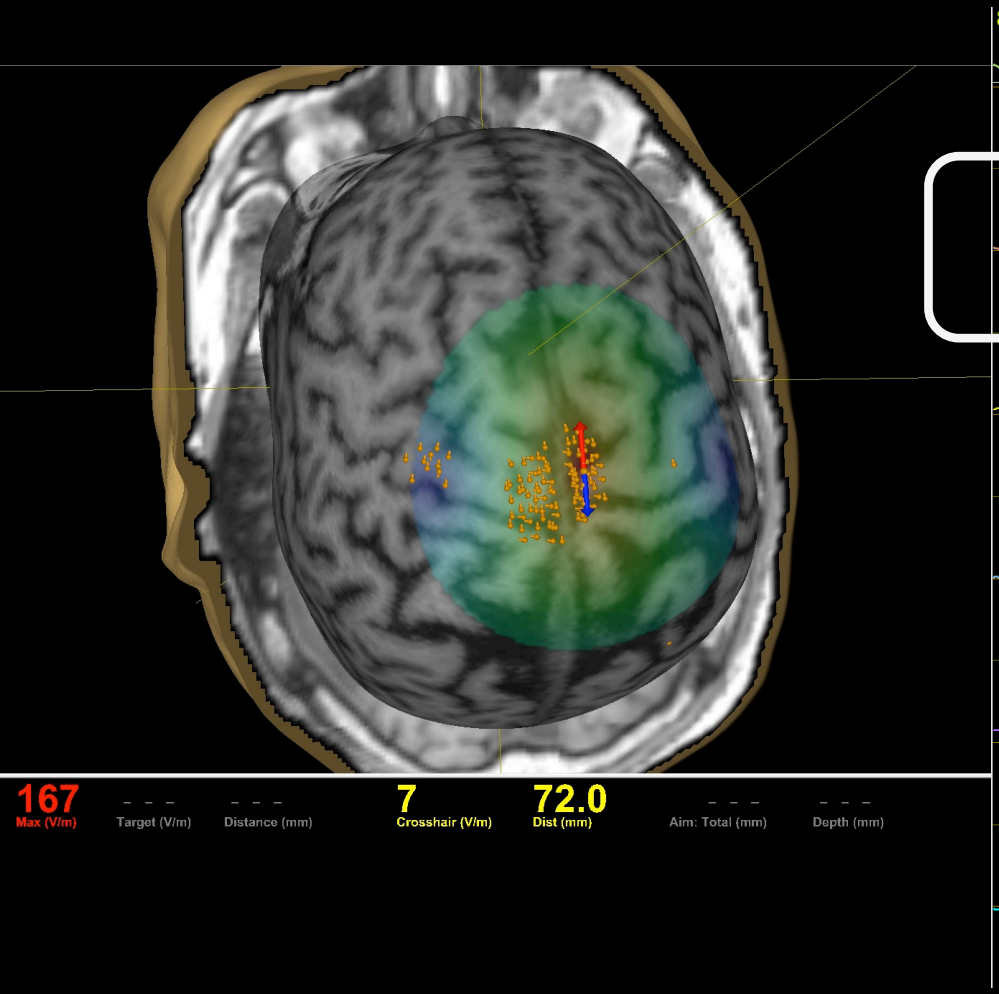
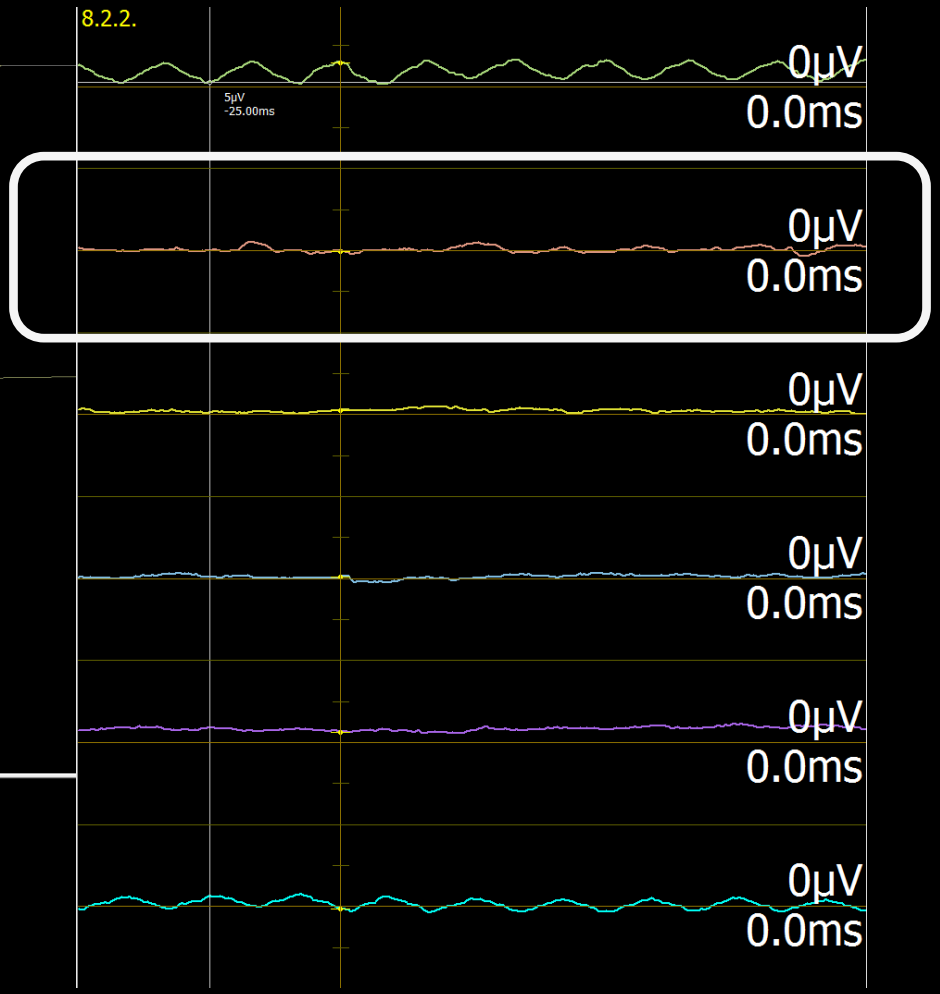
Post-operative Day 3





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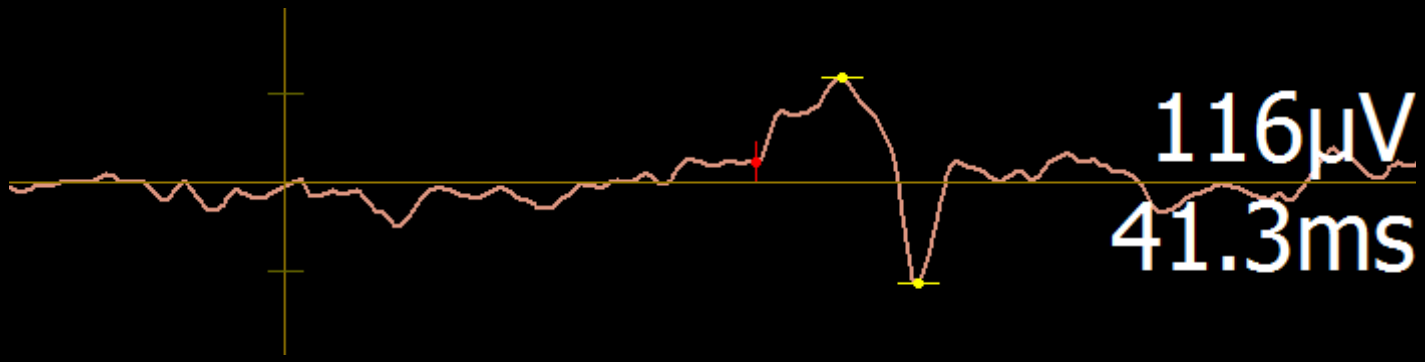
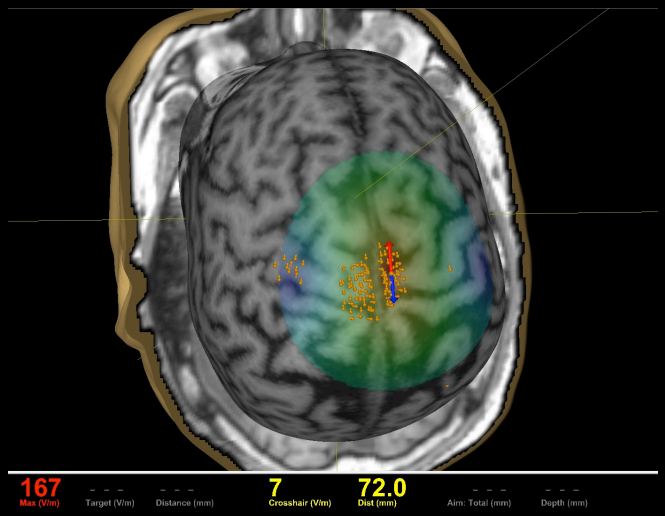
Post-operative Day 3





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Lessons Learned

- MEPs correlate closely with motor examination in acute cervical spinal cord injury
- MEPs can be extremely valuable for following the exam in a patient who is unable to participate
- Therapeutic intervention may be guided successfully by following MEP.

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Aneurysmal SAH

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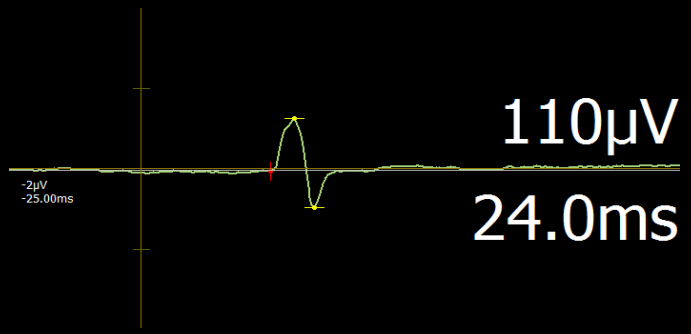
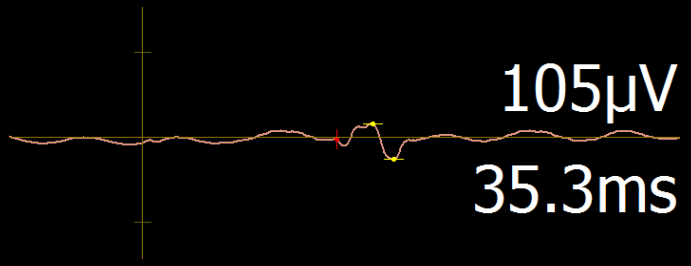
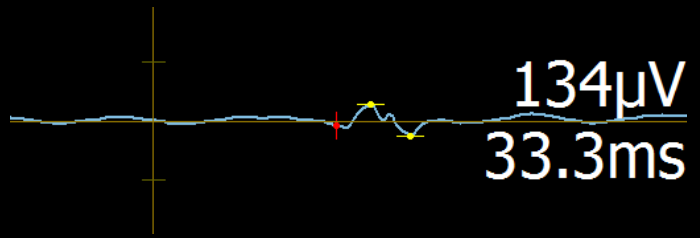
Aneurysmal SAH – Baseline MEPs

	Left	Right
APB (49%)	 110μV 24.0ms	 198μV 24.3ms
TA (80%)	 105μV 35.3ms	 134μV 33.3ms

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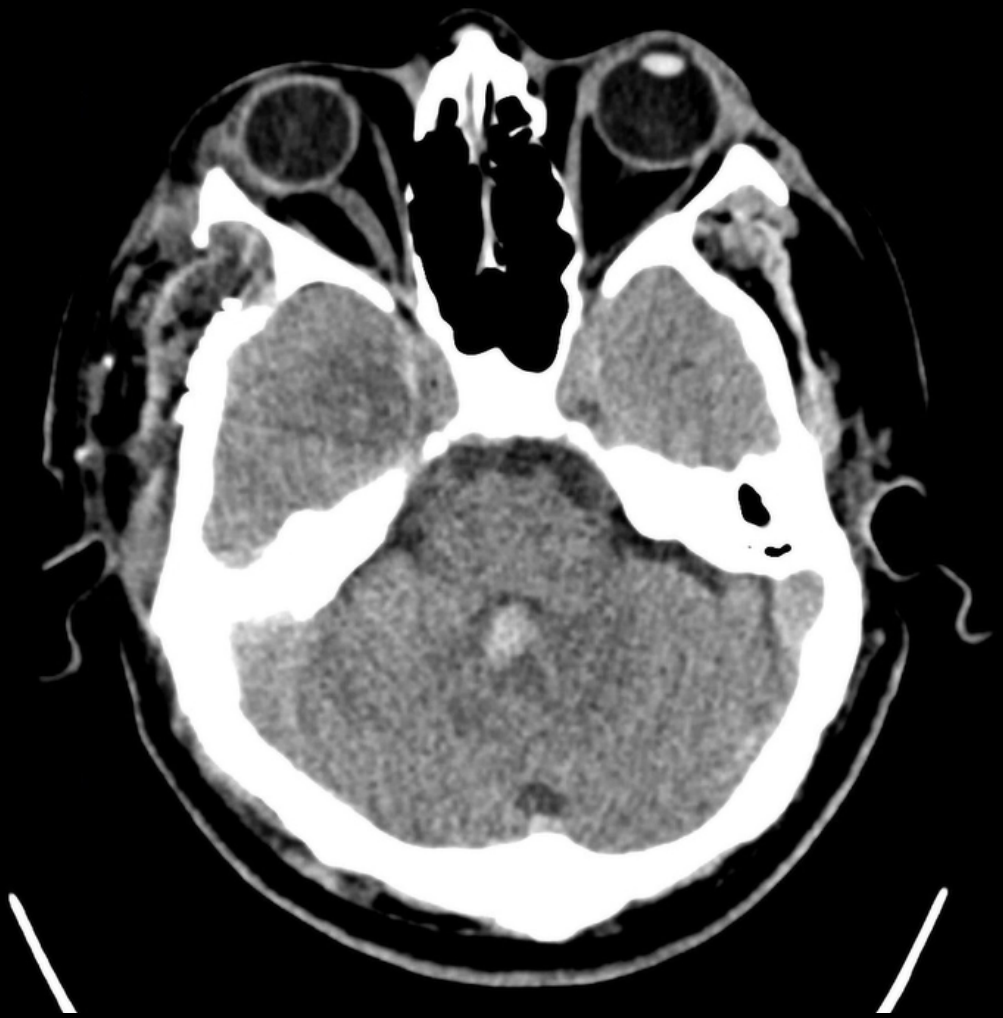
Post-Bleed Day 4



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Post-Bleed Day 7

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A Silver Lining?

APB

ED

ADM

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Lessons Learned

- MEPs can be used to follow cerebral ischemia in real-time
- The localization of function is specific enough that it can distinguish different vascular territories
- Hypoperfused brain tissue (“area at risk”) demonstrates functional changes before it displays radiographic changes

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Conclusions

- nTMS can be safely utilized in the acute inpatient setting
- Exact reproducibility between studies is critical (software-based point selection)
- nTMS provides neurophysiological data that would otherwise be unobtainable
- Trends in MEPs over time seem to have clinical significance
- nTMS can help guide clinical management in a variety of neurological injury states

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Future Directions

- More patients
- More disease states
- Effects of anesthetics?
- Medium and long-term follow-up studies

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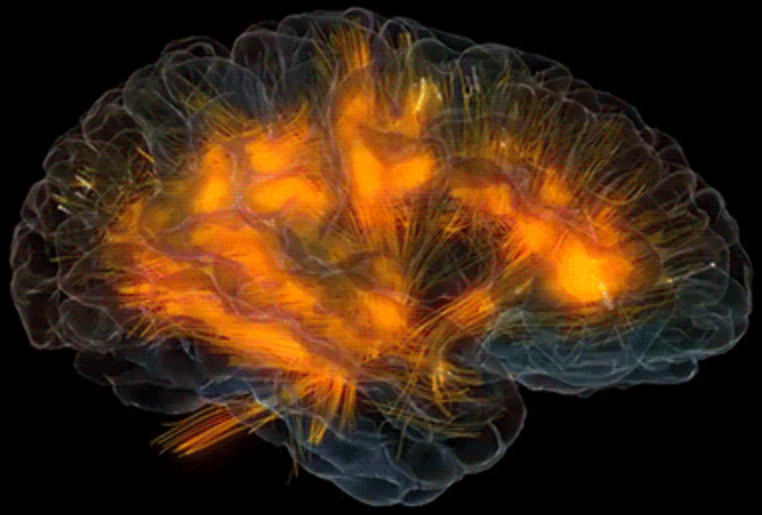

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