

Resection of high frequency oscillations predicts seizure outcome in the individual patient

<https://www.nature.com/articles/s41598-017-13064-1>

<https://doi.org/10.1038/s41598-017-13064-1>

Tommaso Fedele, PhD^{1,*}; Sergey Burnos, MSc^{1,2,*}; Ece Boran, MSc¹; Niklaus Krayenbühl, MD¹; Peter Hilfiker, PhD³; Thomas Grunwald, PhD, MD³; Johannes Sarnthein, PhD^{1,4}

¹ University Hospital Zurich, Neurosurgery Department, Zurich, Switzerland

² ETH Zurich, Institute of Neuroinformatics, Zurich, Switzerland

³ Swiss Epilepsy Centre, Zurich, Switzerland

⁴ University of Zurich, Zurich Neuroscience Centre, Zurich, Switzerland

* These authors contributed equally to the manuscript

Corresponding author: Johannes Sarnthein

Klinik für Neurochirurgie, UniversitätsSpital Zürich,
8091 Zürich, Switzerland

Tel: +41 44 255 5672

johannes.sarnthein@usz.ch

SUPPLEMENTARY MATERIAL

Table 1S: HFO rates of all patients. For each patient, we list the postsurgical seizure outcome (ILAE) and the names of the implanted channels. Channels excluded from the analysis are marked in gray. The resected area (RA) is highlighted in red. The rates of ripple, FR and FRandR events are given in events/minute for each channel. Channels with the HFO rate exceeding the 95% percentile of the HFO distribution define the HFO area and are highlighted in green.

Figure 1S: Electrode types and implantation sites. Subdural strip and grid electrodes as well as depth electrodes were placed according to the findings of the non-invasive presurgical evaluation. In TLE patients, depth electrodes (1.3 mm diameter, 8 contacts of 1.6 mm length, spacing between contacts centres 5 mm, ADTech®, www.adtechmedical.com) were implanted bilaterally into the amygdala (AL, AR), the entorhinal cortex (ECL, ECR), anterior hippocampus (AHL, AHR) and the posterior hippocampus (PHL, PHR). In ETE patients, a combination of depth and subdural grid and strip electrodes (contact diameter 4 mm with a 2.3 mm exposure, spacing between contact centers 10 mm, ADTech®) was placed after craniotomy. The placement of the electrodes in each patient is illustrated schematically.

Patient 1		ILAE 1																						
Channels		'AR1-2' 'AR2-3' 'AR3-4' 'AR4-5' 'AR5-6' 'PR1-2' 'PR2-3' 'PR3-4' 'ER1-2' 'ER2-3' 'ER3-4' 'AL1-2' 'AL2-3' 'AL3-4' 'AR1-2' 'AR2-3' 'AR3-4' 'HL1-2' 'HL2-3' 'HL3-4' 'PR1-2' 'PR2-3' 'PR3-4'																						
Ripples	33.8	55.2	40.2	26.7	31.1	0.6	1.7	11.8	19.8	21.4	19.7	3.2	0.6	0.2	47.8	48.2	4.3	49.3	60.6	105.1	22.8	20.2	11.8	
FR	2.9	3.7	2.9	2.8	2.8	2.4	2.6	2.4	3.3	4.4	3.0	2.3	2.7	2.6	5.3	5.1	2.8	2.6	2.2	2.2	2.5	4.9	3.0	
FRandR	0.9	0.8	0.9	0.2	0.4	0.0	0.0	0.0	0.9	2.4	0.4	0.0	0.0	0.0	0.0	2.7	0.1	0.2	0.2	0.4	0.4	2.4	0.4	
Patient 2		ILAE 1																						
Channels		'AL1-2' 'AL2-3' 'AL3-4' 'AR1-2' 'AR2-3' 'AR3-4' 'EL1-2' 'EL2-3' 'EL3-4' 'ER1-2' 'ER2-3' 'ER3-4' 'HL1-2' 'HL2-3' 'HL3-4' 'HR1-2' 'HR2-3' 'HR3-4' 'PL1-2' 'PL2-3' 'PL3-4' 'PR1-2' 'PR2-3' 'PR3-4'																						
Ripples	44.3	17.7	5.1	52.6	16.2	1.4	2.6	1.5	2.7	51.4	11.7	0.6	4.8	1.8	71.4	19.7	1.6	16.3	2.8	0.4	48.9	18.1	0.8	
FR	9.1	4.1	3.4	3.4	1.5	1.5	2.0	2.4	1.4	5.4	2.4	1.7	2.7	1.9	2.9	14.1	2.9	1.5	13.1	0.8	2.9	16.2	6.9	
FRandR	4.6	1.4	0.9	7.5	1.0	0.0	0.0	0.0	0.1	2.7	0.2	0.0	0.0	0.0	0.0	6.7	0.3	0.0	1.7	0.1	0.1	9.8	3.7	
Patient 3		ILAE 1																						
Channels		'AL1-2' 'ALH1-3' 'ALH2-3' 'ALH3-4' 'AR1-2' 'ARH2-3' 'ARH3-4' 'AL1-2' 'AL2-3' 'AL3-4' 'EC1-2' 'EC2-3' 'EC3-4' 'PH1-2' 'PH2-3' 'PH3-4'																						
Ripples	12.5	7.3	2.5	10.1	5.9	5.1	2.4	2.3	2.5	2.7	2.7	2.8	3.5	3.0	6.8									
FR	9.1	2.6	0.0	5.2	2.4	2.5	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.4	0.1									
Patient 4		ILAE 1																						
Channels		'AL1-2' 'AL2-3' 'AL3-4' 'AR1-2' 'AR2-3' 'AR3-4' 'EL1-2' 'EL2-3' 'EL3-4' 'ER1-2' 'ER2-3' 'ER3-4' 'HL1-2' 'HL2-3' 'HL3-4' 'HR1-2' 'HR2-3' 'HR3-4' 'PL1-2' 'PL2-3' 'PL3-4' 'PR1-2' 'PR2-3' 'PR3-4'																						
Ripples	2.0	0.9	0.2	39.6	32.5	11.0	0.3	0.1	0.1	3.9	1.7	3.0	140.6	128.2	63.8	41.6	36.5	20.4	82.0	161.3	44.6	12.2	3.7	0.6
FR	2.3	2.3	2.8	2.8	2.4	5.5	2.8	2.9	2.4	2.9	2.5	2.3	5.3	5.2	19.0	13.5	2.5	2.9	2.4	8.4	3.7	2.7		
FRandR	0.0	0.0	0.0	14.0	12.3	2.3	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.6	1.7	9.0	6.4	5.0	0.6	1.2	0.2	5.2	0.6	
Patient 5		ILAE 1																						
Channels		'AL1-2' 'AL2-3' 'AL3-4' 'AR1-2' 'AR2-3' 'AR3-4' 'EL1-2' 'EL2-3' 'EL3-4' 'ER1-2' 'ER2-3' 'ER3-4' 'HL1-2' 'HL2-3' 'HL3-4' 'HR1-2' 'HR2-3' 'HR3-4' 'PL1-2' 'PL2-3' 'PL3-4' 'PR1-2' 'PR2-3' 'PR3-4'																						
Ripples	14.2	3.3	1.8	43.0	30.1	8.2	2.8	2.6	1.1	6.9	4.7	6.6	4.0	3.3	1.4	18.4	7.2	1.6	17.6	3.3	1.6	117.1	25.3	
FR	3.8	2.8	2.4	12.6	2.6	2.4	2.6	2.4	2.1	3.2	2.5	2.3	2.6	2.2	3.1	2.4	2.3	2.7	2.5	2.0	14.0	3.4		
FRandR	0.7	0.3	0.0	6.2	0.3	0.1	0.3	0.1	0.0	0.4	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	9.4	0.7	
Patient 6		ILAE 1																						
Channels		'AL1-2' 'AL2-3' 'AL3-4' 'AR1-2' 'AR2-3' 'AR3-4' 'EL1-2' 'EL2-3' 'EL3-4' 'ER1-2' 'ER2-3' 'ER3-4' 'HL1-2' 'HL2-3' 'HL3-4' 'HR1-2' 'HR2-3' 'HR3-4' 'PL1-2' 'PL2-3' 'PL3-4' 'PR1-2' 'PR2-3' 'PR3-4'																						
Ripples	83.8	59.5	5.3	27.0	20.3	2.8	2.3	1.5	0.6	13.6	9.6	0.7	0.1	0.0	0.4	0.3	0.2	45.4	76.3	1.9	147.3	14.2	0.5	
FR	9.2	2.2	0.8	6.6	2.2	2.3	2.3	2.3	2.2	3.0	2.2	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	18.1	1.6		
FRandR	4.3	2.4	0.0	4.0	3.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	2.8		
Patient 7		ILAE 3																						
Channels		'AR1-2' 'AR2-3' 'AR3-4' 'AL1-2' 'AL2-3' 'AL3-4' 'HR1-2' 'HR2-3' 'HR3-4' 'HL1-2' 'HL2-3' 'HL3-4' 'HL1-2' 'HL2-3' 'HL3-4' 'HR1-2' 'HR2-3' 'HR3-4' 'PL1-2' 'PL2-3' 'PL3-4' 'PR1-2' 'PR2-3' 'PR3-4'																						
Ripples	5.2	3.4	0.6	5.3	3.4	3.6	17.4	21.8	27.0	36.9	18.0	6.0	3.4	3.8	5.0	2.0	3.2	6.0	6.2	4.4	7.8	17.4	5.0	
FR	0.4	0.0	0.0	1.0	0.0	0.0	6.0	7.6	7.6	7.4	1.6	0.0	0.0	0.0	0.0	2.0	2.2	1.4	4.0	0.8	0.2	0.0		
Patient 8		ILAE 3																						
Channels		'AL1-2' 'AL2-3' 'AL3-4' 'AR1-2' 'AR2-3' 'AR3-4' 'EL1-2' 'EL2-3' 'EL3-4' 'ER1-2' 'ER2-3' 'ER3-4' 'HL1-2' 'HL2-3' 'HL3-4' 'HR1-2' 'HR2-3' 'HR3-4' 'PL1-2' 'PL2-3' 'PL3-4' 'PR1-2' 'PR2-3' 'PR3-4'																						
Ripples	14.4	1.5	0.1	4.6	8.2	1.7	3.4	1.1	0.5	2.6	2.4	4.4	1.7	0.5	3.3	4.4	2.6	0.1	1.8	0.1	0.1	0.1		
FR	11.5	5.3	5.3	5.5	2.2	2.4	2.4	2.4	2.2	2.4	2.3	2.1	2.4	2.1	2.4	2.1	2.1	2.4	2.2	2.2	3.2	6.2		
FRandR	7.0	0.4	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Patient 9		ILAE 5																						
Channels		'AL1-2' 'AL2-3' 'AL3-4' 'AR1-2' 'AR2-3' 'AR3-4' 'EL1-2' 'EL2-3' 'EL3-4' 'ER1-2' 'ER2-3' 'ER3-4' 'HL1-2' 'HL2-3' 'HL3-4' 'HR1-2' 'HR2-3' 'HR3-4' 'PL1-2' 'PL2-3' 'PL3-4' 'PR1-2' 'PR2-3' 'PR3-4'																						
Ripples	35.7	12.8	3.6	22.9	7.3	1.6	59.0	27.2	1.9	22.0	9.0	6.8	6.4	6.7	14.4	2.9	23.3	23.8	15.8	28.3	14.5	6.6	52.5	4.9
FR	11.5	5.5	5.3	5.5	2.2	2.5	4.5	2.0	5.8	1.9	2.3	2.2	1.9	2.0	8.5	2.6	2.3	11.1	5.5	3.2	6.2	2.0		
FRandR	7.0	0.8	1.0	2.6	0.1	0.0	1.5	0.2	0.0	1.1	0.1	0.0	0.0	0.0	4.0	0.8	0.1	5.9	1.2	0.2	3.6	0.2		
Patient 10		ILAE 1																						
Channels		'GR1-2' 'GR3-4' 'GR5-5' 'GR6-6' 'GR7-7' 'GR8-8' 'GR9-10' 'GR10-11' 'GR11-12' 'GR12-13' 'GR13-14' 'GR14-15' 'GR15-16' 'GR16-17' 'GR17-18' 'GR18-19' 'GR19-20' 'GR20-21' 'GR21-22' 'GR22-23' 'GR23-24' 'GR25-26' 'GR26-27' 'GR27-28'																						
Ripples	9	14	11	4	2	29	57	42	44	60	38	25	35	61	13	9	3	8	14	0	2	3		
FR	3	5	2	2	2	2	3	3	2	2	3	3	3	4	5	2	2	3	3	3	3	0		
FRandR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Patient 11		ILAE 1																						
Channels		'GR1-2' 'GR3-4' 'GR4-5' 'GR5-6' 'GR6-7' 'GR7-8' 'GR8-9' 'GR9-10' 'GR10-11' 'GR11-12' 'GR12-13' 'GR13-14' 'GR14-15' 'GR15-16' 'GR16-17' 'GR17-18' 'GR18-19' 'GR19-20' 'GR20-21' 'GR21-22' 'GR22-23' 'GR23-24' 'GR25-26' 'GR26-27' 'GR27-28'																						
Ripples	75.1	44.8	65.5	107.3	142.1	84.7	24.0	139.3	144.9	146.6	167.8	145.6	103.4	85.2	106.9	98.2	82.6	136.9	164.7	58.0	84.3	56.2	84.8	
FR	4.6	2.6	2.6	2.8	3.4	3.6	2.2	6.7	6.3	3.0	4.2	3.4	3.3	5.9	4.6	3.0	3.7	3.7	2.5	3.0	15.5	22.4		
FRandR	1.4	0.4	0.4	0.6	1.0	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.4	1.2	0.4	0.3	0.6	4.0		
Patient 12		ILAE 1																						
Channels		'GL1-2' 'GL2-3' 'GL3-4' 'GL4-5' 'GL5-6' 'GL6-7' 'GL7-8' 'GL8-9' 'GL9-10' 'GL10-11' 'GL11-12' 'GL12-13' 'GL13-14' 'GL14-15' 'GL15-16' 'GL16-17' 'GL17-18' 'GL18-19' 'GL19-20' 'GL20-21' 'GL21-22' 'GL22-23' 'GL23-24' 'GL25-26' 'GL26-27' 'GL27-28'																						
Ripples	60.9	42.8	53.1	41.1	15.9	53.4	72.6	58.9	61.8	45.0	10.4	38.2	50.3	35.1	61.4	43.5	45.0	52.5	29.1	37.4	42.8	35.8		
FR	67	2.3	2.8	2.7	3.0	2.7	3.0	2.7	3.0	2.7	3.0	2.7	3.0	2.7	3.0	2.7	3.0	2.7	3.0	3.1	3.1	3.1		
FRandR	0.7	0.3	0.3	0.3	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2		
Patient 13		ILAE 1																						
Channels		'GR1-2' 'GR2-3' 'GR3-4' 'GR4-5' 'GR5-6' 'GR6-7' 'GR7-8' 'GR8-9' 'GR9-10' 'GR10-11' 'GR11-12' 'GR12-13' 'GR13-14' 'GR14-15' 'GR15-16' 'GR16-17' 'GR17-18' 'GR18-19' 'GR19-20' 'GR20-21' 'GR21-22' 'GR22-23' 'GR23-24' 'GR24-25' 'GR25-26' 'GR26-27' 'GR27-28'																						
Ripples	78.1	54.3	75.8	8.2	20.0	7.9	14.8	15.8	12.8	8.8	13.6	16.1	19.4	21.0	21.5	16.1	18.1	14.8	12.1	14.4	16.3	11.2		
FR	2.7	2.5	2.9	2.0	2.2	2.4	3.8	4.3	2.7	3.7	3.3	3.0	3.2	3.1	3.0	2.7	2.5	3.2	2.7	2.8	2.4	3.1		
FRandR	0.6	0.5	0.7	0.0	0.1	0.6	1.6	1.5	0.5	1.1	1.0	1.4	3.0	3.4	3.0	1.7	0.8	0.4	0.2	0.4	0.4	0.2		
Patient 14		ILAE 1																						
Channels		'AR1-2' 'AR2-3' 'AR3-4' 'AR4-5' 'AR5-6' 'AR6-7' 'AR7-8' 'AR8-9' 'AR9-10' 'AR10-11' 'AR11-12' 'AR12-13' 'AR13-14' 'AR14-15' 'AR15-16' 'AR16-17' 'AR17-18' 'AR18-19' 'AR19-20' 'AR20-21' 'AR21-22' 'AR22-23' 'AR23-24' 'AR24-25' 'AR25-26' 'AR26-27' 'AR27-28'																						
Ripples	76.0	57.8	68.8	78.8	142.7	17.5	14.8	56.8	80.4	38.6	7.2	11.4	64.1	26.0	103.1	98.5	104.4	126.5	197.8	224.5	210.7	206.1		
FR	4.7	2.1	2.7	2.1	4.7	3.0	3.1	3.7	2.7	3.0	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7		
FRandR	1.4	1.2	0.5	1.0	1.7	0.2	0.2	0.4	0.7	0.2	0.5	0.5	0.3	2.0	2.8	2.1	0.7	0.8	1.3	2.3	2.2	1.3		