ASEPA Workshop, July 13th - 15th, 2023
Bangkok

Online lecture

Wide-band EEG: a mysterious and very useful technique

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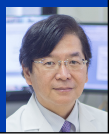


Disclosure Form

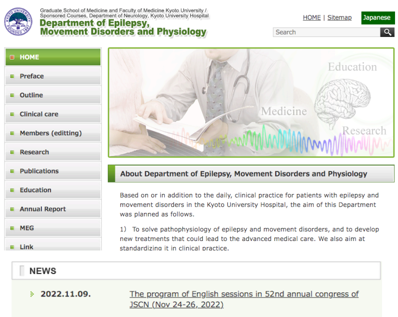
Company Name	Nature of Affiliation
• Eisai, • Nihon-Kohden, Otsuka, UBC Japan	• Industry-Academia Collaboration Courses • Endowed Department
• None	• Grants or Honorariums

Off-Label Product Usage
• None

ikeda epilepsy kyoto University,,,,,,

/http://epilepsy.med.kyoto-u.ac.jp/?lang=en

PW=07152023



22nd Annual Scientific Meeting of the Epilepsy Society of Thailand
Main auditorium of Prasart Neurology Institute
Bangkok, July 19th and 20th, 2018

Epileptogenesis, glia and neurons: is it a paradigm shift?

Akio IKEDA, MD, PhD

Department of Epilepsy, Movement Disorders & Physiology

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Kyoto, JAPAN

3 supportive data for glia as one of the epileptogenicity

1) Neurophysiological biomarkers:

   ictal DC shifts & red slow

2) Pathological endorsement:

   selectively decreased Kir4.1 activity at astrocytes with DC shifts

3) Surgical outcome

Wide-band EEG: a mysterious and very useful technique

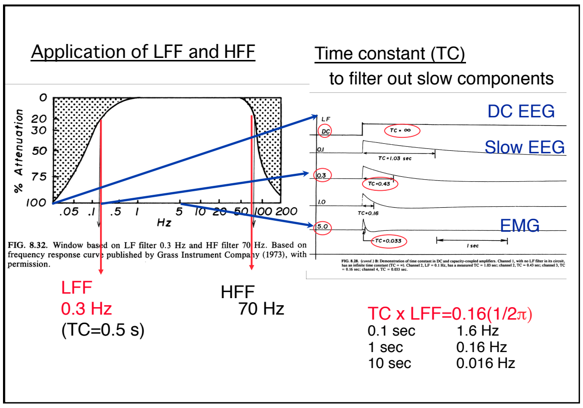
1) active- vs. passive DC shifts
   AMED study in Japan (Multi-institutional study)
   Surgical outcome

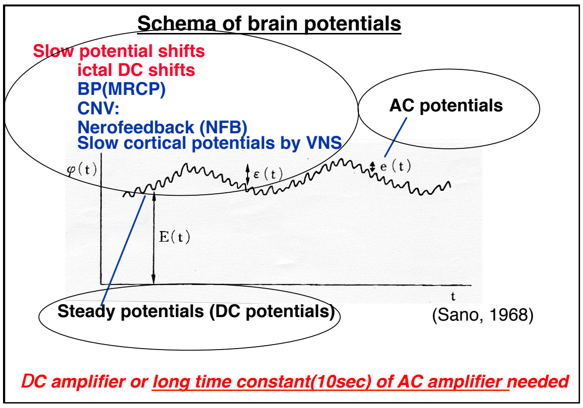
2) 2 types of ictal DC shifts, and pathology

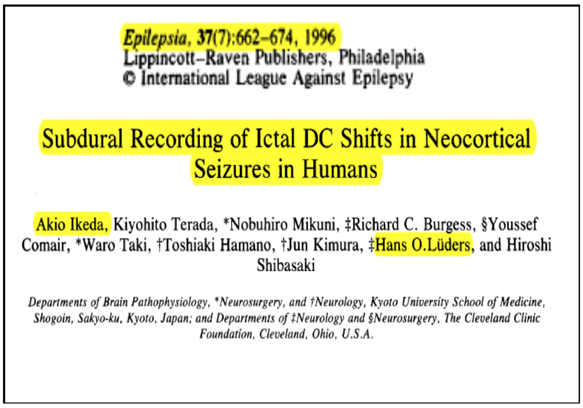
3) Interictal red slow, i.e., co-occurrence of slow and HFO

4) Is it recorded by scalp EEG ?

5) Future: AI analysis, mathematical modeling


Application of LFF and HFF
Time constant (TC)
to filter out slow components
% Attenuation
Hz
DC EEG
Slow EEG
EMG
FIG. 8.32. Window based on LF filter 0.3 Hz and HF filter 70 Hz. Based on frequency response curve published by Grass Instrument Company (1973), with permission.
LFF
0.3 Hz
(TC=0.5 s)
HFF
70 Hz
TC x LFF=0.16(1/2π)
0.1 sec 1.6 Hz
1 sec 0.16 Hz
10 sec 0.016 Hz


Schema of brain potentials
Slow potential shifts
ictal DC shifts
BP(MRCP)
CNV:
Nerofeedback (NFB)
Slow cortical potentials by VNS
AC potentials
φ(t)
ε(t)
e(t)
E(t)
t
Steady potentials (DC potentials)
(Sano, 1968)
DC amplifier or long time constant(10sec) of AC amplifier needed


Epilepsia, 37(7):662–674, 1996
Lippincott–Raven Publishers, Philadelphia
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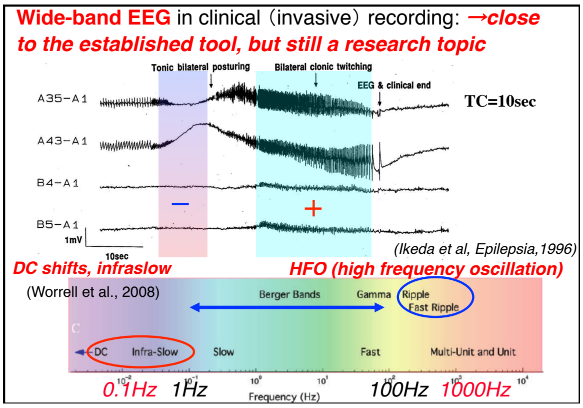
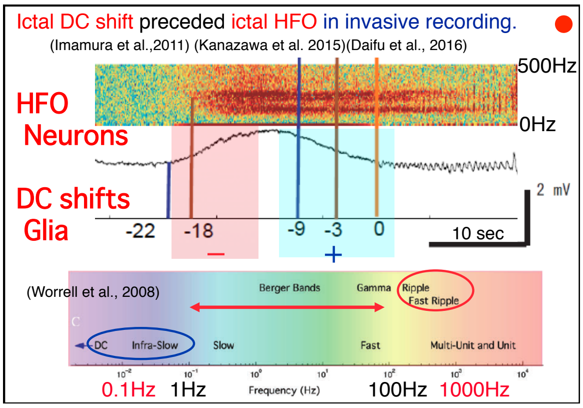
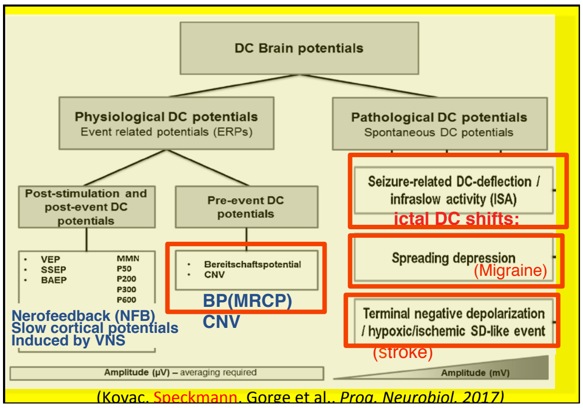
Subdural Recording of Ictal DC Shifts in Neocortical Seizures in Humans
Akio Ikeda, Kiyohito Terada, *Nobuhiro Mikuni, ‡Richard C. Burgess, §Youssef Comair, *Waro Taki, †Toshiaki Hamano, †Jun Kimura, ‡Hans O.Lüders, and Hiroshi Shibasaki
Departments of Brain Pathophysiology, *Neurosurgery, and †Neurology, Kyoto University School of Medicine, Shogoin, Sakyo-ku, Kyoto, Japan; and Departments of ‡Neurology and §Neurosurgery, The Cleveland Clinic Foundation, Cleveland, Ohio, U.S.A.


Wide-band EEG in clinical（invasive）recording: →close to the established tool, but still a research topic
Tonic bilateral posturing
Bilateral clonic twitching
EEG & clinical end
TC=10sec
A35−A1
A43−A1
B4−A1
B5−A1
1mV
10sec
−
+
(Ikeda et al, Epilepsia,1996)
DC shifts, infraslow
HFO (high frequency oscillation)
(Worrell et al., 2008)
Berger Bands
Gamma
Ripple
Fast Ripple
DC
Infra-Slow
Slow
Fast
Multi-Unit and Unit
0.1Hz 1Hz
Frequency (Hz)
100Hz 1000Hz


Ictal DC shift preceded ictal HFO in invasive recording.
(Imamura et al.,2011) (Kanazawa et al. 2015)(Daifu et al., 2016)
500Hz
0Hz
HFO
Neurons
DC shifts
Glia
2 mV
-22
-18
-9
-3
0
10 sec
−
+
(Worrell et al., 2008)
Berger Bands
Gamma
Ripple
Fast Ripple
DC
Infra-Slow
Slow
Fast
Multi-Unit and Unit
0.1Hz 1Hz
Frequency (Hz)
100Hz 1000Hz


DC Brain potentials
Physiological DC potentials
Event related potentials (ERPs)
Pathological DC potentials
Spontaneous DC potentials
Post-stimulation and post-event DC potentials
Pre-event DC potentials
Seizure-related DC-deflection / infraslow activity (ISA)
ictal DC shifts:
VEP
SSEP
BAEP
MMN
P50
P200
P300
P600
Bereitschaftspotential
CNV
BP(MRCP)
CNV
Spreading depression
(Migraine)
Terminal negative depolarization / hypoxic/ischemic SD-like event
(stroke)
Nerofeedback (NFB)
Slow cortical potentials
Induced by VNS
Amplitude (μV) – averaging required
Amplitude (mV)
(Kovac, Speckmann, Gorge et al., Prog. Neurobiol. 2017)

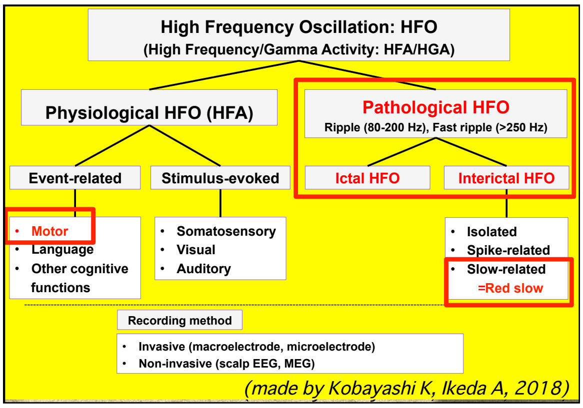
Role of astrocyte in brain disease as revealed by DC shifts EEG:

1) epilepsy
- active DC shifts, AI analysis
- red slow

2) migraine
- delta slow, subdelta slow (1Hz>)

3) cerebrovascular disease
- transient neurological episode (TNE), infaslow activity (0.3Hz>)
- Amyloid spell in cerebral amyloid angiopathy (CAA)

4) Critical care EEG
- Burst suppression and SISA(short infraslow activity)
- passive DC shifts



1) Normal HFO (IPSP by interneurons)

2) Pathologic HFO (population spikes from clusters of abnormally bursting of neurons) (Engel et al., 2009)

Interictal HFO vs. ictal HFO

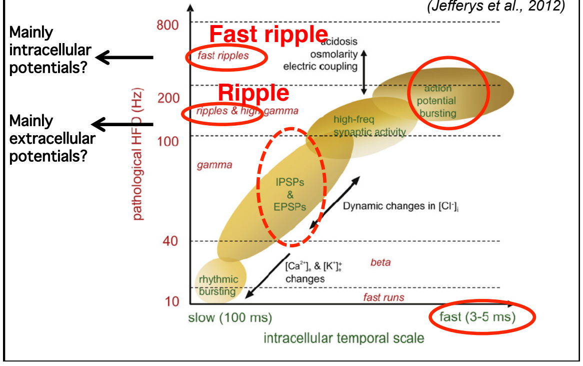
Bursts of neuronal activity mediated by gap junctions (Traubs et al., 2001,2003): synchronous **action potential** firing of a group of principal cells

100-200 Hz : ripple: (normal and epileptic in hipp)
250-500 Hz : fast ripple (only epileptic in hipp)

HFO located in a more restricted area as compared with conventional EEG
(Jirsch et al. 2006, Ochi et al.,2007)

Cellular mechanisms underlying pathological HFOs.

(Jefferys et al., 2012)



Terminology: Ictal DC (direct current) shifts

Also described as very slow, infra-slow, steady,

Recorded by

DC amplifier	DC shifts
AC (alternative current) amplifier	Slow shits

long time constant, i.e. 10 sec、

small low frequency filter (LFF) i.e., 0.016Hz

Terminology: Ictal DC (direct current) shifts

Also described as very slow, infra-slow, steady,

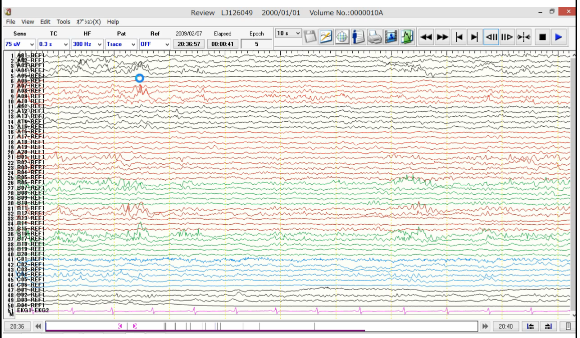
Recorded by

DC amplifier	DC shifts
AC (alternative current) amplifier	Slow shits

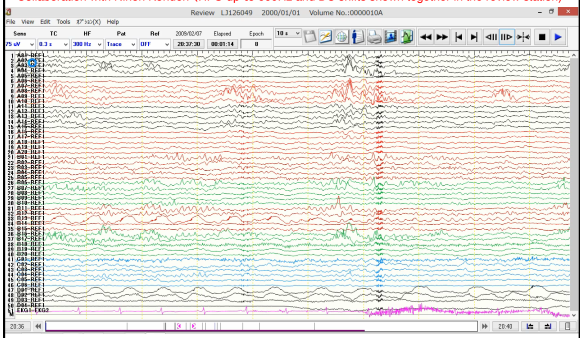
long time constant, i.e. 10 sec、 ***2 sec for scalp***

small low frequency filter (LFF) i.e., 0.016Hz

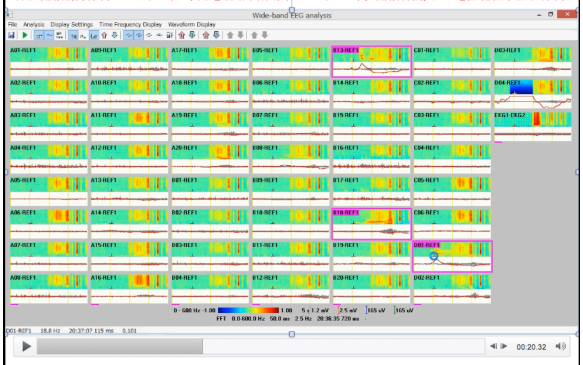
Recording condition: Sampling rate=2kHz, TC=10s, HFF=300Hz
diplay condition changed: from TC0.3 to 10、time window=20,30,60sec, 2m, 3m,



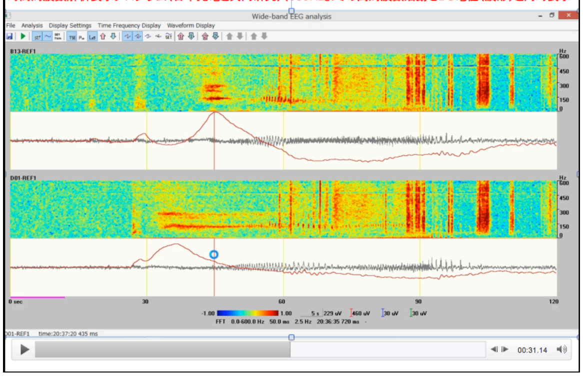
Time frequency analysis on the EEG review station (+-60sec)
Collaboration with Nihon Kohden (HFO up to 600Hz and DC shifts shown together in the review station)



Time frequency analysis on the EEG review station (+-60sec)
時間周波数解析表示プログラム（日本光電と共同研究）(600Hzまでの高周波数活動をDC電位（波形）と同時表示



Time frequency analysis on the EEG review station (+-60sec)
時間周波数解析表示プログラム（日本光電と共同研究）(600Hzまでの高周波数活動をDC電位（波形）と同時表示



Wide-band EEG:
a mysterious and very useful technique

1) **active- vs. passive DC shifts**
AMED study in Japan (Multi-institutional study)
Surgical outcome

2) 2 types of ictal DC shifts, and pathology

3) Interictal red slow, i.e., co-occurrence of slow and HFO

4) Is it recorded by scalp EEG ?

5) Future: AI analysis, mathematical modeling

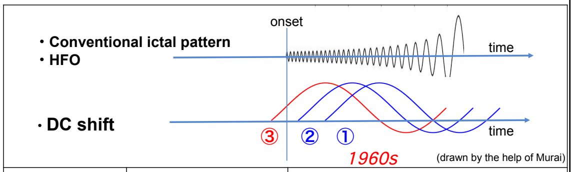
Clinical neurophysiological features of epileptic seizures
1) PDS (paroxysmal depolarization shifts)
2) Impaired extracellular K homeostasis by deceased Kir4.1, related ictal DC shifts

Contents lists available at ScienceDirect
Neuroscience Research
journal homepage: www.elsevier.com/locate/neures
ELSEVIER
Review article
Neuroscience Research 156 (2020) 95–101

Active direct current (DC) shifts and "Red slow": two new concepts for seizure mechanisms and identification of the epileptogenic zone

Akio Ikeda[a,*], Hirofumi Takeyama[b], Christophe Bernard[c], Mitsuyoshi Nakatani[d,e], Akihiro Shimotake[a], Masako Daifu[d], Masao Matsuhashi[a], Takayuki Kikuchi[f], Takeharu Kunieda[f,g], Riki Matsumoto[h], Tamaki Kobayashi[f], Kazuaki Sato[d]

Hypothesis of active vs. passive DC shift in the ictal period

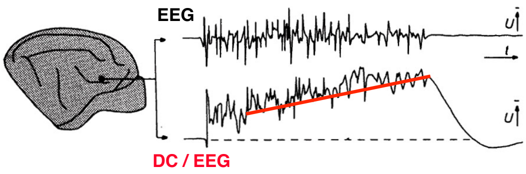


		③Active DC shift	② ① Passive DC shift
Clinical state		Chronic epilepsy	Acute symptomatic seizure
Clinical	patients	Habitual seizures	Non-habitual seizures
Basic	animals	Chronic model	Acute model
		Chronic pilocarpine model LGi1 rat model NER(=Noda epilepsy rat model)	Acute pilocarpine model

(by Ikeda et al) (as the working hypothesis of AMED research team of Epilepsy and Glia, chaired by Maehara, Japan, 2015-2018)

Ictal activity by pentylentetrazole

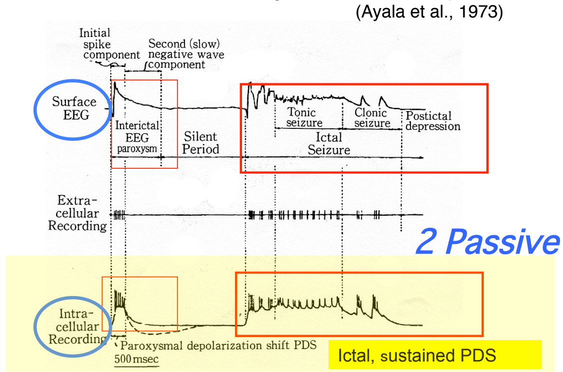
(acute animal model)



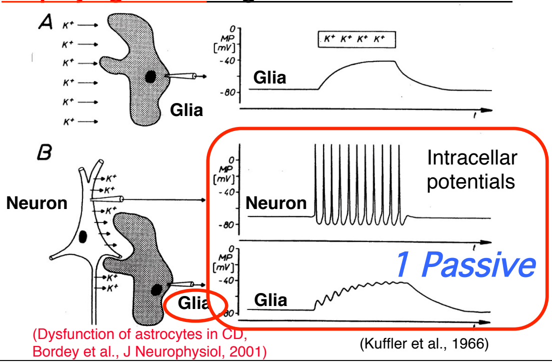
(Speckmann & Elger, 1987)

EEG and intracellular recording in interictal and ictal periods

(Ayala et al., 1973)



Amplifying effects of glial cells on slow shifts



(Kuffler et al., 1966)

Impaired K+ homeostasis *is important both after seizure and before seizure, that may triggger (seizure as the humoral factor)?*

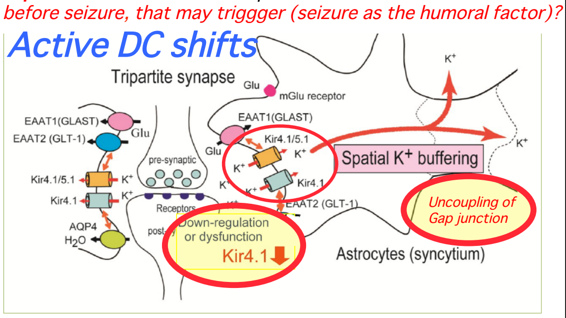
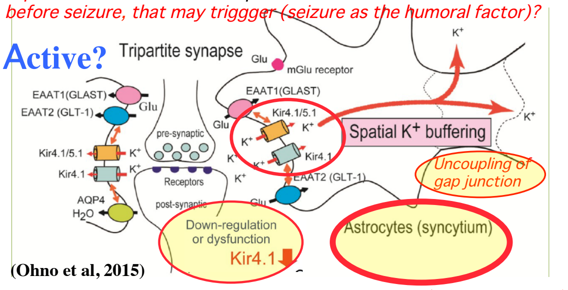


Figure 1. Astroglial spatial K+ buffering and Kir4.1 channels. Astrocytes play a key role in controlling environmental K+ concentrations at tripartite synapses via spatial K+ buffering function, which also regulates extracellular glutamate concentrations. Kir4.1 channels, which consist of the homo-tetramer of Kir4.1 (Kir4.1) and the hetero-tetramer of Kir4.1 and Kir5.1 (Kir4.1/5.1), conduct K+ buffering currents in astrocytes.

(Ohno et al, 2015)

Impaired K+ homeostasis is important both after seizure and before seizure, that may triggger (seizure as the humoral factor)?



(Ohno et al, 2015)

(recently shown by animal study, human sample from epileptogenic zone generating ictal DC shifts)

Astrocyte depolarization (including DC shifts)
→ inhibition of astrocyte glutamate clearance
→enhancing neuronal activation by glutamate
(Armbruster et al, Nature Neurosciece, 2022)

Epilepsia, 37(7):662–674, 1996
Lippincott–Raven Publishers, Philadelphia
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Subdural Recording of Ictal DC Shifts in Neocortical Seizures in Humans

Akio Ikeda, Kiyohito Terada, *Nobuhiro Mikuni, ‡Richard C. Burgess, §Youssef Comair, *Waro Taki, †Toshiaki Hamano, †Jun Kimura, ‡Hans O.Lüders, and Hiroshi Shibasaki

*Departments of Brain Pathophysiology, *Neurosurgery, and †Neurology, Kyoto University School of Medicine, Shogoin, Sakyo-ku, Kyoto, Japan; and Departments of ‡Neurology and §Neurosurgery, The Cleveland Clinic Foundation, Cleveland, Ohio, U.S.A.*

Brain (1999), 122, 827–838

Focal ictal direct current shifts in human epilepsy as studied by subdural and scalp recording

Akio Ikeda,[1] Waro Taki,[2] Takeharu Kunieda,[2] Kiyohito Terada,[1] Nobuhiro Mikuni,[2] Takashi Nagamine,[1] Shogo Yazawa,[1] Shinji Ohara,[1] Tomokatsu Hori,[4] Ryuji Kaji,[3] Jun Kimura[3] and Hiroshi Shibasaki[1]

Departments of [1]Brain Pathophysiology, [2]Neurosurgery and [3]Neurology, Kyoto University School of Medicine, Kyoto and [4]Department of Neurosurgery, Tottori University School of Medicine, Tottori, Japan

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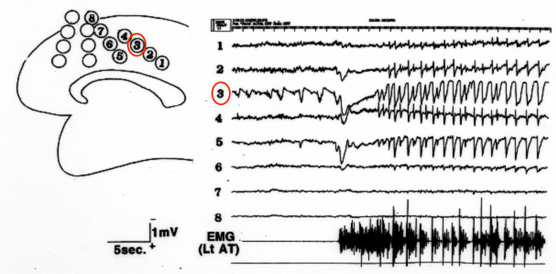
E-mail: akio@kuhp.kyoto-u.ac.jp*

Subdurally recorded ictal EEG in Patient 1
TC=10sec, Focal, ictal slow shifts



(Ikeda et al, Brain,1999)

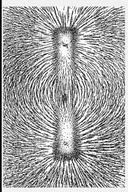
Ictal DC shifts (invasive recording): summary

1) Ictal DC shifts recorded by invasive electrodes, especially subdural ones, in humans were almost invariably recorded regardless of underlying etiology or epilepsy type.

2) 96 % of patients showed ictal DC shifts, incidence rate being 42~100% (87%) of seizures in each patient.

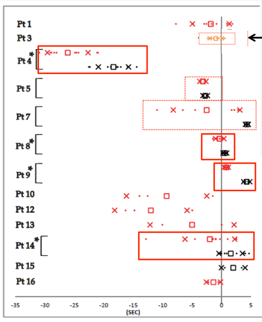
2) Its more restricted localization could aid in delineating ictal onset zone clinically before surgery presumably as a core epileptogenic zone, if present.

Ictal DC shifts occurred earlier than or as early as ictal HFO.



Alligned iron sand by the magnetic field.

Magnetic field= modified extracellular circumstances



DC onset plotted as compared with HFO onset at 0 sec.

*=P<0.05

· DC onset (0=C-EEG onset)
☐ Mean
× ±SD
· HFO onset (0=C-EEG onset)
☐ Mean
× ±SD

(Kanazawa et al., Clin Neurophysiol, 2015)

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Surgical outcome

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4) Is it recorded by scalp EEG ?

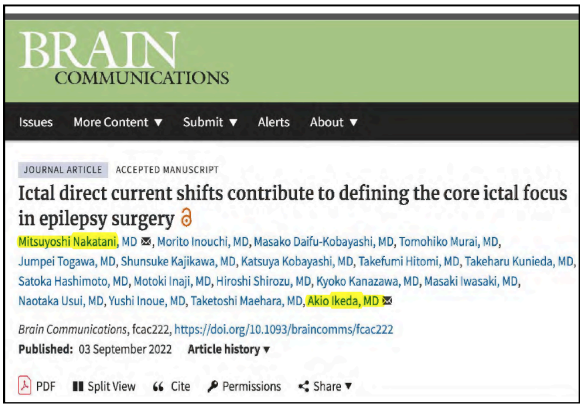
5) Future: AI analysis, mathematical modeling

Brain communications (2022, September 3rd, e-pub)

Ictal DC Shifts Contribute to Defining the Core Ictal Focus in Epilepsy Surgery

Mitsuyoshi Nakatani, MD[1) 2)], Morito Inouchi, MD[3) 4)], Masako Daifu-Kobayashi, MD[1)], Tomohiko Murai, MD[1)], Jumpei Togawa, MD[1)], Shunsuke Kajikawa, MD[1)], Katsuya Kobayashi, MD[1)], Takefumi Hitomi, MD[5)], Satoka Hashimoto, MD[6)], Motoki Inaji, MD[6)], Hiroshi Shirozu, MD[7)], Kyoko Kanazawa, MD[8)], Masaki Iwasaki, MD[9)], Naotaka Usui, MD[10)], Yushi Inoue, MD[11)], Taketoshi Maehara, MD[6)], Akio Ikeda, MD[3)]

Ictal DC shifts as epilepsy surgery biomarker : Multi-institutional study in Japan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JOURNAL ARTICLE ACCEPTED MANUSCRIPT
Ictal direct current shifts contribute to defining the core ictal focus in epilepsy surgery
Mitsuyoshi Nakatani, MD, Morito Inouchi, MD, Masako Daifu-Kobayashi, MD, Tomohiko Murai, MD, Jumpei Togawa, MD, Shunsuke Kajikawa, MD, Katsuya Kobayashi, MD, Takefumi Hitomi, MD, Takeharu Kunieda, MD, Satoka Hashimoto, MD, Motoki Inaji, MD, Hiroshi Shirozu, MD, Kyoko Kanazawa, MD, Masaki Iwasaki, MD, Naotaka Usui, MD, Yushi Inoue, MD, Taketoshi Maehara, MD, Akio Ikeda, MD
Brain Communications, fcac222, https://doi.org/10.1093/braincomms/fcac222
Published: 03 September 2022 Article history ▼
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Methods: patients and recording

AMED(Japan Agency for Medical Research and Development) study

5 institutes in Japan have participated in the study
- Kyoto University Graduate School of Medicine, Kyoto
- Tokyo Medical and Dental University, Tokyo
- Nishi-Niigata Chuo National Hospital, Niigata
- National Center Hospital, National Center of Neurology and Psychiatry, Tokyo
- Shizuoka Institute of Epilepsy and Neurological Disorders, Shizuoka

Medically intractable focal epilepsy patients
- chronic placement of intracranial electrodes
- ECoG : sampling rate 1000 or 2000 Hz, time constant 10 sec

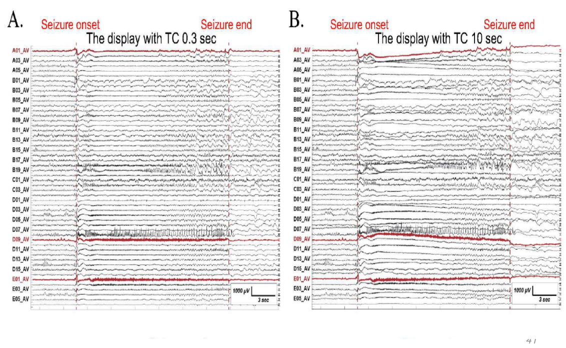
icDCs were defined as sustained negative and/or positive potentials longer than 3 sec, at least 200microV, preferentialy >1mV, viewed in a setting of a TC of 10 sec (Ikeda et al., 1999, Brain)

Large cohort studies on postoperative outcomes are still lacking.

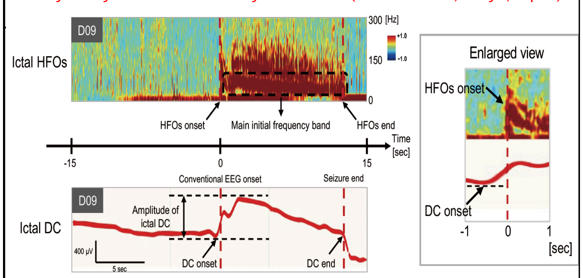
EEG Data acquisition (n=61)
↓ → Patient excluded
- only induced Sz (n=1)
- recorded with TC 2 sec (n=1)
- SOZ supposed to be outside of implanted electrodes (n=6)

EEG Data for DC/HFO analysis (n=53)
↓ → Patient excluded
- SOZ was supposed to be in bilateral temporal (n=1)
- palliative surgery (n=1)
- only MST operation (n=2)

EEG Data for outcome analysis (n=49)

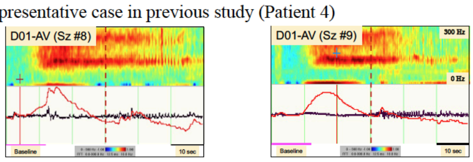


Analyzed by wide-band EEG analysis software (Nihon Kohden, Tokyo, Japan)

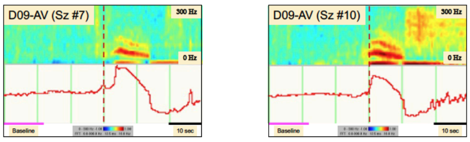


Reproducible, patient-specific patterns were identified.
Ictal HFO frequency band was either stable or became slower

A. Representative case in previous study (Patient 4)

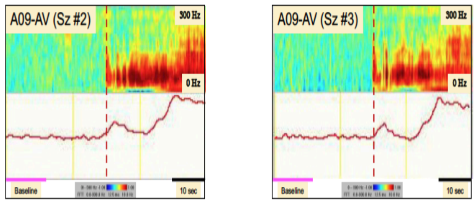


B. Patient 10



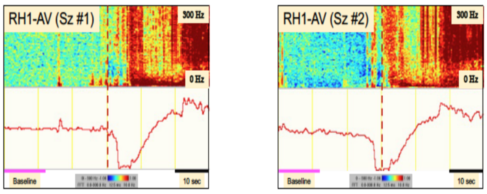
Two humped icDCs,
Repetitive spikes prominent, clear ictal band-like HFOs obscuring

C. Patient 13



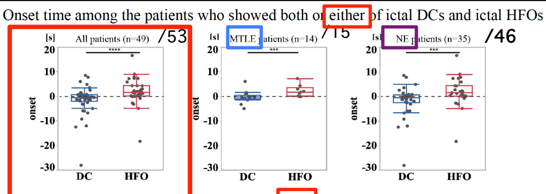
Infrequently, positive polarity of icDCs can be sometimes observed
Obvious ictal band-like HFOs were not detected

E. Patient 32

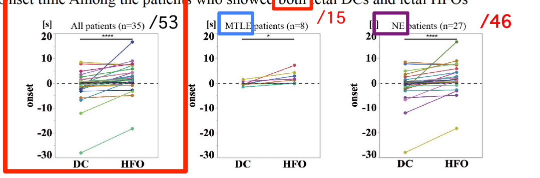


	Mesial temporal epilepsy (MTLE)	Neocortical epilepsy (NE)
Patients # (n=61)	15	46
Gender		
Male	7	30
Female	8	16
Age at onset (mean ± SD)	12.0 ± 7.0 (3 - 27)	11.7 ± 9.8 (0 - 43)
Age of surgery (mean ± SD)	31.5 ± 10.9 (11 - 52)	27.8 ± 12.2 (12 - 61)
Lesion		
Frontal	0	25
Temporal	15 (mesial)	11 (lateral)
Parietal	0	4
Occipital	0	4
fronto-parietal	0	1
templo-parietal	0	1

A. Onset time among the patients who showed both or either of ictal DCs and ictal HFOs



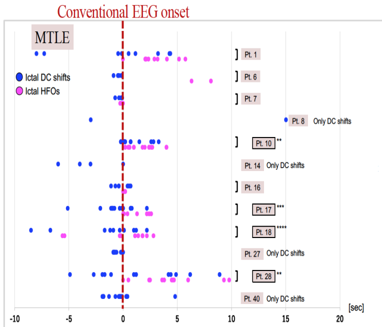
B. Onset time Among the patients who showed both ictal DCs and ictal HFOs



*: P < 0.05 ,**: P < 0.03 , ***: P < 0.01 , ****: P < 0.001, *****: P < 0.0001

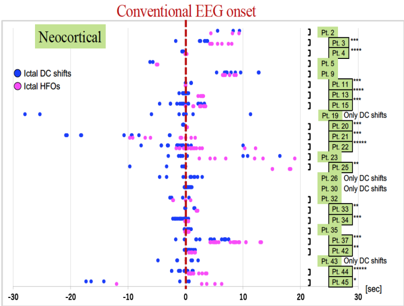
C. Onset time of ictal DCs and ictal HFOs in each patients

*: P < 0.05
**: P < 0.03
***: P < 0.01
****: P < 0.001
*****: P < 0.0001



C. Onset time of ictal DCs and ictal HFOs in each patients

*: P < 0.05
**: P < 0.03
***: P < 0.01
****: P < 40.001
*****: P < 0.0001



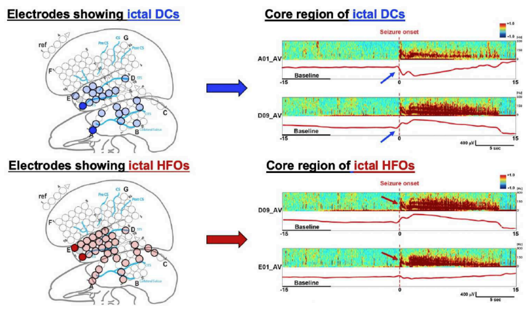
	HS* (n = 5)	FCD type I (n = 11)		FCD type II (n = 16)		Others (n =17)	Total (n = 49)
		type Ia (n = 8)	type Ib (n = 3)	type IIa (n = 9)	type IIb (n = 7)		
Occurrence ratio [%]							
Ictal DC	78	86	82	77	99	87	86
Ictal HFOs	63	86	38	49	83	58	65
Surgical outcome							
Engel I	5	5	3	3	5	12	32
Engel II	0	0	0	1	0	3	4
Engel III	0	2	0	2	1	0	5
Engel IV	0	1	0	3	1	2	10

HS: Hippocampal sclerosis, FCD: Focal cortical dysplasia
*: including the FCD IIIa pathology of Pt. 8 and Pt. 10

	Amplifier	Occurrence rate among patients (%)		Occurrence rate among seizures (%)		Correspondence of core electrodes of ictal DC and HFOs (%)	ictal DC amplitude (μV)	ictal DC duration (sec)	ictal HFOs frequency (Hz)	ictal HFOs duration (sec)
		ictal DC	ictal HFOs	ictal DC	ictal HFOs					
Nakatani et al., 2021 (n=61)	AC	92 >	71	86 >	62	39	1037 ± 570	15.8 ± 7.8 *	R (FR)	7.0 ± 4.1 *
Ikeda et al., 1999[18] (n=9)	AC	82 (subdural) 84 (scalp)	–	85 (subdural) 23 (scalp)	–	–	200 – (subdural) 50 – (scalp)	–	–	–
Modur et al., 2009[25] (n=1)	AC	100	100	100	75	10 – 75 ? (no detail)	–	– 25	R	Sustained (no detail)
Kim et al., 2009[41] (n=11)	DC	91	–	69.5	–	–	800 – 10,000	1 – 493	–	–
Wu et al., 2014[4] (n=15)	AC	100	67	91	81	19.3	1,700 ± 910	5 – 180	R, FR	–
Kanazawa et al., 2015[5] (n=16)	AC	75	50	71.3	46.3	–	903.1 ± 462.8	35.5 ± 15.6	R, FR	10.7 ± 9.7
Thompson et al., 2016[24] (n=15)	AC	100	–	100	–	–	300 – 8,500	– over 100	–	–

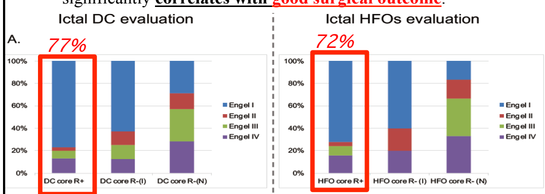
*: Long-lasting icDC or icHFOs beyond 30 sec analysis time-window after the seizure onset were excluded due to the limitation of the software.

Core electrode of ictal DCs and ictal HFOs overlapped by 39 %



Results: surgical outcome

Complete resection of ictal DC and ictal HFOs 'core' areas significantly **correlates with good surgical outcome**.



B.

	Good	Bad
DC core R+	23	7
DC core R-	7	9

(p=0.044, Pearson's chi-square test)

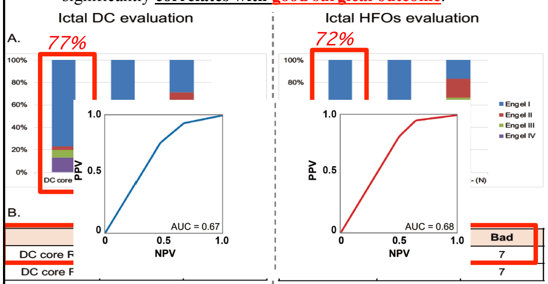
	Good	Bad
HFOs core R+	18	7
HFOs core R-	4	7

(p=0.043, Pearson's chi-square test)

Overall, 66% in Engel I *Overall, 61% in Engel I*

Results: surgical outcome

Complete resection of ictal DC and ictal HFOs 'core' areas significantly **correlates with good surgical outcome**.



(p=0.044, Pearson's chi-square test) (p=0.043, Pearson's chi-square test)

Overall, 66% in Engel I *Overall, 61% in Engel I*

Conclusion

1) It is the first large cohort multi-institutional study on wide-band EEG analysis and postoperative outcomes in Japan.

2) icDCs onset was statistically earlier than icHFOs onset in both MTLE and Neocortical epilepsy.

3) icDCs more frequently recorded than icHFOs among both patients (92% vs. 71%) and seizures (86% vs. 62%).

4) Complete resection of the core area of icDCs significantly correlated with favorable outcomes, similar to icHFOs outcomes.

5) The independent significance of icDCs and icHFOs should be considered as reliable biomarkers to achieve favorable outcomes in epilepsy surgery.

Standards as clinical practice parameters for recording and analysis of ictal DC shifts and HFO

Initially made by AMED research group in Japan
approved by JES, Japan Epilepsy Surgery Society
currently on the investigation by Japan Clinical Neurophysiology Society

てんかん研究　2017；35：3–13

難治部分てんかん患者の焦点検索における、発作時 DC 電位・HFO の記録および解析の標準化案

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金澤 恭子[7]　渡辺 裕貴[8]　臼井 直敬[9]　井上 有史[10]
前原 健寿[5]　池田 昭夫*[,3]

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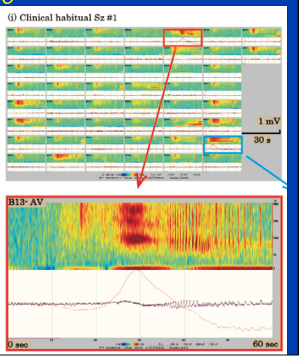
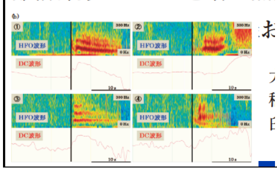
難治部分てんかん患者の焦





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    Surgical outcome

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3) Interictal red slow, i.e., co-occurrence of slow and HFO

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5) Future：virtual brain model, mathematical modeling

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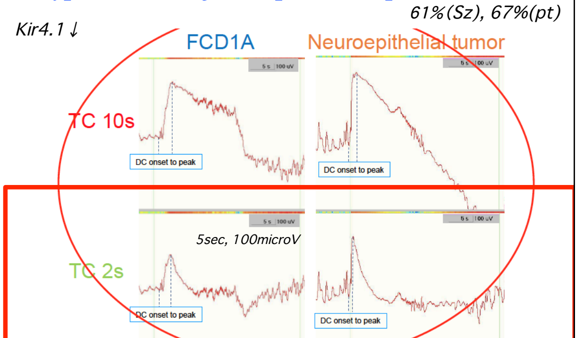
Two types of clinical ictal direct current shifts in invasive EEG of intractable focal epilepsy identified by waveform cluster analysis

Shunsuke Kajikawa[a], Masao Matsuhashi[b], Katsuya Kobayashi[a], Takefumi Hitomi[c], Masako Daifu-Kobayashi[a], Tamaki Kobayashi[d,e], Yukihiro Yamao[e], Takayuki Kikuchi[e], Kazumichi Yoshida[e], Takeharu Kunieda[e,f], Riki Matsumoto[a,g], Akiyoshi Kakita[h], Takao Namiki[i], Ichiro Tsuda[j], Susumu Miyamoto[e], Ryosuke Takahashi[a], Akio Ikeda[b,*]

Type#1 DC shifts =rapid development, FCD1A

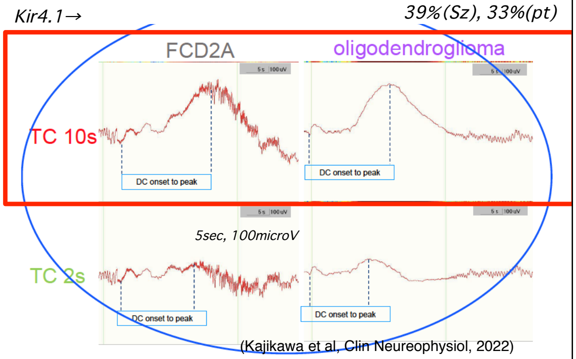
61%(Sz), 67%(pt)



(Kajikawa et al, Clin Neureophysiol, 2022)

Type#2 DC shifts =slow development, FCD2A

Kir4.1→ *39%(Sz), 33%(pt)*



(Kajikawa et al, Clin Neureophysiol, 2022)

Methods

Subjects: 21 patients with intractable partial epilepsy

ECoG recording:

#1. band-pass filter of 0.016-600 Hz sampling rate of 2,000 Hz

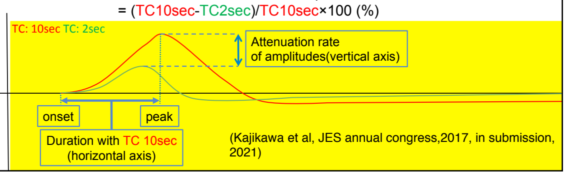
#2. band-pass filter of 0.016-300 Hz sampling rate of 1,000 Hz

Analysis software: EEG review program (Nihon Kohden, Tokyo, Japan)

Selection of electrode: 1 electrode with the earliest ictal DC shifts with TC 10 sec

Parameters: #1. the amplitude and duration from onset to peak of ictal DC shifts with TC 10 sec and TC 2 sec superimposed TC 10 sec.

#2. the attenuation rate of the amplitudes = (TC10sec-TC2sec)/TC10sec×100 (%)



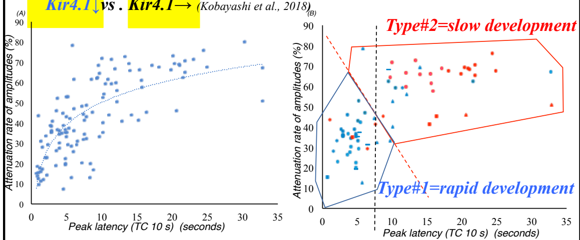
(Kajikawa et al, JES annual congress,2017, in submission, 2021)

FCD1A vs. FCD2A (including comorbid with glioma)

(Kajikawa et al., 2022)

Type#1 vs. Type#2

Kir4.1↓vs . Kir4.1→ *(Kobayashi et al., 2018)*



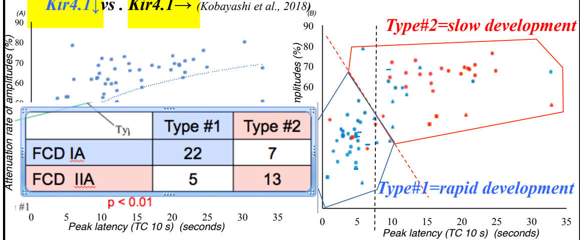
FCD1A	29 Sz (5 Pt)	Type#1>Type#2
Oligoastrocytoma/FCD1A	9 Sz (1 Pt)	Type#1>Type#2
HS/FCD1A	6 Sz (1 Pt)	Type#1&Type#2
Oligodendroglioma/FCD1B/FCD2A	10 Sz (1 Pt)	Type#2
FCD2A	18 Sz (4 Pt)	Type#1<Type#2

FCD1A vs. FCD2A (including comorbid with glioma)

(Kajikawa et al, 2022)

Type#1 vs. Type#2

Kir4.1↓vs . Kir4.1→ *(Kobayashi et al., 2018)*



	Type #1	Type #2
FCD IA	22	7
FCD IIA	5	13

$p < 0.01$

FCD1A	29 Sz (5 Pt)	Type#1>Type#2
Oligoastrocytoma/FCD1A	9 Sz (1 Pt)	Type#1>Type#2
HS/FCD1A	6 Sz (1 Pt)	Type#1&Type#2
Oligodendroglioma/FCD1B/FCD2A	10 Sz (1 Pt)	Type#2
FCD2A	18 Sz (4 Pt)	Type#1<Type#2

Impaired K^+ homeostasis is important both after seizure and before seizure, that may trigger (seizure as the humoral factor)?

Active?

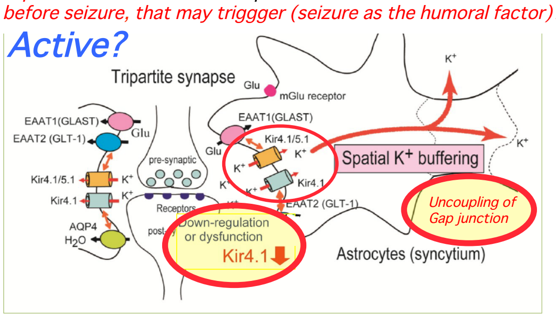


Figure 1. Astroglial spatial K^+ buffering and Kir4.1 channels. Astrocytes play a key role in controlling environmental K^+ concentrations at tripartite synapses via spatial K^+ buffering function, which also regulates extracellular glutamate concentrations. Kir4.1 channels, which consist of the homo-tetramer of Kir4.1 (Kir4.1) and the hetero-tetramer of Kir4.1 and Kir5.1 (Kir4.1/5.1), conduct K^+ buffering currents in astrocytes. (Ohno et al. 2015)

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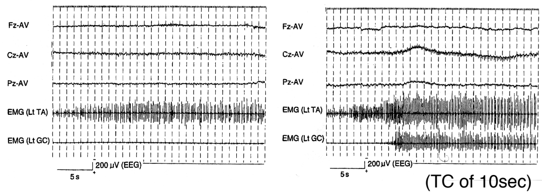
Scalp-recorded slow (DC) EEG with Lt focal motor seizures

Short duration | Long duration



(TC of 10sec)

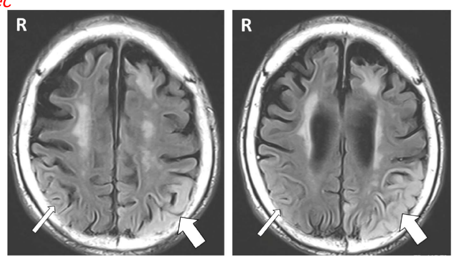
Ictal DC shifts (scalp recording)
1) Incidence rate: 14~40% (22%) in 73 seizures.
2) Detected particularly when seizures were clinically intense, but not in small seizures. (Ikeda et al., 1999)

-> Future advancement in recording condition is warranted.

Scalp EEG Could Record Both Ictal DC Shift and HFO Together Even With a Time Constant of 2 Seconds (J Clin Neurophysiol 2020;37: 191–194)

Tomohiko Murai,* Takefumi Hitomi,*† Masao Matsuhashi,‡ Riki Matsumoto,* Yuki Kawamura,§ Masutaro Kanda,§ Ryosuke Takahashi,* and Akio Ikeda‡

TC 2sec



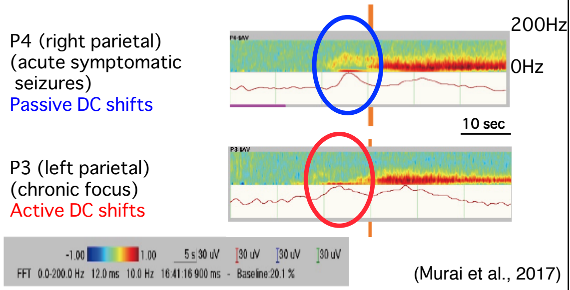
(Murai et al., 2020) acute chronic

Scalp-recorded slow (DC) EEG at P3 vs P4 onset (TC of 2sec)

1) Time constant 2 sec could record ictal DC shifts even in scalp EEG.
2) Acute symptomatic seizure showed passive DC shifts whereas chronic focus showed active DC shifts.

P4 (right parietal)
(acute symptomatic seizures)
Passive DC shifts

P3 (left parietal)
(chronic focus)
Active DC shifts



(Murai et al., 2017)

---

1) TC is the attenuation marker for constant voltage activity
2) Brain DC (infraslow) activity is not constant, but dynamically changing with increment and decrement.

Application of LFF and HFF | Time constant (TC) to filter out slow components

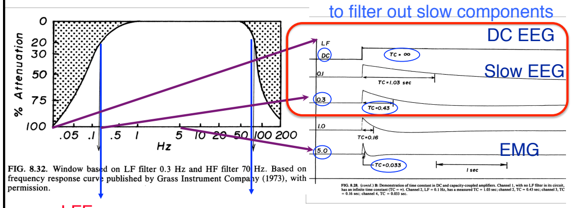


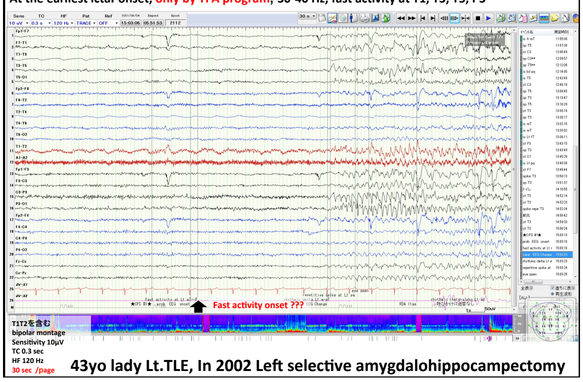
FIG. 8.32. Window based on LF filter 0.3 Hz and HF filter 70 Hz. Based on frequency response curve published by Grass Instrument Company (1973), with permission.

LFF
0.3 Hz
(TC=0.5 s)

HFF
70 Hz

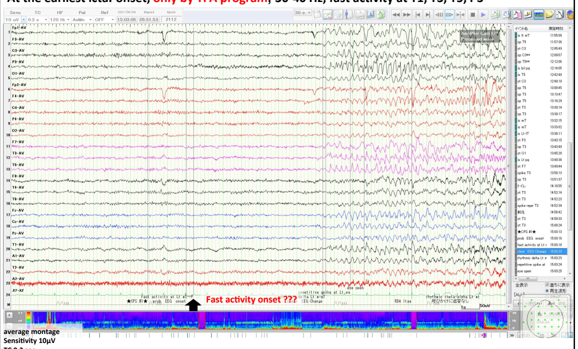
TC	x LFF =	0.16(1/2π)
0.1 sec	1.6 Hz	
1 sec	0.16 Hz	
10 sec	0.016 Hz	

At the earliest ictal onset, only by TFA program, 30-40 Hz, fast activity at T1, T3, T5, P3



43yo lady Lt.TLE, In 2002 Left selective amygdalohippocampectomy

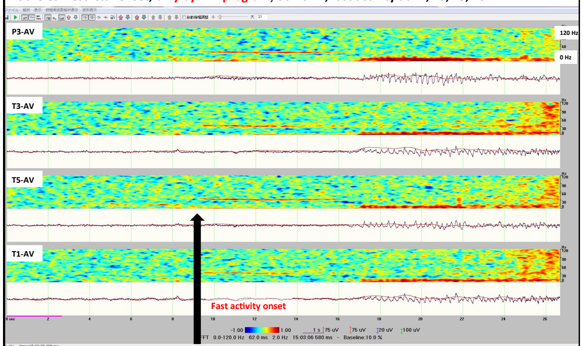
At the earliest ictal onset, only by TFA program, 30-40 Hz, fast activity at T1, T3, T5, P3



average montage
Sensitivity 10μV
TC 0.3 sec
HF 120 Hz
30 sec /page

43yo lady Lt.TLE, In 2002 Left selective amygdalohippocampectomy

At the earliest ictal onset, only by TFA program, 30-40 Hz, fast activity at T1, T3, T5, P3



43yo lady Lt.TLE, In 2002 Left selective amygdalohippocampectomy

Japan Agency for Medical Research and Development (AMED)
International Collaborative Research Program

Implementation study of wide band EEG recording, analysis and dissemination in epilepsy care using digital EEG in Indonesia 2022—2026

インドネシアでの、てんかん診療の質向上をめざしたデジタル脳波のワイドバンド成分の記録解析普及の実装研究

日本医療研究開発機構
地球規模保健課題解決推進のための研究事業
キックオフミーティング

京都大学大学院医学研究科てんかん･運動異常生理学講座教授
京都大学医学部附属病院てんかん診療支援センター長
池田昭夫

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AI auto-detection of ictal DC shift to facilitate its clinical application as a surrogate biomarker for epilepsy surgery

Masahiro Gotoh[1)], Katsuya Kobayashi[1)], Masao Matsuhashi[2)], Yukihiro Yamao[3)], Takayuki Kikuchi[3)], Kazumichi Yoshida[3)], Keiichi Ueda[4)], Takao Namiki[5)], Ichiro Tsuda[6)], Ryosuke Takahashi[1)], Akio Ikeda[2)]

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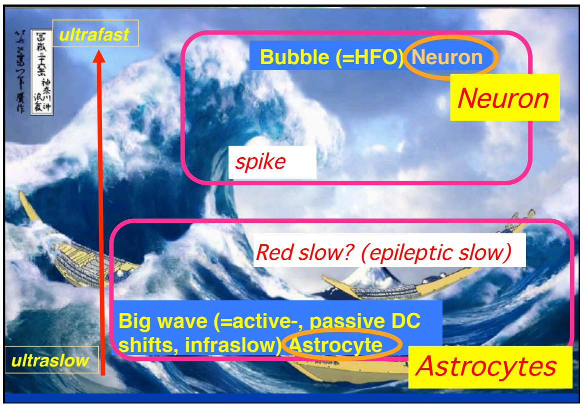
2) Department of Epilepsy, Movement Disorder and Physiology, Kyoto University Graduate School of Medicine
3) Department of Neurosurgery, Kyoto University Graduate School of Medicine
4) Graduate School of Science and Engineering, University of Toyama
5) Department of Mathematics, Faculty of Science, Hokkaido University
6) Chubu University Academy of Emerging Sciences

63rd Annual Meeting of the Japanese Society of Neurology
Neuroscience Frontier Symposium 01: New insights of epilepsy research



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