February 28, 2025

AMED (Japan Agency for Medical Research and Development) Supports

International Collaboration

Implementation of wide band EEG in epilepsy care by digital EEG

No.3
One point comment:
Wide Band EEG Analysis
Now ready for clinical implementation

Akio IKEDA, MD, PhD, FACNS
Department of Epilepsy, Movement Disorders & Physiology
Kyoto University Graduate School of Medicine
Kyoto, JAPAN

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Disclosure Form

Company Name	Nature of Affiliation
• Sumitomo Pharma Co • Nihon-Kohden	• Industry-Academia Collaboration Courses • Collaboration study
• UCB Japan • Eli Lilly Japan • RICHO	• Collaboration study
Off-Label Product Usage	
• None	

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31st January 2025
(Friday)

Wide-band EEG from DC shifts to HFO 1

Moderator
Dr. Fitri Octaviana (Dr. Cipto Mangunkusumo Hospital, Indonesia)

Contents
- ✔ Mini lecture from Prof. Ikeda (Kyoto University, Japan) [30 min.]
- ✔ Presentation from Dr. Katsuya Kobayashi (Kyoto University, Japan) [30 – 60 min.]

14th February 2025
(Friday)

Wide-band EEG from DC shifts to HFO 2

Moderator
Dr. Aris Catur Bintoro (Central General Hospital Dr. Kariadi, Indonesia)

Contents
- ✔ Mini lecture from Prof. Ikeda (Kyoto University, Japan) [30 min.]
- ✔ Presentation from Dr. Masao Matsuhashi (Kyoto University, Japan) [30 – 60 min.]

India (New Delhi)	IST	2:30 PM –
Indonesia (Jakarta)	WIB	4:00 PM –
Thailand (Bangkok)	ICT	4:00 PM –
Taiwan (Taipei)	CST	5:00 PM –
Japan (Tokyo)	JST	6:00 PM –

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Wide-band EEG: a mysterious and very useful technique

1) What is the wide-band EEG?
2) Special machine? Special technique?
3) Is it useful? Is it redundant? Just only research?
4) Useful only in invasive EEG?
5) Is it recorded by scalp-EEG?
6) EEG technologist could analyze?

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Application of LFF and HFF

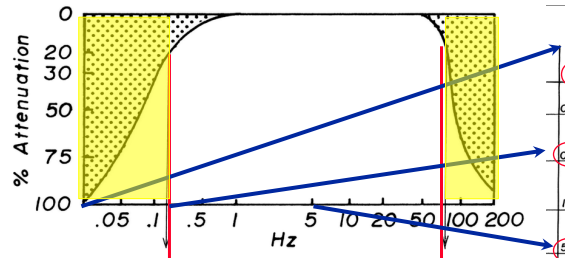

FIG. 8.32. Window based on LF filter 0.3 Hz and HF filter 70 Hz. Based on frequency response curve published by Grass Instrument Company (1973), with permission.

LFF=0.5 Hz
TC=0.3 s

HFF
70 Hz

Time constant (TC)

to filter out slow components

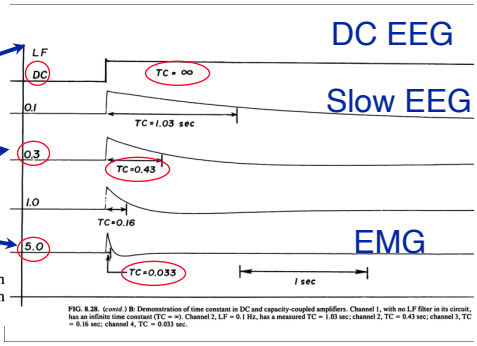

FIG. 8.28. (cont.) B: Demonstration of time constant in DC and capacity-coupled amplifiers. Channel 1, with no LF filter in its circuit, has an infinite time constant (TC = ∞). Channel 2, LF = 0.1 Hz, has a measured TC = 1.03 sec; channel 2, TC = 0.43 sec; channel 3, TC = 0.16 sec; channel 4, TC = 0.033 sec.

TC	x	LFF	=0.16(1/2π)
0.1 sec		1.6 Hz	
0.3 sec		0,5Hz	
1 sec		0.16 Hz → scalp ?	
2 sec		0.08 Hz → scalp, invasive	
10 sec		0.016 Hz → invasive ~~scalp~~	

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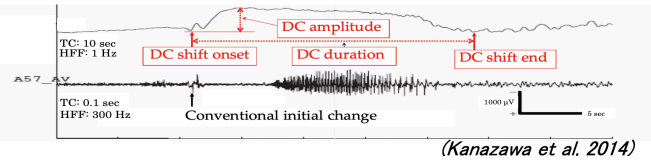
Practical (operational) definition of ictal DC/ slow shifts (Ikeda et al.,1999)

1) Not detected by LFF of 0.1Hz, but only detected by opened LFF (=becomes clearer with longer time constant, i.e., by changing from 0.1 to 10)

2) Usually negative (or infrequently positive) in polarity, >3sec in duration, peak to peak amplitude along the entire waveform of at least 200microV, preferably >1mV.

3) Reproducible in waveforms, duration and location.



(Kanazawa et al. 2014)

Negative polarity
Duration >3sec

Invasive EEG >1mV

Reproducible

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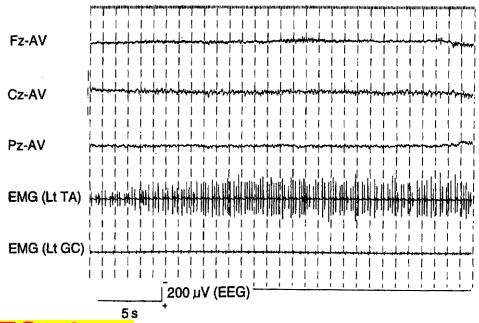
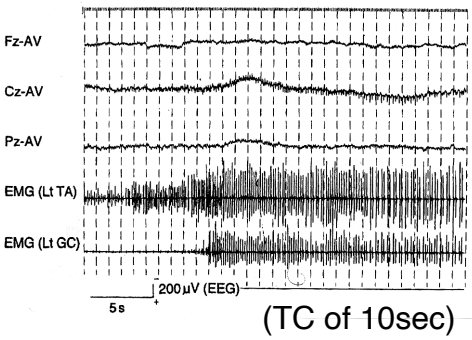
Scalp-recorded slow (DC) EEG with Lt focal motor seizures

Short duration



TC 10sec

Long duration



(TC of 10sec)

Ictal DC shifts (scalp recording):

Incidence rate: 14~40% (22%) in 73 seizures.

1) Detected particularly when seizures were clinically intense, but not in small seizures. (Ikeda et al., 1999)

-> Future advancement in recording condition is warranted.

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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,*]

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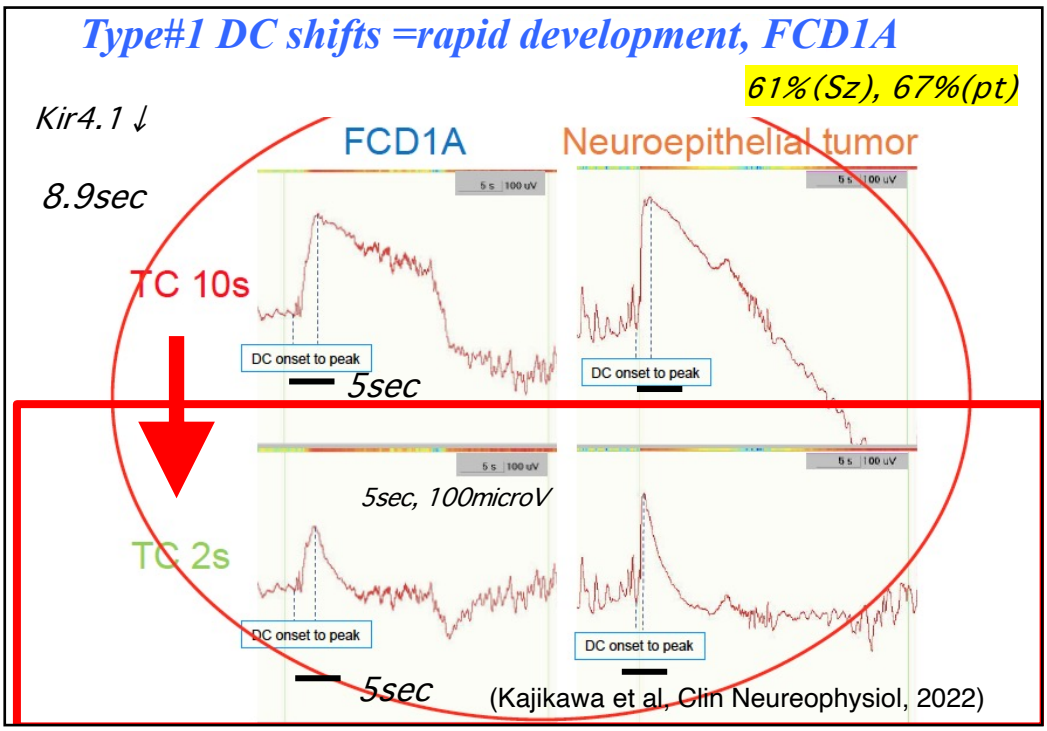
Type#1 DC shifts =rapid development, FCD1A
61%(Sz), 67%(pt)
Kir4.1↓
8.9sec
FCD1A
Neuroepithelial tumor
TC 10s
DC onset to peak
5sec
5sec, 100microV
TC 2s
DC onset to peak
5sec
(Kajikawa et al, Clin Neureophysiol, 2022)

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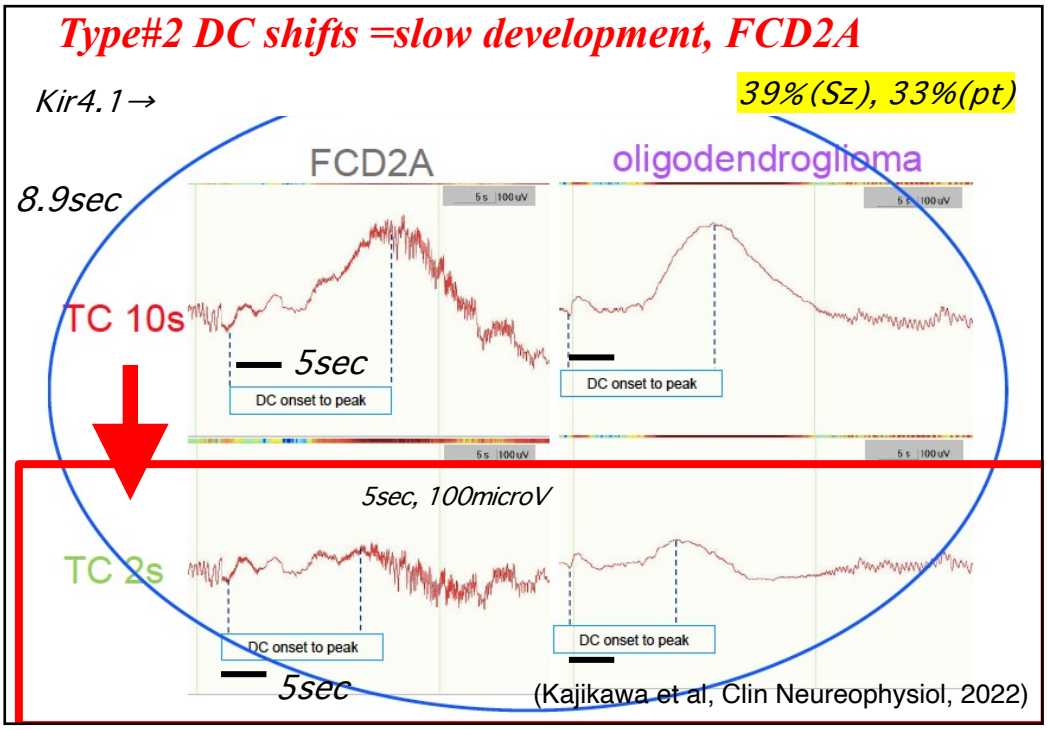
Type#2 DC shifts =slow development, FCD2A
39%(Sz), 33%(pt)
Kir4.1→
8.9sec
FCD2A
oligodendroglioma
TC 10s
5sec
DC onset to peak
5sec, 100microV
TC 2s
DC onset to peak
5sec
(Kajikawa et al, Clin Neureophysiol, 2022)

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DOI: 10.1111/epi.17782

Epilepsia™

RESEARCH ARTICLE

Focal ictal direct current shifts by a time constant of 2 seconds were clinically useful for resective epilepsy surgery

Masaki Izumi[1,2] | Katsuya Kobayashi[3] | Shunsuke Kajikawa[4] | Kyoko Kanazawa[5] | Yutaro Takayama[6] | Keiya Iijima[7] | Masaki Iwasaki[7] | Yoji Okahara[2] | Seiichiro Mine[8] | Yasuo Iwadate[1] | Akio Ikeda[9]

Most commonly used digital EEG (TC of 2sec) in the world is available, being as good as EEG used lesser (long TC of 10 sec)

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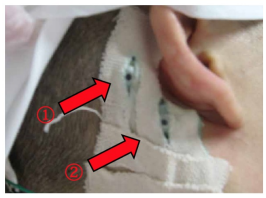
Recording condition

1) LFF is kept open for continuous monitoring.
2) System reference electrode should not be epileptically irritative and the metal should be identical to that of recording electrode, i.e., platinum scalp electrodes,
3) Scalp electrodes made by platinum are placed as the ① system reference and ② ground electrode.
Electrode impedence of the two is kept below <5kohm

(Ikeda et al., 1999; Kanazawa et al,2014)



Recording

Invasive recording
Ground electrode
System reference electrode
Platinum electrode

Scalp recording as usual
Ground electrode
System reference electrode
Ag/AgCL electrode

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Display condition

1) Referential montage is recommended as display montage
2) System reference electrode should not be epileptically irritative and the metal should be identical to that of recording electrode, i.e., platinum scalp electrodes,
3) System reference electrode and display reference electrode are initially identical in order to avoid any mis-reformating, i.e., mastoid process skin electrodes.
4) Once initial, display reference electrode was not suitable (i.e., motion artifacts, etc.), it could be changed to 1) non-irritative subdural electrode or 2) averaged electrode activity.

(Ikeda et al., 1999; Kanazawa et al, 2014)

Display of EEG

1) Referential montage
invasive, scalp

reference electrode
one of silent electrodes
averaged reference

If scalp EEG is good without artifacts, referential montage can be used

2) Bipolar montage
invasive, scalp

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Recording condition of ictal DC shifts

1) DC amplifier
AC amplifier with opened LFF: 0.016 or 0.05 Hz
(time constant of 5 or 10 sec)

2) huge input impedance of amplifier (>50 MΩ) →***200 MΩ***

3) *Non-polarized (reversible) electrodes*
Ag/AgCl for scalp recording (not for invasive)
platinum for subdural recording →***may not a big deal by 2)***

4) *Large recording surface, i.e., subdural electrodes rather than depth electrodes* →***not a big deal by 2)***

Subdural electrodes
sEEG

both well record DC shift activity

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Terminology: Ictal DC (direct current) shifts

Also described as very slow, infra-slow, steady, ~~baseline shifts~~

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→***0.08Hz***

1) Invasive EEG
TC 10sec (LFF 0.16Hz)
TC 2sec (LFF 0.08Hz)

2) Scalp EEG
~~TC 10sec~~
TC 2sec (LFF 0.08Hz)
TC 1sec (LFF 0.16Hz) ?

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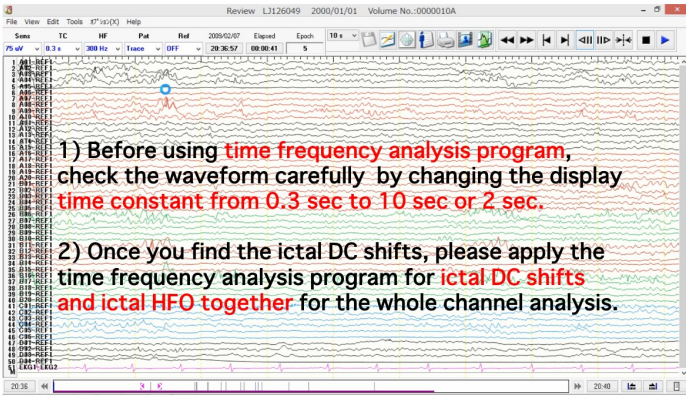
Recording condition: Sampling rate=2kHz, TC=10s, HFF=300Hz
display condition changed: from TC0.3 to 10、time window=20,30,60sec, 2m, 3m,



1) Before using time frequency analysis program, check the waveform carefully by changing the display time constant from 0.3 sec to 10 sec or 2 sec.

2) Once you find the ictal DC shifts, please apply the time frequency analysis program for ictal DC shifts and ictal HFO together for the whole channel analysis.

At first wave form visual inspection

↓

Time frequency analysis program

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Wide-band EEG: a mysterious and very useful technique

Long introduction

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

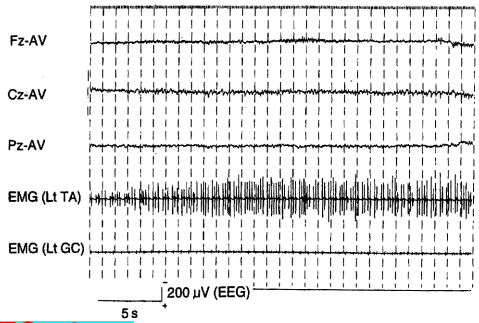
2) 2 types of ictal DC shifts, and pathology

3) Is it recorded by TC 2sec EEG ?

4) **Is it recorded by scalp EEG ?**

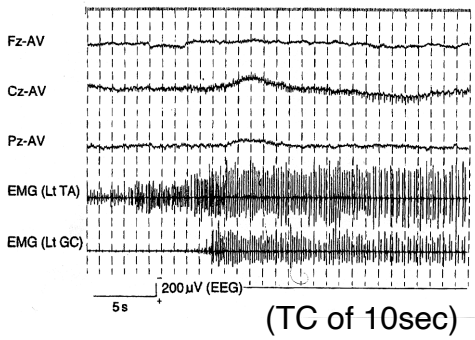
Scalp-recorded slow (DC) EEG with Lt focal motor seizures

Short duration



TC 10sec

Long duration



(TC of 10sec)

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-> Future advancement in recording condition is warranted.

Currently now ready for DC shifts & HFO analysis for scalp EEG

1) 1990s, waveform analysis of HFO (SEPs, spikes) was introduced.
2) It was done by high value of LFF, but was not ideal method or rather skeptical because it would easily produce artifact mimicking HFO.

3) We now have strong tools and situation after 2000 ! as follows

1. **Wide-band EEG analysis**
2. **Basic and animal study HFO for epileptic activity**
3. **Wide frequency range time-frequency analysis program**
4. **TC 2sec is better to record DC shifts in scalp EEG than TC 10sec**

It is ready to apply DC shifts and HFO for scalp EEG

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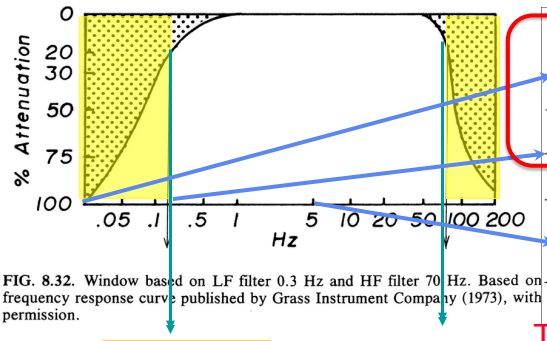
1) TC is the attenuation marker for constant voltage activity

2) Brain DC (infraslow) activity is not constant, but dynamically changing with increment and decrement.

Application of LFF and HFF



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HFF
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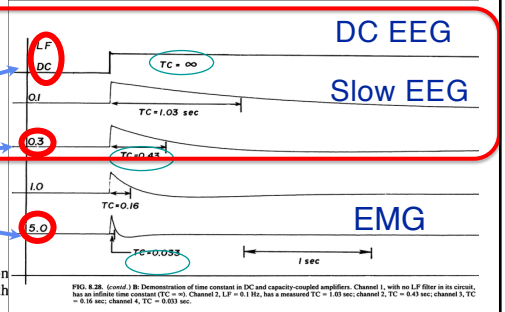
Time constant (TC) to filter out slow components



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