

Frequency and clinical importance of electrically stimulation-induced seizures by intracerebral and subdural electrodes

National Hospital Organization, Nara Medical Center

T. Hoshida, K. Kawata, H. Hirabayashi

Abstract

Purpose: This study evaluates the frequency of stimulation-induced seizures by electrical cortical and intracerebral stimulation and determines the sensitivity and specificity of induced secondary generalized seizures (SGS), complex partial seizures (CPS), and simple partial seizures (SPS).

Methods: In a consecutive 62 patients with implantation of subdural and intracerebral electrodes, functional mapping was evaluated on 2074 contacts in right hemisphere and 2734 contacts in left hemisphere in 52 patients. 7546 unifocal or bifocal stimulations trials were performed on total 275 days. Stimulation parameters were 0.2msec, 50Hz alternative electric currents and duration of 2 to 5 seconds. We routinely begin at 1mA and increase until a functional change occurs, afterdischarges are present, or we reach the maximum intensity of 10mA.

Results: Frequency of spontaneous seizures in this study was 4 times of induced seizures in 40 patients, i.e. total 1129 seizures with 86 SGSs in 23 patients, 377 CPSs in 33 patients, and 666 SPSs in 25 patients. On stimulation, we elicited 277 seizures in 40 patients and 3.7% in all stimulation trials. SGS was elicited in 28 seizures (0.37%) of 14 patients, CPS was in 47 seizures (0.62%) of 16 patients, and SPS was 202 seizures (2.7%) of 30 patients. Location of 185 electrodes with induced-seizures was within the resection area, and location of 92 electrodes with induced-seizures was beyond the resected region. If it is assumed that postsurgical outcome is good after resection of all of seizure-induced electrodes, sensitivity and specificity of induced SGS was 92% and 13%, induced CPS was 59% and 90%, and induced SPS was 69% and 56%, respectively. Frequency of induced seizures not correlated to seizure related zone was 14%. 74% of seizure-unrelated zone were around pre- and post- central gyri.

Conclusions: Induced generalized seizure was lower frequency (0.37%) on stimulation study. Clinical importance of stimulation-induced seizure was CPS, followed by SPS, and SGS. Although seizure-induced area was not always included seizure onset zone, electrical stimulation study plays a partial role to detect of excitability in epileptogenic zones and facilitated pathways.

Evaluation of the frequency and clinical importance of electrically-induced seizures by using intracerebral and subdural electrodes

**Epilepsy Center, Nara Medical Center
National Hospital Organization, Nara, Japan**

Hoshida T, Kawata K, Hirabayashi H

Purpose

We reviewed 62 cases of resective surgery with intracranial recording during ten years for intractable epilepsy . Electrical stimulation studies were performed in 52 patients. This study evaluates the frequency of seizures induced by electrical stimulation of the cortical and intracerebral regions, and determines the sensitivity and specificity of the induced secondary generalized seizures (SGSs), complex partial seizures (CPSs), and simple partial seizures (SPSs).

Subjects

★ **52 cases of functional mapping using chronically implanted subdural grid and depth electrodes**

★ **Age at onset : 0~63 years of age, mean 12.9 years**

★ **Age at surgery : 1~67 years of age, mean 27.5 years**

★ **Gender : male in 35, female in 17**

★ **Focus side : right in 17, left in 29, bilateral in 6**

★ **Number of implanted electrodes**

right in 39 : 6~122 electrodes, mean 53.2

left in 47 : 6~126 electrodes, mean 58.2

total in 52 : 44~144 electrodes, mean 92.5

2074 in right and 2734 in left hemisphere, and total 4808 electrodes

★ **Including 34 cases of language mapping**

Subjects

- ★ **Epilepsy type: TLE 21 (40%), XTLE 31 (60%): FLE 13, PLE 3, OLE 2, Multilobar 7 (TPO 3, FT 3, FP 1), Bilateral 6 (FT 3, T 2, F 1)**
- ★ **Seizure outcome after surgery: Engel class I 31, II 6, III 13, IV 2**
→ good result in 71%
- ★ **Normal MRI 14: Engel class I 4, II 3, III 5, IV 2 → good in 7 (50%)**
- ★ **Pathology: microdysplasia 13, hippocampal sclerosis 12, gliosis 10, tumor 7, cavernoma 5, focal cortical dysplasia 3, tuberous sclerosis 1, chronic inflammation 1**
- ★ **Stimulation study: 1 ~ 10 days, total 275 days, 5.2 days in each case**
- ★ **Monofocal in 6852 and bifocal in 692 stimulations, total in 7546 trials (electrodes or electrode pairs)**

Cortical Stimulation

- ★ **modified Johns Hopkins Hospital Technique**
- ★ **after recording some spontaneous seizures for a week**
- ★ **1-5-10 s trains of 50 Hz alternating positive and negative square pulses lasting 0.2 ms delivered an Ojemann Cortical Stimulator (OCS 1)**
- ★ **usually starting at 1mA, increasing in steps of 0.5 to 1mA, up to an maximum of 10 (15) mA until**
 - 1) afterdischarges occurred**
 - 2) experienced primary positive responses including auras and seizures (subjective symptoms)**
- ★ **bifocal (pair of adjacent contacts) or monofocal (defined a reference electrode) stimulation**

Result 1

Subjective symptoms (52 cases, 3359 trials, 44.5%)

	case	trial	positive ratio	
★motor	:49	1211	16.0%	
★motor + somatosensory	:32	146	1.9%	
★sensory	:46	1435	19.0%	
somatosensory 757 (41 cases), pain 265 (33), visual 309 (18), auditory 79 (19), olfactory 8 (3), taste 11 (2), vestibular 6 (4)				
★emotional	:18	224	3.0%	
★experiential	: 3	15	0.2%	
★induced seizure	:40	277	3.7%	
*2nd generalized seizure	:14	28	0.37%	(10%)
*complex partial seizure	:16	47	0.62%	(17%)
* simple partial seizure	:30	202	2.68%	(73%)
* resection area	within	185		(67%)
	without	92		(33%)
★ (not working	:20	51	0.7%)	

Result 2

**When primary responses are not detected,
task performance are needed during electrical stimulation**

	case	trial	positive trial		positive ratio
Negative motor response	:43	1866	:30 cases	156 trials	8.4%
motor task					
★ hand grasping	:43	1220	:25	80	6.6%
★ tongue movement	:33	384	:25	47	12.2%
★ eyes movement	:24	213	: 9	15	7.0%
★ toes wiggling	:13	49	: 8	14	28.6%

Negative motor response

(motor performance are decreased or stopped after stimulation without loss of awareness)

Result 3

**When primary responses are not detected,
task performance are needed during electrical stimulation**

	case	trial	positive trial	positive ratio
Language area	:41	8918	:34 cases 1242 trials	13.9%
language task				
★spontaneous speech	:41	2580	:28 182	7.2%
★picture naming	:38	1580	:31 329	20.9%
★auditory comprehension	:35	1415	:31 328	23.3%
★responsive naming	:34	1350	:30 220	16.3%
★reading	:32	935	:24 99	10.6%
★repetition	:33	949	:21 71	7.5%
★sing a song	: 2	109	: 2 13	11.9%

Result 4

**When primary responses are not detected,
task performance are needed during electrical stimulation**

	case	trial	positive trial		positive ratio
higher brain functions	:21	623	:14 cases	43 trials	6.9%
task					
★ memory	: 7	58	: 5	24	41.4%
★ calculation	:15	157	: 6	9	5.7%
★ finger recognition	: 4	96	: 2	2	2.1%
★ left-right recognition	: 8	99	: 1	1	1.0%
★ watch reading	: 6	74	: 1	1	1.4%
★ geography	: 2	44	: 0	0	0.0%
★ others	:10	95	: 5	6	6.3%

Result 5

Spontaneous and induced seizures

seizure type	spontaneous			induced		
	case	times	mean	case	times	mean
* secondary generalized	23	86	3.7	14	28	2.0
* complex partial	33	377	11.4	16	47	2.9
* simple partial	25	666	26.6	30	202	6.7
total	40	1129	28.2	40	277	6.9

seizure frequency	spontaneous	induced
* 1~2 times	1 case	11 cases
* 3~5	10	11
* 6~10	7	9
* 11~20	13	7
* 21~	9	2

Validity of induced seizure 1

Postoperative seizure outcome:

Engel's Class	I	II	III	IV
	24	5	9	2

good: $24+5=73\%$, poor: $9+2=23\%$

Not induced group: 12 cases (23%), Engel's class: mean 1.75

Induced group: 40 cases (77%), Engel's class: mean 1.73

Seizure induction does not contribute to postoperative good seizure outcome.

Validity of induced seizure 2

Induced seizure	SGS	CPS	SPS
<i>induced electrode site</i>	14 cases <i>within beyond</i> <i>resection area</i>	16 cases <i>within beyond</i> <i>resection area</i>	30 cases <i>within beyond</i> <i>resection area</i>
<i>postoperative seizure outcome</i>			
Good	12 cases 11 14 (44%) (56%)	7 cases 22 1 (96%) (4%)	23 cases 94 29 (76%) (24%)
Poor	2 cases 1 2 (33%) (67%)	9 cases 15 9 (61%) (39%)	7 cases 42 37 (53%) (47%)

Hypothesis:

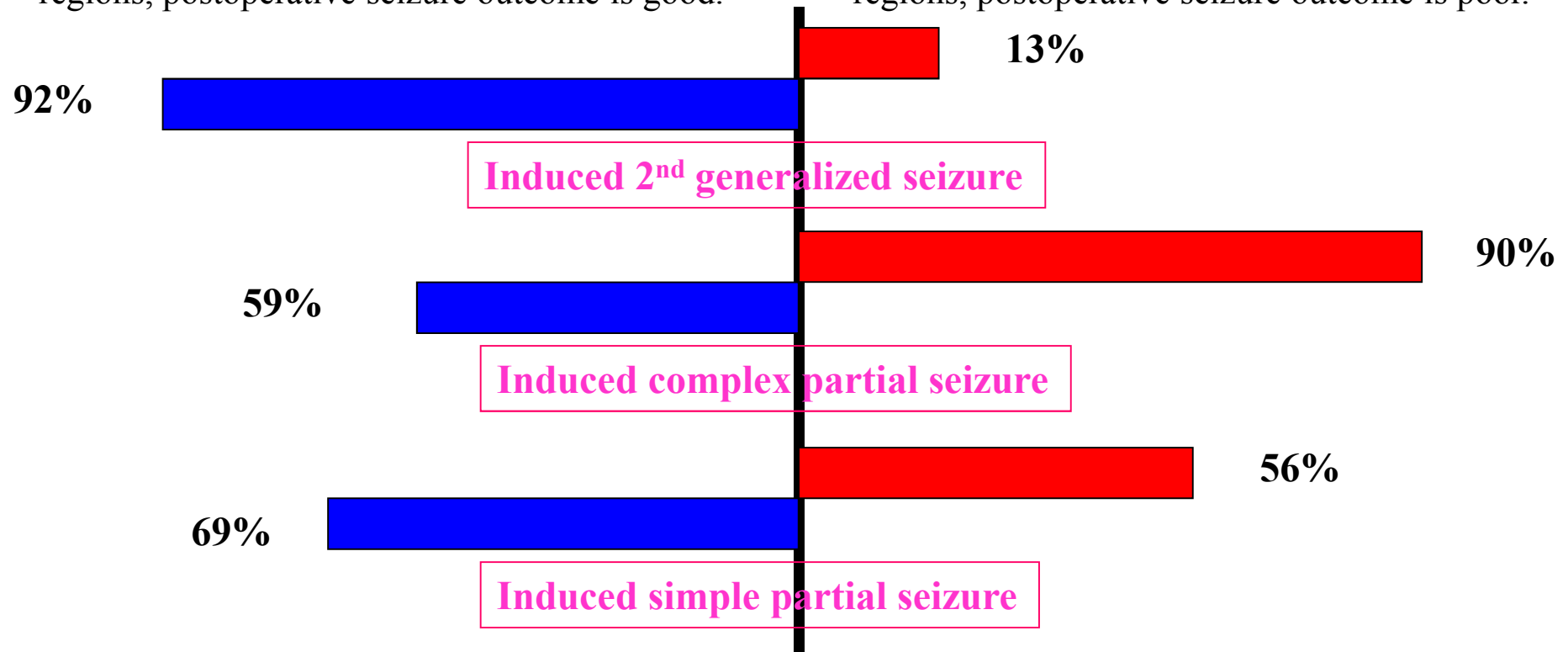
Postsurgical outcome is good after resection of all the seizure-induced electrodes.

Sensitivity

If induced seizure areas are within the resected regions, postoperative seizure outcome is good.

Specificity

If induced seizure areas are not within the resected regions, postoperative seizure outcome is poor.



The frequency of the induced seizures not correlated to the seizure-related zone was 14%, 74% of which was observed around the pre- and post-central gyri.

Discussions

- ★ **Primary positive responses (subjective symptoms) after electrical stimulation are detectable less than a half of electrical cortical stimulations on 7546 electrodes or electrode pairs (44.5%). All of induced seizures including auras were detected in 3.7% of stimulation trials. Induced secondary generalized seizures were only 0.37% of all stimulations.**
- ★ **Several tasks have to perform during stimulation when primary responses are not detectable, but positive ratio was relatively very low (8.4% in negative motor area, 13.9% in language area, 6.9% in other higher functional areas).**
- ★ **Spontaneous seizures were detected four times of induced seizures in 40 patients.**
- ★ **Two thirds of stimulation-induced seizure zone was included within the resection area.**

Conclusions

- ★ **The induced generalized seizure showed a low frequency (0.37%) during the cortical stimulation study.**
- ★ **The clinical importance of the stimulation-induced seizure is that the specificity of CPS induction is higher than that of SPS and SGS.**
- ★ **Although the seizure-induced region is not always included in the seizure-onset zone, the electrical stimulation study plays a partial role in the detection of excitability in the epileptogenic zones and facilitates the identification of the seizure-propagation pathways.**