

흰쥐에서 체감각유발장전위의 기록부위별 특성과 경로분석*

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= Abstract =

Characteristics and Pathways of the Somatosensory Evoked Field Potentials in the Rat

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Objective : Somatosensory evoked potentials(SSEPs) have been used widely both experimentally and clinically to monitor the function of central nervous system and peripheral nervous system. Studies of SSEPs have reported the various recording techniques and patterns of SSEP. The previous SSEP studies used scalp recording electrodes, showed mean vector potentials which included relatively constant brainstem potentials(far - field potentials) and unstable thalamocortical pathway potentials(near - field potentials). Even in invasive SSEP recording methods, thalamocortical potentials were variable according to the kinds, depths, and distance of two electrodes. So they were regarded improper method for monitoring of upper level of brainstem. The present study was conducted to investigate the characteristics of somatosensory evoked field potentials(SSEFPs) of the cerebral cortex that evoked by hindlimb stimulation using ball electrode and the pathways of SSEFP by recording the potentials simultaneously in the cortex, VPL nucleus of thalamus, and nucleus gracilis.

Methods : In the first experiment, a specially designed recording electrode was inserted into the cerebral cortex perpendicular to the cortical surface in order to recording the constant cortical field potentials and SSEFPs mapped from different areas of somatosensory cortex were analyzed. In the second experiment, SSEPs were recorded in the ipsilateral nucleus gracilis, the contralateral ventroposterolateral thalamic nucleus(VPL), and the cerebral cortex along the conduction pathway of somatosensory information.

Results : In the first experiment, we could constantly obtain the SSEFPs in cerebral cortex following the transcutaneous electrical stimulation of the hind limb, and it revealed that the first large positive and following negative waves were largest at the 2mm posterior and 2mm lateral to the bregma in the contralateral somatosensory cortex. The second experiment showed that the SSEPs were conducted by way of posterior column somatosensory pathway and thalamocortical pathway and that specific patterns of the SSEPs were recorded from the nucleus gracilis, VPL, and cerebral cortex.

Conclusion : The specially designed recording electrode was found to be very useful in recording the localized SSEFPs and the transcutaneous electrical stimulation using ball electrode was effective in evoking SSEPs. The characteristic shapes, latencies, and conduction velocities of each potentials are expected to be used the fundamental data for the future study of brain functions, including the hydrocephalus model, middle cerebral artery ischemia model, and so forth.

KEY WORDS : Somatosensory evoked potential · Cortex · Thalamus · Nucleus gracilis · Pathway.

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서 론

(somatosensory evoked potential ;
SSEP)

1)3)7)19)21),
4-6)9-11)13)16)22)
(experimental spinal cord injury ; SCI)
, Nashmi ¹²⁾ SSEP가

8) SSEP
SSEP
Skarphedinsson ¹⁸⁾
(cerebral blood flow ; CBF) SSEP
가 SSEP amplitude

SSEP (sciatic nerve)
SSEP
Hurlbert ⁸⁾ 14msec
가 (positive wave) 19msec
(negative wave)
⁶⁾ 12~20msec -
13msec (positive - nega-
tive peak complex)

Raines ¹⁶⁾ SSEP
(brain - stem potential) 가

SSEP
SSEP 가
SSEP

가 SSEP
가 SSEP
가 SSEP

(somatosensory evoked field poten-
tial : SSEFP)

SSEFP
가

(primary neuron)
(nucleus gracilis)
(nucleus cuneatus)
(medial lemniscus)
(ventral posterolateral nucleus ; VPL)
(synapse)

가
SSEP
가 SSEP
SSEP
SSEP
2
SSEP
SSEP
SSEP

재료 및 방법

1. 실험 1 : 흰쥐에서 체감각 피질의 기록위치별 SSEFP의 파형 변화

SSEP (uni-
polar electrode)
platinum (screw electrode)
²⁾⁸⁾¹²⁾ (ball - shaped platinum electrode)
SSEP

SSEP
가
(stainless steel, NE -
120, Rhodes Medical Instruments, Inc. USA)
SSEFP SSEFP
SSEP SSEFP 가

1) 실험대상 및 방법

(1) Sprague - Dawley (340~400g) entobar (50mg/kg), atropine sulfate(0.8mg/Kg) (femoral artery, femoral vein) 30 pancronium (1mg/kg) (Model 683, Harvard Apparatus, South Natik, MA, U.S.A.) (Capnometer, model 2200, Transverse medical monitors, Saline, Michigan, U.S.A.).

(Stereotaxic frame, Narishige, Scientific instrument laboratory, Setagayaka, Tokyo, Japan) (rectal temperature) 36~37

(2) SSEFP SSEP (craniectomy) (bregma) 4mm, 7mm 가 가 4mm 가 7mm (cisterna magna) SSEFP 1.4mm 0.2mm 1.5mm SSEFP 1mm 18 SSEFP SSEFP CED 1401 IBM 586 computer spike2 SSEFP 30~3,000Hz (filter) 5,000~50,000 80~100 (ball electrode) (transcutaneous)

(A365D stimulus isolator, A365 high current stimular isolator, World Precision Instruments, Inc. New Haven, Connecticut, U.S.A.) (Pulsemaster A300, Inc. New Haven, Connecticut, U.S.A.) 0.1msec 1~4Hz 1mA 1mA 가 가

2. 실험 2 : 흰쥐의 체감각피질, 시상과 박속핵(Nucleus gracilis)에서 SSEFP의 특성

1 SSEFP가 가 SSEP SSEP

1) 실험대상 및 방법

(1) 1 SSEFP 2mm, 2mm 1 (VPL)(AP ; - 1.8, ML ; 1.45, DV ; 6.5, Bregma : Paxinos Watson¹⁵⁾) SSEP 1mm, 1.8 mm (stainless steel, #00 insect pin) 25 ° VPL 가 가 (AP ; - 14, ML ; 0.4, DV ; 7.5, Bregma : Paxinos Watson¹⁵⁾) SSEP (cisterna magna) 1 0.2~0.4mm (stainless steel, #00 insect pin) VPL 0.1mm , VPL SSEP SSEP

SSEP, VPL, 1

5mA 1mA 가

결 과

5~7mA 1 1. 실험 1
5mA SSEP가 16 11 18

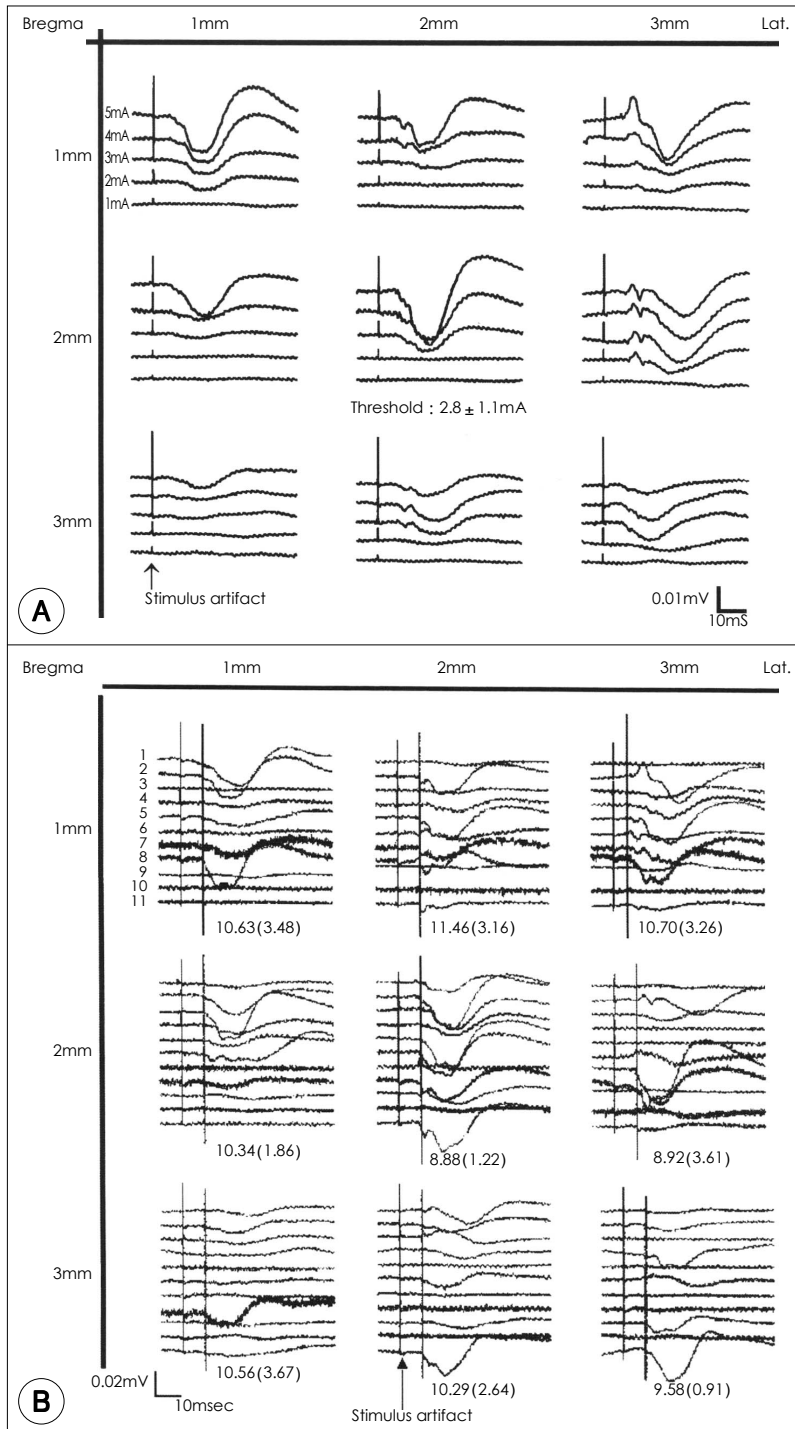


Fig. 1. A : Recordings of SSEFP monitored at each sites of cerebral cortex during stimulation of left sciatic nerve. Stimulus intensities were ranged from 1mA to 7mA. When stimulus intensity was increased upto 5mA, response frequency and amplitude increased, but beyond 5mA, they showed no change. SSEFP detection at 4 to 6mm lateral and posterior to bregma was failed. B : Recordings of SSEFP monitored at each sites of cerebral cortex in each experimental rats during 5mA stimulation of left sciatic nerve. The vertical line indicate corresponding SSEFP mean onset latency, with standard deviation in (), with time in msec.

SSEFP, 5, 5 SSEFP가, 2mm,
 SSEFP 1mm 11 7,
 11 SSEFP 3mm, 1mm 11 9 SSEFP
 2mm, SSE-
 2mm 11 SSE-
 FP 가
 SS-
 , 5mA
 P1 N1 peak-to-peak
 SSEFP (peak latency) (amplitude) peak-to-peak
 amplitude mapping (contour map)
 (Fig. 2A, B).
 Fig. 2 A B, 5mA P1
 2mm, 가 amplitude, 2mm,
 SSEFP 가 P1 N1
 가, 5mA 가 am- amplitude
 plitude 1~3mm, 1~3mm P1 N1
 4mm SSEFP (Fig. 1A). 가
 Fig. 1B 5mA 2mm, 2mm
 1mm, 1mm 11 5mA

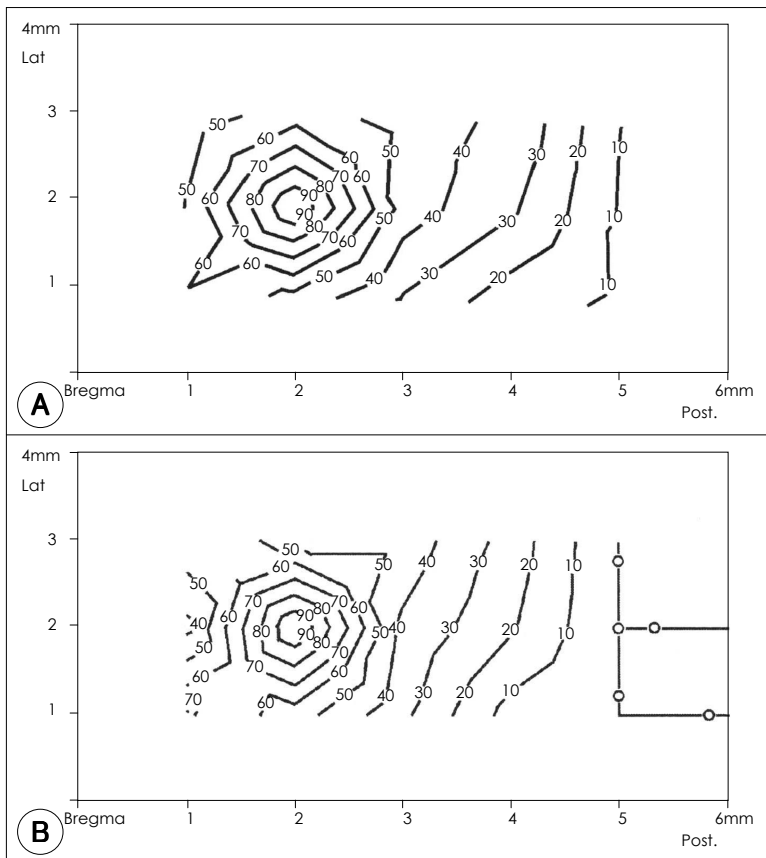


Fig. 2. A : Amplitude distribution of P1 wave of SSEFP according to the recording sites. Stimulus intensity was 5mA. The numbers indicate the percentile size of SSEFP compared to maximal amplitude. B : SSEFP N1 wave distribution according to the recording sites. Sciatic nerve stimulation with 5mA and the numbers indicate percentile SSEFP.

8.88 ± 1.22msec . SSEEP

P1

SSEP가

가

P1

peak latency 23.5 ± 5.0msec , N1 34.67 ± 21.2msec . P1 N1 peak latency P2

N1, N2, P1,

가

가

(amplitude) peak - to - peak amplitude

baseline peak

2. 실험 2

12 7

VPL, amplitude

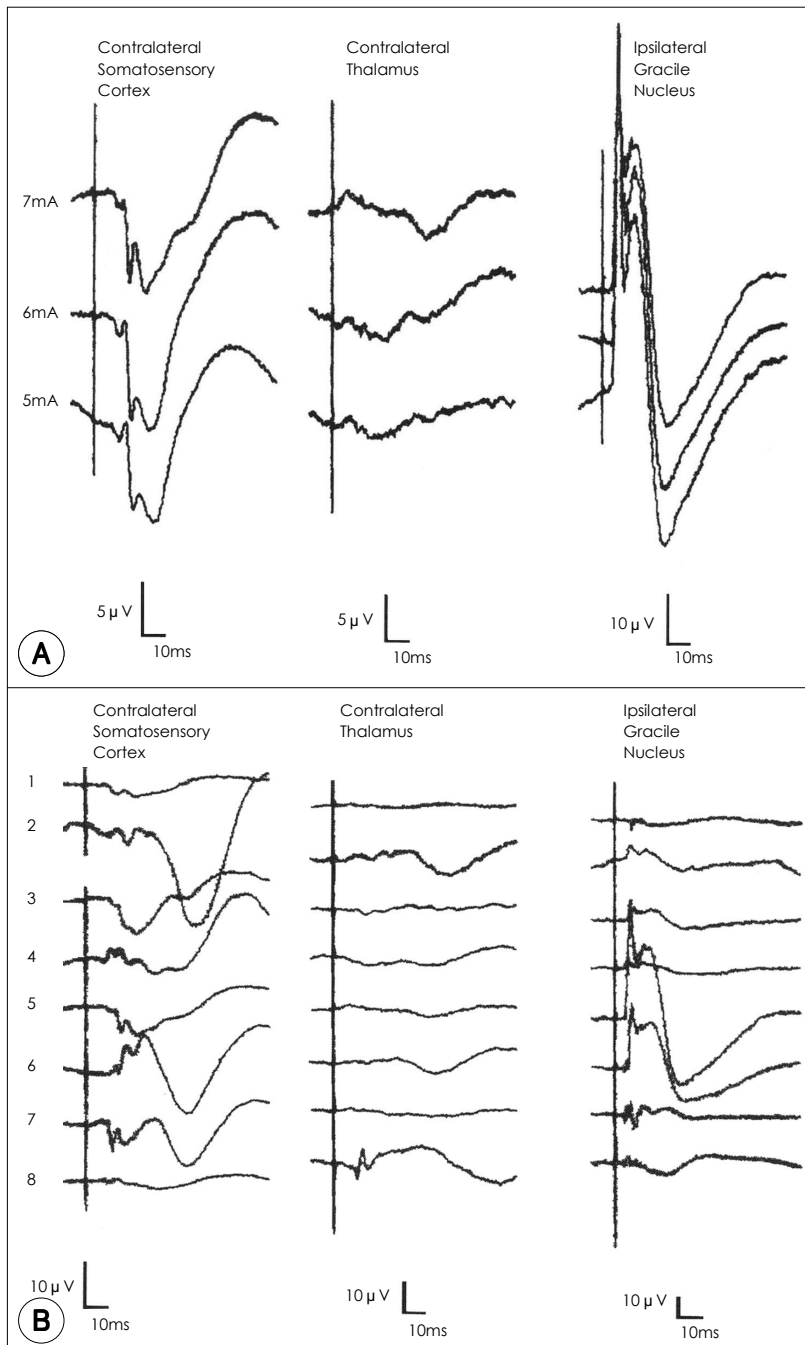


Fig. 3. A : Simultaneously recorded SSEFPs at three different sites(contralateral cortex, contralateral thalamus, ipsilateral gracile nucleus). The sciatic nerve was stimulated with varying stimulus intensities ranging from 5mA to 7mA. Note the different amplitude scales. B : Representative stimulus recordings of SSEFPs at three different sites in all experimental rats. Sciatic nerve was stimulated by a single square pulse of 7mA with 0.1msec duration.

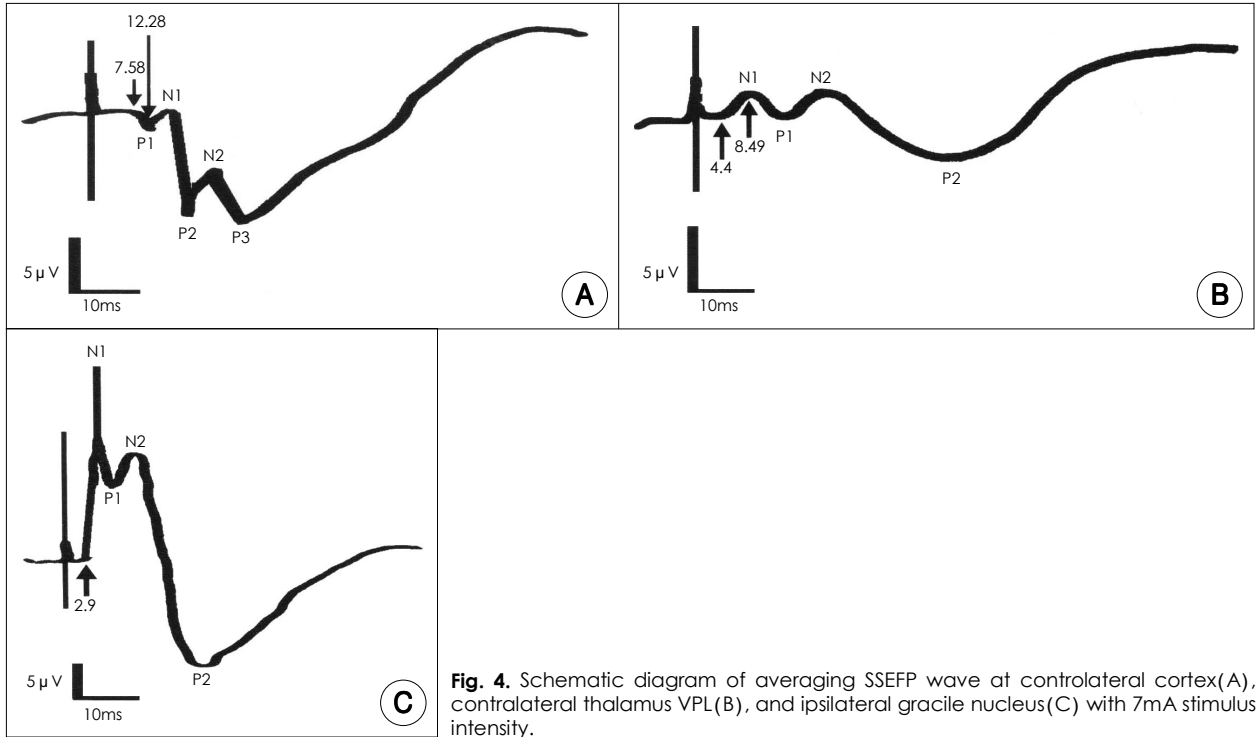


Fig. 4. Schematic diagram of averaging SSEFP wave at contralateral cortex(A), contralateral thalamus VPL(B), and ipsilateral gracile nucleus(C) with 7mA stimulus intensity.

Table 1. Mean peak latency and mean peak-to-peak amplitude of SSEFP at contralateral cortex when SSEFP were simultaneously recorded at three sites(contralateral cortex, contralateral thalamus, ipsilateral gracile nucleus). Sciatic nerve was stimulated by a single square pulse of 7mA with 0.1msec duration

Latency	Onset	P1	N1	P2	N2	P3
Mean(msec)	7.58	12.38	15.28	19.85	26.67	35.75
S.D.	2.58	2.22	1.9	0.21	6.67	17.12
Amplitude	Base-P1	P1-N1	N1-P2	P2-N2	N2-P3	
Mean(μV)	4.64	4.47	5.83	6.35	14.74	
S.D.	4.02	4.12	3.35	5.12	14.12	

S.D. : standard deviation

Table 2. Mean peak latency and mean peak-to-peak amplitude of SSEFP at contralateral thalamus VPL nucleus when SSEFP were simultaneously recorded at three sites(contralateral cortex, contralateral thalamus, ipsilateral gracile nucleus). Sciatic nerve was stimulated by a single square pulse of 7mA with 0.1msec duration

Latency	Onset	N1	P1	N2	P2
Mean(msec)	4.4	8.49	13.78	19.54	44.55
S.D.	1.9	2.26	2.14	4.84	4.12
Amplitude	Base-N1	N1-P1	P1-N2	N2-P2	
Mean(μV)	1.36	3.64	2.96	5.51	
S.D.	0.69	3.94	2.98	4.82	

S.D. : standard deviation

1) 대측 체감각피질에서 동시에 기록한 SSEFP

SSEFP 3 2
가 (Fig. 3A, B).
SSEFP 7mA
7.58 ± 2.58msec
Fig. 4A 7mA
SSEFP
peak
peak - to - peak amplitude Table 1

2) 대측 VPL에서 동시에 기록한 SSEFP

VPL SSEFP

가 ,

(Fig. 3A, B).

7mA 4.4 ± 1.9msec

Fig. 4B 7mA VPL SSEFP

peak peak - to - peak amplitude Table 2

3) 동측 박속핵에서 동시에 기록한 SSEFP

SSEFP

2~3

Table 3. Mean peak latency and mean peak-to-peak amplitude of SSEFP at ipsilateral gracile nucleus when SSEFP were simultaneously recorded at three sites (contralateral cortex, contralateral thalamus, ipsilateral gracile nucleus). Sciatic nerve was stimulated by a single square pulse of 7mA with 0.1msec duration

Latency	Onset	N1	P1	N2	P2
Mean(msec)	2.9	6.6	9.9	12.8	28.7
S.D.	0.5	1.1	1.6	2.1	3.0
Amplitude	Base-N1	N1-P1	P1-N2	N2-P2	
Mean(μV)	13.64	8.45	4.53	18.34	
S.D.	17.26	8.24	4.34	20.16	

S.D. : standard deviation

가
SSEFP
7mA
SSEFP
peak
peak - to - peak amplitude Table 3

4) 동시에 기록한 체감각피질, VPL, 그리고 박속핵의 SSEP 의 비교

7mA
SSEP 가 VPL (Fig. 4A, B, C).
SSEP 가 가 , SSEP , VPL
SSEP SSEP peak - to - peak amplitude가 , VPL 가
SSEP amplitude 가
(Fig. 3A, B).
SSEP 가 VPL, SSEP 가 SSEP
2 VPL (Table 4).
SSEP 가 N1 peak
amplitude , SSEP N1 peak 8.1msec 8.49msec
2~3 , 가 가
, VPL, 가 가
7mA 7.58 (synaptic delay)
msec, 4.4msec, 2.9msec , 가

Table 4. Conduction velocities of each sites, onset latency, peak latency of waves and estimated latency(msec) according to nucleus gracilis onset latency

Cortex	OL ¹	P ₁	N ₁	P ₂	N ₂	P ₃
Latency (SD ²)	7.58 (2.58)	12.38 (2.22)	15.28 (1.90)	19.85 (0.21)	26.67 (6.67)	35.75 (17.12)
E. Lat ³		11.28	14.58	17.48	33.38	
CV ⁴	25.67	15.72	12.74	9.80	7.30	5.44
VPL ⁵	OL	N ₁	P ₁	N ₂	P ₂	
Latency (SD)	4.4 (1.9)	8.49 (2.26)	13.78 (2.14)	19.54 (4.84)	44.55 (4.12)	
E. Lat		8.1	11.4	14.3	30.2	
CV	44.02	22.81	14.06	9.91		
Nuc. gra. ⁶	OL	N ₁	P ₁	N ₂	P ₂	
Latency (SD)	2.9 (0.5)	6.6 (1.1)	9.9 (1.6)	12.8 (2.1)	28.7 (3.0)	
CV	62.07	27.55	18.37	14.06	6.34	

1 : onset latency(msec) 2 : standard deviation

3 : estimated latency(msec) according to nucleus Gracilis onset latency

OL(cortex or VPL) - OL(Nuc. Gra)+Nucleus Gracilis peak latency

4 : conduction velocity(m/sec)

Distance ; cortex - stimulus=194.58mm,

VPL - stimulus= 193.68mm

Nucleus Gracilis - stimulus = 181.83mm

5 : ventro posterolateral nucleus of thalamus

6 : nucleus gracilis

25.67mm/msec, 44.02mm/msec,
62.07mm/msec
la fiber (70~120m/sec)
Zileli Schramm²³⁾
percutaneous SSEP
9.1 ± 1.2msec 2
SSEP 7.58 ±
(Table 4).
N1 peak
N1 peak 8.1msec 8.49msec
가 가
가 가
(synaptic delay)
가

30msec 가 1~2 1 SSEFP

가 SSEP , SSEP

SSEP 11)17)

SSEP 2)7)8)11)

VPL (primary somatosensory cortex)

고 찰 parietal 1 parietal 1

1 parietal 1

SSEFP 14) cuff 1~3mm,

Sakatani 17) 2~3mm SSEP 가 3

(scalp electrodes) Koyanagi Tator¹¹⁾ mm SSEP가 가

(vector) 2mm, 2mm SSEP

far - field potential (thalamocortical pathway) near - field potential (ball electrode) (transcutaneous) SSEP

가 mapping 가 SSEP

(brain - stem potential) 가 (unipolar electrode) (bipolar electrode) 2 SSEP VPL, SSEP

가 SSEP , VPL, VPL SSEP

가 SSEP SSEP SSEP 가 가

SSEFP VPL SSEP 가

Wiederholt Iragui - madoz²⁰⁾ , VPL,

SSEP, VPL, SSEP, SSEFP, (dorsal column pathway) 가 2 SSEP, SSEP가 SSEP, SSEP가 SSEP

5) VPL SSEP, VPL SSEP 가 6) VPL SSEP 7mA 2.9msec, 4.4msec, 7.58msec, 62.07m/sec, 44.02m/sec, 25.67m/sec fiber (70 120 m/sec) VPL, 7) VPL, SSEP early stage 가 (averaging) 8)

결론

VPL, SSEFP, SSEFP, SSEFP mapping 가

가, : 2000 10 23, : 2001 6 14, : 120 - 752 134, : 02) 240 - 5246, : 02) 393 - 9979, E - mail : ygpark@yumc.yonsei.ac.kr

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