Standards and Clinical Applications of Visual, Auditory and Somatosensory Evoked Potentials

- Technical basics
  - Components of the system
  - Averager
  - Nomenclature and normal values
- Neurophysics of the generation of evoked potentials
  - Intra-extra cellular currents
  - Electrical fields
  - Generation of far-field potentials
- Visual potentials / Auditory potentials / Somatosens...
  - Anatomy and physiology of the system
  - Stimulus
  - Recommended standard protoco... ...rors
  - Clinical applications and ad...

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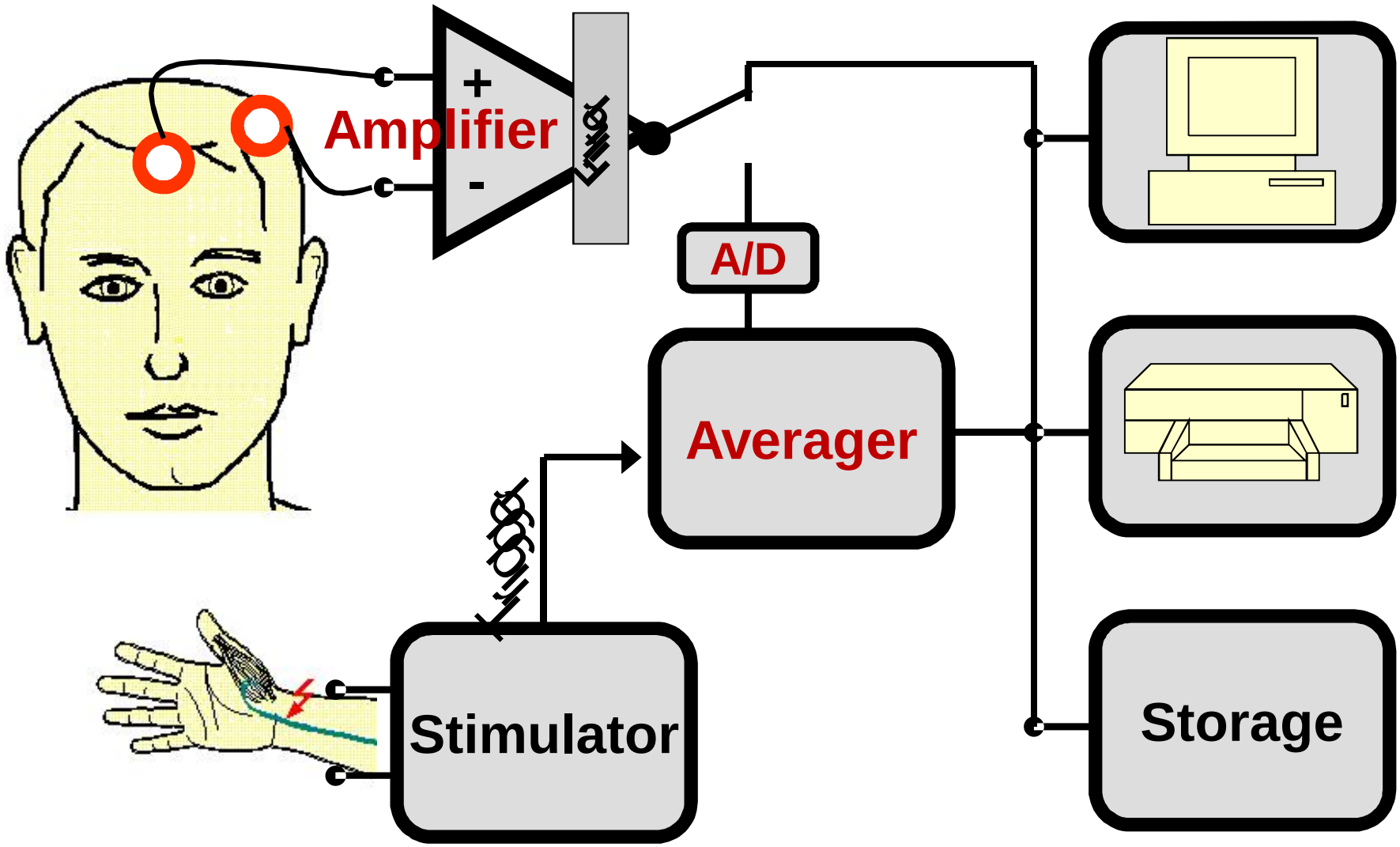
helmut.buchner@klini...

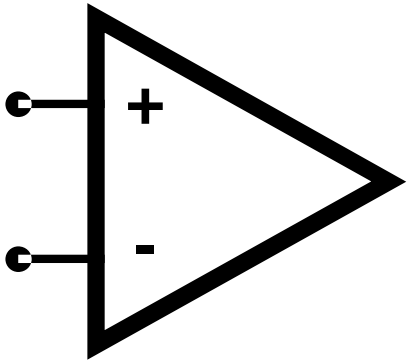
Evoked Potentials are electric potentials occurring in the peripheral and the central nervous system
time locked to a natural or artificial sensory stimulus.

I have nothing to disclose

§ Components of the system



§ Averager

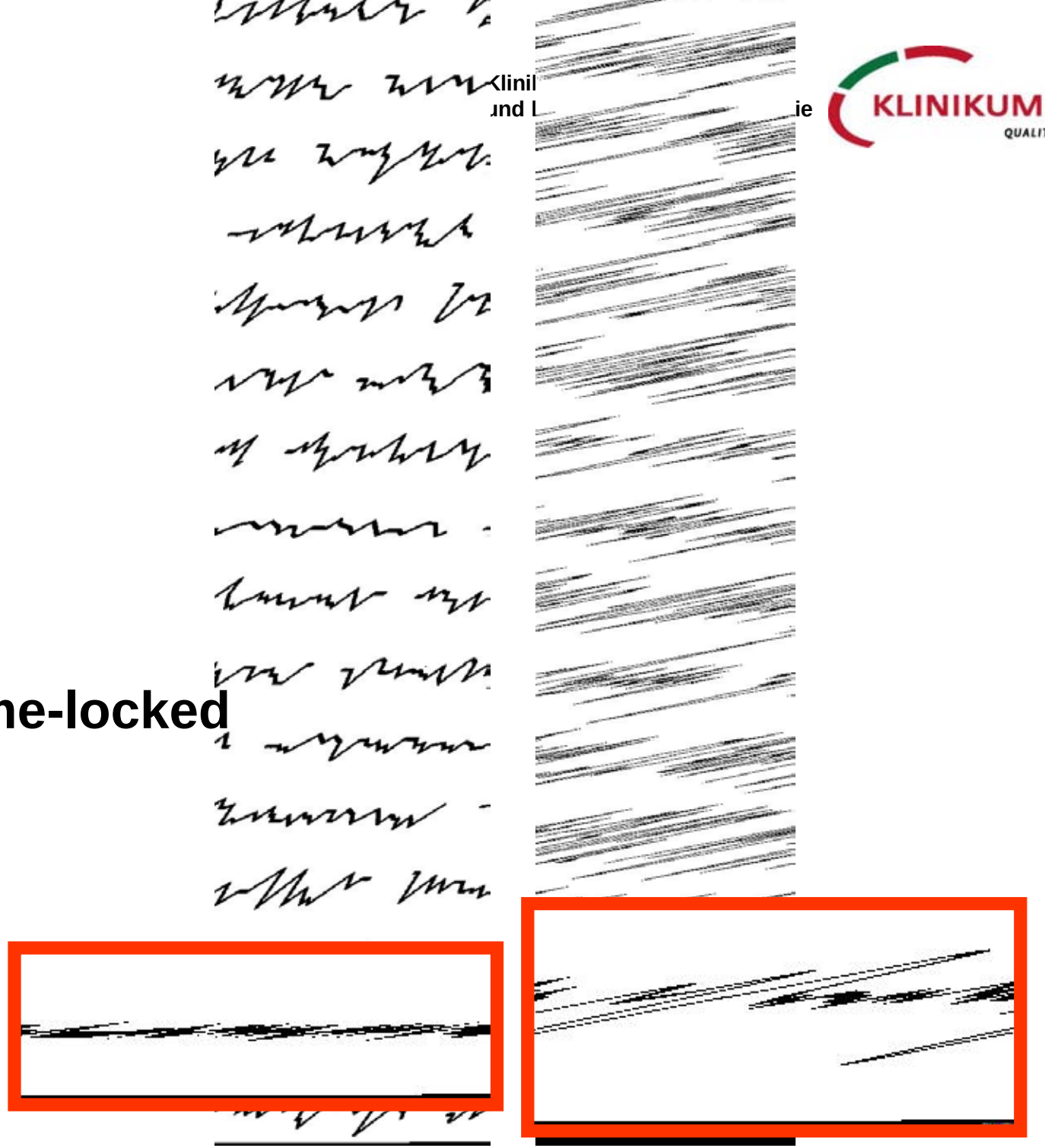


Prerequisites:

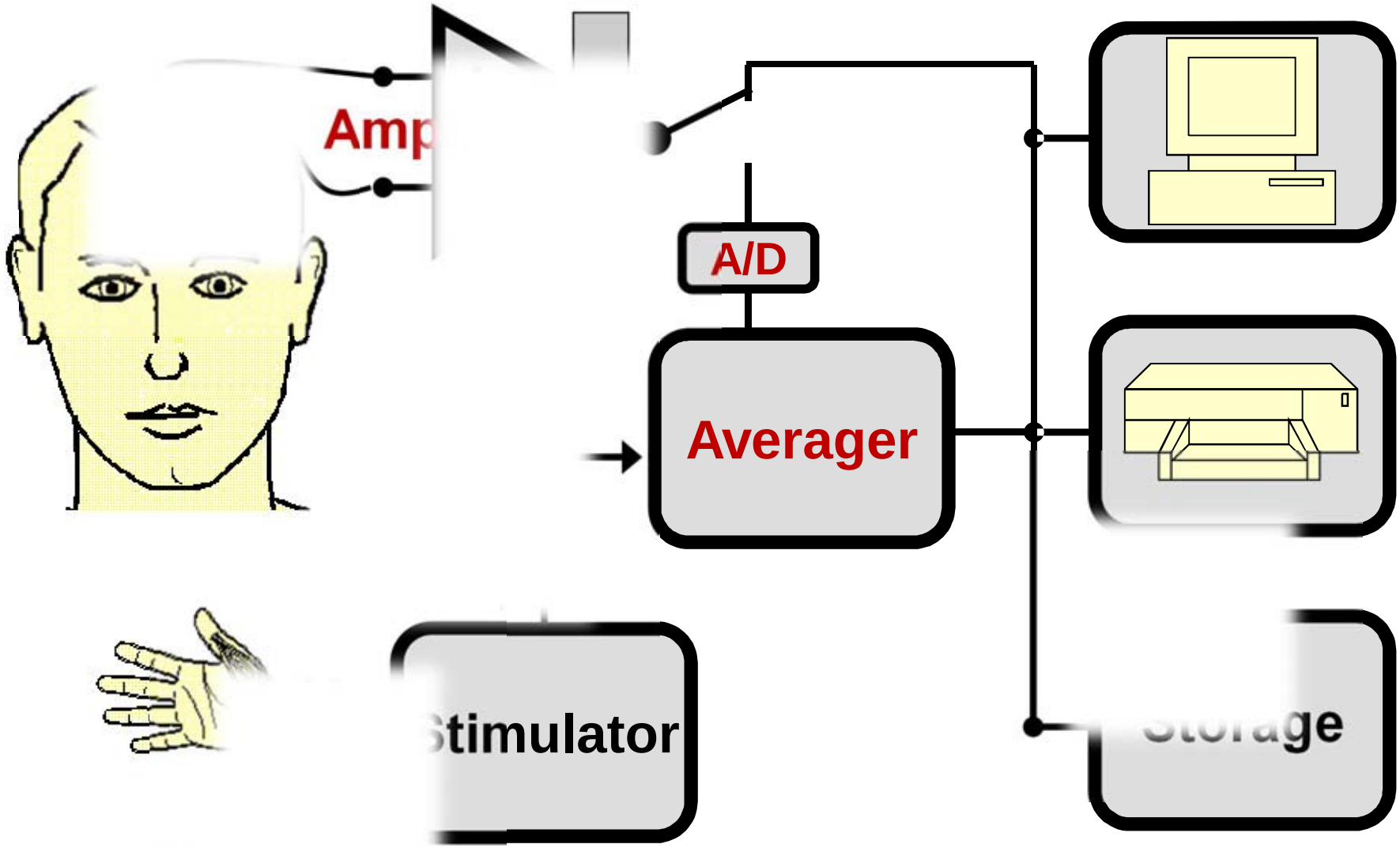
- Signal Stimulus time-locked
- Noise random

$$\frac{1+2+3+....+16}{16}$$

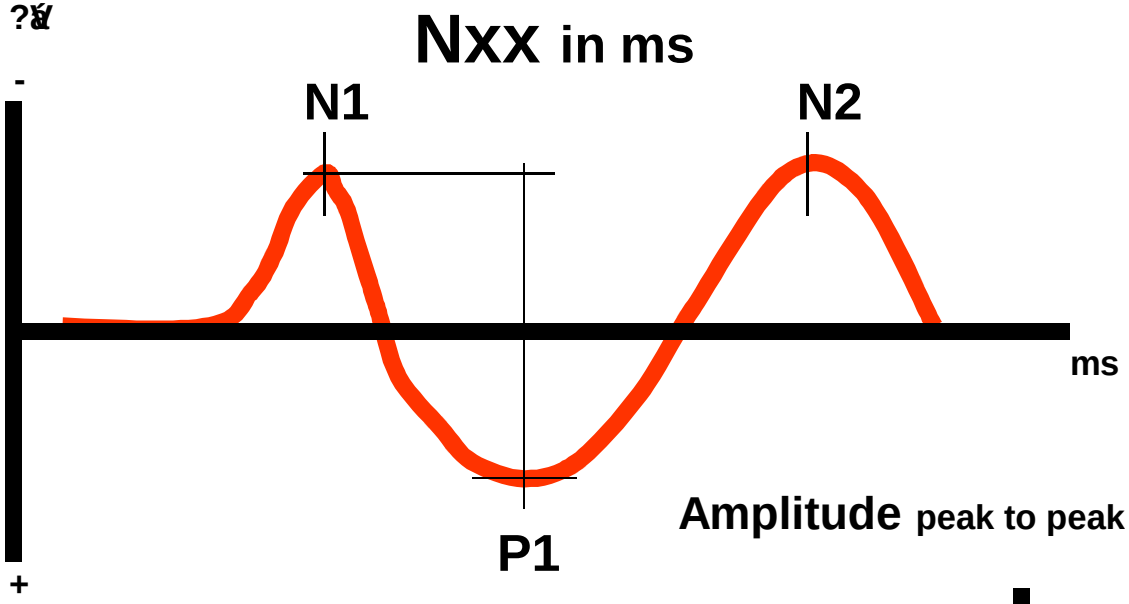
$$S/N \sim ?\sqrt{p}$$



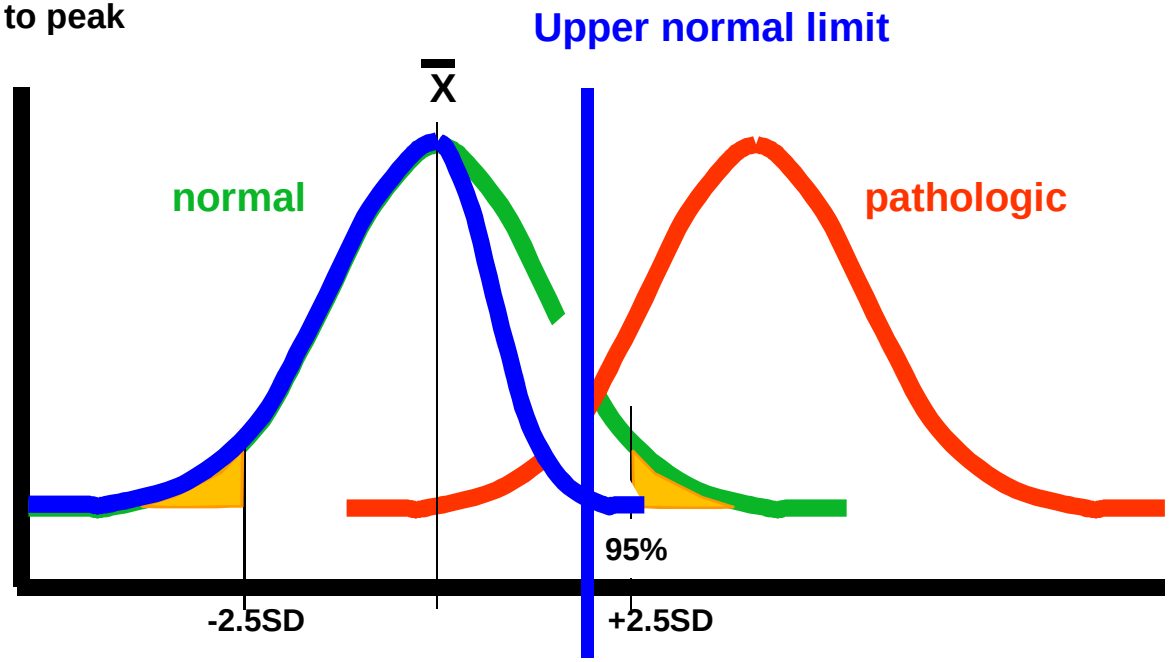
§ Check of the system



§ Nomenclature

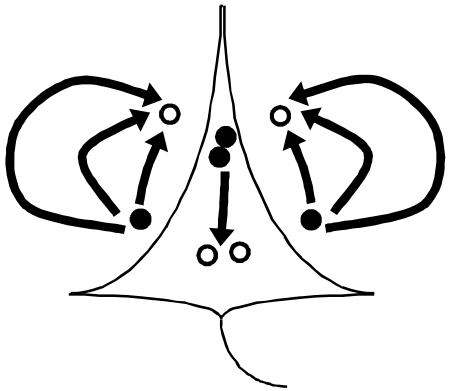


§ Normal values

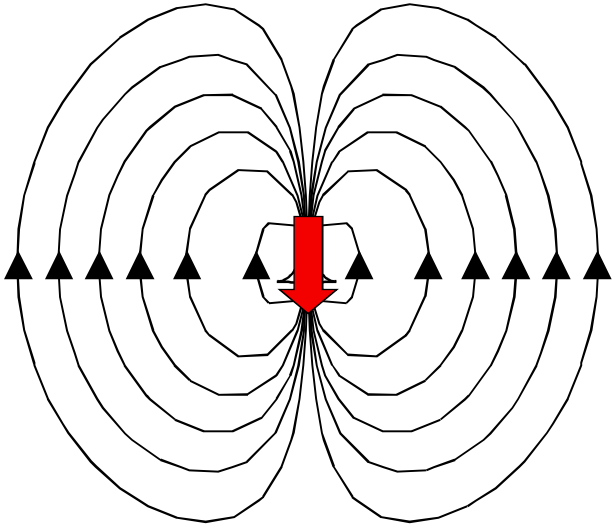


§ Generation of evoked potentials

§ Intra-extra cellular currents

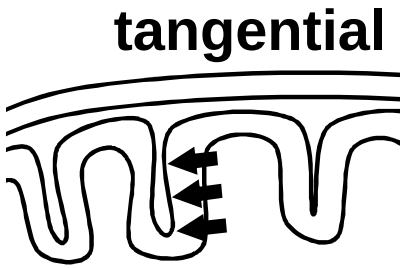


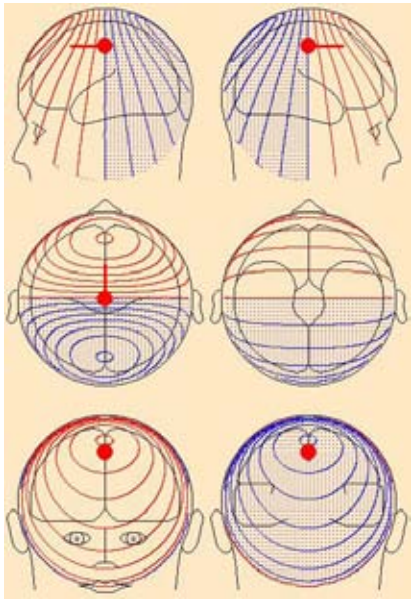
intra- and extracellular:
source ● → ○ sink

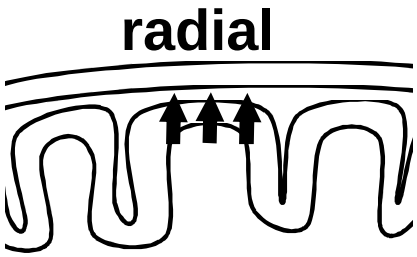


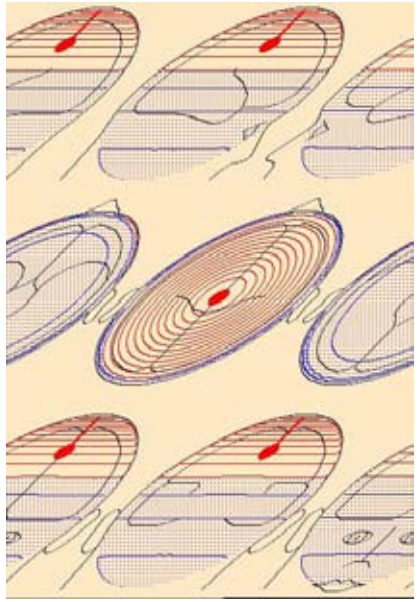
extracellular volume current
equivalent Dipole

§ near-fields









DipoleSimulator © P. Berg (2002)

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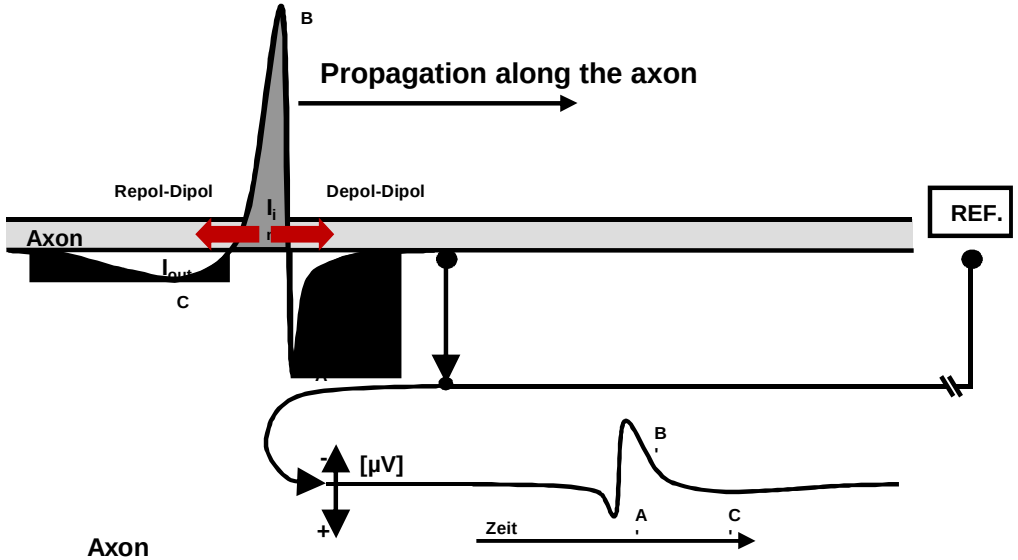
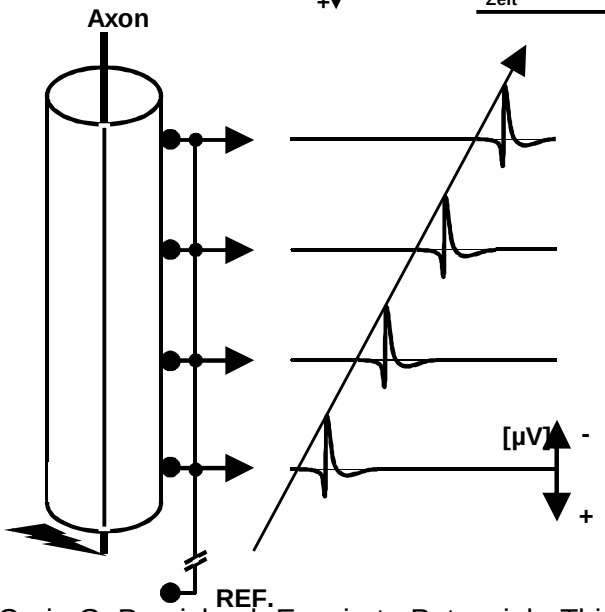
§ Generation of evoked potentials

§ Generation of far-field potentials





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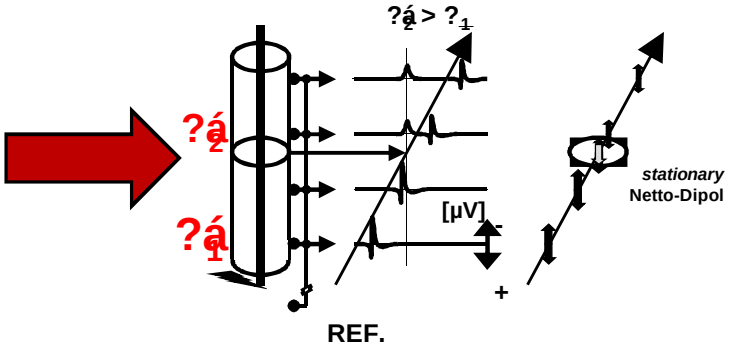
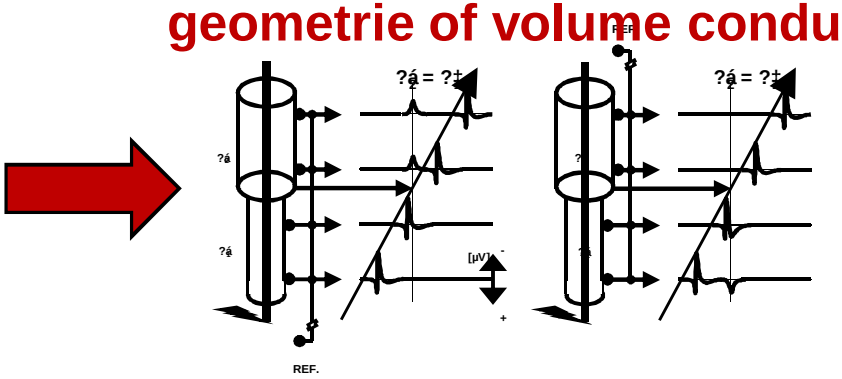
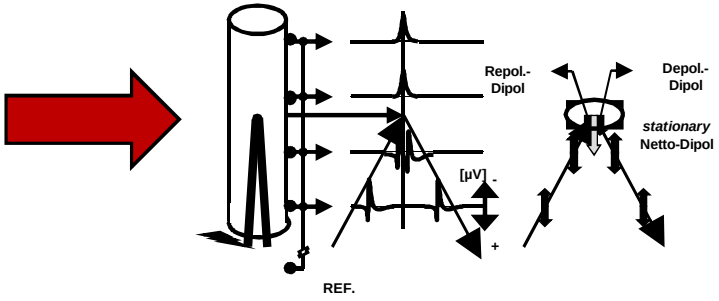
conductivity



geometrie of volume conductor



change in propagation direction



§ Visual evoked potentials

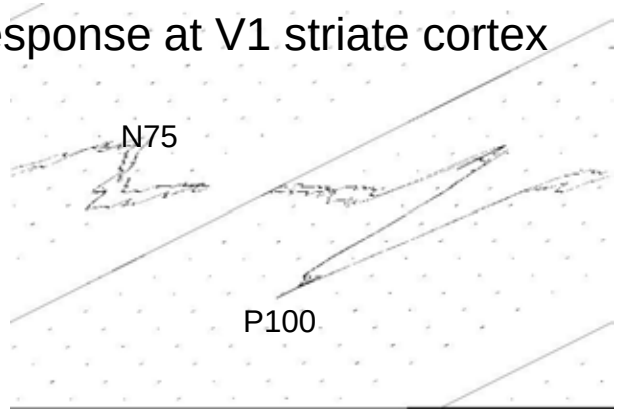
§ Anatomy and physiology of the system

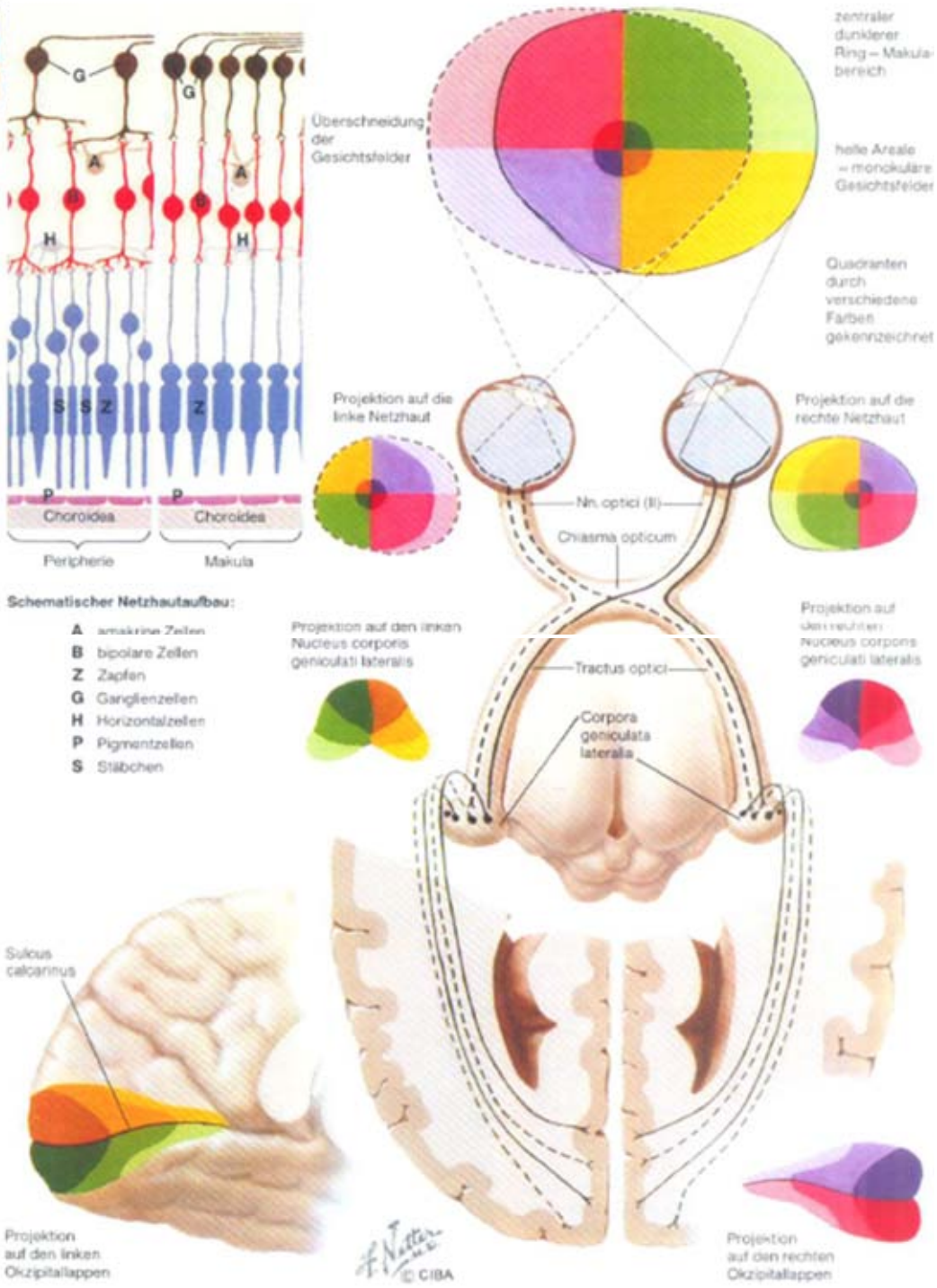
- Stimulus
- Recommended standard protocols and sources of errors
- Clinical applications and advanced use

- Cones – color sensitive, fovea
- Rods – light sensitive, outside fovea
- Retinal ganglion cells
  - magnocellular – direction of contrast and motion
  - parvocellular - color

N75 – input from LGN to striate cortex

P100 – secondary response at V1 striate cortex





§ Visual evoked potentials

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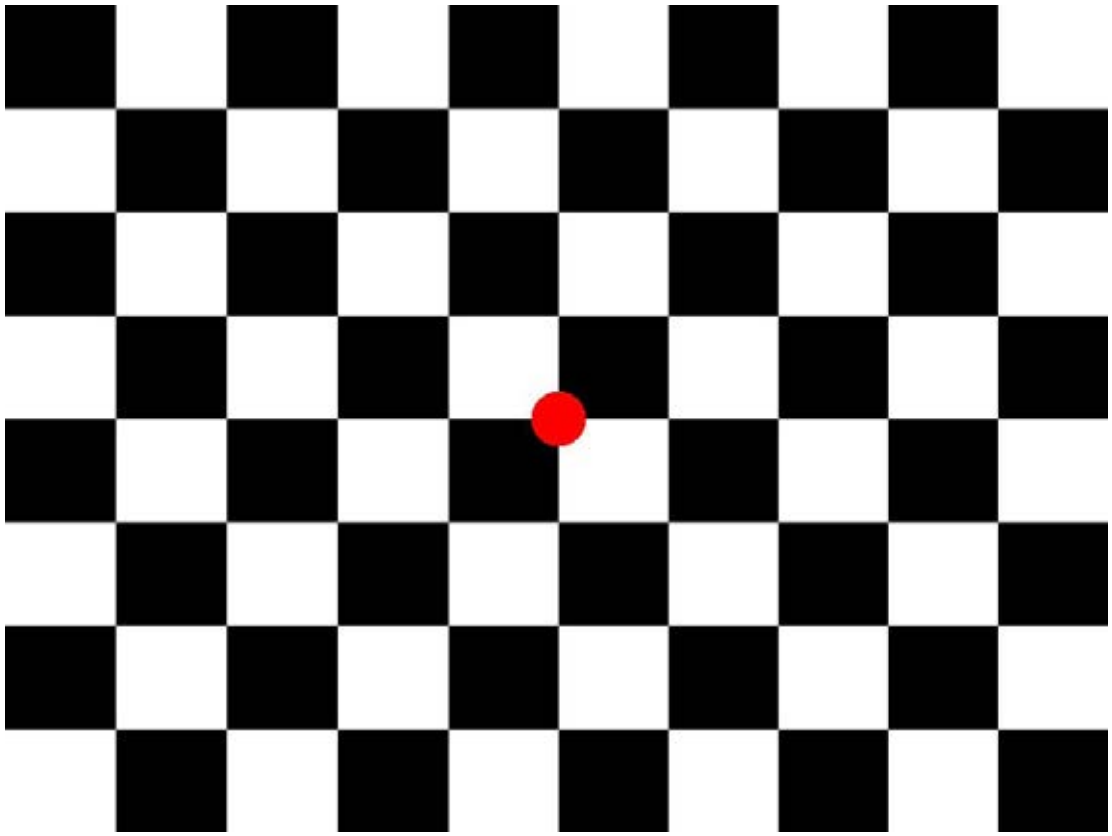
Ø Pattern reversal

§ Stimulus

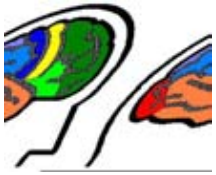
- Recommended standard protocols and sources of errors
- Clinical applications and advanced use

- One eye full-field stimulation
- Stimulus field ≥ 12-15 °
- Check size (15'/50-60')
- **Contrast black/white >80%**
- Reversal rate 1-2 Hz
- Fixation: central

- app. 80% of VEP from central 8 dg. of visual field



§ Visual evoked potentials



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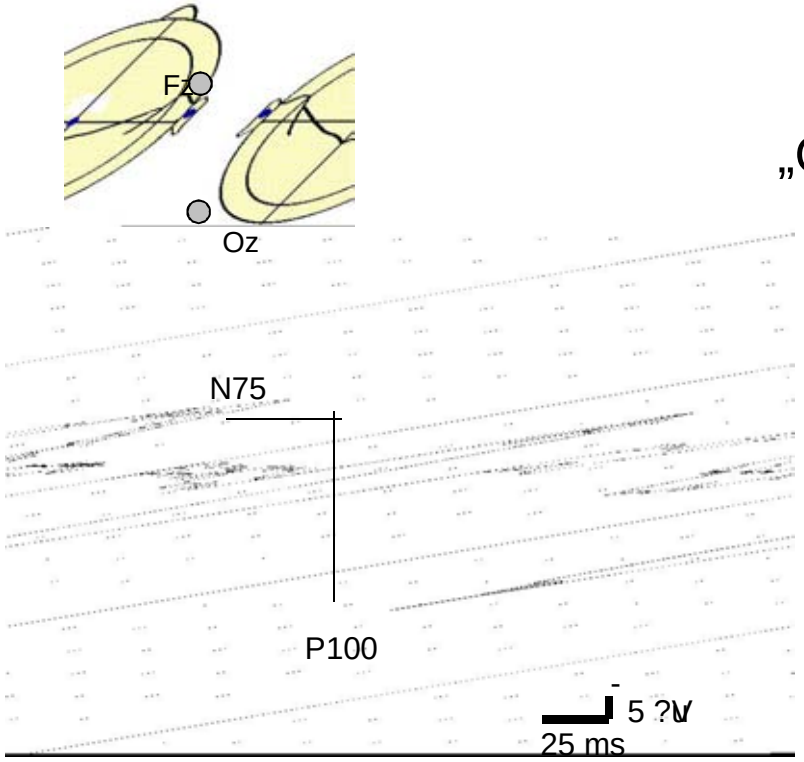
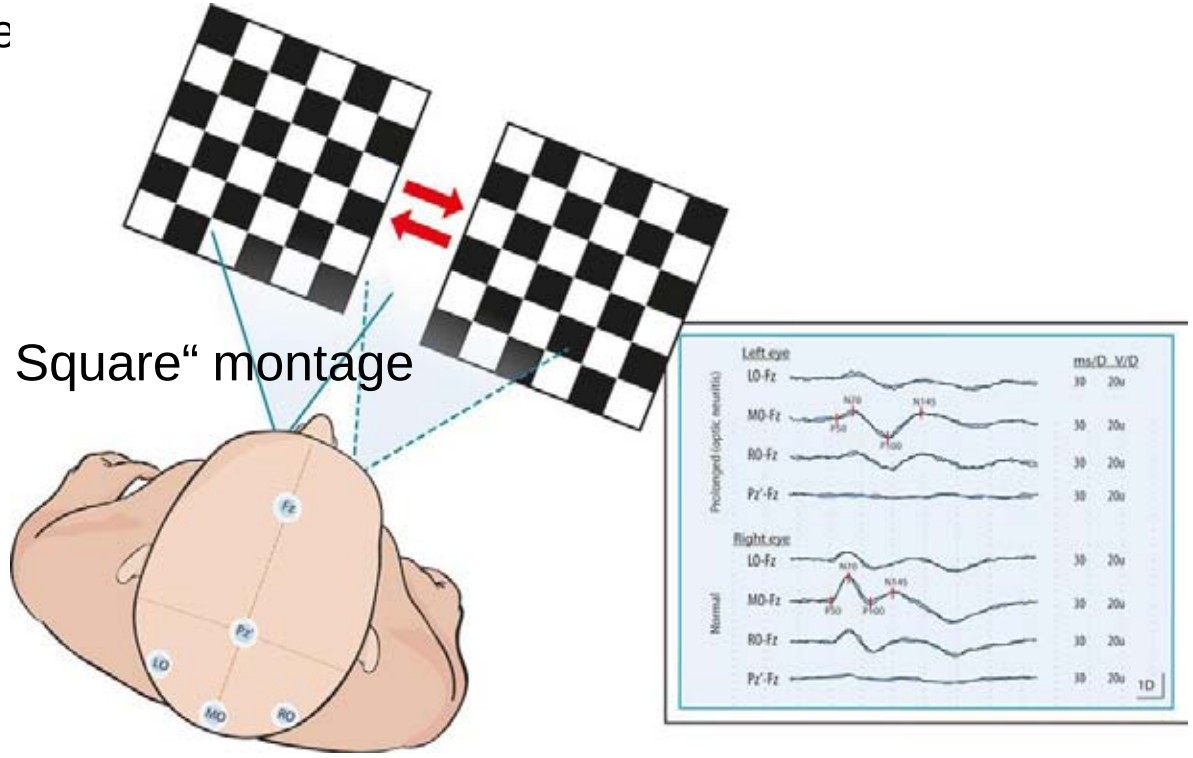
§ Recommended standard protocols and sources of errors

– Clinical applications and advanced use



„Queen Square“ montage



quality control

§ two measurements
§ reproduction with:
§ Latencies below 1 ms
§ Amplitudes of + / - 20%

§ Visual evoked potentials

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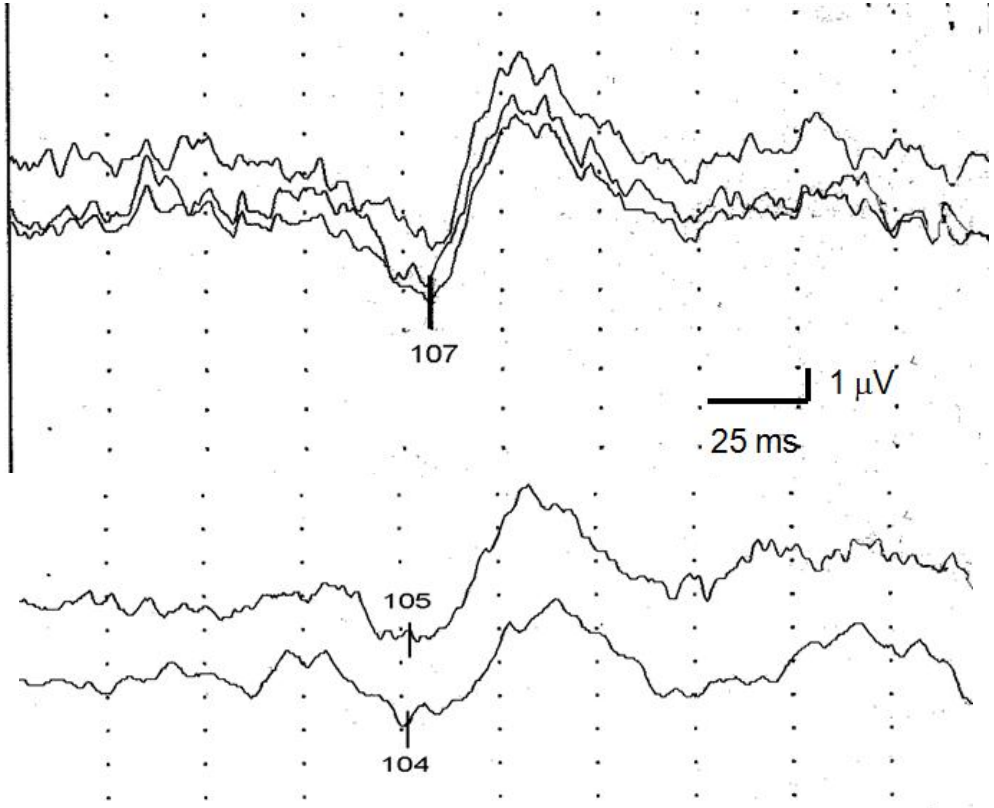
§ Sources of errors

– Stimulus parameters

• **Contrast black/white > 80%**

darkened room

illuminated room



§ Visual evoked potentials

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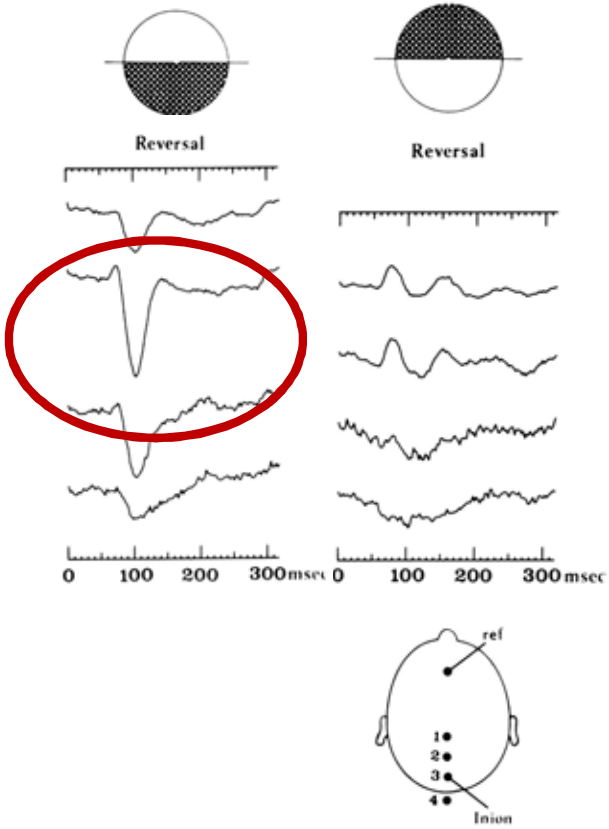
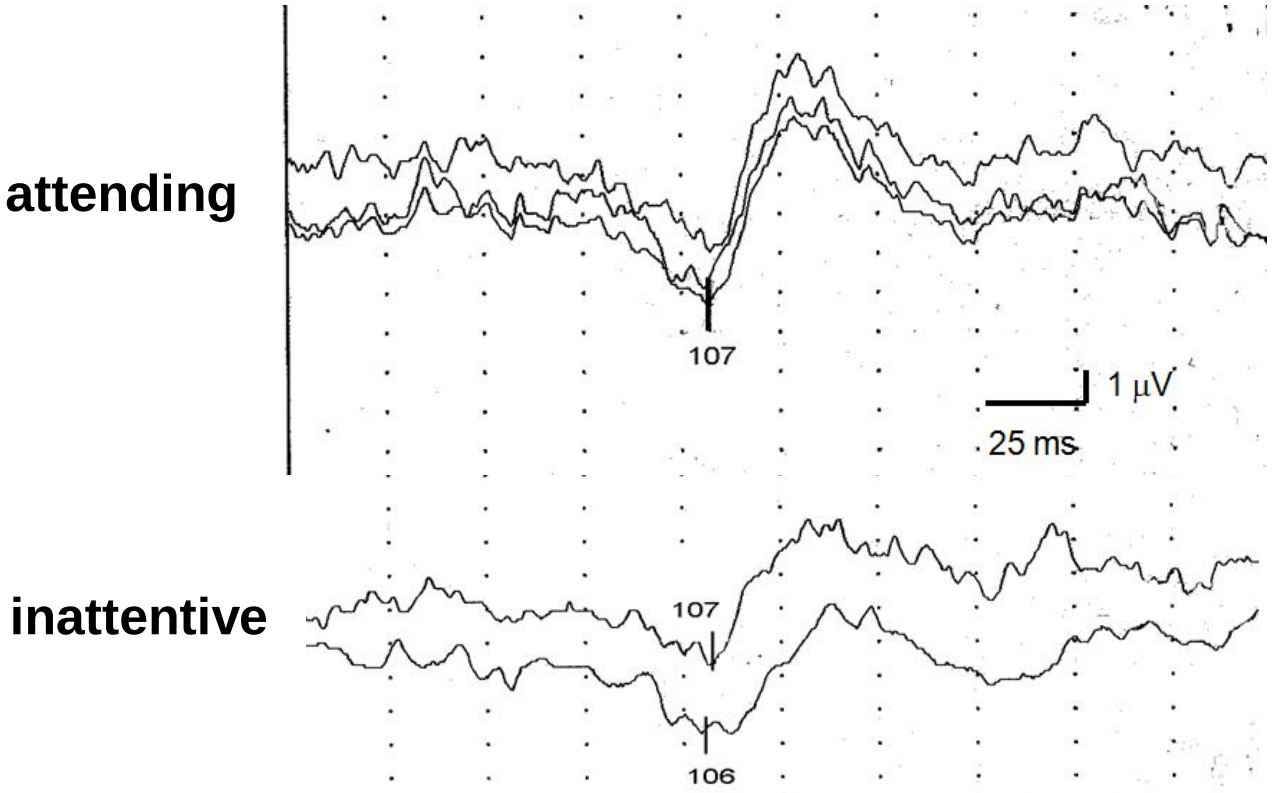
§ Sources of errors

– Fixation of stimulus

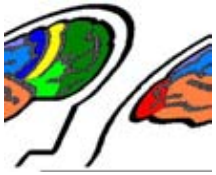
- **Fixation: central**





- **Minor influence**
- Age / Gender
- Head Size
- Pupil Size
- Temperature

§ Visual evoked potentials



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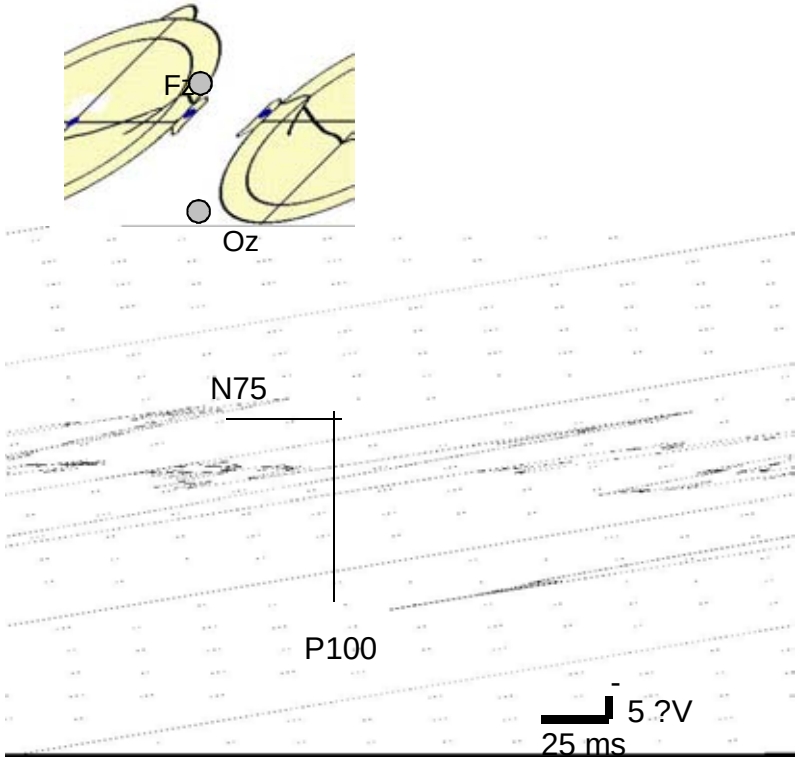
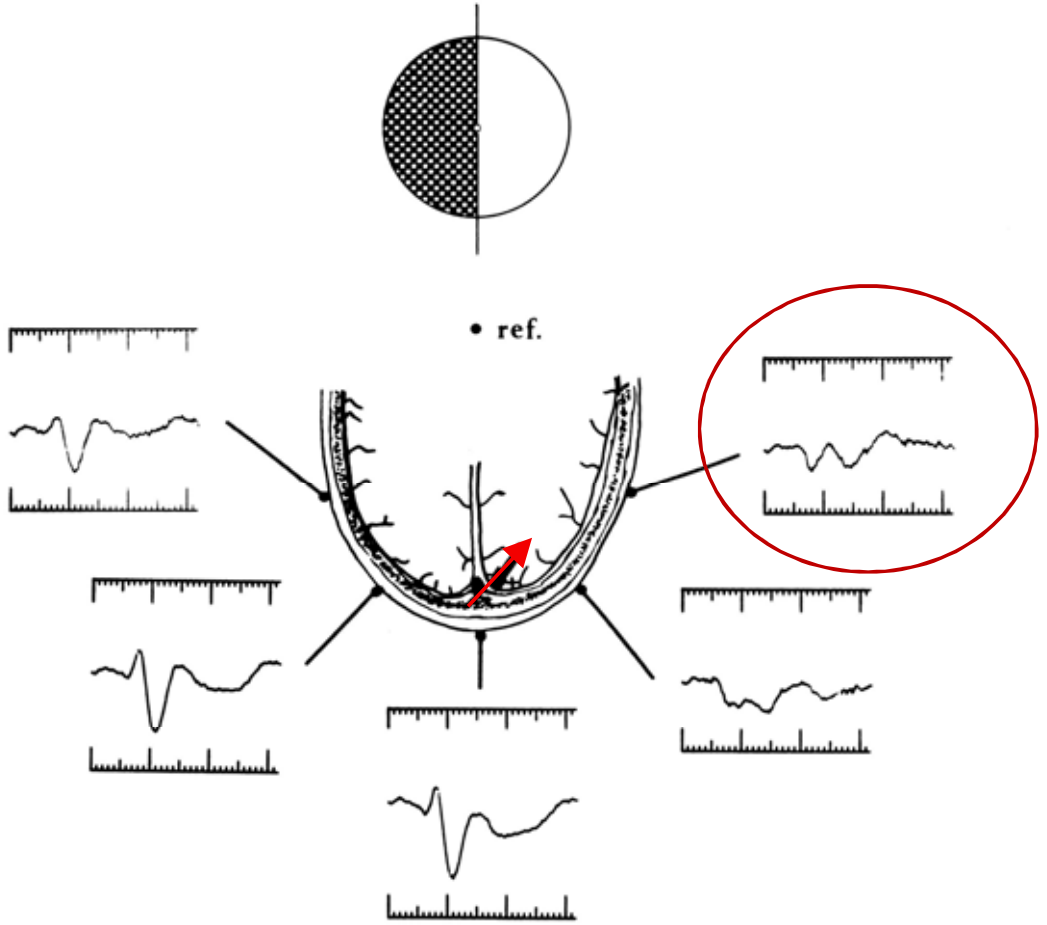
§ Normal and pathological VEPs

- P100 identification
- P100 latency
- P100 amplitude





Barrett et al., 1976

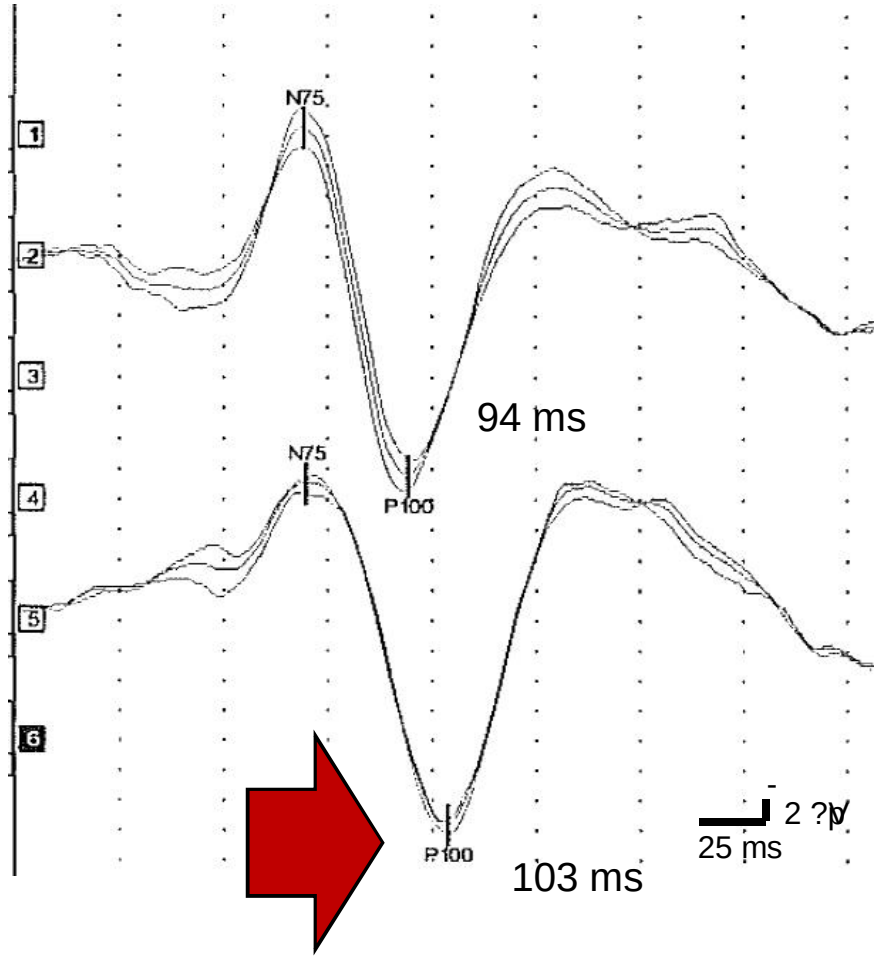
§ Visual evoked potentials

§ Normal and pathological VEPs

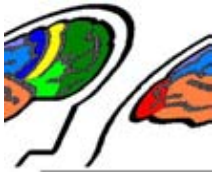
- P100 identification
- P100 latency
- P100 amplitude

P100

- Upper normal limit **111 ms**
- Upper normal limit of side difference **5 ms**



§ Visual evoked potentials



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§ Clinical applications and advanced use

Ø Hard rocks

MS – diagnosis

optic neuritis

neuromyelitis optica

anterior ischemic optic neuropathy

compressive optic neuropathy

Ø Soft rocks

MS – history

Degenerative diseases

Friedreich ataxia, familial spastic paraplegia, hereditary neuropathies …

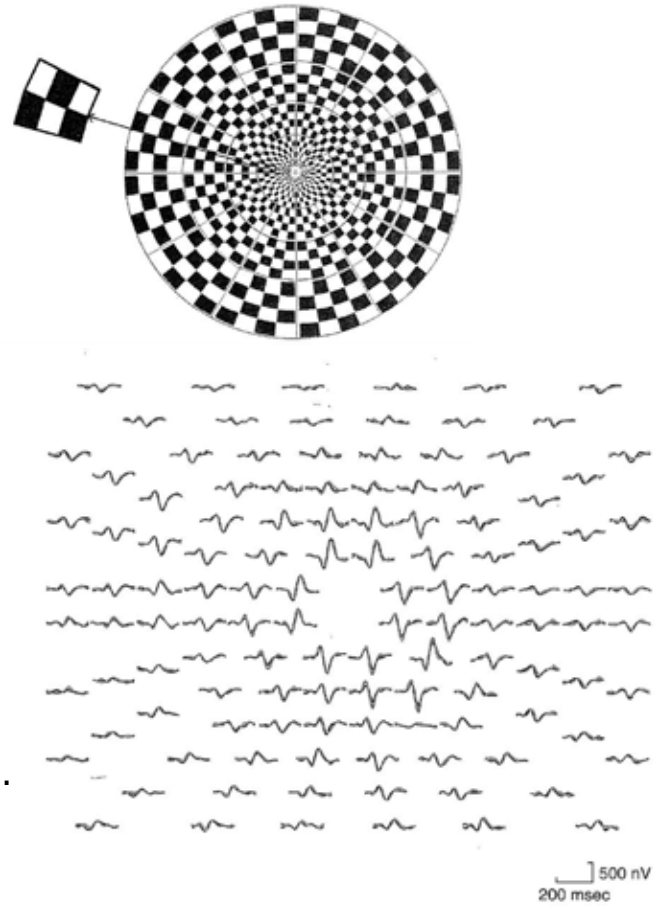
Toxic neuropathies

Ø The beach

Paraneoplastic disorders

Visual field defects

Cortical blindness



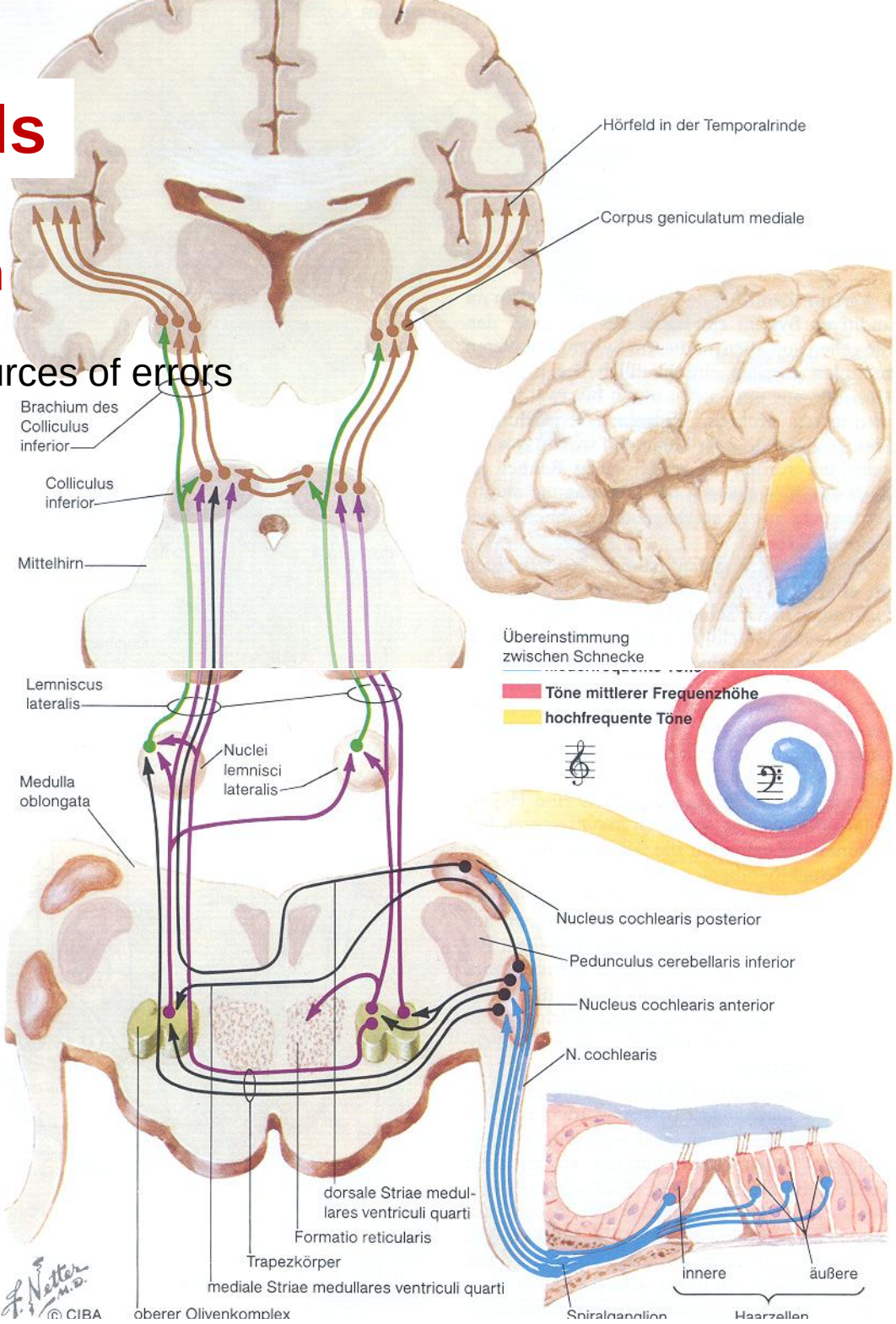
multifocal stimulated VEP

With compliments to D. J. Jewett Berlin conference 1986

subjective opinion and incomplete list

§ Auditory evoked potentials

§ Anatomy and physiology of the system
- Stimulus
- Recommended standard protocols and sources of errors
- Clinical applications and advanced use



Anatomy and Physiology

§ ear - sound management
§ compressor – cavity
§ inner ear - Sound-mechanical conversion
§ gain 1:22
§ cochlea - mechanical-electrical conversion
§ "Traveling wave" hypothesis
§ cochlear nerve
§ compound action potential
§ brainstem

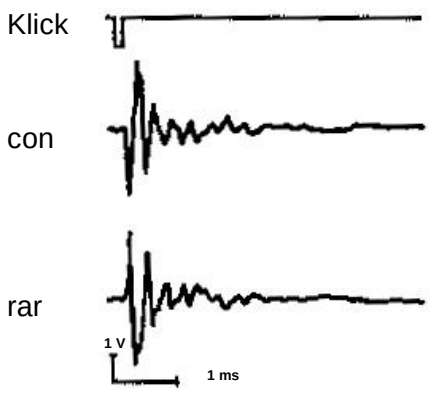
Buchner: Standards

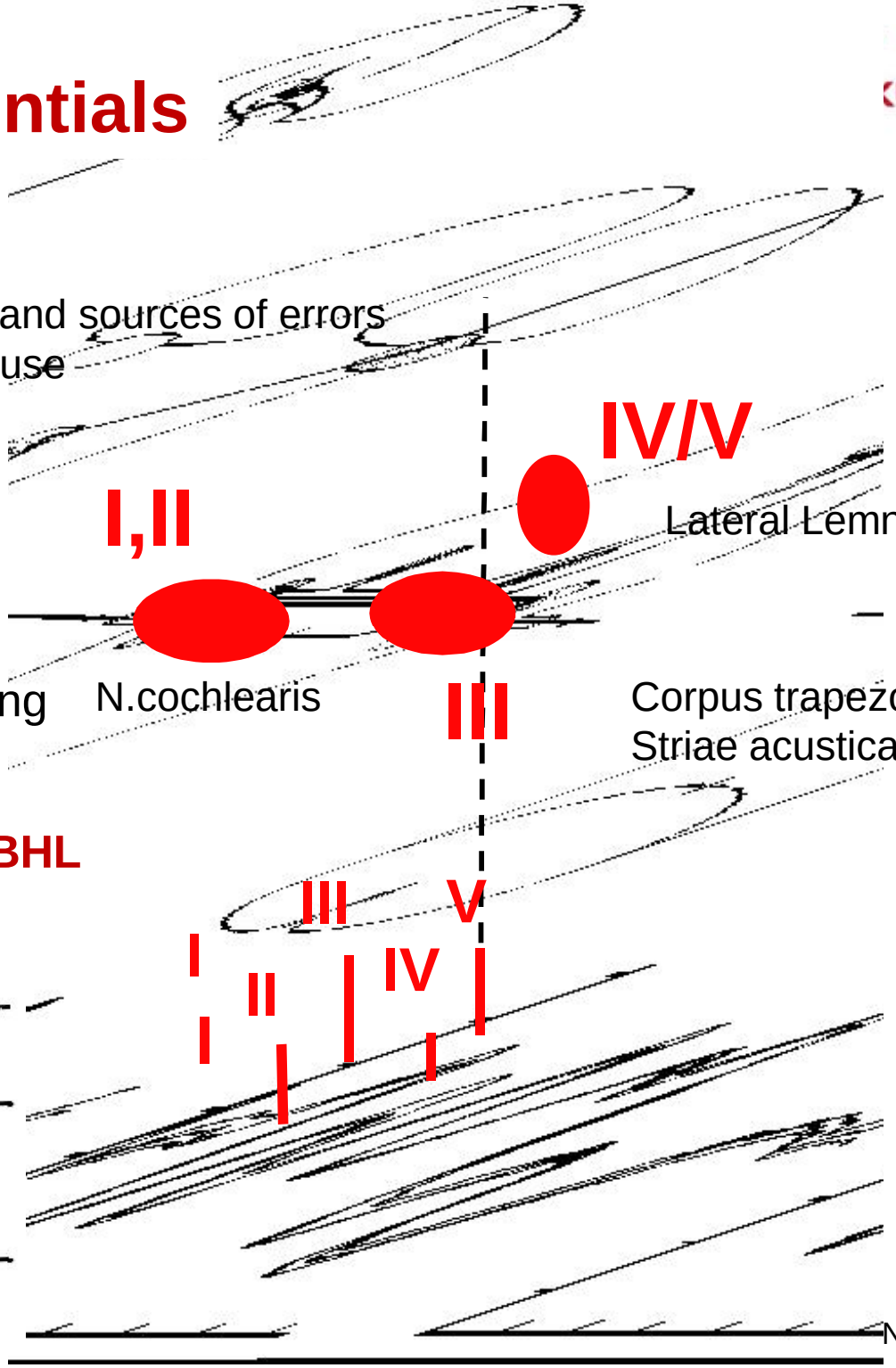
§ Auditory evoked potentials

§ Stimulus
- Recommended standard protocols and sources of errors
- Clinical applications and advanced use

Stimulus parameter

- Klick duration 100 us
- Polarity
- condensation - rarefaction = alternating
- Frequency 10 - 20 Hz (14,7)
- **Intensity 70 dBSL max. 90 dBHL**
- Contralateral - 40 dB of stimulus intensity

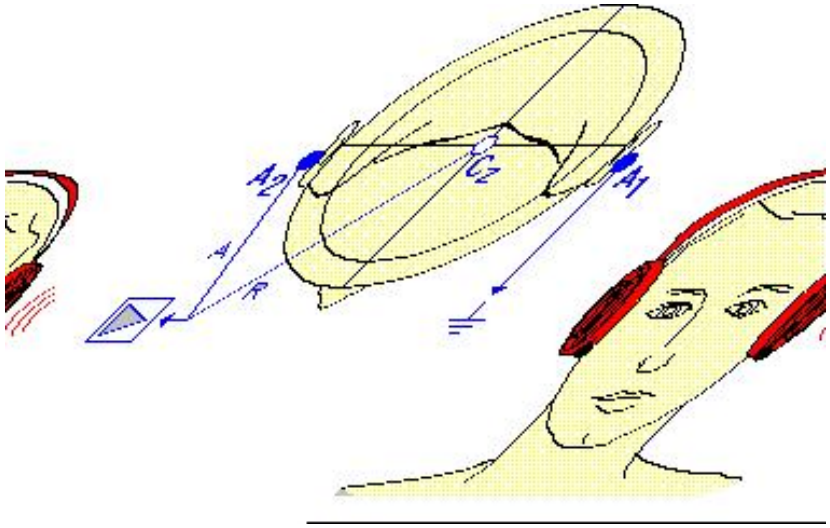


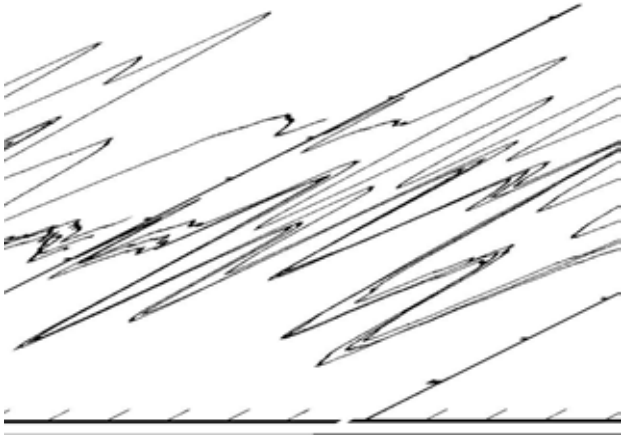


§ Auditory evoked potentials

§ Recommended standard protocols and sources of errors
  – Clinical applications and advanced use

§ Acquisition





quality control
§ two measurements
§ Reproduction with:
§ Latencies below 0.1 ms
§ Amplitudes of + / - 20%

measurement parameters
§ Channel 1 Ai – Cz
§ Channel 2 Ac – Cz
§ Filters 100 - 3000 Hz
§ Gain about 100,000 times (about 1-5 uV / dev)
§ Measuring time 10 ms

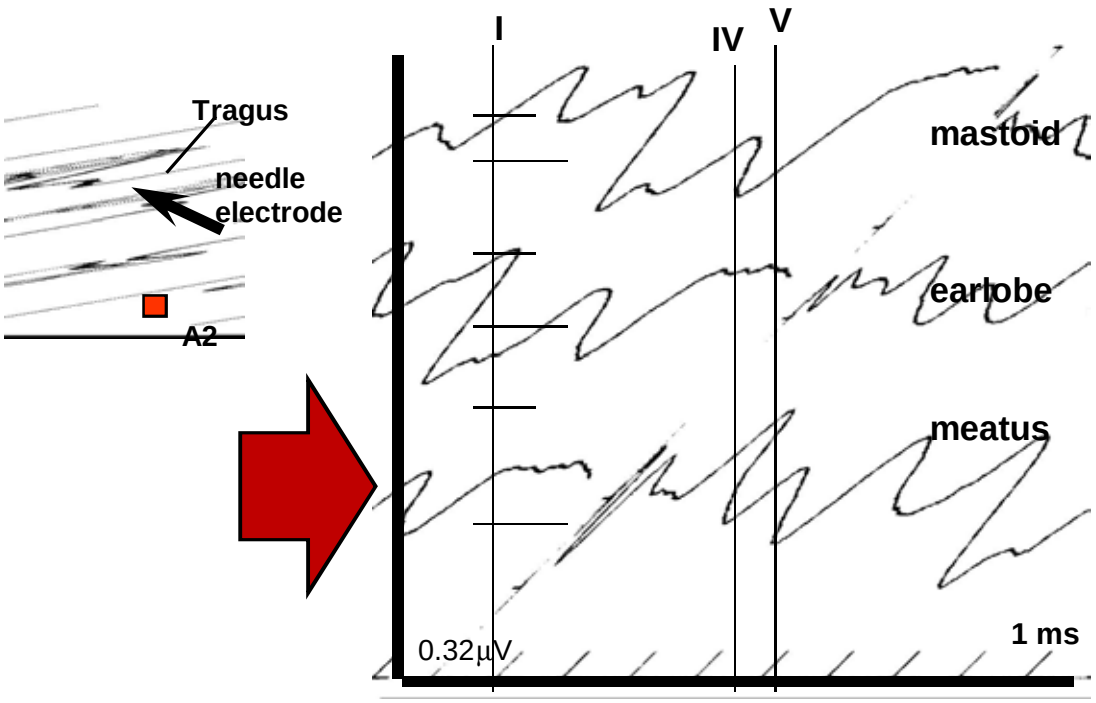
Upper normal limits

- I-III 2.5 ms – side difference 0.5 ms
- III-V 2.4 ms – side difference 0.5 ms
- I-V 4.5 ms – side difference 0.5 ms

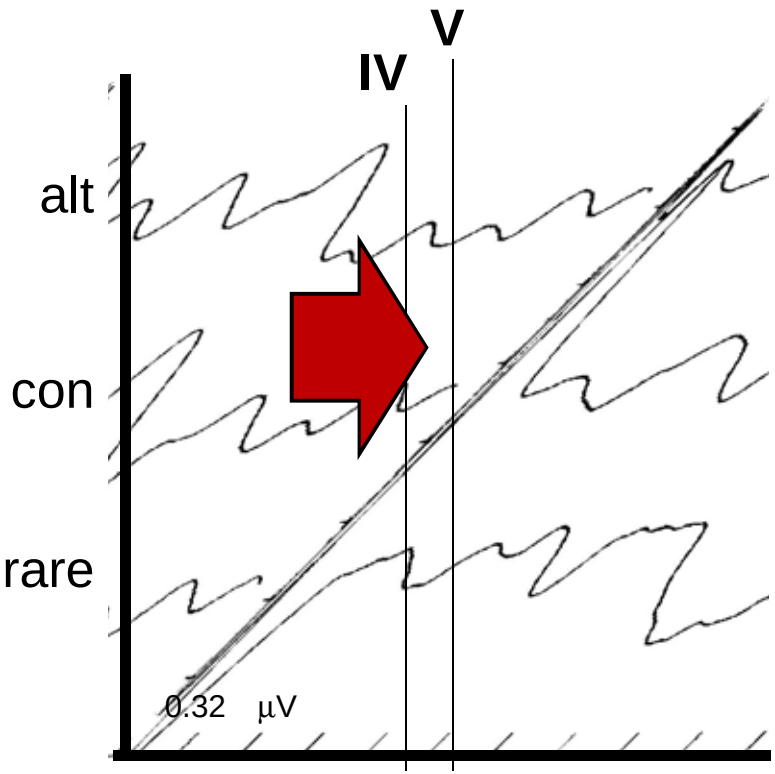
§ Auditory evoked potentials

§ Recommended standard protocols and sources of errors
- Clinical applications and advanced use

§ Acquisition



Identification of wave V



§ Auditory evoked potentials

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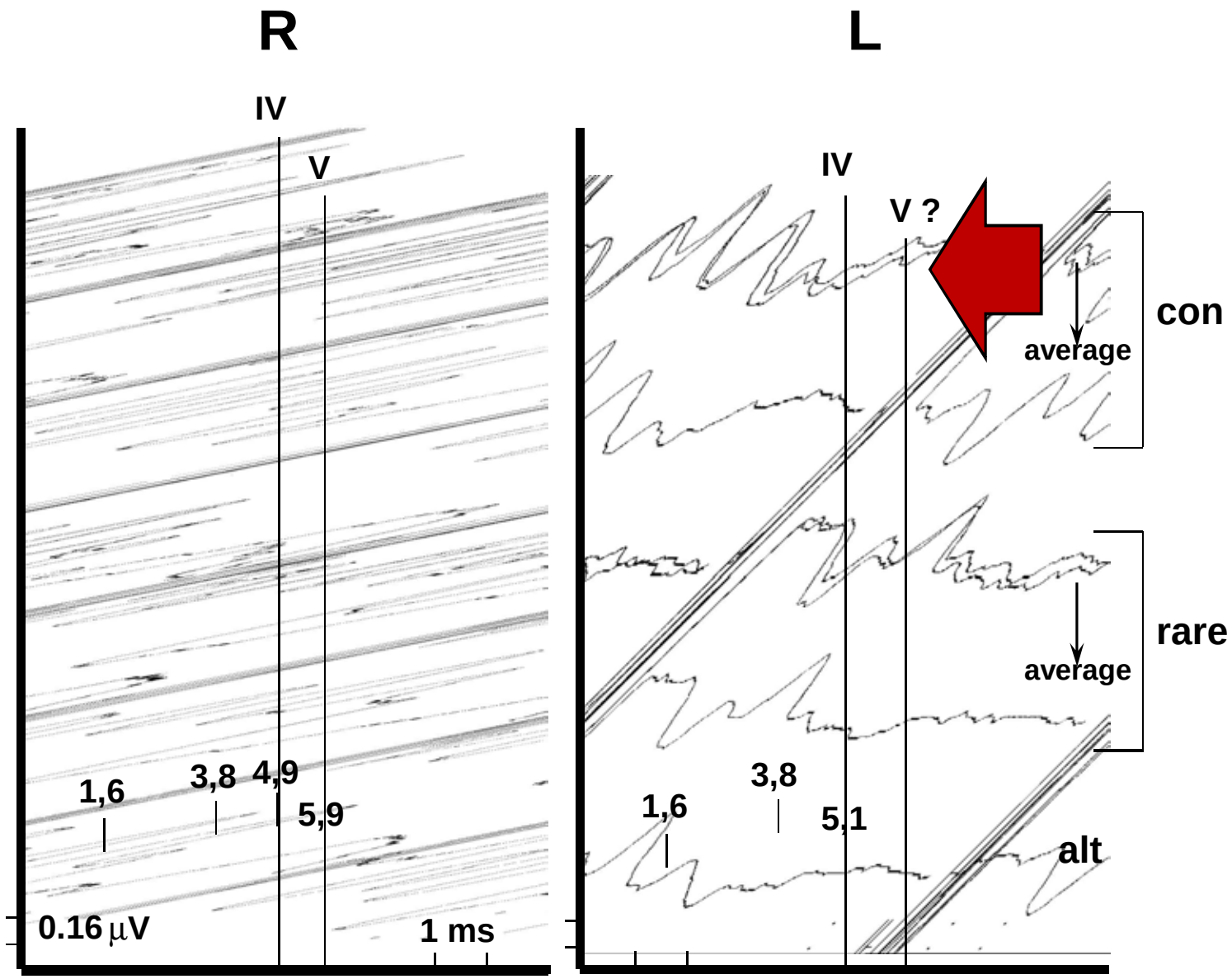
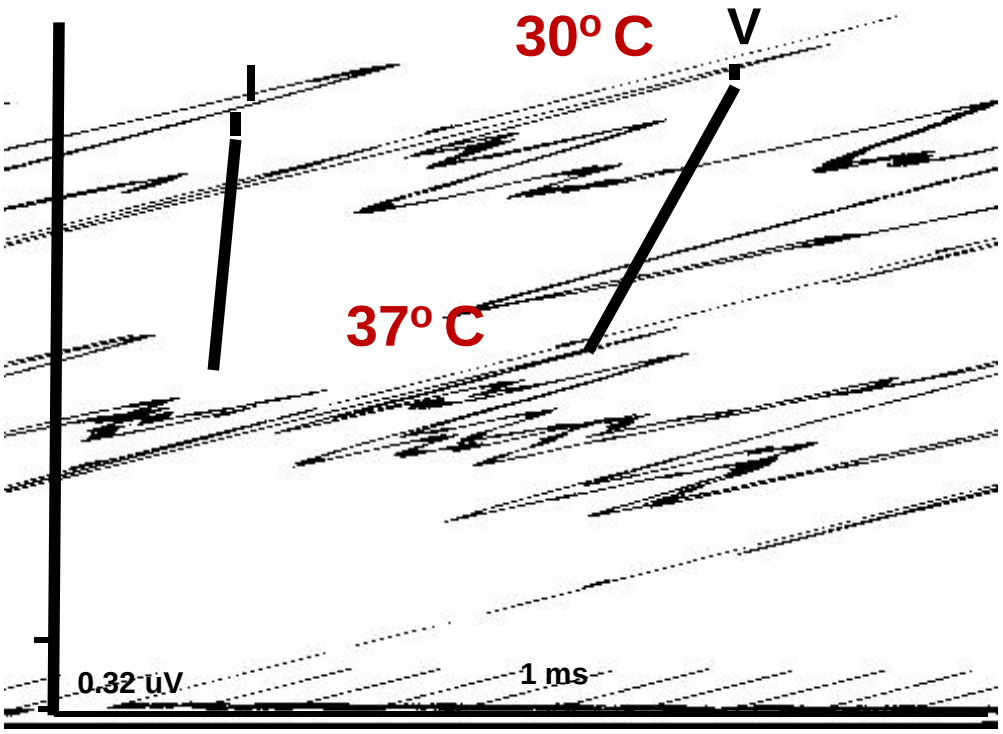
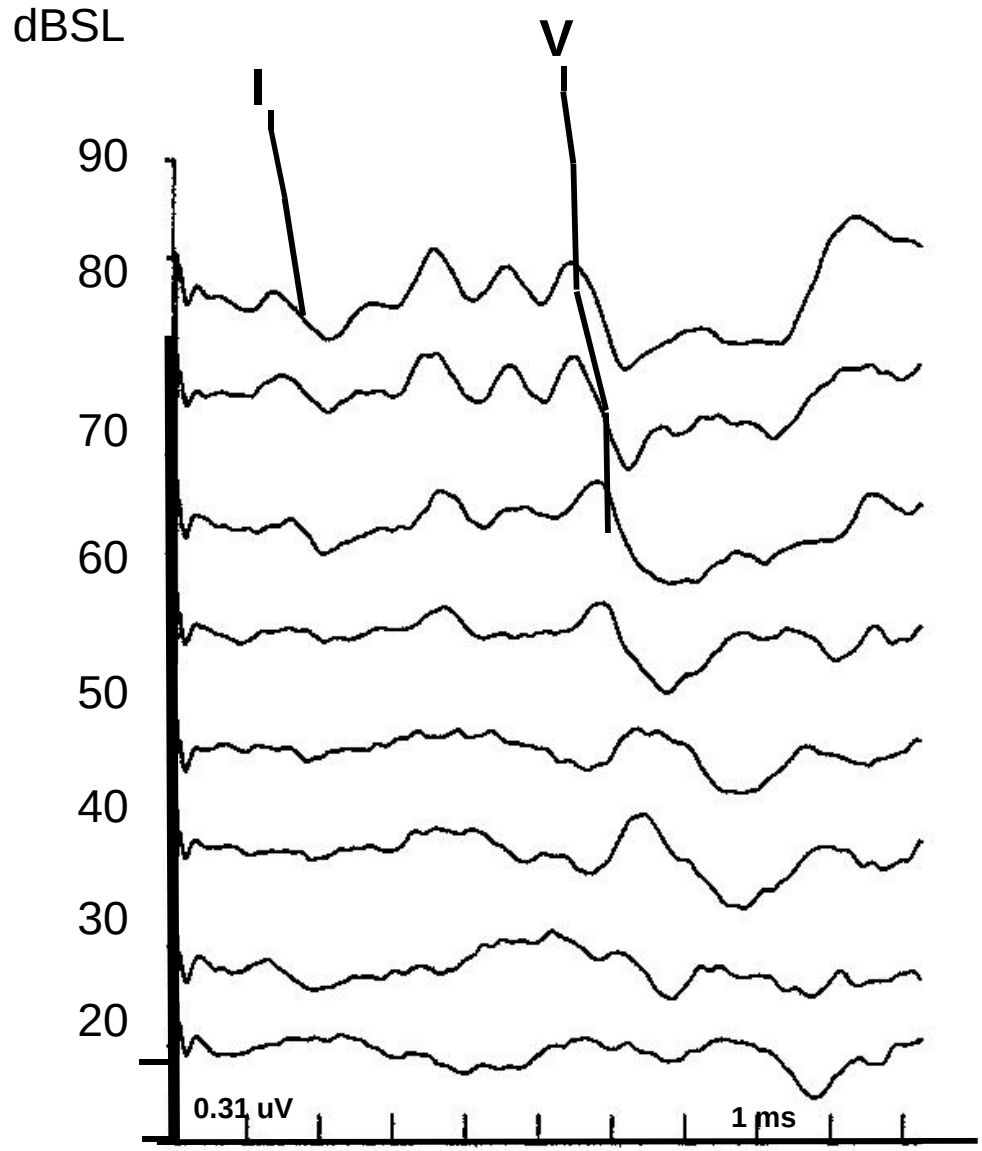


§ Auditory evoked potentials

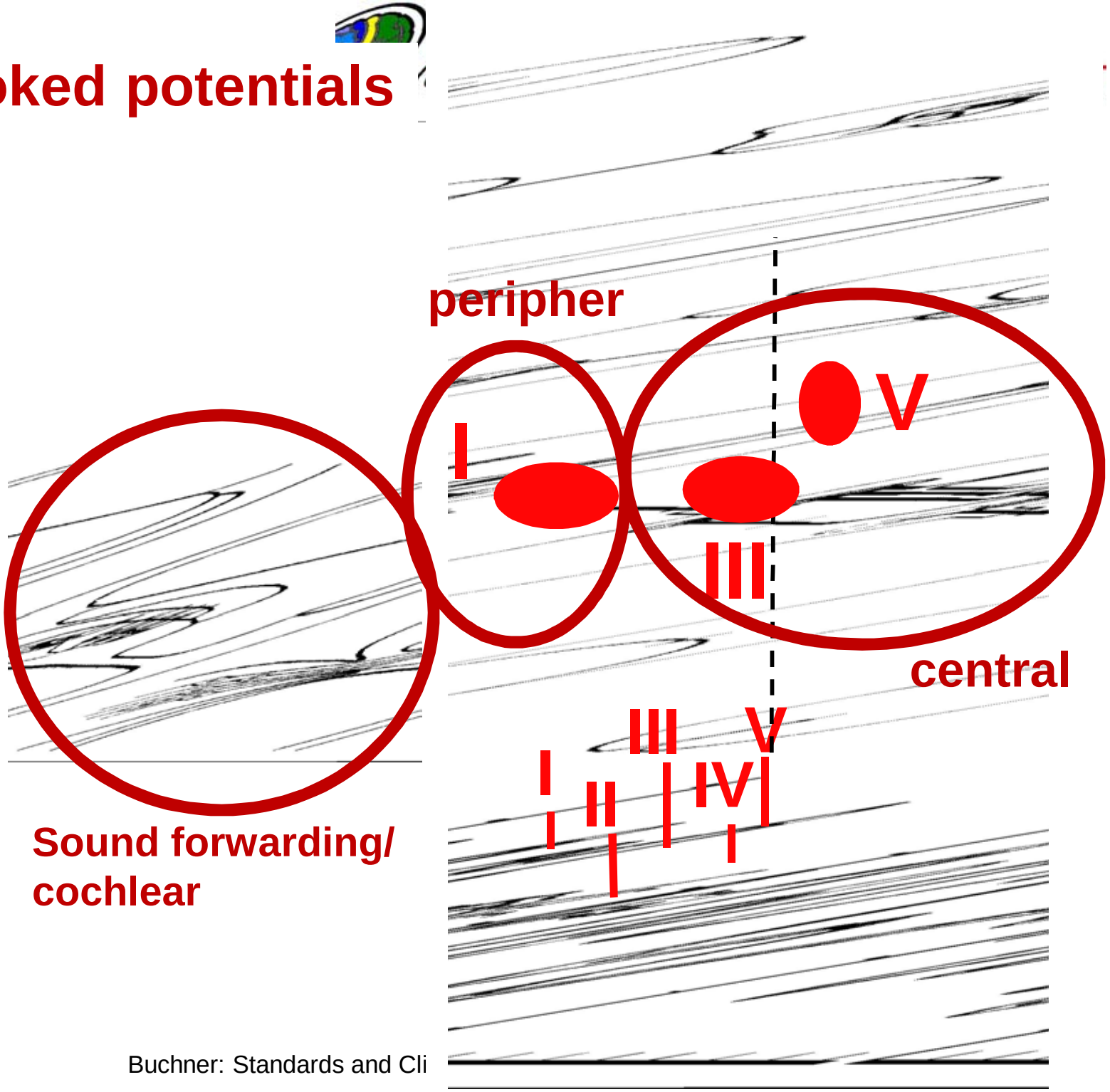
§ sources of errors

- body temperature
- peripheral vs. central hearing





§ Auditory evoked potentials



Buchner: Standards and Cli

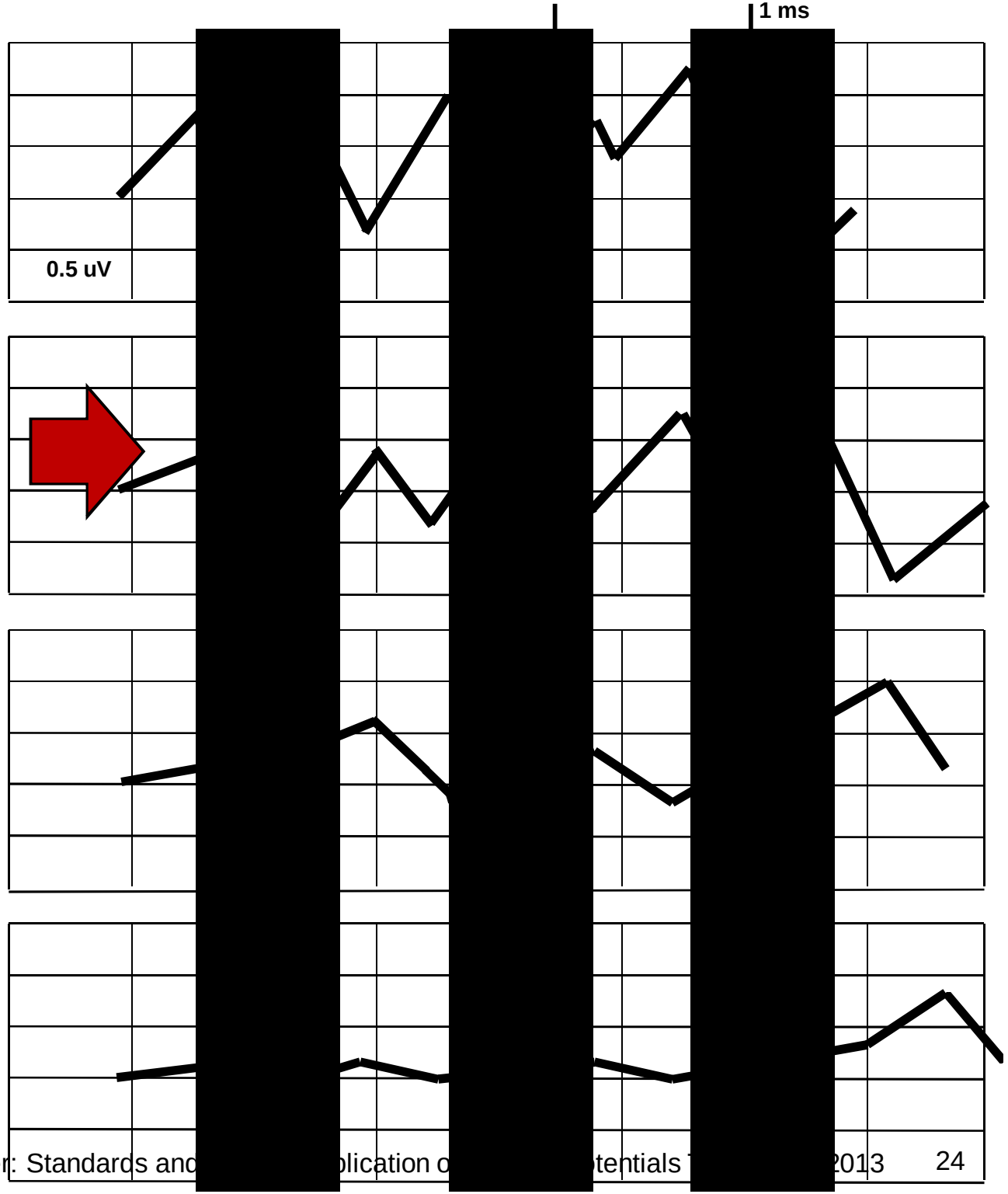
Somatosensory evoked potentials

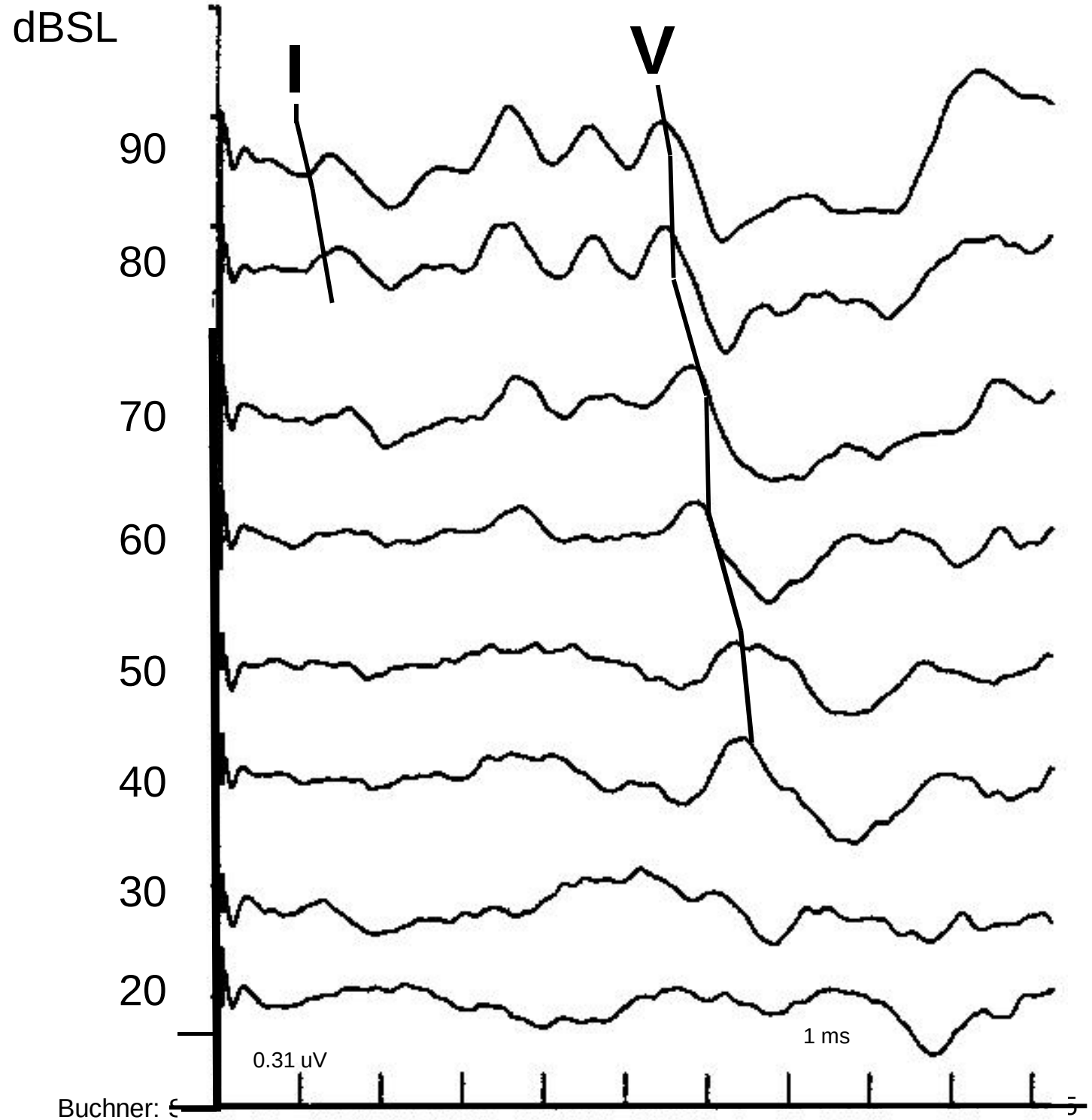
normal

delayed I to V

delayed I to V
loss of II to IV

delayed V
loss of I to IV



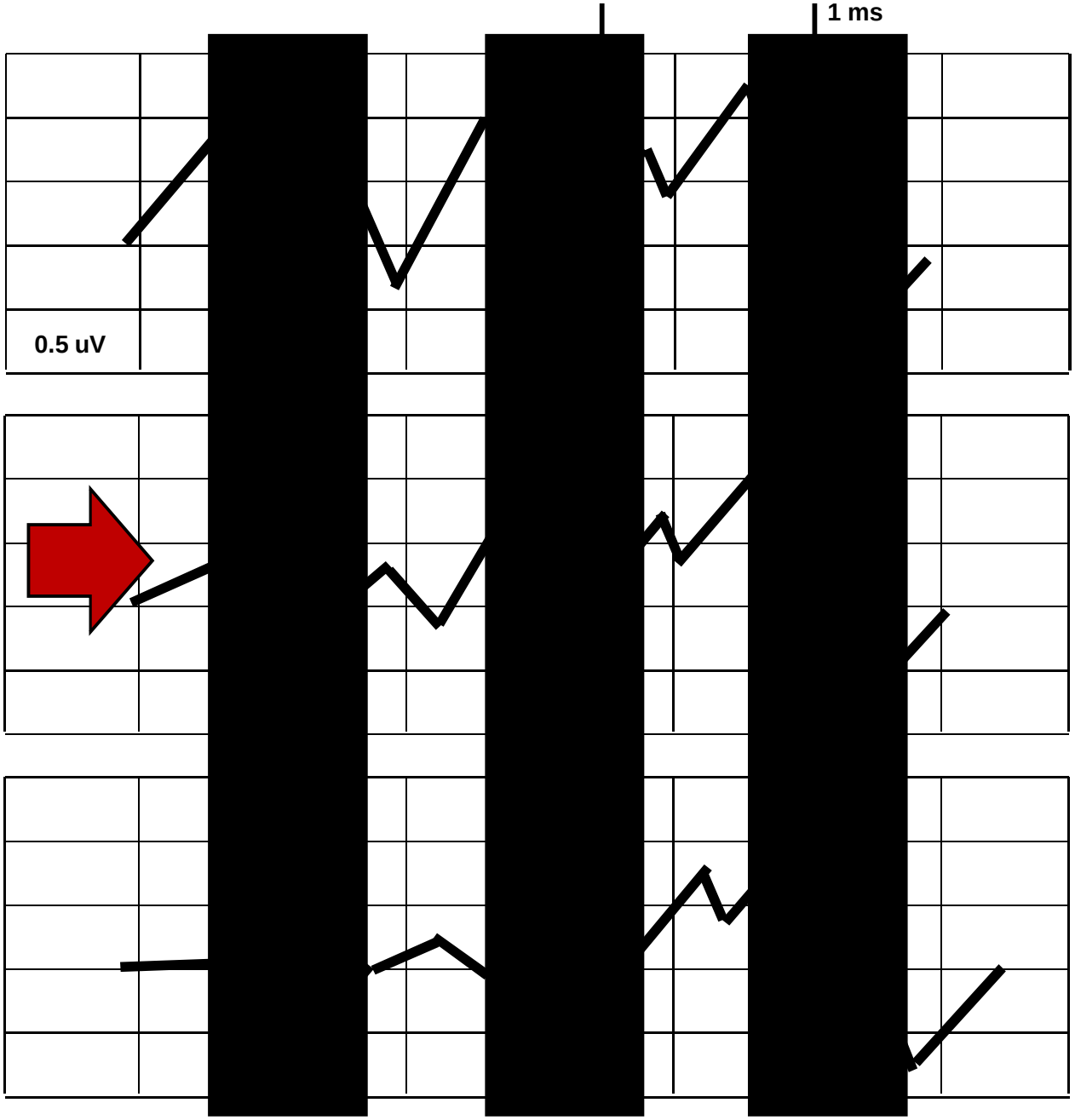


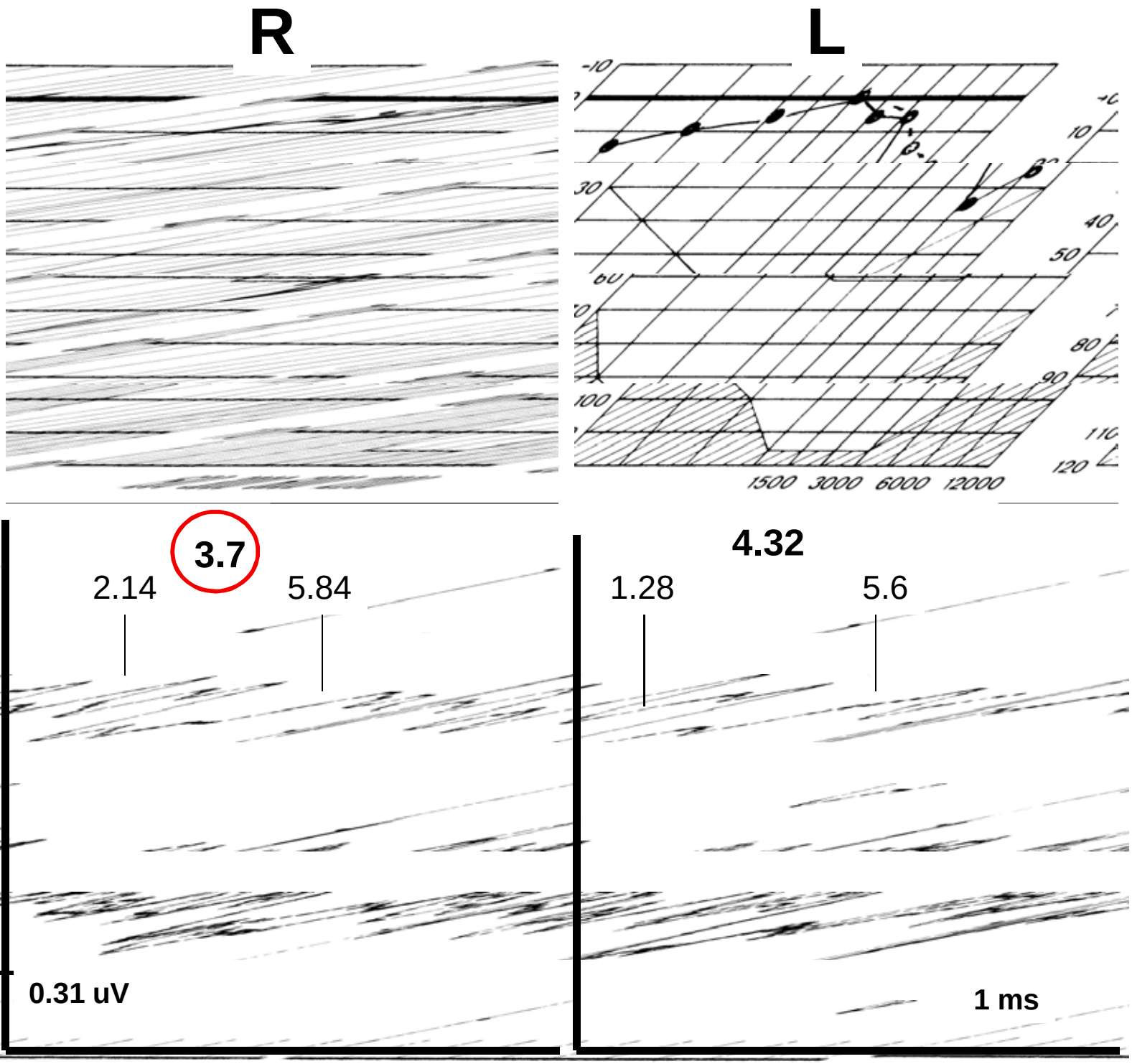
Buchner: [illegible]

normal

delayed I
- normal V
- shortened I-V

delayed I
- delayed V
- shortened I-V





Upper limits

- I-III 2.5 ms
- III-V 2.4 ms
- I-V 4.5 ms

Conductive hearing loss

normal

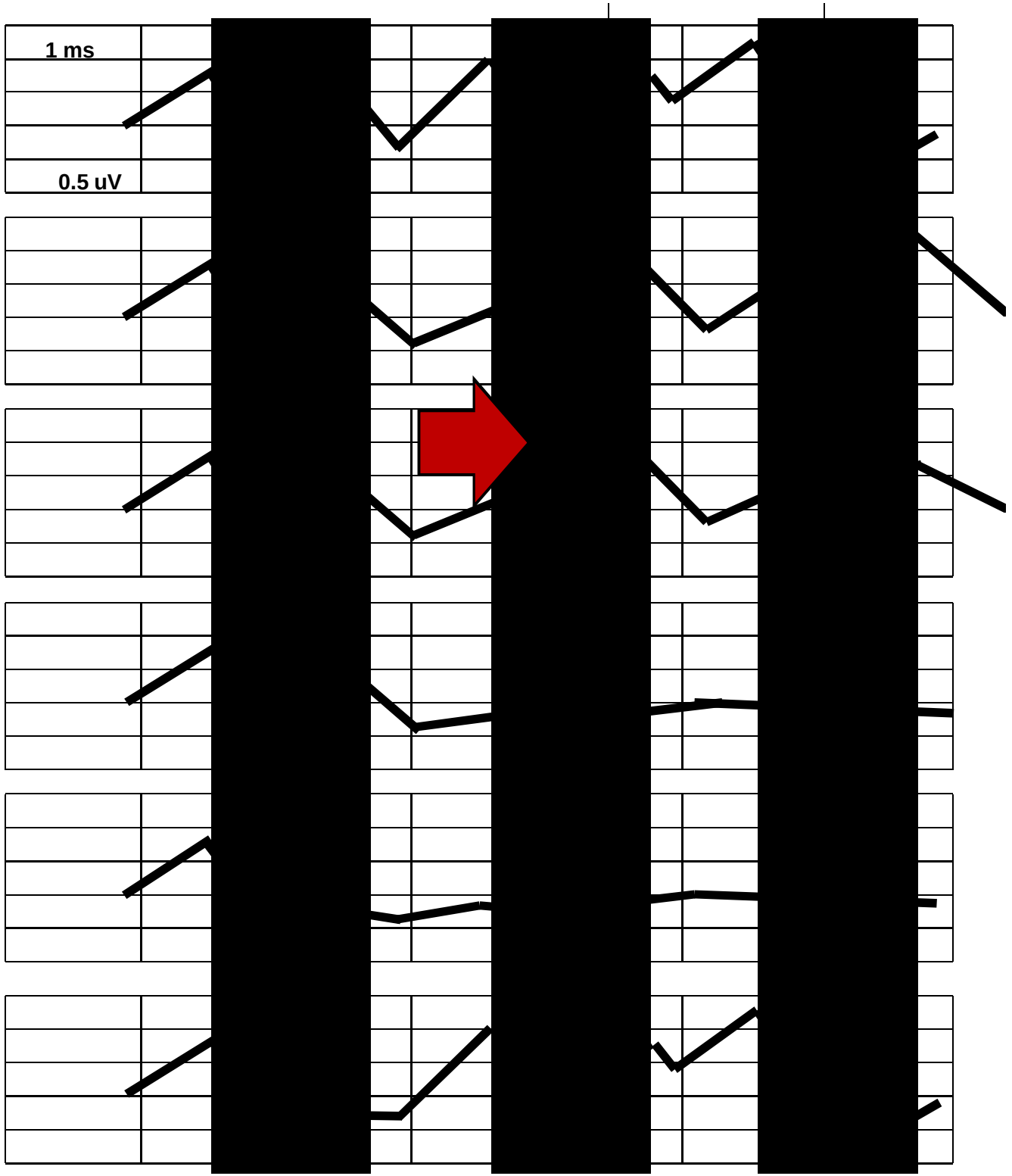
delayed III
prolonged I-III

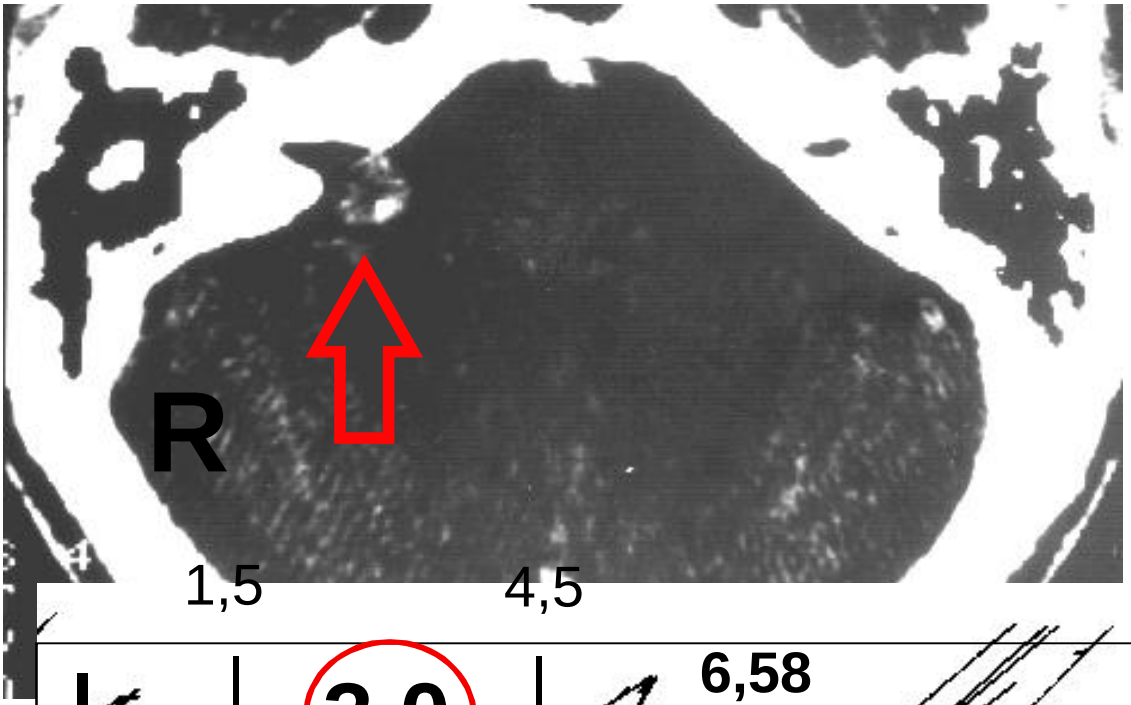
delayed III
prolonged I-III
reduced amplitude V

reduced amplitude III

reduced amplitude II

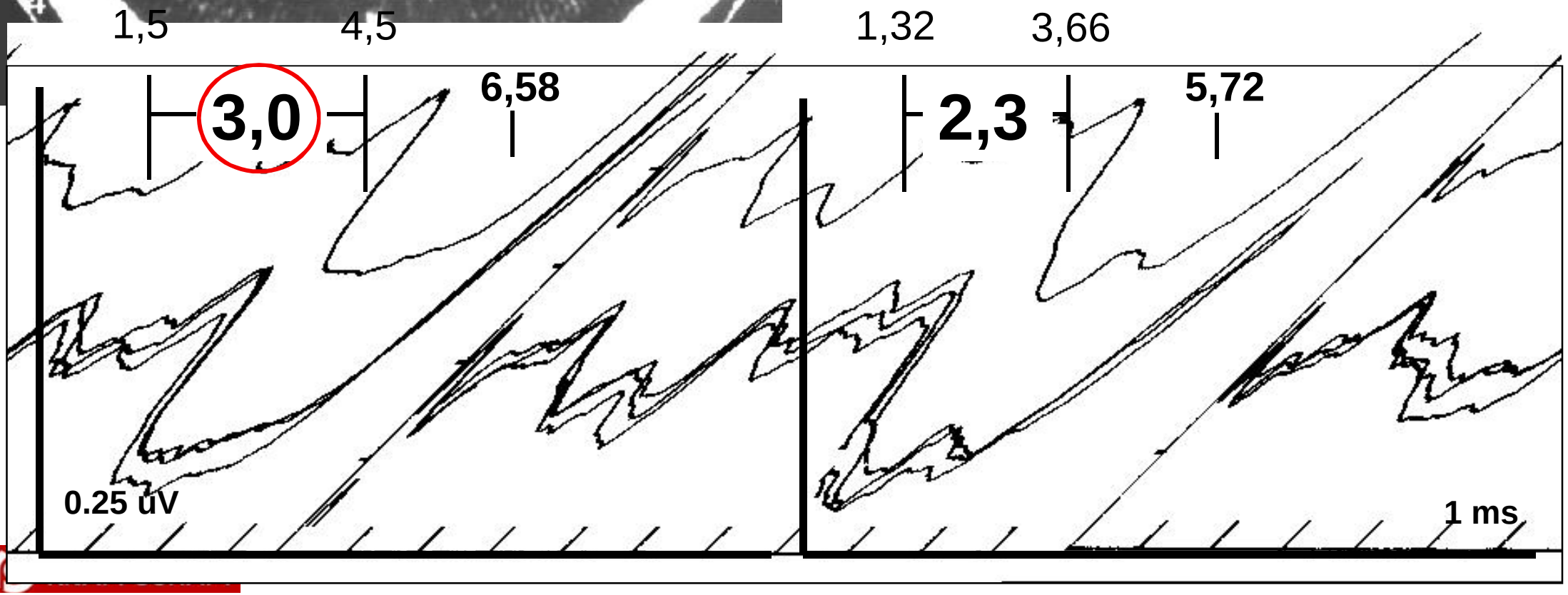
Isolated
loss of II





Upper limits

- I-III 2.5 ms
- III-V 2.4 ms
- I-V 4.5 ms



normal

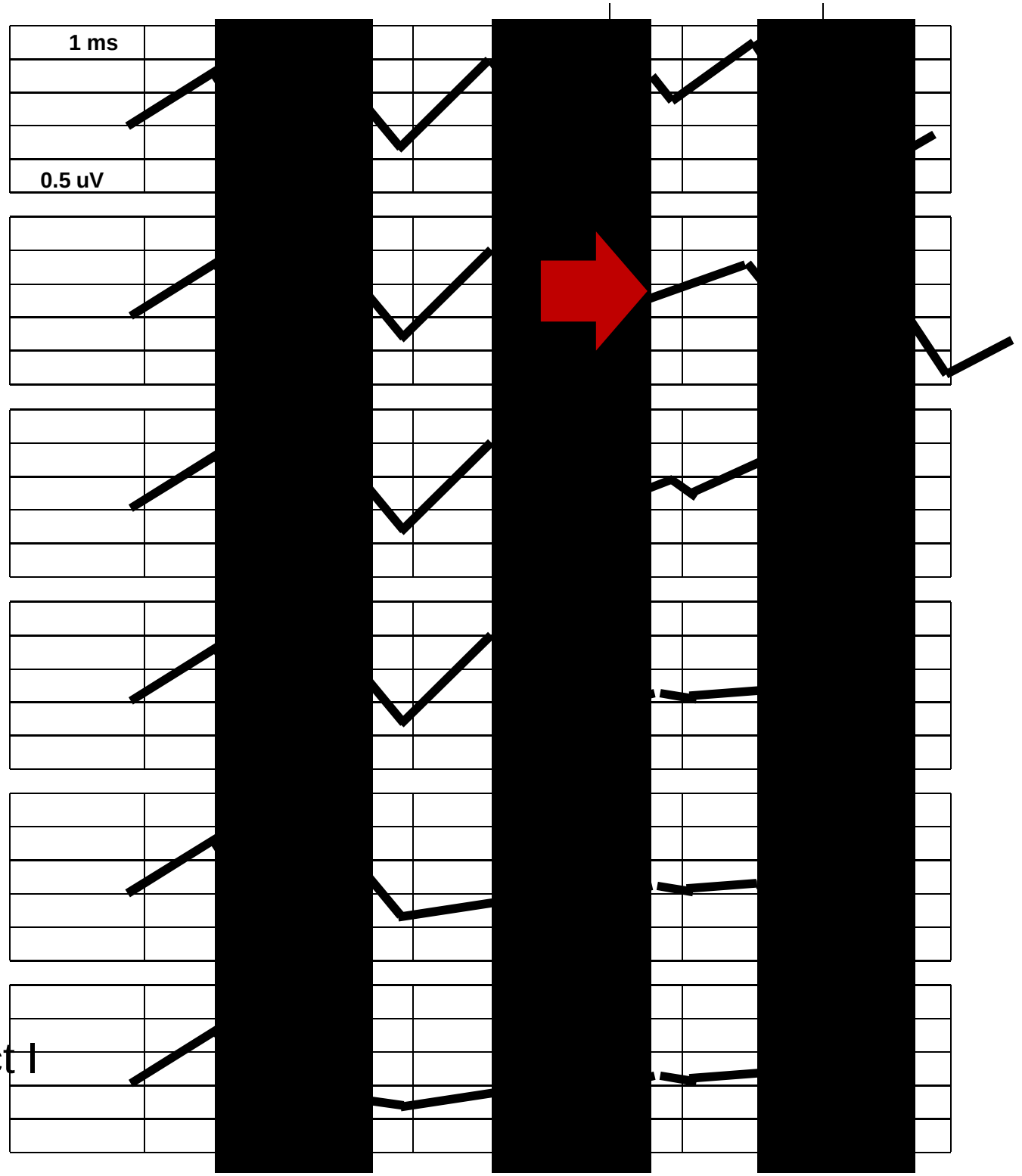
delayed V

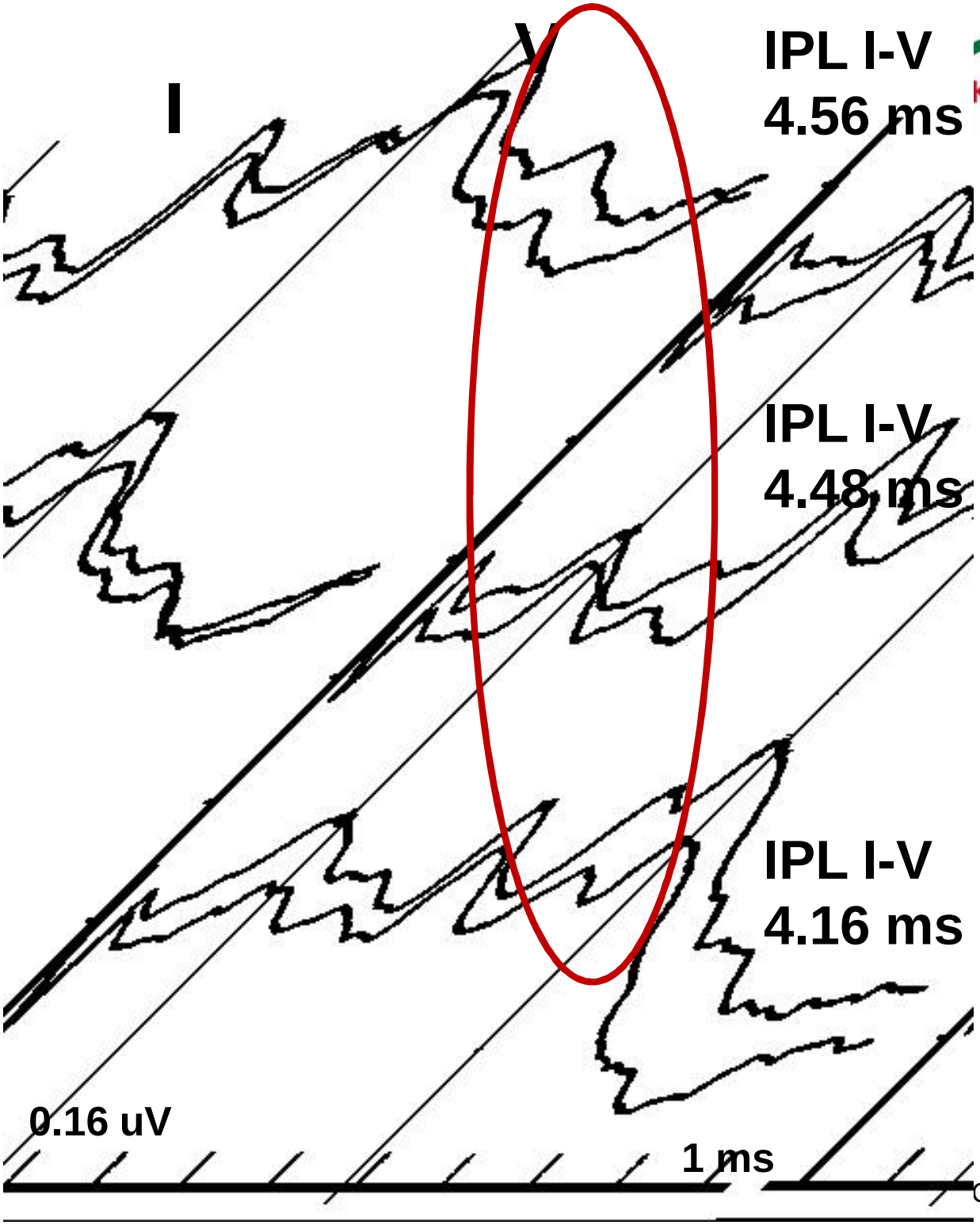
delayed V
reduced amplitude V

loss of IV/V

loss of III and IV/V

loss of all waves expect I



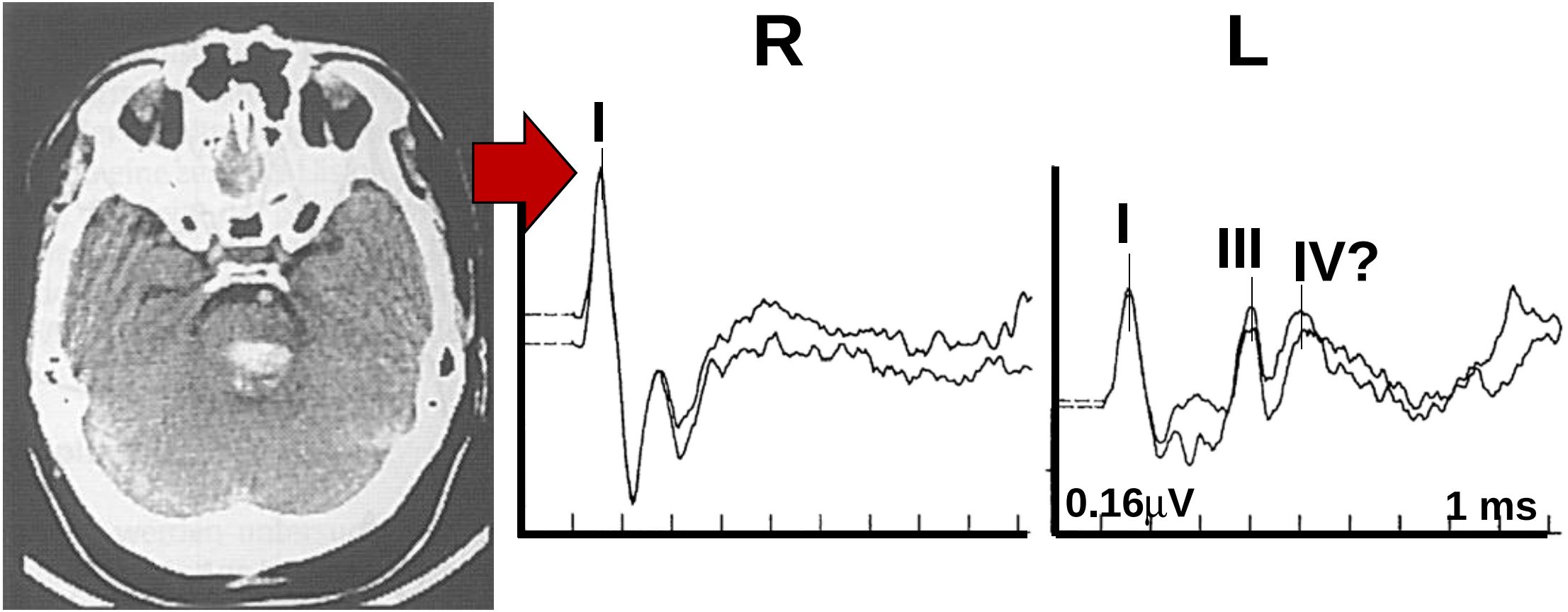


KLINIKUM VEST
QUALITÄT VERBINDET

upper normal limit 4,5 ms

§ Auditory evoked potentials

Klinik für Neurologie
und klinische Neurophysiologie

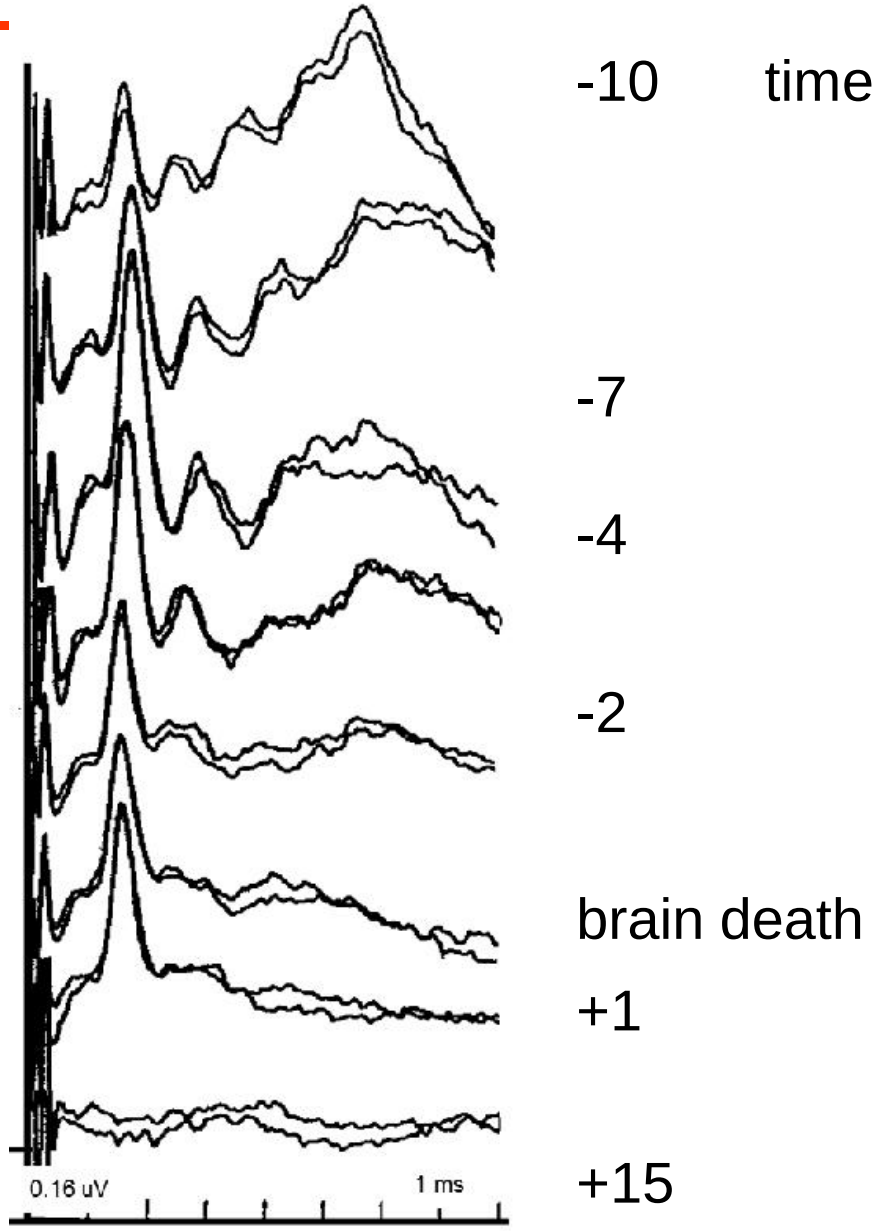


brain death

validity

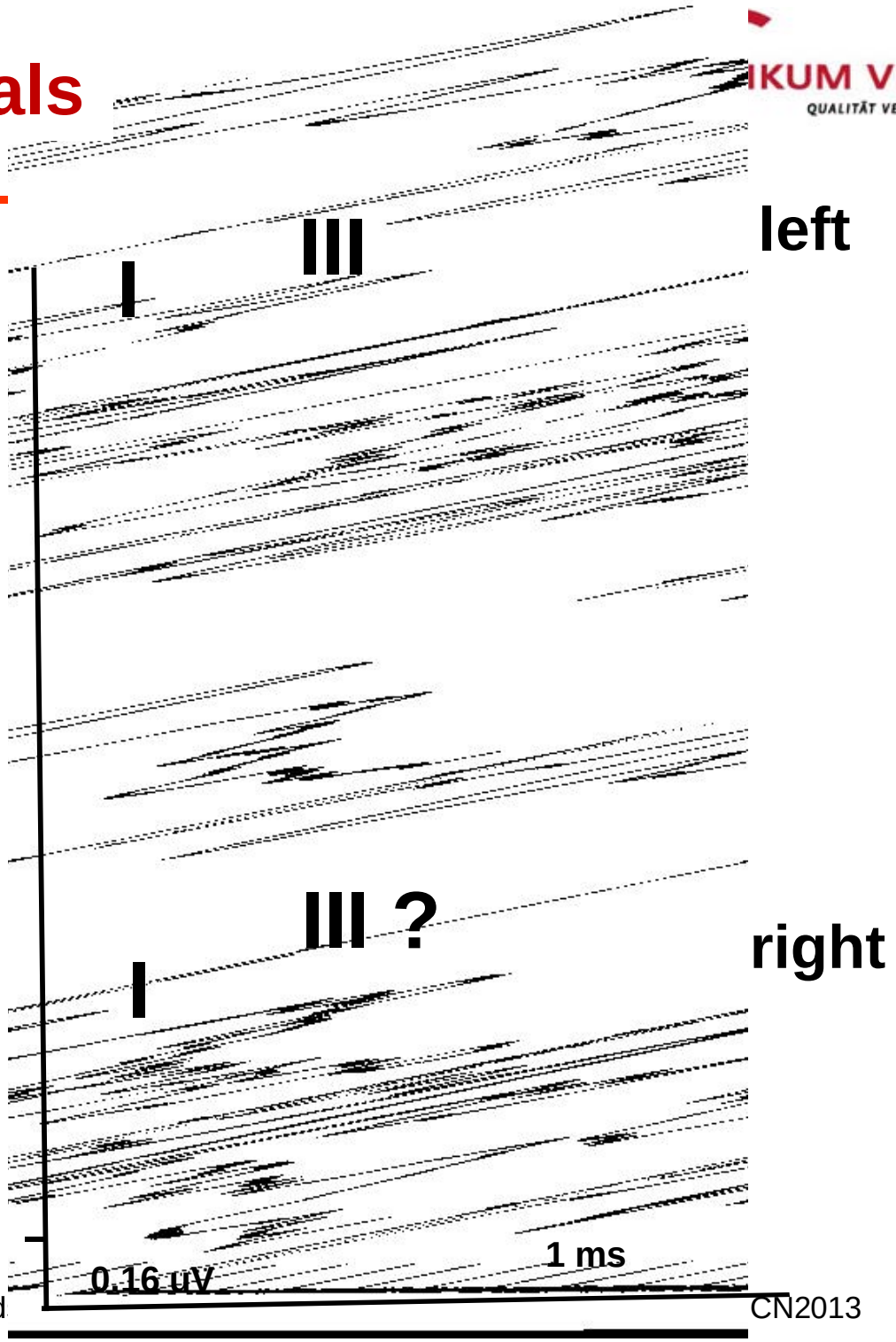
130 HT from examination
6 (4,6%) with preserved waves III or IV/V

Facco et al. 2002 Clin Neurophysiol



§ Auditory evoked potentials

Multiple sclerosis



§ Auditory evoked potentials

§ Clinical applications and advanced use

Ø Hard rocks

retrocochlear hearing impairment
posterior fossa tumors
MS - diagnosis
Prognosis in coma

Ø Soft rocks

brain death
intoxication
peripheral hearing loss

Ø The beach

dizziness
MS - history
diagnosis of ischemic brainstem lesions

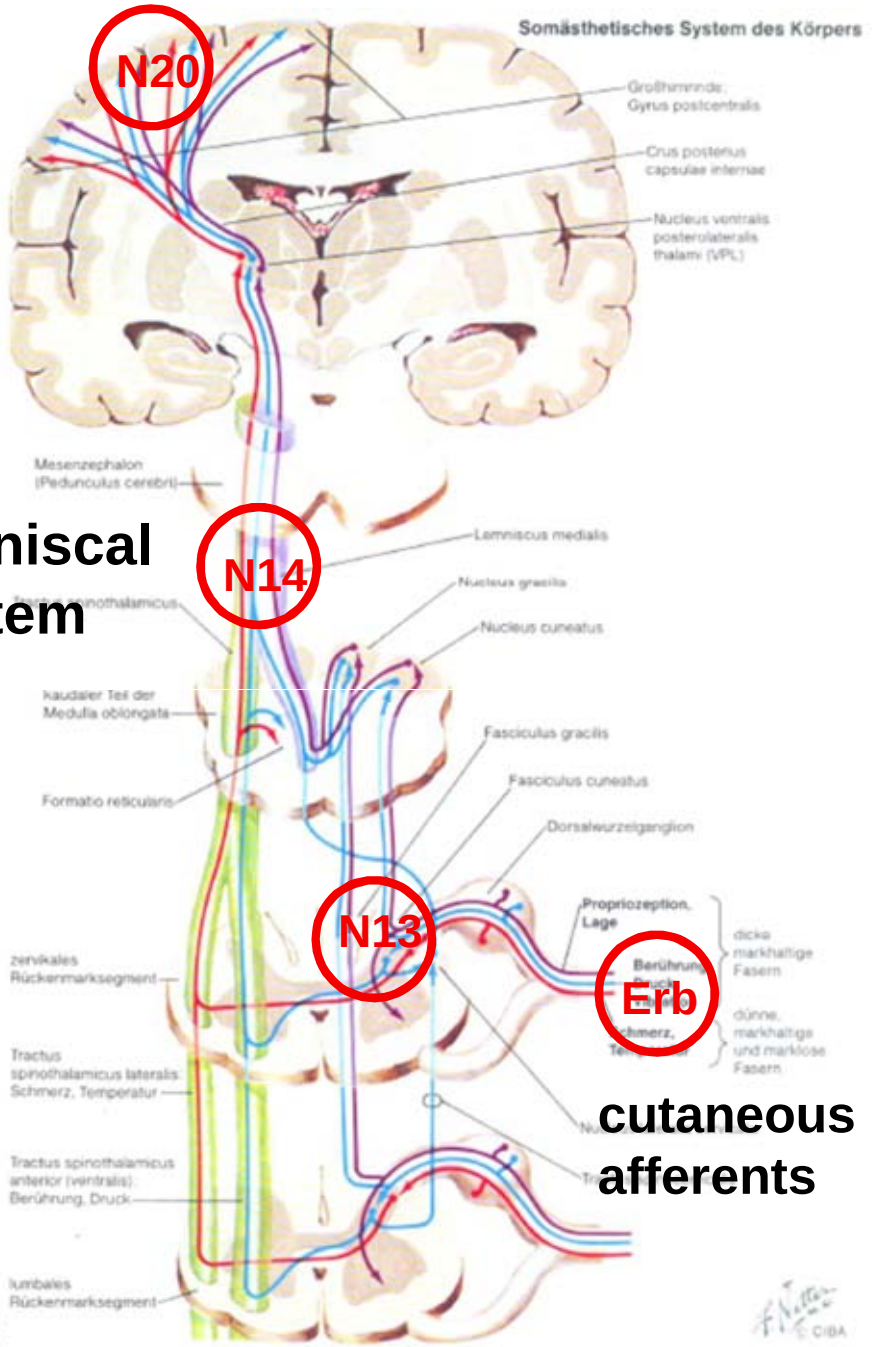
subjective opinion and incomplete list

With compliments to D. J. Jewett Berlin conference 1986

§ Somatosensory evoked potentials

§ Anatomy and physiology of the system

- Stimulus
- Recommended standard protocols and sources of errors
- Clinical applications and advanced use

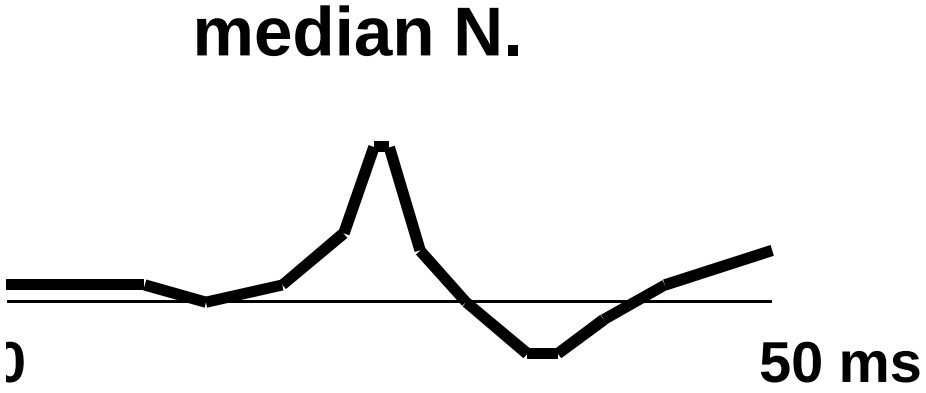


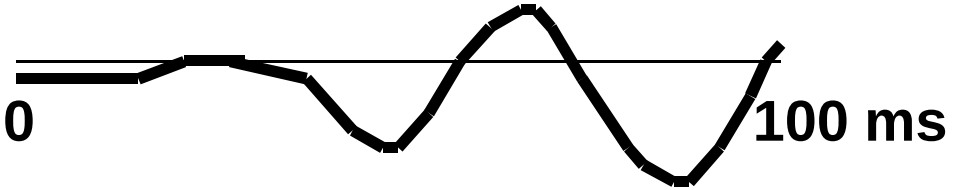
§ Somatosensory evoked potentials

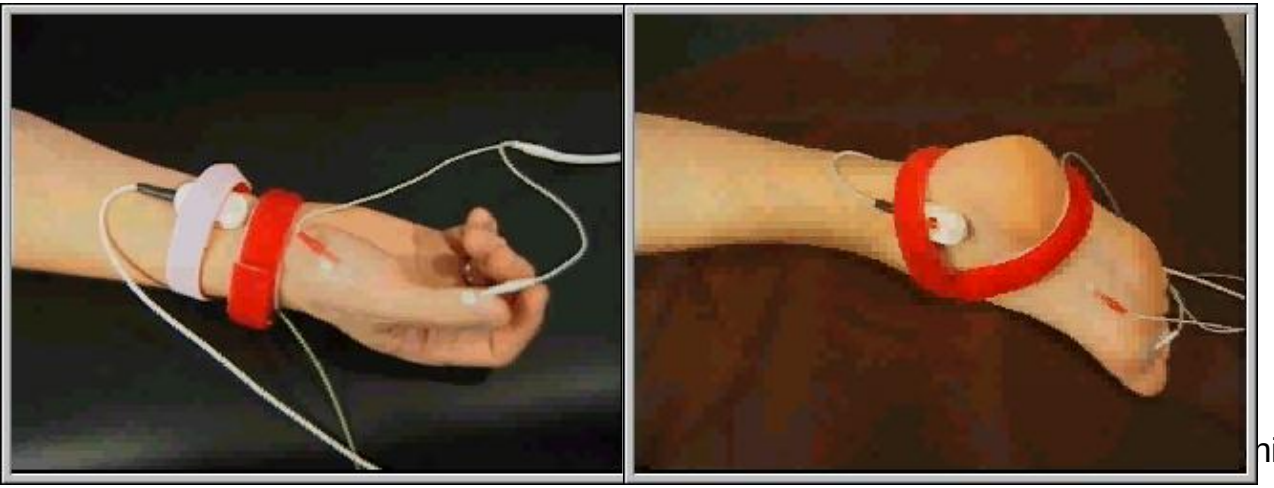
§ Stimulus
- Recommended standard protocols and sources of errors
- Clinical applications an advanced use

Stimulus parameter

- constant current; duration 0,2 ms
- cathode proximal
- 1 - 10 /sec; 4,3 /sec
- **intensity above motor threshold**



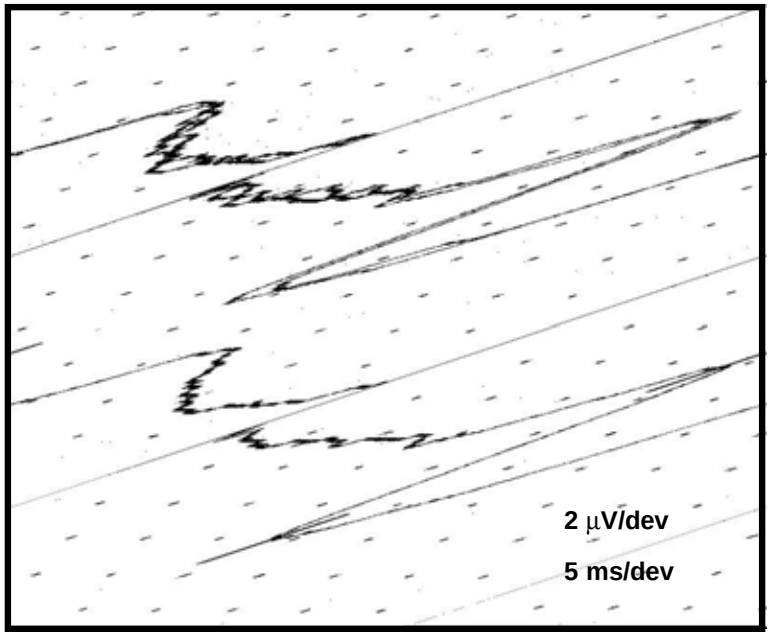


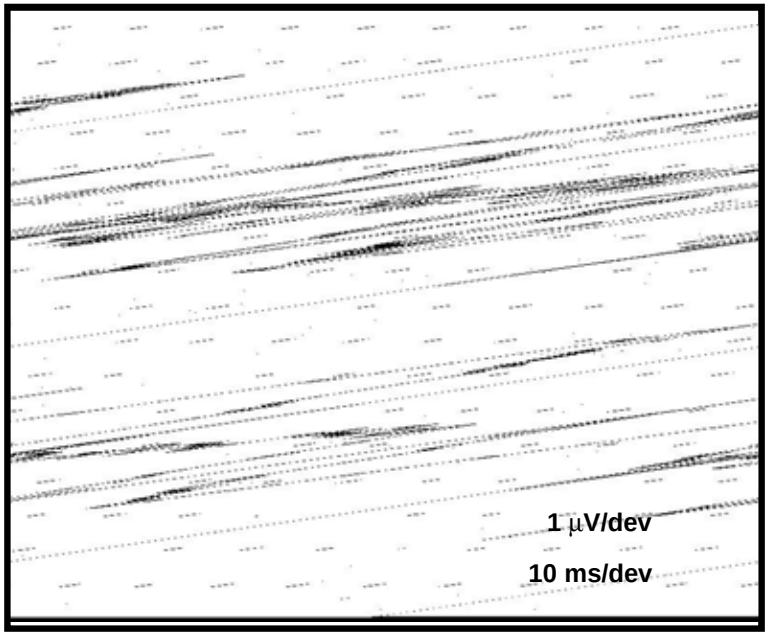


§ Somatosensory evoked potentials

§ quality control

- § two measurements
- § Reproduction with:
- § Latencies
  - § Arm nerves below 0.25 ms
  - § Leg nerves below 0.5 ms
- § Amplitudes of + / - 20%



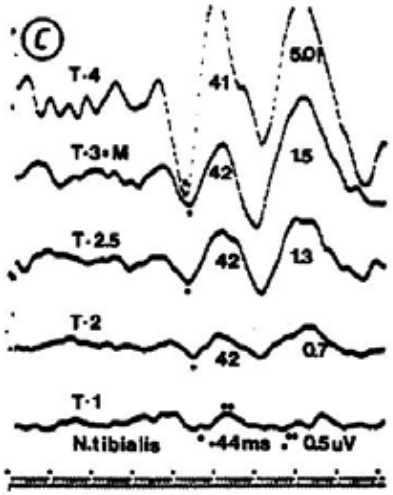


§ Somatosensory evoked potentials

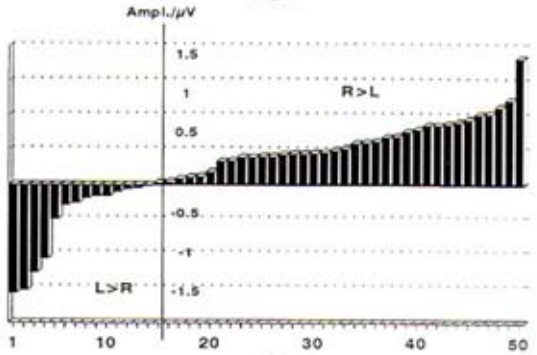
§ sources of errors

- body temperature
- body size
- muscle artifacts

Stimulus intensity



Electrode placement



Vogel et. al. J Neurol 1982, 228,97-111

Buchner et al. Electromyogr. Clin. Neurophysiol. 1995, 35, 207-215

Factors

§ Height

parallel with body size - but only very small effects on
N. median N9-N20 and N. tibial N22-P40
1.50 to 1.90 cm

§ Temperature

in parallel with the conduction time of the peripheral nerves

§ Gender

Women shorter latencies

§ Drugs

little to no effect - only when intoxication prolonged N13-N20

§ Sleep – attention

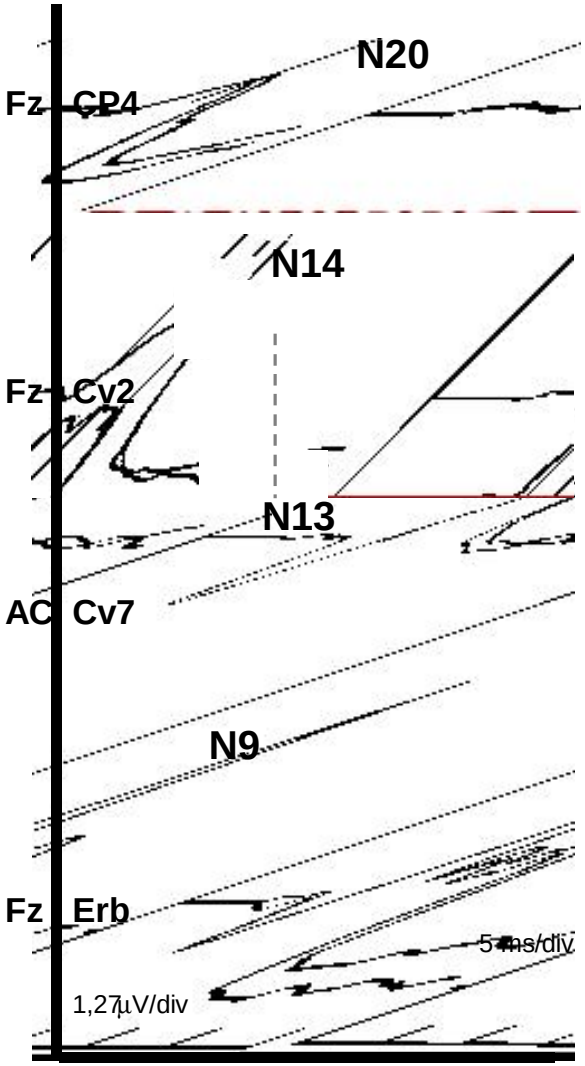
no effects

§ Age

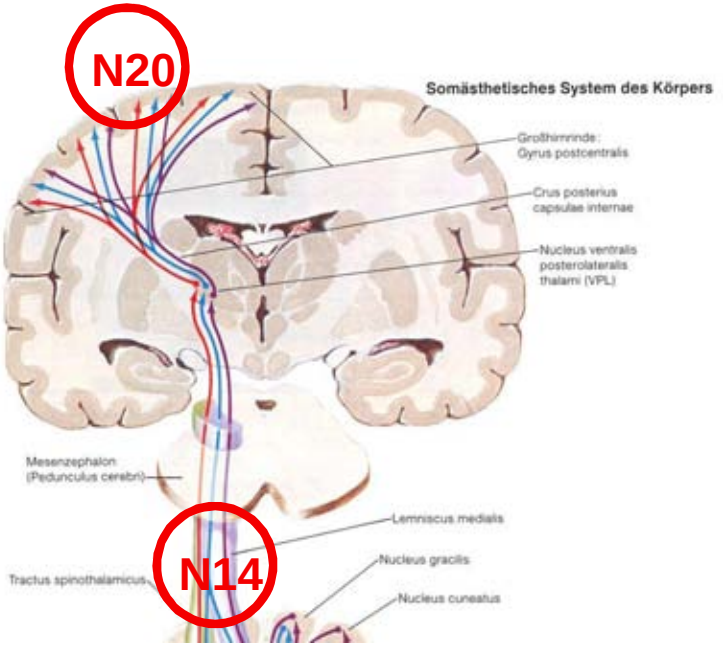
Tendency to higher amplitudes and longer latencies

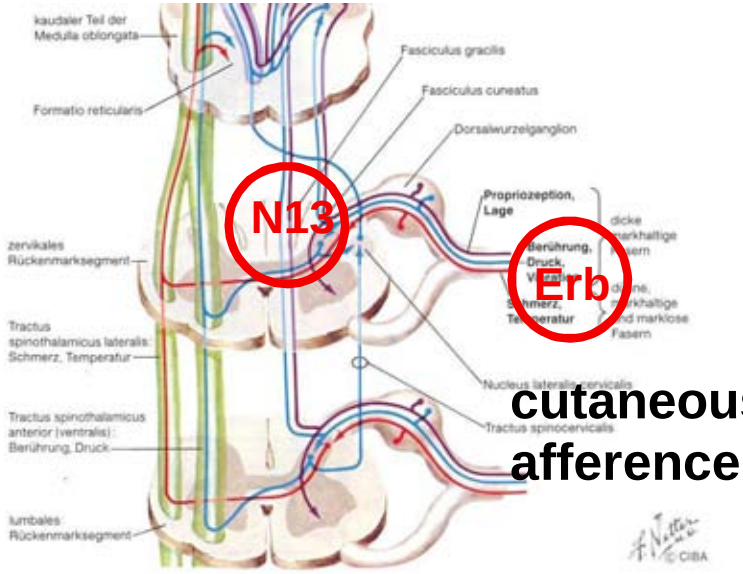
§ Somatosensory evoked potentials

§ Median nerve



lemniscal system





cutaneous afference

§ Normal values N. medianus

Latency

	mean	+ 3 SD	re - li
N9	9.8	11.5	-
N13	10.1	14.5	-
N14	14.3	16.7	0.8
N20	19.8	23.0	1.4
N9-N13	3.5	4.5	1.3
N13-N20	5.7	7.2	1.0
N14-N20	4.6	6.0	1.1

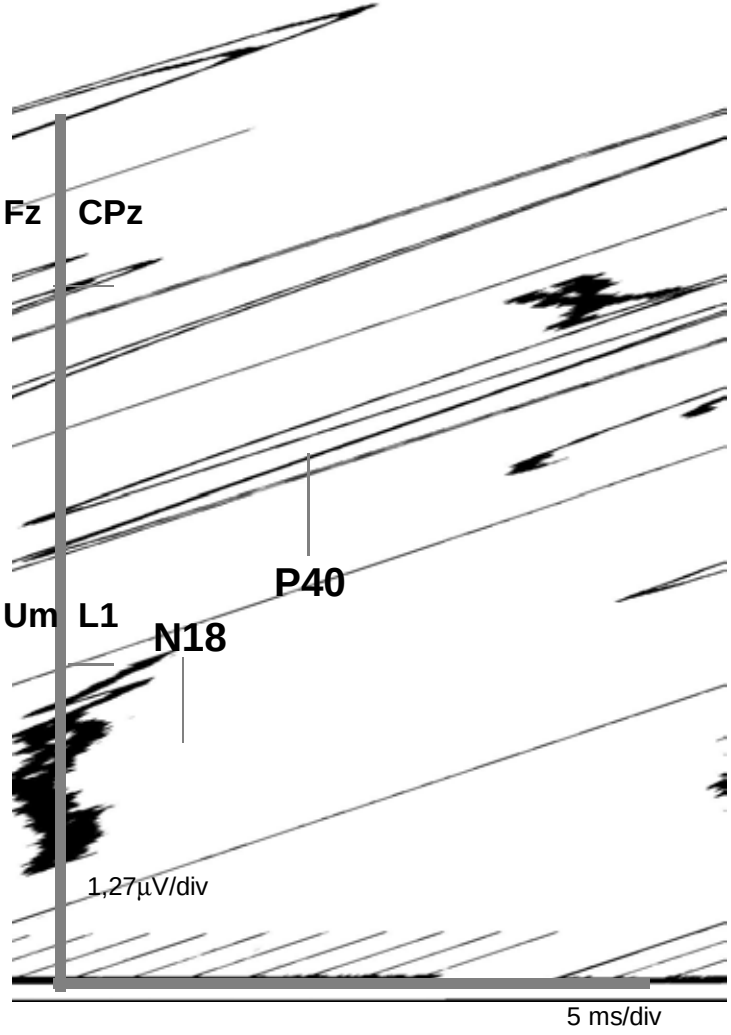
Amplitude

	mean	lower limit	re-li
N9 (baseline to peak)	4.8	1.0	50%
N13 (baseline to peak)	2.3	0.5	-
N20 (baseline to peak)	2.2	0.6	47%
N20-P25 (peak to peak)	3.2	0.8	-

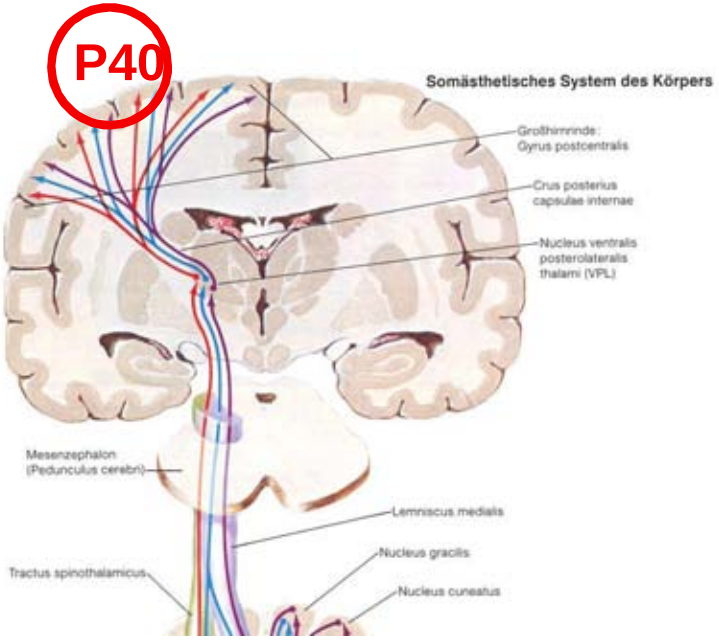
Mauguière et al. (1999) Electroenceph. clin. Neurophysiol. supp. 52 79-90

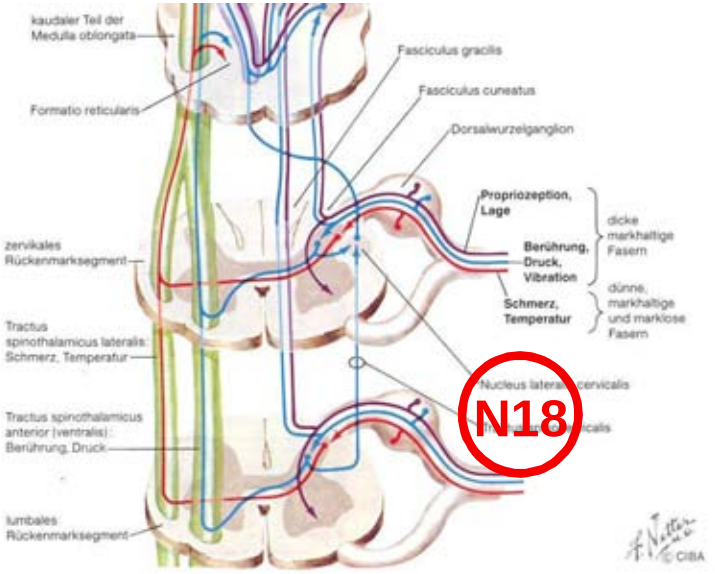
§ Somatosensory evoked potentials

§ Tibial nerve



Lemniscal plus extra-lemniscal





§ Normal values N. tibialis

Latency			
	mean	+ 3 SD	re - li
N22	21.8	25.2	1.1
P40	38.0	43.9	2.1
N22-P40	16.0	20.6	2.1

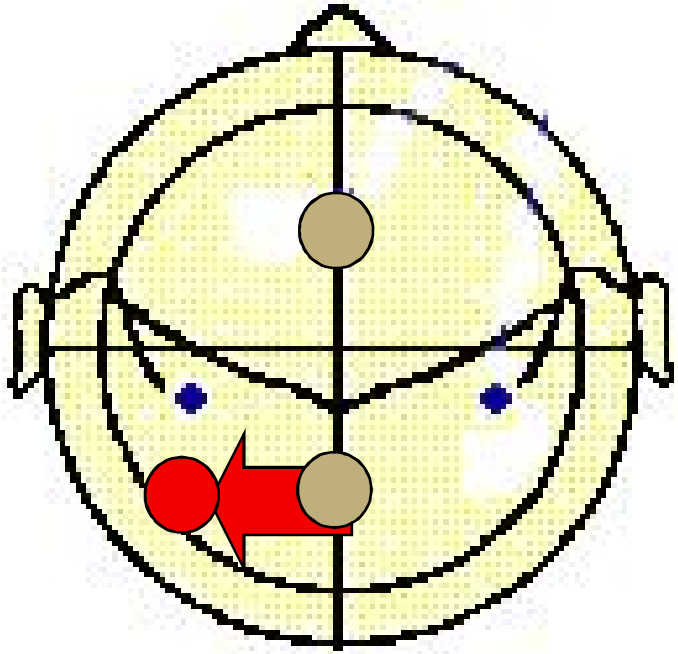
Amplitude			
	mean	lower limit	re-li
N22 (baseline to peak)	1.1	0.3	-
P40-N50 (peak to peak)	1.8	0.5	-

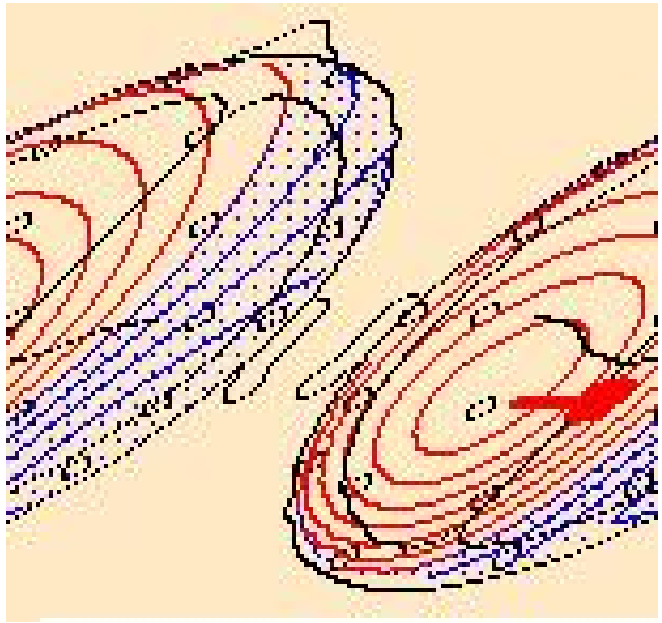
Mauguière et al. (1999) Electroenceph. clin. Neurophysiol. supp. 52 79-90

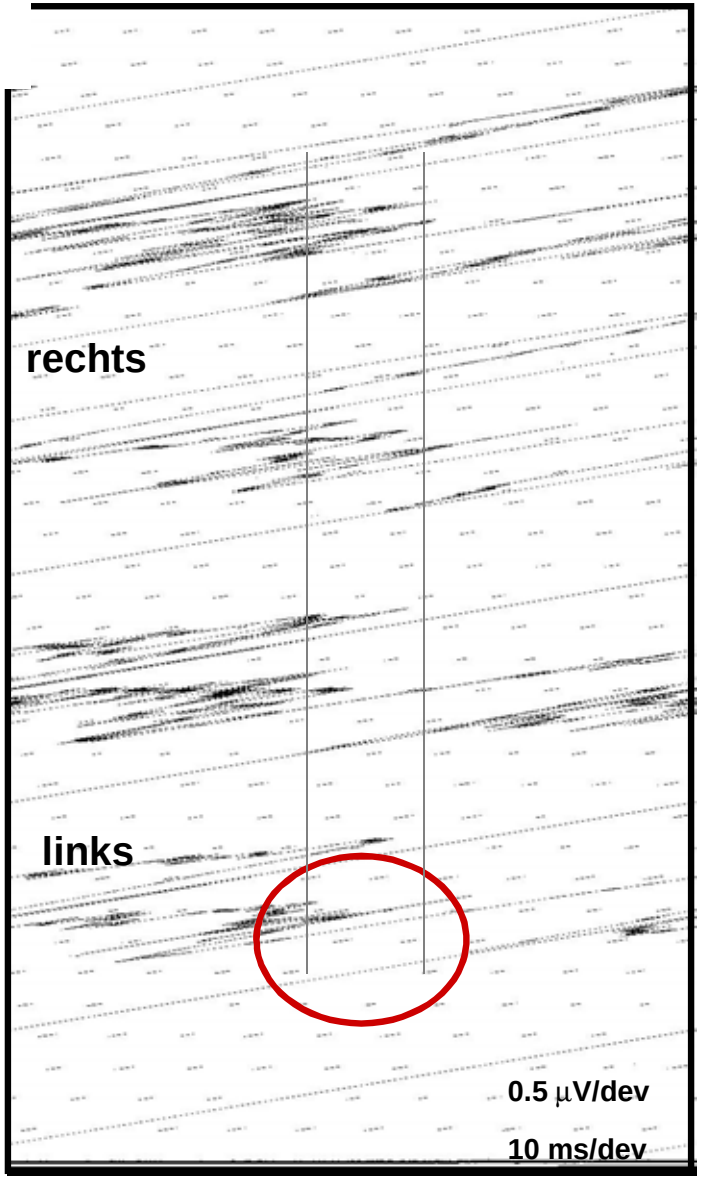
§ Somatosensory evoked potentials

§ Tibial nerve

– paradoxical lateralization of P40







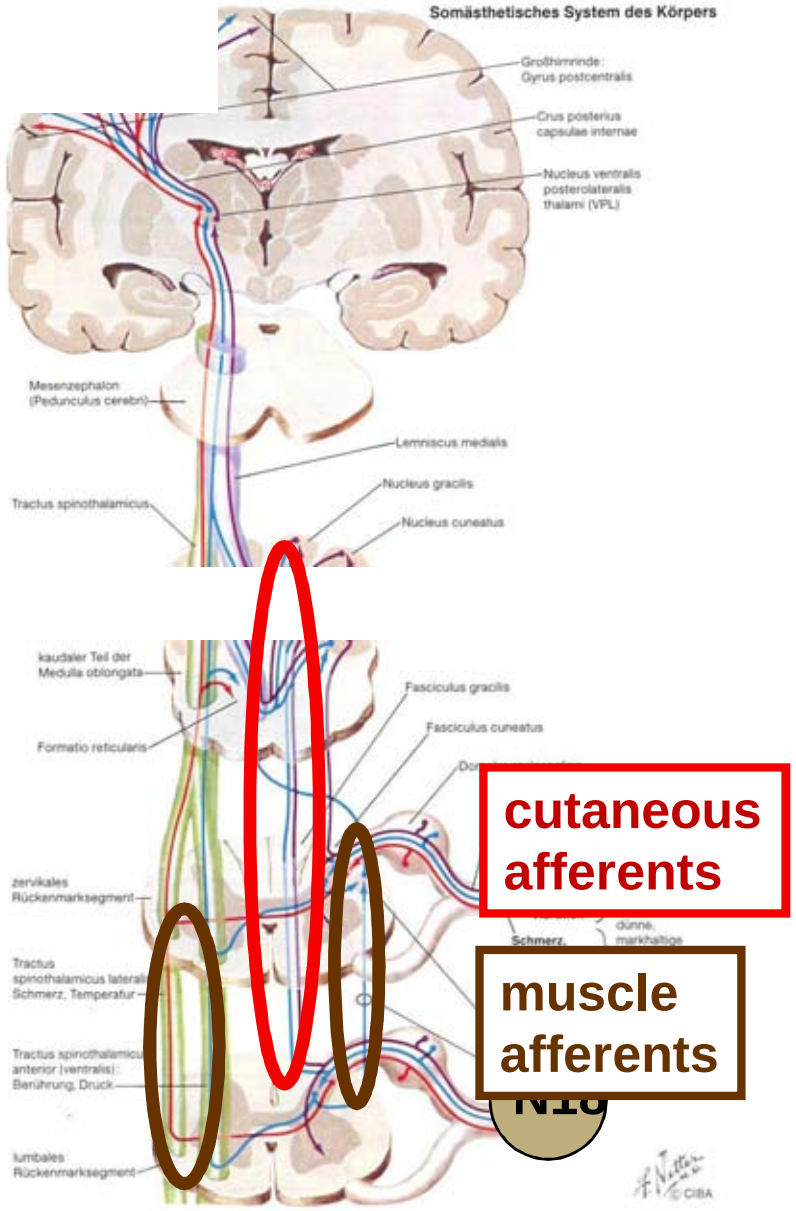
§ Somatosensory evoked potentials

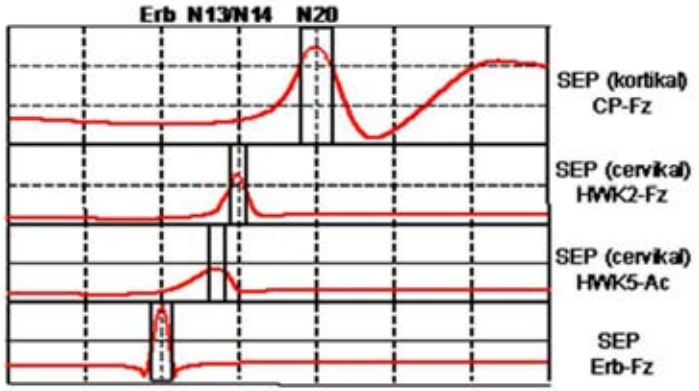
§ Tibial vs. Sural nerve

- Spinal pathway
  - **Tibial nerve**

    muscle afferents and tractus spino-cervicalis and / or frontal column
  - **Sural nerve**

    Cutaneous afferents and dorsal column





Zervikale
extramedulläre Läsion
N9-N13/N14 verzögert
N20 normal oder verzögert/erniedrigt

Zervikale
intratramedulläre Läsion
N13 ausgefallen

Medulla oblongata Läsion
Ausfall ab N14

Pontine Läsion
Normal bis N14
amplitudengeminderte / Ausfall N20

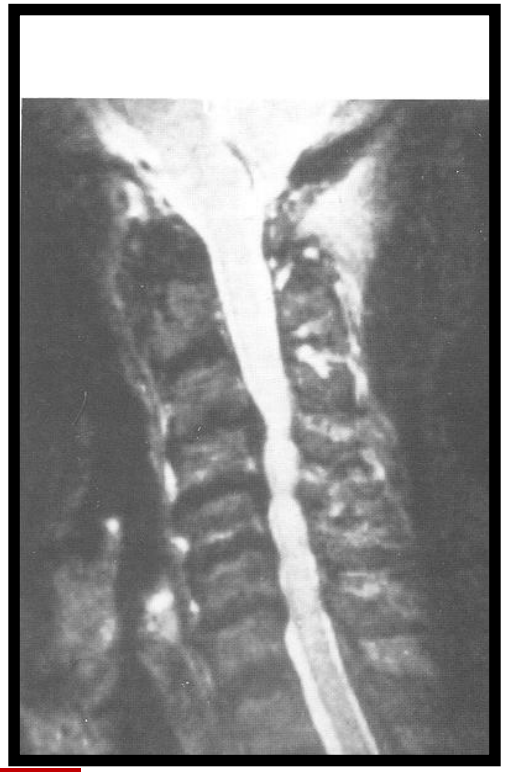
10ms

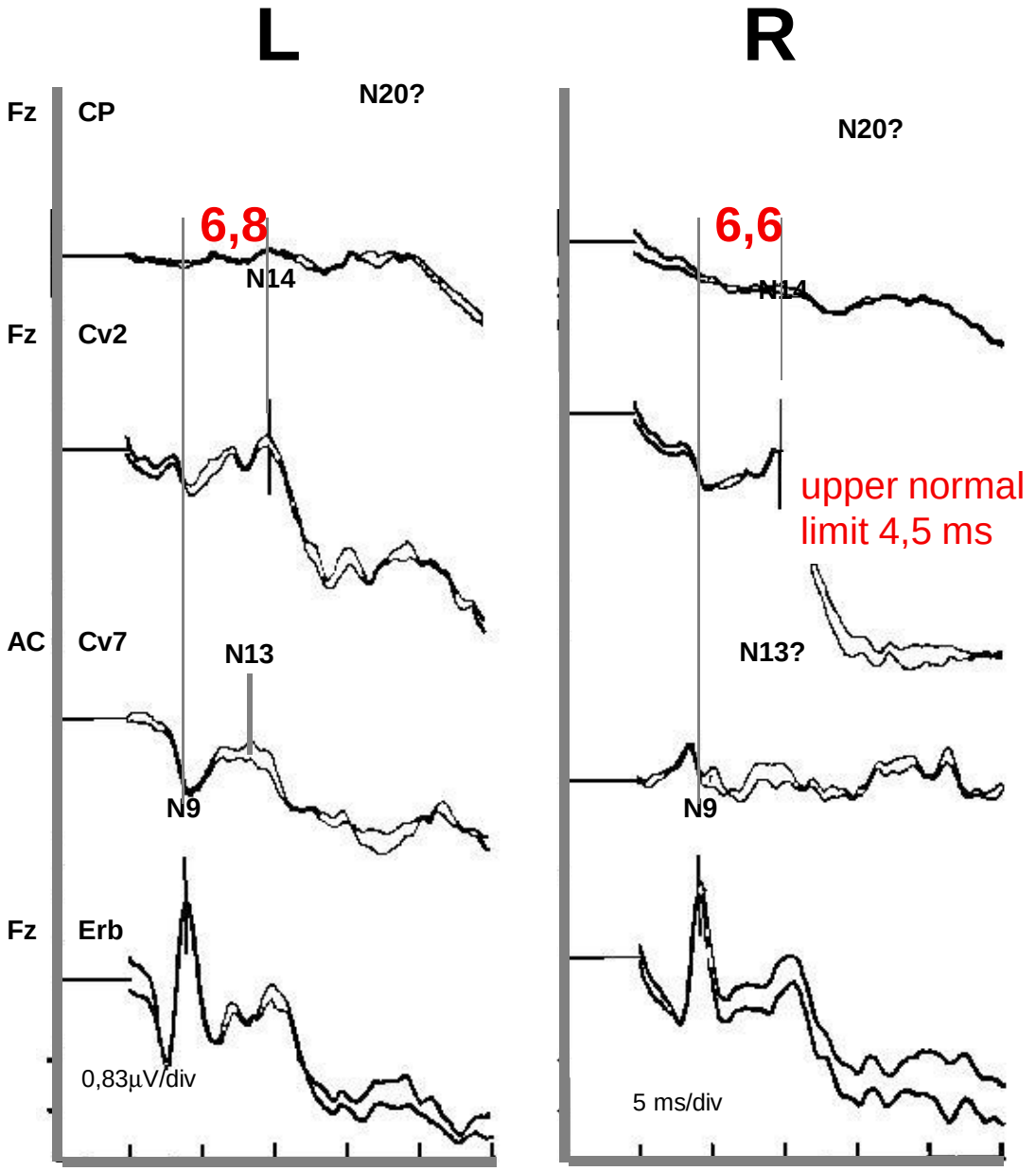
§ Somatosensory evoked potentials

cervical

extra medullary Lesion

- **prolonged N9-N14**



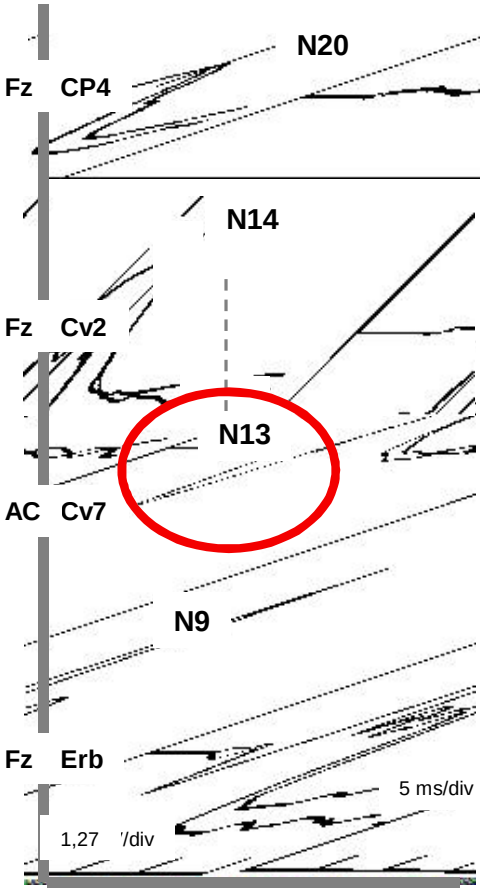


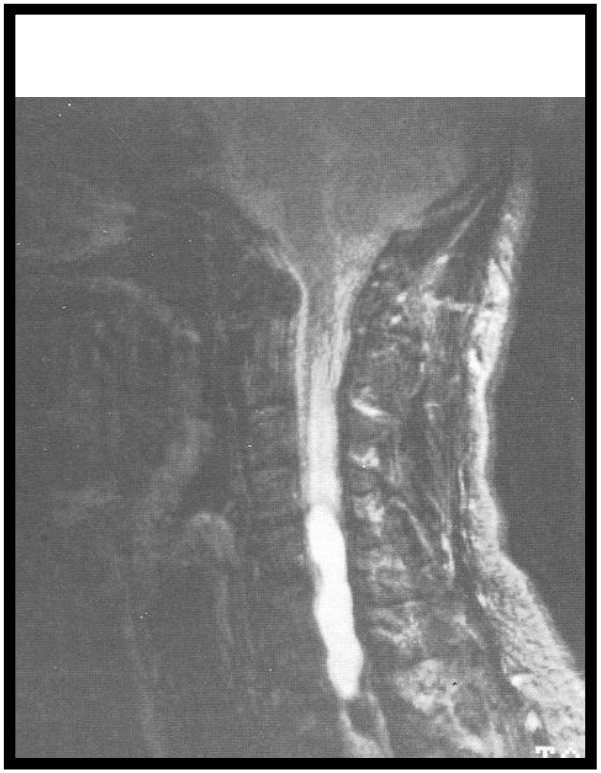
§ Somatosensory evoked potentials

cervical

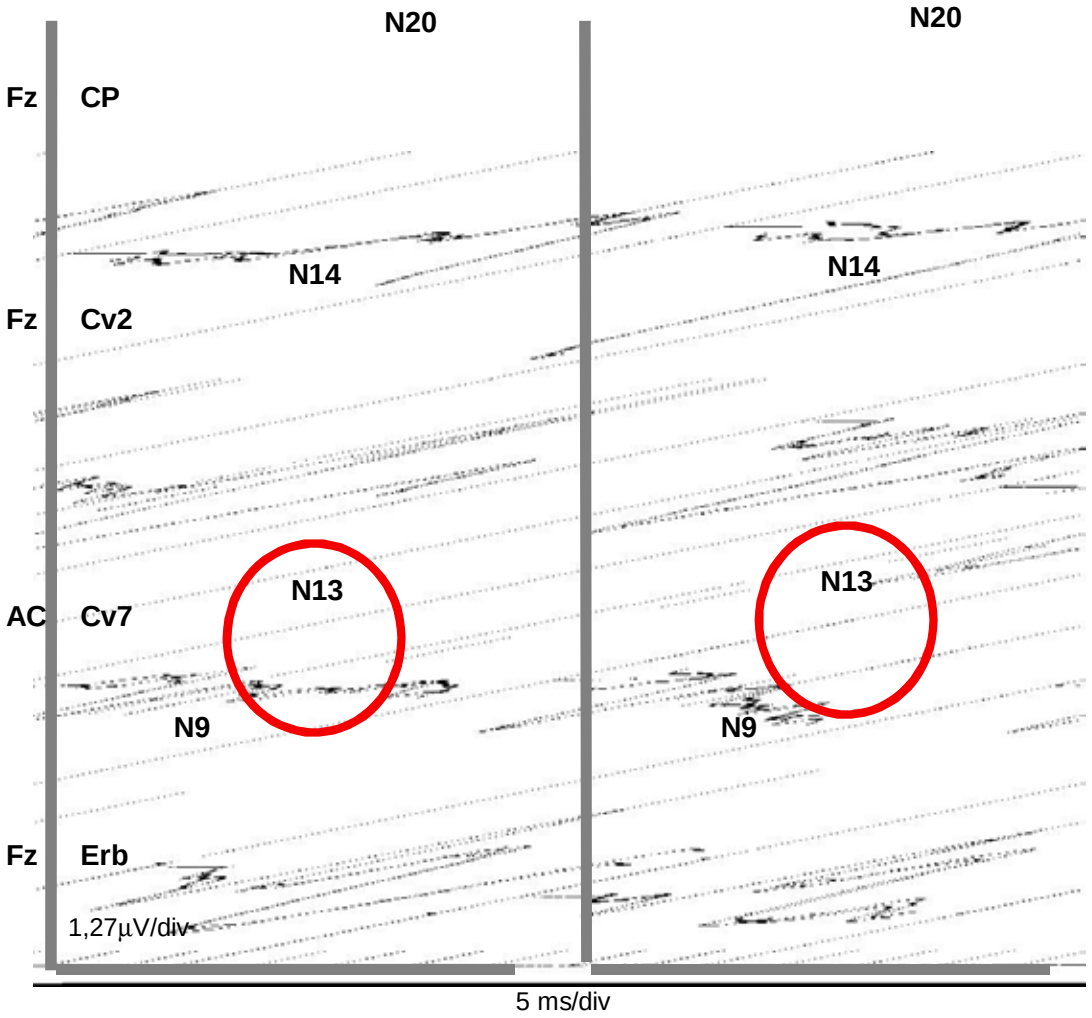
Intra medullary Lesion

- **loss of N13**





L **R**

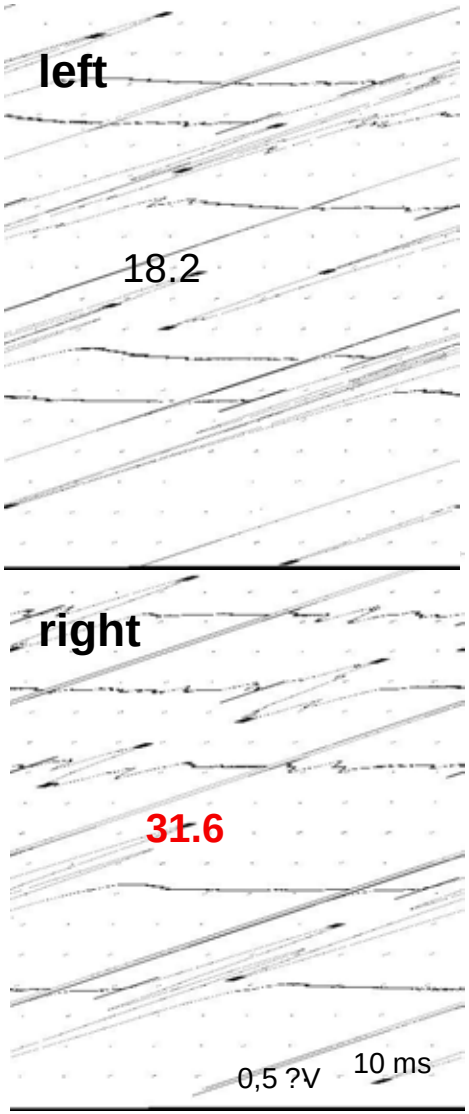


§ Somatosensory evoked potentials

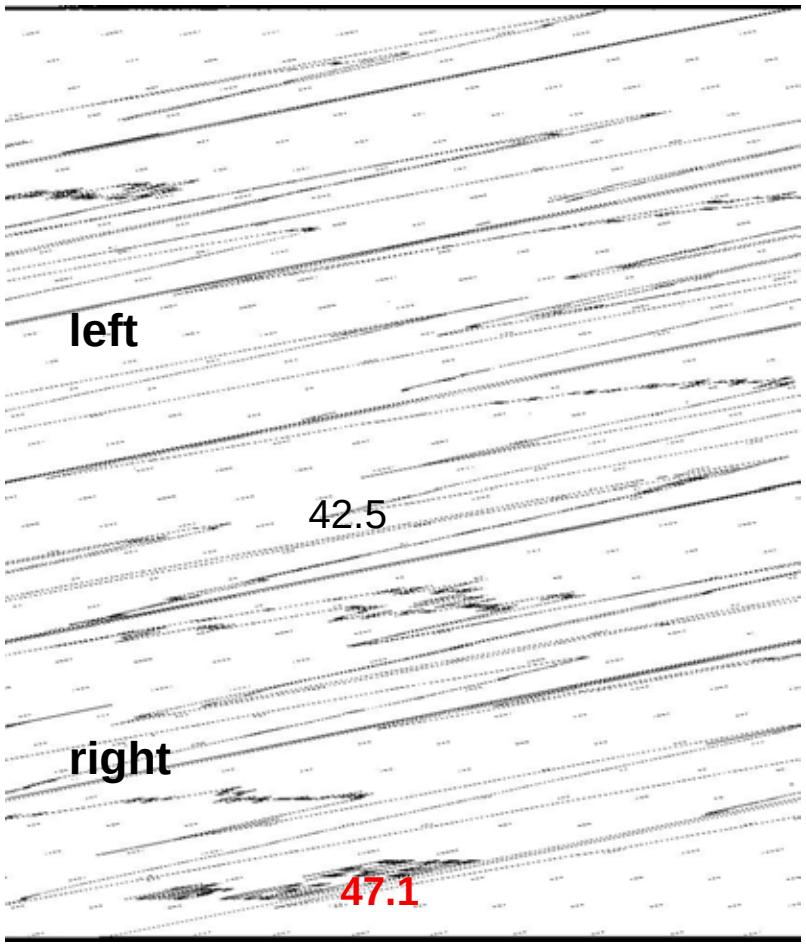
urologie
e Neurophysiologie

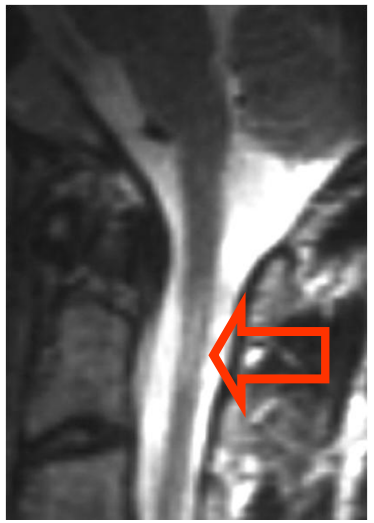
KLINIKUM VEST
QUALITÄT VERBINDET

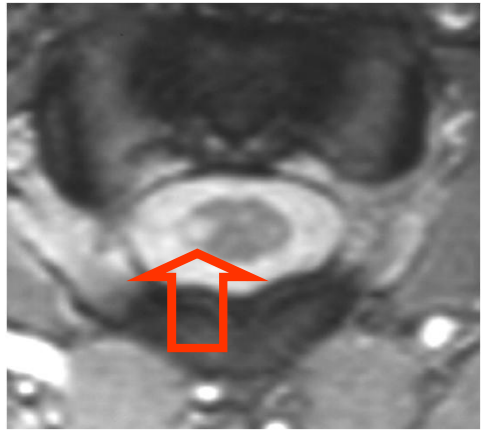
MEP



SEP







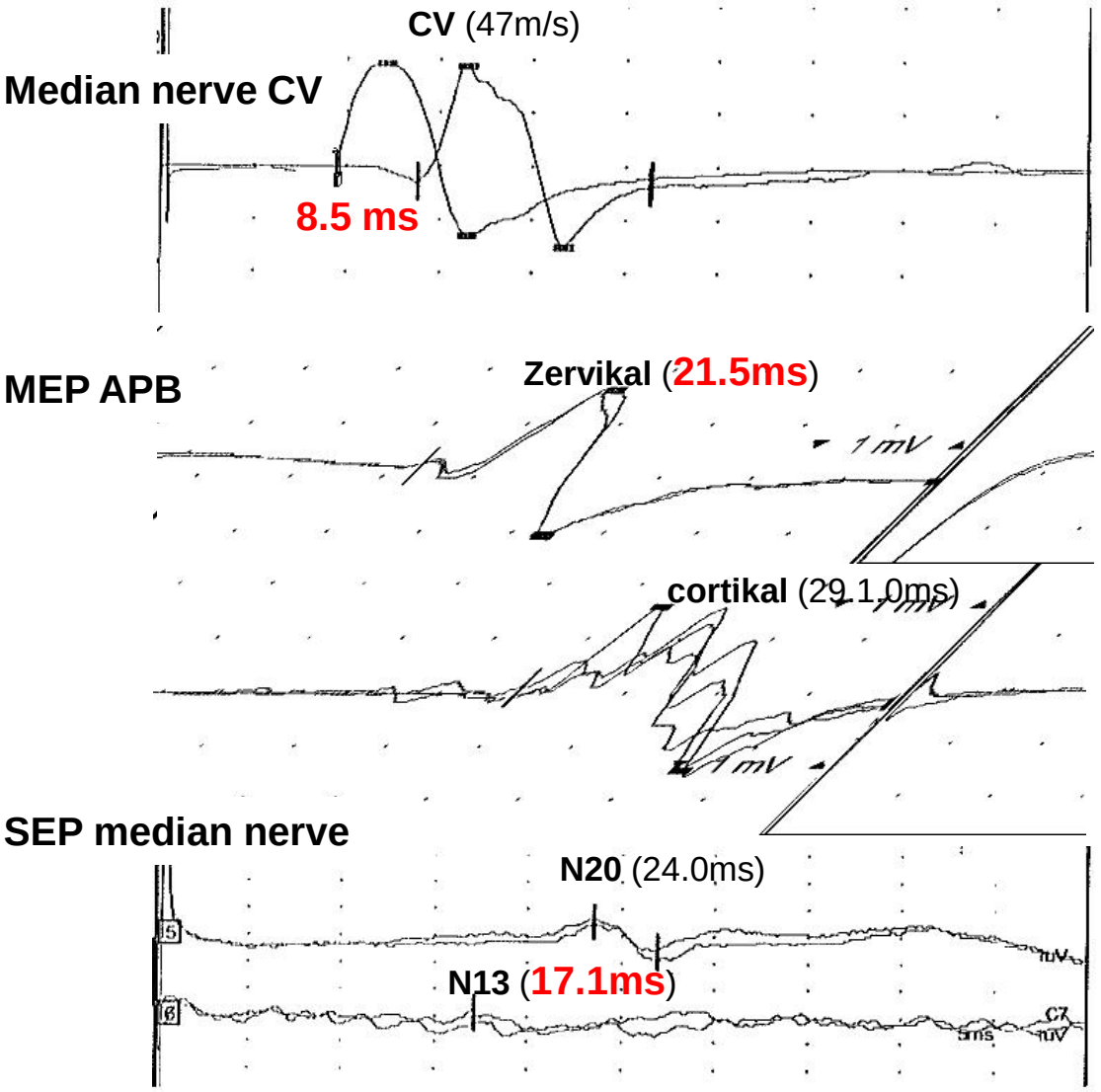
§ Somatosensory evoked potentials

- peripheral nerve lesions
  proximal neuropathies

HNPP

Heriditary neuropathy with liabiltity to pressure palsies
17p11.2-p12 deletion

Prominent slowing of
distal and proximal and motor
conduction

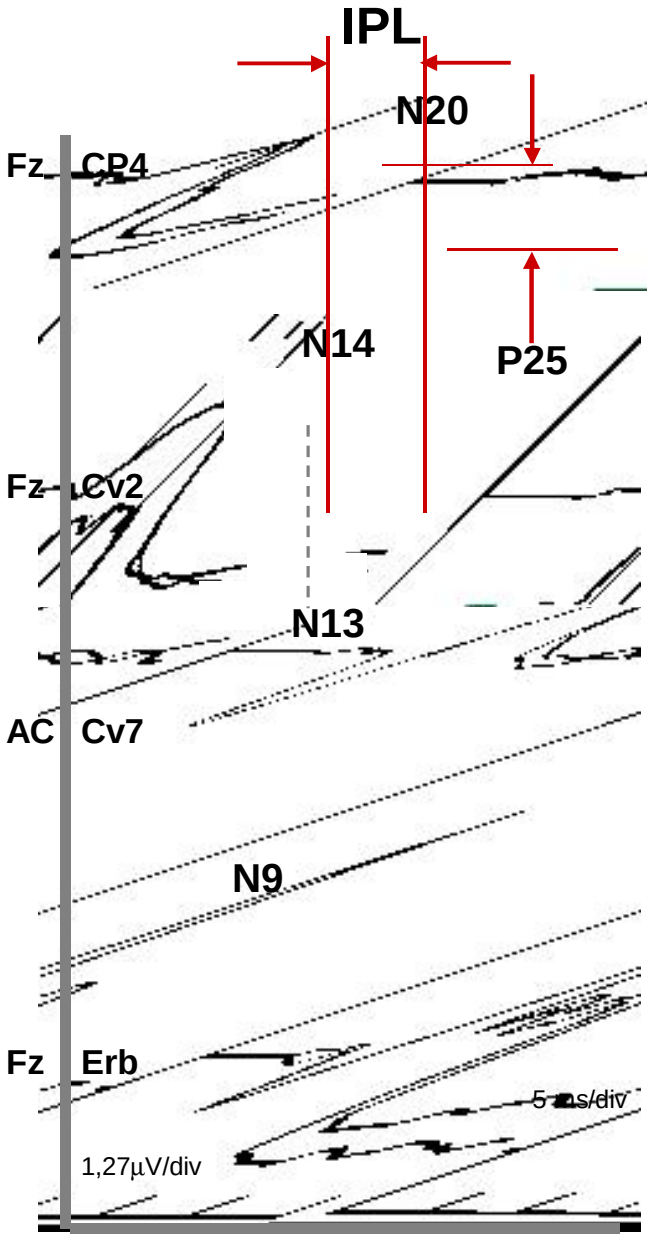


§ Somatosensory evoked potentials

§ Prognosis in coma

- Prolonged N14-N20
- Reduced N20/P25 amplitude
- loss of N20

Ø **bilateral loss N20 = poor prognosis**



§ Somatosensory evoked potentials

§ Prognosis in coma

Prognoses – outcome – sever SHT

N20 – Bilateral loss – Prognosis: wake up <1%

Guérit 2005 Prog Brain Res
Morgalla et al. 2006 Anaesthesist
Amantini et al. 2005 Clin Neurophysiol

Prognoses – outcome – cerebral Hypoxia

N20 – Bilateral loss – Prognosis: persistent coma

Tiainen et al. 2005 Crit Care Med
Zandbergen et al. 2006 Neurology
Robinson et al. 2003 Crit Care Med

60 Pat. Hypothermia within 24-28h after Hypoxia – Prognosis: persistent coma

Tiainen et al. 2005 Crit Care Med

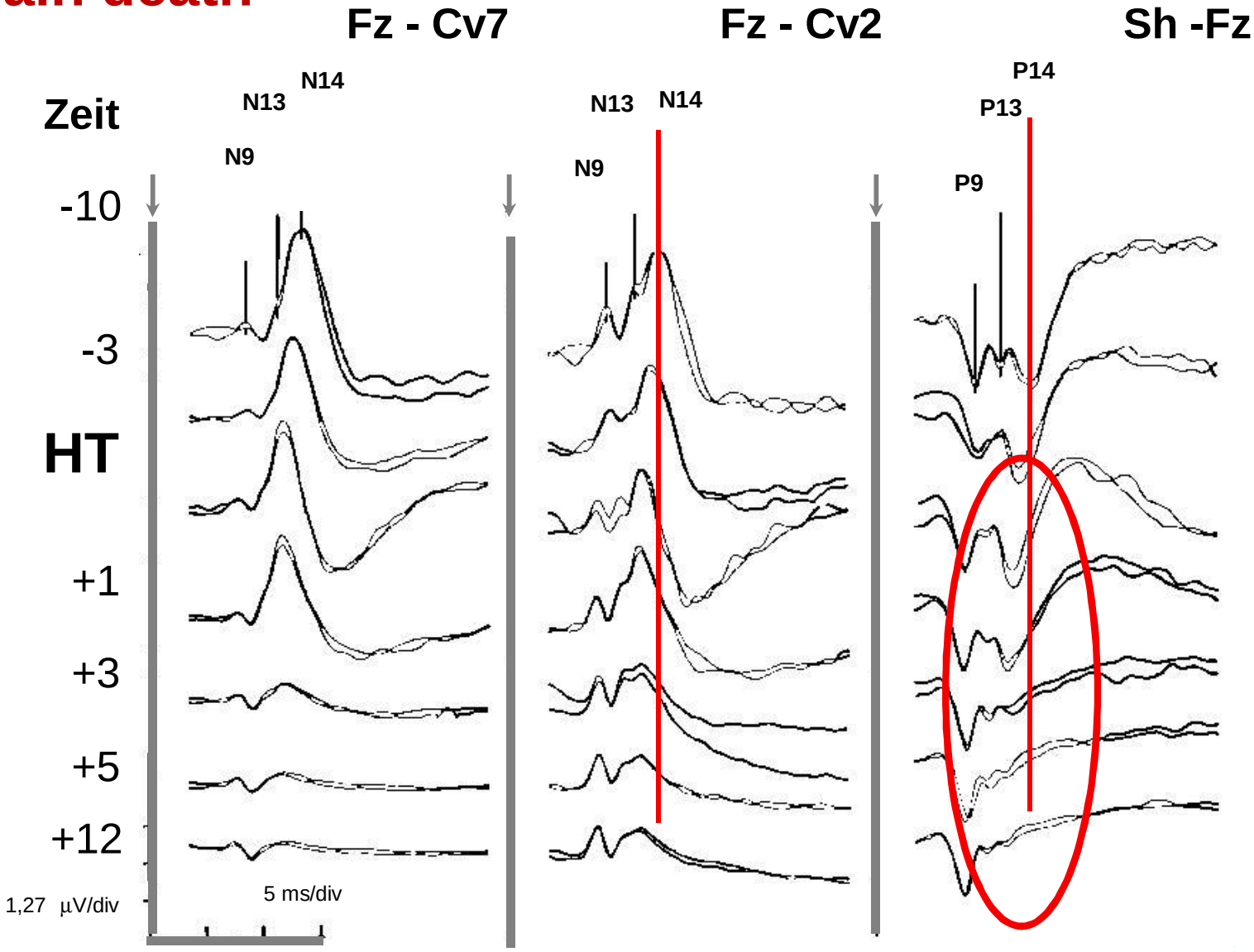
- **Recovery from bilateral loss of N20 in rare cases after cardiac arrest and hypothermia**

  Leithner et. al. Neurology 2010; 74:965-969

§ Somatosensory evoked potentials

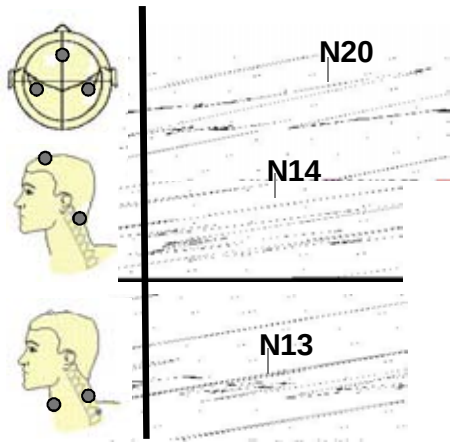
§ Diagnosis of brain death

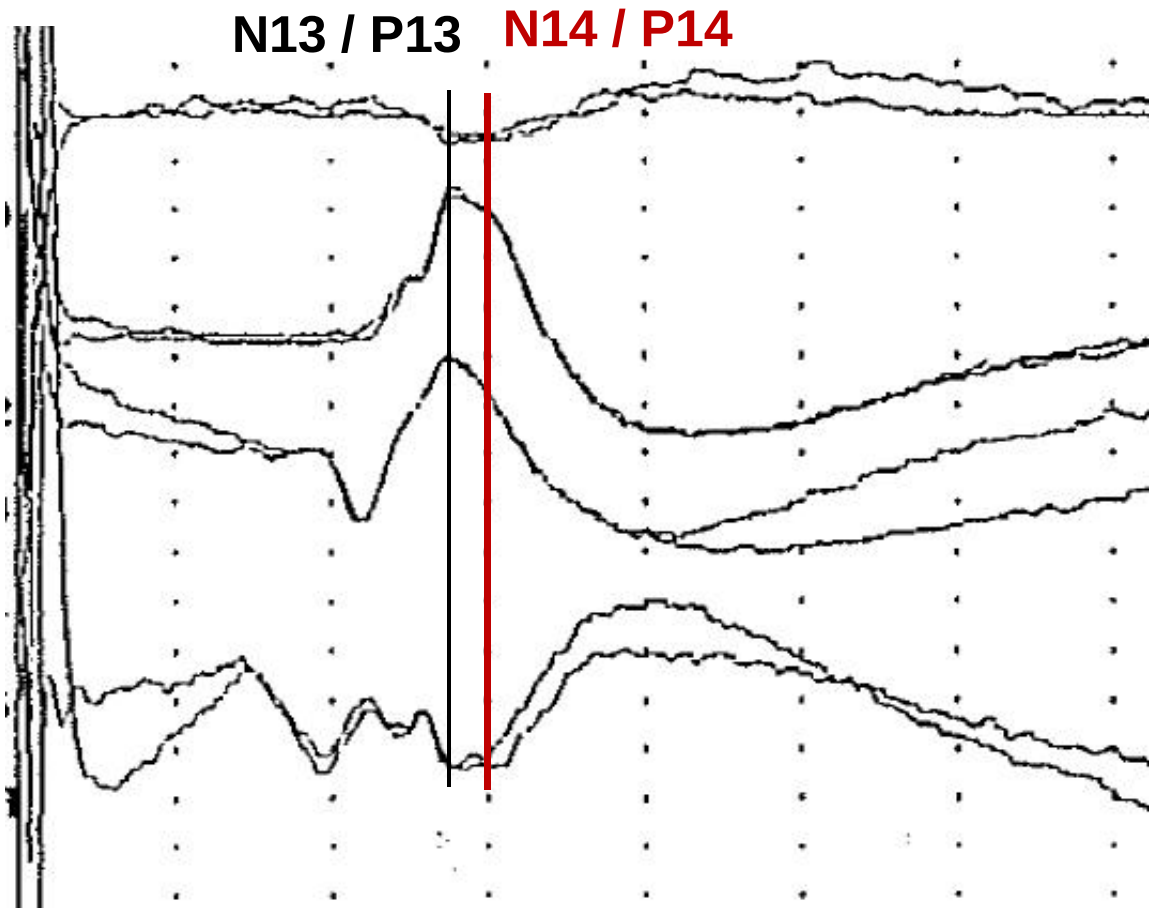
Ø **bilateral loss N14 / P14**



§ Somatosensory evoked potentials

§ Diagnosis of brain death

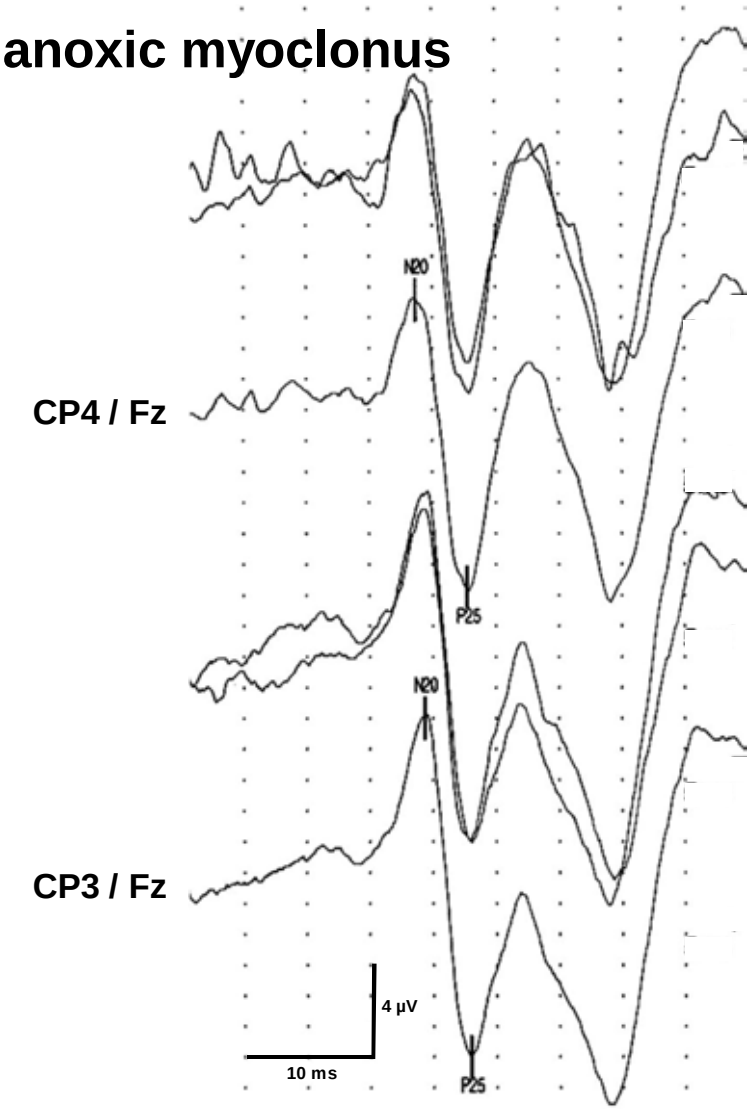




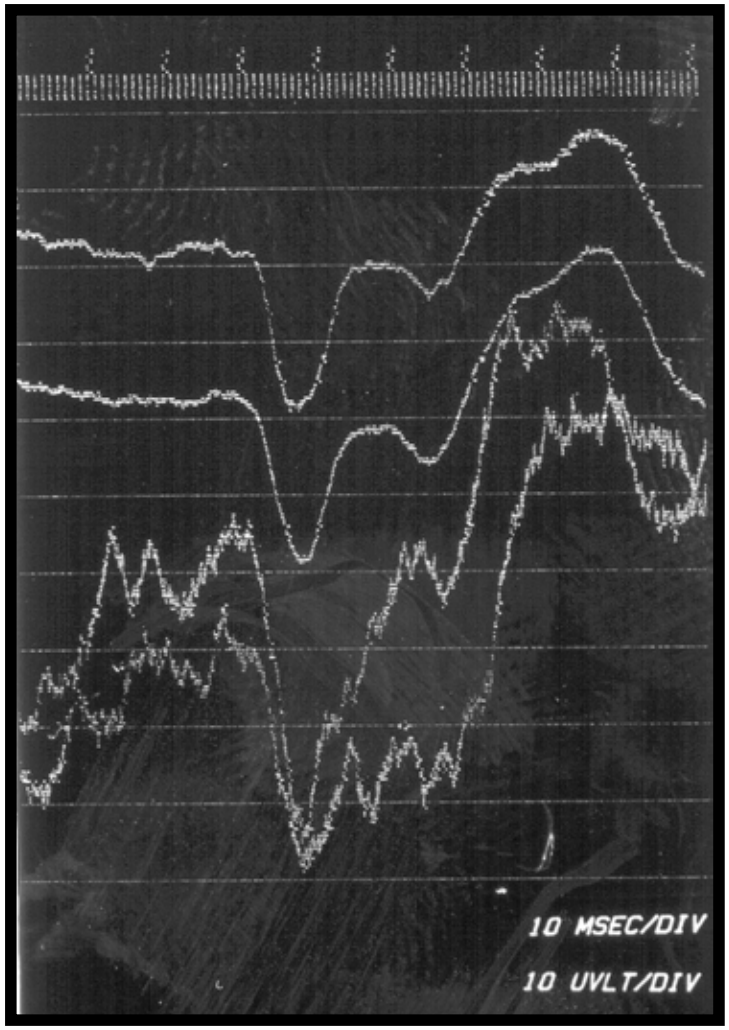
§ Somatosensory evoked potentials

§ Giant SEP

post anoxic myoclonus



myoclonus epilepsy



§ Somatosensory evoked potentials

§ further SEPs

- **sural - SEP**
  - Additional to tibial nerve SEP in some cases
- **ulnar - SEP**
  - Only in rare questions concerning the brachial plexus
- **dermatomal - SEP**
  - Not reliable
- **trigeminal - SEP**
  - Not reliable

§ Somatosensory evoked potentials

§ Clinical applications and advanced use

Ø Hard rocks

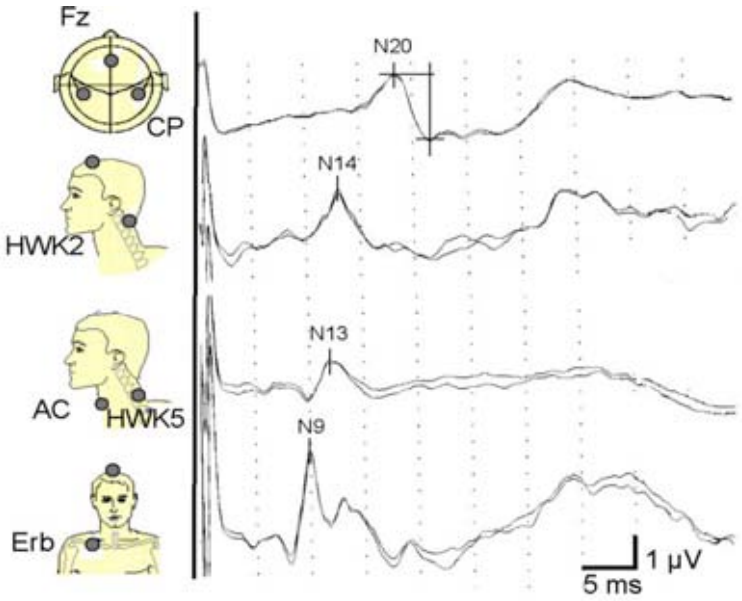
central demyelinating lesions
spinal lesions
MS - Diagnosis
Prognosis in coma
peripheral nerve lesions
proximal neuropathies
intraoperative monitoring / location of central sulcus
cortical myoclonus

Ø Soft rocks

brain death
intoxication
MS - History

Ø The beach

stimulation of cutaneus nerves / dermatomal stimulation
pudendal / trigeminal stimulation



multichannel SEP

With compliments to D. J. Jewett Berlin conference 1986

subjective opinion and incomplete list

Reference

Aminoff M. J. Aminoff´s Electrodiagnosis in Clinical Neurology 6. Ed. Elsevier 2012

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