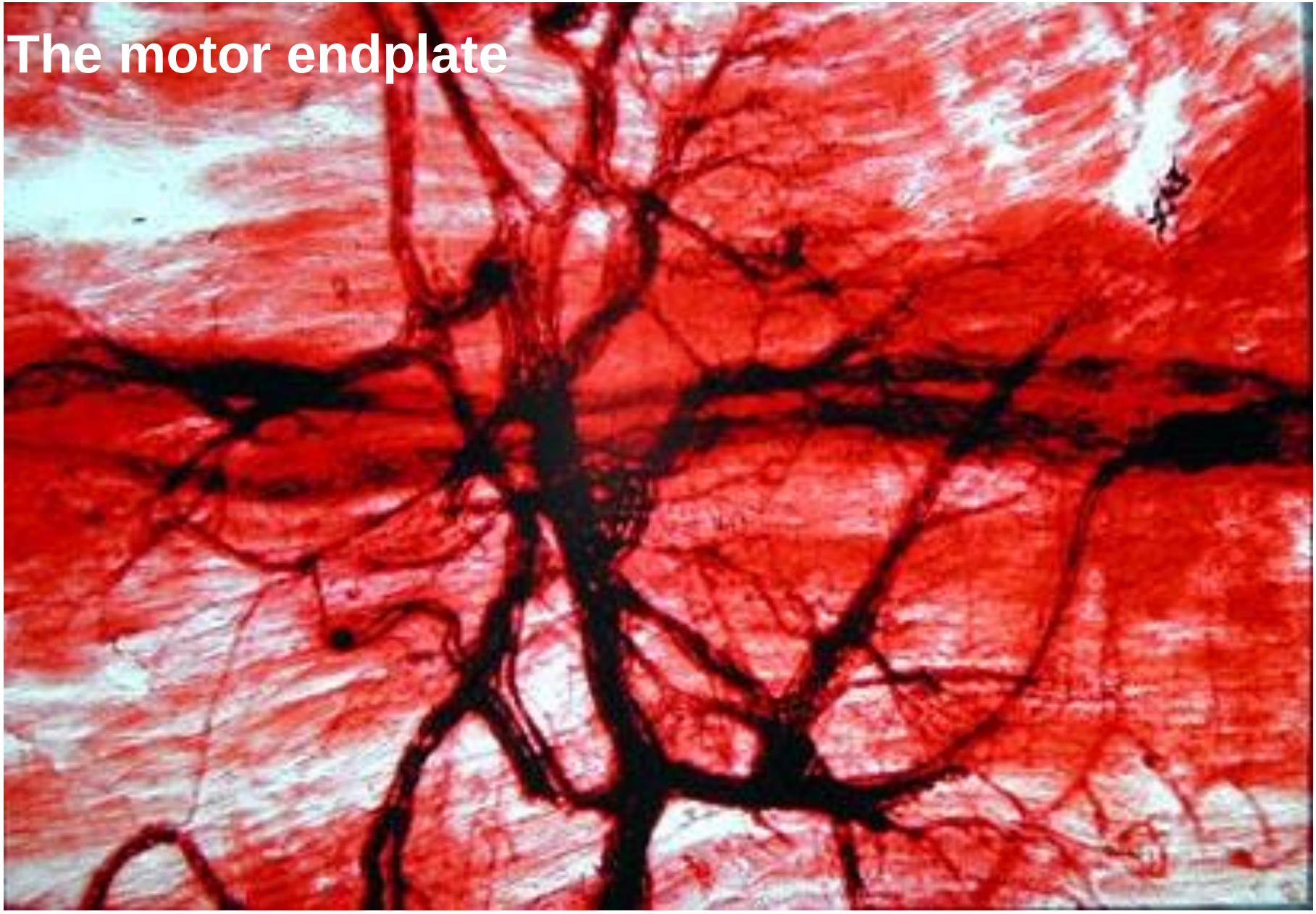
EMG signs of denervation and reinnervation

Markus Weber, MD

International Advanced Neurophysiology Course
March 21- March 23, 2024
Muskelzentrum/ALS Clinic Kantonsspital St.Gallen
Switzerland

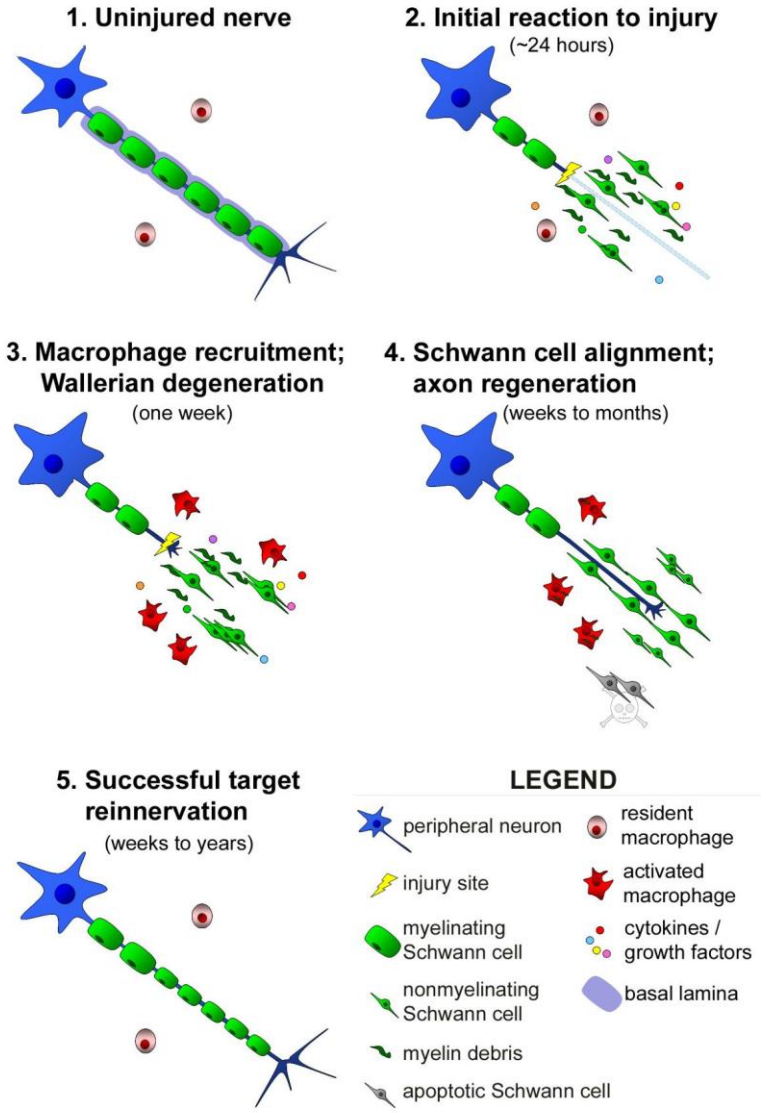
The motor endplate



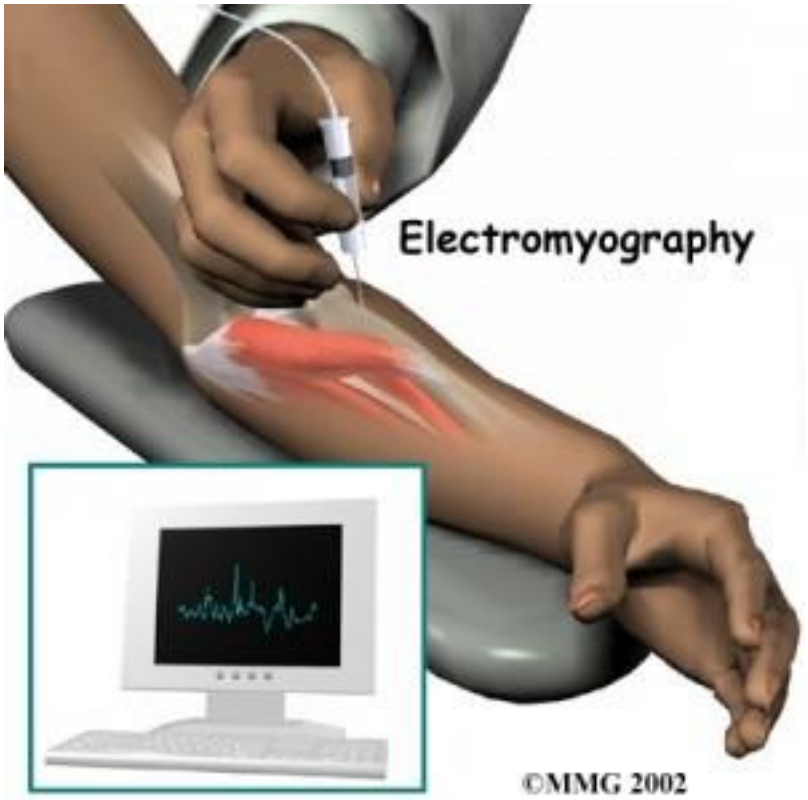
Etiology of axonal damage and denervation

- Acute (injury, trauma)
  - Complete axonal damage
  - Incomplete (partial) axonal damage
- Chronic
  - Compression (carpal tunnel syndrome, herniated disc, etc)
  - Neuropathies (diabetes, alcohol abuse, autoimmune)
    - Axonal
      - Inherited/acquired
    - Demyelinating neuropathies
      - Inherited/acquired
  - Neurodegeneration/ amyotrophic lateral sclerosis

Pathophysiology of denervation and reinnervation

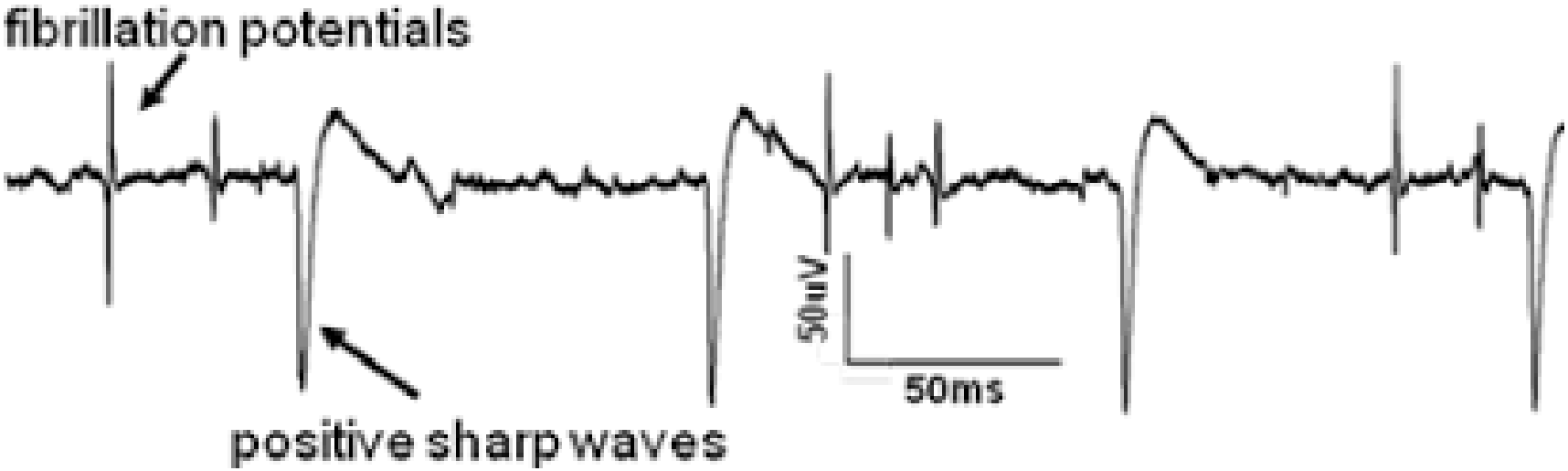


Clinical Neurophysiology



EMG signs of denervation

- Abnormal spontaneous activity
  - positive sharp waves
  - fibrillation potentials



Christian Krarup, EAN teaching course 2017

MUSCLE & NERVE 19:221–226 1996

SINGLE MUSCLE FIBER DISCHARGES (INSERTIONAL ACTIVITY, END-PLATE POTENTIALS, POSITIVE SHARP WAVES, AND FIBRILLATION POTENTIALS): A UNIFYING PROPOSAL

DANIEL DUMITRU, MD

MUSCLE & NERVE 19:216–220 1996

ARE FIBRILLATION POTENTIALS AND *POSITIVE* SHARP WAVES THE SAME? NO

GEORGE H. KRAFT, MD

tion of PSWs conform to that of a blocked fibrillation potential.

Muscle Nerve **36:** 349–356, 2007

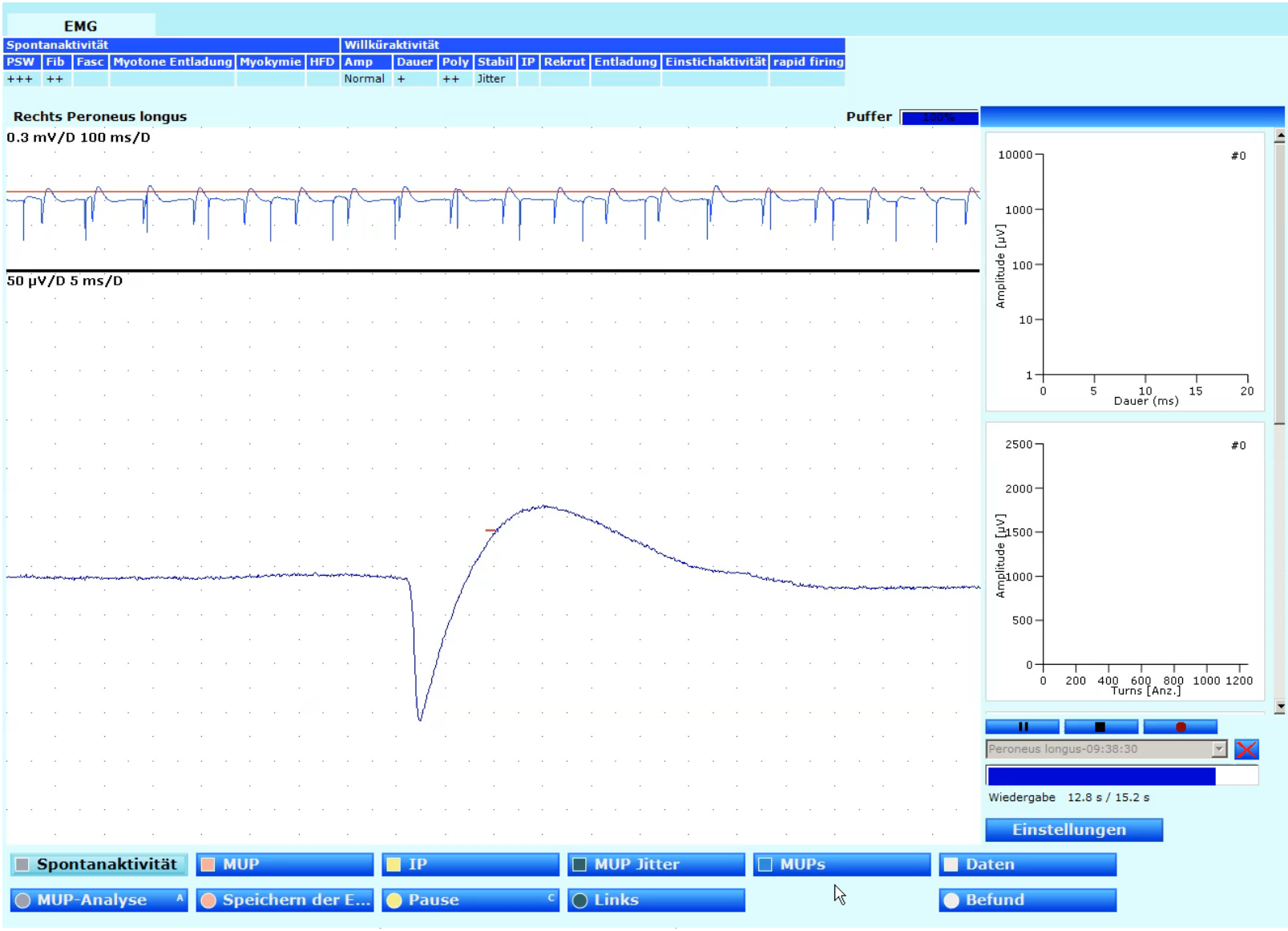
POSITIVE SHARP WAVE ORIGIN: EVIDENCE SUPPORTING THE ELECTRODE INITIATION HYPOTHESIS

DANIEL DUMITRU, MD, PhD, and DANIEL L. SANTA MARIA, MD

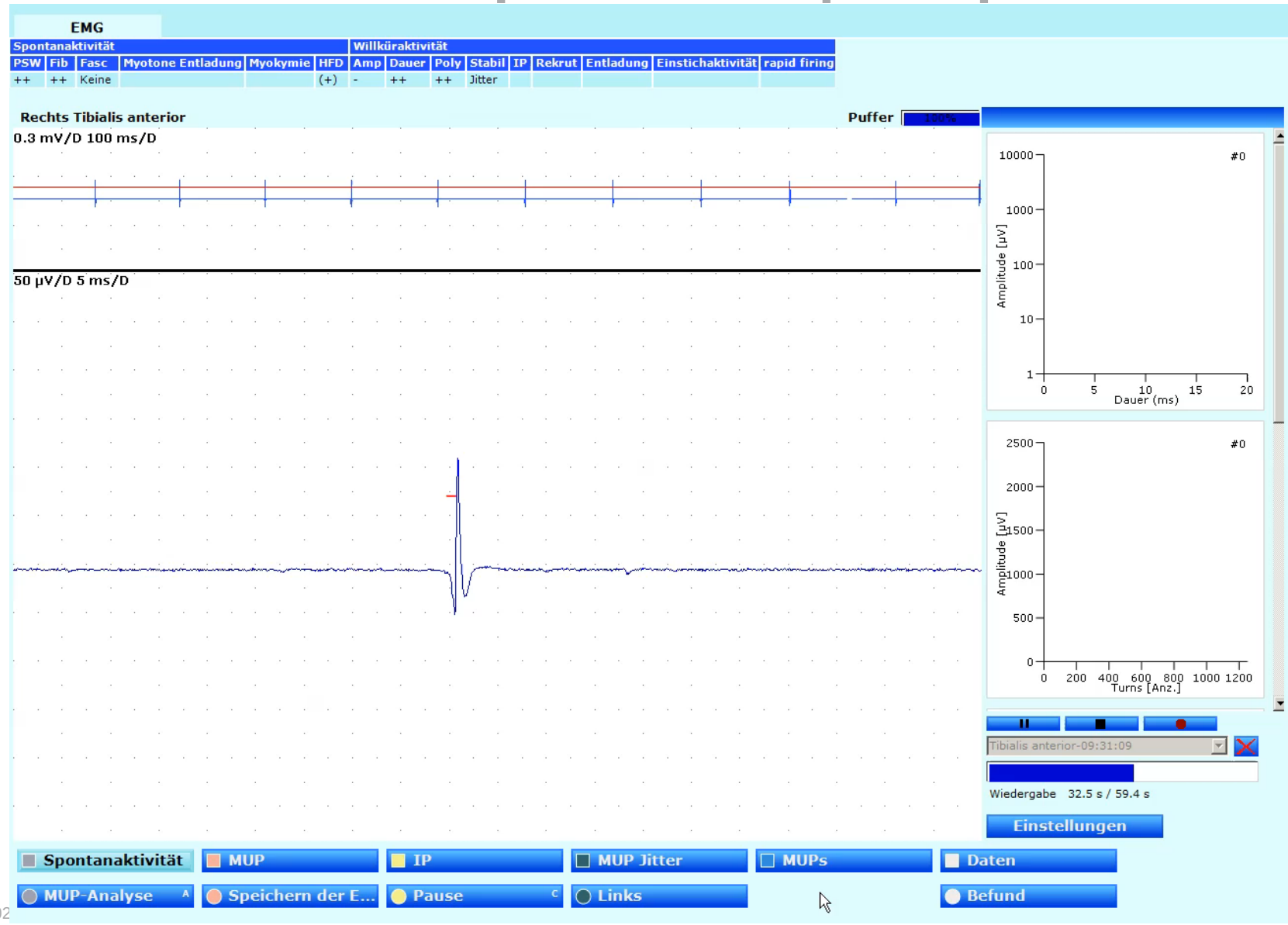
Department of Rehabilitation Medicine, University of Texas Health Science Center, 7703 Floyd Curl Drive, San Antonio, Texas 78229-3900, USA

Accepted 28 March 2007

Denervation after complete nerve injury



Fibrillation potential superimposed

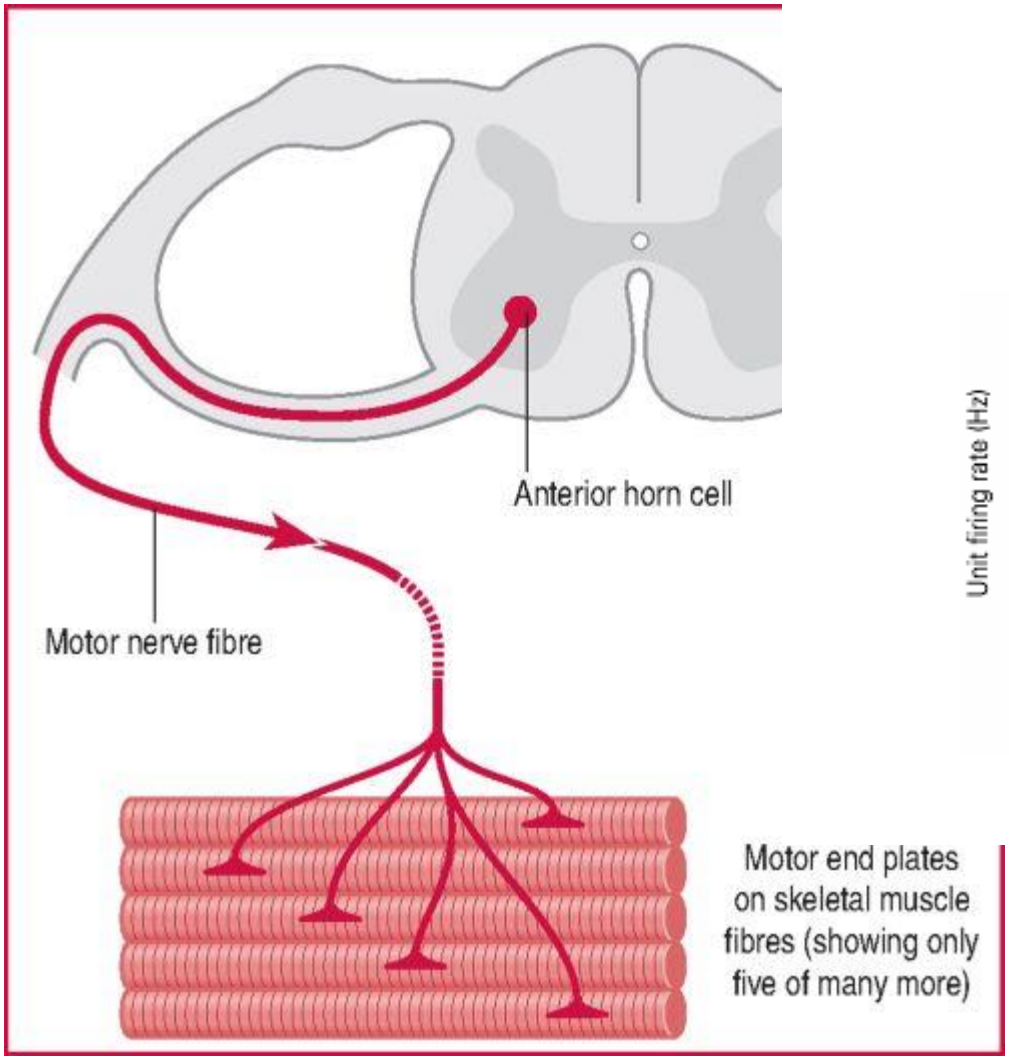


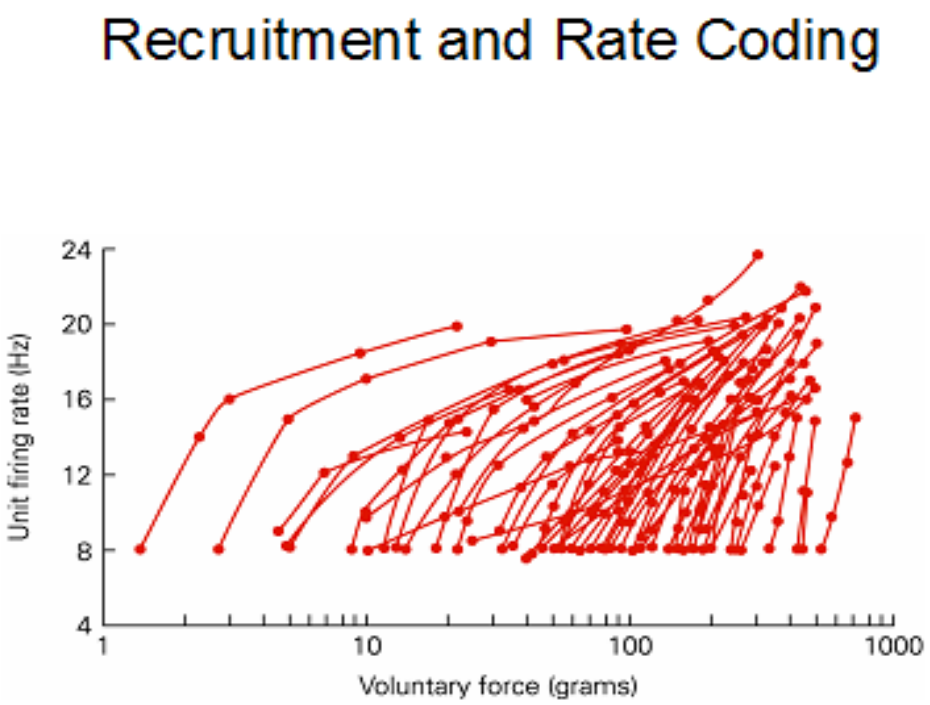
Nerve lesion and voluntary EMG

- Complete axonal
  - Spontaneous activity (positive waves and fibs)
  - No voluntary activity
- Partial axonal
  - Spontaneous activity
  - Voluntary activity
    - Time dependent

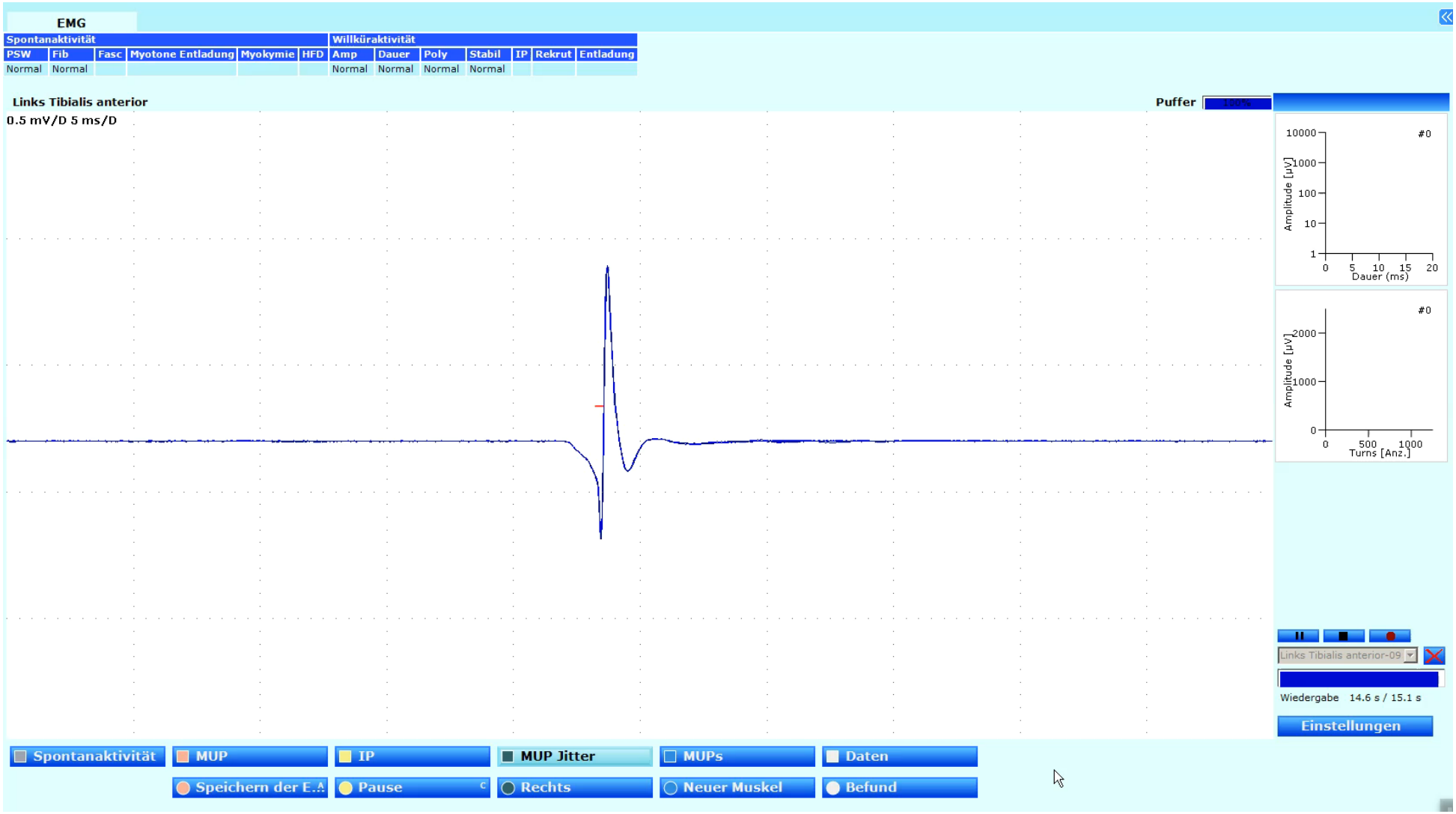
Motor unit firing

The motor unit and voluntary recruitment

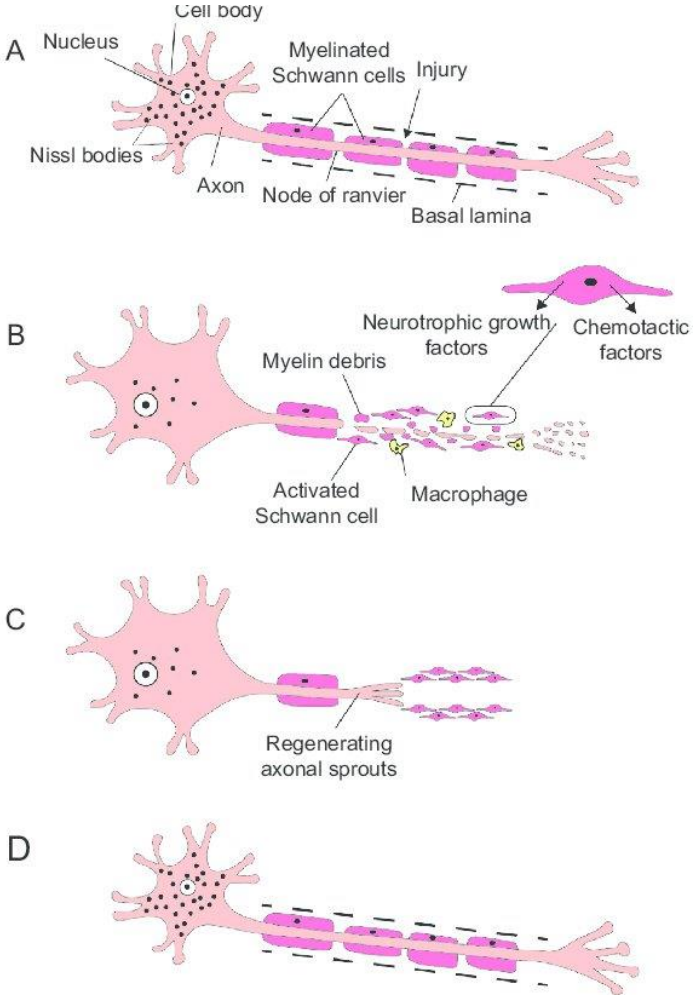




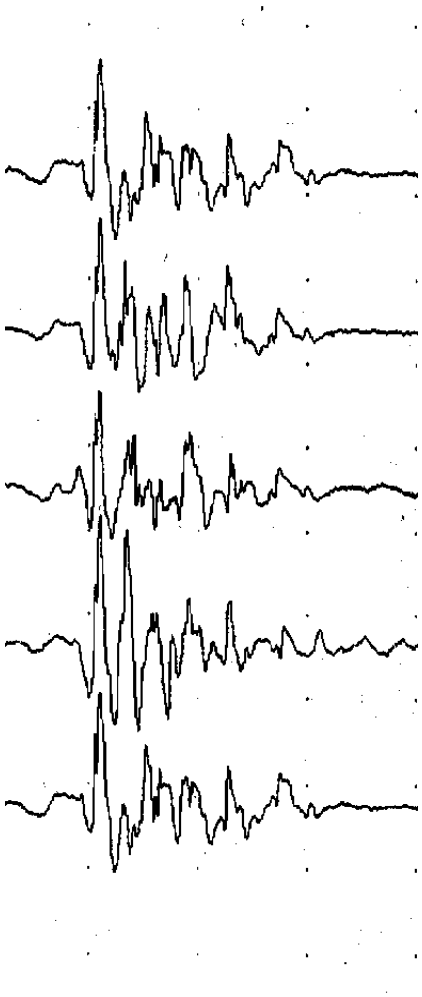
Normal MU stable superimpose



Nascent reinnervation after complete axonal damage and Wallerian degeneration

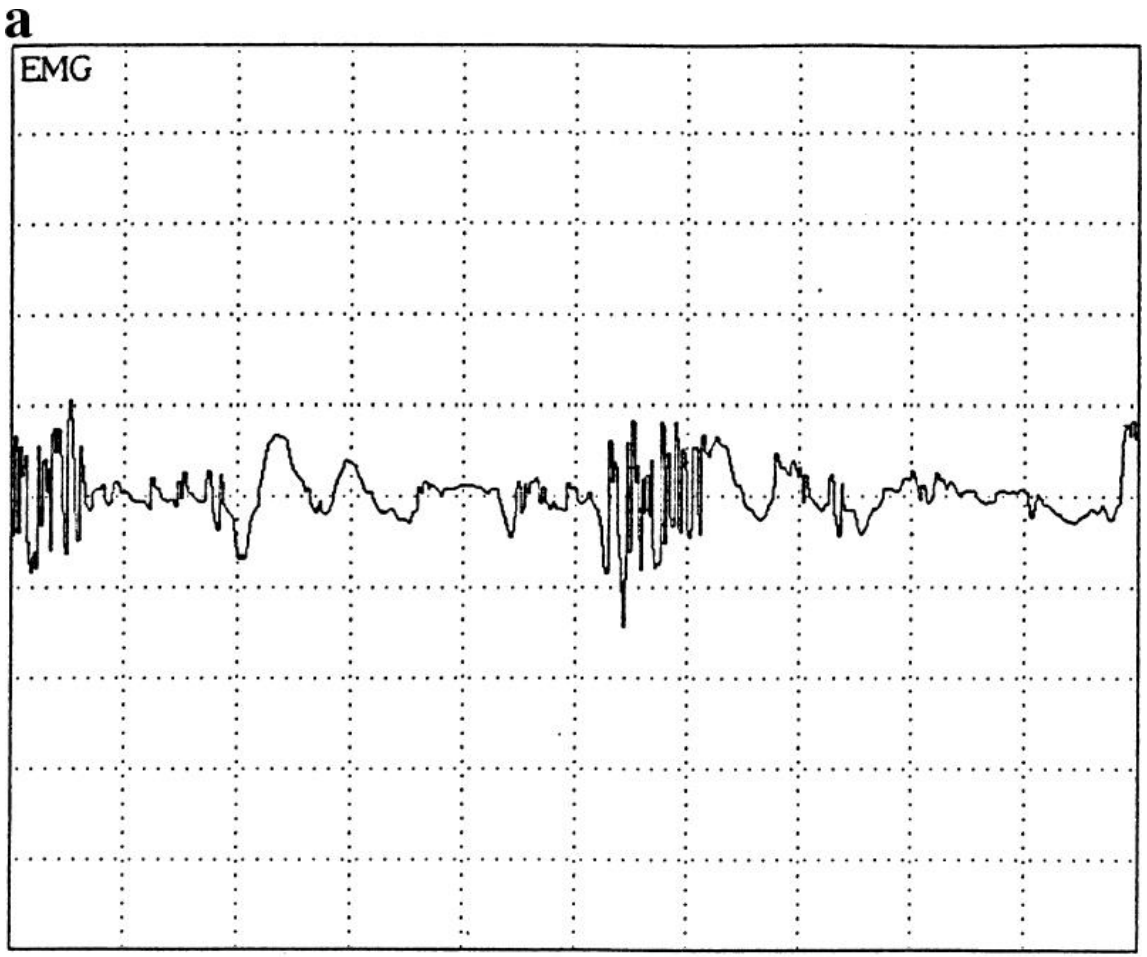


EMG



https://www.researchgate.net/publication/289525755

Nascent reinnervation



Ch	Hicut	Locut	Gain (μV/div)	Sweep (ms/div)
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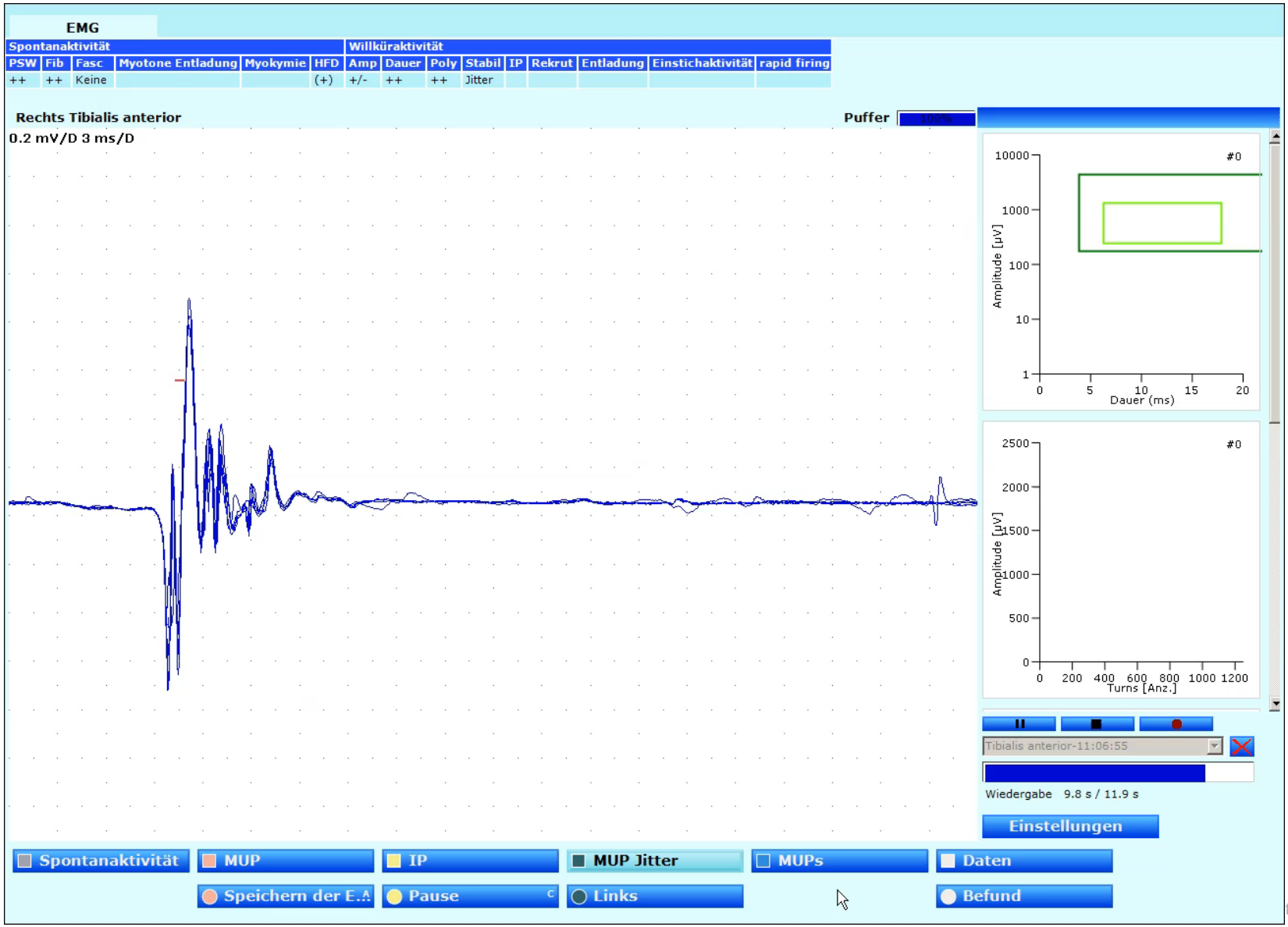
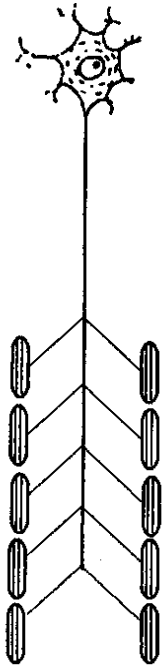
HHS journal Feinberg 2006

Nascent reinnervation after complete nerve injury



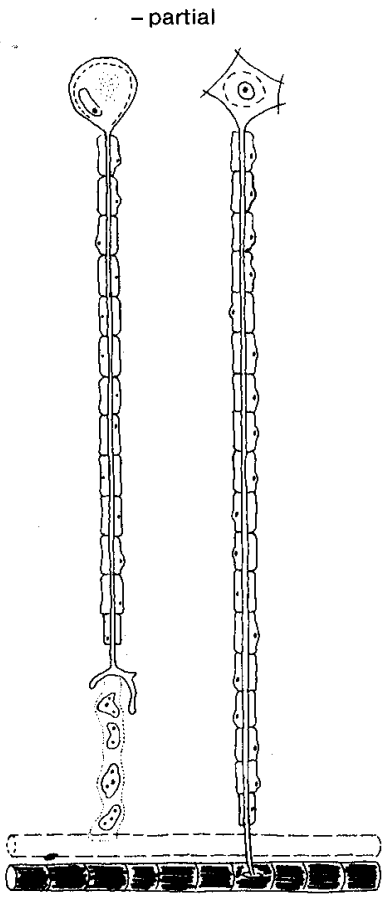
EMG changes with partial nerve lesion: terminal sprouting

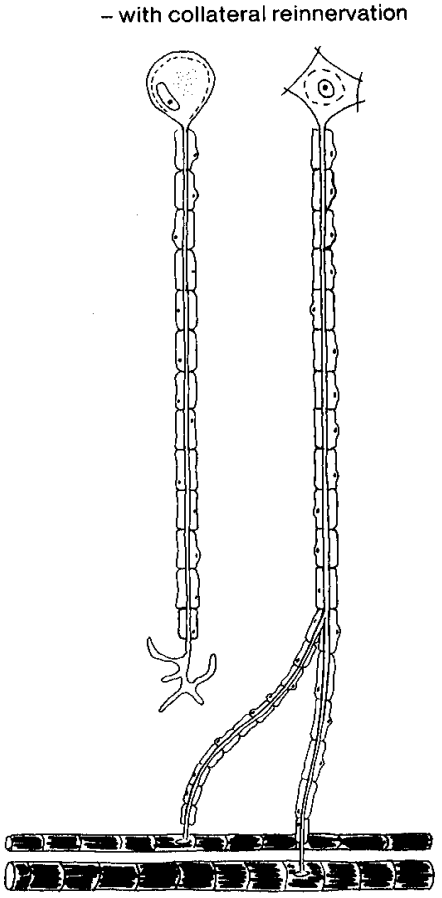
Normal



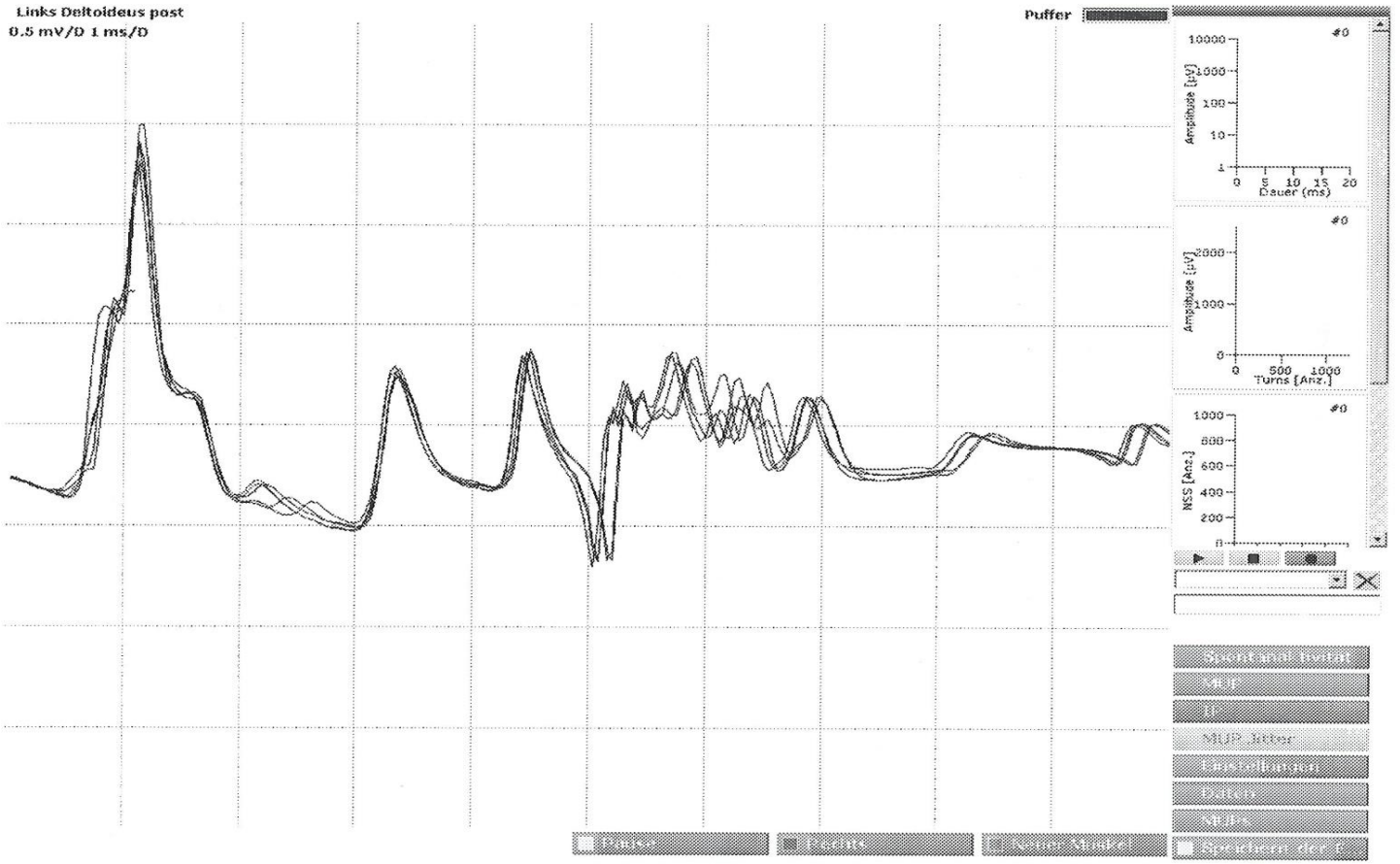
MUAP

Histology

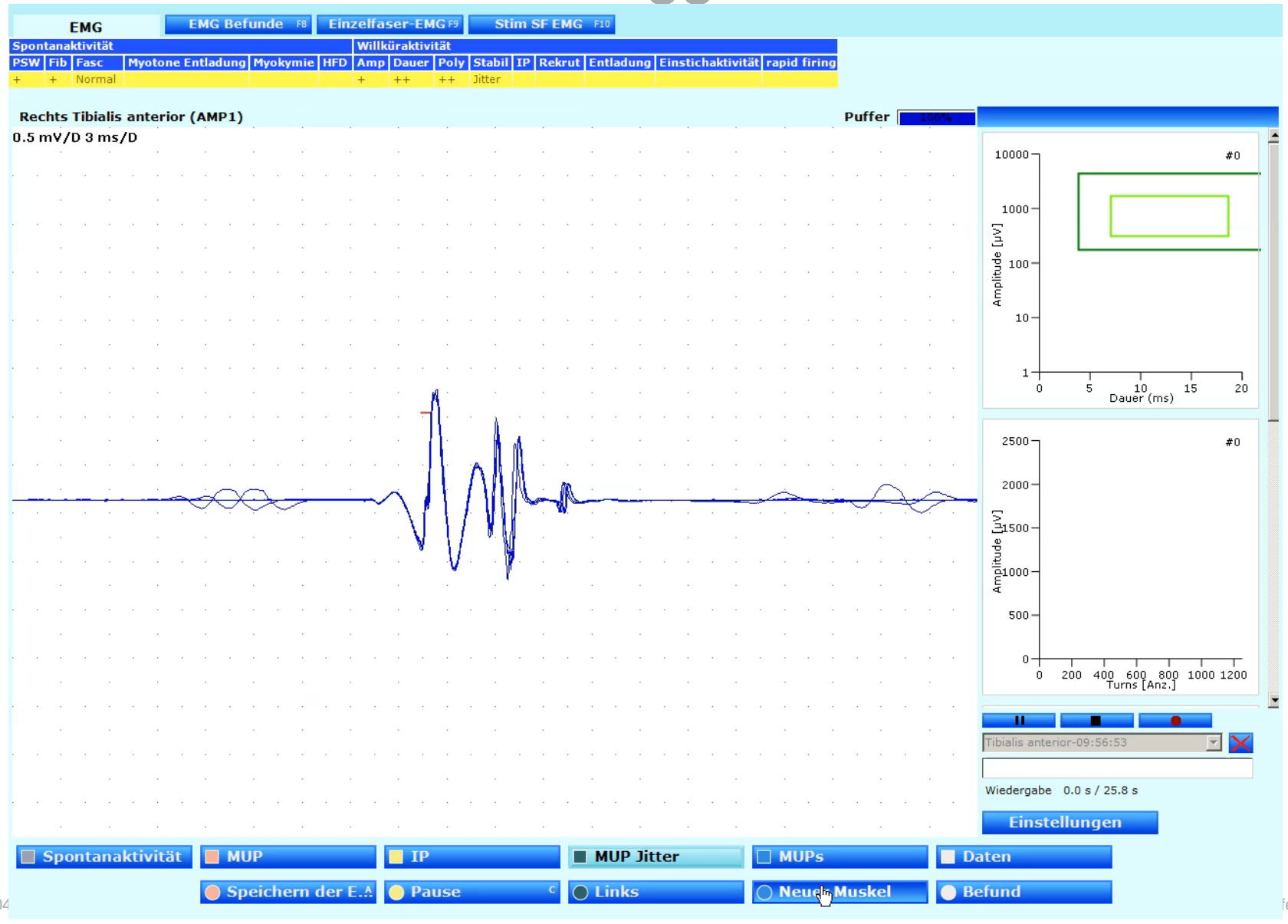




Reinnervation- terminal sprouting



Jiggle


EMG
EMG Befunde F8
Einzelfaser-EMG F9
Stim SF EMG F10
Spontanaktivität
Willkürаktivität
PSW Fib Fasc Myotone Entladung Myokymie HFD Amp Dauer Poly Stabil IP Rekrut Entladung Einstichaktivität rapid firing
+ + Normal + ++ ++ Jitter
Rechts Tibialis anterior (AMP1)
0.5 mV/D 3 ms/D
Puffer
100%
#0
Amplitude [µV]
Dauer (ms)
Turns [Anz.]
Tibialis anterior-09:56:53
Wiedergabe 0.0 s / 25.8 s
Einstellungen
Spontanaktivität
MUP
IP
MUP Jitter
MUPs
Daten
Speichern der E.A
Pause
Links
Neuer Muskel
Befund

EMG changes over time

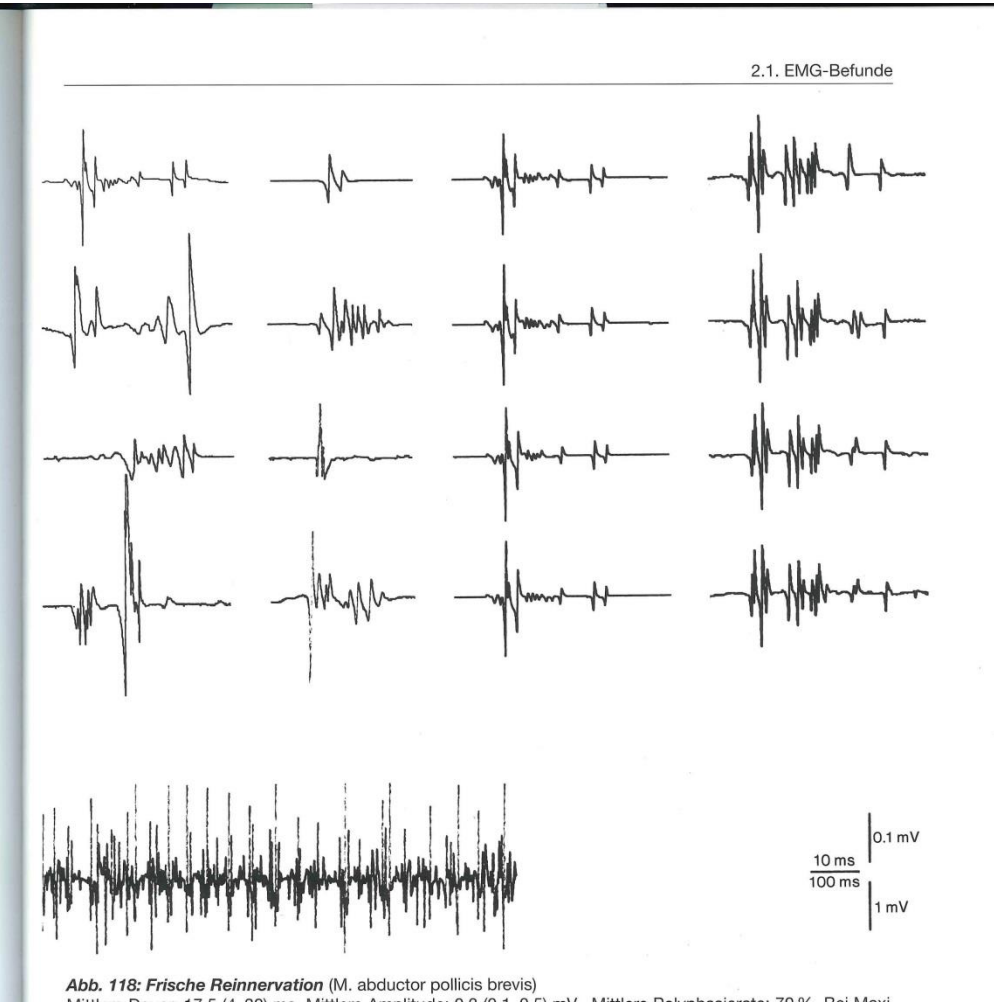


Abb. 118: Frische Reinnervation (M. abductor pollicis brevis)

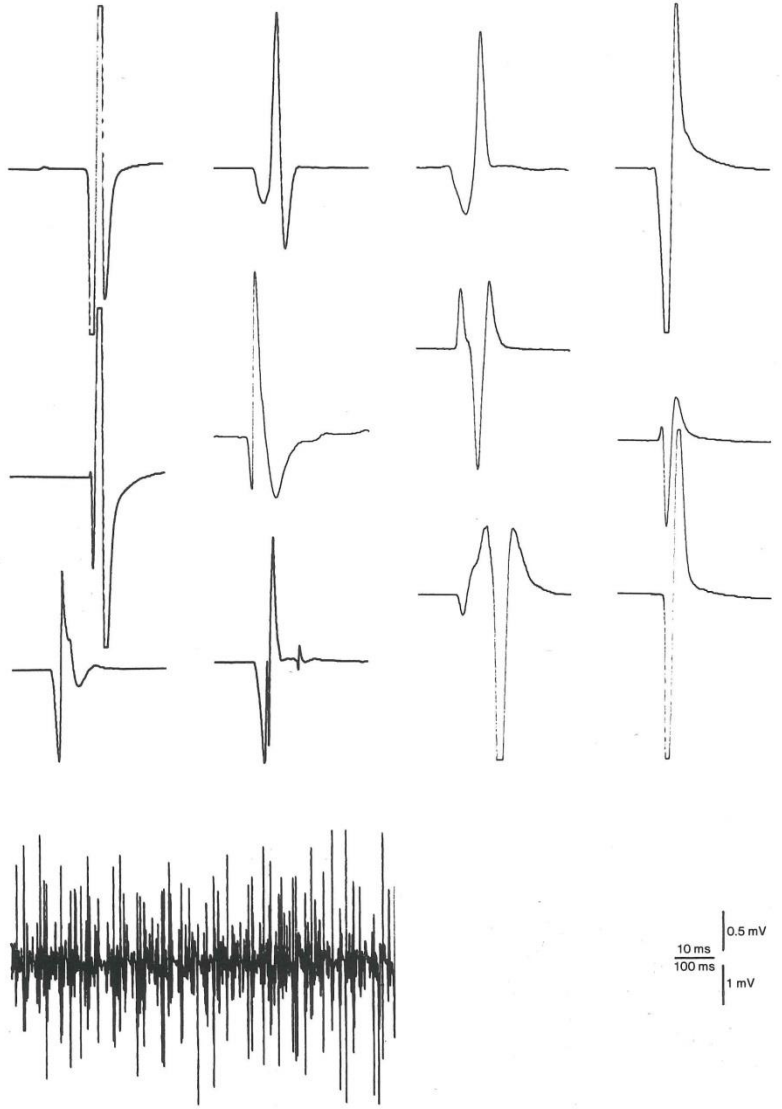


Abb. 120: Spätes Reinnervationsstadium

Comparison of EMG changes

complete

- Spontaneous activity +++
- Nascent reinnervation
  - Months-years
  - MUPS:
  - small
  - complex
  - unstable
  - fatigues easily

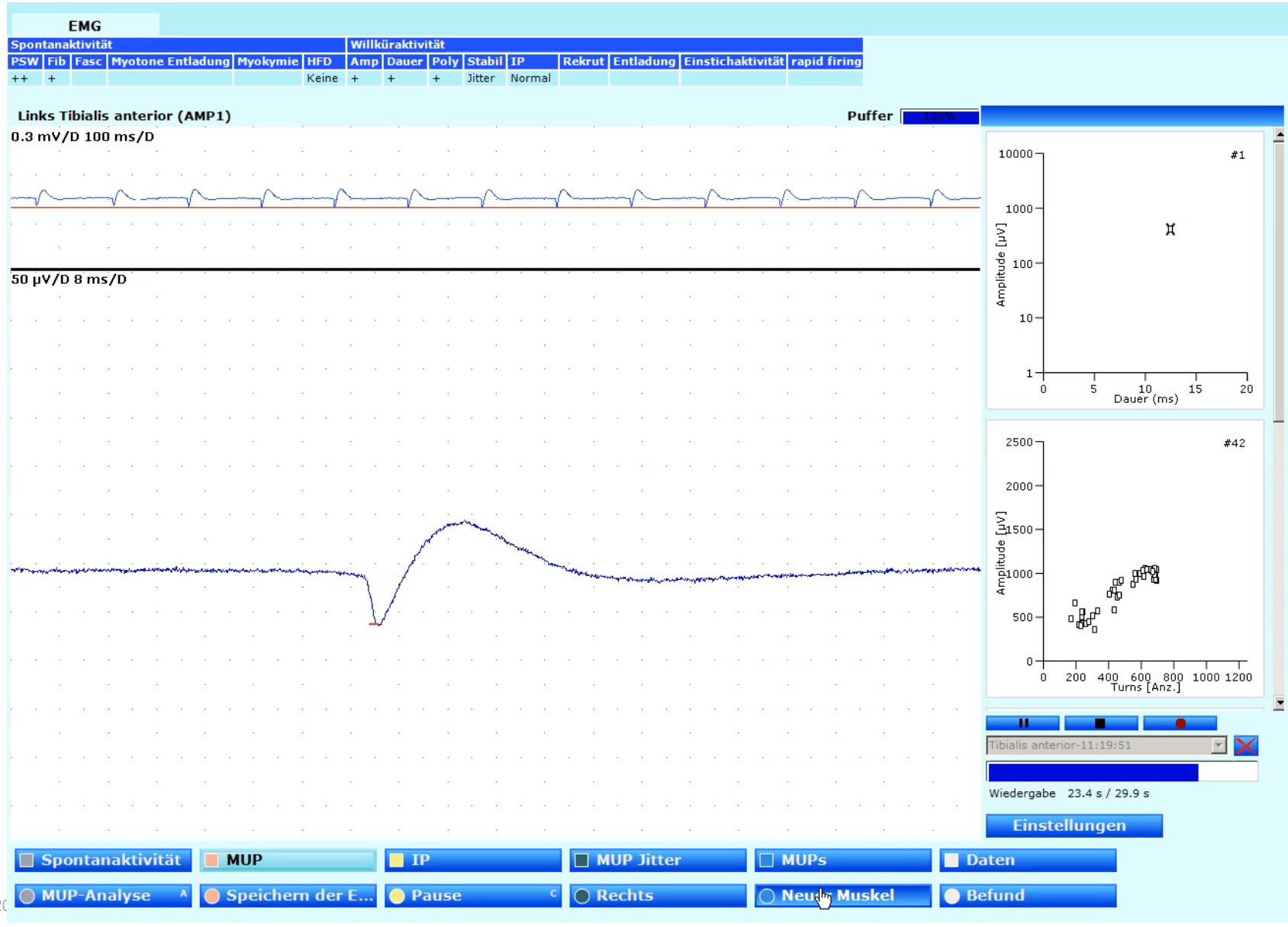
partial

- Spontaneous activity +, ++
- Terminal sprouting
  - Weeks-years
  - MUPS
  - Normal to large, «mother» unit
  - complex (satellites)
  - unstable (Jiggle)

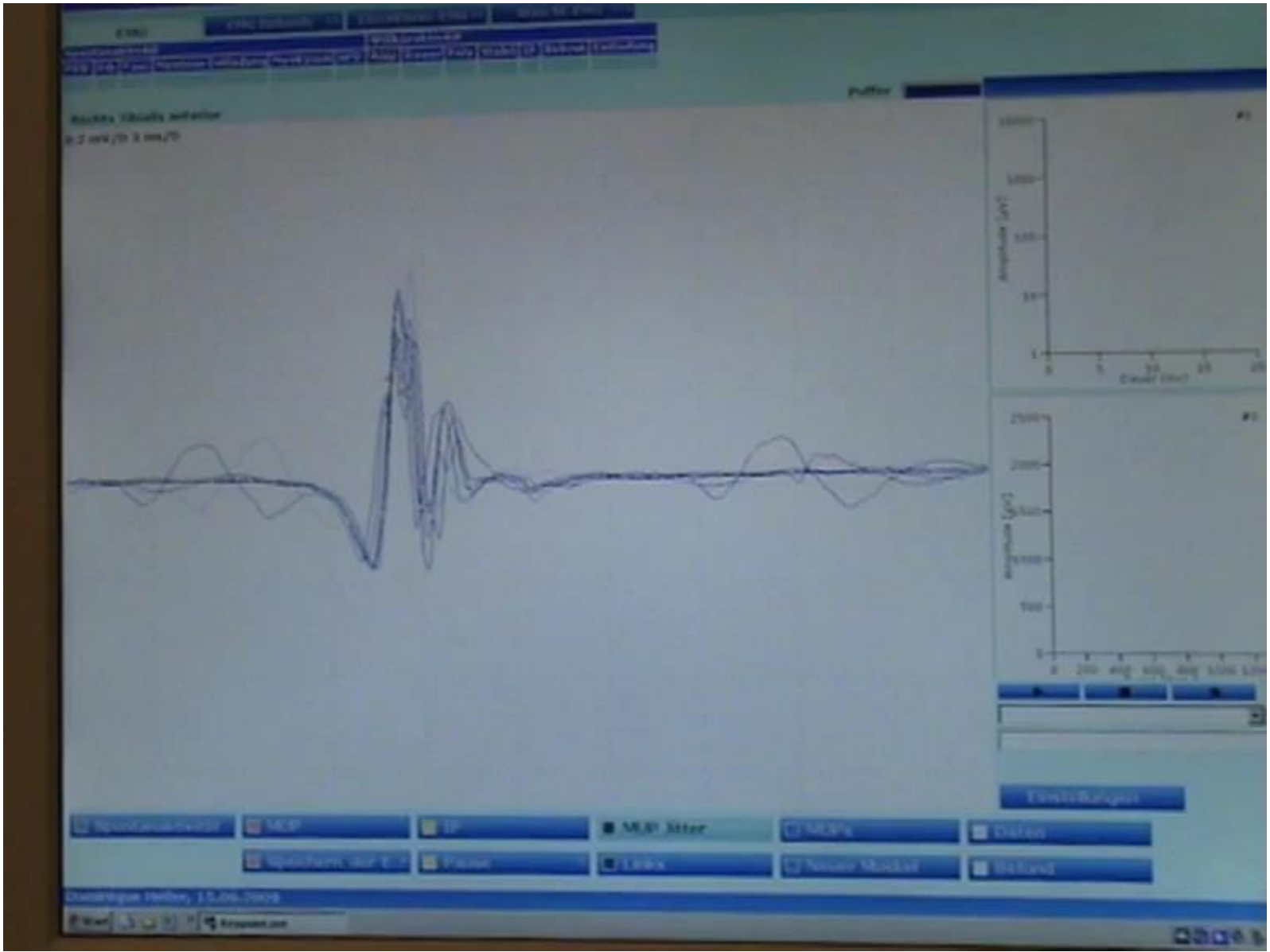
Clinical examples: Amotrophic lateral sclerosis

- Signs of active denervation
- signs of chronic denervation («chronic neurogenic»)
- Fasciculation potentials

EMG changes in ALS: denervation

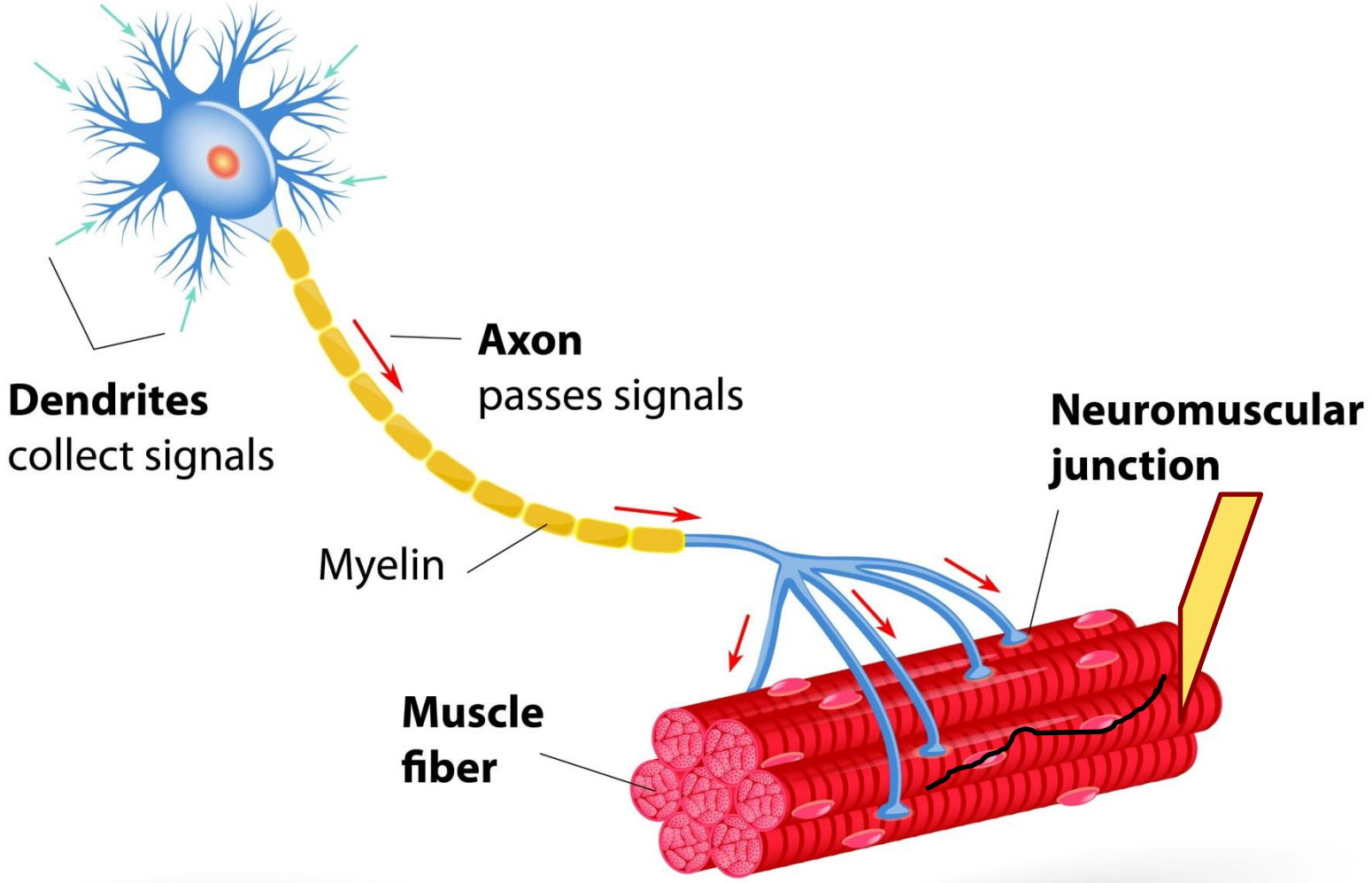


Chronic neurogenic…. unstable MUPs (Jiggle)



EMG changes in ALS: chronic neurogenic

Signs of denervation in myopathy



Electrophysiological Features of LMN Dysfunction (revised El Escorial criteria 2000)

- ***Conventional EMG studies***
  The features of LMN dysfunction …are defined by electromyographic ….evidence of
  - ***active and***
  - ***chronic denervation***
  - ***fasciculations.***

EMG findings

- Active denervation:
  - spontaneous activity (fibrillation potentials, positive sharp waves)
- Chronic denervation:
  - impaired MUP recruitment (rapid firing)
  - unstable MUPs (Jiggle)
  - abnormal MUP size and shape (polyphasic potentials)

ELSEVIER

Clinical Neurophysiology 119 (2008) 497–503

www.elsevier.com/locate/clinph

Review

Electrodiagnostic criteria for diagnosis of ALS ☆

Mamede de Carvalho [a], Reinhard Dengler [b], Andrew Eisen [c], John D. England [d], Ryuji Kaji [e], Jun Kimura [f], Kerry Mills [g], Hiroshi Mitsumoto [h], Hiroyuki Nodera [i], Jeremy Shefner [j], Michael Swash [k,*]

[a] *Department of Neurology, Hospital de Santa Maria, University of Lisbon, Lisbon, Portugal*
[b] *Department of Neurology, Medizinische Hochschule Hannover, Germany*
[c] *Department of Neurology, University of British Columbia, Vancouver, Canada*
[d] *Department of Neurology, Billings Clinic, Billings, MT, USA*
[e] *Department of Neurology, Tokushima University Graduate School of Medicine, Tokushima-city, Japan*
[f] *Department of Neurology, University of Iowa, Iowa City, USA*
[g] *Department of Neurology, Kings College Hospital, Guys Kings and St. Thomas's School of Medicine, London, UK*
[h] *Eleanor and Lou Gehrig ALS Center, Neurological Institute, Columbia University, NY, USA*
[i] *Department of Neurology, Tokushima University, Tokushima-city, Japan*
[j] *Department of Neurology, Upstate Medical University, Syracuse, NY, USA*
[k] *Department of Neurology, Royal London Hospital, Queen Mary University of London, London, UK*

Awaji consensus

1. *Edx and clinical data* are of equal and interchangeable value in diagnosing ALS
2. *In the presence of signs of partial denervation*, Fasciculation potentials (preferably of complex morphology) are equivalent to fibs-psw, indicating ongoing denervation
3. Fibs and psws are usually recorded in strong, non-wasted muscles
4. *Unstable MUPs & FPs* are especially relevant

Contents lists available at ScienceDirect

Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

Opinion Paper

A proposal for new diagnostic criteria for ALS

Jeremy M. Shefner [a,*], Ammar Al-Chalabi [b], Mark R. Baker [c], Li-Ying Cui [d],

- EMG abnormalities that must include:
- Both evidence of chronic neurogenic change, defined by large motor unit potentials of increased duration and/or increased amplitude, with polyphasia and motor unit instability regarded as supportive but not obligatory evidence.
- And evidence of ongoing denervation including Fibrillation potentials or positive sharp waves, or fasciculation potentials

RESEARCH PAPER

Fasciculation potentials and earliest changes in motor unit physiology in ALS

Mamede de Carvalho,[1,2] Michael Swash[1,2,3]

Carvalho M, et al. J Neurol Neurosurg Psychiatry 2013;84:963–968

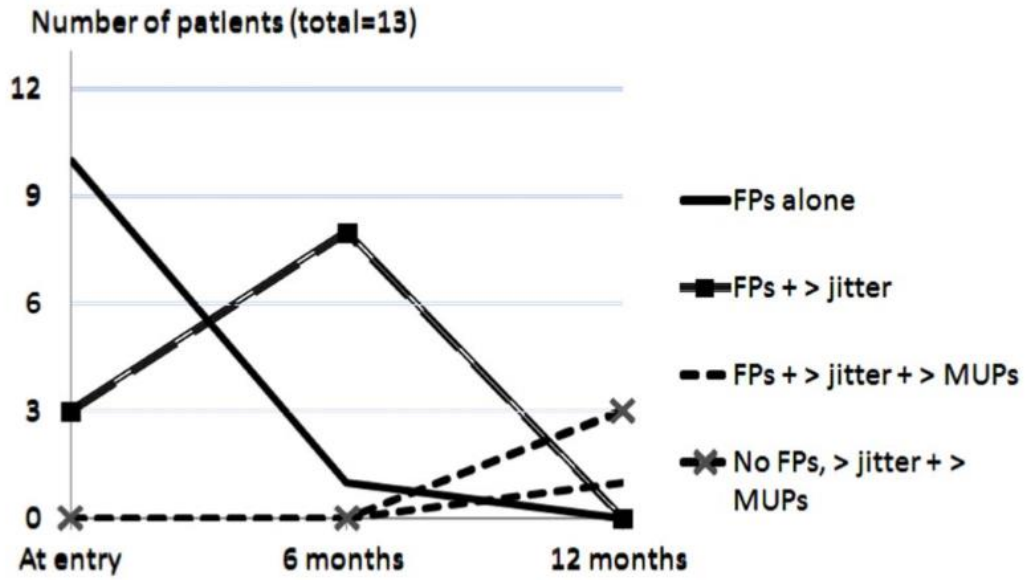
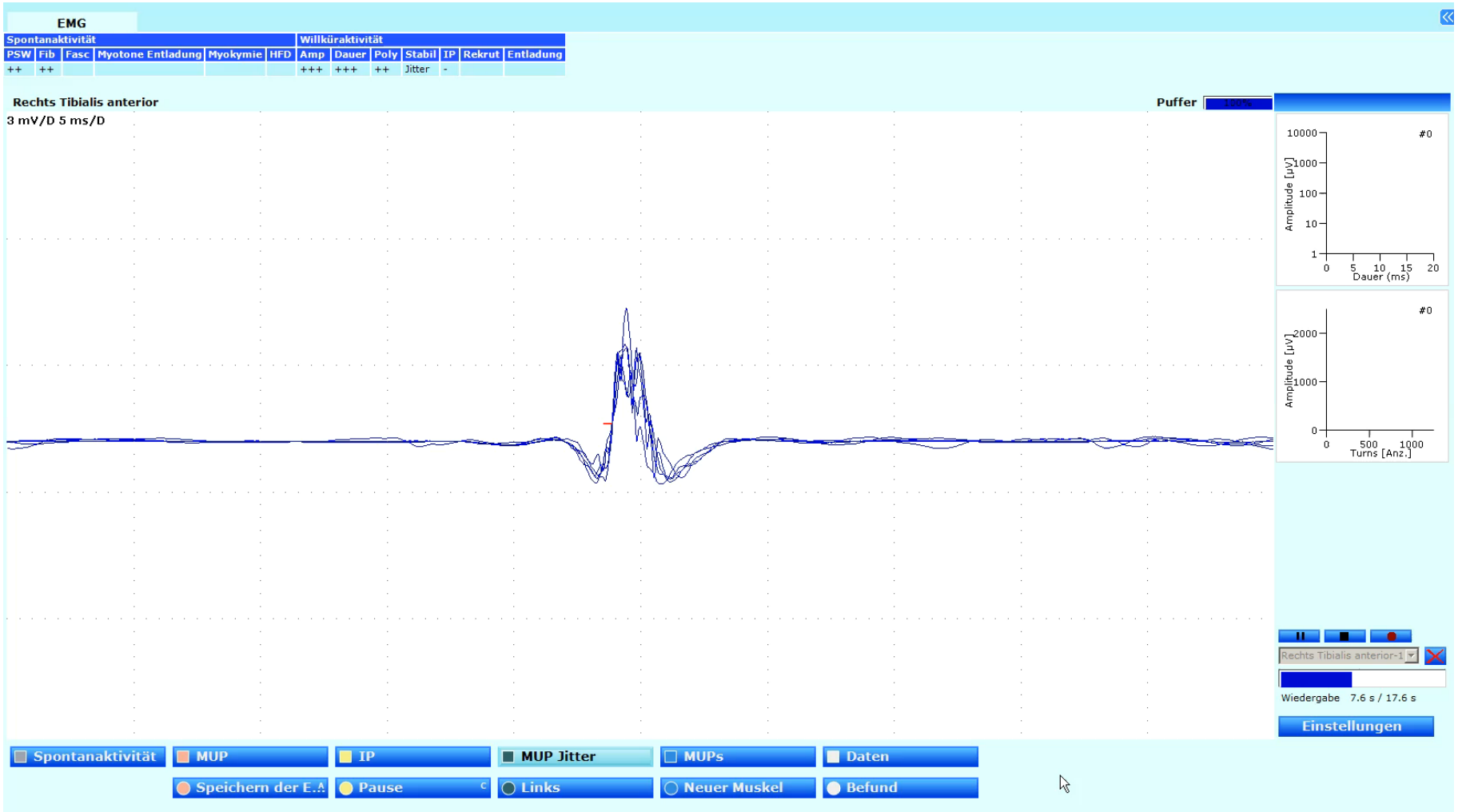
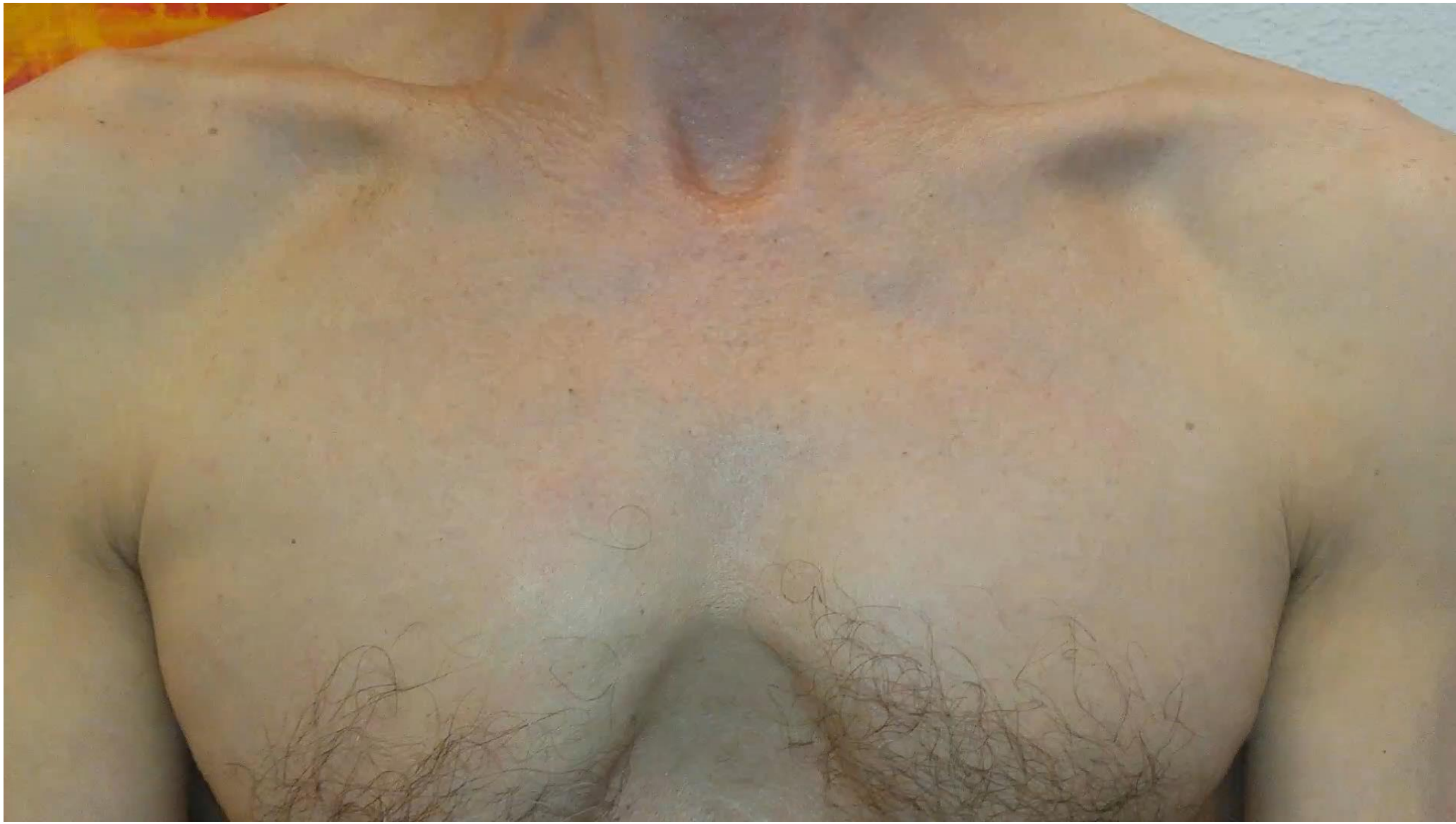


Figure 2 Progression of 13 amyotrophic lateral sclerosis patients with isolated fasciculation potentials (FPs) (normal motor unit potential (MUP) and no fibrillation/sharp-waves (fibs-sw)). All patients were evaluate 6 months later, but only four had preserved normal tibialis anterior strength 12 months after study entry. The Y-axis represents the number of patients.

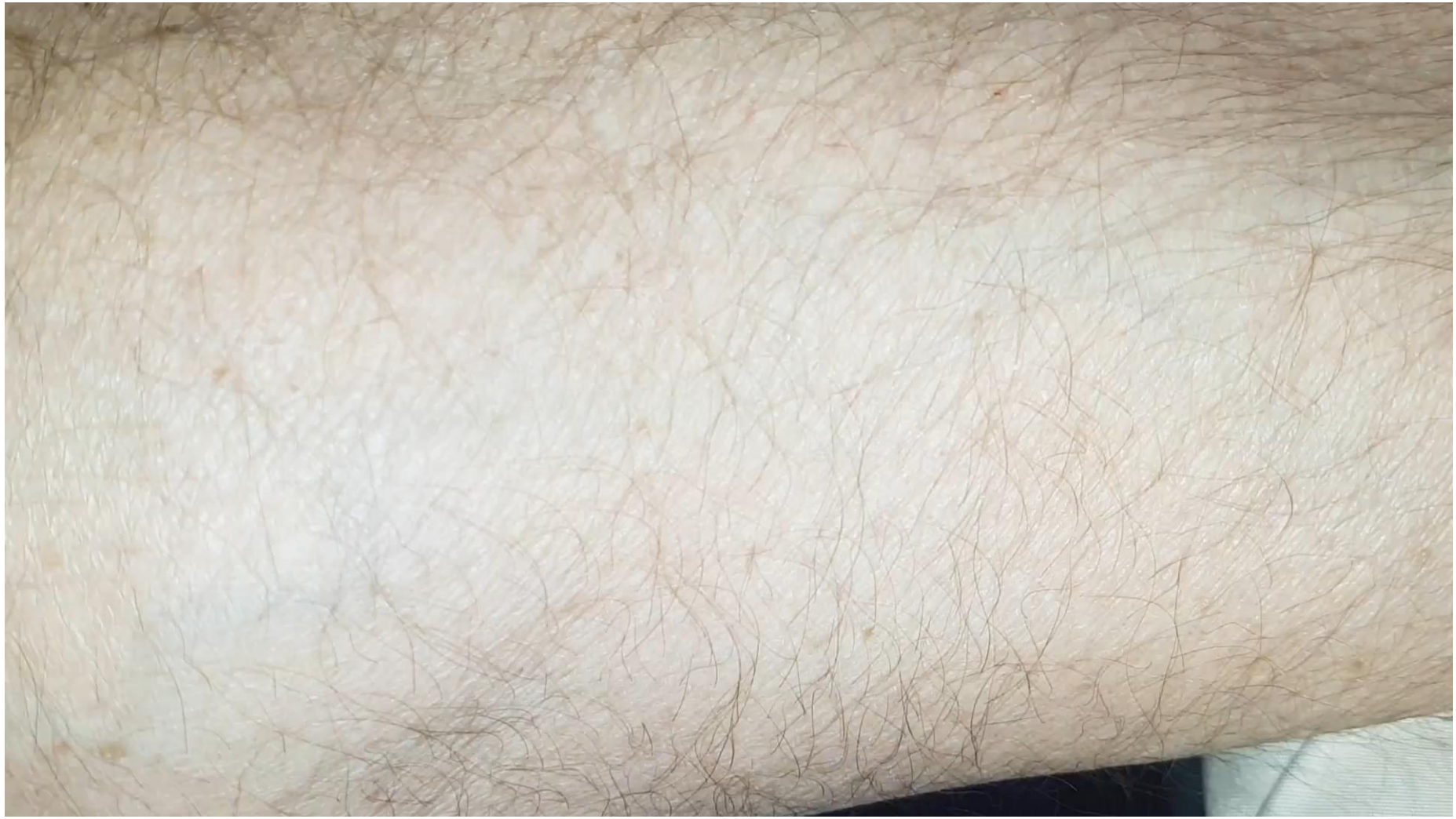
Jiggle CMT II



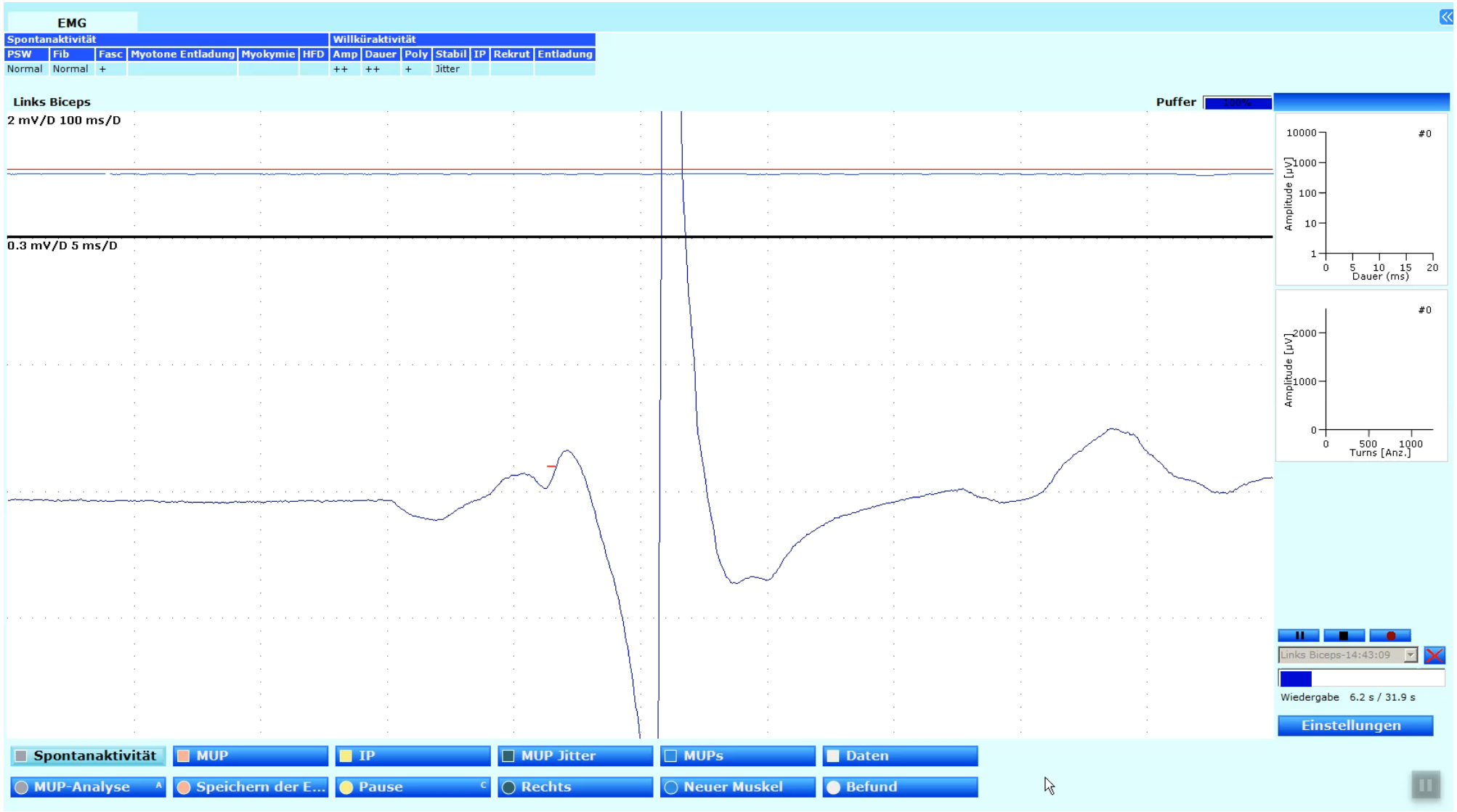
Fasciculations



Fasciculations



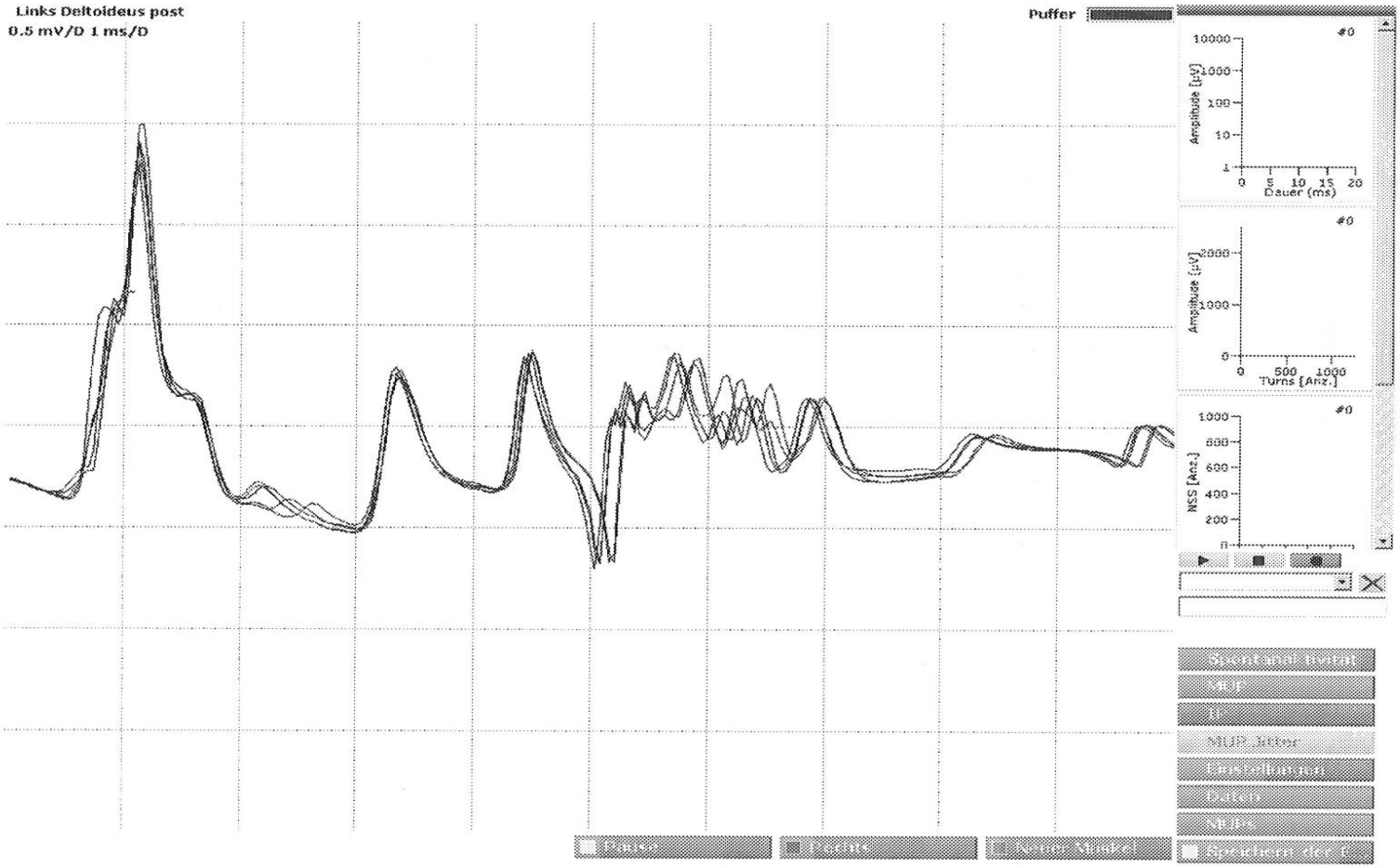
EMG changes in ALS: Fasciculations



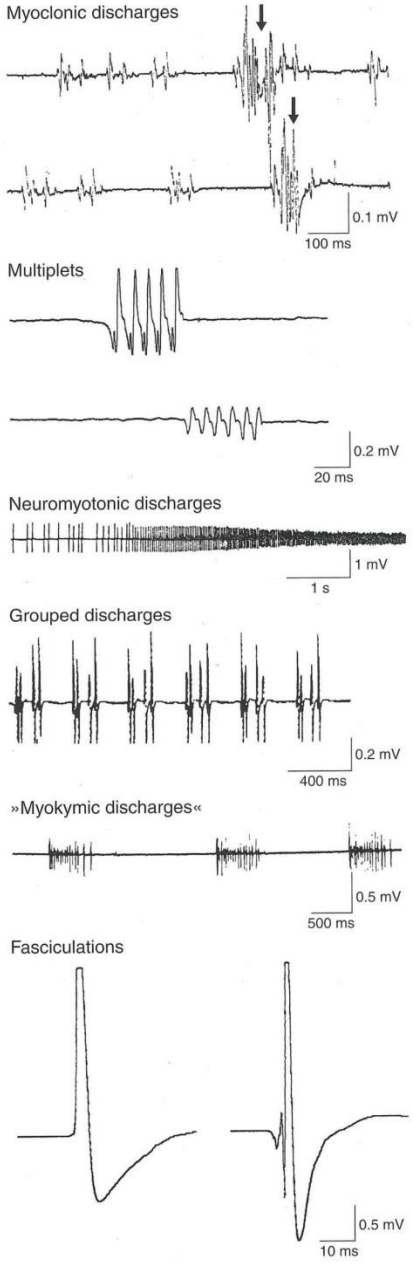
Clinical examples: Chronic inflammatory demyelinating neuropathy (CIDP)

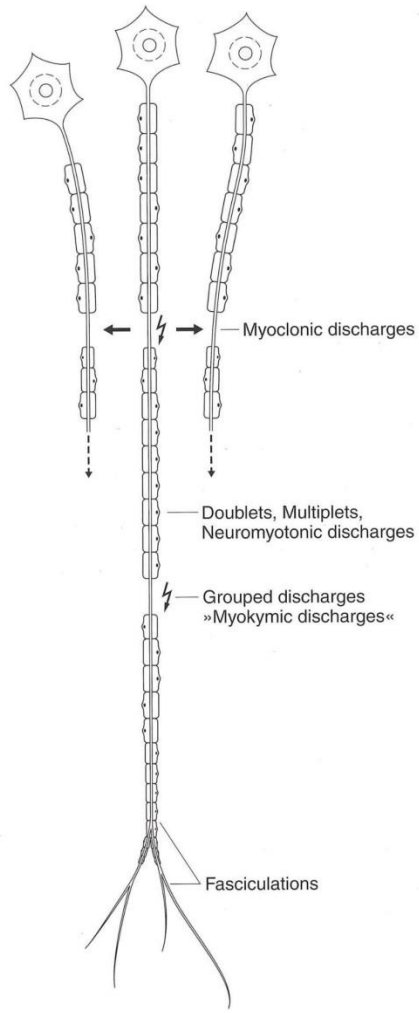
- Demyelinating disease
- Autoimmune
- Secondary axonal loss
  - Very slowly
  - Lots of time to reinnervate
  - Very complex unstable MUPs

CIDP

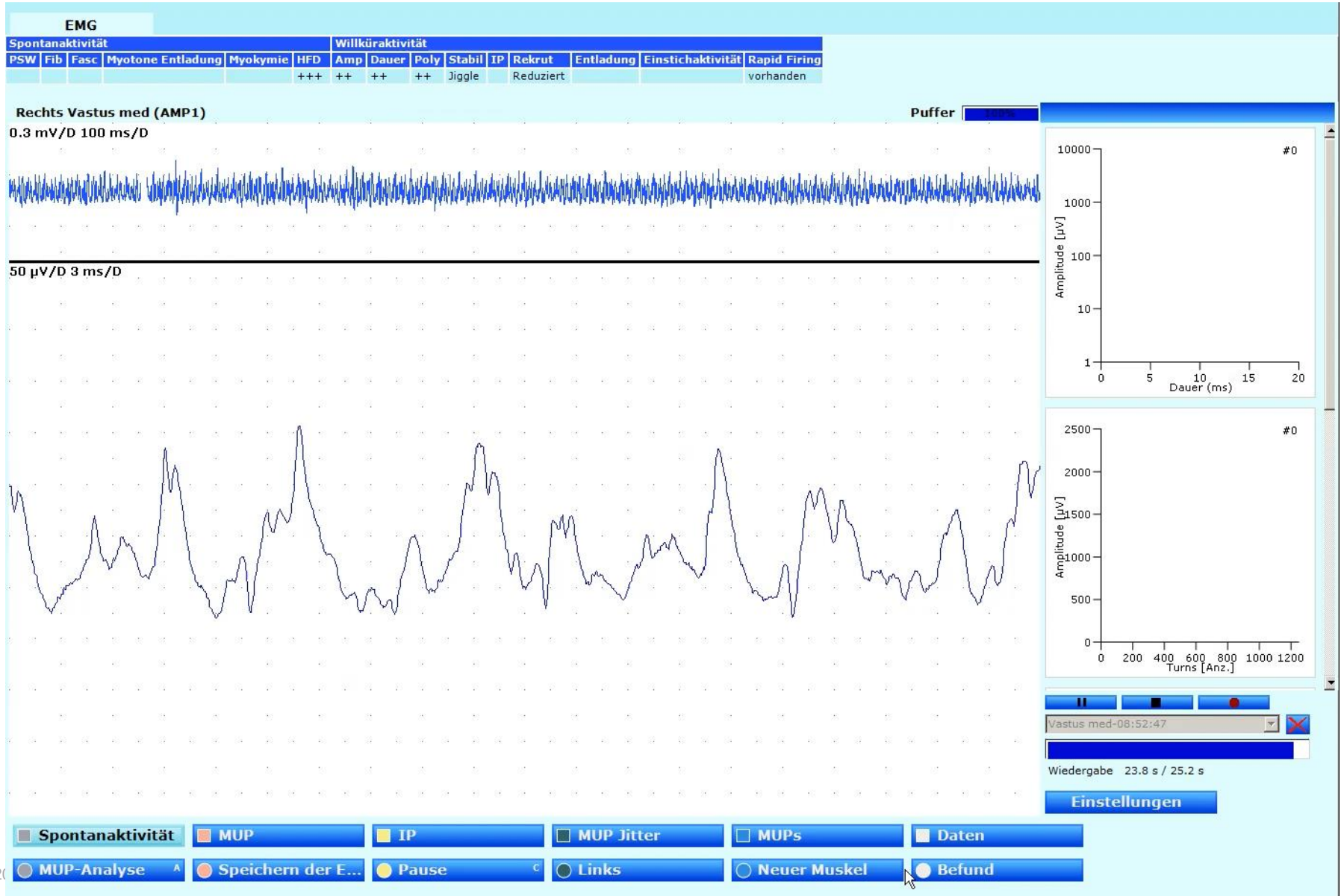

Links Deltoideus post
0.5 mV/D 1 ms/D
Puffer
Amplitude [µV]
Dauer (ms)
Turns [Anz.]
NSS [Anz.]

Other signs of hyperexcit ability

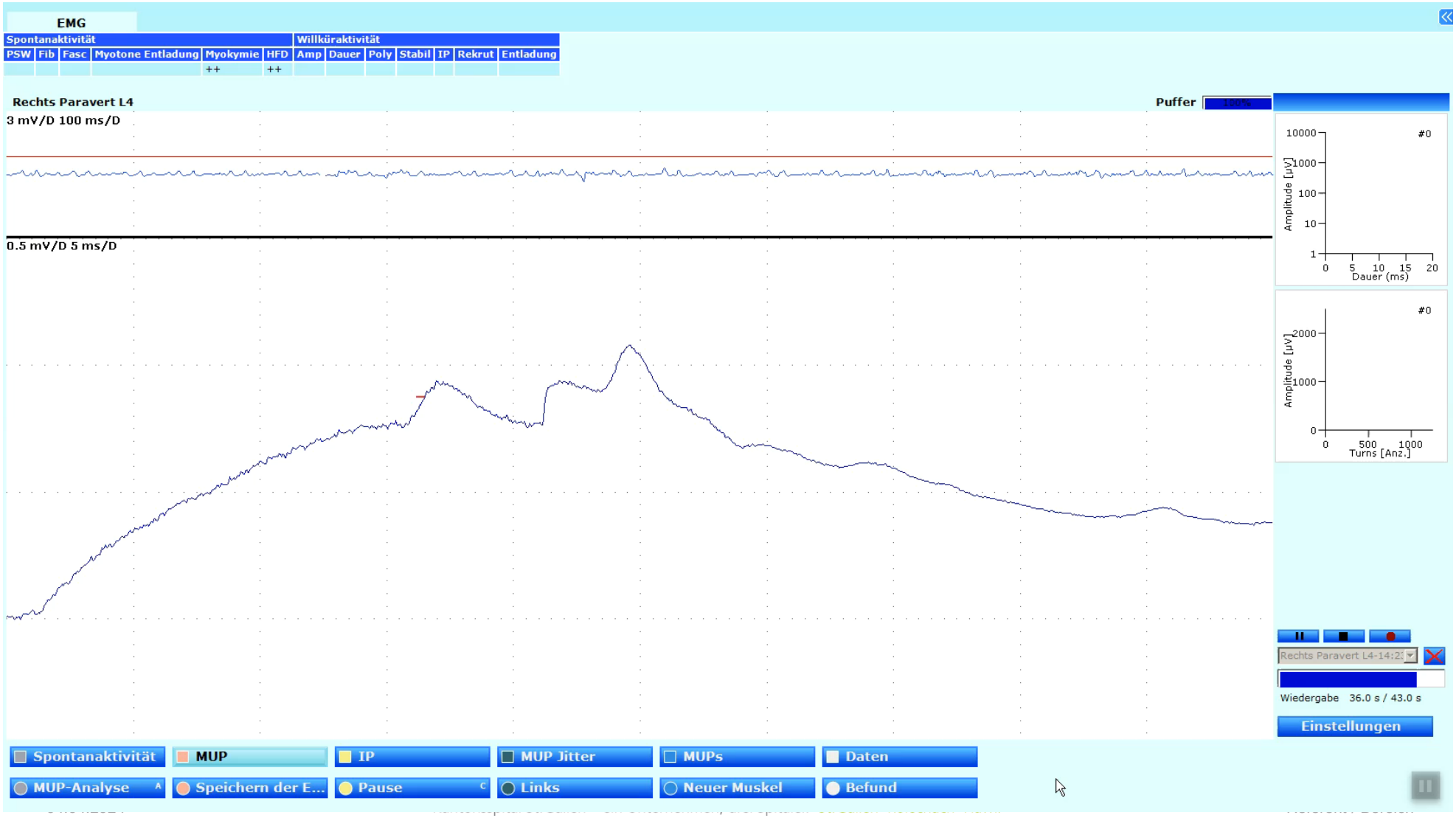




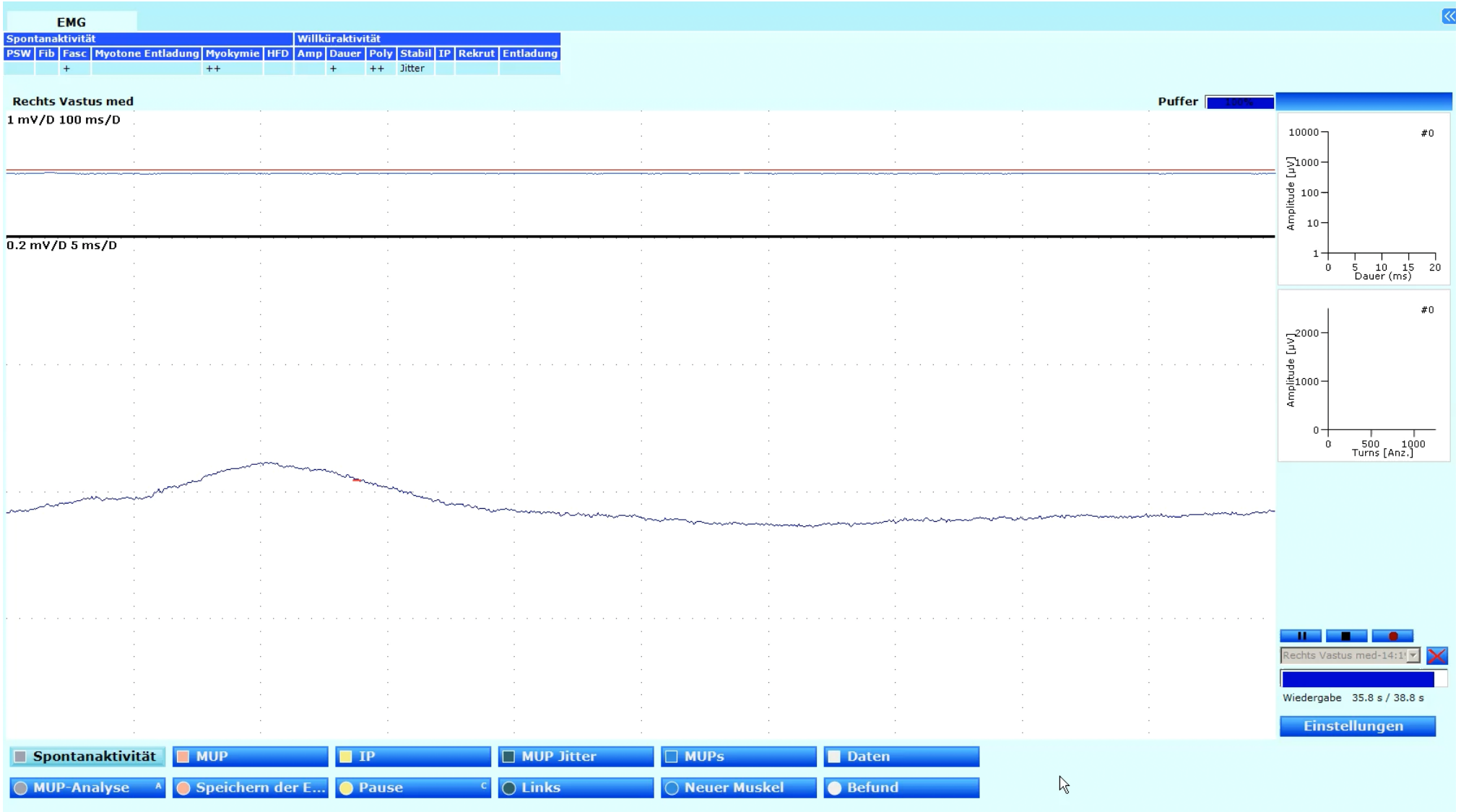
Hyperexcitability



Hyperexcitability



Hyperexcitability




QUIZ
TIME!

Question 1

- Nascent reinnervation occurs within

A. Hours
B. Days
C. Weeks
D. Months
E. Years

Question 2

- Terminal sprouting occurs within

A. Hours
B. Days
C. Weeks
D. Months
E. Years

Question 3

- Which statement is **wrong**
- Signs of active denervation include:

A. Fibrillation potentials
B. Positive sharp waves
C. Fasciculation potentials
D. All oft he above

Question 4

- Which statement is **wrong**
- With nascent reinnervation MUPs are

A. Complex
B. Unstable
C. Large
D. Fatigue easily

Question 5

- Which statement is **wrong**
- With terminal sprouting MUPs are

A. Complex
B. Stable
C. Normal to large
D. Show Jiggle
E. Long duration

Question 6

- The following statements relate to the triggered MU
- What do you see ?

A. A complex unstable MU

B. A normal MU

C. Satellite potential

D. All 3

Question 7

- The following statements relate to the recorded potentials.
- Which statement is **wrong** ?

A. All potentials are fasciculation potentials

B. They might occur in demyelinating diseases (e.g. CIDP)

C. They are typical in ALS patients

D. Fasciculation potentials are always abnormal

Question 8

- The following MUP suggests

A. An acute complete nerve lesion

B. An acute partial nerve lesion

C. An intermediate stage of reinnervation

D. A very chronic disease

Question 9

- The following recording suggests which etiology

A. Complete nerve cut

B. Partial nerve lesion

C. Radiation

D. Chronic nerve compression

Question 10

- The duration of the recorded MUP is (sweep speed 8 ms/Div)

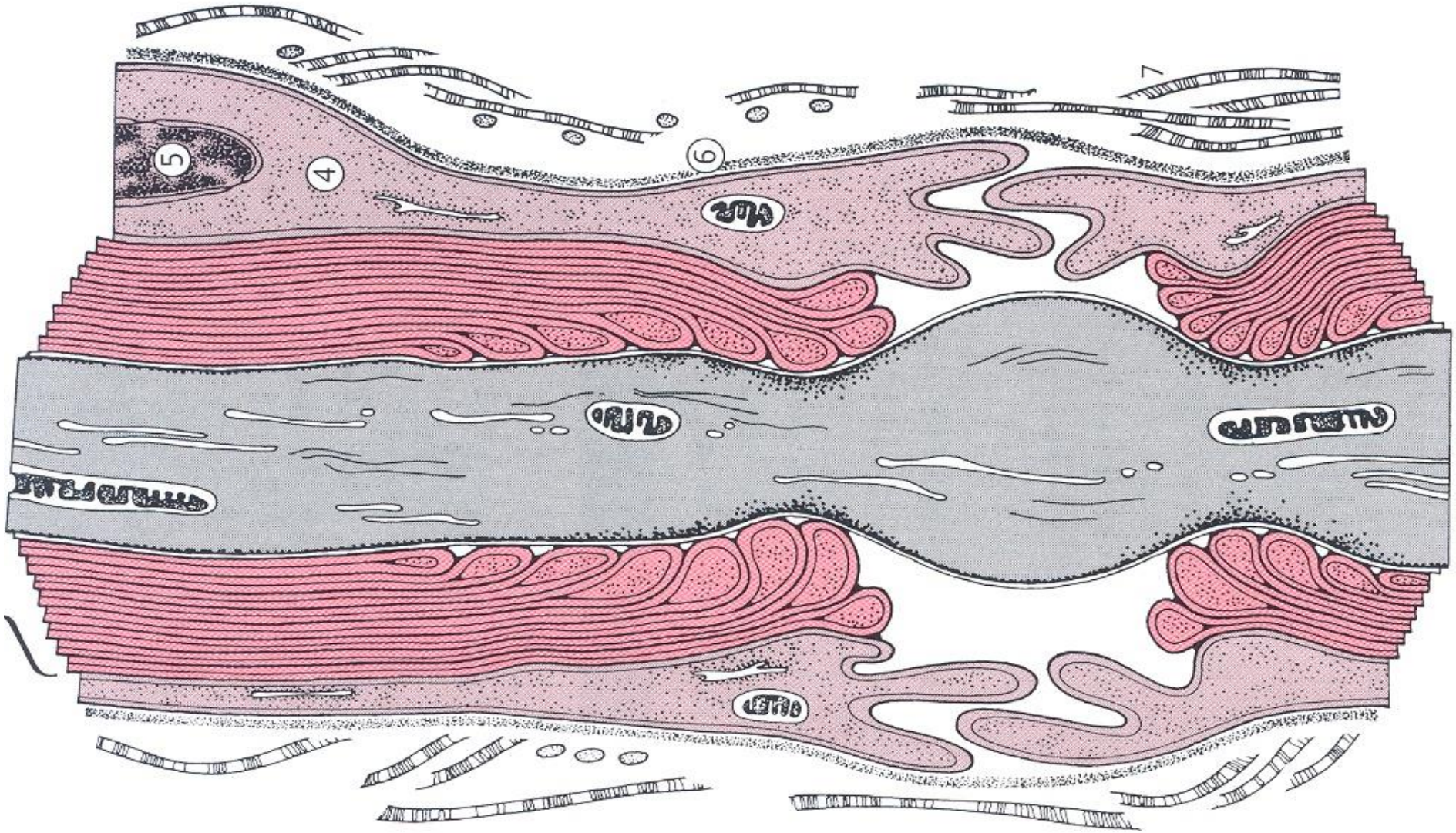
A. 8 ms

B. 16 ms

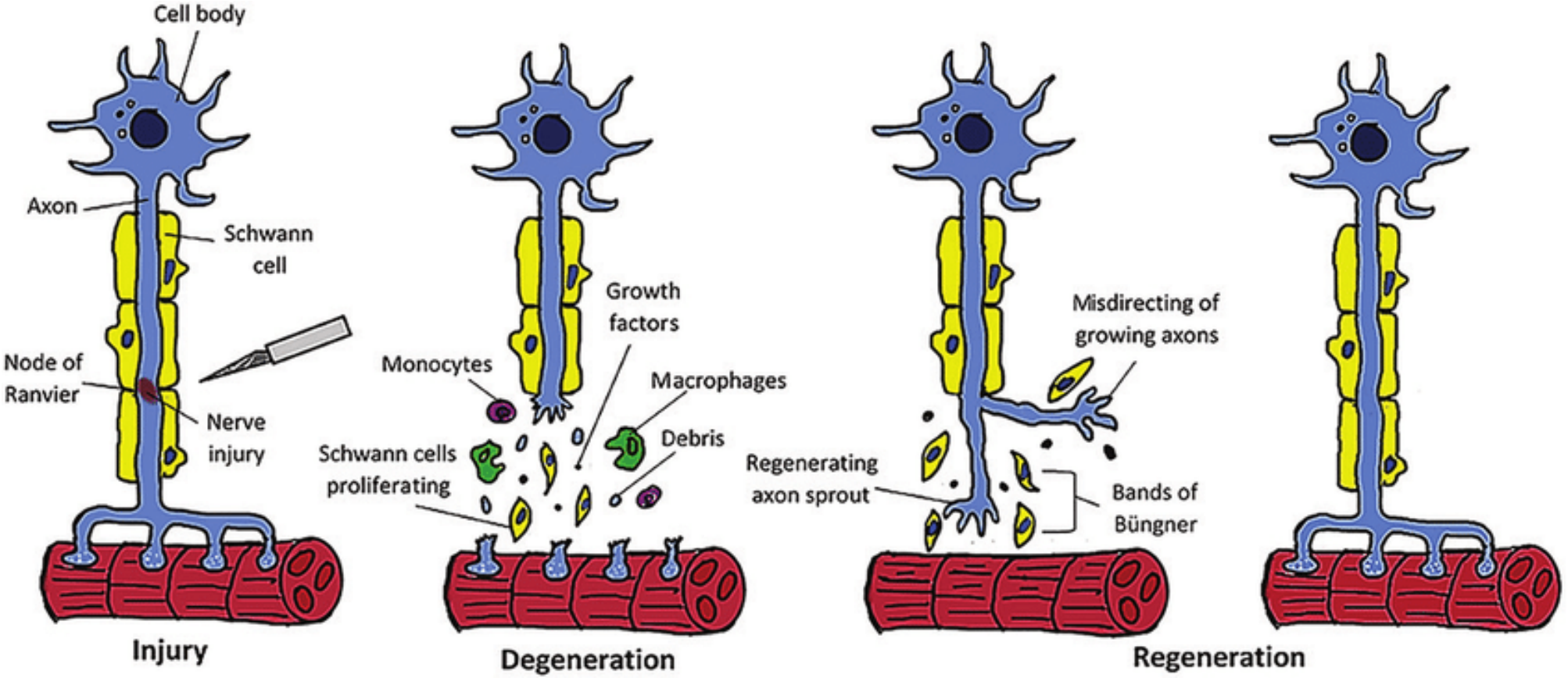
C. 32 ms

D. More than 32 ms

Nerve longitudinal

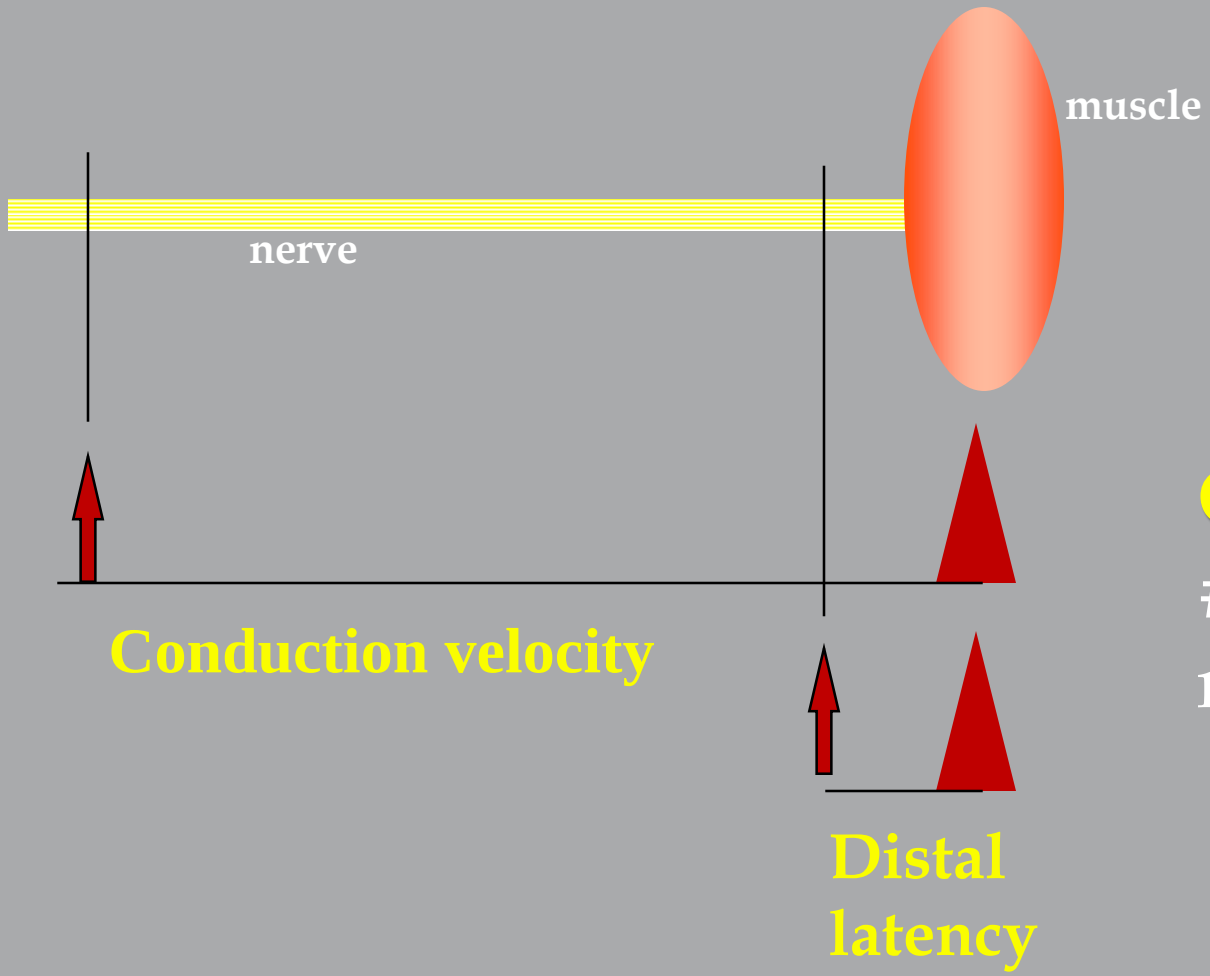


Pathophysiology of denervation and reinnervation Wallerian dgeneration



- DOI:10.5772/intechopen.68174 Alvites et al.
- In book: Mesenchymal Stem Cells - Isolation, Characterization and Applications

Motor nerve conduction study

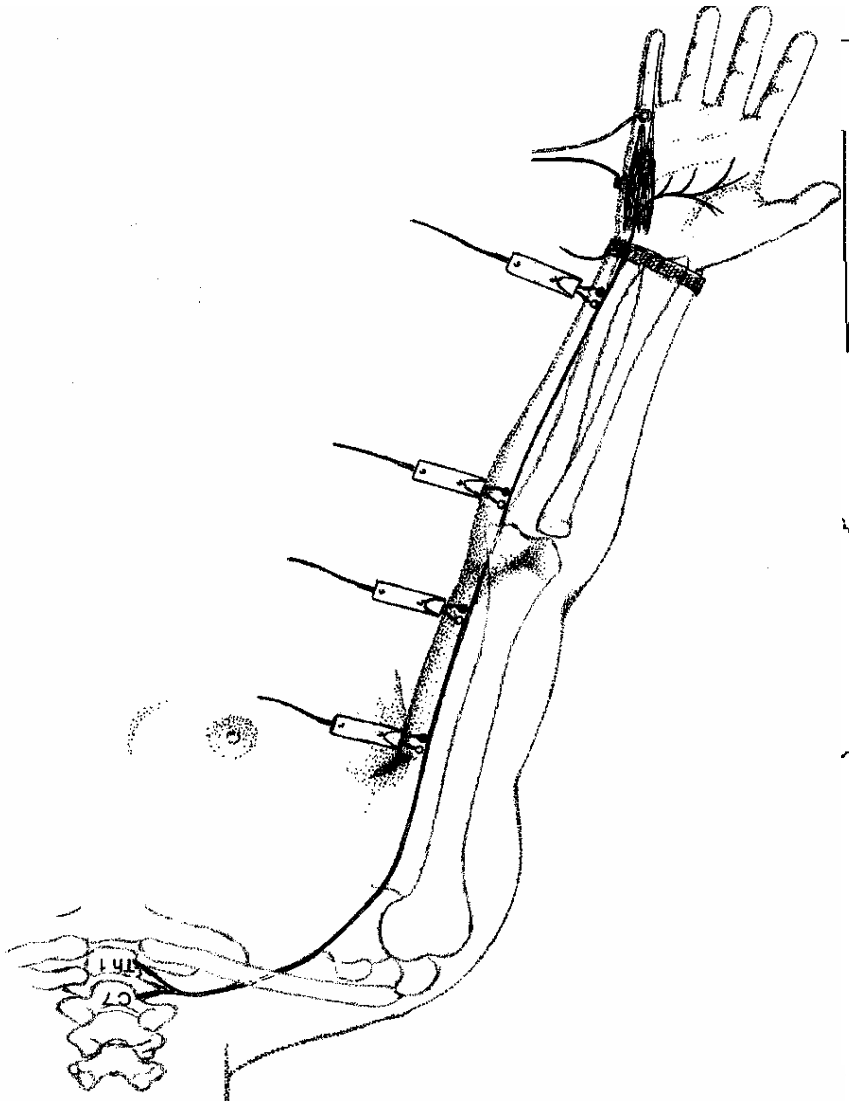


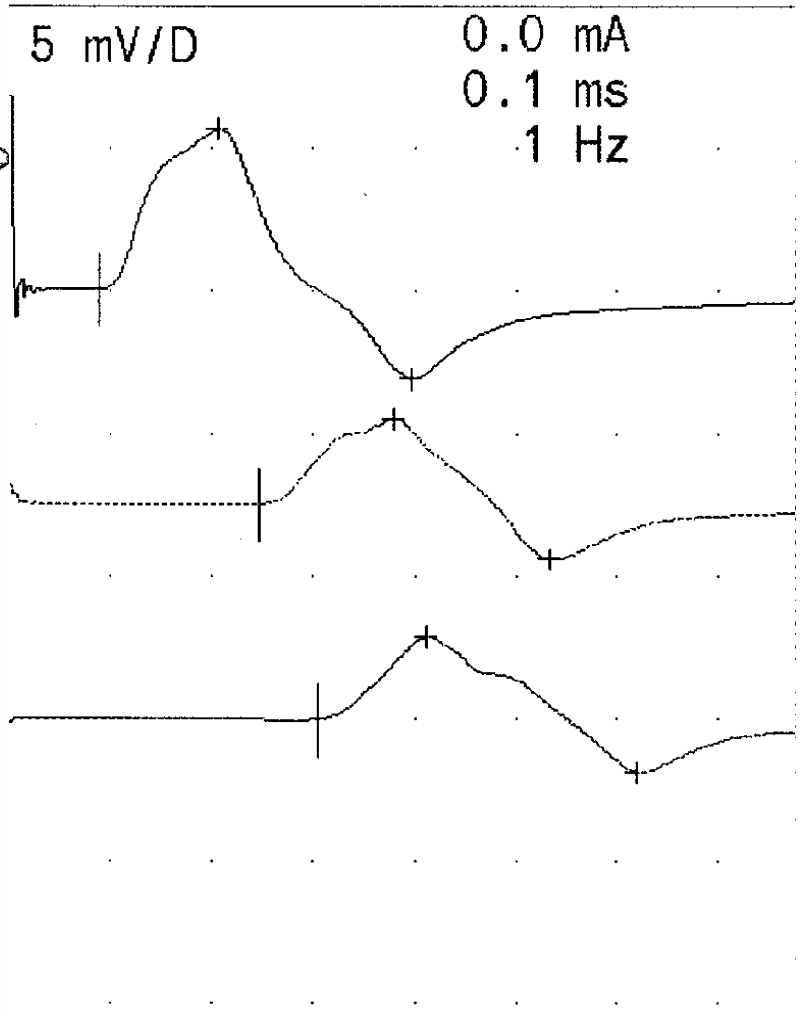
CMAP Amplitude:

# of axons

n-m transmission

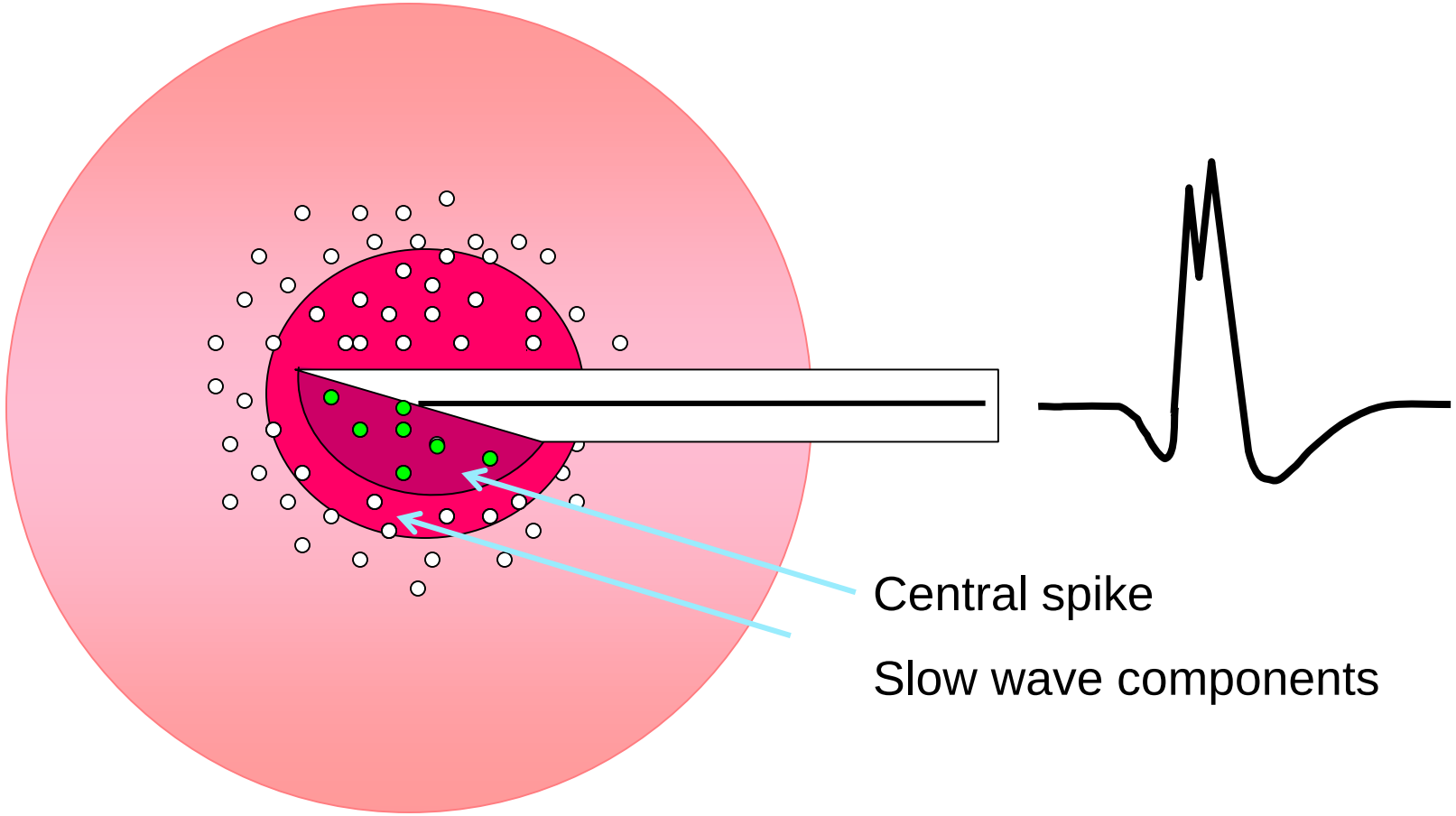
Motor nerve conduction study and compound muscle action potential (CMAP)





dLAT/CV	AMP
2.7	8.7
46.8 m/s	-44 %
7.4	4.9
55.6 m/s	-3 %
9.2	4.7

Electromyography with concentric needle: signals from 2-15 muscle fibres



Spontaneous activity in normal

- insertional activity
- end-plate noise
- ”nerve spikes”
- positive wave at end-plate zone