

CME & UEMS-EACCME® Meeting

EMG WITHOUT PAIN:

Advanced Course on Patient-Centered Needle EMG Examination

April 20-21, 2026

Genoa, NH Marina



CME & UEMS-EACCME® Meeting

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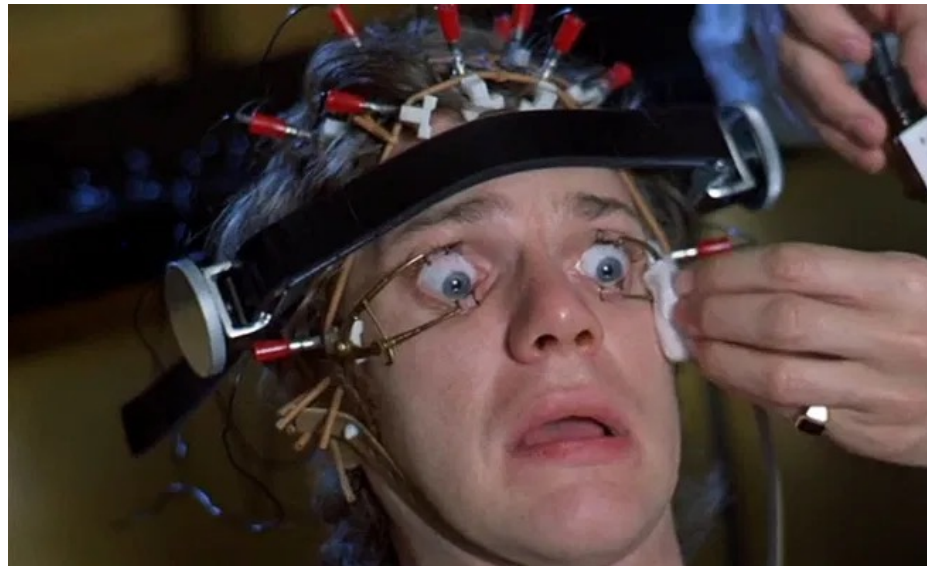
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Electrical stimulation and pain

François Charles WANG



A Clockwork Orange, Stanley Kubrick (1971)

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 ITALIAN ACCREDITATION (CME)

Conflict of Interest Declaration

I, the undersigned **François Charles WANG**, in my capacity
as Faculty Member of the event

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declare

that I have NOT had any financial relationships
with entities holding commercial interests
in the healthcare sector over the past two years.

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EUROPEAN ACCREDITATION (EACCME®)

Conflict of Interest Disclosure Form

(to be completed by Scientific/Organizing Committee Members)

EMG WITHOUT PAIN: ADVANCED COURSE ON PATIENT-CENTERED NEEDLE EMG EXAMINATION

NAME: **WANG**

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DISCLOSURE

☒ I have no potential conflict of interest to report

☐ I have the following potential conflict(s) of interest to report

_____ *Type of affiliation / financial interest & Name of commercial company*

Receipt of grants/research supports:

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Participation in a company sponsored speaker's bureau:

Stock shareholder:

Spouse/partner:

Other support (please specify):

- The same actions improve both the **tolerance** and the **quality** of the examination



- Each test can be made **painless**, provided one consistently pays attention to it

- It is never pointless to **test the procedures on myself**

General Considerations

Collective unconscious

- death in the electric chair
- torture by electricity



One Flew Over the Cuckoo's Nest, Milos Forman (1975)

Subjectivity of Pain

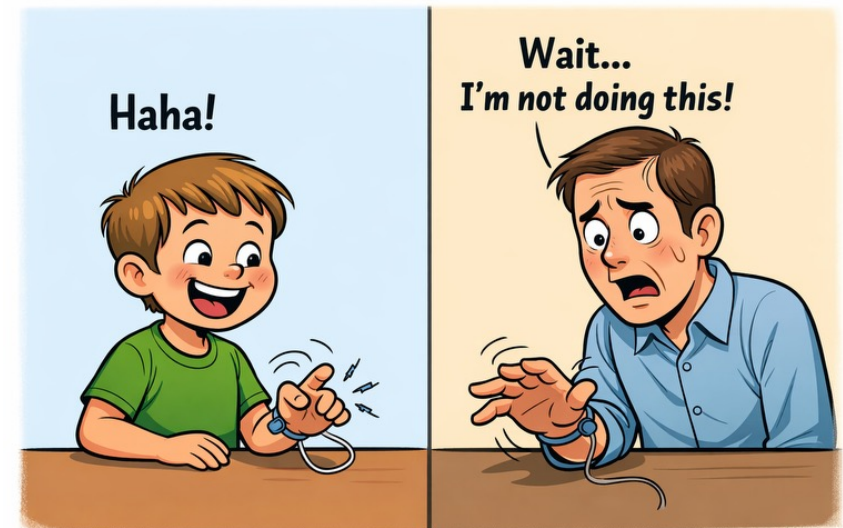
The perception of electrical stimulation varies considerably from one individual to another

- **In children**, it is most often described as a tickling sensation
- **In patients who have previously experienced an electric shock**, stimulation may be perceived as very, or even extremely, unpleasant, due to its association with a prior traumatic experience
- **In anxious individuals**, anticipatory mechanisms enhance pain perception: the expectation of stimulation increases the intensity of the sensation (ex : electrician)

Pain... or Loss of control?

– a child may enjoy seeing their hand move on its own

– more difficult to tolerate for an adult who likes to stay in control of what happens to them



Role of Anticipation

- Pain perception is not purely peripheral; it is strongly **modulated by the central nervous system**
- Anxiety enhances **cortical and subcortical pain processing** through anticipatory mechanisms
- Expectation of discomfort lowers the subjective pain threshold and amplifies perceived intensity
- Conversely, reassurance and clear explanation can reduce anticipatory anxiety and attenuate pain perception via **top-down modulation** mechanisms

Practical consequences

These factors should be taken into account during the examination. It is advisable to:

- **Reassure** the patient;
- Clearly **explain** the procedure;
- Pay **special attention** to anxious patients or those who have previously had a distressing experience involving electrical current

In practice, most patients experience **no discomfort** with properly administered stimulation

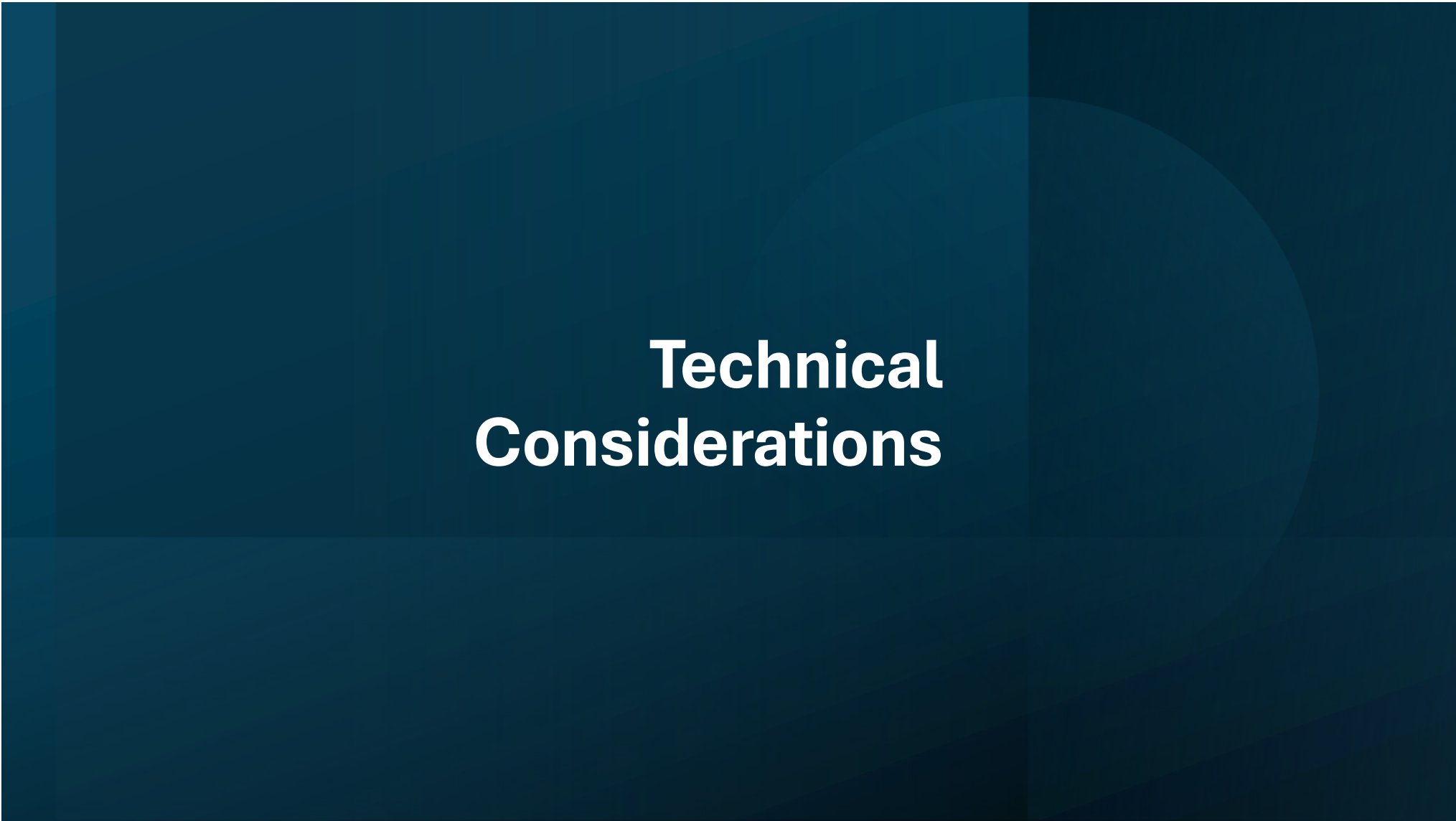
Practical consequences

- avoid any unexpected stimulation
- increase the intensity of the currents only **gradually**, so that the patient can become accustomed to their effects and does not experience the unpleasant element of surprise

It is advisable to ask the patient to report any painful or unpleasant sensations, so that appropriate measures can be taken to eliminate them

The importance of the first step in apprehensive patients

- Suggest performing a minimal procedure, a single test, on a trial basis: a sural nerve study, or a decrement test on the anconeus muscle
- If the first step goes well, propose a second one
- Ultimately, the patient is the one who asks for the examination to be completed in full



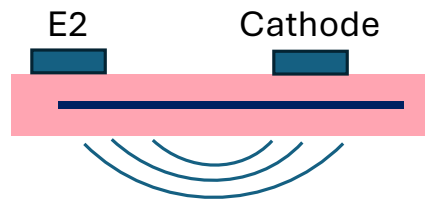
Technical Considerations

Stimulation parameters

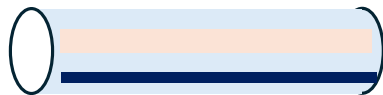
- Intensity**
- Duration**
- Frequency**
- Number of stimulations**

Stimulation parameters

- Intensity
- Duration
- Frequency
- Number of stimulations

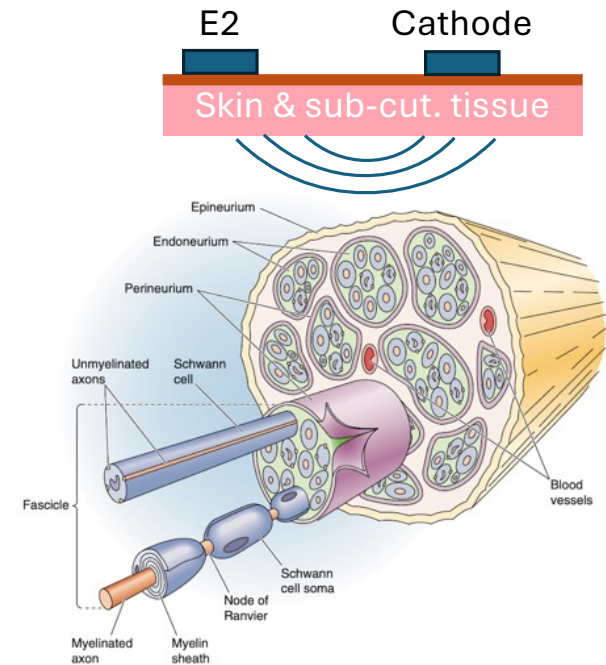


Cutaneous nociceptive fibers



Motor & Sensory fibers
Nervous nociceptive fibers

Topographical factors

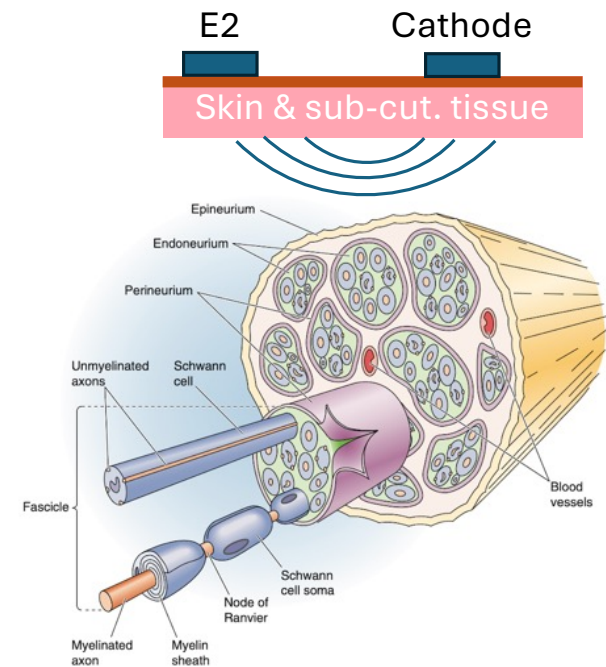


Stimulation parameters

- Intensity
- Duration
- Frequency
- Number of stimulations

Anatomical factors

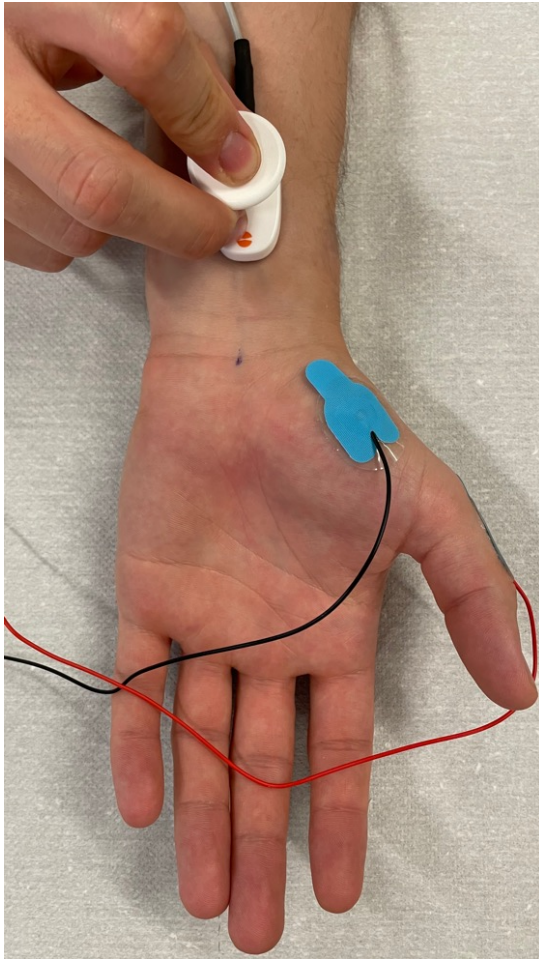
Topographical factors



	Large-diameter sensory and motor fibers (A α and A β fibers, groups Ia, Ib, and II).	Small Nociceptive fibers (A δ and C fibers, groups III and IV)
Myelin thickness	1.7 – 3.5 μ m	< 1 μ m
Axonal diameter	10 – 20 μ m	< 5 μ m
Conduction velocity	40 – 80 m/s	< 20 m/s
Excitability	High	Low

The detection

Motor response detection

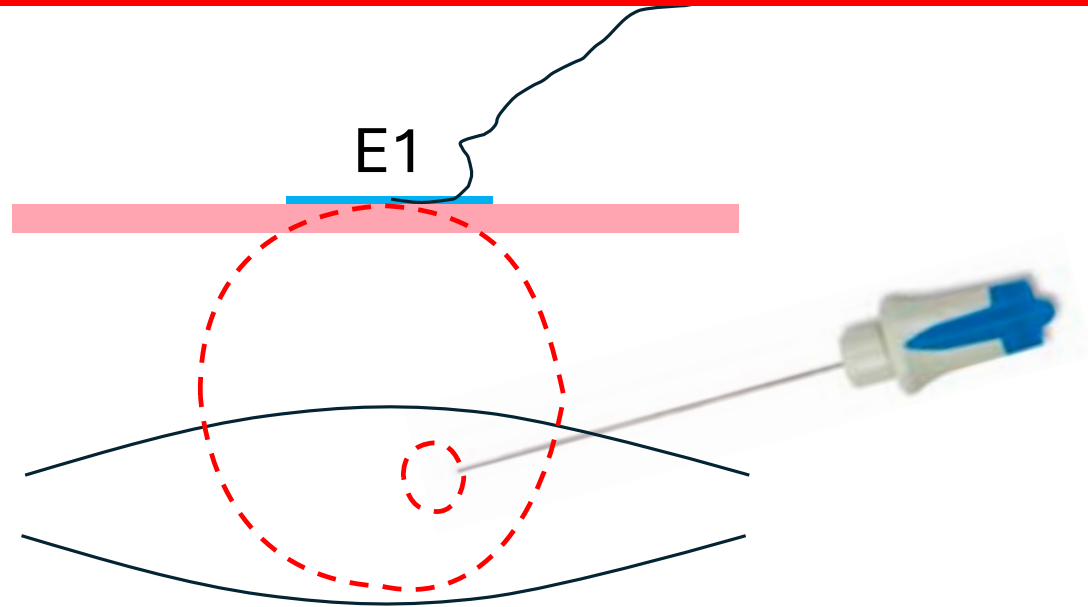
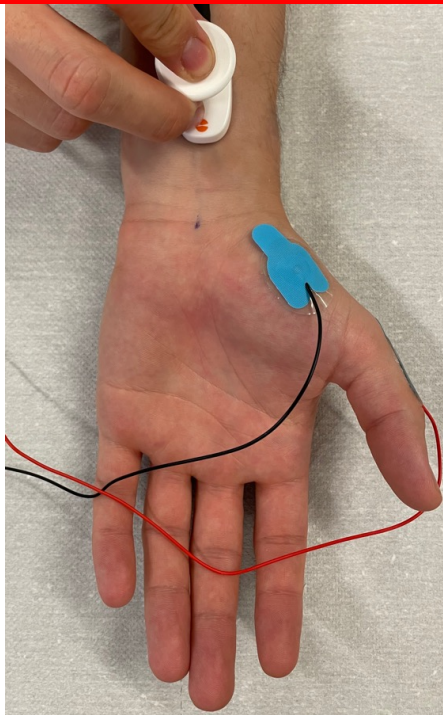


Detection with a needle electrode produces a **tearing muscle pain** related to needle movement caused by electrical stimulation and the resulting muscle contraction



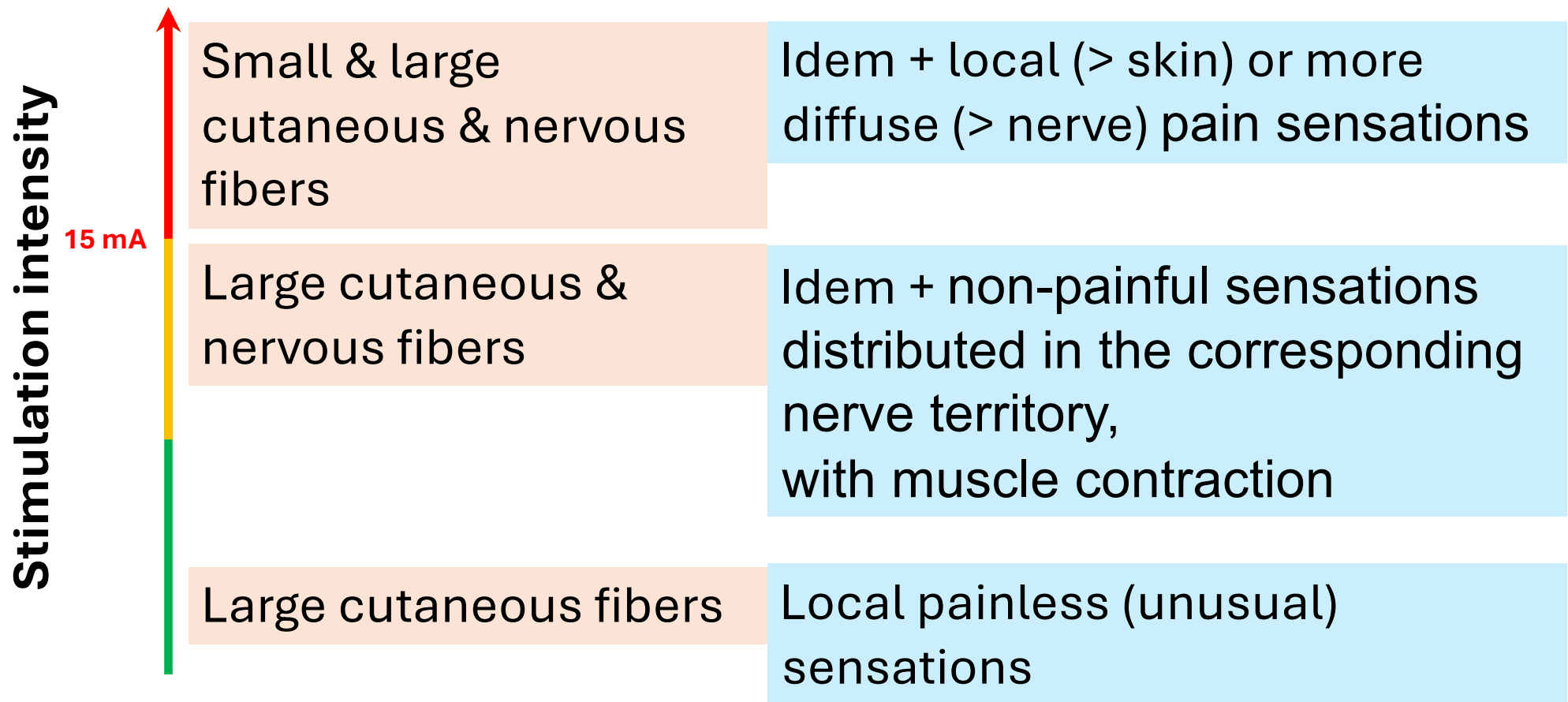
Motor response detection

This is actually advantageous, since in practice recording with surface electrodes provides a more global—and therefore more faithful—representation of the muscle response than needle electrode detection



The stimulation

The lowest possible stimulation intensity



The lowest possible stimulation intensity

In practice : use the minimum stimulation intensity necessary, keeping in mind that if 10 mA are sufficient, 50 mA will be **painful**

- position the **stimulating electrodes** as accurately as possible so as to place them close to the course of the nerve and obtain the desired response with the **lowest possible current intensity**
- do not exceed **10 – 20 % above the maximal intensity**

The lowest possible stimulation intensity

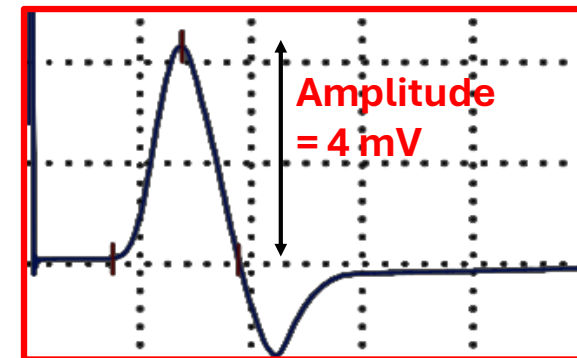
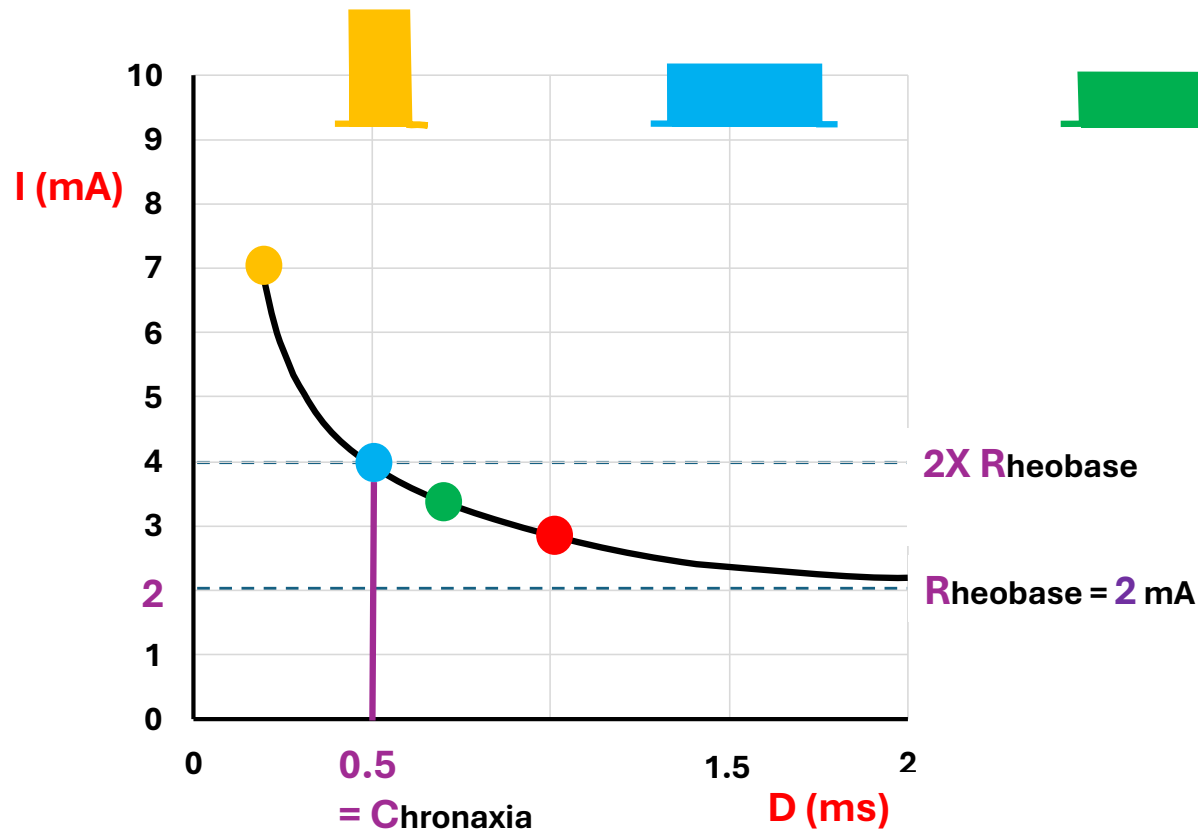
Skin Impedance

- Skin impedance varies depending on its level of hydration, temperature, the thickness of the *stratum corneum*, and the quality of skin preparation
- High impedance (**dry** or **poorly prepared skin**) requires a higher voltage to achieve the same current, which may **increase discomfort**
- Adequate skin preparation (**cleaning** and, when appropriate, **gentle abrasion**) reduces impedance and allows effective stimulation with **lower perceived intensity**

Scientific evidence
?

The lowest possible stimulation intensity

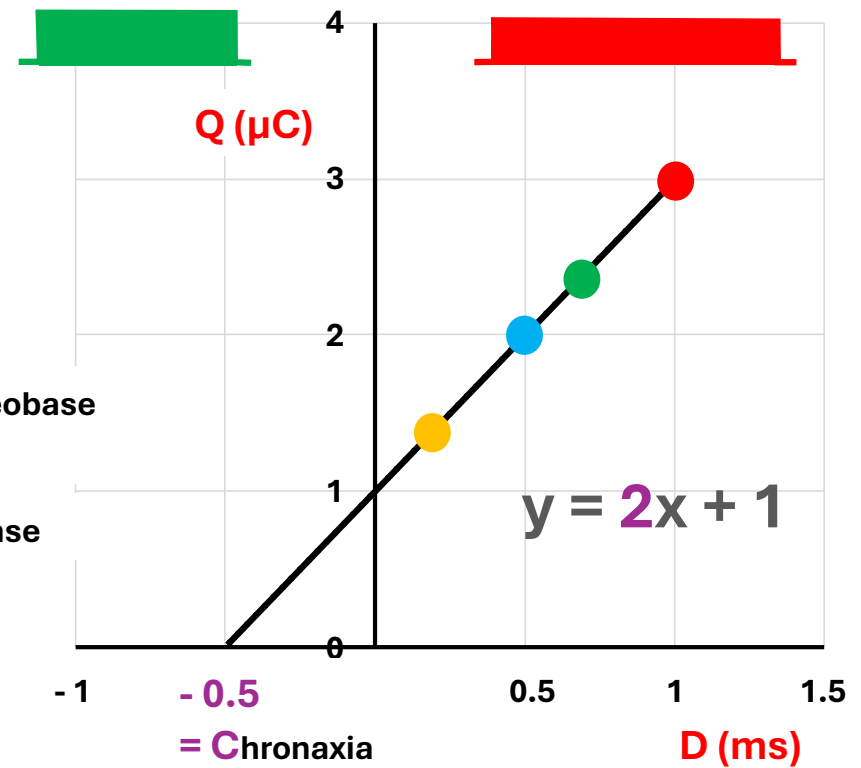
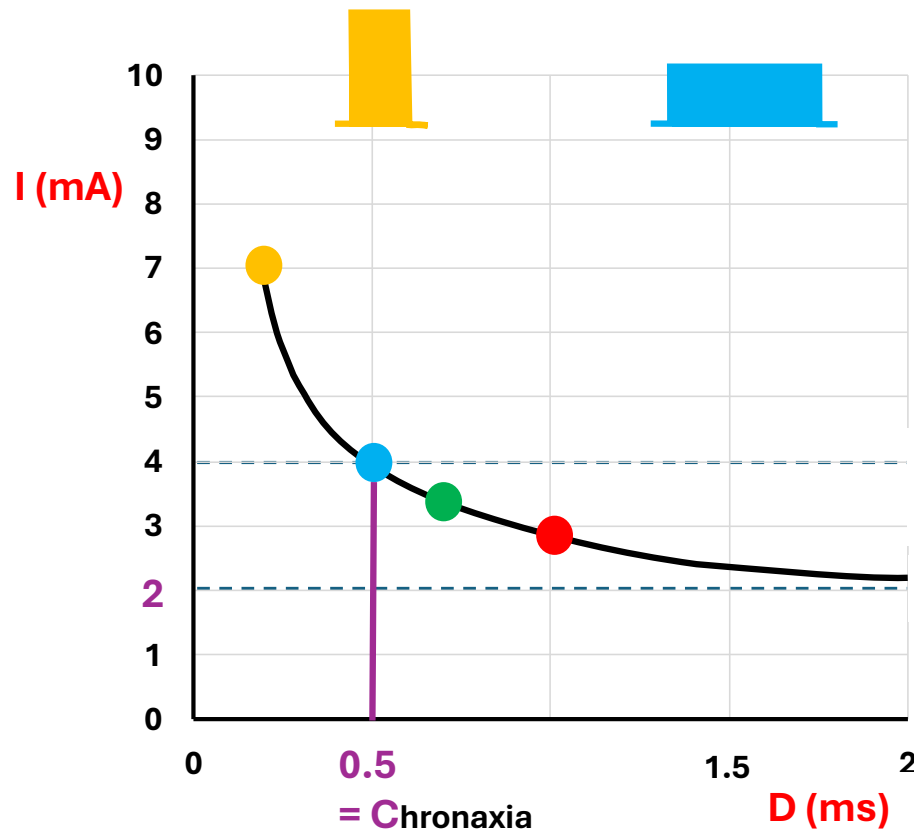
Skin Impedance



CMAP

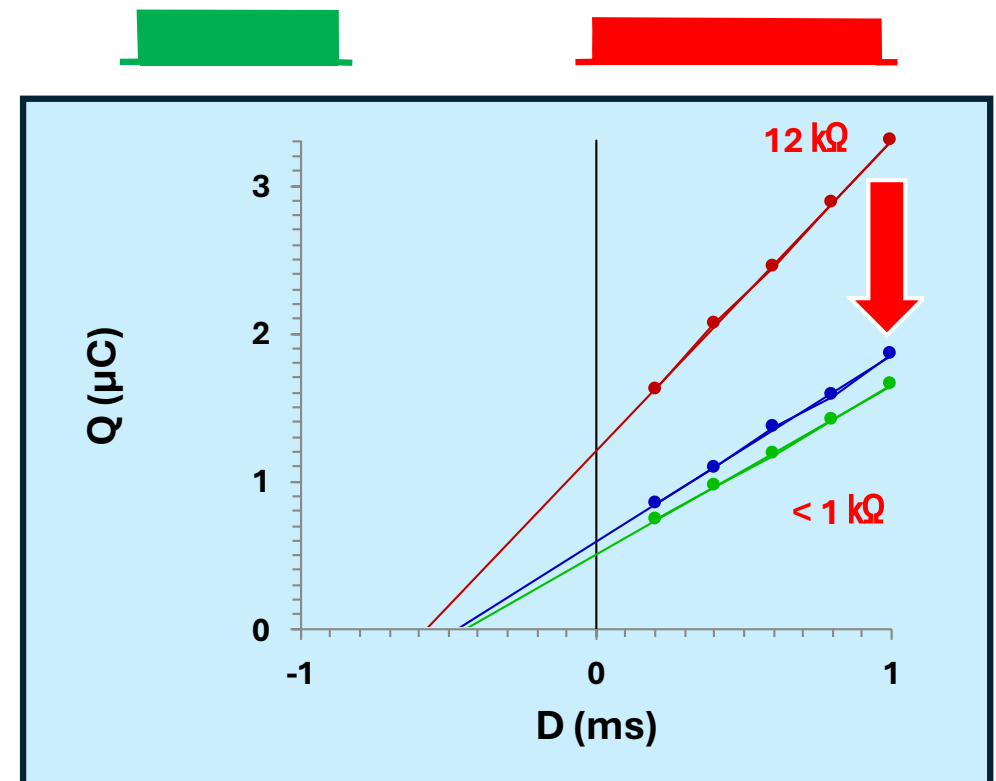
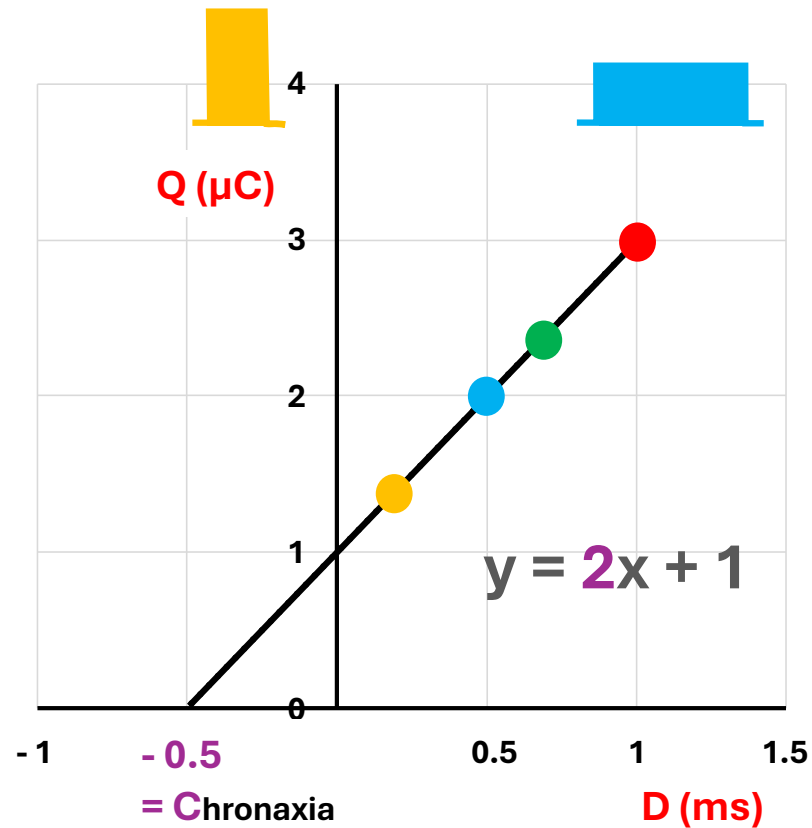
The lowest possible stimulation intensity

Skin Impedance



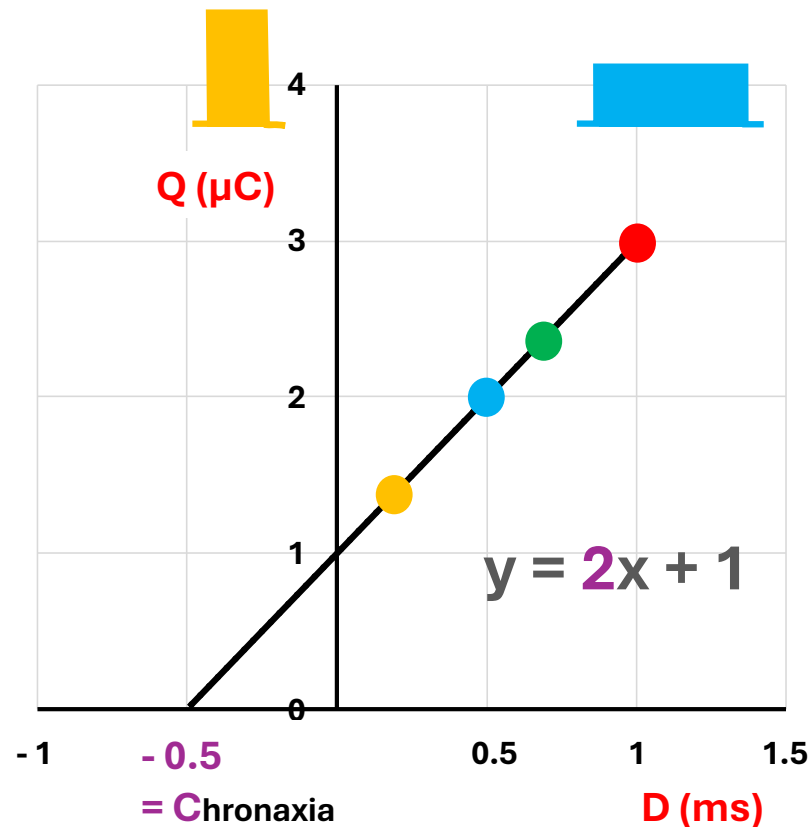
The lowest possible stimulation intensity

Skin Impedance



The lowest possible stimulation intensity

Skin Impedance



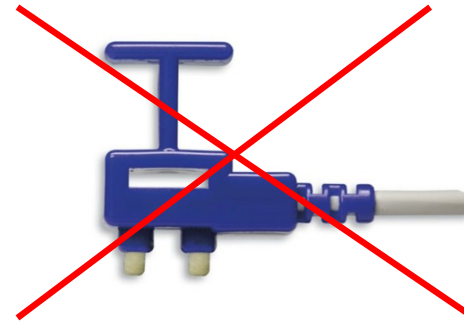
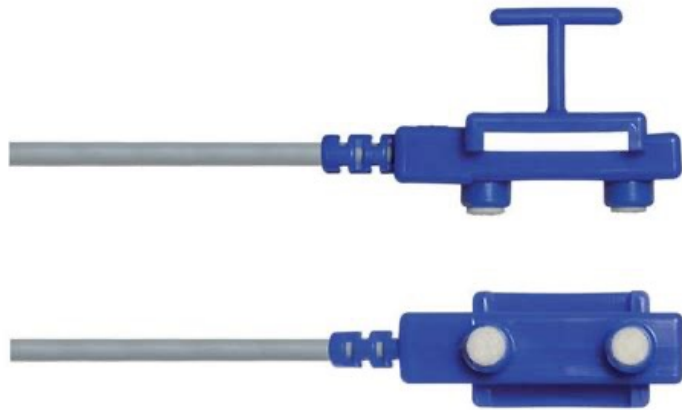
Moreover, to make the stimulation less painful increasing the stimulus duration is sometimes suggested

But this increase in duration:

- increases the total charge delivered,
- may favor the activation of nociceptive fibers, whose chronaxia is longer than that of large-diameter fibers

**Which type of stimulator
?**

The lowest possible current density



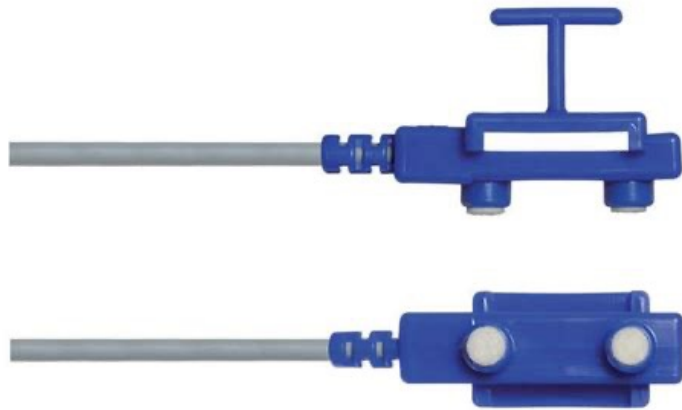
Pediatric stimulator

Electrode Surface Area

Current density is a key determinant of **discomfort**

- Small electrodes concentrate the current over a limited area, increasing current density and thereby **pain**
- **Larger electrodes** distribute the current more evenly, reducing local current density and **improving tolerance**

Pad or metal-tipped electrodes

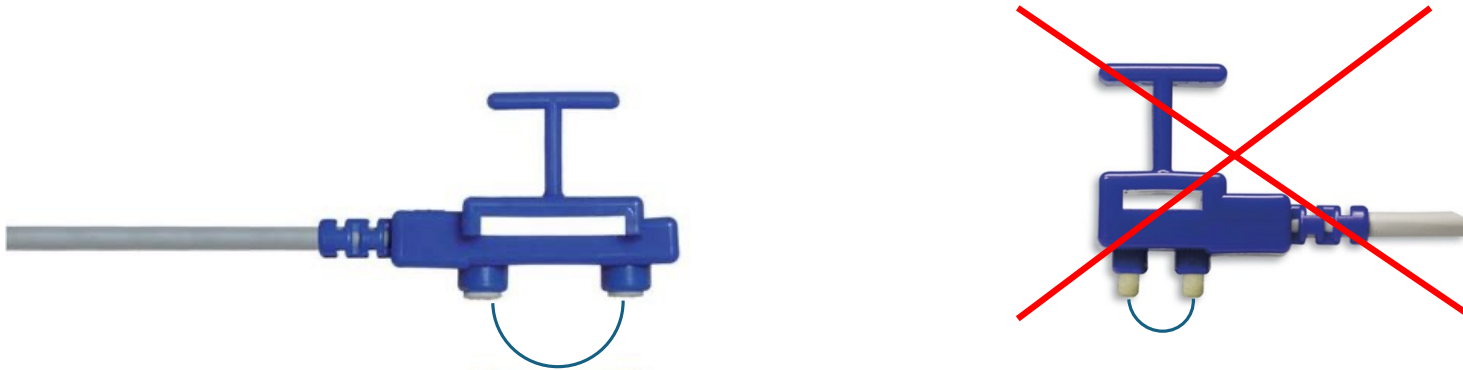


Metal-tipped

By allowing the current lines to concentrate at the surface, metal-tipped electrodes produce a sharp painful sensation on the skin

In practice: always stimulate using electrodes with moistened felt or sponge pads

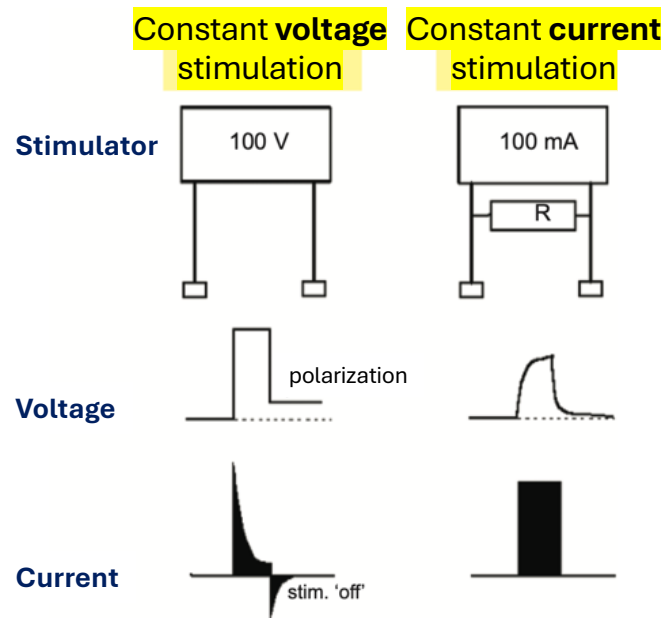
Distance Between Anode and Cathode



The interelectrode distance influences the depth and spatial distribution of the electric field

- A **shorter distance** concentrates the electric field superficially, **increasing activation of cutaneous nociceptors**
- A greater distance spreads the field more broadly and may reduce local peak current density, potentially improving comfort

Constant current or constant voltage stimulation ?



Pierre GUIHENEUC

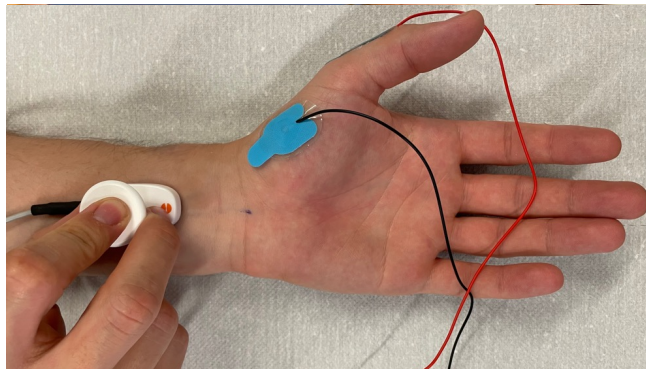
Constant current stimulation

- current more stable
- **better tolerated**
- reduced artefact

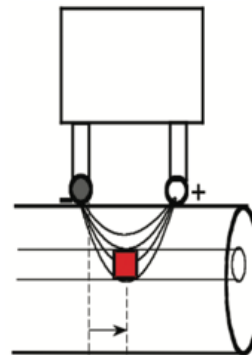
Constant voltage stimulation

- initial current spike
- **pain**
- polarization
- stimulation off

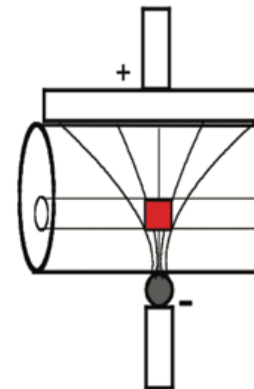
Bipolar or monopolar stimulation ?



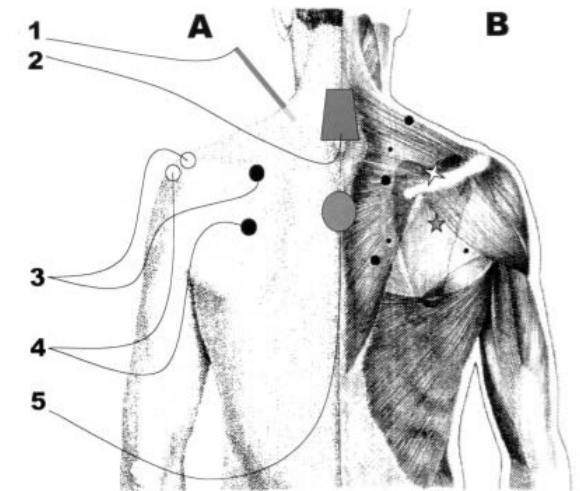
Bipolar stimulation



Monopolar stimulation



Pierre GUIHENEUC



Guy MONNIER

	Bipolar stimulation	Monopolar stimulation
Electric field density under the cathode	Low	Higher
Stimulation artefact	Reduced	Larger
Exact stimulation site	Shifted between the two electrodes	Directly beneath the cathode

Bipolar or monopolar stimulation ?

In practice : favor current delivery to the nerve under study.

- stimulate the nerves at sites requiring the lowest activation intensities, in practice where the nerves are most superficial

Median nerve

At the wrist

Ulnar nerve

At the wrist & above the elbow

Fibular nerve

At the ankle & *poplita fossa*

Tibial nerve

At the ankle

Facial nerve

At the cheek

Bipolar or monopolar stimulation ?

In practice : favor current delivery to the nerve under study.

- Press the stimulator against the skin, without excessive force, to bring it closer to the nerve

Median nerve

At the elbow

Ulnar nerve

Below the elbow

Fibular nerve

Below the *fibula* head

Tibial nerve

At the *poplitea fossa*

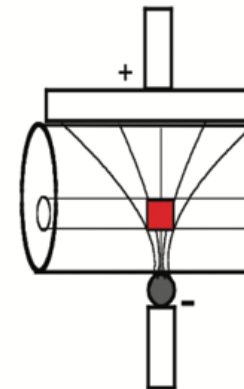
Bipolar or monopolar stimulation ?

- Monopolar stimulation is :

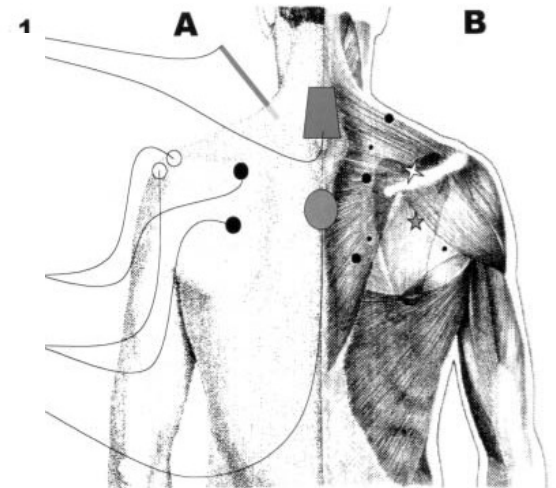
more effective and **less painful** when the nerves are deep (e.g., Erb's point at the brachial plexus)



Monopolar stimulation



Pierre GUIHENEUC



Guy MONNIER

Repetitive Nerve Stimulations

Stimulation frequency

Repetitive Nerve Stimulation (RNS)

- A stimulation that is not painful when delivered in isolation may become painful when repeated too frequently
- Through a **temporal summation effect**, repetitive stimulation (> 3 Hz) produces a painful sensation.

It is all the more painful:

- the higher the repetition frequency
- the longer the stimulation lasts
- when motor fibers are activated (due to muscle tetanization)
- and even more so, when nociceptive fibers are activated

Stimulation frequency

Repetitive Nerve Stimulation (RNS)

Motor nerve conduction study

- space the stimulations at intervals of at least 1.5 to 2 seconds (0.7 – 0.5 Hz)
- **in patients with neuropathic pain, the temporal summation effect may be more pronounced, the stimulation frequency should therefore be reduced further**

Sensory nerve conduction study

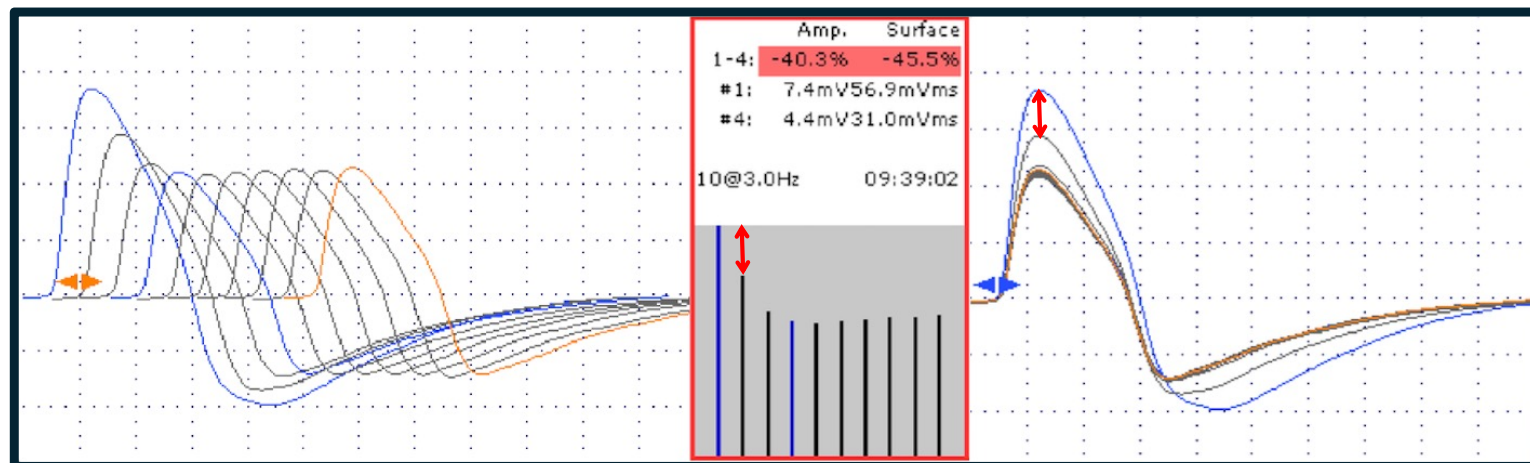
- during studies involving averaging, reduce, if necessary, the frequency at which successive electrical stimulations are delivered
- 1 Hz may be tolerated, whereas 3 Hz is not

Stimulation frequency

Repetitive Nerve Stimulation (RNS)



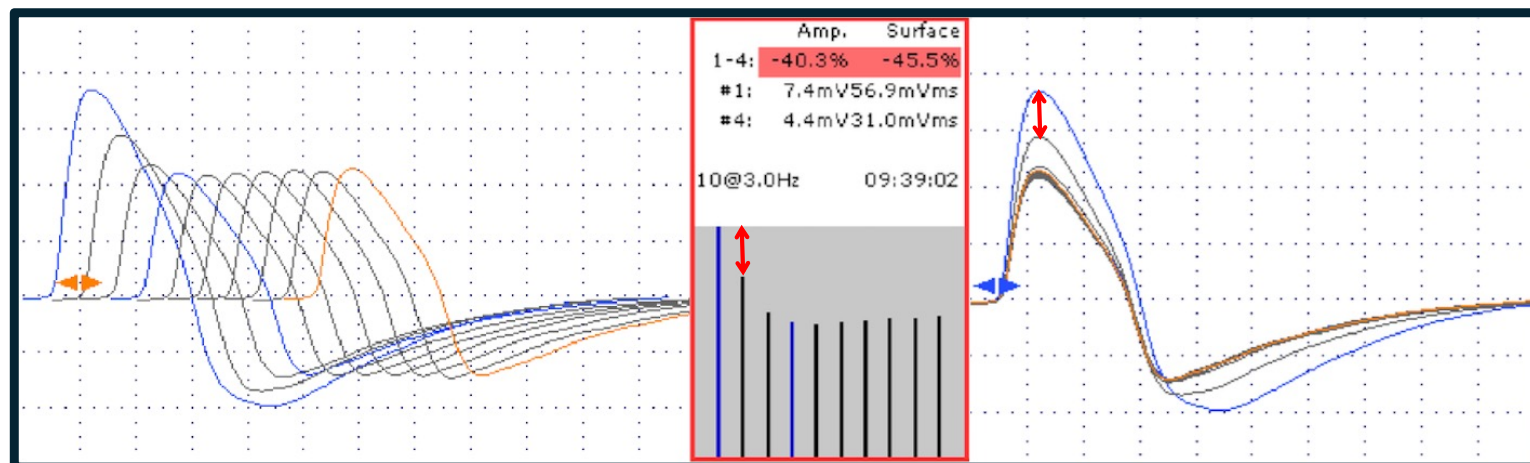
- RNS is more **painful** than random single-pulse stimulation
- RNS should be avoided, especially at frequencies > 1 Hz
- RNS is only justified for studying neuromuscular transmission



RNS and the diagnostic of myasthenia



- In a MG patient, during a train of 10 stimuli at 2 - 3 Hz, the greatest CMAP decrement occurs between the first two stimuli
- In a patient, particularly refractory to electrical stimulation, **two** supramaximal repetitive **stimuli** (2 or 3 Hz) **may be sufficient**



Stimulation frequency



ABSTRACT: We retrospectively evaluated the effect of exercise on the degree of decrement in ulnar, spinal accessory, and facial repetitive nerve stimulation (RNS) in 179 patients with myasthenia gravis (MG) to assess whether exercise increases the diagnostic yield of identifying significant decrements. The mean worsening of decrement following exercise was 1.9% (ulnar nerve), 1.9% (spinal accessory nerve), and 1.3% (facial nerve). Abnormal ($\geq 10\%$) decrement solely following exercise occurred in the ulnar nerve in 7% of patients, accessory nerve in 5%, and facial nerve in 7%. When analyzed according to Myasthenia Gravis Foundation of America class of disease, the likelihood of producing $\geq 10\%$ decrement only after exercise was greatest in class I MG with facial RNS and in class II and III generalized MG with ulnar and spinal accessory RNS. In all other disease stages, the likelihood of producing $\geq 10\%$ decrement only after exercise was $\leq 7\%$. This study suggests that exercise increases the yield of diagnosis of MG by RNS in only a small percent of patients. Therefore, in most patients with suspected MG, RNS at rest is sufficient and the additional time required for prolonged postexercise RNS may be better spent in examining other muscle-nerve combinations.

Muscle Nerve 35: 103–106, 2007

- for the diagnosis of myasthenia, exercise tests are not necessary

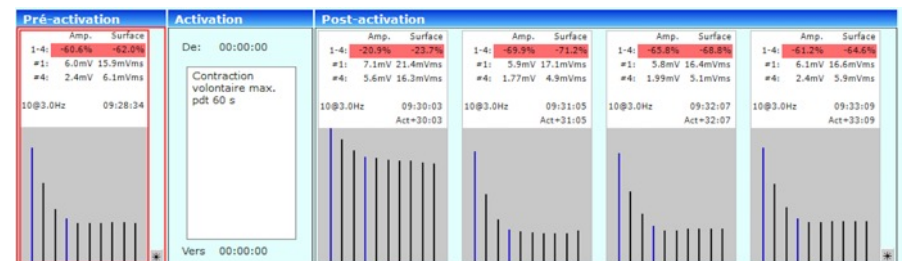
- It is preferable to increase the number of nerve-muscle pairs studied

IS EXERCISE NECESSARY WITH REPETITIVE NERVE STIMULATION IN EVALUATING PATIENTS WITH SUSPECTED MYASTHENIA GRAVIS?

DEVON I. RUBIN, MD, and KENNETH HENTSCHEL, DO, PhD

Department of Neurology, Mayo Clinic, 4500 San Pablo Road, Jacksonville, Florida 32224, USA

Accepted 11 August 2006

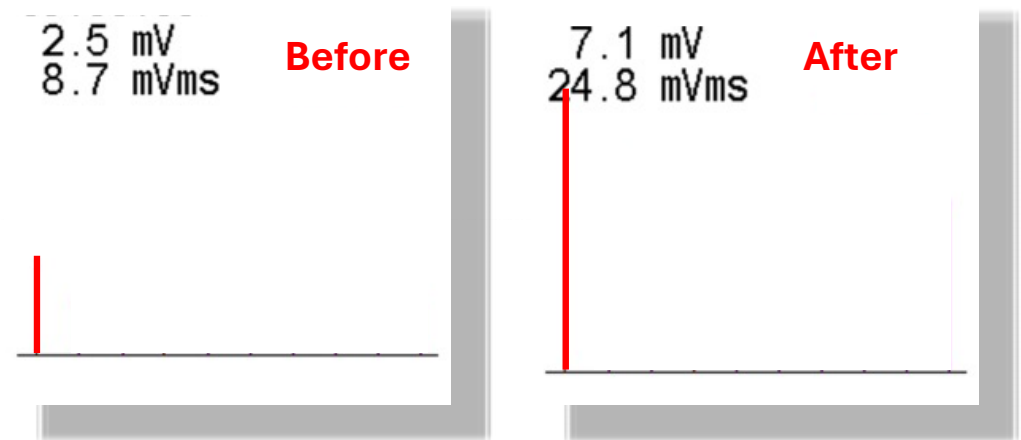
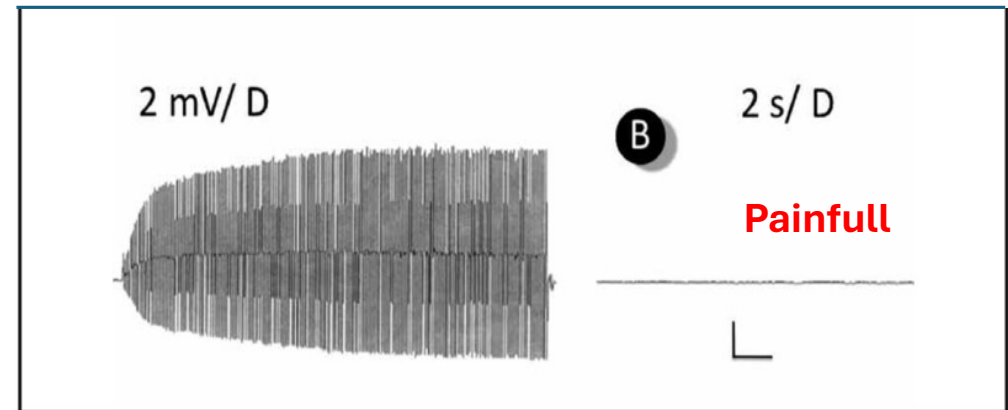


Stimulation frequency



- Repetitive nerve stimulation at **30 Hz** to document an increment is clearly **painful** and **unnecessary**

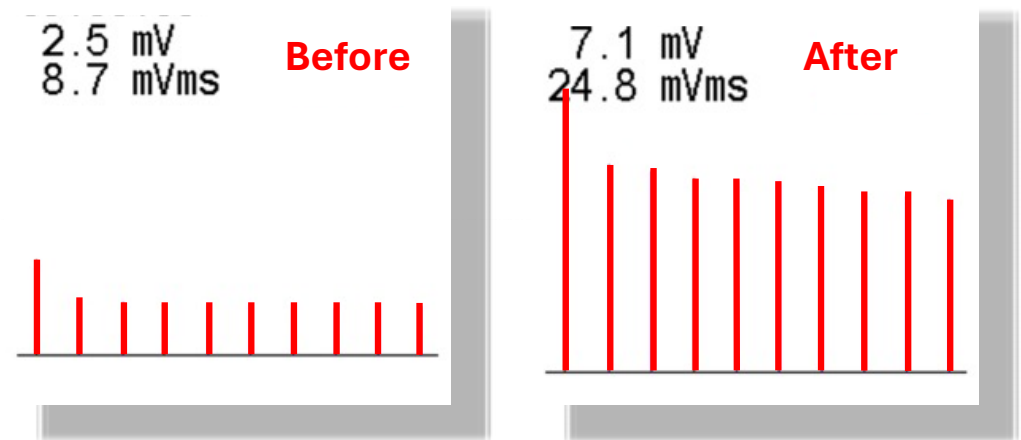
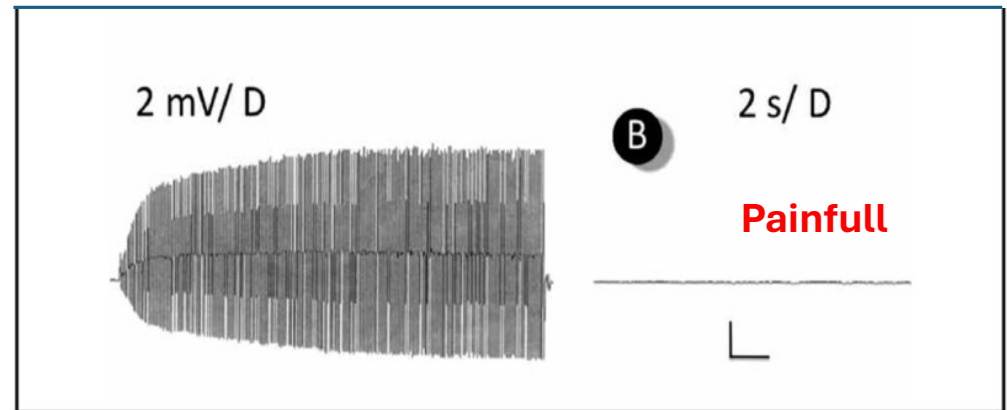
- **A single supramaximal stimulation** before and after 10 seconds of voluntary muscle contraction **is sufficient**



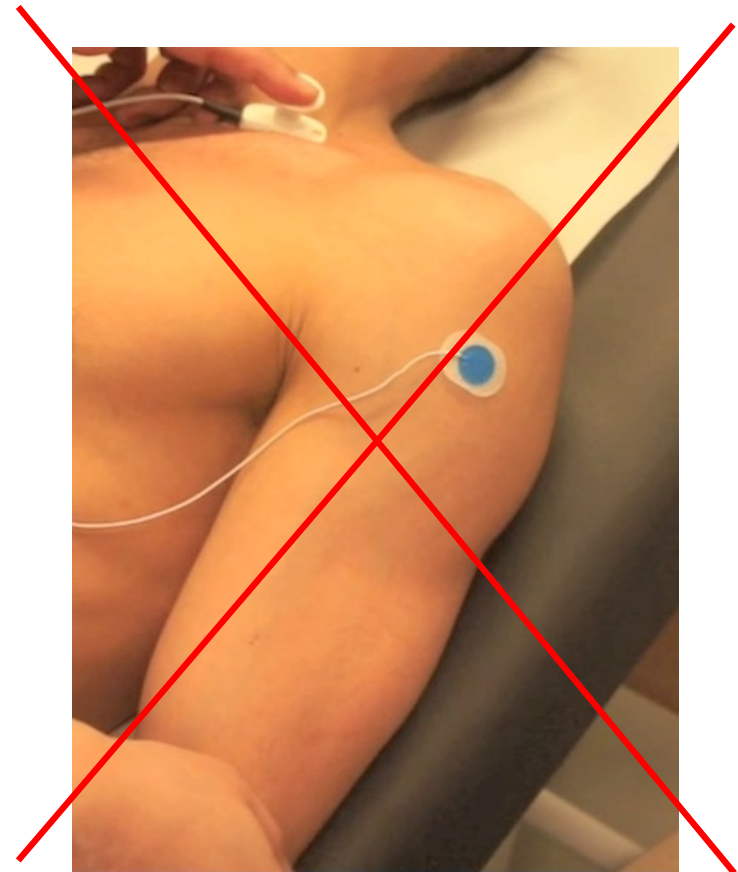
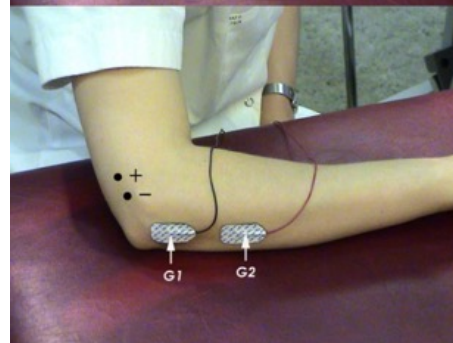
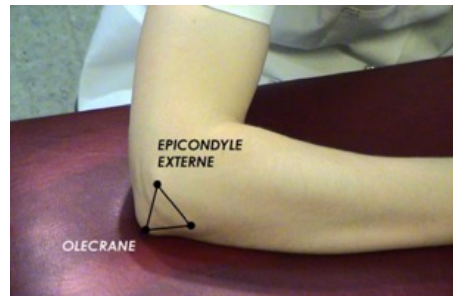
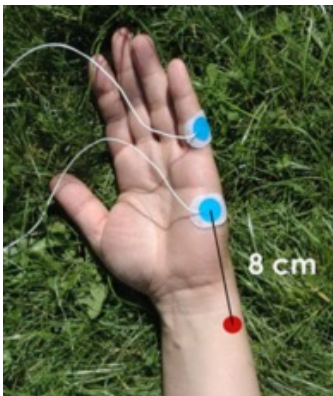
Stimulation frequency



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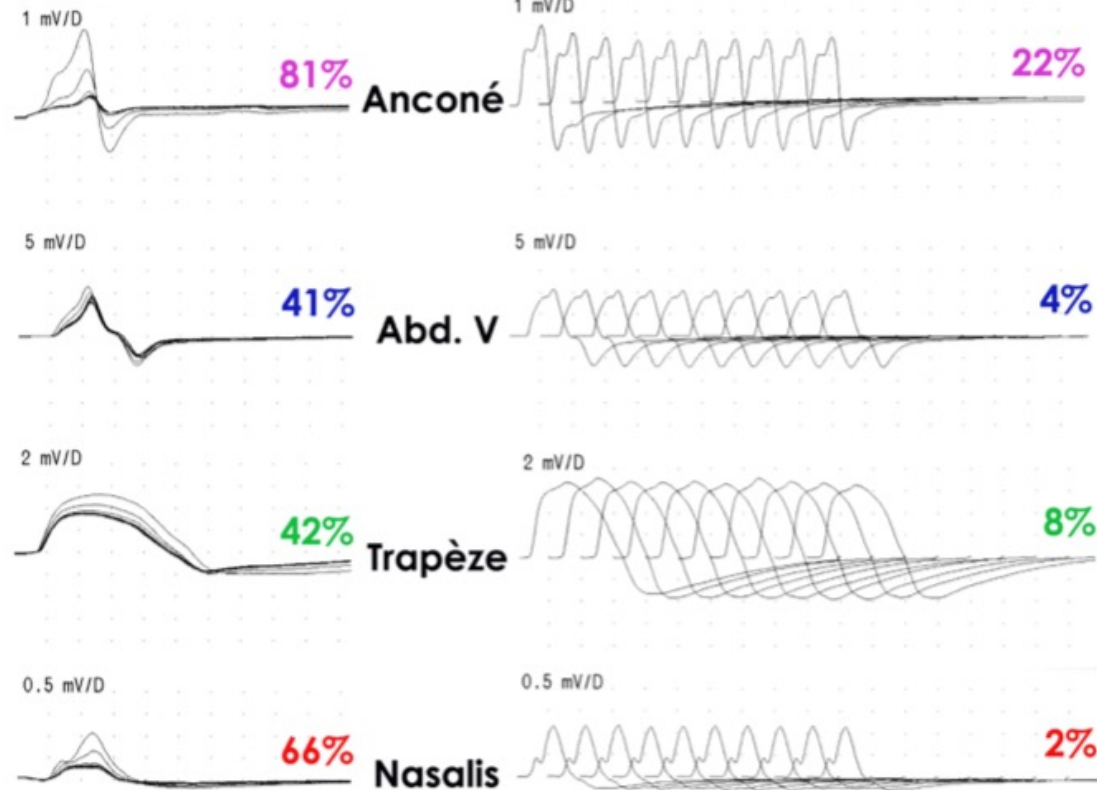
The study of certain nerve–muscle pairs is
more comfortable than others



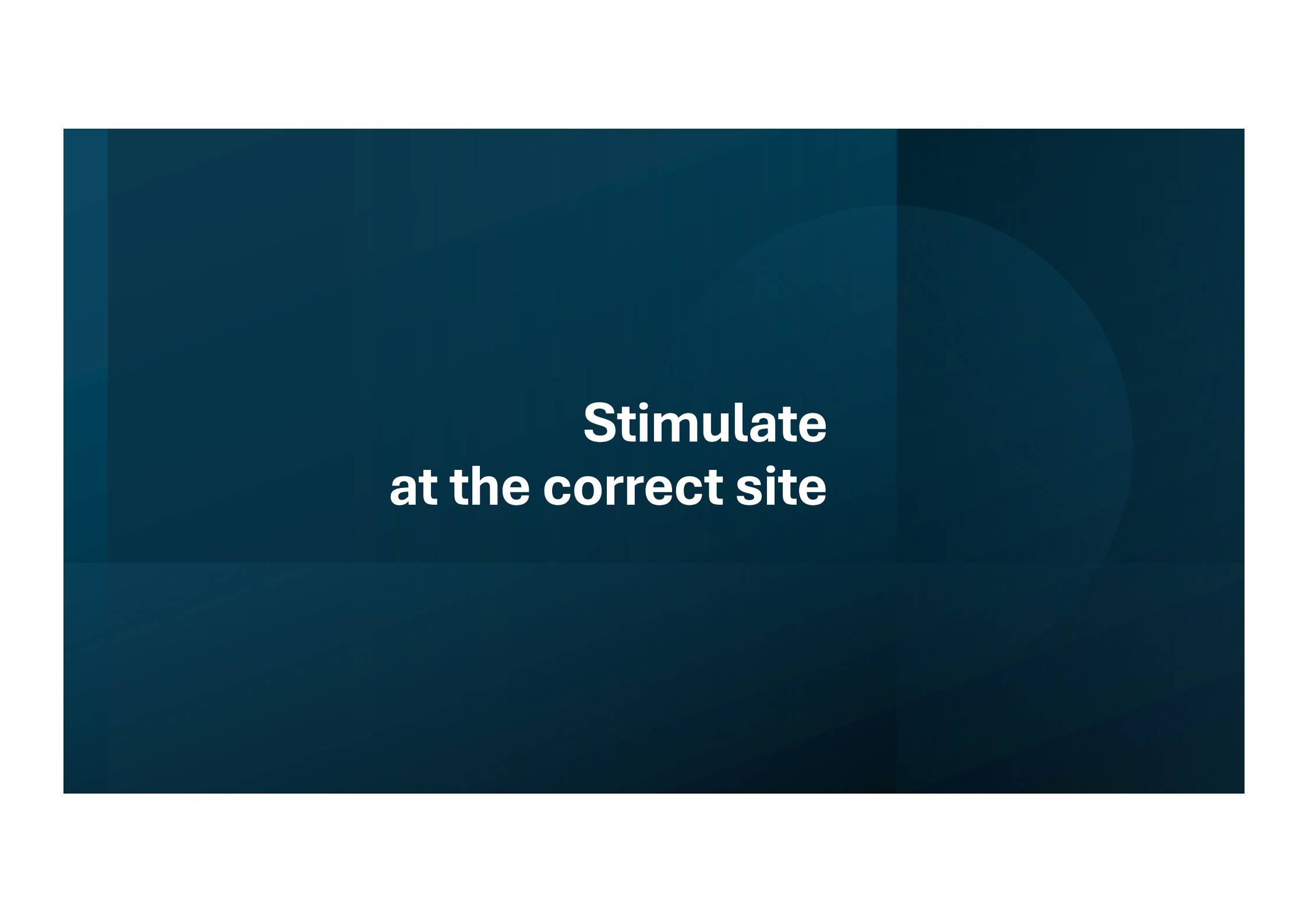


A) 3/12/99

B) 1/3/04

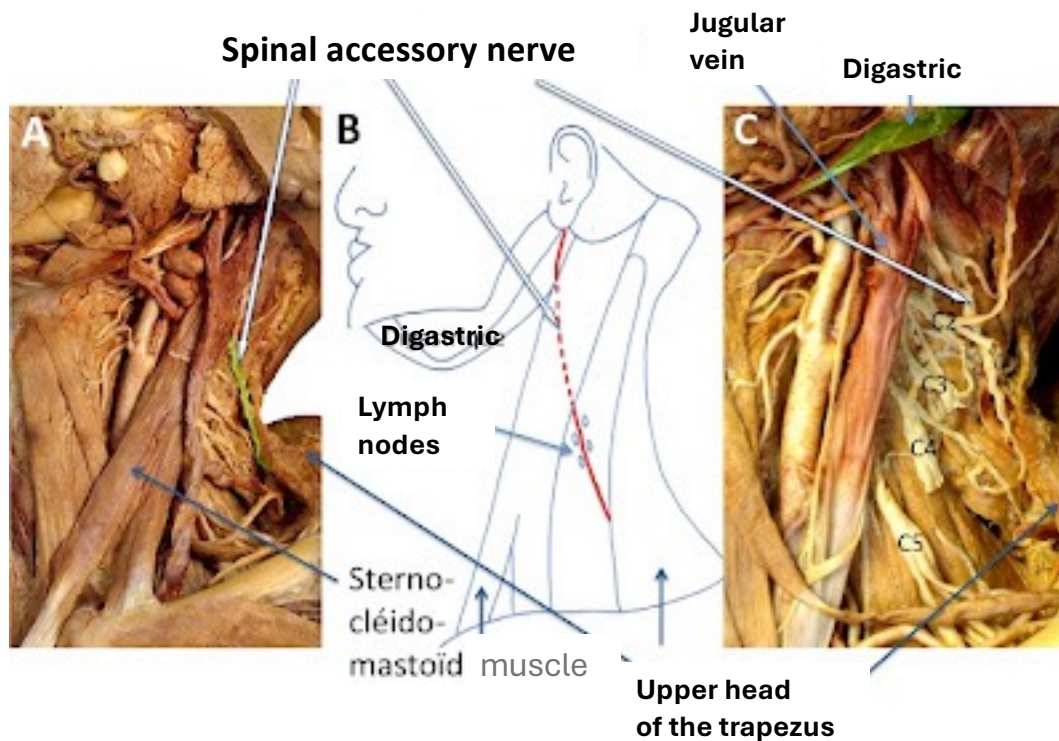


**Before and
after
treatment**

The background is a dark blue gradient. It features several abstract geometric elements: a large, semi-transparent circle on the right side, a vertical rectangular bar on the left, and various overlapping translucent shapes that create a layered effect.

**Stimulate
at the correct site**

The spinal accessory nerve



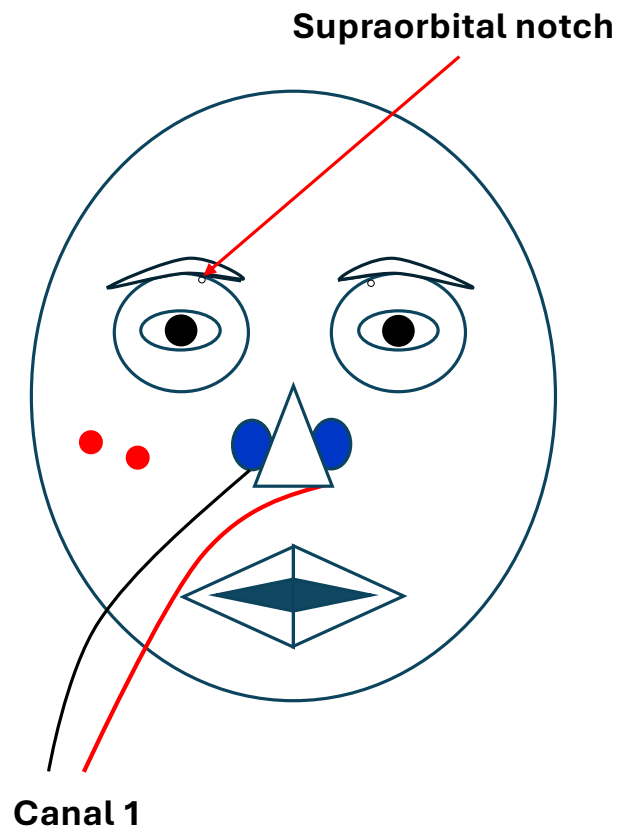
Muscular detection

- upper head of the *trapezus*



- just behind the posterior border of the sternocleidomastoid muscle and midway between the mastoid bone and the clavicle
- stimulus duration: 0.2 ms
- stimulus intensity: **< 10 mA**

Facial nerve



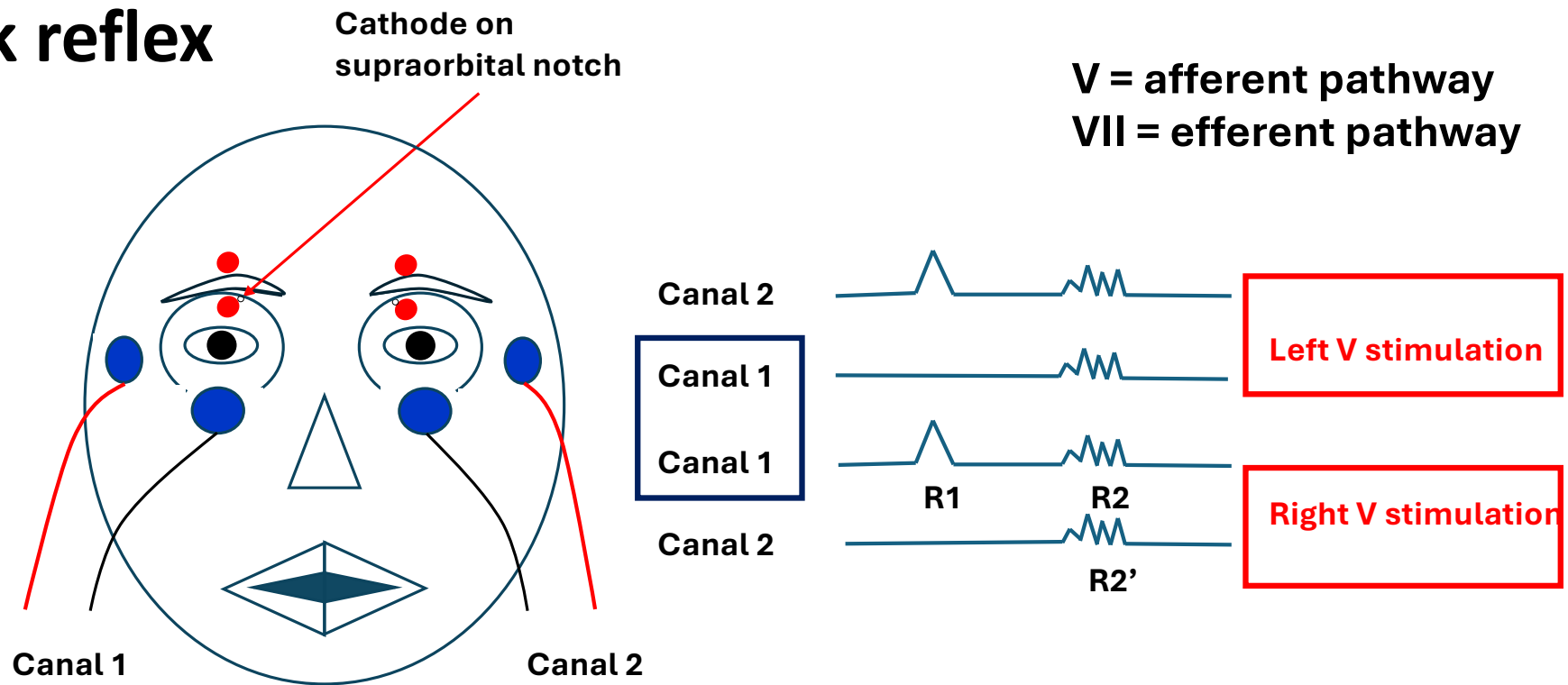
Sanjee NANDEKAR

- **stimulation** on the cheek rather than at the exit of the stylomastoid foramen
- below the zygomatic bone
- stimulus duration: 0.2 ms
- stimulus intensity: **< 10 mA**

Muscular detection

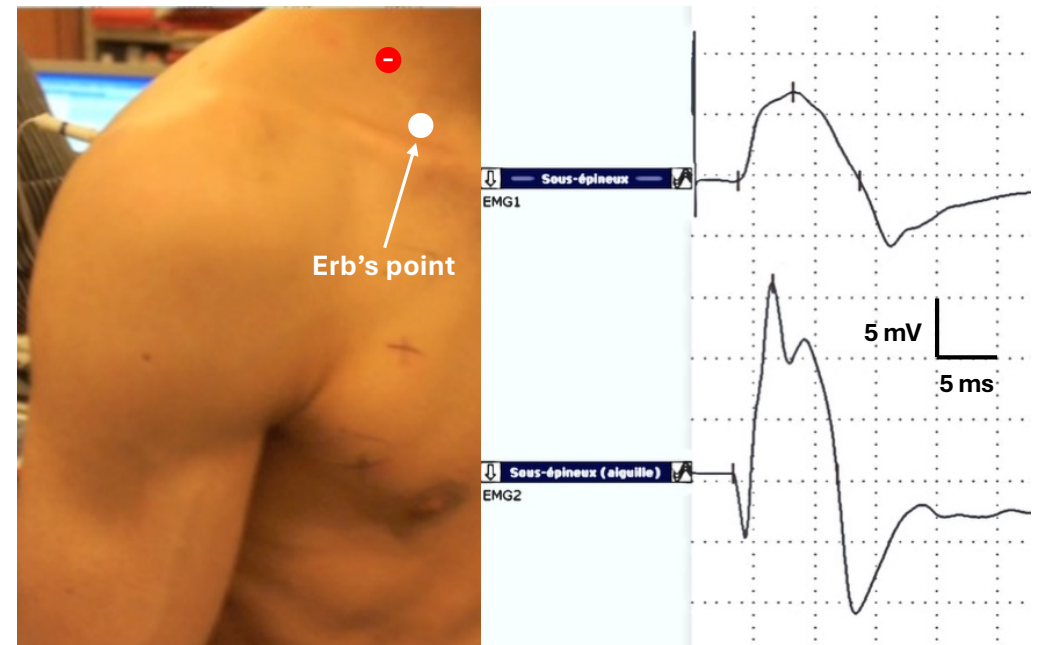
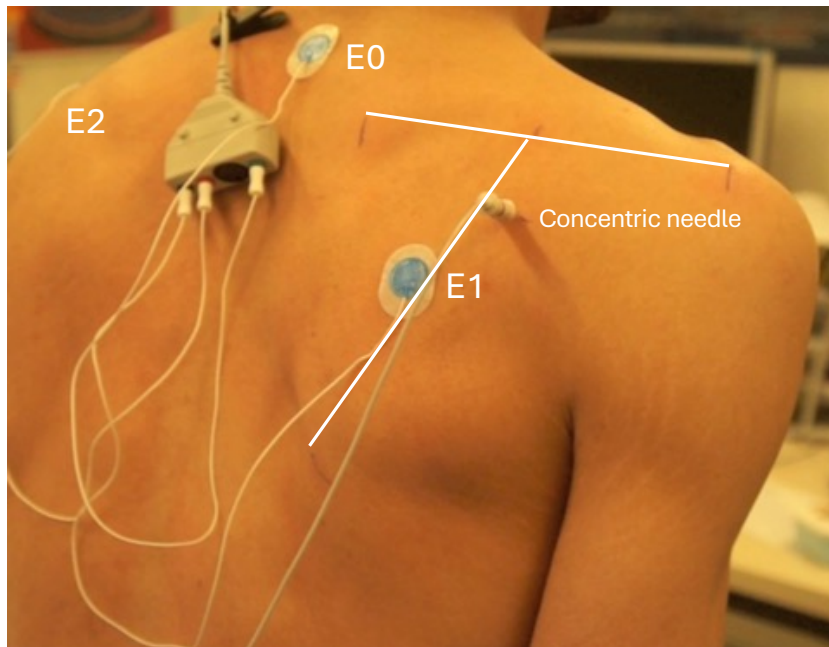
- *frontalis*
- *orbicularis oculi*
- *nasalis*
- *orbicularis oris*

Blink reflex



- the cathode should be placed on the supraorbital notch, below the eyebrow
- the **R2** component of the reflex **involves stimulation of nociceptive fibers**
- stimulation should be delivered at an **intensity three times the R2 threshold (< 15 mA)**
- **stimulation frequency: 0.1 Hz** to avoid any habituation of the reflex

The suprascapular nerve



The suprascapular nerve is stimulated above and lateral to Erb's point (**< 15 mA**).

Number of stimulations

Number of stimulations

- After an initial phase of surprise, and provided that the current remains at moderate intensities, patients generally become accustomed to electrical stimulation
- This phase of acceptance is replaced by a gradual decrease in tolerance to the current if the number of stimulations delivered (even at low frequency) increases

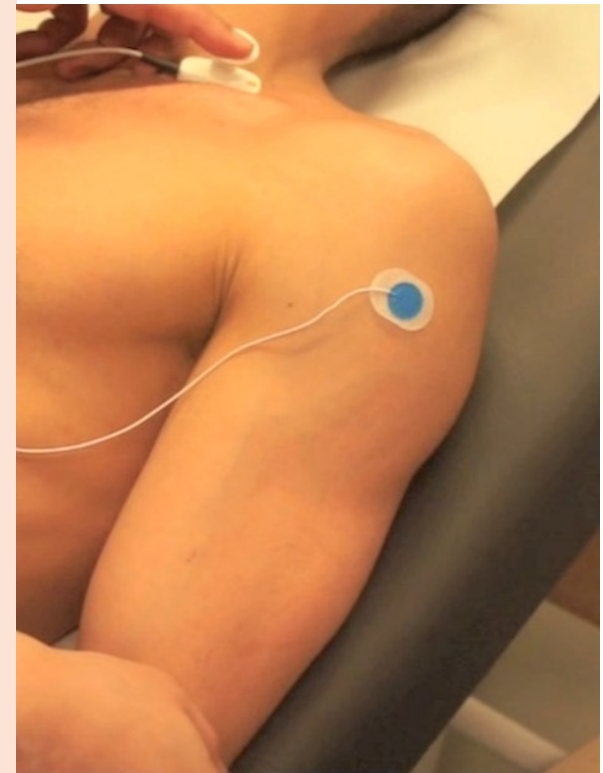
In practice : use as few stimulations as possible

Reach the required intensity in four or five stimulations (in increments of 3 mA), delivered at a steady, not too rapid pace

If stimulation is expected to be difficult (Erb's point in an overweight patient)

- Explain clearly to the patient what is going to happen and how we will proceed
- use a monopolar stimulator
- prepare the skin to reduce impedance
- increase the stimulus duration to 1 ms
- determine the motor response threshold
- deliver **a single stimulus at** an intensity equal to **3 times the threshold**

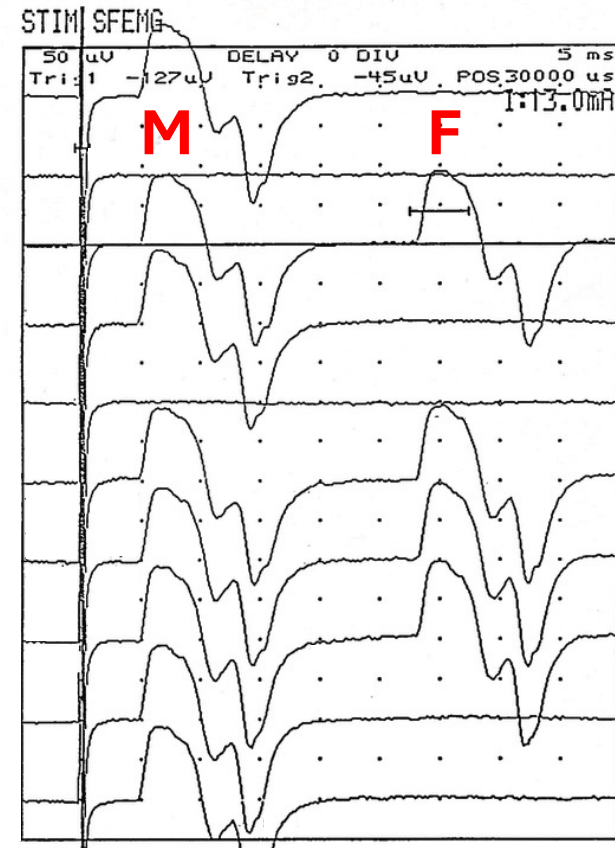
Number of stimulations



**What about late
responses ?**

F waves & stimulation intensity

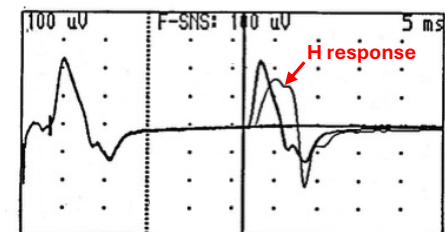
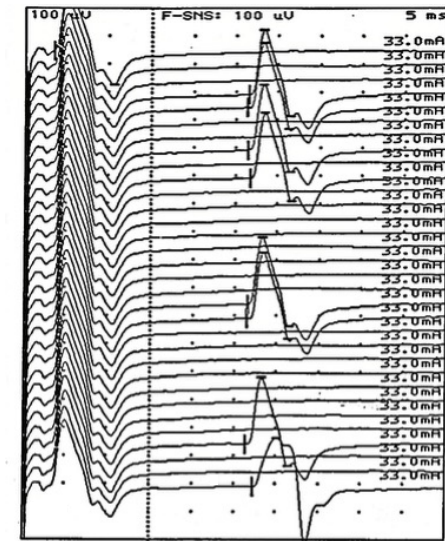
- the stimulation intensity does not necessarily have to be supramaximal
- it is possible to record F-responses at the threshold of activation of a single motor unit = **Single MU F-wave**
- in this case, the direct (M) and indirect (F) responses have an identical morphology



F waves & stimulation intensity

- stimulation is usually supramaximal in order to activate as many motor units as possible and thereby increase F-wave persistence
- supramaximal stimulation also helps prevent the occurrence of an H-response

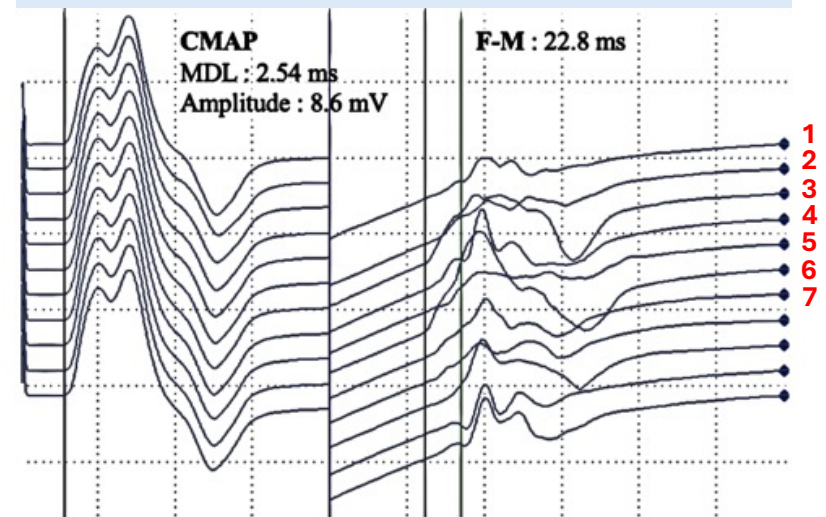
However, in practice, if repeated supramaximal stimulations are painful, it is possible to use submaximal stimulations



F waves & number of stimulations

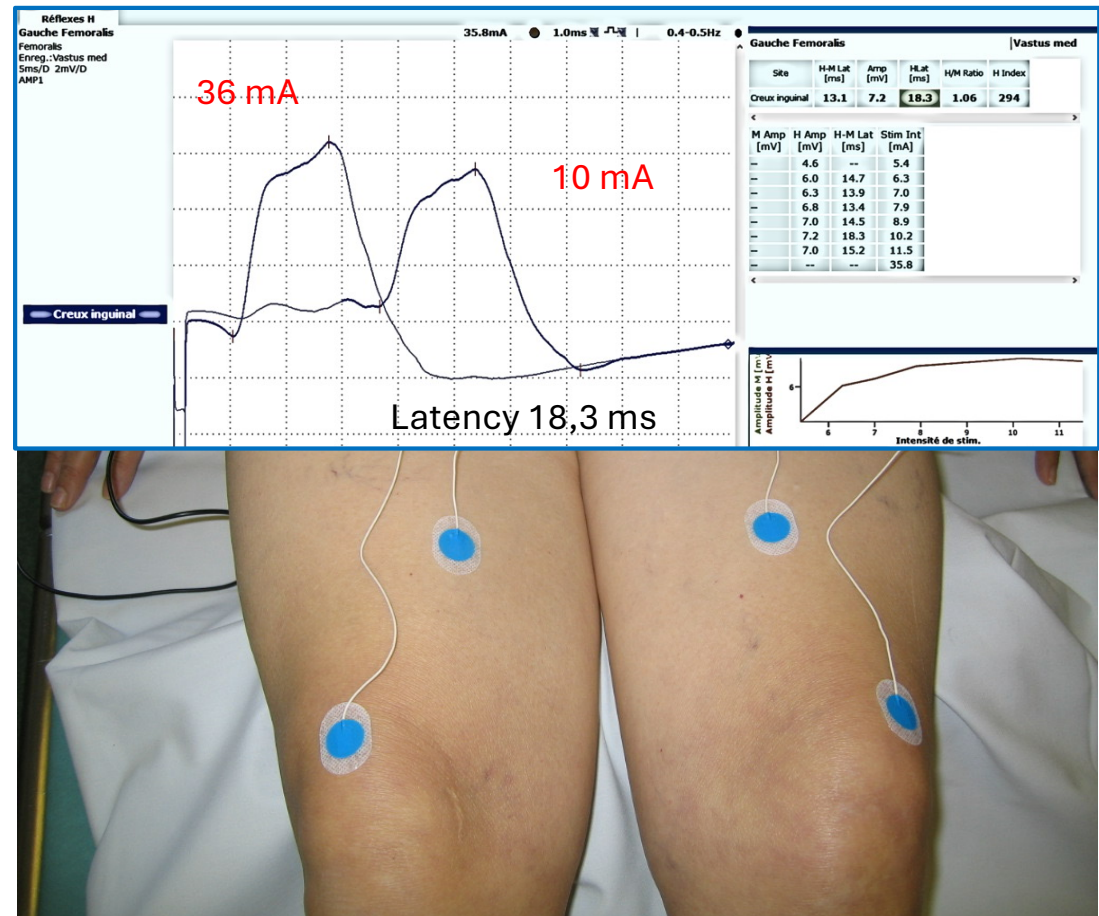
- the most useful analysis parameter is the **F-wave minimal latency**.
- how many stimulations should be delivered to assess this parameter?

At least **7** clearly identifiable F-wave responses are required to reliably estimate the minimal F-wave latency



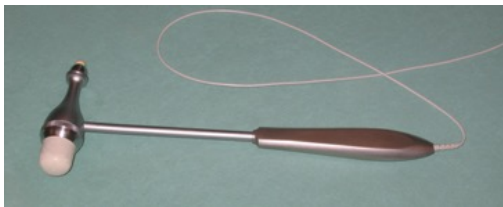
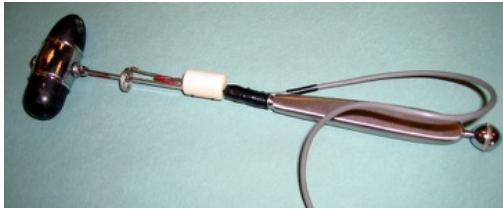
H or T responses

When the nerve is deep (e.g., the femoral nerve at the inguinal fold), electrical stimulation may be **painful** and even ineffective in obtaining a maximal response

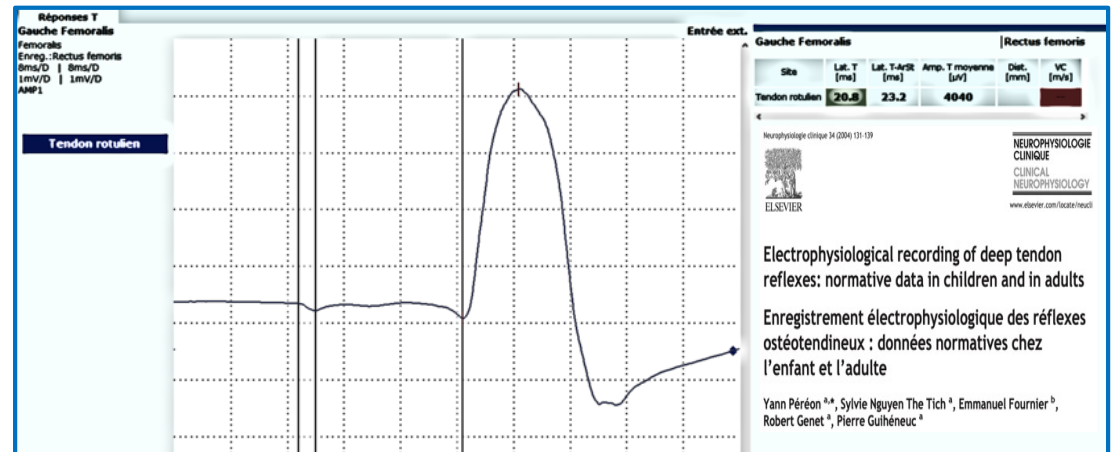


André TRUFFERT

H or T responses

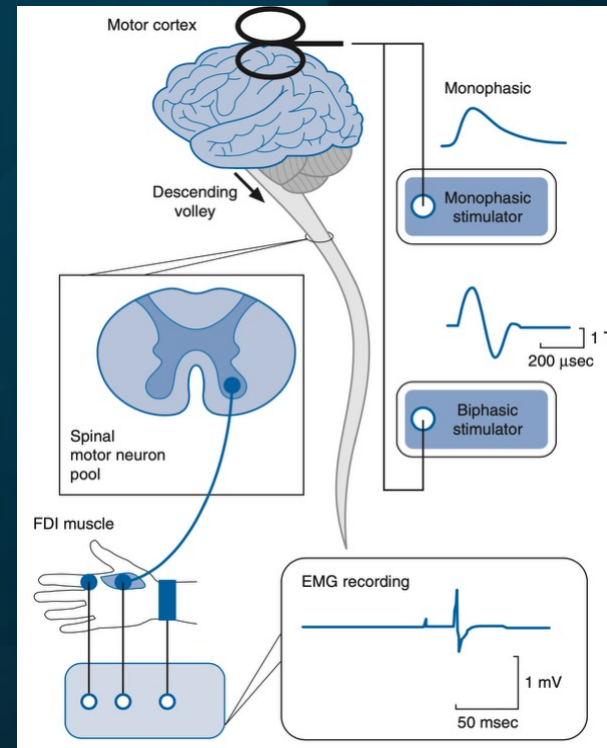


**Absolutely
painless**



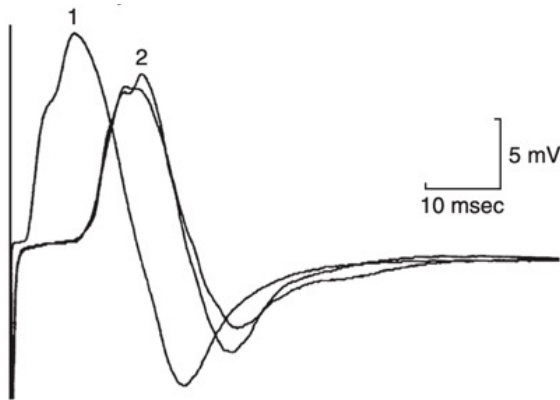
André TRUFFERT

Magnetic stimulation

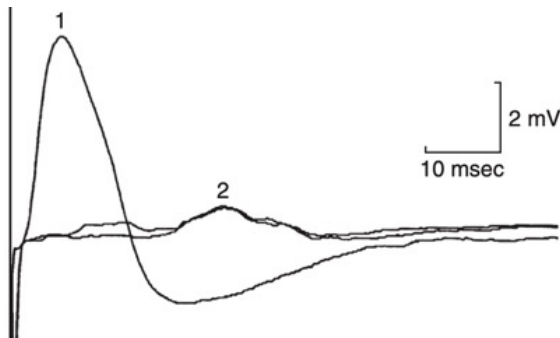


Magnetic Stimulation

Normal subject



ALS patient



- It is not necessary to systematically stimulate at 100 % of the magnetic stimulator
- It is preferable to determine the threshold (**without facilitation**), then stimulate at an intensity 30 % above the threshold (**with facilitation**)

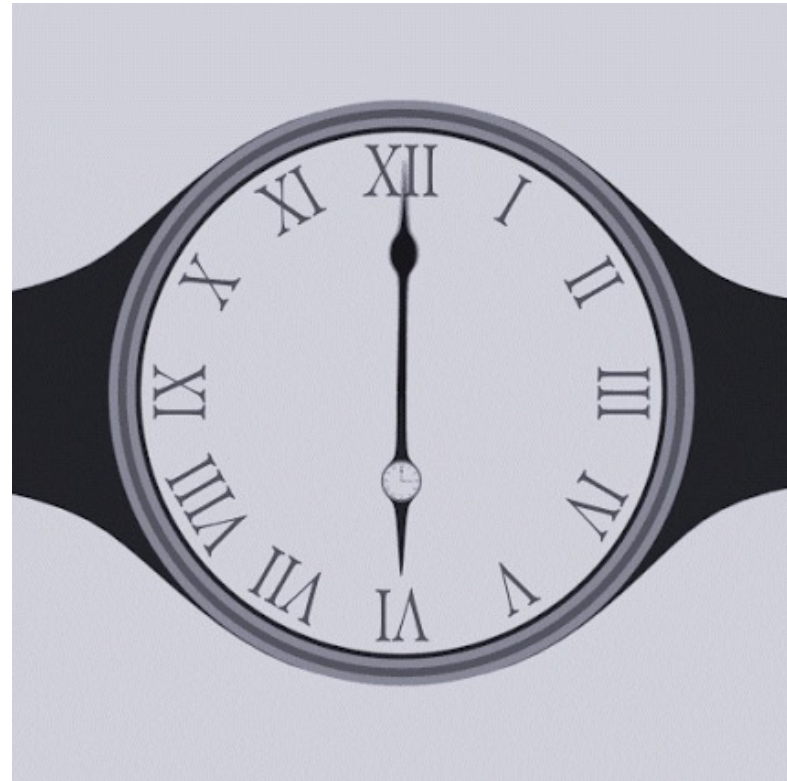
Threshold = the intensity required to obtain a 100 μ V motor response, one out of two times

Facilitation = slight voluntary muscle contraction

Duration of examination

The duration of a neurophysiological examination

- should not exceed
- one hour in adults
 - 20 to 30 minutes in children



Practical exercise

Superficial fibular nerve (antidromic)

- stimulation intensity and duration:
10 mA ; 0.1 ms
- We do not record any sensory
response
- what should we do first ?
- increase the stimulation intensity?
- move the recording electrodes?
- move the stimulator?



Superficial fibular nerve (antidromic)

- **move the stimulator**

- We record a sensory response, but it is too small
- what should we do first ?

- increase the stimulation intensity?
- move the recording electrodes?
- move the stimulator?



Superficial fibular nerve (antidromic)

- **move the recording electrodes**

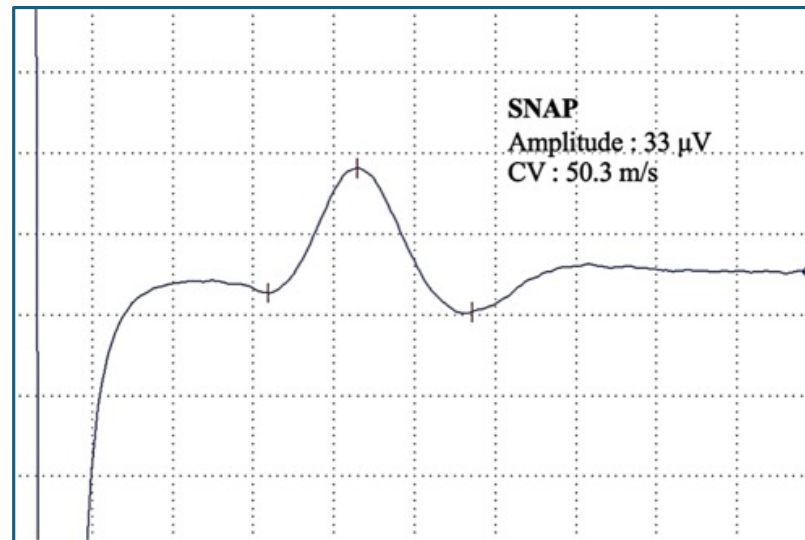
- We record a sensory response, but it is **still** too small
- what should we do first?

- increase the stimulation intensity?
- move the recording electrodes?
- move the stimulator?



Superficial fibular nerve (antidromic)

- increase the stimulation intensity



Guidelines for pain-free nerve stimulation

- **Use the lowest possible stimulation intensity**
 - properly prepare the skin to reduce skin impedance
 - stimulate where the nerve is most superficial
 - positioning of the stimulating electrode :
the closer you are to the nerve, the less current you need
 - when the nerve is slightly deeper, gently press the stimulator against the skin
 - monopolar stimulation is more effective for deeper nerves
- **Take into account current density & the distance between anode and cathode**
 - avoid pediatric stimulator
- **Moistened pads are less painful than metal balls to deliver stimulation to the nerve**

- **Use constant current stimulation because the current delivered to the nerve**
 - is more stable
 - is better tolerated
 - produced fewer artefacts
- **Space stimuli every 1.5 – 2 seconds to avoid temporal summation effect**
- **Use as few stimulations as possible**
 - 4 to 5 steps to get maximal responses
- **The examination time should be less than 1 h**

- **In a clinical context of MG:**
 - facilitation by a one-minute exercise is not really useful
 - high-frequency stimulation is unnecessary
 - do not stimulate deep nerves repetitively
- **For F-waves, supramaximal stimulation is not always necessary**
- **T-responses are completely painless (unlike H-responses)**
- **Take into account the subjectivity of pain**
 - reassure the patient
 - clearly explain the procedure
 - pay special attention to anxious patients



Conclusions

Electrical stimulation does not have to be painful. If we:

- understand the physiology
- respect the patient
- and optimize our technique

Then most examinations can be performed with little or no discomfort

Grazie per la vostra
(at)tensione!!!



From my part, I would also like to thank :

André Truffert, Emmanuel Fournier, Pierre Guihéneuc, Sanjee Nandedkar & Yann Péréon

In neuropathies

- When the neuropathy is strictly axonal, pain is generally milder, especially when there is a sensory component.
- When the neuropathy has a primary or secondary demyelinating component, it is often necessary to increase the intensity of nerve stimulation to obtain a maximal response. As a result, the stimulation is often more painful.