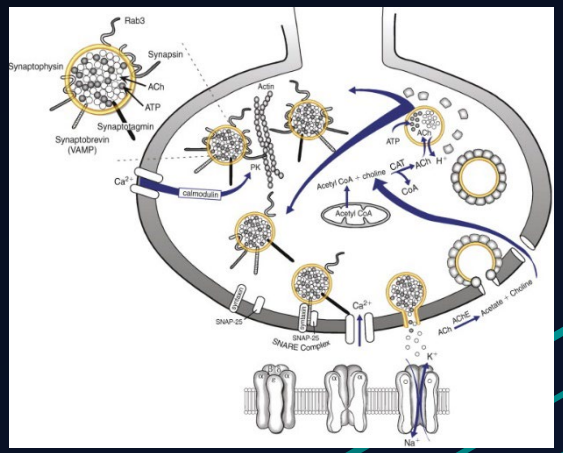
Metody monitorace svalové relaxace

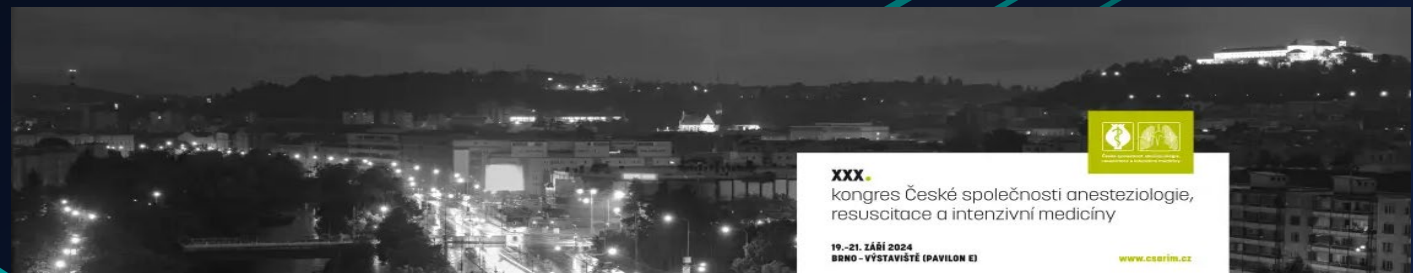
– update 2024

TOMÁŠ TYLL
KARIM 1.LF UK A ÚVN PRAHA



ÚVN
ÚSTŘEDNÍ VOJENSKÁ NEMOCNICE
Vojenská fakultní nemocnice Praha

19. září 2024



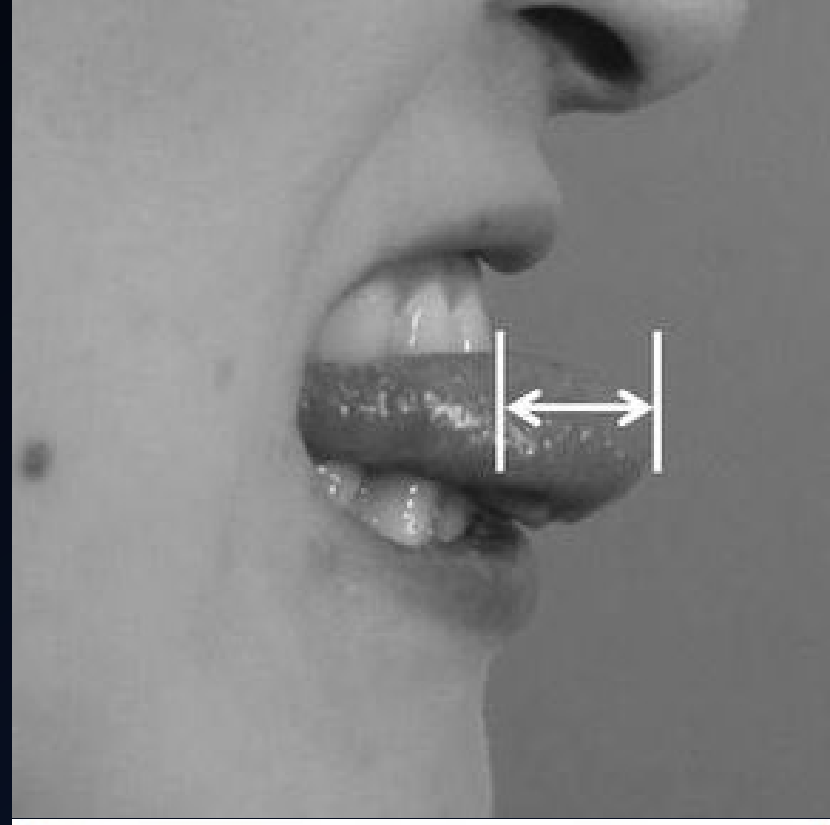
1737 – 1798

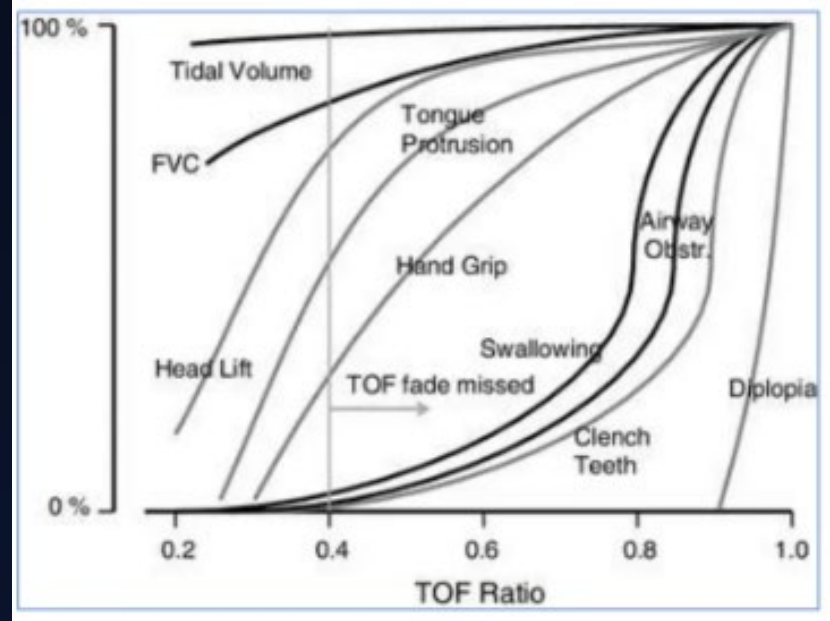
Klinické sledování

- Síla
- Udržení hlavy nad podložkou

? anestezie

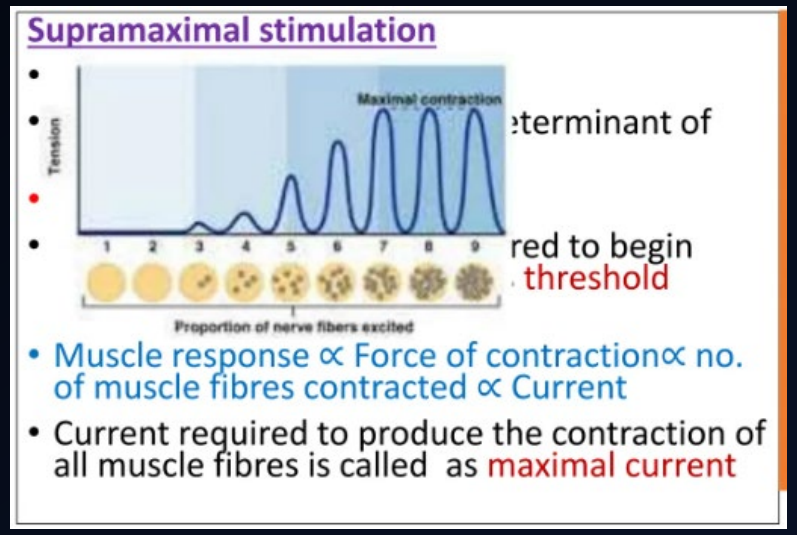
Non-Instrumental Clinical Tests
Unreliable
Eyes opening
Sticking out the tongue
Hand raising
Normal tidal volume
Max inspiratory pressure
Head lift >5s
Leg lift >5s
Hand grip >5s
Tongue depressor test for 5s

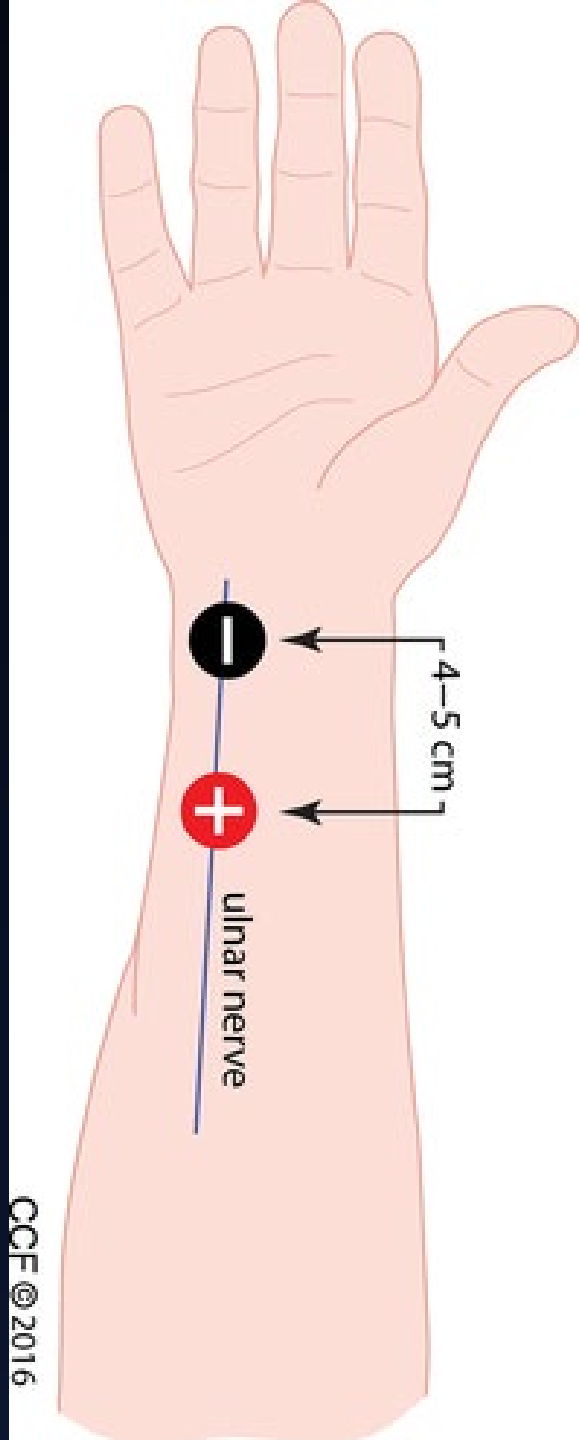




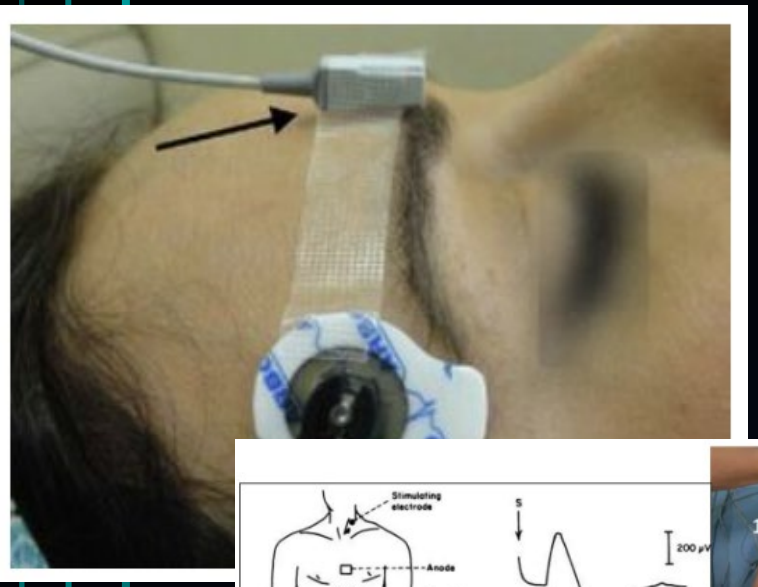
- Supramaximální stimulus
- 15 – 40 (50-60) mA
- 0,2 – 0,3ms

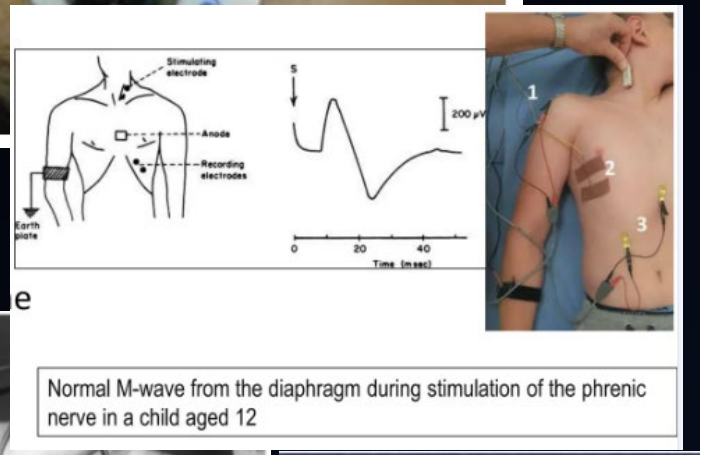
- Magnetická stimulace





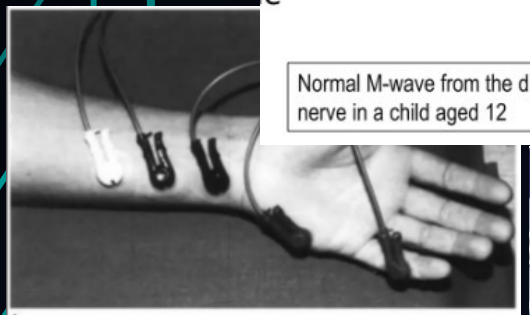
Procedure	Paralysis required
Intubation time	Laryngeal, diaphragm, abdominal ms
Surgical maintenance time	Abdominal ms, peripheral muscles
Extubation time	No muscle paralysis required





e

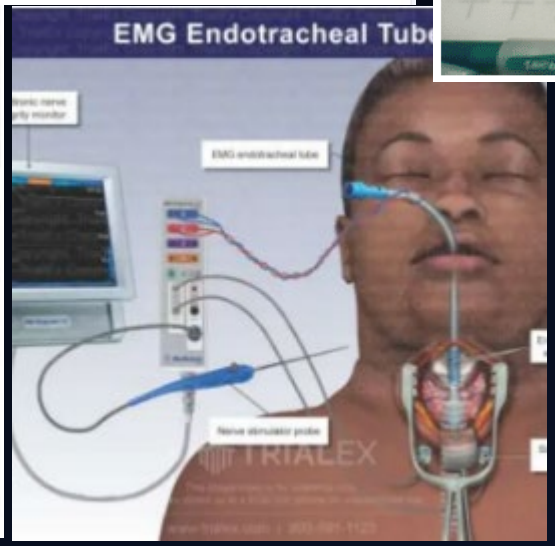
Normal M-wave from the diaphragm during stimulation of the phrenic nerve in a child aged 12

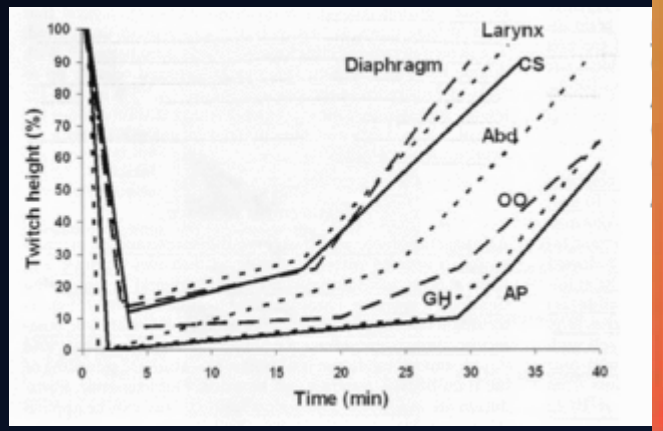


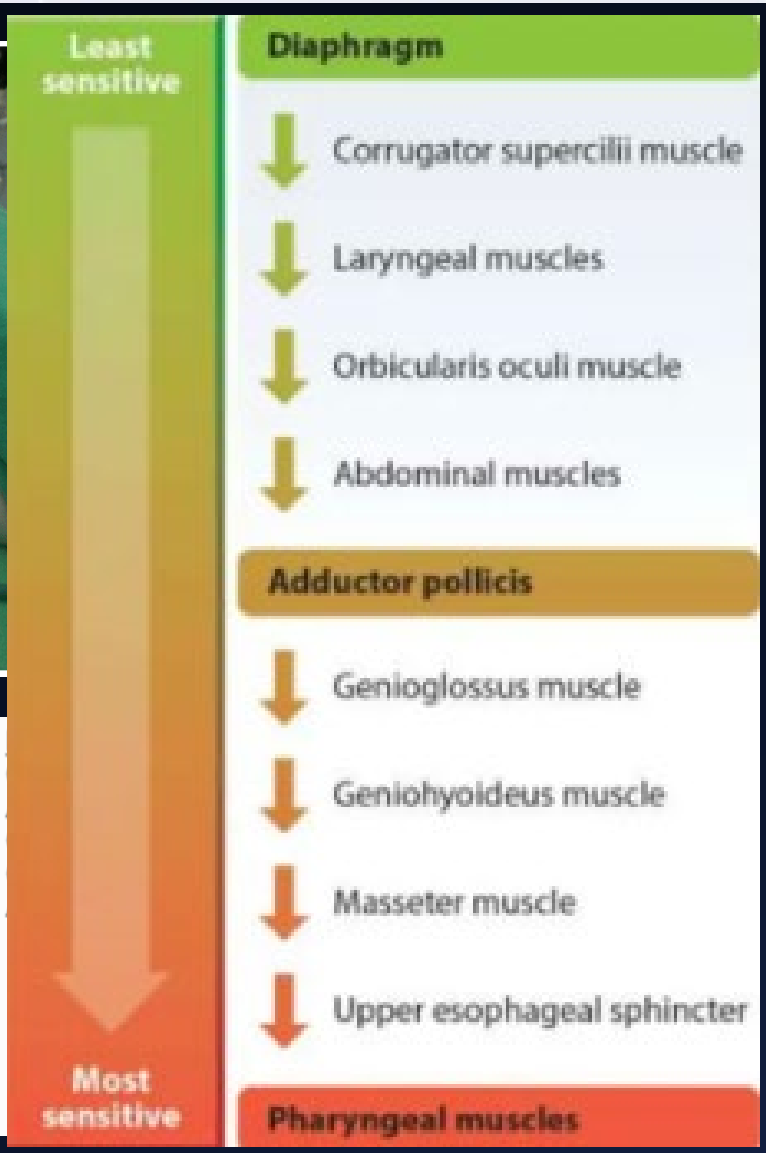
A

B

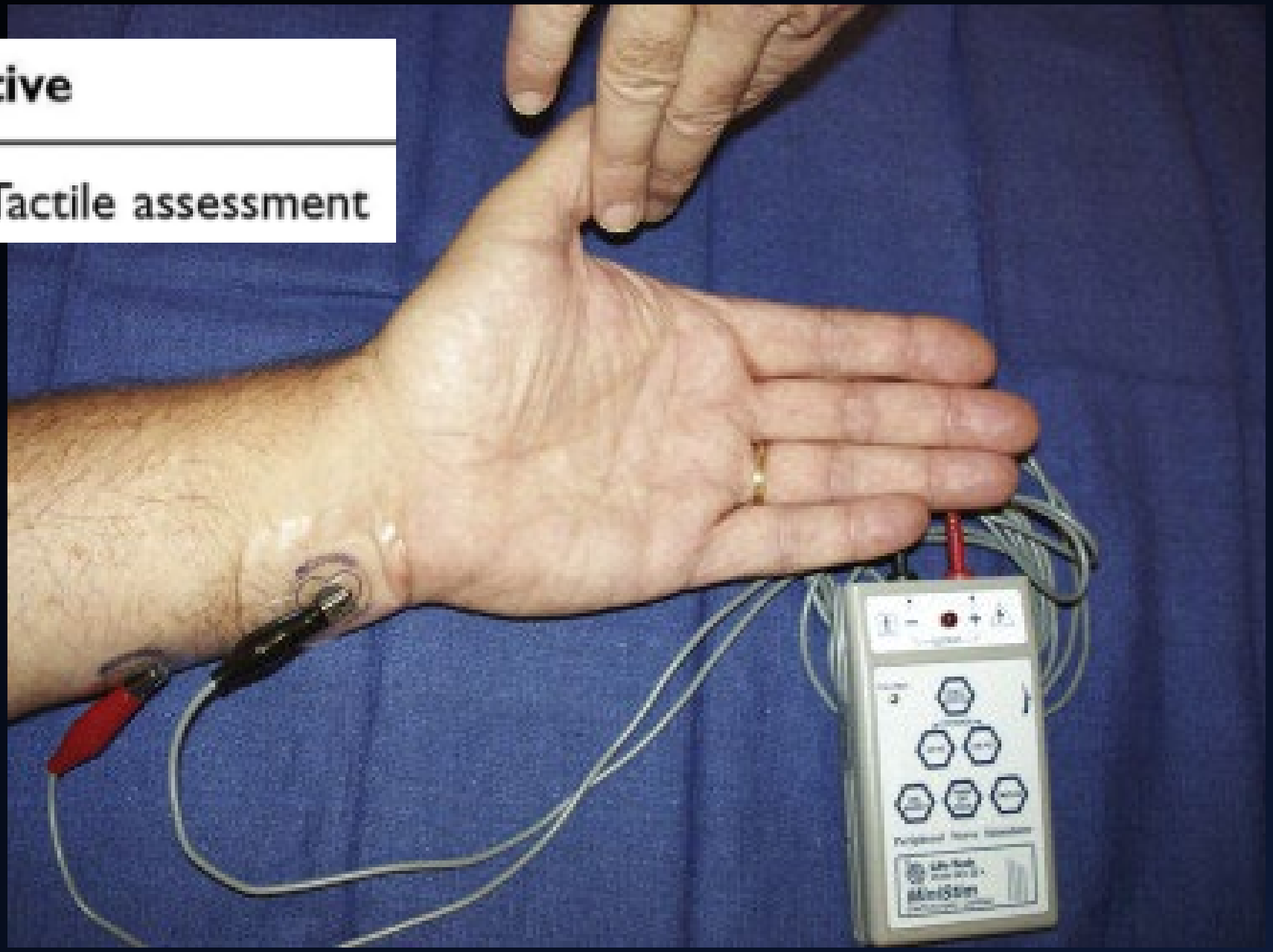
C

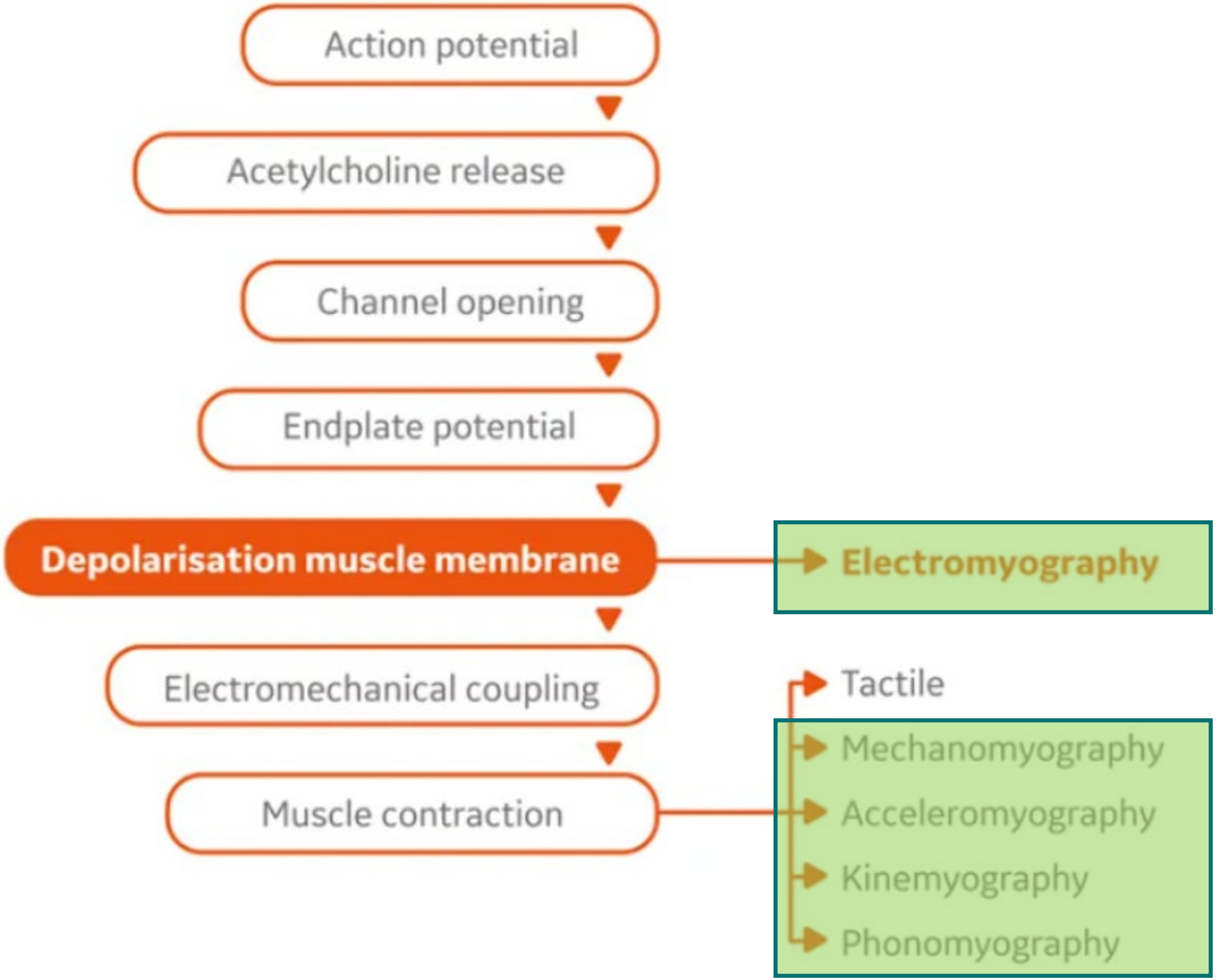






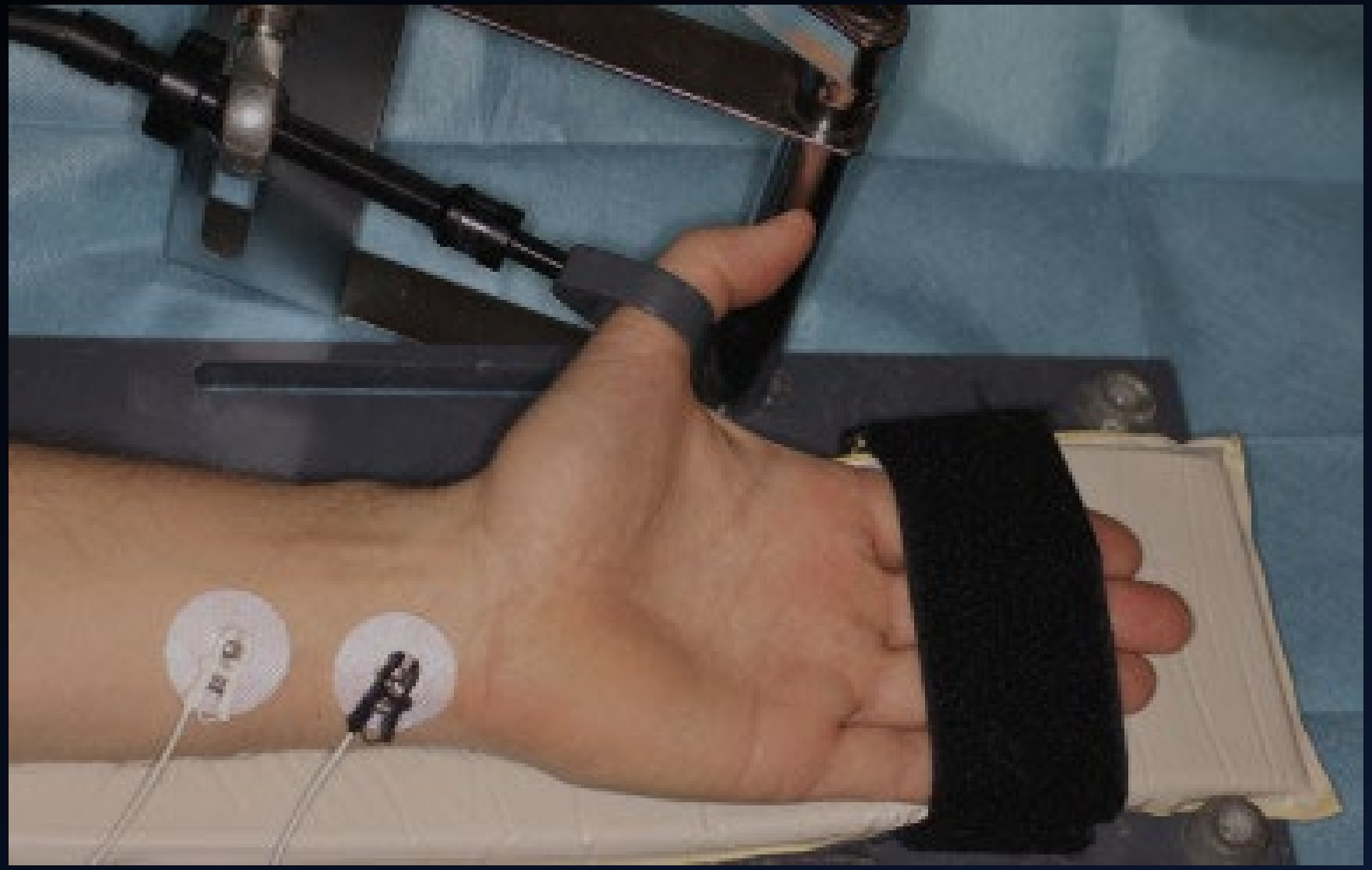
Subjective	
Visual assessment	Tactile assessment



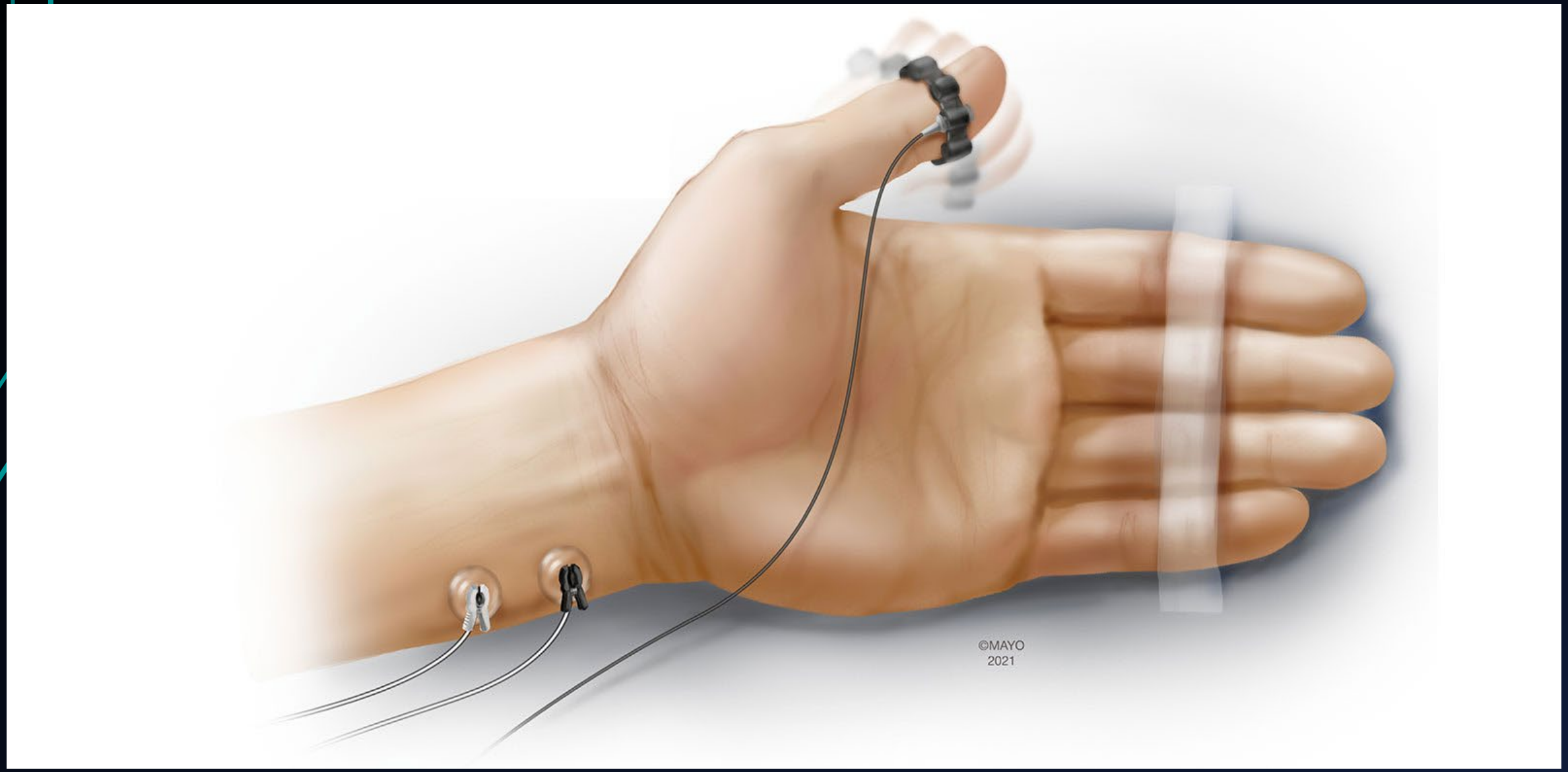


https://clinicalview.gehealthcare.com/article/experts-guide-neuromuscular-transmission

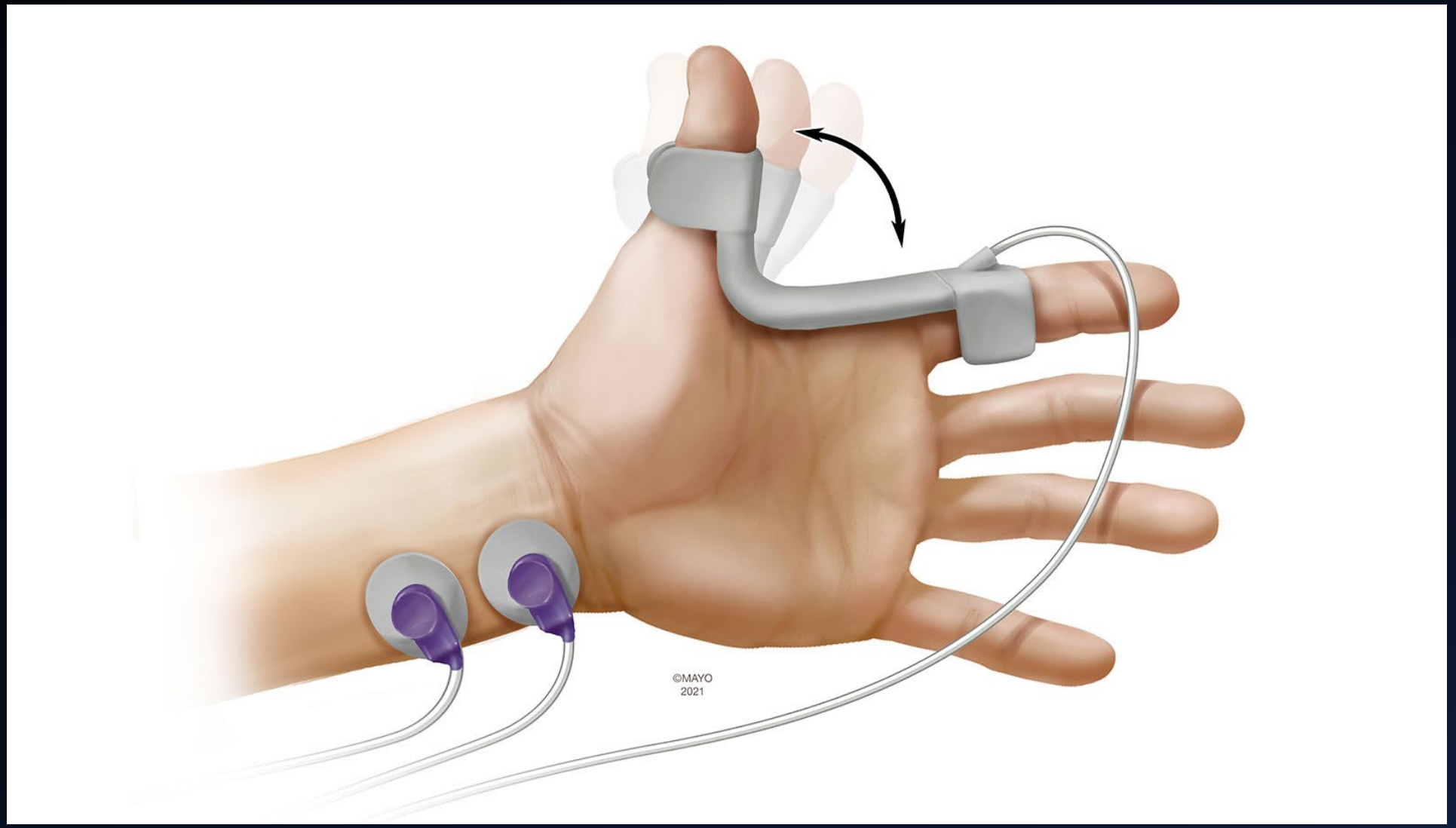
Mechanomyogrfie



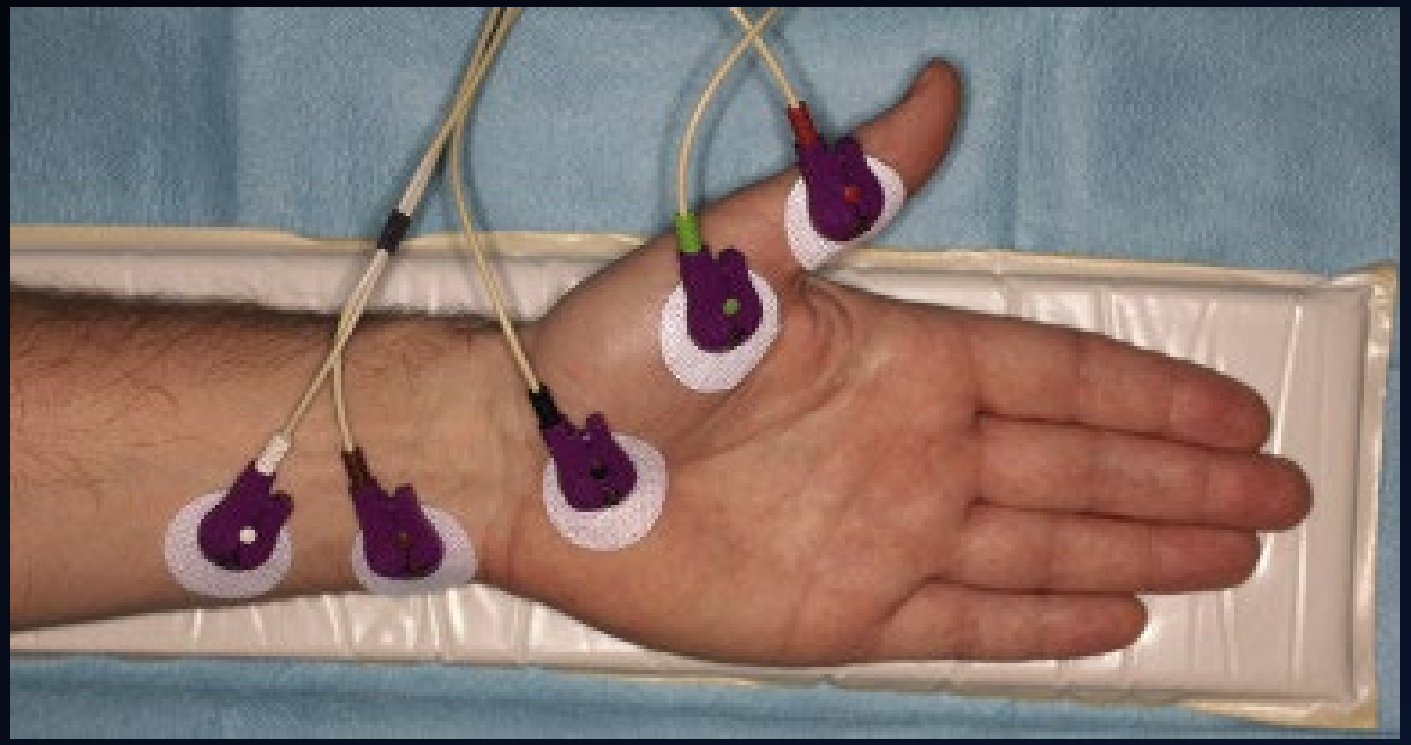
Akcelerometrie



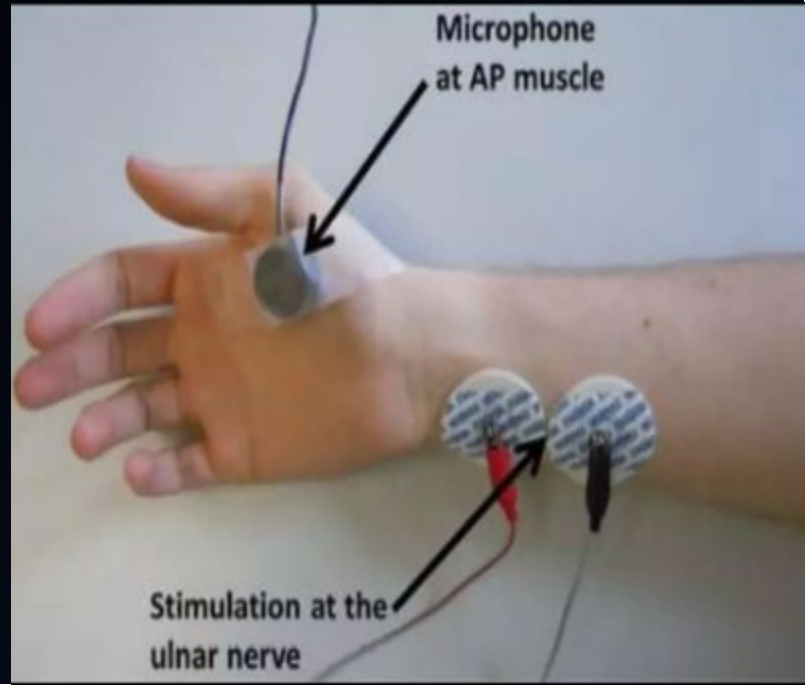
Kinemyografie

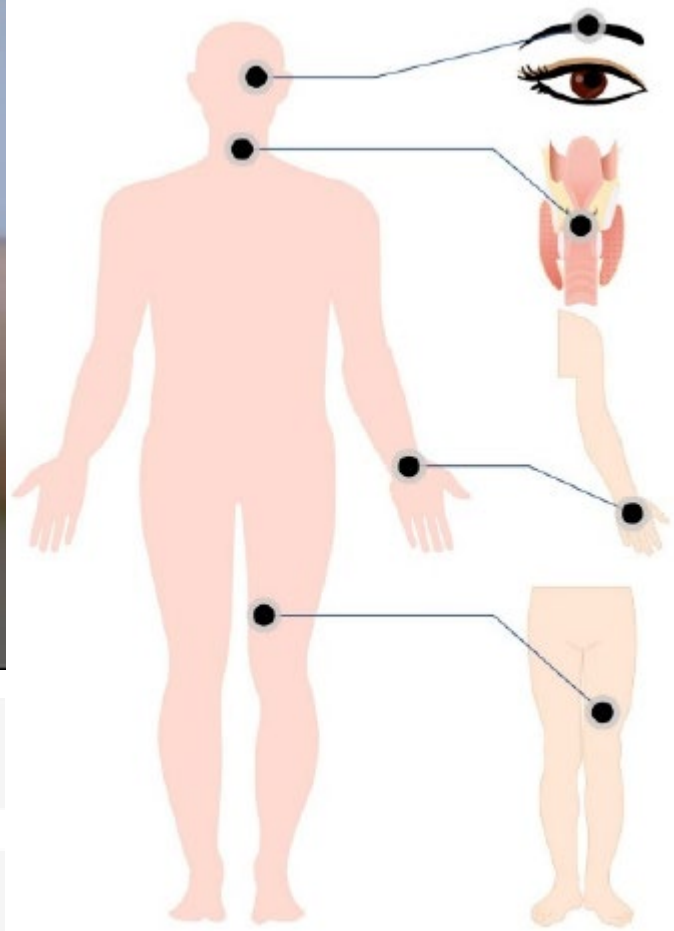


Elektromyografie



Phonomyografie

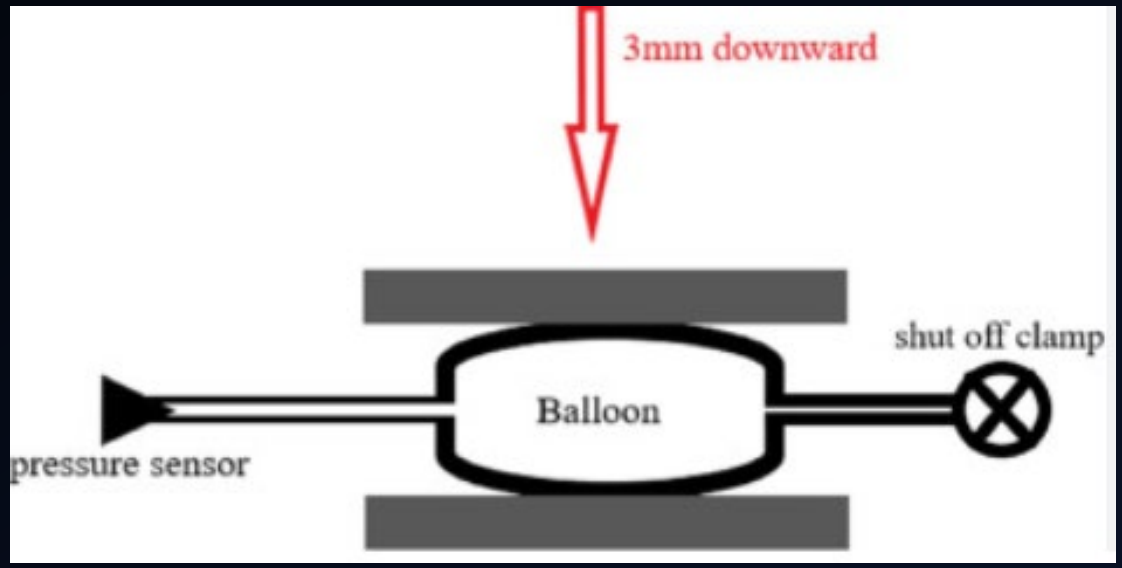




1665	Muscle sound was firstly discovered
1810	Muscle sound was firstly detected by stethoscope
1999–2004	The feasibility and stability of PMG on neuromuscular monitoring was discussed
2005–2012	PMG was applied in clinical studies for multiple purposes on neuromuscular monitoring
2012–now	Innovative PMG-based equipment was invented successively

Sensors **2022**, *22*, 2448

Kompresomyorafie



A compressomyograph train of four monitoring device

Medical Engineering & Physics
Volume 125, March 2024, 104127

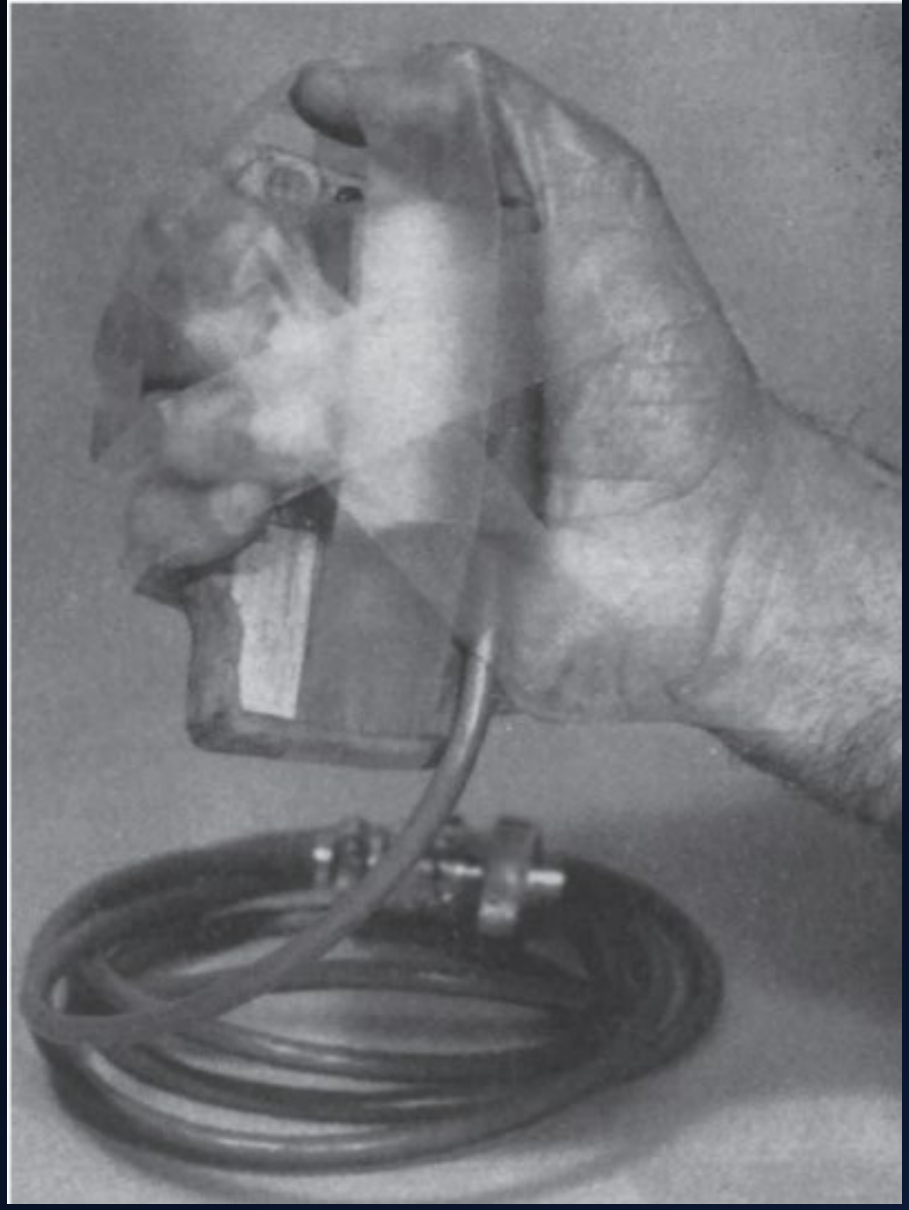
Table 2. Quantitative Monitoring Technologies Used in Research and Clinical Care

Modality	Principle	Advantages	Disadvantages	Monitoring Site	Clinical Availability
Mechanomyography	Directly measures isometric muscle contraction force.	- Measures muscle force directly. - The "reference" modality.	Cumbersome and time-consuming setup. Not suitable for clinical practice.	- Ulnar nerve - adductor pollicis muscle; - posterior tibial nerve - flexor hallucis brevis muscle	Commercially not available
EMG	Measures compound muscle action potentials evoked by neurostimulation.	- Many different muscles can be examined. - Does not require freely moving limbs. - Easy and fast set up and short calibration.	Possible interference from other electrical equipment (electrocautery).	- Ulnar nerve - adductor pollicis, abductor digiti minimi and first dorsal interosseous muscles; - posterior tibial nerve - flexor hallucis brevis muscle; - phrenic nerve - diaphragm	-E-NMT (GE DATEX-Ohmeda NMT; USA); https://www.gehealthcare.com -TetraGraph (Senzime Inc.; USA); https://www.senzime.com -TwitchView (Blink Device Company; USA); https://www.blinkdc.com -StimPod (Xavant Technology; South Africa; awaiting Food and Drug Administration clearance as of September 1, 2021); https://www.xavant.com
Acceleromyography	Measures the acceleration of the thumb or any freely moving muscle. The acceleration is directly proportional to the force according to Newton's second law.	- Current neuromuscular blockade management guidelines are based on acceleromyography measurements. - Most widely used technique.	Requires use of hand adapter (increases precision), fixation of arm and fingers, free movement of thumb, normalization of recovery train-of-four ratios.	- Ulnar nerve - adductor pollicis muscle; - facial nerve - orbicularis oculi, corrugator supercilii muscles; - posterior tibial nerve - flexor hallucis brevis muscle	-Infinity Trident NMT SmartPod (Dräger; Germany); https://www.draeger.com -IntelliVue NMT (Philips; The Netherlands); https://www.usa.philips.com -TOF-Scan (IDMed; France); https://www.idmed.fr -StimPod (Xavant Technology; South Africa); https://www.xavant.com
Kinemyography	Measures the distortion of a piezoelectric film sensor. The level of distortion is proportional to the force of thumb contraction.	- Easy to apply.	Available only in modular form. Validation *vs.* mechanomyography and electromyography questionable.	- Ulnar nerve - adductor pollicis muscle	M-NMT (GE DATEX-Ohmeda NMT; USA); https://www.gehealthcare.com
Cuff pressure modality	Measures the pressure change in a modified non-invasive blood pressure cuff due to upper arm muscles' contraction in response to brachial plexus neurostimulation.	- Easy to apply.	Needs further validation, overestimates the train-of-four ratio at the adductor pollicis by mechanomyography and acceleromyography.	- Brachial plexus - muscles of upper arm	TOF-Cuff (RGB Medical Devices; Spain); https://www.rgb-medical.com

EMG, electromyography.

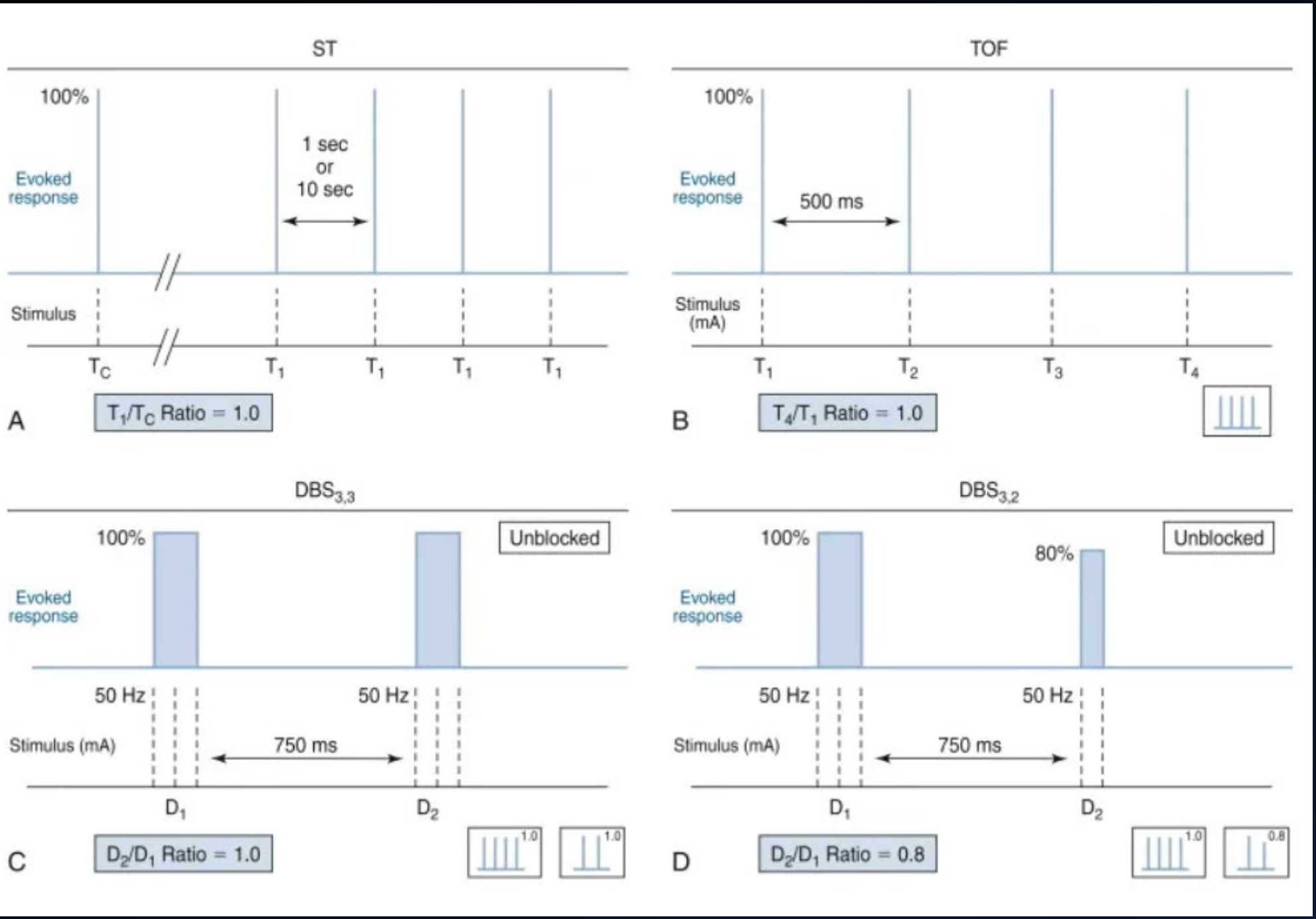
Anesthesiology 2022; 136:345–61

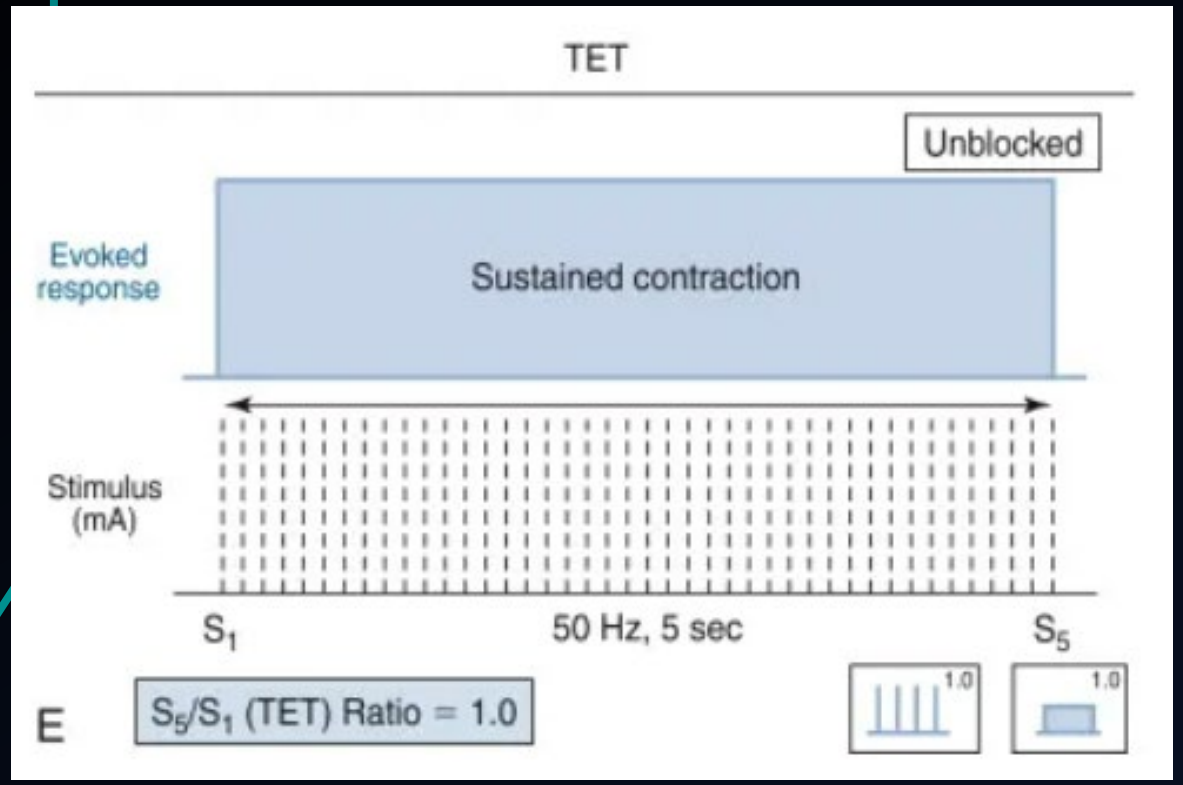
Stimulační vzorce

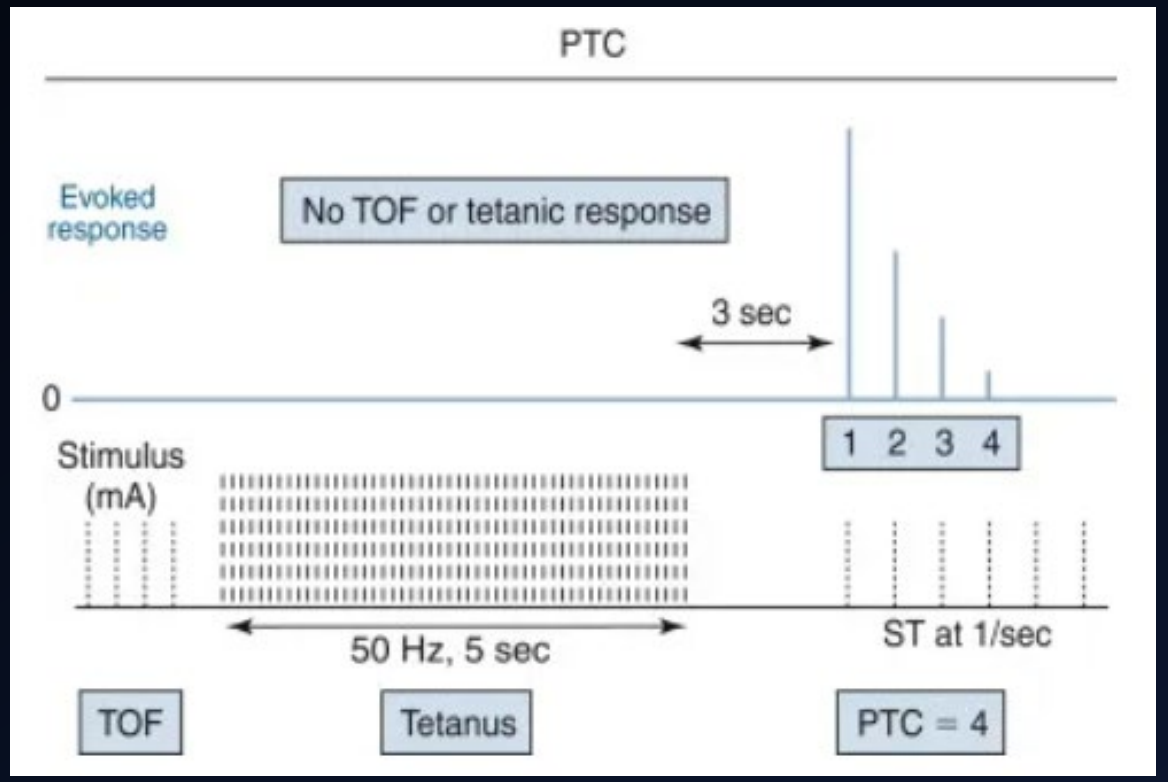


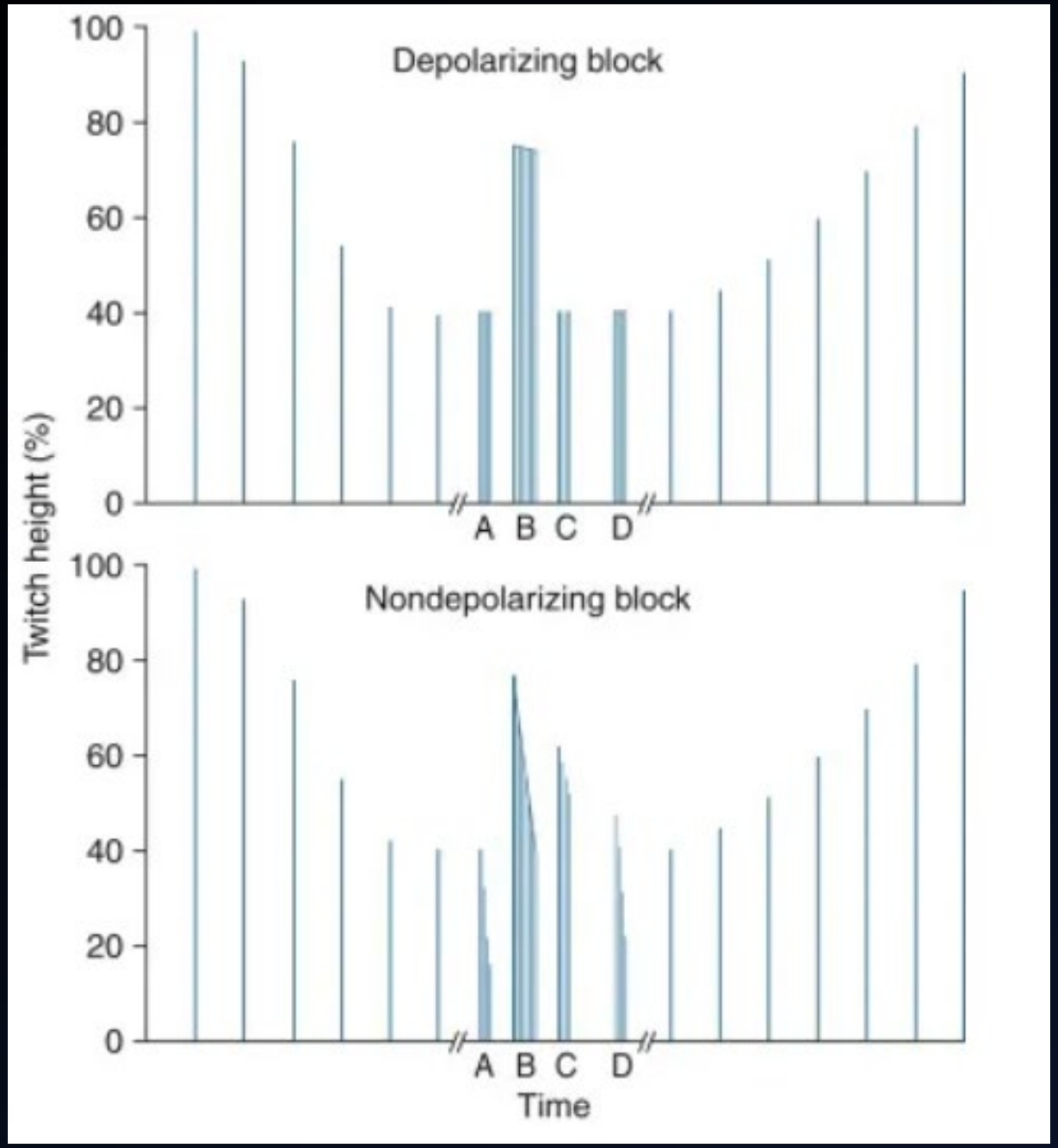
Anesthesiology 2022; 136:345–61

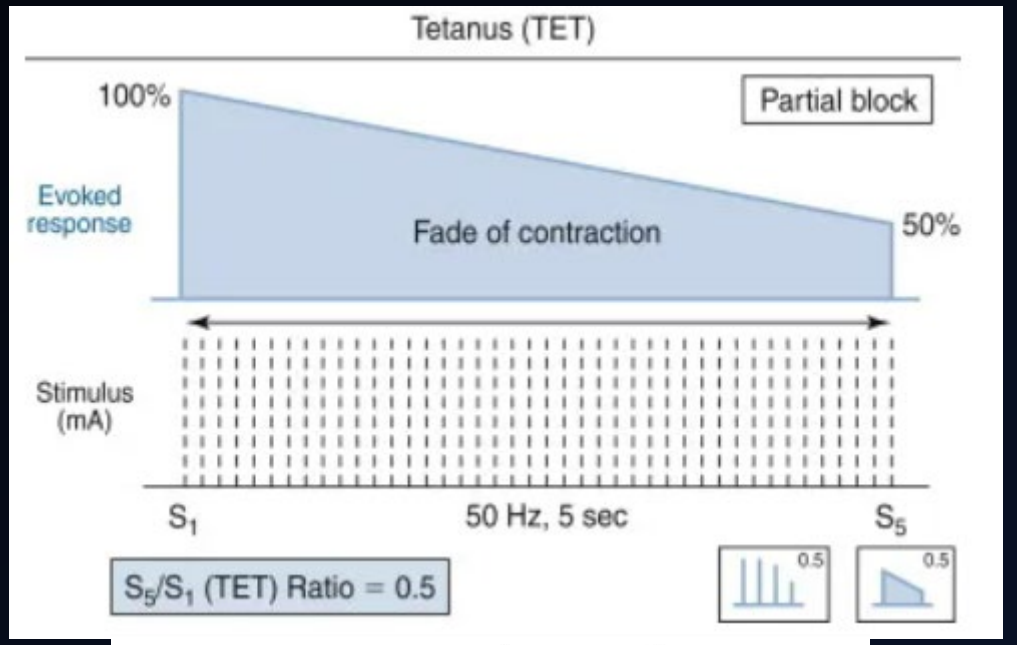
Fig. 1. Photograph of the apparatus designed to in response to ulnar nerve stimulation.[9] Republished with permission of Elsevier Science & Technology Journals. From Ali HH: A new device for monitoring force of thumb adduction. Br J Anaesth 1970; 42:83–5; permission conveyed through Copyright Clearance Center, Inc..

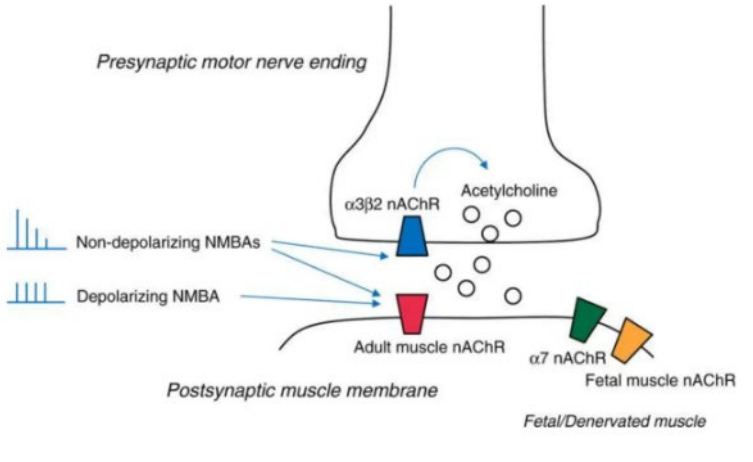

ST
100%
Evoked response
1 sec or 10 sec
Stimulus
T_C
T_1
T_1
T_1
T_1
A
T_1/T_C Ratio = 1.0
TOF
100%
Evoked response
500 ms
Stimulus (mA)
T_1
T_2
T_3
T_4
B
T_4/T_1 Ratio = 1.0
$DBS_{3,3}$
100%
Unblocked
Evoked response
50 Hz
50 Hz
Stimulus (mA)
750 ms
D_1
D_2
C
D_2/D_1 Ratio = 1.0
1.0
1.0
$DBS_{3,2}$
100%
80%
Unblocked
Evoked response
50 Hz
50 Hz
Stimulus (mA)
750 ms
D_1
D_2
D
D_2/D_1 Ratio = 0.8
1.0
0.8

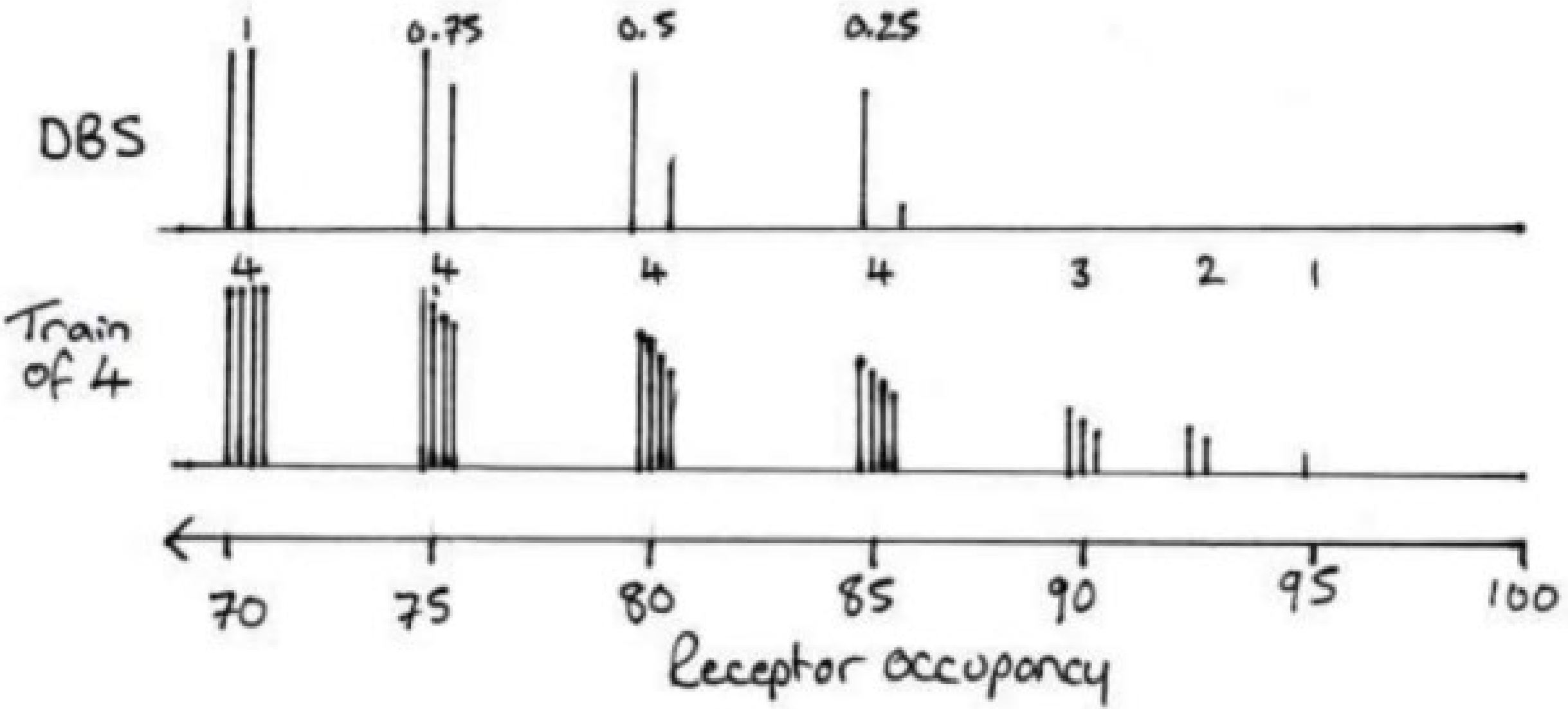

TET
Unblocked
Evoked response
Sustained contraction
Stimulus (mA)
S1
50 Hz, 5 sec
S5
E
S5/S1 (TET) Ratio = 1.0
1.0
1.0

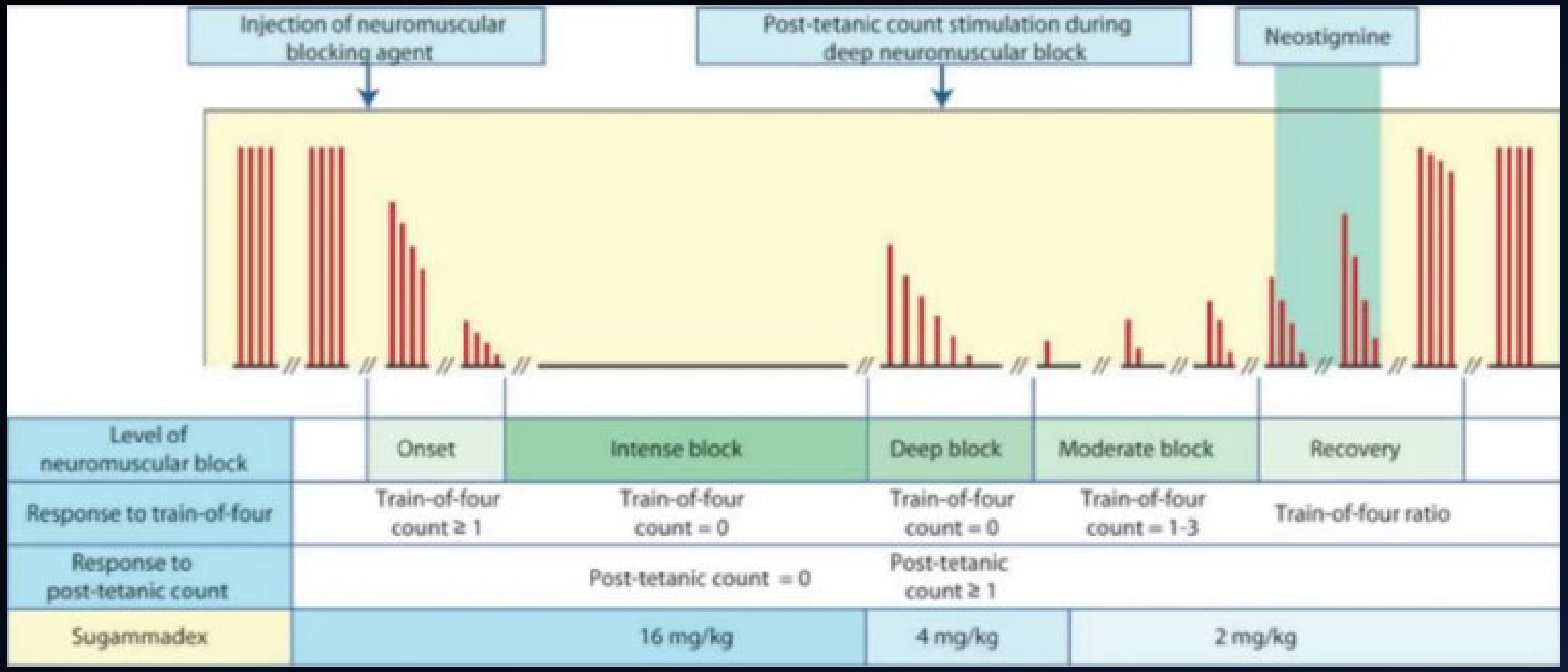

PTC
Evoked response
No TOF or tetanic response
3 sec
0
1 2 3 4
Stimulus (mA)
50 Hz, 5 sec
ST at 1/sec
TOF
Tetanus
PTC = 4


Depolarizing block
Nondepolarizing block
Twitch height (%)
100
80
60
40
20
0
A B C D
Time


Tetanus (TET)
100%
Partial block
Evoked response
Fade of contraction
50%
Stimulus (mA)
S1
50 Hz, 5 sec
S5
S5/S1 (TET) Ratio = 0.5
0.5
0.5

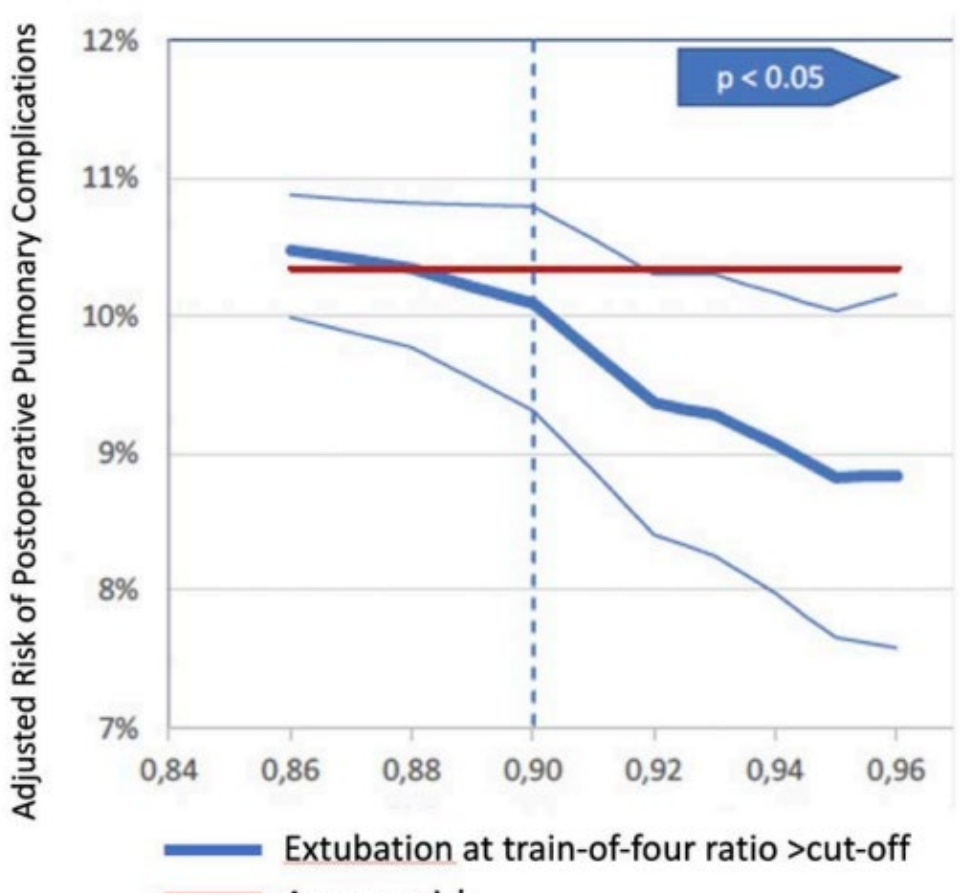

Presynaptic motor nerve ending
α3β2 nAChR
Acetylcholine
Non-depolarizing NMBAs
Depolarizing NMBA
Adult muscle nAChR
α7 nAChR
Fetal muscle nAChR
Postsynaptic muscle membrane
Fetal/Denervated muscle


1
0.75
0.5
0.25
DBS
4
4
4
4
3
2
1
Train of 4
70
75
80
85
90
95
100
Receptor occupancy


Injection of neuromuscular blocking agent
Post-tetanic count stimulation during deep neuromuscular block
Neostigmine
Level of neuromuscular block
Onset
Intense block
Deep block
Moderate block
Recovery
Response to train-of-four
Train-of-four count ≥ 1
Train-of-four count = 0
Train-of-four count = 0
Train-of-four count = 1-3
Train-of-four ratio
Response to post-tetanic count
Post-tetanic count = 0
Post-tetanic count ≥ 1
Sugammadex
16 mg/kg
4 mg/kg
2 mg/kg

	Train-of-Four Ratio						
Type of Monitoring for RNMB	≤4/4 Twitches	≤0.4	≤0.5	≤0.6	≤0.7	≤0.8	≥0.9
Quantitative Monitoring (qTOFR)	X	X	X	X	X	X	X
Tetanic Stimulation	X	X	X	X	X	X	
Double Burst Stimulation	X	X	X	X	X	X	
Clinical Signs (e.g., head lift, hand grip, tongue protrusion	X	X	X	X	X	X	
Subjective Train-of-Four (TOFR)	X	X					

J Clin Med. 2024 Feb; 13(3): 861.
Published online 2024 Feb 1. doi: 10.3390/jcm13030861



Incidence, risk factors, and consequences of residual neuromuscular block in the United States: The prospective, observational, multicenter RECITE-US study

J Clin Anesth. 2019 Aug:55:33-41. doi: 10.1016/j.jclinane.2018.12.042.

Main results: Most of the study population, 64.7% (n = 165) had rNMB (TOF ratio < 0.9), among them, 31.0% with TOF ratio <0.6. Among those receiving neostigmine and/or qualitative peripheral nerve stimulation per clinical decision, 65.0% had rNMB. After controlling for confounders, we observed male gender (odds ratio: 2.60, P = 0.008), higher BMI (odds ratio: 1.04/unit, P = 0.043), and surgery at a community hospital (odds ratio: 3.15, P = 0.006) to be independently associated with increased odds of rNMB.

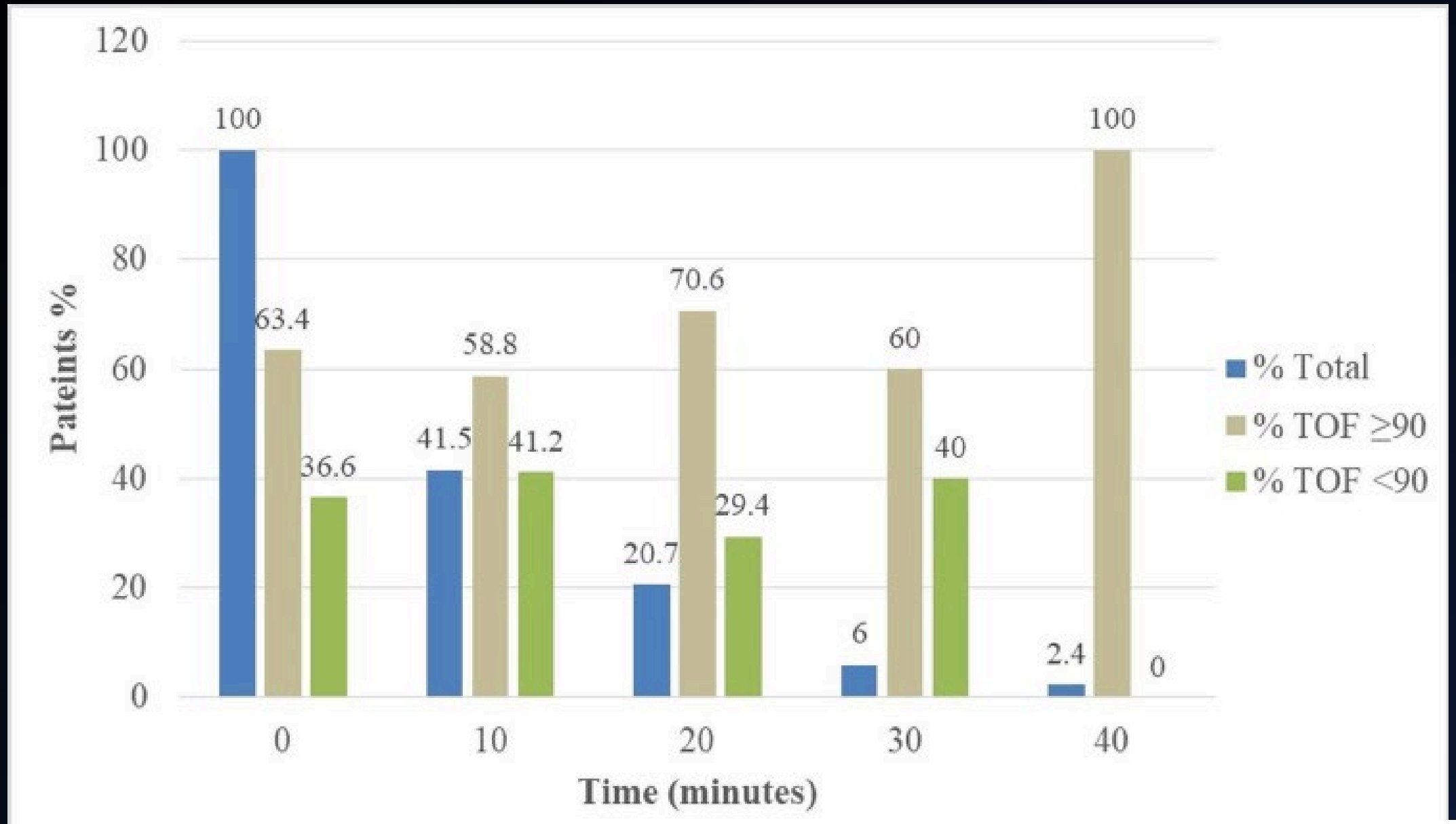
Conclusions: Assessing TOF ratios blinded to the care team, we found that the majority of patients (64.7%) in this study had rNMB at tracheal extubation, despite neostigmine administration and qualitative peripheral nerve stimulation used for routine clinical care. Qualitative neuromuscular monitoring and clinical judgement often fails to detect rNMB after neostigmine reversal with potential severe consequences to the patient. Our data suggests that clinical care could be improved by considering quantitative neuromuscular monitoring for routine care.

	Acceleromyography Group	Conventional Peripheral Nerve Stimulator Group	Difference (99% CI)	*P* Value
Number (n)	89	90	—	—
Spo_2 on PACU arrival, %	97 (90 to 100)	95 (72 to 100)	2 (1 to 3)	< 0.0001
No. with Spo_2 90–93% on arrival in PACU	5 (5.6%)	22 (24.4%)	−18.8% (−32.9 to −5.5%)	< 0.001
No. with Spo_2 < 90% on arrival in PACU	0 (0%)	9 (10.0%)	−10.0% (−21.1 to −2.7%)	0.003
No. with episodes of Spo_2 90–93% in PACU	6 (6.7%)	39 (43.3%)	−36.6% (−51.2 to −21.1%)	< 0.0001
No. of Spo_2 90–93% episodes in PACU	0 (0 to 4)	0 (0 to 12)	0 (−1 to 0)	< 0.0001
No. with episodes of Spo_2 < 90% in PACU	0 (0%)	19 (21.1%)	−21.1% (−34.0 to −12.2%)	< 0.0001
No. of Spo_2 < 90% episodes in PACU	0 (0 to 0)	0 (0 to 6)	0 (0 to 0)	< 0.0001
Lowest Spo_2 in PACU, %	96 (90 to 100)	93.5 (80 to 100)	3 (2 to 4)	< 0.0001
No. requiring airway maneuver in PACU	0 (0%)	4 (4.4%)	−4.4% (−13.8 to 2.7%)	0.12
No. requiring stimulation to maintain Spo_2 in PACU	0 (0%)	7 (7.8%)	−7.8% (−18.3 to −0.5%)	0.014

Anesthesiology 2022; 136:345–61

	Year	Trial Design	Threshold of Recovery	Number of Subjects	Quantitative Monitor	Control Group	Muscle Relaxant	Criteria for Extubation	Incidence of Residual Block (percentage of patients)
Mortensen[39]	1995	Randomized	Train-of-four < 0.7	40	Acceleromyography	No monitor	Pancuronium	Control group: clinical criteria Study group: clinical + train-of-four > 0.7	50% in control group 5.3% in acceleromyography group
Gätke[40]	2002	Randomized	Train-of-four < 0.8	120	Acceleromyography	No monitor	Rocuronium	Control group: clinical criteria Study group: clinical + train-of-four > 0.8	16.7% in control group 3% in acceleromyography group
Wardhana[41]	2019	Randomized	Train-of-four < 0.9	72	Acceleromyography	Peripheral nerve stimulator	Rocuronium	Control group: > 15 min after reversal; Study group: train-of-four ≥ 0.9	16.7% in control group 2.8% in acceleromyography group
Murphy[42]	2008	Randomized	Train-of-four < 0.9	185	Acceleromyography	Peripheral nerve stimulator	Rocuronium	Control group: clinical criteria Study group: clinical + train-of-four > 0.8	30% in control group 4.5% in acceleromyography group
Murphy[43]	2011	Randomized	Train-of-four < 0.9	155	Acceleromyography	Peripheral nerve stimulator	Rocuronium	Control group: clinical criteria Study group: clinical + train-of-four > 0.8	50% in control group 14.5% in acceleromyography group
Domenech[44]	2019	Retrospective cohort	Train-of-four < 0.9	240	Kinemyography	No monitor	Rocuronium Vecuronium Atracurium	Not stated	32% in control group 1.6% in kinemyography group

Anesthesiology 2022; 136:345–61



Cureus. 2023 Dec; 15(12): e51013.
Published online 2023 Dec 23. doi: 10.7759/cureus.51013

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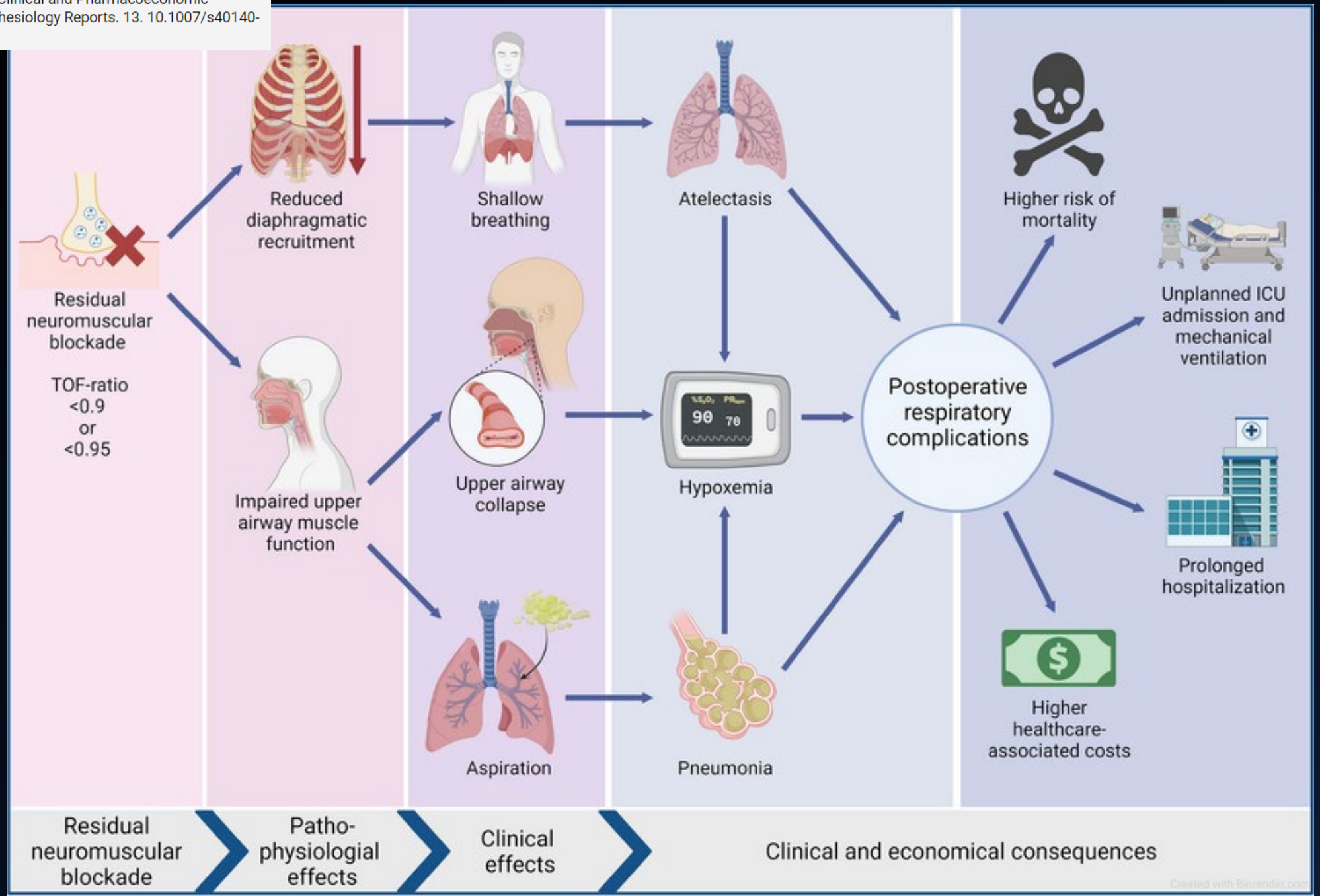


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