NEUROMUSCULAR MONITORING

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Introduction

Why monitoring is required ?

1. Asses onset of NM block (intubation)
2. Obtain good muscle relaxation at surgical site
3. Smooth extubation
4. Minimize residual paralysis ; **PORC –post op residual curarization**

Monitoring is a tool , but not cure

Muscle relaxants acts over narrow range of receptor occupancy

Inter individual variability in response



So, clinician needs to assess the effects without confounding influence of volatile agents, inductional agents & opioids

Indication for monitoring

1. Liver disease
2. Renal impairment
3. Neuromuscular disorder like MG, LE syndrome, UMN, LMN lesions
4. Obesity
5. Severe pulmonary disease
6. NMB infusions or long acting NMB
7. Long surgeries

Principles of PNS

- Each muscle fibre follows all or none law
- Response to stimulus decreases when more fibers are blocked
- Reduction in response during constant stimulus reflects degree of blockade
- For this reason stimulus is called **supramaximal**

Terms related to PNS

- **Stimulus strength** – depolarizing intensity of a stimulus (depends on pulse width & current intensity)
- **Pulse width** – duration of individual impulse
- **Current intensity** – it is mA current delivered ; it depend upon resistance , impedance of electrode, skin & tissues.

Reduction of temperature increases tissue resistance & causes low current delivery below the supramaximal range

Cont..

- **Threshold current** – lowest current required to depolarize most sensible nerve fibre to elicit a response
- **Supramaximal current** – 2 to 3 times higher than threshold current
- **Submaximal current** – intensity of current that depolarize only fraction of nerve fibre, it is less painful than supramaximal current.
- **Stimulus frequency** – rate at which each impulse is repeated in cycles per second (Hz)

Stimulator characteristics

PNS are constant current & variable voltage delivery devices

Response of nerve to stimulation depends upon

1. Current applied (max range 60 to 80 mA)
2. Duration of the current (0.1 to 0.2 ms)
3. Position of electrodes

Cont..

- Duration of current should be long enough to depolarize all the axons
- But , it should not exceed the refractory period
- Proper functioning display monitor should be ensured

Electrodes

Surface electrodes

1. Made of pregelled silver chloride
2. Transcutaneous impedance reduced by conducting gel
3. Conducting area 7 – 11 mm

Needle electrodes

- Needle introduced to vicinity of nerve
- Overcome the tissue impedance

Drawbacks

I. Infection
II. Burns
III. Intraneural placement
IV. Direct muscle stimulation
V. Over stimulation due increased current flow

Metal ball electrodes



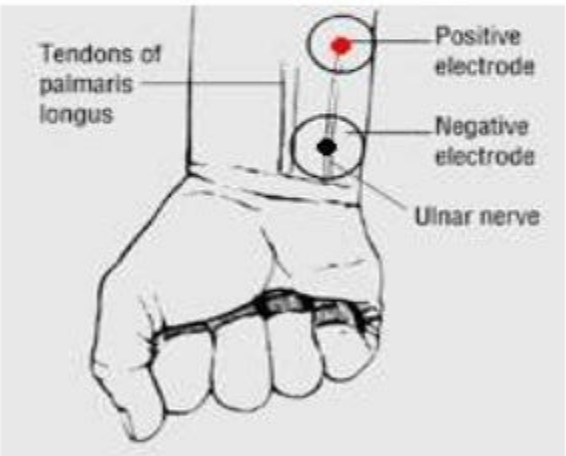
Convenient to use but no good contact and can cause burns.

Polarity

- Stimulators produce a direct current by using one negative and one positive electrode
- Should be indicated on the stimulator
- Maximal effect is achieved when the **negative** electrode is placed **directly over the most superficial part of the nerve** being stimulated
- The **positive** electrode should be placed along the course of the nerve, **usually proximally** to avoid direct muscle stimulation

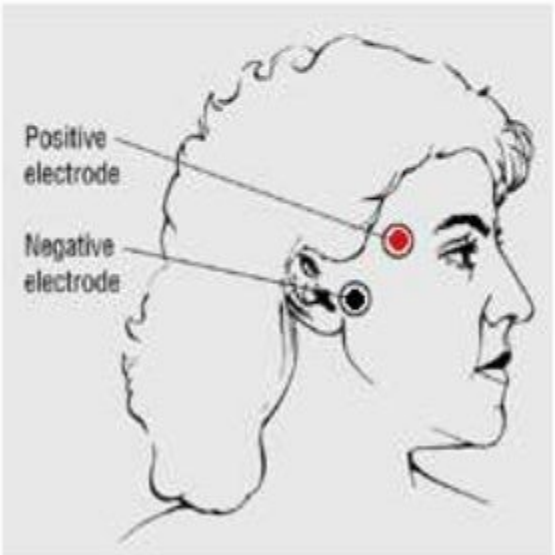
Electrode placement

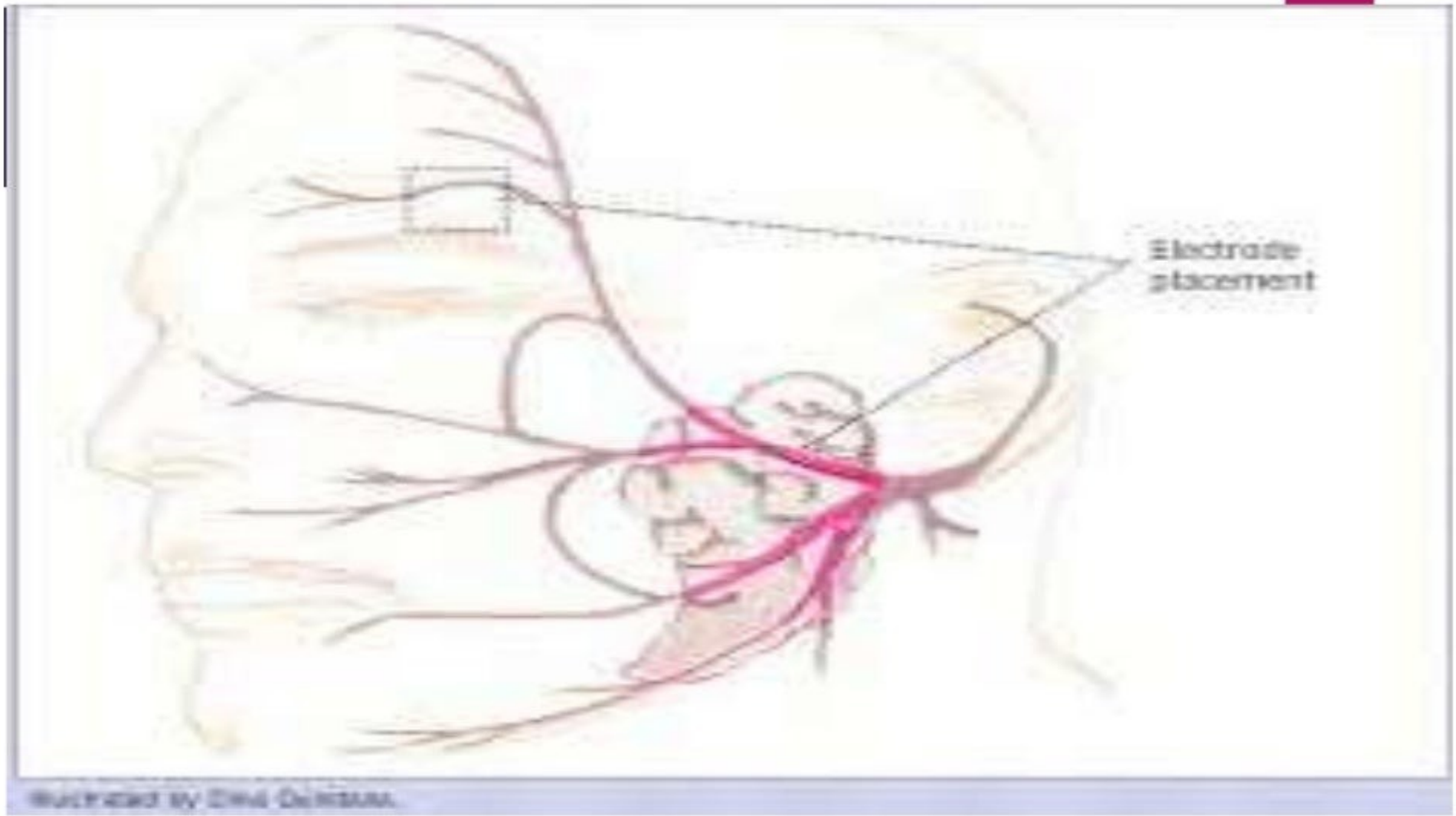
Response adductor policis muscle – thumb adduction



Facial nv

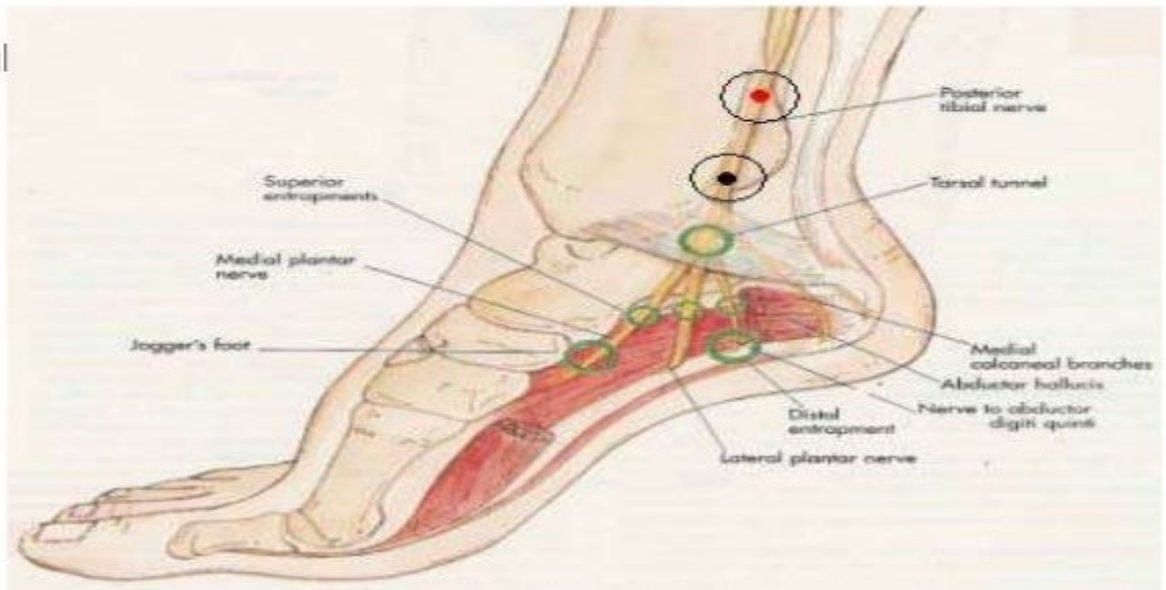
Response orbicularis oculi – eyelid twitching




Electrode
placement

Posterior tibial nv

- Negative (black) over inferolateral aspect of medial malleolus (palpate post tibial atery pulse)
- Positive 2 – 3cm proximal

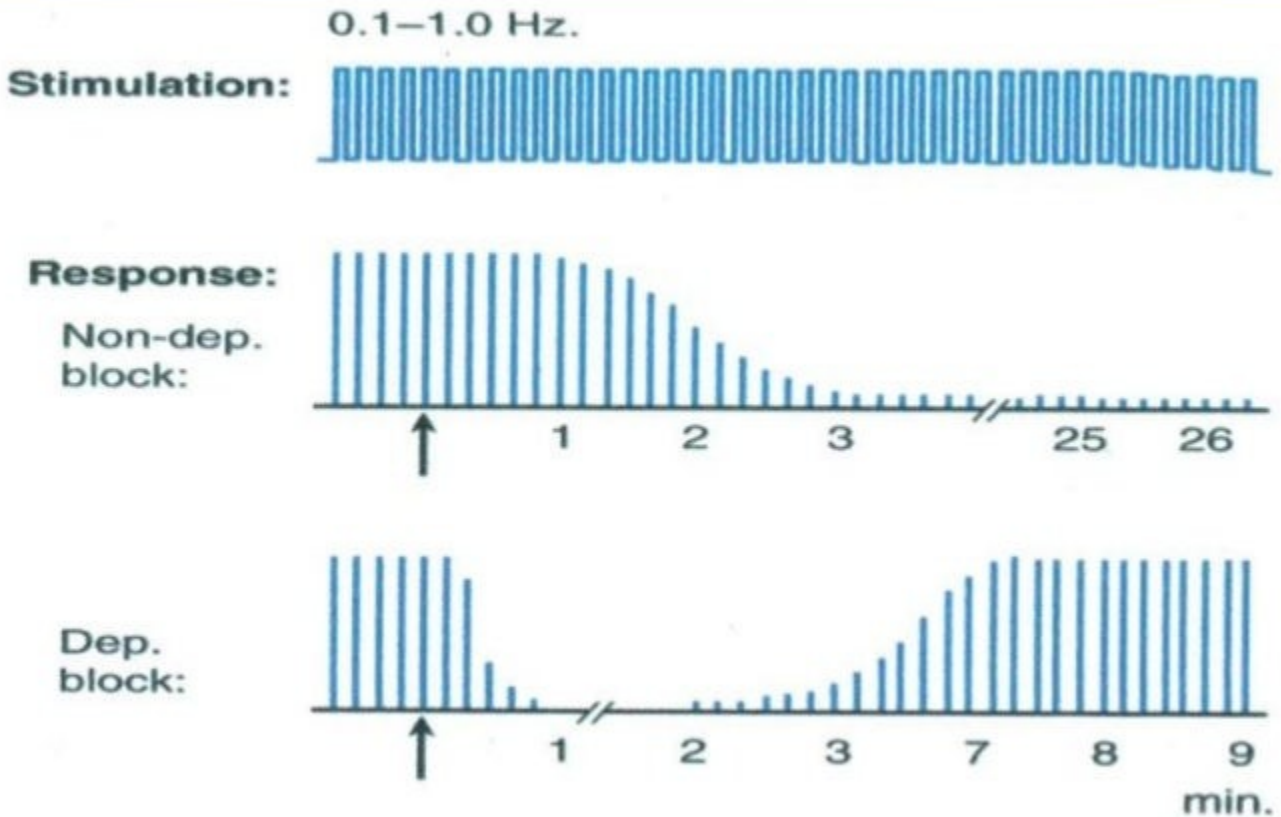


Monitoring modalities

- Single twitch
- Tetanus
- Train of four
- Post tetanic count
- Double burst stimulation

Single twitch

- Single supramaximal stimulus is given for 0.1 to 0.2 msec impulse
- It induces a single nerve action potential in each nerve fibre
- **Height of evoked muscle response depends on number of unblocked junctions**
- Prerelaxant control value is required to interpret the magnitude of response
- Monitoring device is required
- Doesn't detect receptor block of less than 70%
- Used to **asses potency of drugs**
- **Stimulation dependent onset time**


0.1–1.0 Hz.
Stimulation:
Response:
Non-dep.
block:
1
2
3
25
26
Dep.
block:
1
2
3
7
8
9
min.

Train of four

- Described by Ali et al
- Four successive stimuli delivered at 2 Hz (every 0.5 sec)
- Fade in the response is basis for evaluation
- Ratio of response to 4th response **(T4)** to 1st response **(T1**) gives **TOF ratio**

Correlation to extent of block

- Disappearance of 4th response represents 75% block
- Disappearance of 3rd twitch represents 80 % block
- And , 2nd 90 % block
- **Clinical relaxation requires 75% to 95% neuromuscular blocks.**

TOF in muscle relaxants

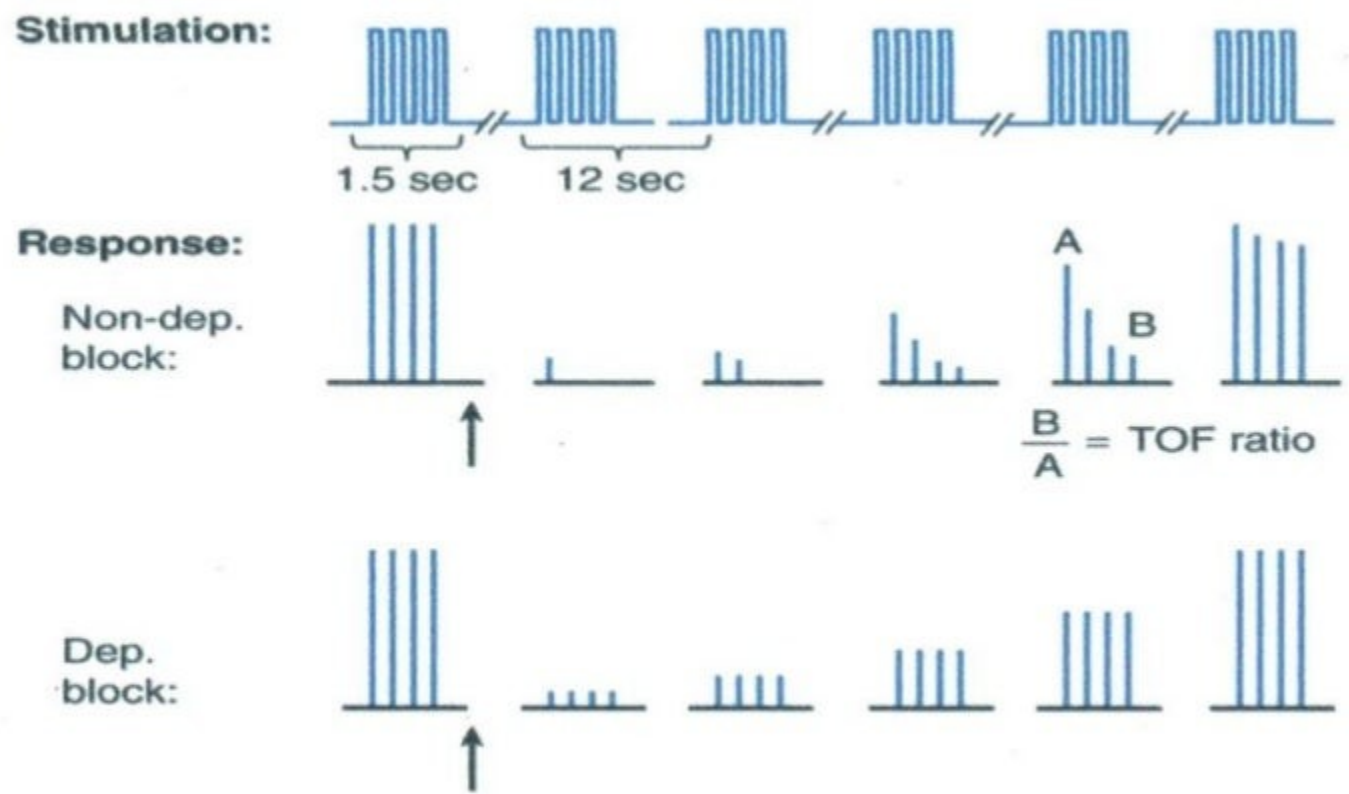
- Depolarising block does not produce fade
- If fade appears then phase 2 block
- Non depolarising block produces progressive fade
- TOF ratio ~ 1 / blockade in ND blocks

Normal Responses (No drugs present)	Nondepolarizing Block	Depolarizing Block (Succinylcholine)	
		Phase I	Phase II
			
Train of four at (2 HZ)	$\frac{4}{1}$ = TOF ratio	Constant but diminished	TOF <0.3
	Fade		Fade

Common TOF Guidelines:

TOF 0.15-0.25: indicates adequate surgical relaxation

TOF >0.9: needed for safe extubation & recovery after surgery


Stimulation:
1.5 sec
12 sec
Response:
Non-dep. block:
A
B
B/A = TOF ratio
Dep. block:

Advantages of TOF

- Can be used to **quantify depth of block** without the need for control measurement before relaxant administration
- Frees clinician from recording devices
- Does not affect the neuromuscular blockade
- May be delivered at **submaximal** current which is less painful

Tetanic stimulation

- Stimulation at 50 Hz for 5 sec
- Sustained tetanic contraction of muscle is evoked response
- **Progressive depletion of acetylcholine output is balanced by increased synthesis & transfer of transmitter from its mobilization stores .**

Response to blocks

- During non depolarizing & phase 2 blocks response fades
- During normal NM transmission & depolarizing block response sustains

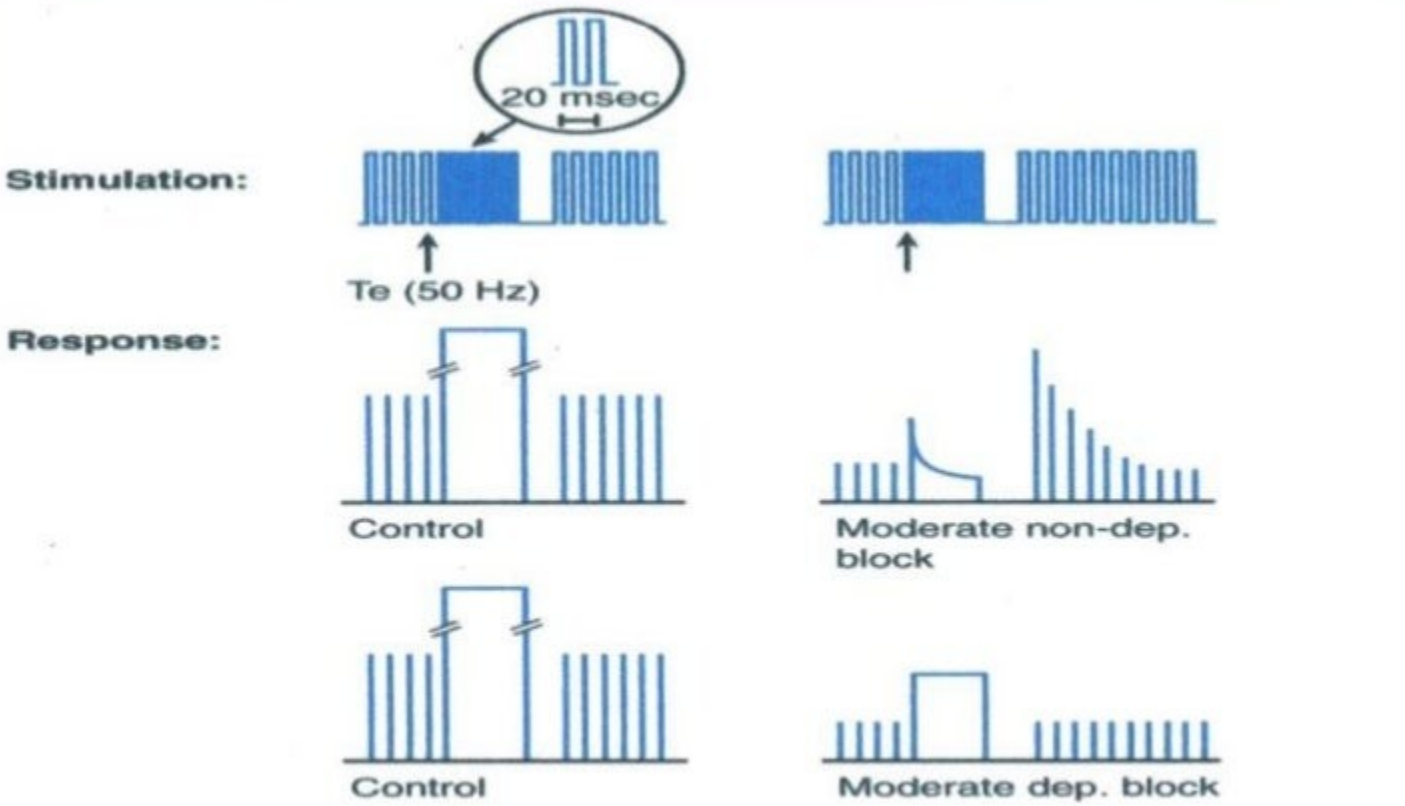
↓ **number of free choline receptors**

\+

↓ **mobilisation of stores**

} **contribute to fade**

During partial non depolarizing block tetanic stimulation is followed by post tetanic facilitation.


20 msec
Stimulation:
Te (50 Hz)
Response:
Control
Moderate non-dep. block
Control
Moderate dep. block

Post tetanic count stimulation

Tetany → increased production of transmitter & mobilisation after cessation of tetanic stimulation

↓

increase quata of acetyl choline

↓

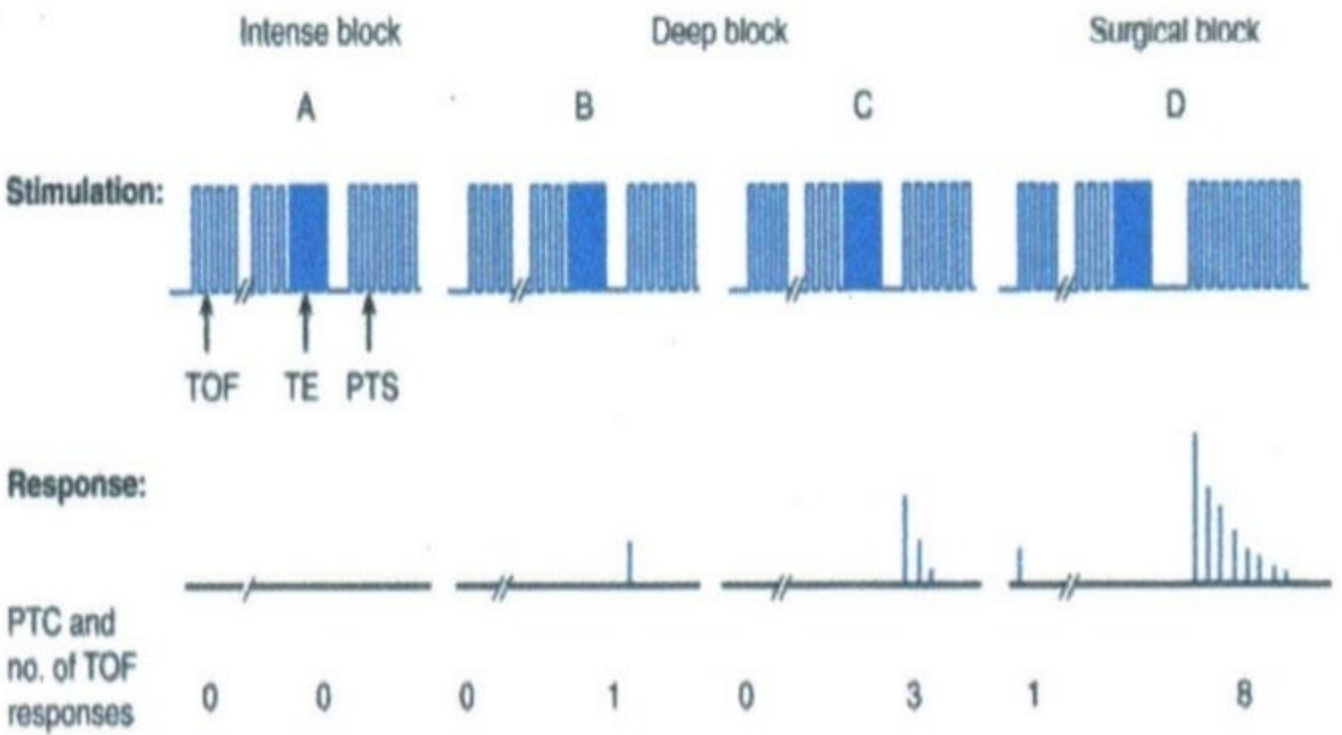
after 3 seconds single twitch stimulation given at 1 Hz

↓

evoked post tetanic twitches is **called post tetanic count (PTC)**

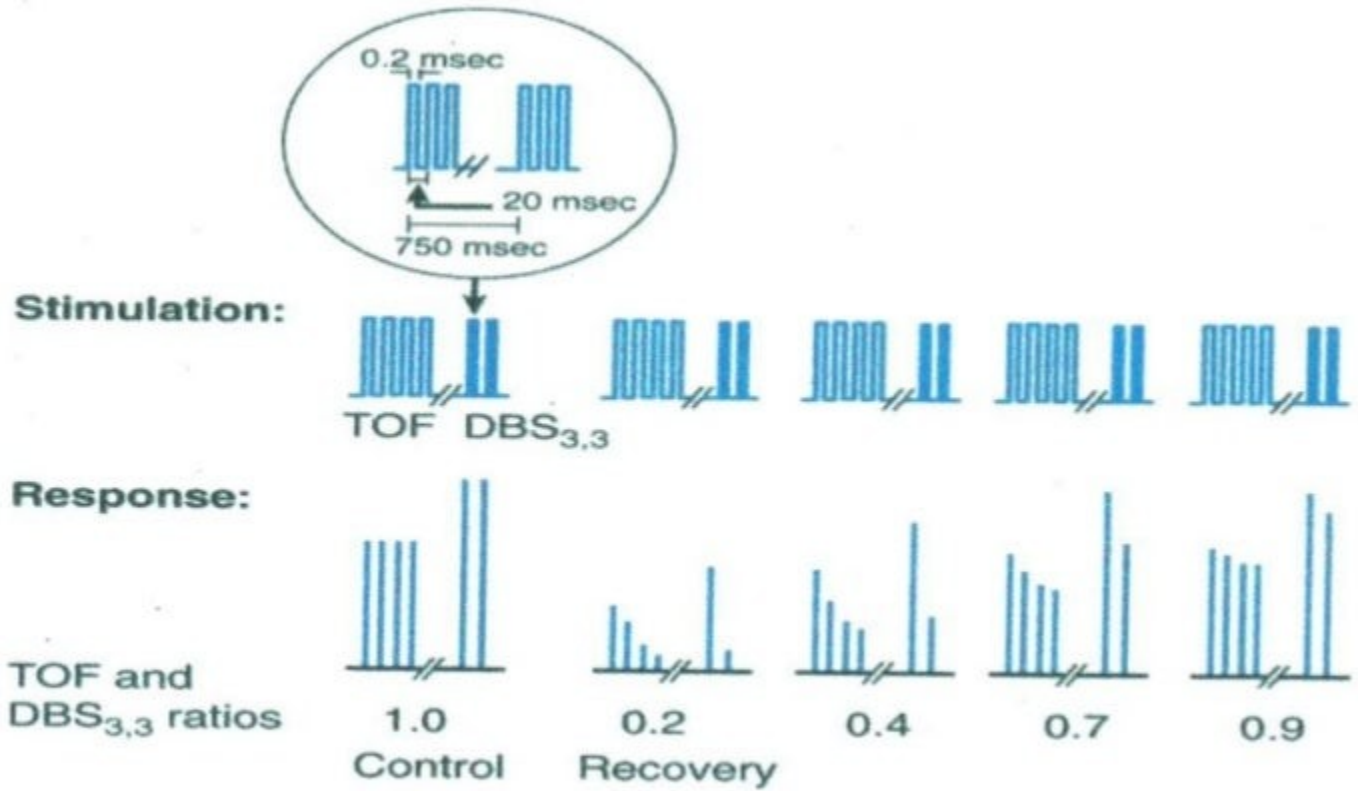
Clinical significance of PTC

- Used when there is no response to single twitch or TOF
- Used for surgery where sudden movement is avoided like ophthalmic surgery
- **Number of twitch correlates inversely with time to recovery**
- During NMDRs infusion
- Correct time to give reversal

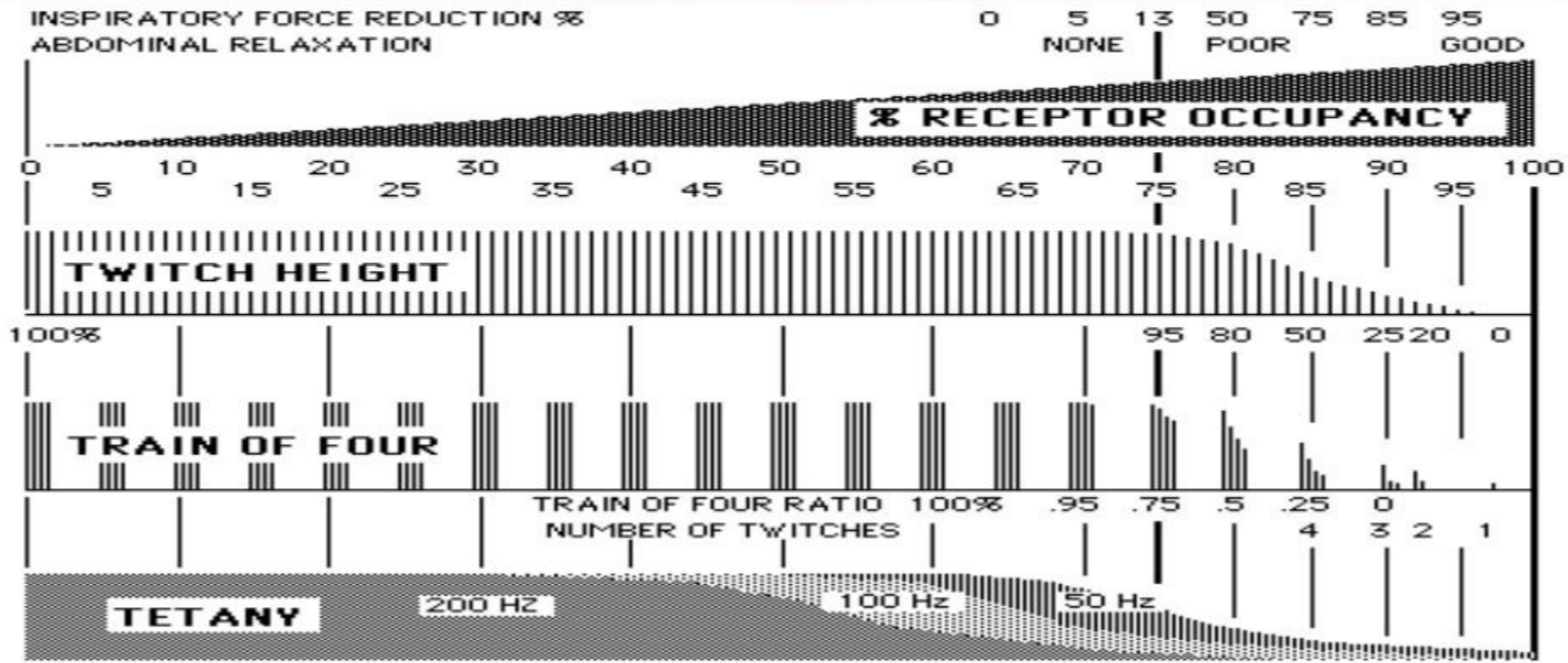

Intense block
Deep block
Surgical block
A
B
C
D
Stimulation:
TOF
TE
PTS
Response:
PTC and no. of TOF responses
0
0
0
1
0
3
1
8

Double burst stimulation

- Two train of 3 impulses at 50 Hz separated by 750 ms
- Magnitude of fade is similar to TOF but human senses detect DBS better
- At least 12 to 15 sec must be given between two consecutive stimuli
- **Allows manual detection of residual blockade**


0.2 msec
20 msec
750 msec
Stimulation:
TOF DBS3,3
Response:
TOF and
DBS3,3 ratios
1.0
Control
0.2
Recovery
0.4
0.7
0.9

Correlation with receptor occupancy



Feature	ST	TOF	Tetanus	DBS	PTC
Current strength	Supra-maximal	Supra or submaximal	Supra or submaximal	Supra or submaximal	Supra or submaximal
Frequency / Description	0.1 to 1 Hz	2 Hz four stimuli	30-50 Hz for 5 sec	3 impulses at 50 Hz repeated after 750 msec	30 Hz for 5 sec, 3 sec later ST at 1Hz
Prerelaxant Control	Needed	Not needed	Not needed	Not needed	Not needed
Pain on stimulation	-	- / +	+ +	+	+ +
Sensitivity of manual detection (visual/tactile)	Not sensitive	Not sensitive at TOF ratio of 0.4-0.7	Sensitive	Highly sensitive	Sensitive
Alteration of subsequent responses	Not altered	Not altered	Altered (post-tetanic facilitation)	Not altered	Altered
Interval between successive stimuli	5 sec	12 sec	6 min	12-15 sec	6 min
Receptor occupancy detection	75-90%	70-90%	70-90%	70-90%	>90% also
Sensitivity for detection of subtle block	Not sensitive	Sensitive	Sensitive	Sensitive	Not applicable
Monitoring of profound block	Not useful	Not useful	Not useful	Not useful	Useful

Non depolarizing MR

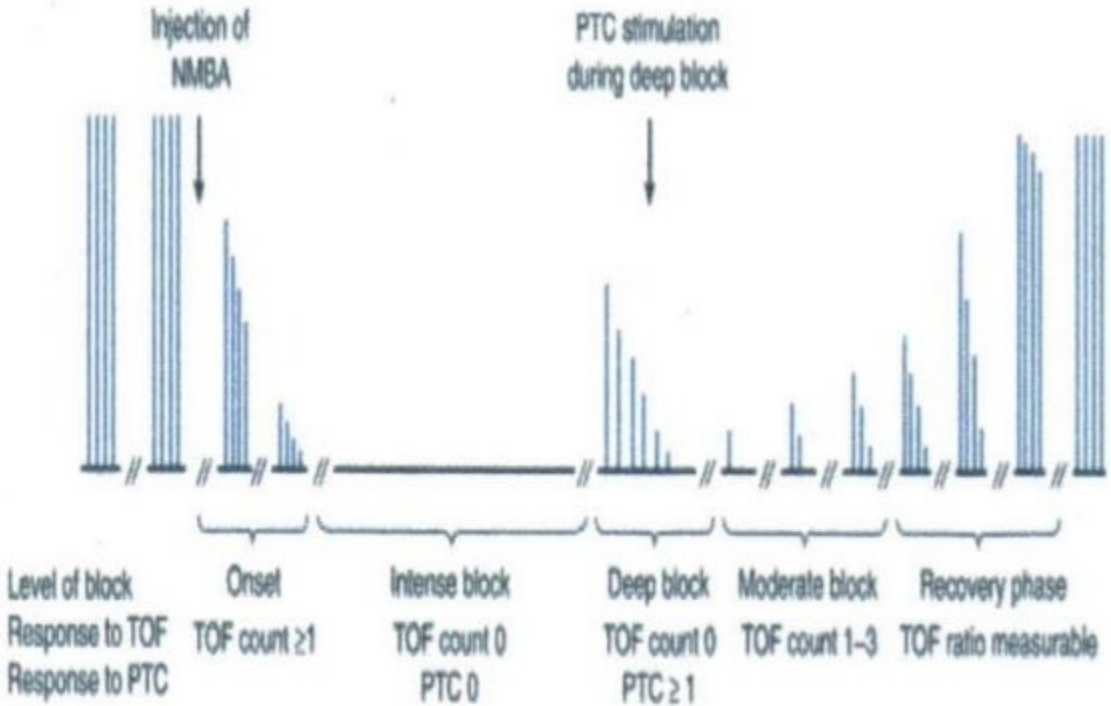
Intense NM blockade- period of no response

Deep NM blockade- TOF response absent, post tetanic twitches present

Surgical blockade- begins when 1st response to TOF stimulation is seen, 1 or 2 response indicates sufficient relaxation

Recovery – return of 4th response

- Return of spontaneous respiration does not imply full recovery
- TOF ratio> 0.9 excludes clinically important residual paralysis
- Reversal may given after 2 response


Injection of NMBA
PTC stimulation during deep block
Level of block
Response to TOF
Response to PTC
Onset
TOF count ≥1
Intense block
TOF count 0
PTC 0
Deep block
TOF count 0
PTC ≥1
Moderate block
TOF count 1–3
Recovery phase
TOF ratio measurable

Depolarizing MR

Phase 1 block

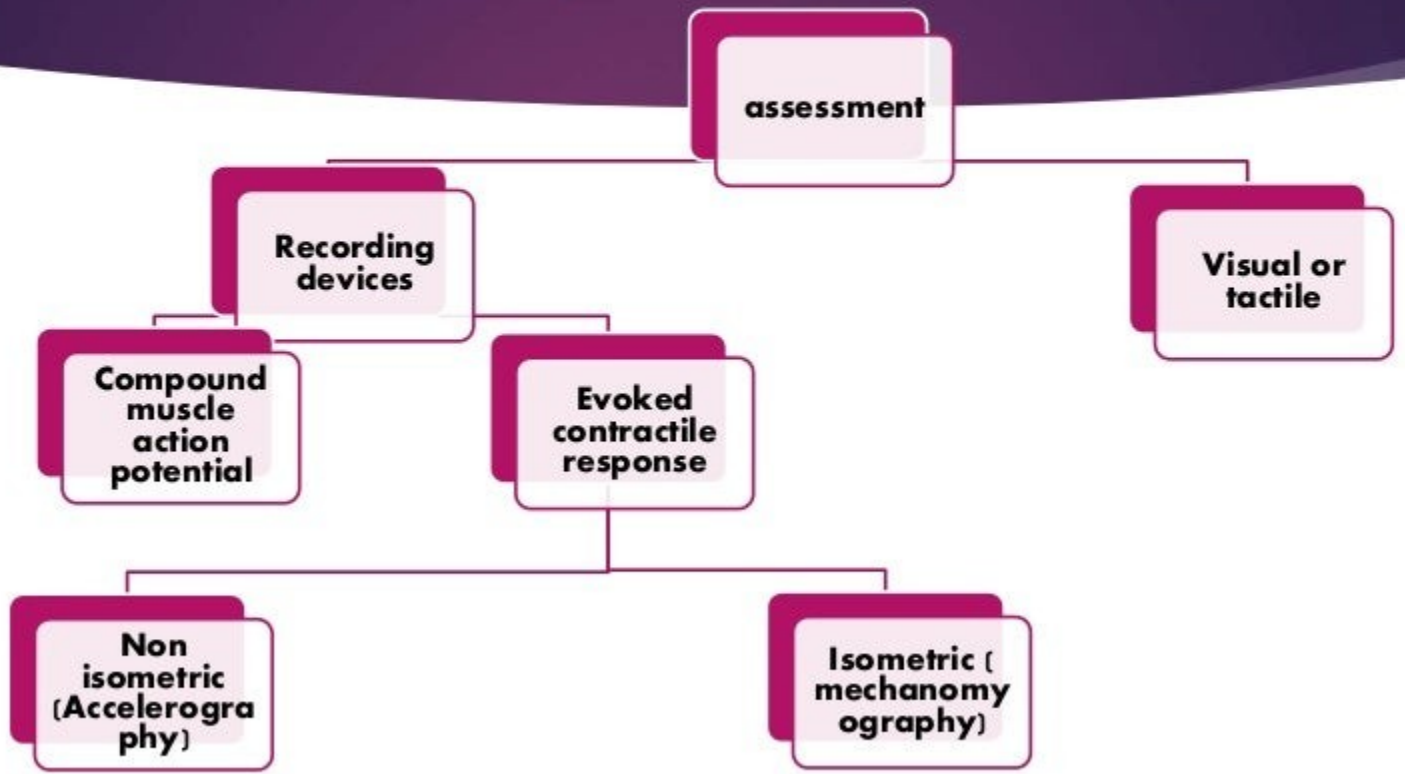
no fade to TOF, tetany, no PTC

Phase 2 block

fade to TOF indicates phase 2 block

Occurs in abnormal cholinesterase activity or reccurent dosage of scoline

Assessment of response



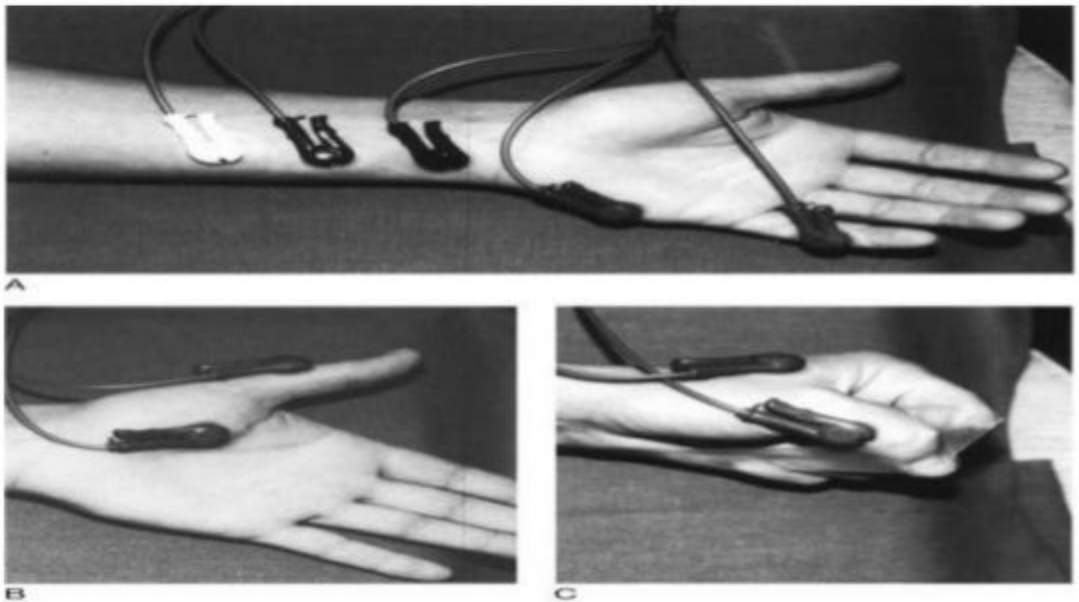
Recording Device

Compound muscle action potential: It is the cumulative electrical signal generated by the individual action potentials of the individual muscle fibers.

Electromyogram (EMG)

- Records compound MAP electrodes placed at midpoint of muscle
- The latency of the compound MAP is the interval between stimulus artifact and evolved muscle response.

For experimental studies



Mechanomyographic device
(isometric)
(Adductor pollicis force translation monitor)

- **Quantifies the force of isometric contraction**
- **The force → electrical signal → pressure monitor and recorded.**
- *Key features :*

a. Alignment of the direction of thumb movement with that of the pressure transducer.

b. Application of consistent amount of baseline muscle tension (preload 200-300 gms)

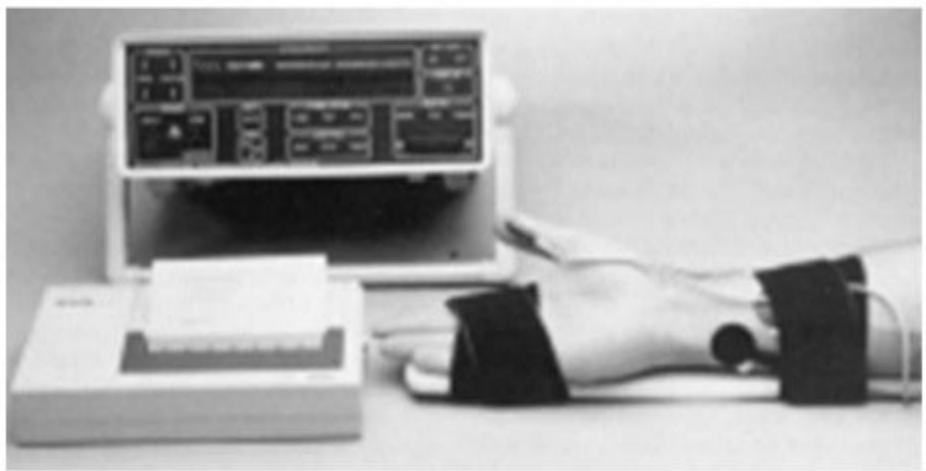
c. Transducer and monitor with adequate monitoring range and zeroing of the monitor before stimulation

Disadvantage of MMD

- These devices are difficult to set up for stable and accurate measurements
- Proper transducer orientation, isometric conditions, and application of a stable preload are required
- Maintenance of muscle temperature within limits is important

Accelerography
(non isometric)

- a miniature piezoelectric transducer to determine the rate of angular acceleration.
- **Newton's second law, F = m × a**
- Muscle must be able to move freely.



<u>Commercially available monitors</u>

1) TOF guard
2) Paragraph NMB monitor
3) Part of DATEX AS/3 monitoring system

Clinical tests of Postoperative Neuromuscular Recovery

RELAIBLE

- Sustained head lift for 5 sec
- Sustained leg lift for 5 sec
- Sustained "tongue depressor test"
- Maximum inspiratory pressure 40 to 50 cm H2O or greater

Non reliable

- Sustained eye opening
- Protrusion of tongue
- Arm lifted to the opposite shoulder
- Normal tidal volume
- Normal or nearly normal vital capacity
- Maximum inspiratory pressure less than 40 to 50 cm H2O

Table 4 : Relationship between clinical and train-of-four-evoked stimulation	
Test	**TOF Equivalent**
5-sec head or leg lift	0.6
Normal grip strength	0.7
Masseter	0.86
All subjects uncomfortable at TOF < 0.75	



Characteristics of the Three Muscle Fiber Types

	Slow-Twitch (Type I)	Fast-Twitch A (Type IIa)	Fast-Twitch B (Type IIb)
contraction time	slow	fast	very fast
size of motor neuron	small	large	very large
resistance to fatigue	high	intermediate	low
activity	aerobic	long-term anaerobic	short-term anaerobic
force production	low	high	very high
mitochondrial density	high	high	low
capillary density	high	intermediate	low
oxidative capacity	high	high	low
glycolytic capacity	low	high	high
major storage fuel	triglycerides	creatine phosphate, glycogen	creatine phosphate, glycogen

Table 3: Relative sensitivities of muscle groups to nondepolarizing muscle relaxants

Muscle	Sensitivity
Vocal cord	Most resistant
Diaphragm	
Orbicularis oculi	
Abdominal rectus	
Adductor pollicis	
Masseter	
Pharyngeal	
Extraocular	Most sensitive

Limitations of NM Monitoring

- Neuromuscular responses may appear normal despite persistence of receptor occupancy by NMBs.
- T4:T1 ratios is one even when 40-50% receptors are occupied
- Patients may have weakness even at TOF ratio as high as 0.8 to 0.9
- Adequate recovery do not guarantee ventilatory function or airway protection
- Hypothermia limits interpretation of response

Bibliography

1. Dr. D. Padmaja, Dr.Srinivas Mantha ; monitoring of neuromuscular junction :Indian j. Anaesth 2002 ; 46 (4) :279-288
2. 12th edition Lee's synopsis of Anaesthesia
3. 5th edition, clinical anaesthesiology by Morgan & Mikhail
4. 7th edition, clinical anaesthesia by Paul G Barash

THANK YOU