TOF 3D

Training

Preparation

Make sure to have the TOF3D Simulator installed on your computer.

In addition to that training you should read the user manual. Contact MIPM if you have any questions.

Agenda

- How muscles contract (brief reminder)
- Why relaxation of the muscles?
- Neuromuscular Transmission Monitoring (NMTM) in Clinical Practice
- TOF3D
- Trouble shooting
- Hands on
- Q&A

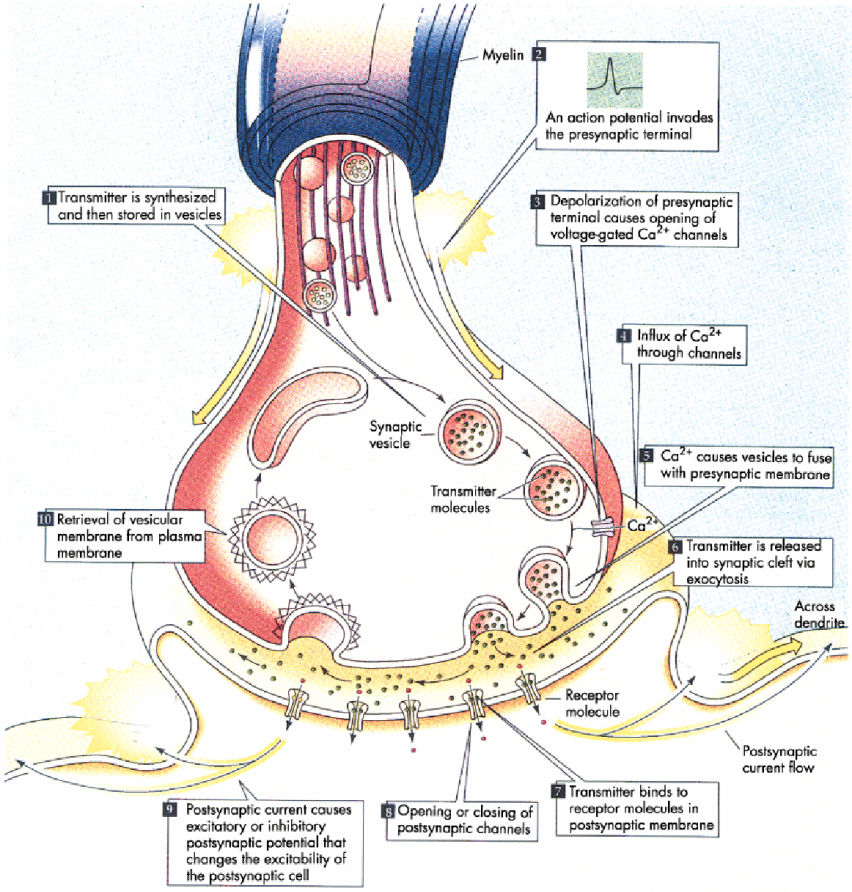
Terms

- Acetylcholine (ACh): Neurotransmitter responsible for stimulus transfer in the synaptic cleft at the neuromuscular end plate
- NMBA: Neuromuscular Blocking Agent
- Paralysis: relaxation of muscles due to application of NMBA
- TOF: Train of Four
- PTC: Post Tetanic Count
- AMG: Acceleromyography
- MMG: Mechanomyography
- EMG: Electromyography

How muscles contract

- a nerve is stimulated by impulses coming from the brain (or "artificial" electrical impulse)

- At the motor end plate Acetylcholine is emitted from the neuron in the synaptic cleft. ACh attaches to receptors at the muscle cell and enables contraction of the muscle



How muscles contract

- ACh is consumed and must be reproduced in the nerve

- If receptor is blocked (by NMBA) Acetylcholine cannot attach to receptor

  ➡ muscle cannot contract

  ➡ muscle is relaxed

- NMBA concentration in the synaptic cleft fades over time

  ➡ relaxation of the muscle decreases until complete recovery

  Time to full recovery varies between different patients and NMBA used!

- ***Only after a complete recovery the muscle is fully functional !!***

Why Relaxation?

1. Intubation
2. Required condition during surgery
   - During several surgery procedures surgeon needs the patient's muscles to be paralyzed to optimize surgical conditions.
3. Improve compliance during ventilation on the ICU

Why NMTM?

Residual paralysis may lead to severe complications for the patient.

- pharyngeal dysfunction
- increased risk for aspiration and pneumonia
- Acute respiratory events
- Residual paralysis increases patient's discomfort in general.

NMT Monitoring is used to determine the level of neuro muscular blockade.

- Save tracheal extubation only if TOF Ratio >0.9 (90%)
- Effective management of NMBA administration
  - Economic reason for NMTM
  - Maintain muscle relaxation to ensure proper surgical condition

Methods

- Electromyography - EMG
- Mechanomyography (Clinical reference) – MMG
- Acceleromyography (Clinical practicability) - AMG

NMT Monitoring in clinical practice

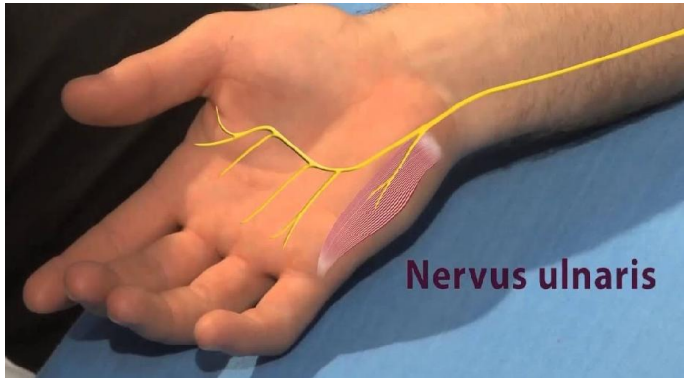
- TOF (Train Of Four) as reference for muscular paralysis and recovery condition of the patient

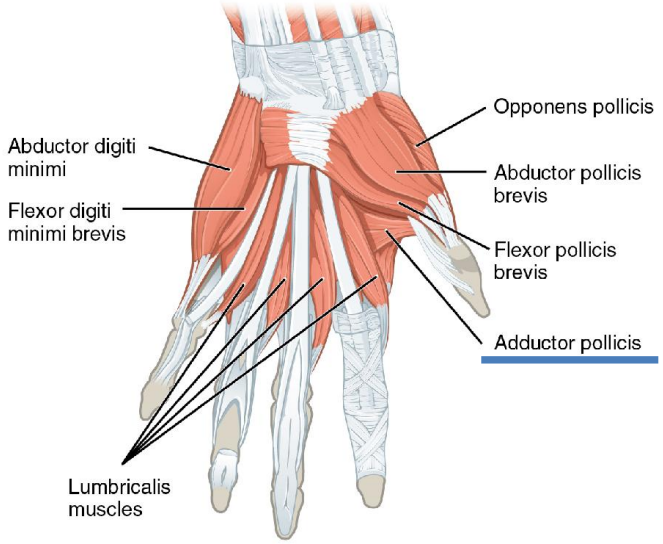
- PTC (Post Tetanic Count) for monitoring of deep muscular blockade

- Subjective neuromuscular monitoring with peripheral nerve stimulator (Subjective!! Based on personal perception)

TOF Stimulation - TOF Count/Ratio

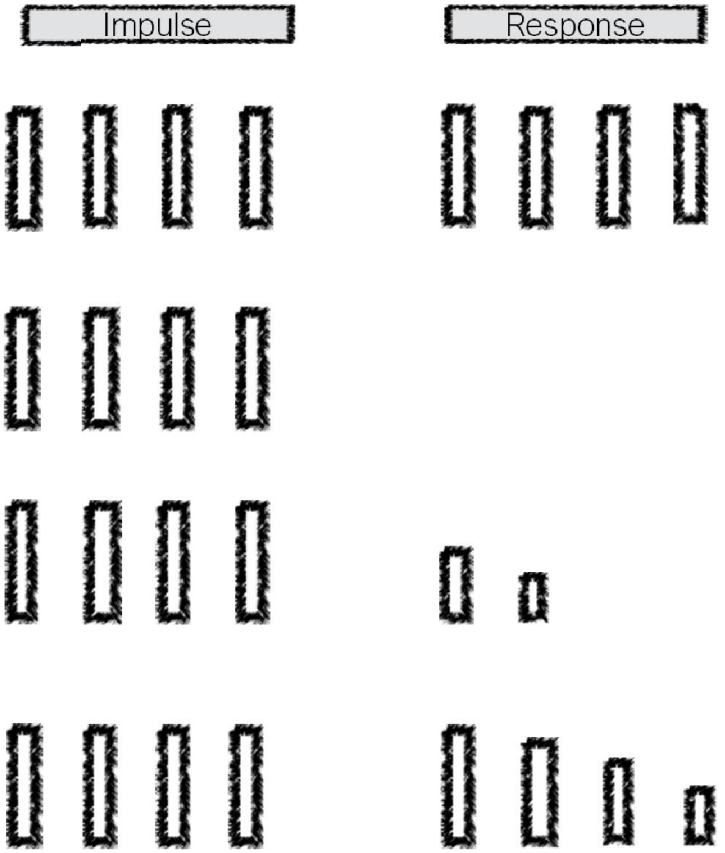
- Nervus ulnaris is innervated with 4 impulses
- Depending on neuromuscular block, 0-4 responses of Musculus Adductor Pollicis are received by TOF Monitor
- TOF Ratio = T4/T1
- TOF Ratio can only be calculated if 4 responses are detected.
  - T1 must be >20% compared to base line (Individual 100% answer)
  - T2, T3, T4 must be >3%
- Otherwise TOF Count 0 – 4
- If 4 responses are detected TOF Ratio is shown as "percentage of recovery"





TOF Count / Ratio - Examples

- Non relaxed patient / full recovery
- Full neuromuscular block
- Recovery: early stadium - (e.g. TOF count 2)
- Recovery: medium stadium - (e.g. TOF ratio 50%)



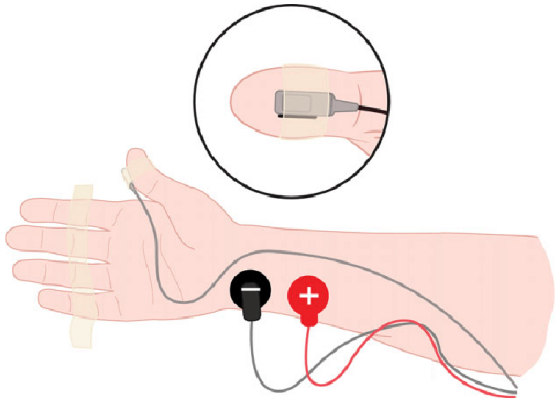
NMT Monitoring - Basics

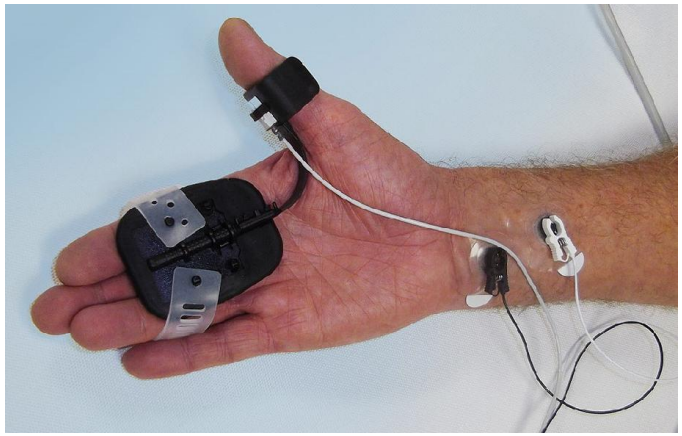
It all starts with the correct setup of stimulation electrodes and acceleration sensor!
The hand should be fixed to the OR table or the hand adapter should be used.

Use small (pediatric) electrodes to ensure proper placement and skin contact.

Observe polarization of the stimulation cables.

- Positive (White) cable: Proximal
- Negative (Black) cable: Distal





NMT Monitoring - Basics

The more distal the acceleration sensor is placed on the thumb, the stronger the acceleration signal. This effect can be used to adjust the signal strength.

NMT Monitoring - Basics

The shortcoming of AMG technology is that the observed muscle (e.g. adductor pollicis) requires space to move.

Only the movement (acceleration) of the muscles can be picked up by the sensor.

If hands are tucked to the body in an unfavorable way or if the free movement of the muscle is blocked by blankets or surgical drapes AMG will not work!

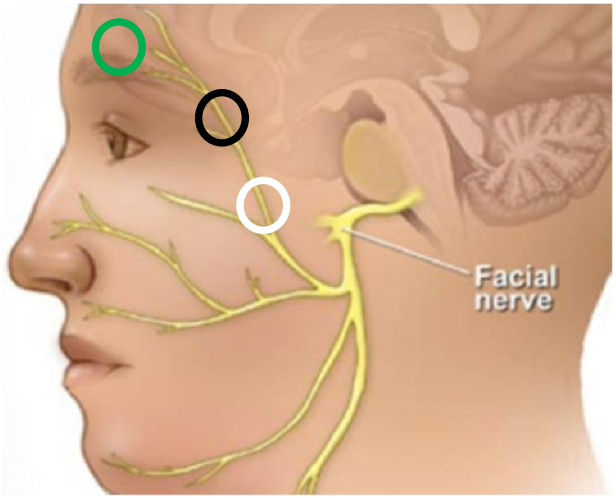
Using the hand adapter improves the performance by holding up the thumb providing space to move.

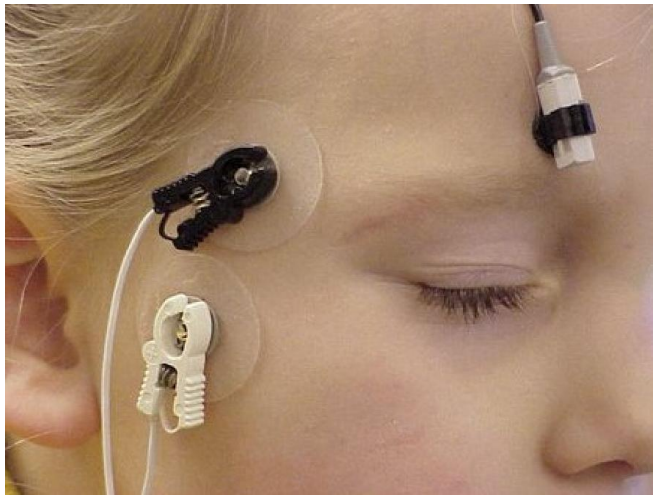
If the monitor cannot be used on adductor pollicis (thumb) you may try different setups:

NMT Monitoring - Basics

Stimulation: Facial nerve
place positive electrode (white) near ear lobe and the negative electrode (black) 2 cm's from the eyebrow (along facial nerve inferior and lateral to the eye)

Response:
Orbicularis occuli muscle – Eyebrow twitching



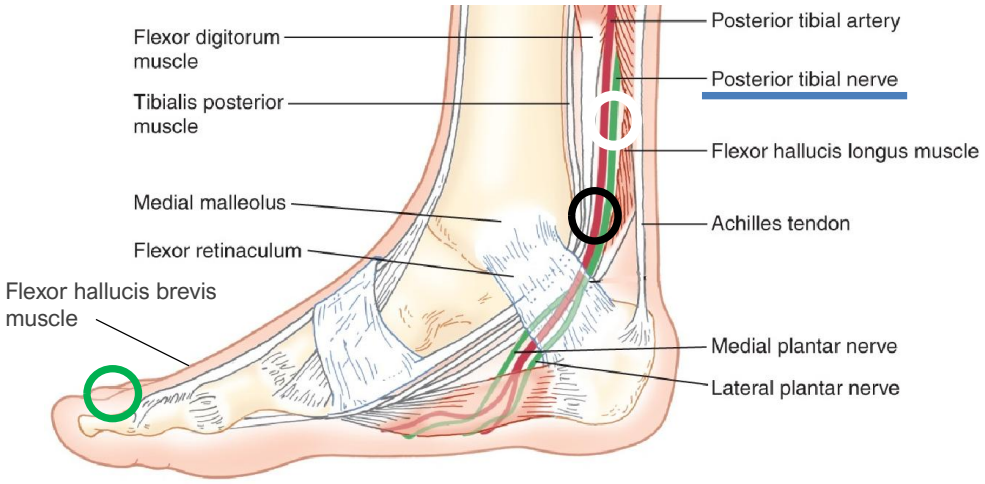


Use the Eye adapters to fix the acceleration sensor to the eyebrow

NMT Monitoring - Basics

Stimulation: Posterior tibial nerve
place the negative electrode (black) over inferolateral aspect of medial malleolus (palpate posterior tibial pulse and place electrode there) and positive electrode (white) 2 – 3 cm proximal to the negative electrode.

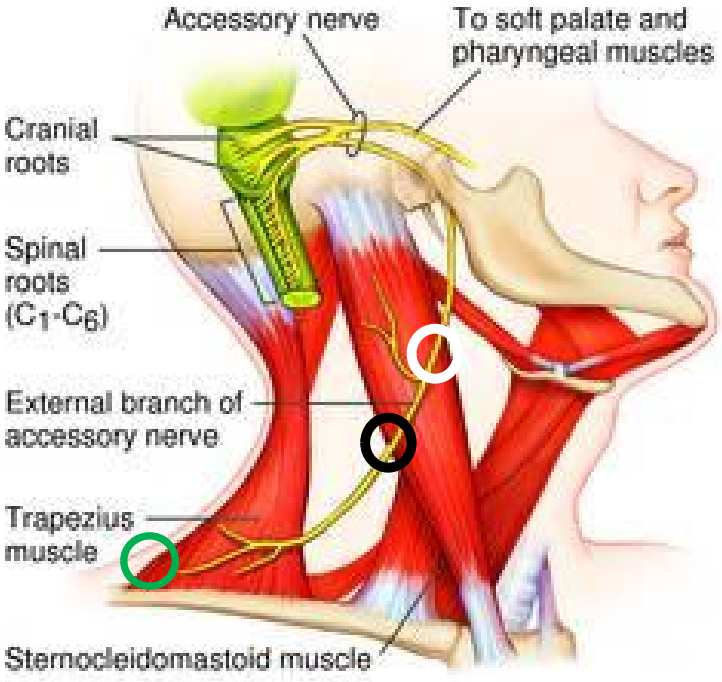
Response:
Flexor hallucis brevis muscle – planter flexion of big toe



Use the thumb adapter or plaster to fix the acceleration sensor to the toe.

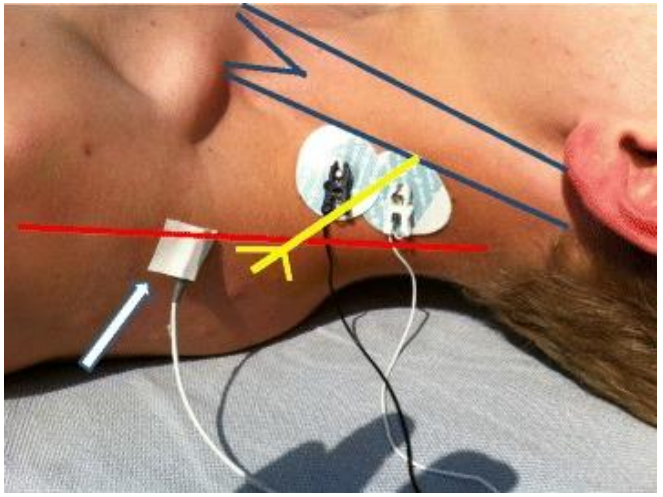
NMT Monitoring - Basics

A study conducted by Dormagen hospital in Germany showed a good correlation between using a setup at the trapezius muscle and using the adductor pollicis setup.



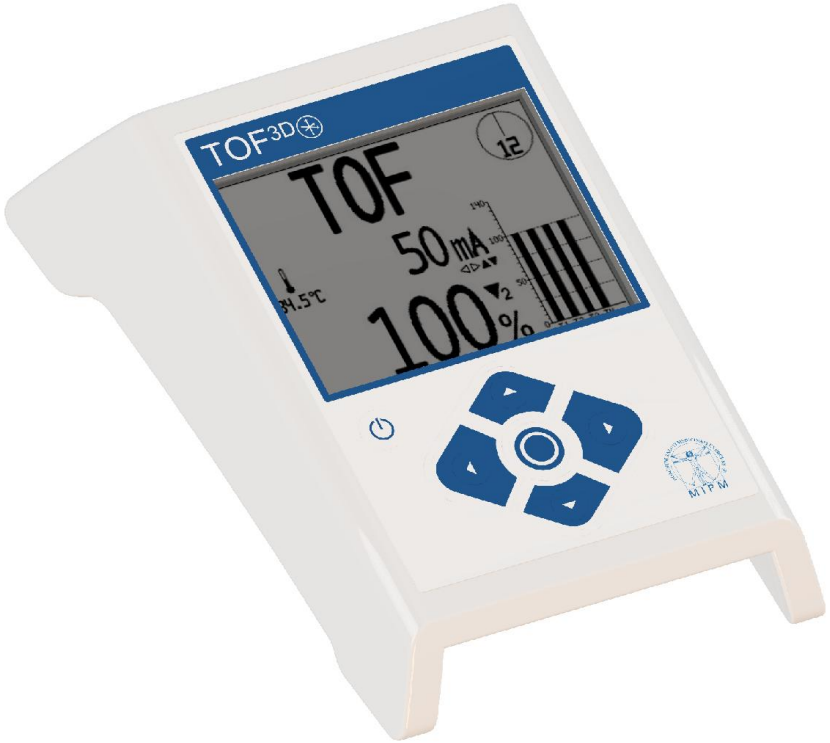
In this setup the Accessory nerve is stimulated provoking a shrug.

Fix the acceleration sensor with tape to the patient's shoulder.



There is no known literature or different studies available about this method. It should not be recommended as a standard method

TOF^{3D}



- Compact design
- Various stimulation modes
  - TOF, PTC, Tet, DBS, Single Twitch
- Big clearly arranged display
- Adjustable continuous measurement
- Calibration Mode

NMT Monitoring in clinical practice

TOF3D

- Using TOF3D is an easy method to monitor the degree of neuromuscular blockade

- AMG: a piezo crystal produces an impulse if accelerated by contraction of the Musculus adductor pollicis (thumb). Impulses are processed and displayed as TOF ratio or single impulse response

NMT Monitoring in clinical practice

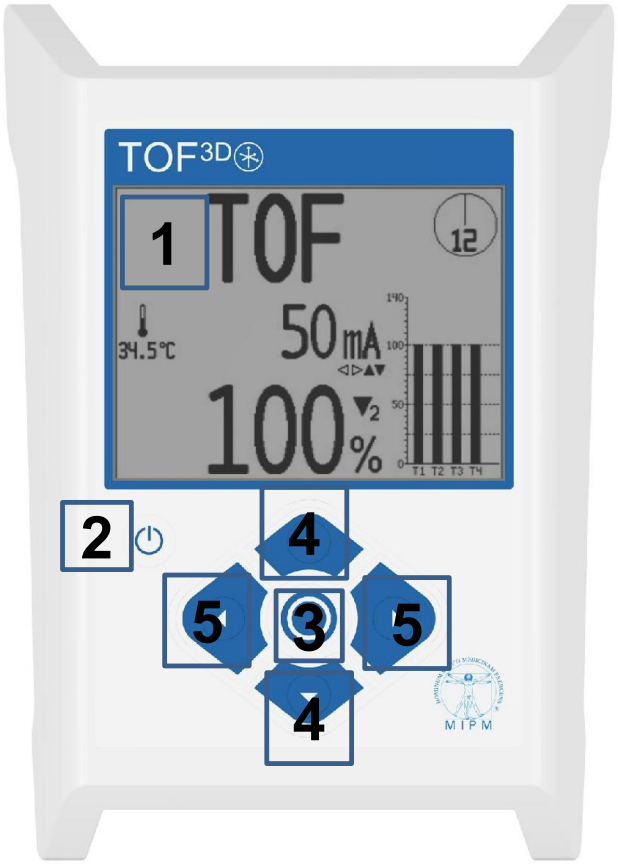
TOF3D

- More reliable than subjective monitoring!
  - Reproducible!
  - Objective!
  - Calibration function normalizes signal amplification and electric stimulus to the respective patient.

TOF^{3D} - In Detail

Front View

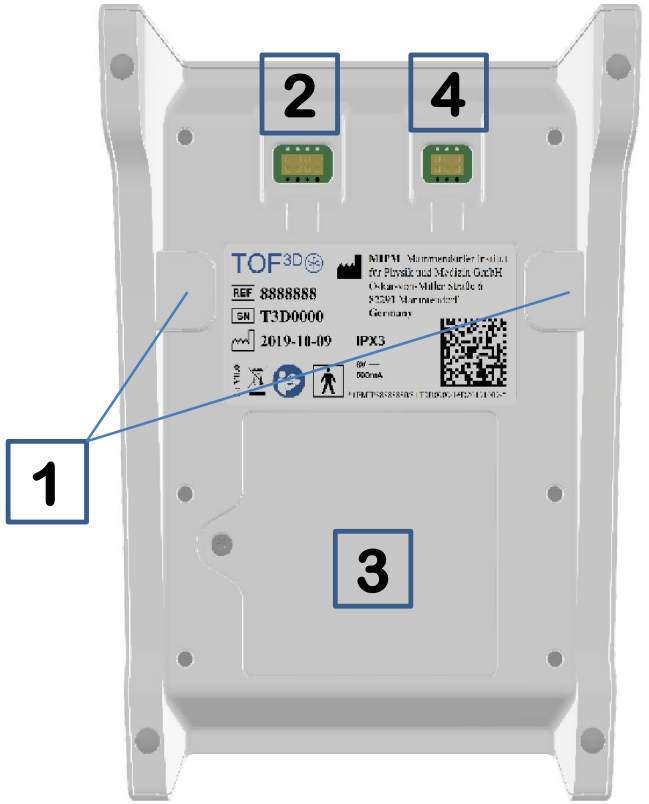
1. Display
2. On / Off key
3. Center Key
4. Up / Down keys
5. Right / Left keys



TOF^{3D} - In Detail

Back

1. Adapter for IV pole holder
2. Socket for Patient cable
3. Battery Compartment
4. USB Interface

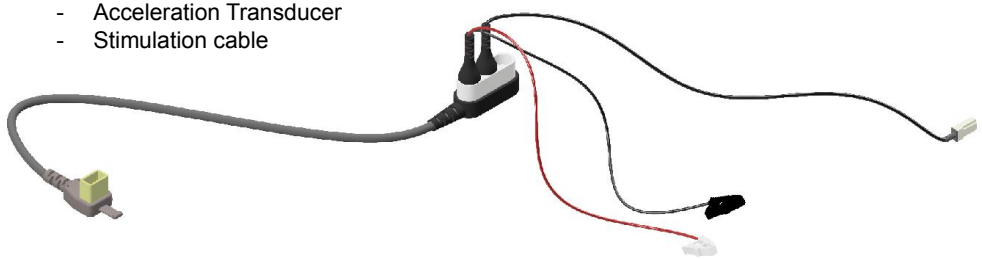


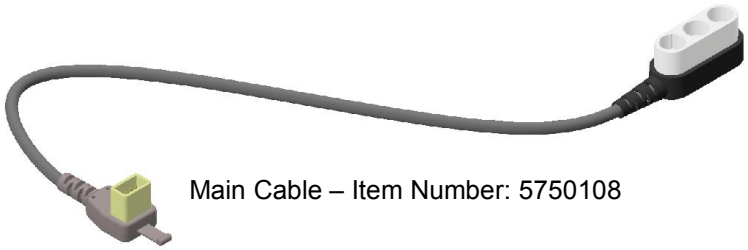
TOF^{3D} - In Detail

Accessories

Complete Patient Cable – Item Number: 5750104

Including:
- Main cable
- Acceleration Transducer
- Stimulation cable

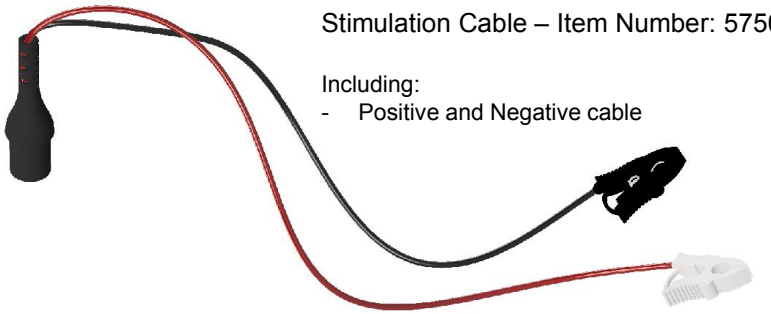




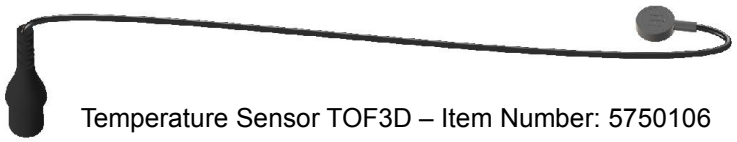
Main Cable – Item Number: 5750108

Stimulation Cable – Item Number: 5750107

Including:
- Positive and Negative cable



Acceleration Sensor TOF3D – Item Number: 5750105



Temperature Sensor TOF3D – Item Number: 5750106

TOF3D - In Detail

Accessories

Hand Adapter TOF3D – Item Number: 5750100

Data Interface Plug TOF3D – Item Number: 5750109

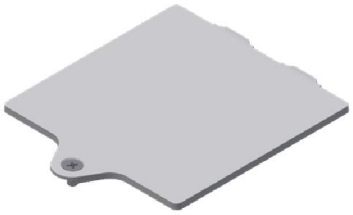
Eye Adapter TOF3D – Item Number: 5750102

Thumb Adapter TOF3D – Item Number: 5750101

TOF3D - In Detail

USB Interface Cable TOF3D – Item number: 5750103

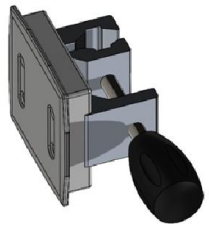
Battery Lid TOF3D– Item number: 5750111



TOF3D Link Interface– Item number: 5750117

Split connector sealing plug TOF3D– Item number: 5750116

IV-pole holder TOF3D – Item number: 5750110



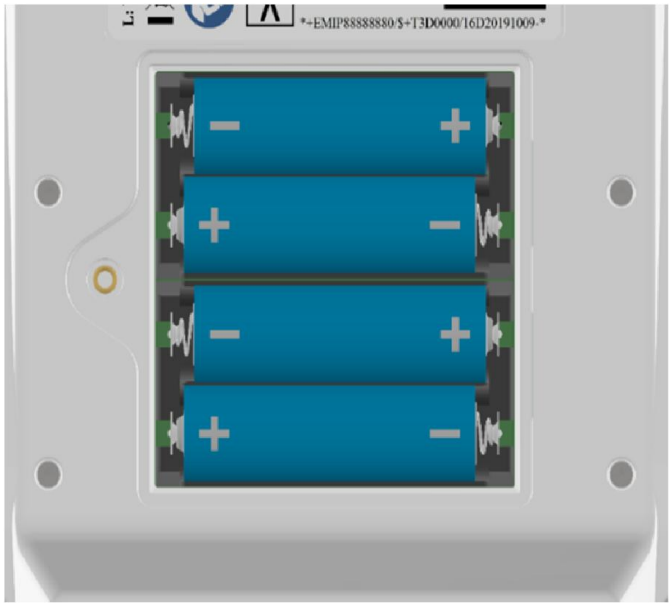
TOF^{3D} - In Detail

The TOF3D is battery powered.

Open the battery lid using a cross tip screwdriver.

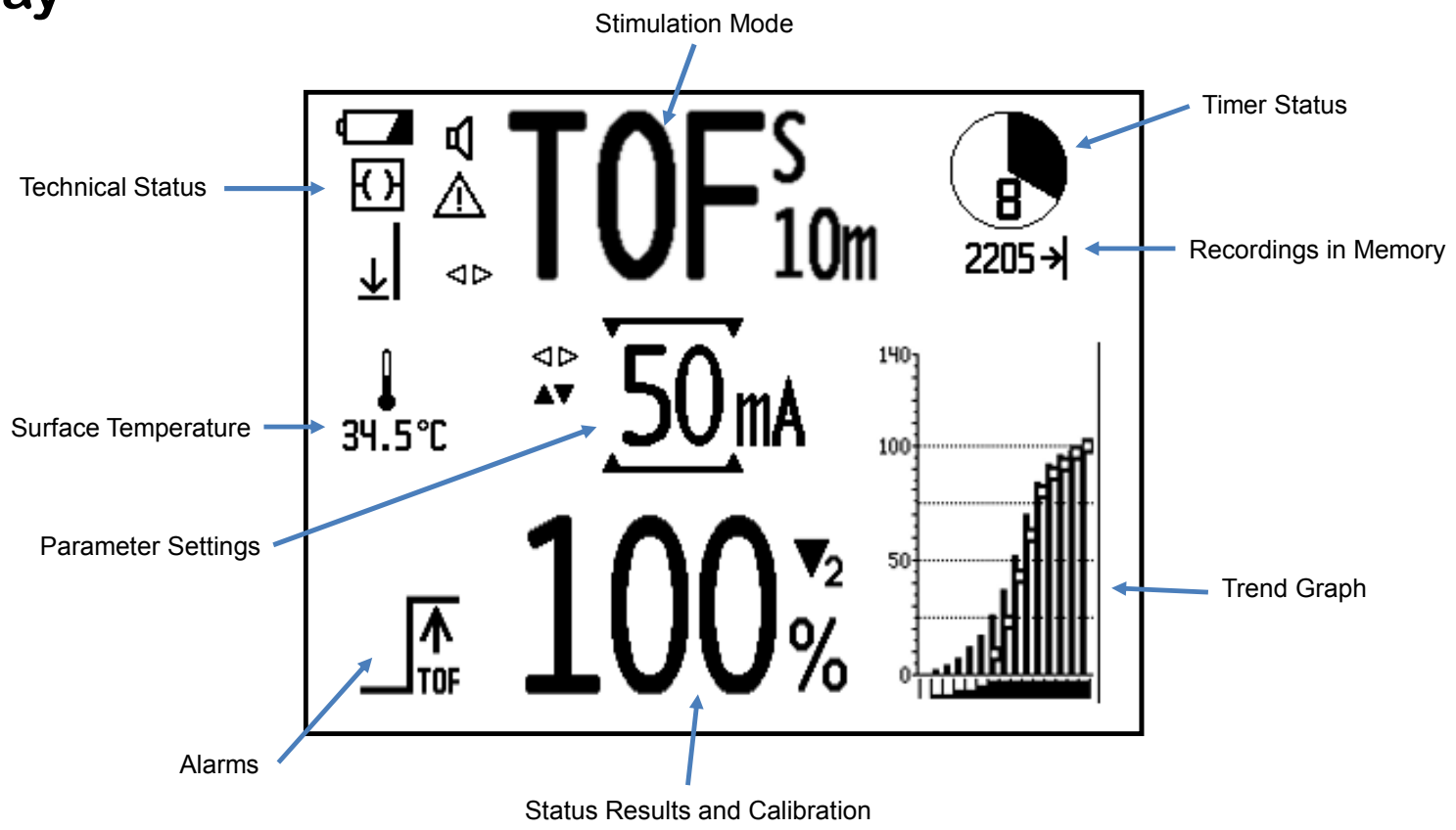
Insert 4 AA batteries as shown on the picture.

Fully charged batteries will give you up to 1500 hours of continuous stimulation.



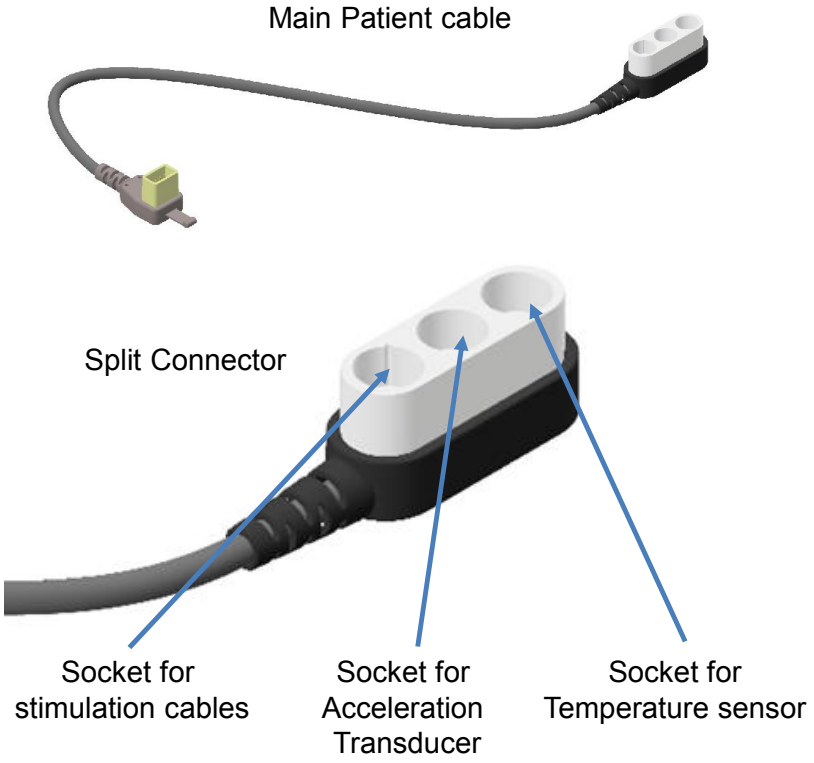
TOF^{3D} - In Detail

The Display



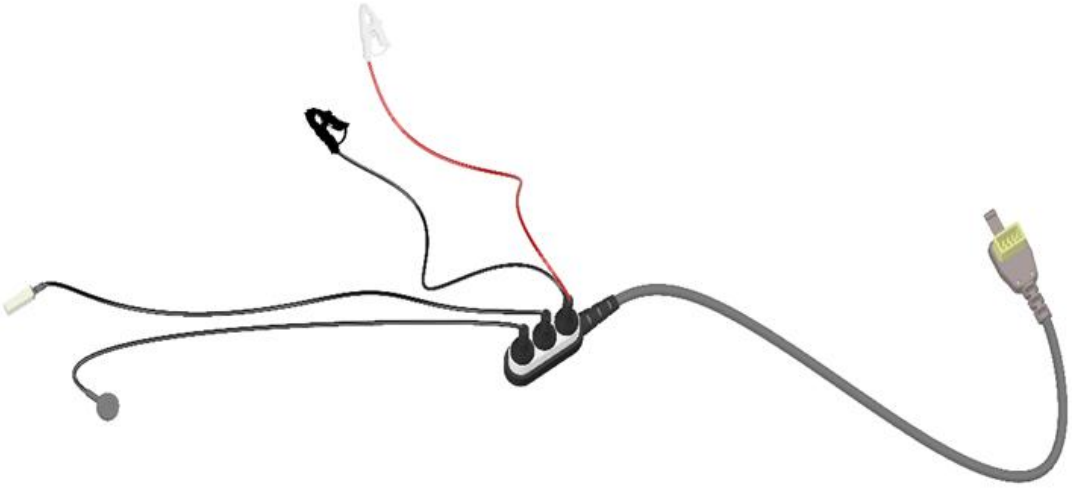
TOF^{3D} - In Detail

Cable connection



Acceleration Transducer, Stimulation cables and temperature sensors need to be connected to the split connector.

Each connector port is mechanically coded to make sure that the cables only fit in their respective position.



TOF^{3D} - In Detail

Cable connection

Connect the patient cable to the patient cable socket on the back side of the monitor.

TOF^{3D} - Quick Guide - Calibration

Calibration

The monitor should always be calibrated before application of NMBA!

The calibration procedure determines the individual patient's muscle response.

This ensures accurate measurements.

CAL 1: The monitor determines the base line (muscle response in the absence of NMBA) for the respective patient.

CAL 2: The monitor determines the base line (muscle response in the absence of NMBA) for the respective patient as well as the supra-maximal stimulation current.

Select CAL1 or CAL2 in the Settings menu.

TOF^{3D} - Quick Guide - Calibration

If patient is already relaxed do not calibrate device as this leads to wrong results!

Use TOF3D without calibration. Keep in mind that the results may not be exact.

Since amplification of the signal and stimulus strength haven't been normalized by calibration process TOF ratio may be above 100%.

TOF^{3D} - Quick Guide

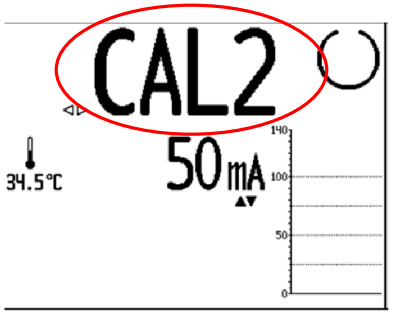
Place the stimulation electrodes and acceleration sensor to the patient as explained before.
Turn ON the monitor.
After a completed self test the monitor automatically goes to CAL Mode.

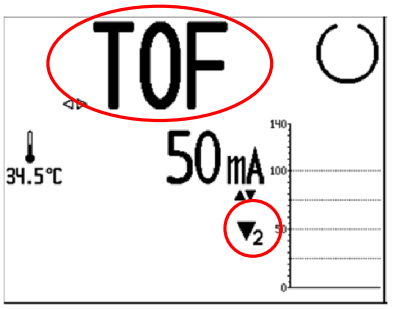
1. Inject sedative (wait for appropriate sedation)
2. Calibrate TOF3D.

   Press and hold the center key for at least 1 second to initiate Calibration.

   Wait until monitor returns to TOF mode and

   “calibration successful” is displayed



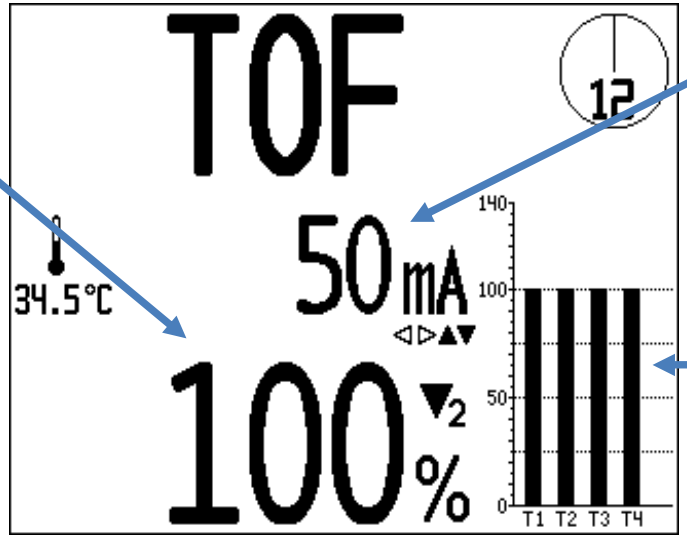


3. Inject blocking agent (NMBA)
4. Start single TOF stimulation by pressing the Center Key once

   (Start continuous TOF stimulation by pressing the Center Key for more than one second)

TOF^{3D} - Quick Guide

After a successful TOF measurement you will see:



TOF Ratio or TOF Count

Applied stimulation current

Number and height of twitches

After 15 seconds the TOF value is faded out and the trend graph is shown.

TOF^{3D} - Quick Guide - PTC

If TOF count = 0
Use PTC to monitor deep muscular blockade.

- Select PTC Mode using the Right – Left Keys
- Press and hold (>1 sec) Center Key to activate PTC
  - The monitor performs a response test (PrePTC - 15 impulses at 1 Hz)
    - If more than 5 impulses > 3% are detected PTC is not carried out
  - If PrePTC is successful tetanic stimulus starts (5 seconds)
  - After tetanic stimulus – 15 impulses (1 Hz)
- TOF 3D displays number of responses (max. 15)
- Monitor goes back to TOF mode
- PTC may only be used every 2 minutes!

Additional functions

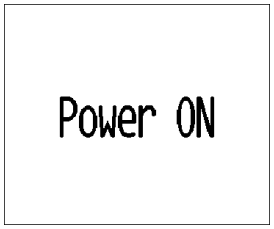
TOF3D offers a variety of functions.

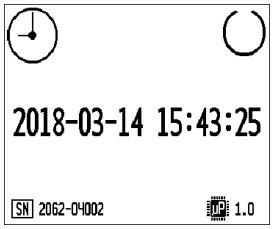
TOF3D can be used for single twitch stimulus and different other stimulation modes.

However the most common function is TOF stimulation. TOF has biggest practical evidence.

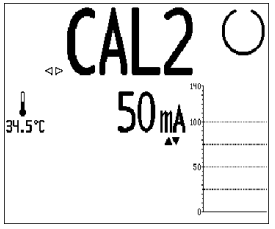
TOF^{3D} - In Detail

A typical TOF Session

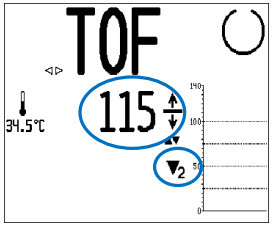




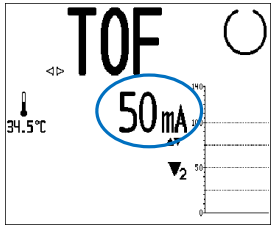
Self Test
Verify Date/Time



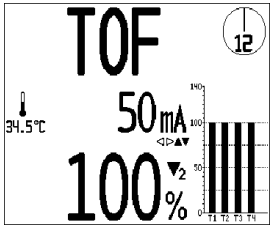
Initiate Calibration with Center Key >1 sec.



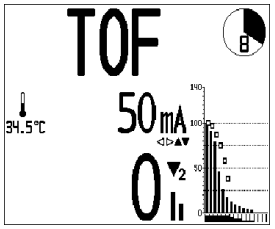
Base line adjustment and CAL confirmation are displayed



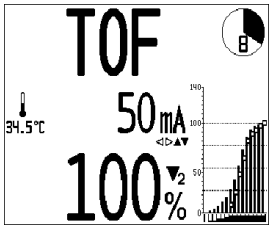
Stimulation current is displayed



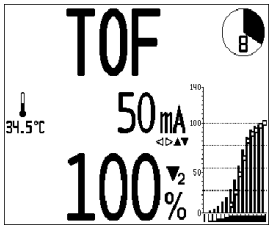
Start continuous TOF Measurement using Center Key > 1 sec.



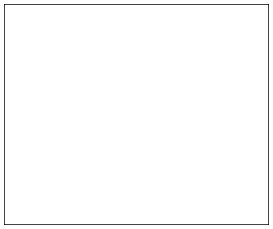
Observe effect of NMBA Bolus



Observe recovery until **FULL** recovery



Stop TOF measurement using Center Key



Turn Off Device

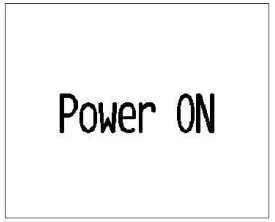
If unit is turned on again within two hours (from last measurement) you can add new data to the patient. If more than two hours have elapsed the patient has to be released and stored data must be transmitted via interface or deleted.

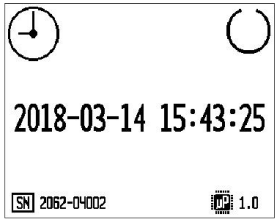
TOF^{3D} - In Detail

Data Management

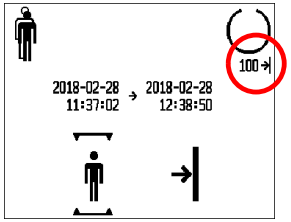
The TOF3D has an integrated memory. If data logging is active the start up procedure may be different depending on if there is still data in the memory.

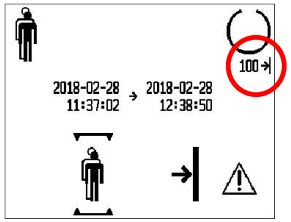
There are 100 logs in the memory.





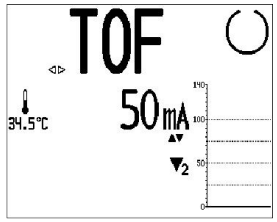
If the data is less than 2 hours old,
you may add new data to the existing patient

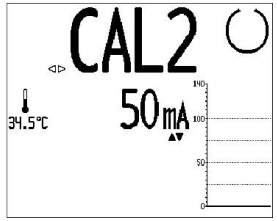




If the data is older than 2 hours,
or you want to clear the memory
the old patient will be replaced by a new one

If the monitor was calibrated
and the existing patient was selected
TOF3D goes to TOF mode





If new patient was selected
or the monitor wasn't calibrated
TOF3D goes to CAL mode

TOF^{3D} - In Detail

Parameter Settings in the main screen

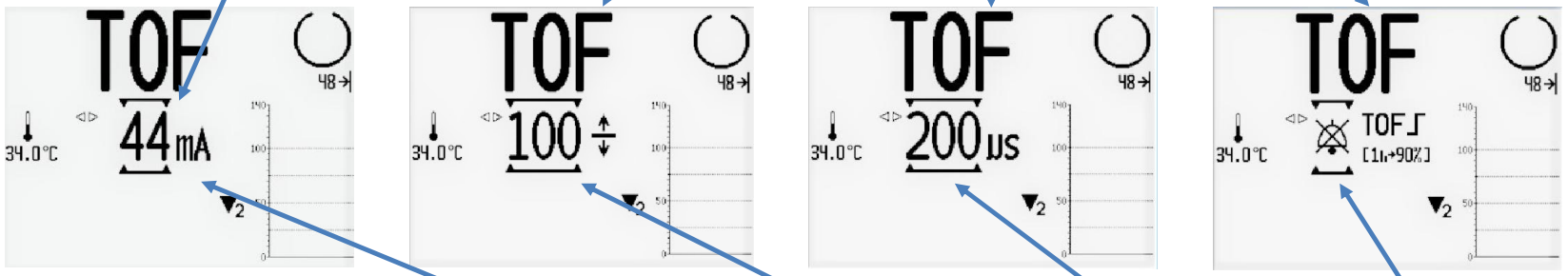
During normal operation you can always have a look at or change certain parameter settings.

Be aware; if the monitor was calibrated and parameter settings are changed manually, the calibration patterns are lost.

Use the Up or Down key in main screen to activate parameter settings.
(If there is no user input within 3 seconds the monitor goes back to normal mode.)

The cursor will be displayed.

Use the Left – Right keys to navigate through the settings.



Use the Up or Down key to change:

Stimulation current

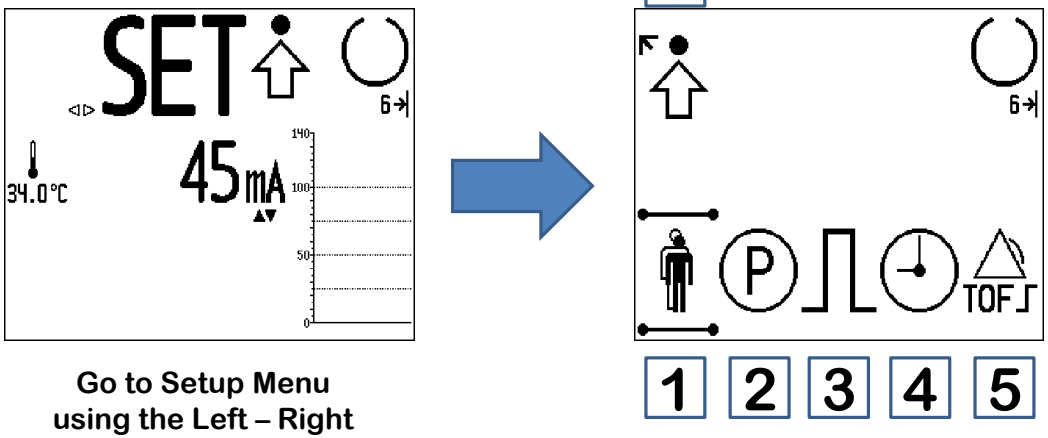
Base Line

Impulse Width

Alarm Sound

TOF^{3D} - In Detail

Setup Menu



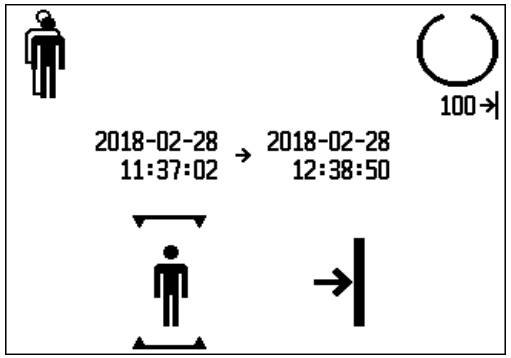
Go to Setup Menu using the Left – Right Keys

1. Data Management
2. Parameter Menu
3. Stimulation settings
4. Date / Time Settings
5. TOF Alarm Settings
6. Exit Setup Menu

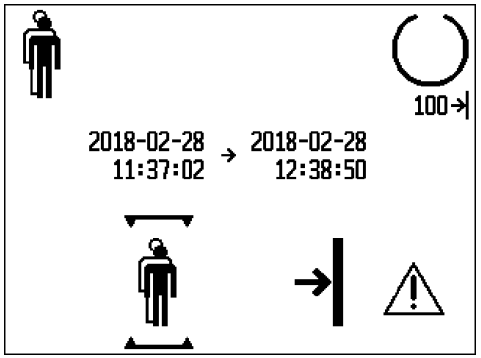
Use Left – Right Keys to navigate in the menu and Up – Down Keys to change settings. Use Center Key to enter or exit menus.

TOF^{3D} - In Detail

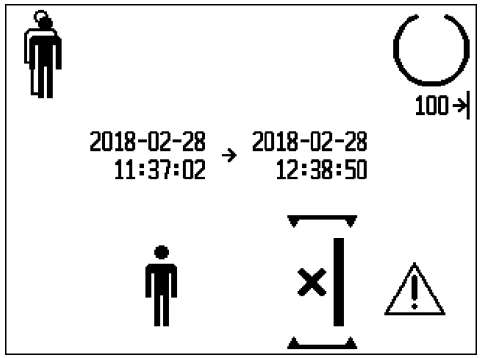
Data Management



New Data will be added to data in memory



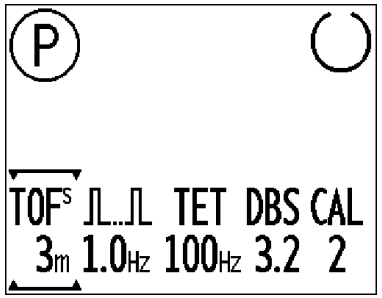
Existing Data will be erased – New Patient



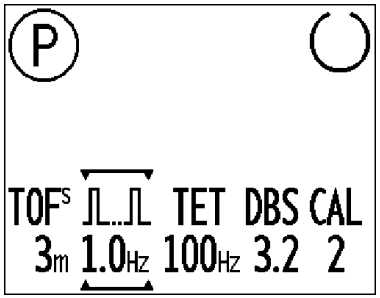
Activate / Deactivate data logging

TOF^{3D} - In Detail

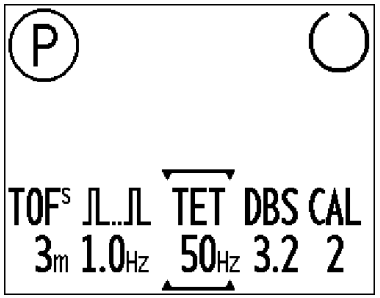
Parameter Menu



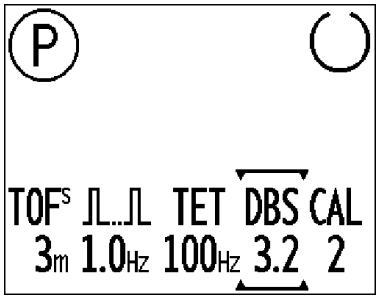
Select interval for continuous TOF Measurement in minutes.



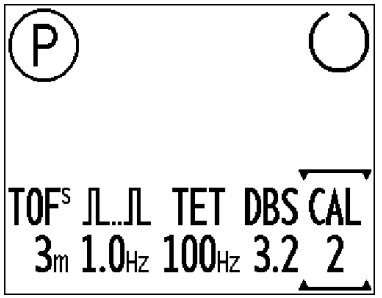
Select frequency for single twitch stimulation



Select frequency for tetanic stimulation



Select between Double Burst 3.2 and 3.3



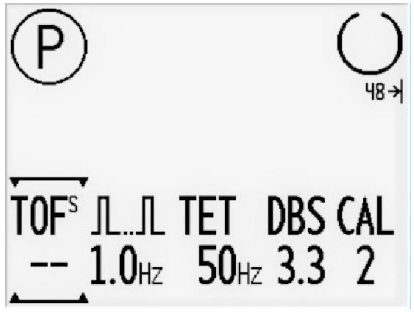
Select CAL 1 or CAL2

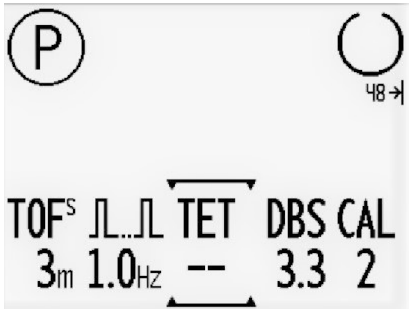
TOF^{3D} - In Detail

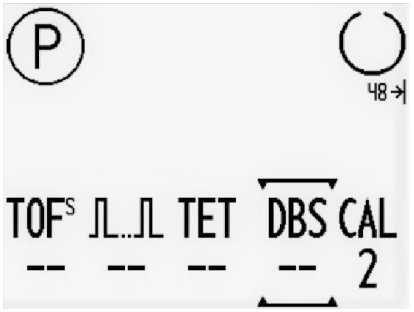
Parameter Menu

It is possible to eliminate stimulation modes from the menu. This will customize the monitor if stimulation modes are not used by customers.

If you want to eliminate a stimulation mode from the menu use the Left – Right Key to select the stimulation mode. Then use the Down key until -- is shown. Repeat this for all stimulation modes you want to eliminate.



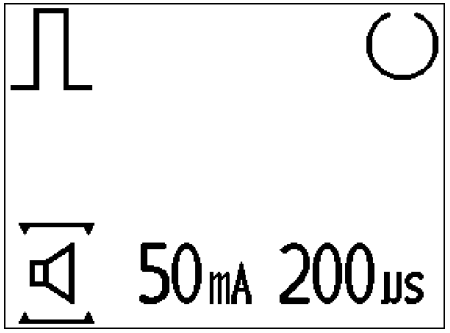




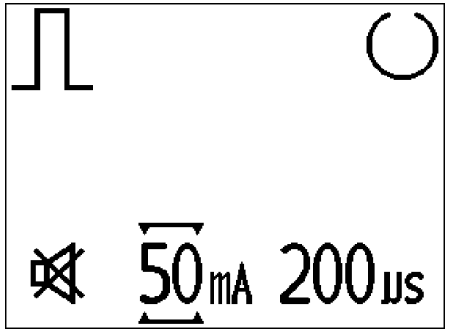
To reactivate eliminated stimulation modes go to the parameter menu again and use the Up Key.

TOF^{3D} - In Detail

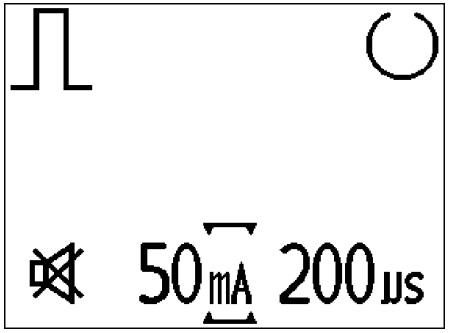
Stimulation Settings



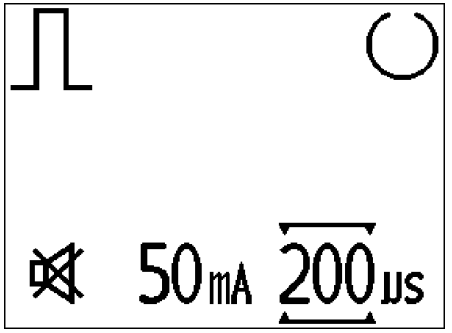
Activate or deactivate stimulation Beep.



Change default stimulation current



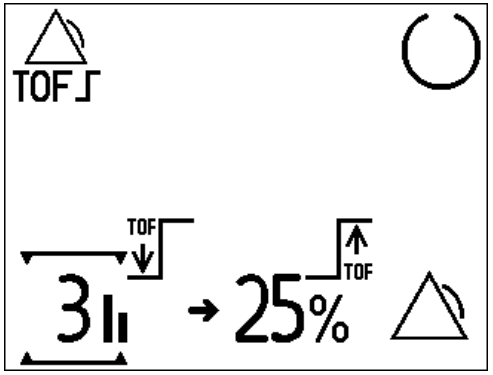
Change measurement unit for stimulation current. mA / µC



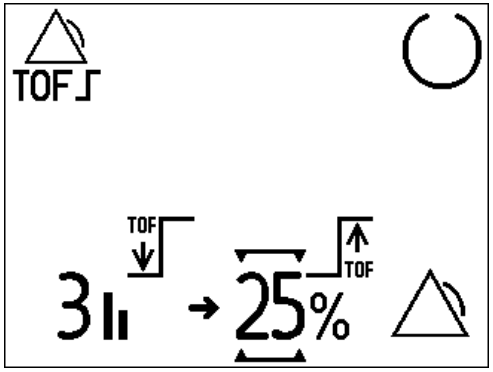
Chose stimulation pulse width. 200/300 µs.

TOF^{3D} - In Detail

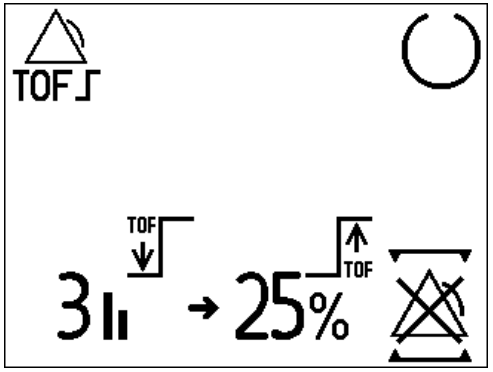
TOF Alarm Settings



Set Lower Alarm Limit



Set Upper Alarm Limit



Activate / Deactivate TOF Alarm sound.

TOF^{3D} - Specs

Technical Specifications	
Device Dimensions	Height : 198 mm Width : 141 mm Depth : 65 mm
Display	Size: 4,4‘‘ – 90 x 67 mm Type: LCD Resolution: 240 x 320
Battery	Technology: Alkaline, NiCd/NiMH Type: 4 x 1,5V AA Operating Time: ≈ 1500 hours of constant TOF monitoring
Electrical Specification	Internally powered handheld device Continous operation IPX3 Operating Voltage: 4 – 6 Volt Max. current: 500 mA Power consumption: max. 2,5 Watt
Stimulation	Waveform: Monophasic rectangular wave Pulse width: 200 µs or 300 µs Constant Current: 0 – 60 mA Load: 100 Ω – 5kΩ
Data Storage	Online Data dump: Yes Data storage in device: Yes Memory capacity: ≈ 45,000 records (e.g. 180 hours of TOF recording)

Competitors - AMG

StimPod
Xavant

TOFscan
idmed

Competitors

Both competitors offer all available stimulation modes.

TOF 3D offers highest resolution display – better readability from greater distances

Alarm Management - Set Alarm Limits for upper and lower TOF Rates.

Competitors claim: No calibration needed.

This is not true!

Modern sensors can compensate variations in the sensitivity (connected to acceleration sensor placement). However the major part of variations in measurement comes from the different patient responses (patient variation). To overcome the variation in patients' responses and ensure correct measurement TOF monitors should always be calibrated.

Competitors - EMG

There are 2 EMG based handheld systems on the market.

TetraGraph
Senzime

TwitchView
Blink DC

EMG devices offer one big advantage compared to AMG based devices.

EMG technology does not depend on free moving muscles as they pick up the muscle's electric potential that is generated independent of the muscle's movements.

However EMG is linked to extremely high cost since the monitors can only be used with a special single use electrode.

A comparison between cost of AMG based monitoring and EMG based monitoring showed that using EMG increases cost for neuromuscular monitoring up to <u>2.000%</u> p.a. depending on the number of cases.

Moreover EMG is susceptive to RF noise coming from various devices used in the OR.

Trouble shooting

Calibration didn't work.

- Check placement of acceleration sensor and stimulation electrodes
  - Maybe the acceleration sensor isn't placed correctly
  - Maybe the electrodes are not placed over Nervus ulnaris
- Maybe the skin resistance is too high
  - Observe messages in display
  - Clean skin with an abrasive gel or isopropyl alcohol solution

Trouble shooting

PTC doesn't start

- Before TOF3D starts the Post Tetanic Count an additional check for muscle relaxation is performed. If the check gives a stimulus response the PTC is not carried out.

- Has PTC been performed within the last 2 minutes?

Trouble shooting

Calibration worked but TOF is not displayed.

- check if patients' hand is still fixed
- check if the thumb is free to move
- check if stimulation cables are still connected to the electrodes
- check if transducer is still positioned correctly

Hands On

To get more familiar with the TOF3D you should use the simulator or a monitor to perform the following tasks.

Consult the user manual if you cannot fulfill a task.

Hands On

1. Setup TOF3D for monitoring at Adductor pollicis muscle. Use the hand adapter.

2. Make TOF3D ready for Use. Initiate continuous TOF measurement

3. Set TOF Time Interval to 5 minutes and upper TOF alarm level to 90%.
   - Initiate TOF interval measurement

4. Delete Patient Memory

Hands On

5. Set Calibration mode to CAL2

6. Set Stimulation pulse width to 300 µs

7. Initiate PTC

8. Connect patient cable with all necessary components.

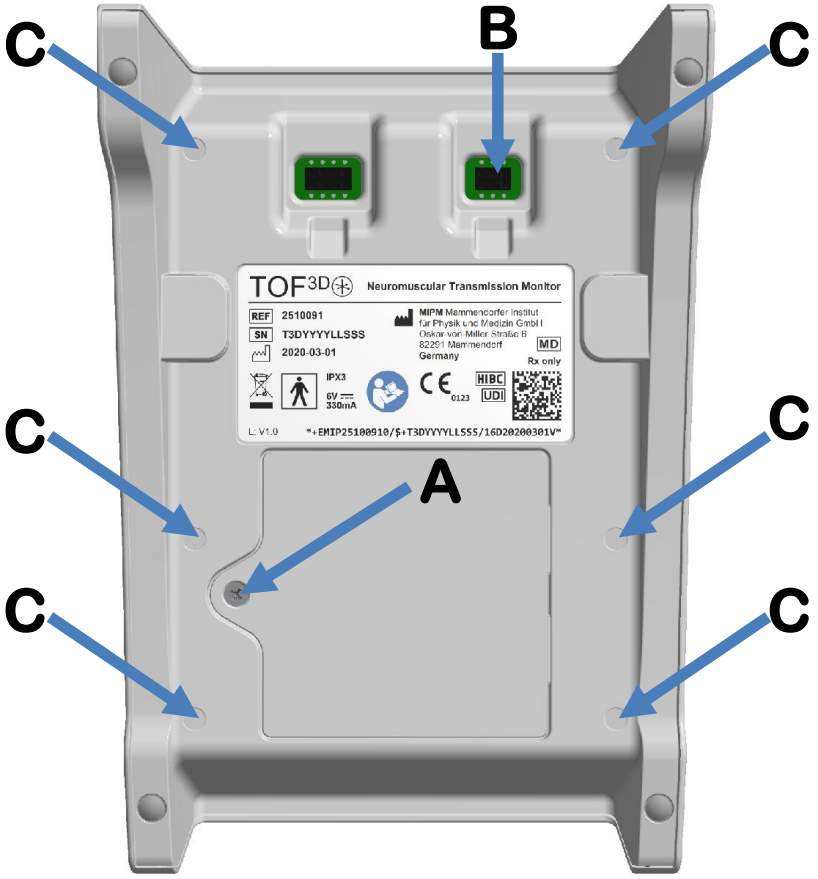
9. Customize the monitor. Remove Single Twitch, TET and DB from the menu.

10. Replace batteries of the unit.

Service

Repair Procedure

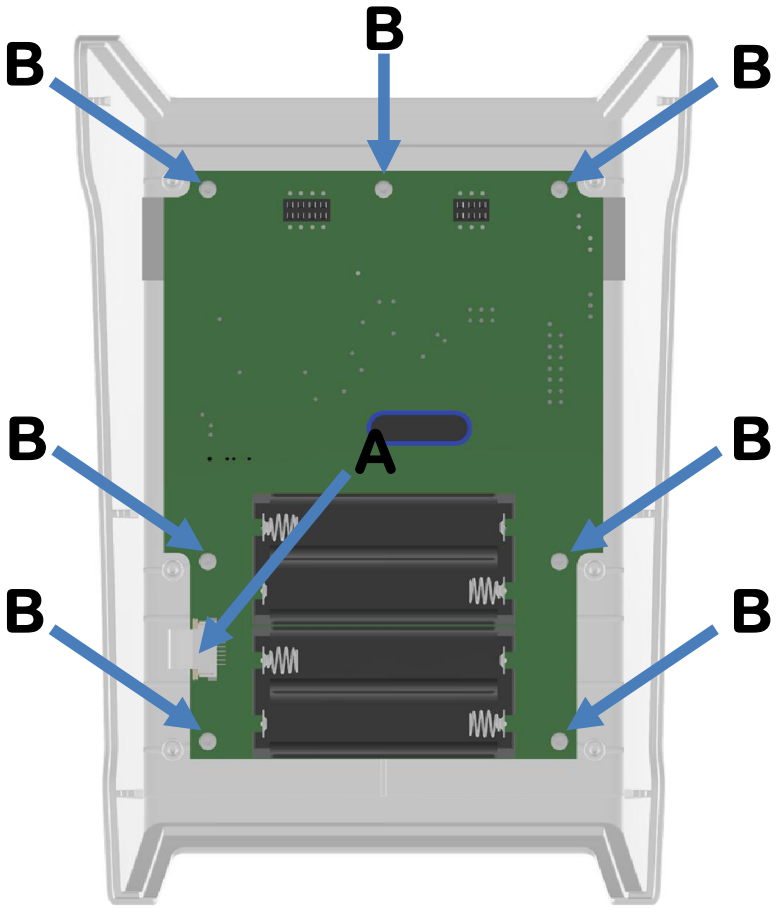
- Remove Battery lid (marker A)
- Remove the four batteries
- Remove the sealing plug (marker B)
- Remove the silicone plugs and the screws below (marker C)
- Remove lower shell



Repair Procedure

- Unplug flat ribbon cable (marker A)
- Remove the screws (marker B)
- Carefully slide out PCB

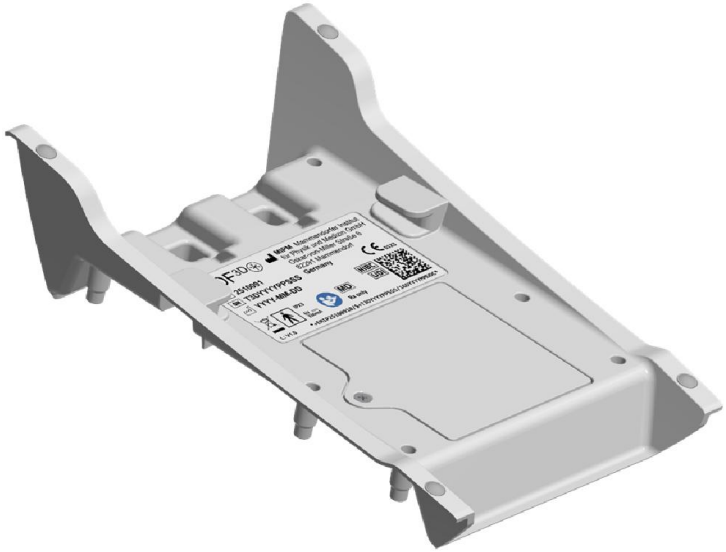
- To reassamble the device do the previous steps backwards.



Spareparts

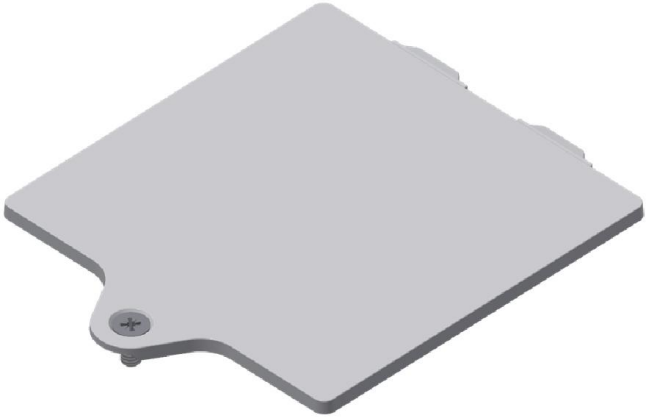
- **Housing TOF3D top shell**
  Partnumber: 5750114

- **Housing TOF3D lower shell**
  Partnumber: 5750115



Spareparts

- **Battery lid**
  Partnumber: 5750111



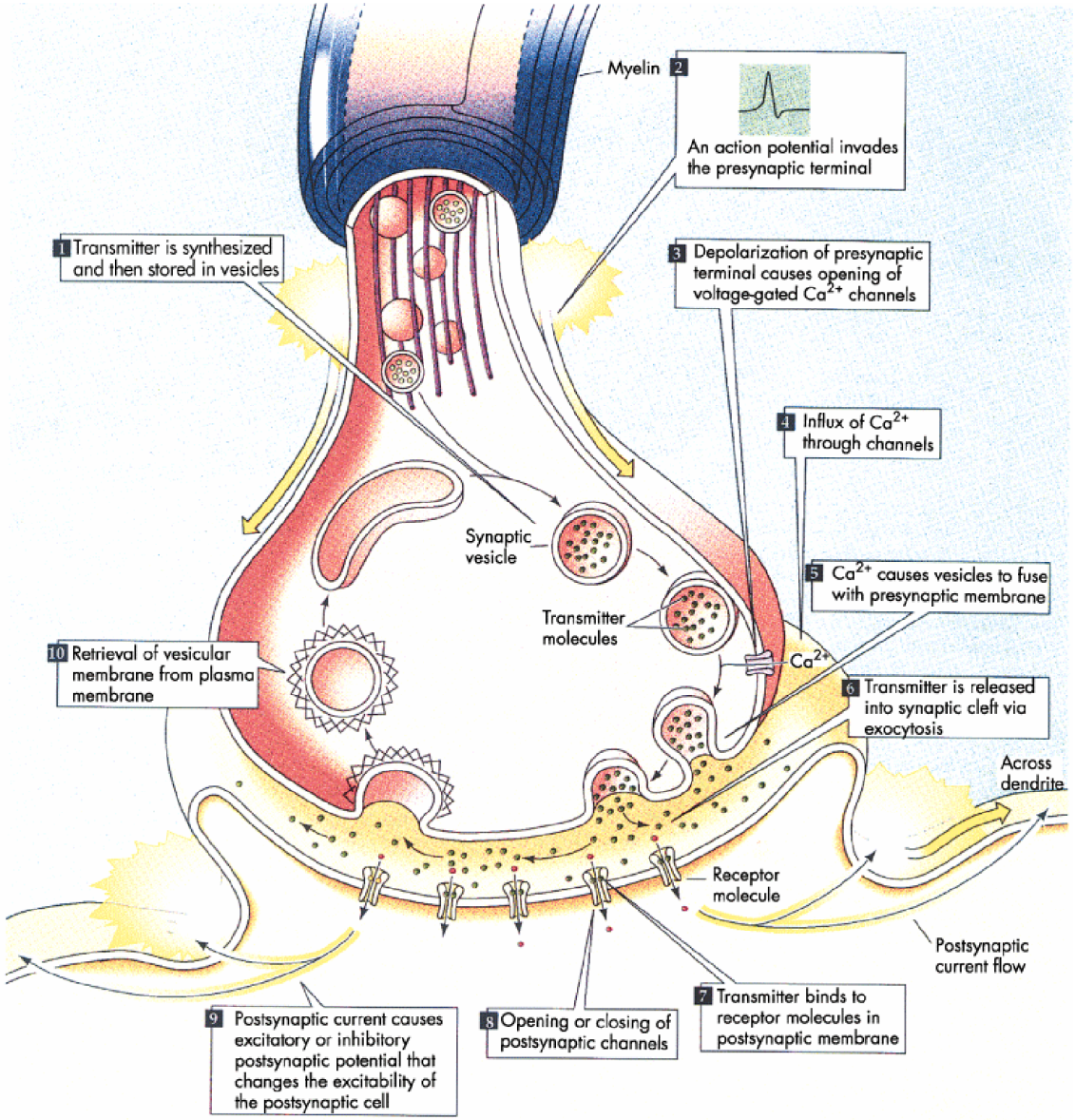
- **Interface Sealing Plug**
  Partnumber: 5750109

Technical Safety Check

- Visual Inspection
  - Check overall condition of TOF3D (Housing / Display / Keys) and Accessories
- Functional Check
  - Measure Voltage of Batteries
  - Check Peak to Peak Voltage on Oscilloscope for correct measurement
  - Check Transducer functionality

Further Information

- Technical Safety check needs to be performed on annual basis
- Batteries only need to be replaced if indicated
- Detailed Information are provided in the Service Manual and the Technical Safety check protocol
- In case of any technical questions, please get in contact with service@mipm.com



Fade of Acetylcholine - An explanation for the decreasing response strength

- ACh is "consumed" in the synaptic cleft.
- It has to be reproduced in the pre synaptic end of the motor neuron.
- The TOF stimulus takes 2 seconds to complete.
- Within the 2 seconds the ACh concentration in the synaptic cleft decreases as it cannot be reproduced quick enough.

Back to Slide 11

Fade of Acetylcholine - An explanation for the decreasing response strength

- In the same time the concentration of NMBA in the synaptic cleft remains constant
- From the first to the fourth impulse the relative concentration of NMBA increases.

More muscle cells are blocked due to relative higher concentration of NMBA in every response.

Strength of the responses fades from first to fourth response.