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Plan

- Reasons to monitor NMB
  - Variability
  - Intubation / surgery / reversal
  - Post Operative Residual Curarization
  - Bad sensibility of subjective tests to rule out PORC
  - Interest of objective NMB monitoring
  - Problems with figures

- Practical use of NMB monitoring
  - Nerve stimulation
    - Electrodes placement
    - Supra maximal stimulation
    - Stabilization
    - Initial calibration
  - Muscular responses recording
    - MMG
    - EMG
      - Polytopic
      - Datex NMT module
      - Stimulation artefact: problems and solutions
  - AMG
    - TOF Watch
  - KMG
  - Problems with AMG (and KMG) in clinical practice
  - Solutions
    - Face ? (AMG / EMG / PMG)
    - Foot ? (AMG / EMG)
    - Agreement between methods and sites ???
    - Adductor pollicis !...Protect the free movement of the thumb
      - Tape
      - Hand adapter / need for normalization
      - TOF tube

- Conclusions
  - Usefullness
  - Methods
  - Placement
  - Devices

*Videos are not available in this word file.*
Before looking at the practical aspects of using objective and quantitative NMBM, which is the subject of my talk, I would like to restate a number of reasons that prompt us to use this type of device on a routine basis in the operating room.

As it is the case with many other drugs, NMB agents vary significantly in terms of duration of action from one individual to another. In two successive patients, the same dose can induce an NMB for a period that may vary by as much as 100%, at least. This variability occurs in almost similar fashion for all relaxing agents, from onset and for the entire duration of the block.

This problem is accentuated by the concomitant administration of vapours, magnesium and amikacin, among others, and of hypothermia – all of which are very frequent in the operating room.
As a consequence of that variability, it is important at many stages in the surgical procedure to know and control the depth of the NMB in every particular patient:

- Good relaxation improves the intubation conditions and limits damage to the vocal cords.
- Maintaining a deep or moderate NMB improves the operating conditions for the surgeon.
- A precise threshold for spontaneous recovery from the block has been determined to enable the administration of pharmacological reversal agents.
- And finally, the recovery of a TOF ratio of 0.9 is the essential condition for safe extubation.

Without monitoring, how could you know if your patient’s block evolves more or less rapidly? Then, how could you insure him the advantages of a correct management?

So, given the importance and usefulness of monitoring the depth of the block during the entire operation, how is this done in practice?

This is not a new question!

In fact, shortly after the introduction of the first relaxing agent in clinical practice, experts were already publishing their recommendations.


Churchill-Davidson HC. The d-tubocurarine dilemma. Anesthesiology 1965;26:132

“The only satisfactory method of determining the degree of neuromuscular block is to stimulate a motor nerve with an electrical current and observe the contraction of the muscles Innervated by that nerve”
Over the years, various stimulation patterns have been described to organise the means of stimulating the motor nerve and hence revealing fatigue linked to the presence of NMBA on the presynaptic ACh receptors.

Katz RL: A nerve stimulator for the continuous monitoring of muscle relaxant action. Anesthesiology 1965; 26: 832-3


The train of four is the most usefull pattern since it is suitable to monitor onset, moderate block and recovery.

The post-tetanic count has made it possible to monitor deep blocks.

But what tests can we do to rule out residual curarisation before extubating our patients?

Numerous tests carried out with this aim have been described. Unfortunately, they have not survived the test of time. Most of the tests based on the subjective assessment of the clinician have proved insufficiently effective to rule out residual curarisation.

Except, perhaps, for tetanic stimulation at 100 Hz.
After the administration of muscle relaxants, the absence of visual fading at the adductor pollicis, elicited in anesthetised patients by 100-Hz, 5-s tetanus, is compatible with a train-of-four ratio above 0.85. But 0.85 is not 0.9!

Moreover, it has been shown that there were numerous false negatives for TOF ratio values measured as low as 0.40. So the absence of fatigue, assessed visually by the clinician, does not entirely rule out residual curarisation.

Tetanic stimulation is very intense and painful. It should not be undertaken on patients who have not been adequately anaesthetised! During NMB, fading is not always easy to appreciate.

The clinical application of this test could be summarised as follows:
When fatigue is present: reverse. But are you really sure that the threshold required for the administration of neostigmine has been reached?
In the absence of fatigue: extubate…but are you sure that there is no longer any residual curarisation?

And so, bearing in mind the weakness of all the above tests, despite the fact that they are easy to carry out, “the clinician should always monitor the extent of neuromuscular recovery using objective means”.


And so we use a measuring device that gives a figure, and hence eliminates the bias of subjective clinical assessment.

But... Figures may be wrong!
But if the monitoring does not work adequately, the figure may be incorrect. As in this example where both the first twitch values (the vertical lines) and the TOF ratio (the purple dots), vary so greatly from one measurement to another that it is impossible to gather any information that could be useful for NMB management!

And this type of problem is not as rare as we might wish. Here are a few illustrations of the most frequent misadventures involving figures obtained by quantitative monitoring:

- The first twitch height increases over time
- The initial and final TOF ratio are significantly more than 100%
- The signal is unstable during the surgical procedure, or varies widely from one measurement to another
- The first twitch recovers values that are significantly higher or lower than the initial value at the end of curarization.

And the list could go on …

So objective NMB monitoring is a valuable aid for the clinician and for the patient when it is a question of ruling out any residual curarization, but in practice using it properly involves the knowledge of certain rules and a few tricks.

Setting many of these out in detail is the main subject of my talk.
The first stage in monitoring neuromuscular transmission is the electrical stimulation of the motor nerve. Like many other things, the important stages in setting up and implementing the monitoring have been described in an article entitled “Good clinical research practice”. For pharmacodynamic studies, but also to standardise daily practice for all clinicians. For instance, it is recommended that the skin be cleaned before the electrodes are applied along the course of the ulnar nerve at the wrist, just inside the tendon of the flexor carpi ulnaris, which is easily palpable in almost all patients. The first electrode should be placed just proximal to the wrist, the second 3 to 5 cm more proximal, along the course of the ulnar nerve.

**Objective NMBM: nerve stimulation**

- Skin preparation
- Ulnar nerve at the wrist
- Inside flexor carpi ulnaris
- Ag/AgCl electrodes 7-11 mm

It is usually recommended that the current intensity corresponding to the supra maximal stimulation of the nerve be sought.

Supra maximal stimulation is the current above which there is no increase in the muscle response evoked. In this case, all motor units are firing in response to nerve stimulation. If not, the degree of NMB may be overestimated.

Among others, Kopman proposed a simple method to obtain this intensity: by gradually increasing the intensity of the stimulation, it is possible to determine the threshold at which the first muscular response appears, the initial threshold of stimulation, and this is multiplied by 2.75…let’s say by 3 to simplify matters, to obtain the supra maximal stimulation for this particular patient.

All this is, however, less important if TOF stimulation is used, thanks to the relative aspect of this T4 divided by T1 ratio.
Moreover, in all patients this level of stimulation lies above 20 mA, frequently between 45 and 60 mA. The default stimulation level of the TOF Watch when it is switched on is set at 50 mA...which is not bad for a great many patients. If need be, it is easy to modify manually the intensity. Some patients will indeed need more, up to 100 mA in the event of a wrist oedema, for example.

But notice that the TOF Watch stops at 60 mA and the Datex NMT at 70.

Like the Datex NMT module, the TOF Watch SX model –and only that one– has an automatic calibration process which seek, among other things, the supra maximal level of stimulation.

**Objective NMBM:** nerve stimulation

- **Supra-maximal stimulation**
  - 15-20 % above the stimulus needed for maximal response
  - Initial Threshold of Stimulation x 2.75
  - 20...45-60 mA
    ...up to 100 mA if oedema

With a view to obtaining results that are as stable as possible over time, and in particular to spontaneously recover T1 values that are close to the initial values, a further two steps are necessary.

The signal is usually stabilised in a few minutes, but sometimes the spontaneous increase in the intensity of muscular responses, attributed to the staircase phenomenon, may last longer. To apply a 5 seconds tetanus may reduce the time needed to reach stable signals. But once again, the use of the TOF ratio as a sign of recovery is independent of this problem... which we will therefore leave to the researchers.

Other aspects of NMB monitoring also play a part in obtaining stable responses, such as a stable temperature, since hypothermia of the hand will reduce the intensity of the responses, or the position in which the hand is placed, as we will see later on.

Calibrating the first twitch at 100% is essential if you wish to use the T1 values over time, in particular for studies.
The initial calibration is, moreover, essential to monitor an NMB induced by the administration of succinylcholine.

In fact, unlike the non-depolarising block which presents the interesting fatigue phenomenon analysed by the TOF ratio, the depolarising block does not induce fatigue. The muscular responses can only be interpreted by referring to the initial value. The initial calibration therefore concerns both the clinician and the researcher. This is a simple manoeuvre on the TOF Watch and is done automatically on the Datex NMT. Doing the calibration process, the TOF Watch also modify the piezoelectric crystal sensibility, setting the gain to the particular strength of contraction of the muscular response analysed.

After these thoughts on stimulating the motor nerve, let us now look at the recording of the muscular responses that depend on this. There are various different techniques. I will only describe those which are currently on the market and generally available for all interested users.

Fuchs-Buder T, Schreiber JU, Meistelman C. Monitoring neuromuscular block: an update. Anaesthesia 2009;64:82-9

Mechanomyography is the standard technique for measuring muscular responses. Because it really records the strength of the adduction of the thumb during an isometric contraction of the adductor pollicis muscle, and perhaps also because it is one of the oldest, this is the established standard of neuromuscular transmission monitoring.

To use the device presented here, the hand and the wrist must be carefully fixed to an arm board, and the traction of the thumb must be in the opposite direction to its natural adduction movement by means of a preload of 200 to 300 g. In this way, the muscular contraction and relaxation are recorded.

The main limitation of this technique is its cumber someness of course, but also its sensitivity to any extrinsic movement or change in position, as it is often the case during surgical procedures. So it may be the gold standard, but, for the moment, only for researchers!

Using the same principle for measuring the strength of an isometric contraction, this other mechanomyographic device, analyses the adduction of the thumb in compression rather than in traction, without real preload. This is an interesting device, which is more compact and probably less sensitive to movement during surgery.
Although considered the standard as regards NMBM, mechanomyographic devices are not widely distributed, or even easily available at the moment. So while waiting for this situation to change, other techniques for recording muscular responses have been developed, most of which include a concern for ease of use.
The principle behind electromyography is to measure the muscular electrical activity by means of surface electrodes. The signal recorded is made up of two consecutive parts: First, an artifact produced by the spread of the electrical wave of the ulnar nervous stimulation. We will refer to this as the stimulation artifact. Secondly, the depolarisation and repolarisation waves of the muscle fibres placed beneath the measuring electrode, in this case the thumb adductor. We will refer to this as the electromyogram, or EMG. This system has the advantage, at least in theory, of not being sensitive to the position or movements of the hand during the surgical procedure. Far less so, in any case, than the mechanomyography in traction represented here in red, compared with the EMG in green, recorded simultaneously during an orthopaedic procedure on the lower limb. Note the artifacts on the MMG recording caused solely by movements of the legs slightly altering the way in which the hand is positioned, and conversely the advantage of the stability provided by the EMG. However, since it analyses small quantities of electricity, the technique will be very sensitive to disruptions caused, among other things, by electrocautery.

**Electromyography**

- Measurement of muscle electric activity
- May be used during surgery under surgical sheets
- Problems: sensibility to electricity
- Placement of surface electrodes !!!
Another particularly interesting aspect of electromyography is that the technique can be applied to numerous different sites. Provided that a motor nerve can be stimulated and the EMGs of the dependent muscles can be analysed by electrodes.

There are therefore three sites on the hand. The electrodes must be very precisely positioned: green on the muscle, red opposite its tendon or a bone to obtain the best possible potential difference. A black ground electrode is placed in a neutral spot, where there is no muscular response. Well, these are the colors used by the Datex NMT.

Similarly, the electrodes can easily be placed on the foot, stimulating the posterior tibial nerve and recording the responses of the flexor hallucis brevis muscle.

The same applies to the facial nerve and the periorbital muscles such as the corrugator supercilli or the orbicularis oculi. We will return to the special interest of these muscles later on.

Finally, it is even possible to monitor the depth of the block in the muscles targeted by the curarisation, such as the diaphragm by means of intercostal or dorsal electrodes, or the adductor muscles of the larynx by fixing the electrodes to the endotracheal tube. For the needs of ENT surgeons, endotracheal tubes are now available, fitted with electrodes just above the cuff.

It is important to note, however, that the recordings made at these different muscles cannot be superimposed on one another, as some evolve more quickly or more slowly than others. This has major clinical consequences which we will talk about later on.

Electromyography: polytopic

- **Hand**
  - Add. pollicis
  - Hypothenar
  - 1° interosseous
- **Foot**
- **Eye**
- **Diaphr**
- **Larynx**
The Datex monitoring company, whose equipment is widely distributed in operating rooms, has equipped its anaesthesia station with an NMBM device which uses, among other things, electromyography. The device is integrated, robust, automatic and configurable. By pressing the start button, an automatic sequence seeks the supra maximal stimulation and calibrates the first twitch before doing a TOF stimulation every 20 seconds. The results are integrated into the anesthesia protocol.

The analysis window on the EMG is located between the two shaded zones.

It is possible, and I would strongly recommend it, to view the EMG curves recorded. The initial wave, obtained at the time of the initial calibration, is presented in grey, along which the recordings pass in an automatic sequence.

Unfortunately, in day-to-day clinical practice, numerous artifacts often interfere with these recordings. A retrospective study conducted in my department showed that the clinician was unable to use up to 25% of the recordings. To back up what I said earlier, carrying out an initial calibration before inducing the block significantly improves the quality of the recordings. It’s an easy maneuver, particularly since this procedure is automatic with the Datex NMT module. Just don’t forget to do it in time before inducing the NMB.

Please notice that the graphic expression of T1 and TOF ratio of the Datex NMT is unfortunately opposite to the TOF Watch: here, T1 is represented as dots, and TOF ratio as vertical lines.
The – **artifactual** – detection of **four small, almost identical** responses shortly after the block has been induced leads to the **erroneous** calculation of a **high TOF ratio** and the false assumption that the patient is not completely paralysed. The presence of these slight responses without fatigue during the deep block was previously attributed to the **direct muscular stimulation**.

However, recent studies have shown that the current used in NMB monitoring (pulse duration 0.2 ms, intensity 20-60 mA) was usually inadequate to induce real direct muscular stimulations which needs much higher intensity. In the particular case of electromyography that we are looking at here, the electrical wave of the nerve stimulation, known as the stimulation artifact, is the first event recorded, **before** the depolarisation of the muscle. Unfortunately, it is blinded by the analysis window of the Datex NMT. The positive wave, when substantial, may last until the moment when the muscular responses are measured, and hence contaminate the course of these responses by means of **four positive deflections of identical, weak intensity**.

Let’s demonstrate its impact on the EMG measurement. **During** the deep block, the amplitude of this artifact grows in proportion to the intensity of the stimulation current.

In the absence of any block, the EMGs of course grow from the initial stimulation threshold to the level of maximal stimulation, but also on a constant basis following the increase in the intensity of the stimulation.

By excluding the artifact recorded in deep block from the raw EMG it is possible to obtain an **ideal twitch height response curve**, with a real supra maximal plateau.

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**EMG: problems**

- **Direct muscle stimulation** or **stimulation artifact**?
  - **Direct muscle stimulation**:
    - 4 small TOF responses during deep NMB
    - Absence of fade
    - Disappearance when changing electrodes location
    - May occur when stimulating ulnar nerve at the wrist
  - **Stimulation artifact**: a small signal is recorded in the EMG analysis window, increasing with the stimulation intensity.
What solutions do we have to reduce the size of this stimulation artifact?
On the one hand, if the distance between the wrist and the first stimulation electrode is increased by a few centimetres, the amplitude of the artifact declines rapidly. The price to pay for this, and to some extent its limitation, is an increase in the intensity of the stimulation current to guarantee a maximum response despite the thickening of the subcutaneous tissue.

On the other hand, the amplitude of the artifact depends on the orientation of the electrodes. If they are placed lengthways to the stimulation wave, they record the greatest artifact. Conversely, placed perpendicular to the direction in which the stimulation wave spreads, the two electrodes record it simultaneously, then, without impacting on the EMG. Positioning the electrodes in this way therefore produces better recordings.

Certain precautions therefore have to be taken to ensure the optimal use of the Datex EMG. When browsing the scroll-down configuration menus, make sure the screen constantly displays both the digital window and the graphic window. You should also configure the window displaying the trends, and always visually confirm the figures indicated. Preferably from before the induction of the block, to enable you to change the position of the electrodes in time if the responses are bad. In addition, as a general remark for all these devices, despite the superiority of the objective assessment provided by their figures, always retain clinical common sense when interpreting figures in the context of the surgical procedure.
Another technique used to assess muscular responses, providing a **simple and cheap** alternative to mechanomyography, is the principle of acceleromyography which is based on Newton’s second law. As the mass of the thumb remains unchanged during the procedure, its acceleration when the movement begins is directly proportional to the force developed. Once the stimulation electrodes have been connected, the piezoelectric crystal can easily be attached to the pulp of the thumb in the direction of the adduction movement using a piece of tape or the elastic band provided for this purpose. The advantage of this technique lies in its **simplicity**. And the **low cost** involved has promoted its distribution.
The TOF Watch uses the AMG principle. The stimulation intensity is set by default at 50 mAmpers but can be configured manually to correspond to the supra maximal threshold as I explained earlier. Only the SX model has an automatic sequence to reach supra maximal stimulation.

An automatic sequence makes it possible to calibrate the first twitch at 100% and to optimise the sensitivity of the crystal to the amplitude of the movement, which is especially useful for adapting the measurements of weak responses.

All the stimulation patterns are available.

But as far as I know, tetanic stimulation uses the 50 Hz frequency … which unfortunately is not really useful except for the post-tetanic count.

There are a number of error signals to help you dealing with common problems.

I would like to make one final comment, but one which is important. Both the crystal and the body of the device are extremely fragile. The crystal can easily be damaged, especially if it is removed from the thumb by pulling on the cable. If a malfunction occurs, the stimulation intensity will be displayed instead of the TOF ratio values. A cable tester is available to confirm its condition.

As for the screen, it does not like being dropped at all – but you will easily see that.

### TOF-Watch®

- **mA**: 50 mA or manual supra-maximal
- Calibration and sensitivity optimization
- Stimulation patterns
- Error signals
  - Acceleration transducer removed/unstable
  - Missing/bad electrode connection
  - Skin resistance too high
  - Battery low/empty
  - Internal error: game over!

- Fragile!
When using acceleromyography in clinical practice, anesthesiologists frequently assess the depth of blockade only **once**, at the **end** of the procedure. This is unfortunately **not always** appropriate to detect low levels of residual paralysis.

I should then emphasize again the need for initial calibration and the interest of **continuous** peroperative monitoring. In addition, recovery of a TOF ratio of 1, rather than 0.9, has been proposed to improve the detection of low levels of residual block with acceleromyography.

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**Single uncalibrated measurement**

- Not appropriate for reliable detection of low levels of residual paralysis.
- Initial calibration
- Continuous monitoring
- Recovery of TOF ratio = 1

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Carr J et al. Reliable detection with tetanic tetanus stimulation using TOF, 2Hz, 4Hz tetanus, and acceleromyography. *Anesthesiology* 2000;92:51-6

Carr J et al. Reliable detection with tetanic tetanus stimulation using TOF, 2Hz, 4Hz tetanus, and acceleromyography. *Anesthesiology* 2000;92:51-6
Somewhat along the same lines, the Datex NMT module proposes another technique for measuring muscular responses: kinemyography. The operating principle here is not MMG as its name “mechanosensor” suggests, but rather the detection of the bending and deformation of a piezoelectric sensor wafer strip by the adduction movement of the thumb. The system is connected to the Datex NMT module and benefits from the same advantages in terms of robustness, automation and results display as the EMG we have just seen. This small device is very easy to install between the thumb and the forefinger. It is important to ensure that it remains correctly positioned using a piece of tape to prevent it moving forward while in operation. There is a model adapted for children. Bearing in mind its configuration, it can however unfortunately only be used on the hand.
Both previous techniques should be simple to use in clinical practice. Their only requirement is that the **thumb can move freely**. When acceleromyography was introduced, this was considered an advantage, since the setup was much simpler than mechanomyography. But the requirement has turned into a major problem in clinical settings: In daily practice it is often not possible to ensure that the thumb moves freely, and that the position of the hand does not change during the surgical procedure. The sterile covers over the patient, the position and the movements of the surgeons as well as the position of the hand in pronation or alongside the body, and the contact of the thumb with the palm or other fingers, are all restrictions to the thumb’s movement and consequently to the quality of the acceleration measurement. Then, the results obtained may vary considerably, often to such a degree that clinicians choose to disregard them. And stop to use those devices routinely.

**AMG and KMG requirement: free movement of the thumb!**

“The results obtained may vary considerably, often to such a degree that clinicians choose to disregard them.”

As monitoring neuromuscular transmission by acceleromyography using the hand involves practical difficulties, some authors and clinicians have sought to apply this technique on other muscle groups. This approach has a twofold interest since the various muscle groups have been shown to have variable sensitivity to neuromuscular blocking agents. It therefore seemed interesting to follow the evolution of the block in the face, which is more often accessible than the hand during a surgical procedure. The sensitivity of the corrugator supercilii corresponded precisely to the depth of blockade of the laryngeal muscles and the diaphragm, which are essential targets of muscular relaxation. On the other hand, the orbicularis oculi responded in a similar manner to the thumb adductor and promised to ensure safe extubation.

In theory, and in research, this has proved to be correct.

In practice, however, there is some confusion between the muscular responses of the two muscles. The video shows a contraction of the orbicular muscle whereas the movement of the eyebrow is not at all obvious. Moreover, the amplitude of the movements recorded in numerous patients is so slight that interpretation of these movements by the TOF Watch leaves something to be desired. The values obtained lack precision, which makes their use hazardous, in particular as regards determining the right moment for extubation.

According to me, acceleromyography is not appropriate to monitor the depth of NMB on the peri-orbital muscles in clinical practice.

There is therefore a potential interest in using there other monitoring techniques. But the best monitoring site and the best monitoring method to take separate recordings of the responses of these small muscles, which are very close to one another, have yet to be determined.
The facial nerve is ideally stimulated using small electrodes with a low current intensity. The stimulation site is just in front of the auditory channel.

Electromyography can be applied specifically both on the orbicularis oculi and on the corrugator supercillii, abiding by the same principle of the perpendicular position of the stimulation electrodes and the recording of muscular responses as we saw previously for the hand.

In this context, phonomyography (PMG), yet another technique which is still in development, could be interesting. The technique records the low-frequency sounds produced by the contracting muscle. The recording site for corrugator supercilii is in the middle of the area just above the eyebrow. Unlike acceleromyography which lacks sensitivity here, phonomyography is a reliable and sensitive method of monitoring NMB at the corrugator supercilii muscle.
At the other end of the patient, stimulating the posterior tibial nerve and recording the responses of the flexor hallucis brevis can be considered for certain surgical procedures, both by acceleromyography and by electromyography.

**Other muscles: Flexor hallucis brevis**

![AMG](image1)

![EMG](image2)


However, all these different techniques, applied to different muscle groups, or with different stimulating patterns, are in most cases neither equal nor interchangeable. Either for determining onset, or for final recovery. Some evolving faster, or slower, than other.

So, on the one hand, it seems interesting to monitor the onset of the block at the corrugator supercili, as well as the depth of the NMB during thoraco-abdominal surgery. On the other hand, there is a potential interest in monitoring the foot to quantify final recovery, although this has yet to be investigated.

But, I would like to stress the interest of the adductor pollicis, where objective neuromuscular monitoring using acceleromyography is the best known and most practical method available to the clinician at the present time. Furthermore, a good knowledge of the ways in which one technique and another, one muscle group and another, correspond to each other is required to adequately manage the NM block of each individual patient.

It is important to ensure that the monitoring technique chosen is implemented under the best possible operating conditions. In particular, since these are the most widely used techniques, acceleromyography and kinemyography require protection against external forces to guarantee the free movement of the thumb. There are various solutions for this.
One simple and inexpensive solution is to use a piece of tape to attach the fingers to the arm board on which it is lying. And hence prevent the fingers from opposing the thumb adduction movement as well as keeping the hand stable in this position while the monitoring is underway.
The Hand Adapter was developed by the Organon company to avoid the opposition of the thumb and the fingers and, by using a certain elastic preload, to help the thumb return to the initial point after each contraction. Unfortunately, the device does not adequately protect the movement of the thumb from external constraints, such as here, along the body of the patient himself.

It has been shown that its application increased the precision of AMG (that is a better repeatability of the measurements) and eliminated the bias in onset time between acceleromyography and mechanomyography.

However, it increased the control TOF ratio, thereby increasing the bias with MMG in late recovery.

This problem of a TOF ratio above 1 before (and after) curarisation has been known since the technique was described, and is said to be due to the difficulty of returning to the same initial point after each of the four contractions. The last three responses are more intense than the first, resulting in a T4 divided by T1 ratio in excess of 1. It is surprising to note that the Hand Adapter does not correct this problem, and even makes it worse in the Claudius study. This gives rise to the need for normalisation to correspond to MMG without a statistically significant difference.
The principle of normalization is to make the final TOF ratio correspond to the initial TOF ratio by a simple rule of three. In fact, it’s a question of **calibrating** the initial TOF ratio at 100%, as was proposed for the first twitch.

And so the results obtained with acceleromyography (with a TOF ratio often higher than 1.10 or even 1.20) correspond perfectly to the results obtained by MMG (which, moreover, are often slightly below 1).

Unfortunately, simple as it may seem, this calibration of the TOF ratio does not exist on any of the devices commercially available at the moment.

Bearing in mind that the acceleromyographic baseline TOF ratio is above 1, notice that the TOF Watch devices, except the SX model, display a **maximum figure of 100%**!

With these simplest devices, you cannot know the real baseline, and normalize if needed. This is an important limitation!
I cannot really end without presenting to you the solution which I am developing in my department. Thanks to its rigid structure, the TOF tube overcomes the major problem of acceleromyography in a clinical setting, that is the requirement for free movement of the thumb.

The TOF tube provides efficient protection for freedom of movement of the thumb during surgical procedures in all installations and all operating conditions.

An elastic band helps the thumb return to the same starting point after each contraction without causing it any real preload. The TOF ratio baseline is closer to unity.

The TOF tube, which provides a very satisfactory degree of precision and performance in comparison with mechanomyography, and has the benefit of excellent clinical applicability, could improve the clinical feasibility of AMG and restore anaesthetists’ confidence in this technique.
Conclusions:

Objective neuromuscular block monitoring is **useful** during the **entire** anesthetic and surgical procedure, and is the only way to rule out residual blockade **before** extubating the patient.

Three different techniques are currently available in clinical practice.

Electromyography requires a correct placement of the electrodes, while kinemyography and acceleromyography need that the thumb moves freely. Several solutions exist.

In all cases, properly stick the stimulation electrodes, and confirm the functioning and the results given by the monitoring.

Different muscles groups are available to the different techniques of neuromuscular transmission monitoring.

But they differ in sensitivity to muscle relaxants. Some may be useful to adequately monitor the onset and the depth of blockade during surgery, and others to ensure complete recovery before extubating the patient.

Different devices exist and have different advantages that the ideal monitor should include:

- Automatic determination of the supra maximal stimulation
- Signal stabilization and T1 calibration before inducing the neuromuscular block, as well as TOF ratio normalization
- Graphic window and trends to evaluate the quality of the measurements and the time course of the block
- Integration of the results into the anesthesia protocol
- Robustness and a price as low as possible.

I hope this will help you in the choice of the device you need, and to monitor properly the neuromuscular transmission every time a patient receives muscle relaxants.
Objective NMB monitoring:
usefullness

- From onset to full recovery
- Clinical test, and TET 100 Hz, lack accuracy to rule out residual block.
- TOF (and PTC) using objective means

Objective NMB monitoring:
techniques

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<th>Method</th>
<th>Description</th>
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<td>MMG</td>
<td>The established standard&lt;br&gt;Cumbersome, ! Stability !</td>
</tr>
<tr>
<td>EMG</td>
<td>Better stability during surgery&lt;br&gt;Polytopic&lt;br&gt;Stimulation artifact !&lt;br&gt;Placement electrodes !</td>
</tr>
<tr>
<td>KMG</td>
<td>Simple&lt;br&gt;Only the hand</td>
</tr>
<tr>
<td>AMG</td>
<td>Simple&lt;br&gt;Inexpensive&lt;br&gt;Fragile&lt;br&gt;Free movement of the thumb !</td>
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**Objective NMB monitoring: placement**

- Stimulation electrodes placement
- Recordings validation, clinical good sense
- Different muscles groups

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<th>EMG</th>
<th>KMG</th>
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**Objective NMB monitoring: devices**

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