What Anesthesiologist Should Know about Neuromuscular Monitoring Today?

Naoyuki UEDA, Takesuke MUTEKI and Hideaki TSUDA

(Key words: nerve stimulator, twitch stimulation, train-of-four, posttetanic count, double burst stimulation)

Since the introduction of muscle relaxants in clinical anesthesia, there has been an increasing interest in the evaluation of the degree of neuromuscular blockade during anesthesia. In 1958 churchill-Davidson[1] described how nerve stimulators could be applied to assess neuromuscular function quantitatively. However, only few anesthesiologists used nerve stimulators routinely, probably because of their higher cost and complexity. Recently some simpler equipments and methods have been introduced which seem to be more acceptable for routine clinical use[2–4]. Advantages of routine use of nerve stimulators are as follows: Firstly, the degree of neuromuscular blockade can be assessed precisely. This becomes particularly important because of varying sensitivity to muscle relaxants in different individuals[5]. Secondary, the does of relaxant can be titrated according to the clinical situation. Thirdly, the optimal time for reversal[6,7] as well as extubation can be decided. In addition, the use of nerve stimulator becomes mandatory for the exact diagnosis of residual block or prolonged apnea.

Department of Anesthesiology, Kurume University, School of Medicine, Fukuoka, Japan

Address reprint requests to Dr. Ueda: Department of Anesthesiology, Kurume University School of Medicine, 67 Asahi-machi, Kurume-shi Fukuoka, 830 Japan

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The purpose of this review is to discuss the practical aspects of neuromuscular monitoring with some physiological consideration. In addition, the reliability of various modes of nerve stimulation in various clinical situation will also be discussed.

I. Physiological considerations related to the nerve stimulation

a. *Principles of nerve stimulation*

The assessment of neuromuscular function is usually based on the stimulation to ulnar nerve near the distal end of ulna and measuring contraction of the transverse head of adductor pollicis muscle. The reaction of a single muscle fiber to stimulus follows all-or-non low. If the borderline stimulus around the threshold is given, each muscle fiber may fully respond or not at all. Any change in the condition of the stimulus or electrodes will result in a significant fluctation in the number of muscle fibers responding. To avoid such technical problems, and to be sure to trigger a maximum response, the intensity of electrical stimulus applied to nerve is kept at supramaximal, that is 20–25% above the level whitch is necessary to evoke a maximum response.

An effective electric stimulus consists of a current sufficient amperage and duration. For this purpose, constant current (not constant voltage)

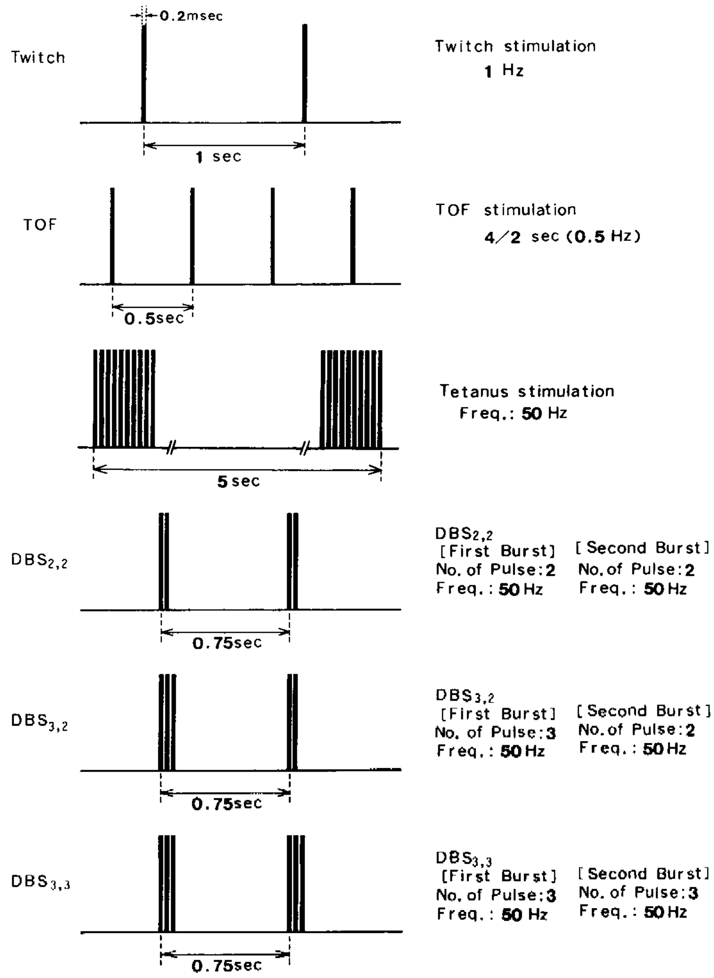


Fig. 1. The stimulation patterns of twitch, train-of-four, tetanus, $DBS_{2\cdot2}$ $DBS_{3\cdot2}$ and $DBS_{3\cdot3}$.

output of monophasic rectangular (square wave) pulse of proper duration, usually 0.2 msec is used. As the stimulus is commonly applied through the skin electrodes, 30–60 mA is required for the ulnar nerve in an adult[8]. For the children smaller current should be selected. The important point is that the stimulus should be applied to the nerve in such a way that the probability of stimulating the muscle directly should be minimum. For this reason, a pulse duration exceeding 0.5 msec should better be avoided. Stimulation of ulnar nerve at the elbow is not as good as stimulation of the same nerve at the wrist, simply because too many muscle groups may be stimulated directly or indirectly.

After administration of muscle relaxants, the response of the muscle decreases in proportional to the number of fibers blocked. The reduction in response to the stimulus reflects the degree of neuromuscular blockade, provided the intensity of the stimulus is kept constant. The response to the stimulus can be assessed in one of three ways, mechanomyographically (MMG) electromyographically (EMG) and manually (visually or tactilely).

b. *Patterns of nerve stimulation* (fig. 1)

Since the introduction of nerve stimulator, various pattern of nerve stimulation has been described. Each pattern has it's own application in various clinical situations, which are discussed here : –

1) Single twitch stimulation

In this stimulation mode, single supramaximal current impulses applied to the nerve at frequencies of 0.1–1.0 Hz. The responses to a single twitch stimulation depends on the frequency with which the individual stimuli are applied. During nondepolarizing blockade if the frequency is increased to more than 0.15 Hz, the evoked response will gradually decreases and settles at lower lower level[9,10]. Therefore, a frequency of 0.1 Hz is commonly used. However a frequency of 1.0 Hz stimulation can also shorten the time taken to obtain supramaximal stimulation and can also be used during induction of anesthesia. Clinically, the use of supramaximal stimulation is important to make sure that all the muscle fibers are activated. For the quantitative evaluation of the response to single twitch, a control twitch height is required.

When depolarizing or nondepolarizing muscle relaxants are given increasing dosage, the evoked twitch decreases in strength and degree of blockade is defined as percent inhibition of the reponse. As the block wears off, the twitch height returns toward base line, so duration of action of the drug can be measured.

2) Train-of-four (TOF) nerve stimulation

In this type of nerve stimulation, four supramaximal stimuli of four supramaximal stimuli applied at intervals of 0.5 sec over a period of 2 sec (2 Hz)[11-13]. When used continuously, each set of stimuli is usually repeated every 10–12 sec. Each stimulus in the train will cause the muscle to contact, and the amplitude of the fourth response in relation to the first provide the TOF ratio.

Before any relaxants has been given, basically all four responses are the same: the TOF ratio is 1.0. Since this method uses the first response as the reference point, no preblock base line needs to be established. The TOF method can be used to monitor both mild and surgical relaxation. For monitoring residual blockade, a TOF ratio of 0.7 has been use as a bench mark to indicate a level of relaxation that does not compromize respiration. Surgical degree of relaxation is monitored by counting the number of twitch respose in the TOF response. Adequate surgical relaxation is usually indicated by the presence of only one or two twitches in the TOF response. During partial depolarizing blockade, no fade occurs in the TOF response, so TOF ratio is approximately 1.0. If fade in the TOF response is observed after administration of depolarizing muscle relaxant, phase II block may be indicated.

The advantages of TOF method include greater sensitivity than single twitch for evaluation of residual neuromuscular blockade, unnecessity of establish a base line response, and performance in awake patients with minimum discomfort. It also has been shown to avoid the distortion of neuromuscular transmission that resulted from tetanic stimulation. A problem with this method is that the TOF ratio can only be determined by quantitative method such as EMG or MMG.

3) Tetanic stimulation

Tetanic stimulus consist of supramaximal 0.1 to 0.2 msec square waves delivered at a very rapid rate, e.g. 50, 100 or even 200 Hz. This is considered as a rapid single twitch stimulation taken to the extreme. In clinical practice, the frequency most commonly used is 50 Hz given for 5 seconds, based on the finding[r] that with 50 Hz stimulation, the force of contraction is the same as that produced by a

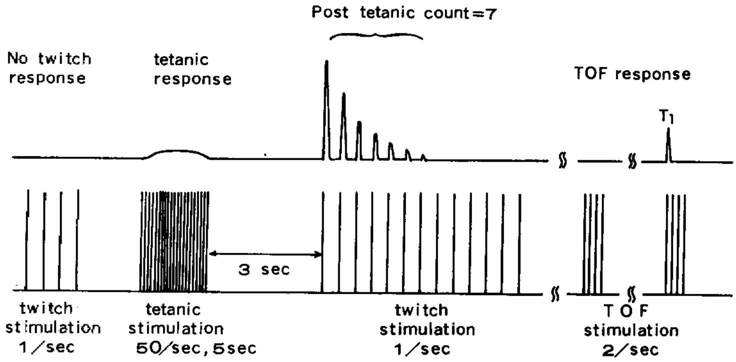


Fig. 2. Illustration of the evoked response to tetanic (50 Hz, 5 sec) and posttetanic twitch stimulation (1 Hz) following injection of a nondepolarizing neuromuscular blocking agent. The number of responses to twitch stimulation following tetanic stimulation is called "posttetanic count (PTC)" (Viby-Mogensen et al[18], 1981).

maximum voluntary effort[14].

During normal neuromuscular transmission and during a pure depolarizing block, the tetanic stimulation results in a sustained tetanic contraction of the muscle. Whereas during nondepolarizing block and a phase II block with depolarizing muscle relaxant, the response will not be sustained and a variable degree of fade will be noticed. At the start of the tetanic stimulation, large amount of acetylcholine is released from the storage sites in the motor neuron terminals. As these stores become depleted, the rate of acetylcholine release decreases until new equilibrium between synthesis release of acetylcholine is attained. Even under this equilibrium, the muscle response to tetanic stimulation of the nerve at 50 Hz is maintained during normal neuromuscular transmission, simply because the release of acetylcholine is many times greater than the amount of necessary to evoke a response[15,16]. On the other hand, when the number of free cholinergic receptors at the postsynaptic membrane is reduced by a nondepolarizing relaxant, deminishing acetylcholine release fails to maintain a sustained response. Consequently a fade in the response to tetanic stimulation is observed. In addition to blocking the post-synaptic membrane, nondepolarizing drugs may also impair the mobilization of acetylcholine within the nerve terminal. This effect may contribute to fade in the response to tetanic stimulation. The degree of fade depends on the degree of neuromuscular blockade, and it also depends on the frequency and duration of the stimulation and on how often the stimulus is applied. If these factors are not kept constant, the results from different situations can not be compared.

There are two limitations to the use of tetanic stimulation: It cause considerable discomfort (pain) and is not suited for use in the concious patients. Secondly, the tetanic stimulation may cause conditioning to the subsequent stimuli for a period of 6 min. Therefore repeated application of tetanic stimulation may indicate a false recovery from neuromuscular blockade[11,16,17] (i.e. decurarizing effect).

During partial nondepolarizing blockade, the post tetanic facilitation (PTF) is a well-known phenomenon[16] that the tetanic stimulation enhances the response of a twitch immediately following it. This may be due to both augumentation of contraction and facilitation of transmission. It is considered as follows, augumentation of contraction occurs as a result of inreased calcium release within muscle fiber; facilitation of transmission occurs only in the presence of nondepolarizing neuromuscular blocking agents and is the result of inreased acetylcholine synthesis/mobilization that persist after

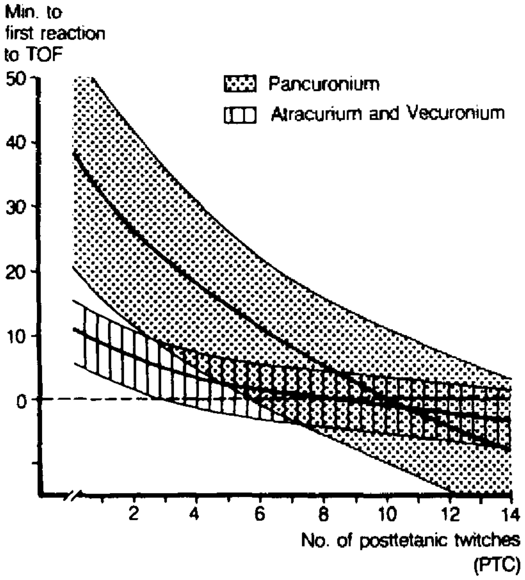


Fig. 3. Relationship between the time (min) to the first response to a train-of-four stimulation and the number of individual posttetanic twitches (PTC) following injection of pancuronium, vecuronium or atraculium. The mean curves and 95% prediction regions are shown respectively. (Viby-Mogensen et al.[18–20], 1981, 1987)

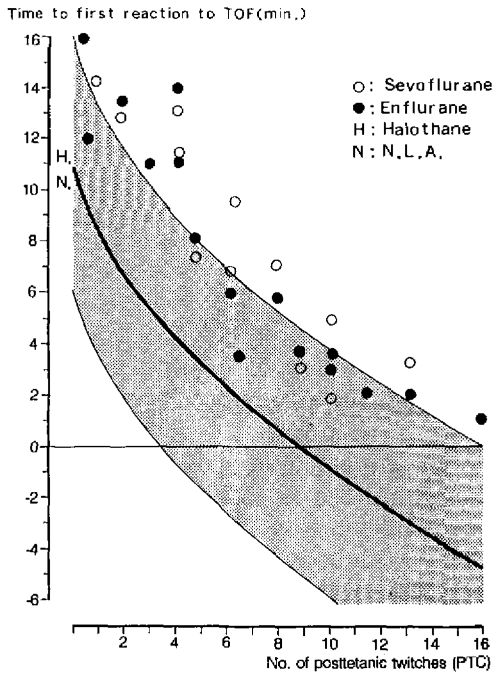


Fig. 4. Relationship between the time (min) to the first response to a train-of-four stimulation and the number of individual posttetanic twitches following the injection of vecuronium during enflurane and sevoflurane anesthesia. The duration of intense neuromuscular blockade induced by vecuronium is prolonged by enflurane and sevoflurane in comparison with halothane and NLA. The PTC was measured mechanically using an Accelograph® (N. Ueda, 1990).

tetanic stimulation.

From the clinical point of view, the PTF can be utilized to quantify a intense nondepolarizing neuromuscular blockade. During intense blockade, single twitch or TOF nerve stimulation does not allow evaluation of the degree of blockade, because there is no response to theses type of stimulation. However, it has been shown that it is possible to quantify the intense blockade by applying tetanic stimulation (50 Hz for 5 sec) and observing the post tetanic response to 1.0 Hz single twitch stimulation, starting 3 sec after end of tetanic stimulation. Viby-Mogensen[18] studied the relationship between the posttetanic twitch response and the first response to TOF nerve stimulation during pancuronium induced neuromuscular blockade. During intense nondepolarizing neuromuscular the number of posttetanic single twitch responses can be counted. This is called the posttanic count (PTC). As the degree of intense blockade dereased, more and more responses to posttetanic single twitch stimulation appear. For each nondepolarizing muscle relaxant an reverse correlation exists between the PTC and the time until return of the first response to TOF nerve stimulation[19,20] (figs. 2-4).

4) Double burst stimulation (DBS) (fig. 5)

Double burst stimulation (DBS) is the newest pattern of stimulation developed to manually identify significant

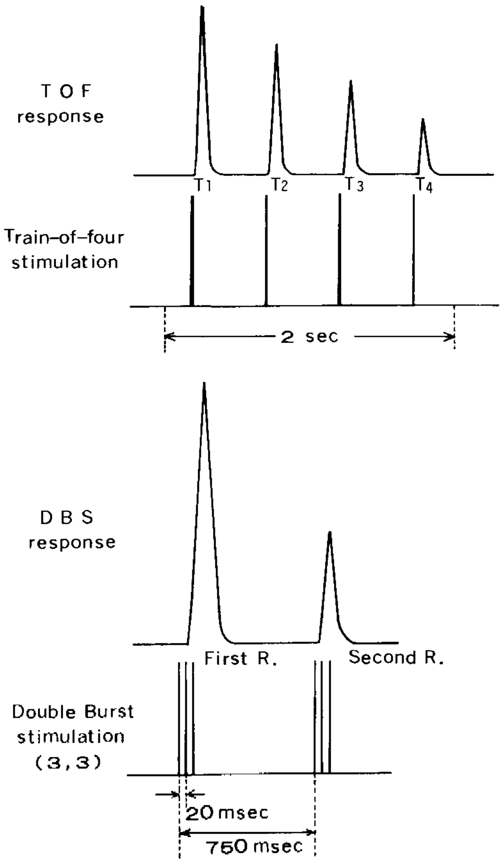


Fig. 5. Illustration of stimulation pattern and the evoked responses to train-of-four and double burst nerve stimulation following administration of a nondepolarizing muscle relaxant (Ueda et al.[22], 1988).

residual nondepolarizing neuromuscular blockade in clinical situations. During the recovery phase, when there is a reaction to all four stimuli on TOF stimulation, and in particular when the TOF ratio measured mechanically (EMG or MMG) exceeds 0.4, it is extremely difficult to detect the fade in the TOF response by the perception of fade[21,22]. To overcome this difficulty, the DBS is applied to manually evaluate neuromuscular transmission[22–24]. DBS consists of two short burst of a 50 Hz tetanic stimulation separated by 750 msec. The response to this type stimulation is two single separate muscle contractions. During nondepolarizing blockade, the response to the second burst of stimulation is less than the first, in accordance with the fade in the TOF response. There is a close positive correlation between TOF and DBS ratios as measured mechanically, and it has been found that the fade in DBS response is more easily felt than the fade in TOF response (fig. 6).

Three different DBS patterns ($DBS_{3\cdot3}$, $DBS_{3\cdot2}$ and $DBS_{2\cdot2}$) have been introduced for clinical use. In $DBS_{3\cdot3}$ three impulses of supramaximal stimulation are given in each burst. In $DBS_{3\cdot2}$ three impulses are given in the first burst and only two in the last. A $DBS_{2\cdot2}$ consists of two impulses in each burst. Because of its short duration, each response is perceived only as an enhanced twitch. If the second response is weaker than the first, clinically significant residual block exists. DBS is less painful than the tetanic stimulation but more painful than twitch stimulation.

II. Equipments

a. Stimulator

Since Churchill-Davidson[25] (1965) introduced a portable peripheral nerve stimulator (fig. 7), several different nerve stimulators for clinical practice with different characteristics have become commercially available[26–29]. In this user's opinions, the important thing is not but which stimulator is but how to use the nerve stimulators to utilize their capacity maximally. There are some important requirments on a nerve stimulator. The stimulator should be compact and simple to use and it should be able to generate the following different patterns of stimuli: TOF, single twitch stimuli at frequencies of 0.1 and 1.0 Hz, a tetanic stimulation of 50 Hz and two modes of double burst stimulation ($DBS_{3\cdot3}$, $DBS_{3\cdot2}$). Ideally the nerve stimulator should have an inbuilt time constant

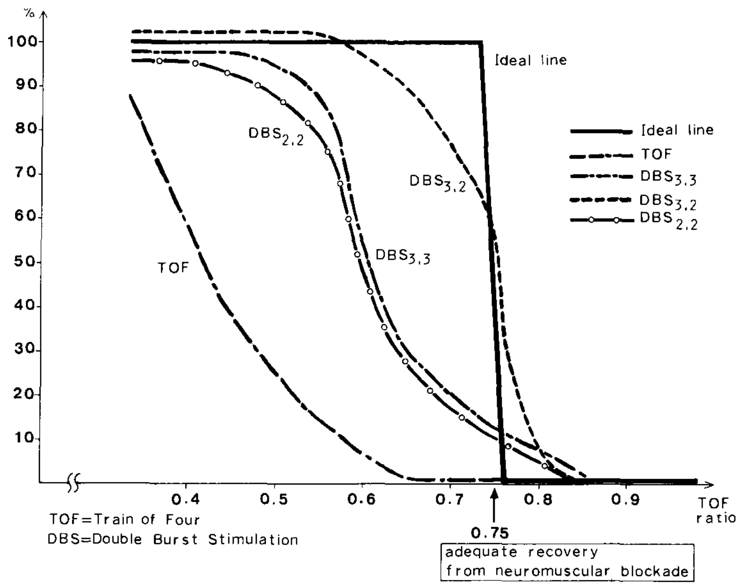


Fig. 6. The manual detectability of fade at different mechanomyographic TOF ratios.

The manual detectability of fade in the response to double burst stimulation ($DBS_{3\cdot3}$, $DBD_{2\cdot2}$, and $DBS_{3\cdot2}$) and train-of-four (TOF) nerve stimulation at different TOF ratios measured mechanomyographically are shown. A TOF ratio of 0.75 is normally taken to reflect adequite recovery of neuromuscular function, so that ideally fade should be felt in all patients with a TOF ratio < 0.75 and no fade should be felt in all patients with a TOF ratio > 0.75. The figure indicates that the $DBS_{3\cdot2}$ mode is closest to the ideal pattern of nerve stimulation (Ueda & Viby-Mogensen[37], 1989).

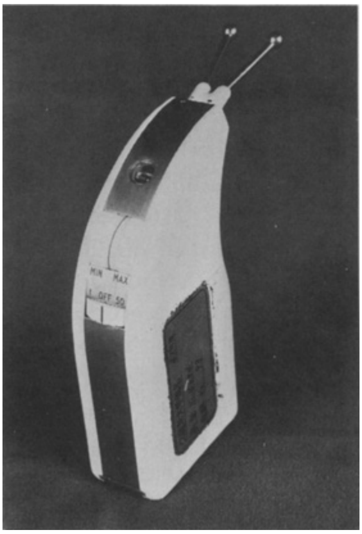


Fig. 7. The portable peripheral nerve stimulator introduced commercially by Churchill-Davidson (1965).

system to facilitate the use of the PTC method. The response to tetanic and posttetanic stimulation is different by the frequency and duration of the applied tetanic stimulus and the interval between the conclusion of tetanic stimulus and the first posttetanic single stimulus. Therefore, it is essential to keep these variables constant[31,32]. When the PTC method is applied, the duration of the tetanic stimulus should be 5 sec and the first posttetanic twitch stimulation should start 3 sec later. The nerve stimulator should be able to maintain a constant current to the nerve which is unaltered by changes in impedance between the electrodes[2]. The main features of nerve stimulators which are commercially available nowaday are summarized in Table. In our department, a Myotest DBS® nerve stimulator is used in clinical anesthesia routinely (fig. 8). The Myotest DBS is battery operated and very simple to use. This stimulator generates a unipolar constant-current impulse with an adjustable amplitude from 0 to 60 mA. TOF stimulation is given every 12 sec, and the pause between each DBS is 20 sec.

Table 1. Characteristics of nerve stimulators for clinical use which are commercially available

	Myotest DBS	Innervator NS252	NS-2C	Digistim III	Rutter 4B
Single twitch at 1 Hz or 0.1 Hz	○	○	○	○	×
Train-of-four	○	○	○	○	○
Programmed PTC 50 Hz and 1 Hz	○	○	×	×	×
Double Burst 3.3 and 3.2	○	(2.2)	×	×	×
Output>50mA	○	○	○	○	○
Light and compact (weight)	○ (450g)	○ (254g)	× (650g)	○ (320g)	○ (170g)
Continuously variable output	○	○ ○ (10mA steps)	○	○	×
High impedance alarm	○	○	○	○	○
Constant current	○	○	×	×	○
Manufacturer	Biometor International Denmark	Fisher & Paykel New Zealand	Professional Instruments U.S.A.	Neuro Technology U.S.A.	Dr. O. Ruller England

* ○: available or appropiate, ×: unavailable or inappropriate

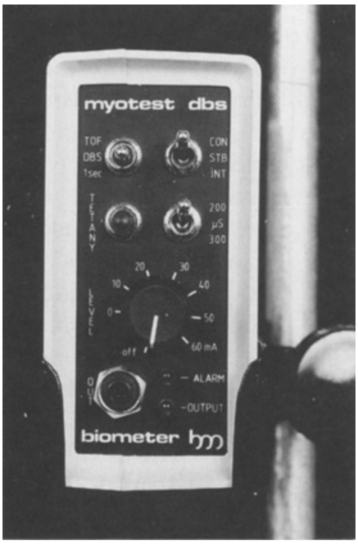


Fig. 8. Front plate of MyotestDBS® nerve stimulator (Biometer International, Denmark, 1986).

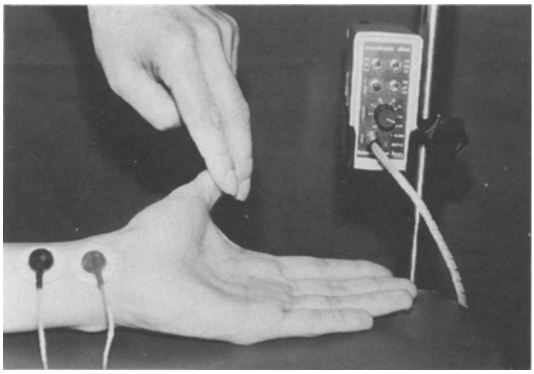


Fig. 9. Monitoring of neuromuscular blockade without recording equipment. A Myotest DBS® nerve stimulator and surface electrodes are used. The evoked response is detected by tactile evaluation.

b. The electrodes and their site in motor nerve stimulation

The stimulation site is commonly selected on the ulnar, but other peri-

	Onset	Intense Blockade	Surgical Blockade		Recovery		
% of control twitch height		0	10	25	50	75	90
Typical TOF count(& ratio)		0/4 (0)	1/4 (0)	3/4 (0)	4/4 (0.15)	4/4 (0.5)	4/4 (0.75)
Surgical relaxation		excellent		adequate	poor	—	—
Sustained headlift(5 sec)		No		No	No	Variable	Yes
Maximum inspired pressure(cmH2O)		—		<-20	-20	-40	-90
Maintain patient airway		No		No	No	Variable	Yes

Fig. 10. The recorded evoked response to TOF nerve stimulation, and correlation between response and clinical parameters (Modified Viby-Mogensen's original illustration[2] 1985).

pheral nerves can be selected as well (the facial nerve, the posterior tibialis nerve or peroneal nerve, for example). Stimulation of the ulnar nerve result in thumb adduction as the adductor pollicis is only muscle innervated by the ulnar nerve. During the assessment of this response, the arm should be abducted 80–90% with the hand in spination (fig. 9). The skin should be properly cleaned before placing the electrodes. The electrodes should be placed to stimulate the nerve (not the muscle). Usually surface electrodes (rubber or disposable E.K.G electrodes of child-size) are sufficient and needle electrodes are rarely used. The peripheral surface temperature should be kept above 33.5°C. The impedance of rubber electrodes increases day by day. Therefore, we are using disposable child-sized E.K.G. electrodes.

III. Evaluation of the response to nerve stimulation

a. *Recorded evoked response, and correlation between response and clinical parameters* (fig. 10)

When only one response to TOF stimulation can be detected, corresponding to about 10% twitch height, the degree of neuromuscular blockade is sufficient for most surgical procedures[30]. At this level of peripheral blockade, however, respiratory movements such as cough or hiccup may occur, because the muscle of the diaphragm is less sensitive to relaxants than the peripheral muscles[31,32]. Therefore, when it is essetial that the patient does not cough nor produce spontaneous respiratory movement, the blockade has to be more intense. In such case the level of blckade can be evaluate by the PTC method. In the maintenance phase, to ensure that the muscles of the diaphragma as well as the peripheral muscles are titally relaxed, the degree of peripheral blockade has to be so intense that no response can be detected to post-tetanic single twitch stimulation, i.e.

Zero PTC[33]. In the recovery phase the TOF ratio is used as an index of recovery. At a TOF ratio of 0.6 the patient is able to maintain head-lift for 3 sec, while a TOF ratio of 0.75 correlates well with the clinical signs of adequate recovery. In these situation, the patient will be able to sustain head-lift for 5 sec., protrude tongue, open eyes and cough sufficiently[34,35].

b. Clinical use of nerve stimulator without recorder

Only seldom is the response to nèrve stimulation recorded in everyday anesthesia, and the response is evaluated visually or tactilely (by touch).

1) Visual evaluation

Historically, the number of responses to TOF stimulation and magnitude of evoked response was evaluated by finger movement visually. If there is a finger movement to all four stimuli the TOF ratio can be estimated, but, it is extremely difficult to do so. On a visual basis it is often impossible to determine whether the TOF ratio is 0.4, 0.7 or 1.0[21,36].

Generally, the authors do not recommend visual evaluation, because this method is too qualitative.

2) Tactile evaluation

With investigator's finger tips resting lightly on the patient's thumb in slight abduction (fig. 9), it is usually possible to gain a better impression of the force of the contraction than can be obtained visually. Probably because in this way the chance of over estimation is less. It is easy to decide by touch if there is any reaction to TOF stimulation and how many responses exsist. Even by touch, however, it is very difficult to determine the TOF ratio when all four responses are present. The methods with which the anesthesists apply the tactile evaluation to ensure that the patient has reached sufficient reversal at the end of anesthesia i.e. TOF ratio > 0.7, is by evaluating the patient's thumb reaction to the double burst stimulation ($DBS_{3\cdot3}$ or $DBS_{3\cdot2}$. The $DBS_{3\cdot2}$ method is more accurate and easier in practice to evaluate whether the neuromuscular function has recovered to the level of TOF ratio > 0.75 after the administration of nondepolarizing neuromuscular blocking agents especially for the inexperienced anesthetists[37,38]. Thus, tactile evaluation of thumb movements is the best way to assess neuromuscular function if recording equipment is not available. No matter how the evaluation is made, it is important to compare the response to nerve stimulation with the clinical signs related to the effects of residual neuromuscular blockade. Especially when the peripheral temperature is very low, there will be some disproportion between the degree of neuromuscular blockade of the peripheral muscles and that of the respiratory and airway protective muscles.

IV. Practical clinical use of a nerve stimulator during the perioperative period

In our department nerve stimulators are used routinely whenever relaxants are administered. When the patient is prepared for anesthesia, the electrodes are placed at the wrist (fig. 9). The nerve stimulator should remain switched off until the patient is nuder anesthesia.

a. During induction of anesthesia

When the the patient is under anesthesia but not yet been given any muscle relaxants, 1 Hz single twitch stimulation is used to obtain supramaximal stimulation, and then the anesthetist should try to feel a fade in the response to the $DBS_{3\cdot2}$. If no fade is felt, the selection of $DBS_{3\cdot2}$ mode will be qualified, if fading is felt (although this is rare) $DBS_{3\cdot3}$

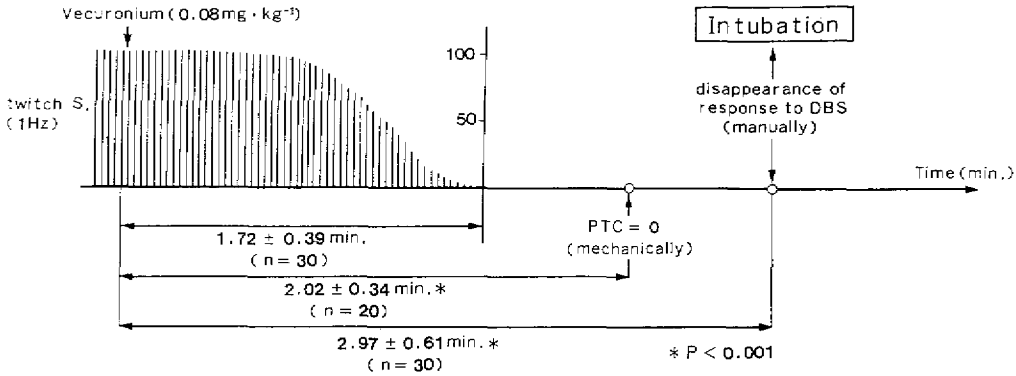


Fig. 11. The optimal time for endotracheal intubation after onset of neuromuscular blockade induced with vecuronium.

After the administration of vecuronium (0.08 $mg \cdot kg^{-1}$), the time required to produce the disappearanse of response to DBS manually is significantly longer than the time required to make the disappearance of the response to single twitch and PTC zero. The disappearance of response to DBS manually will be an excellent indicator of optimal time for intubation during onset of nondepolarizing neuromuscular blockade (Ueda[39], 1990).

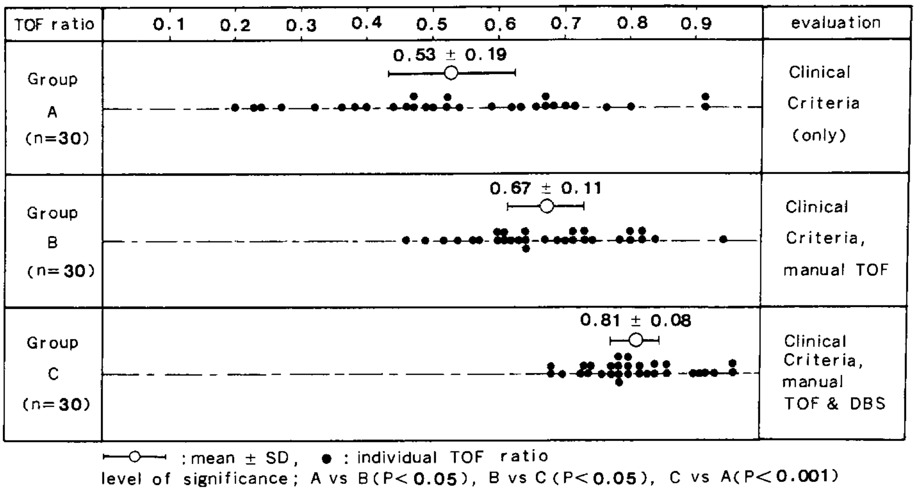
mode instead of $DBS_{3.2}$. mode should be selected. After injection of the relaxants, endotracheal intubation is performed after obtaining the disappearance of the response to DBS during onset of relaxation induced by vecuronium. Our recent study showed that the time required to produce the disappearance of the response to DBS manually with vecurunium was significantly longer than the time required to make the disappearance of the responses to single twitch and TOF stimulation manually[39]. And the intubation score was the best when used the response to DBS as an indicator of optimal time for intubation[39]. We believe that no coughing and bucking will occur during intubation after administration of vecuronium whenever the response to DBS is not present (fig. 11).

b. During operation

During the surgery, the muscle relaxation which is ensured by two (only T_1 and T_2) or three (only T_1, T_2 and T_3) responses to the TOF stimulation are adequate under the equivalent anesthetic condition of 1.5–2.0% inspired concentration of enflurane, isoflurane, or sevofulurane. If a more intense level of blockade is needed for surgical reasons, the degree of blockade should be evaluated by the PTC method.

c. During reversal of neuromuscular blockade

Reversal of a nondepolarizing block is usually possible when the first response (T_1) to TOF stimulation is felt. However , we recommend not to reverse the block until three (T_1, T_2 and T_3) or preferably all four responses (T_1–T_4) to TOF stimulation are felt. This reason is that the reversal time depends on the level of blockade at the time of injection of the antagonist. If all responses to TOF stimulation are present before injection of neostigmine (corresponding to a twitch height of at least 25%), reversal is usually sufficient within 10 min. If no response to TOF stimulation can be felt, reversal will not often be inadequate irrespective of the dose of neostigmine used. However, the anesthesiologist should refrain from the additional over injection of the antagonist because the



N.Ueda, Kurume Unive. 1989.

Fig. 12. The incidences of residual neuromuscular blockade induced by pancuronium in our department.

This study evaluated whether the use of double burst stimulation ($DBS_{3\cdot2}$) enabled the anesthetists to recognize significant residual block and reduced the incidence of postoperative residual block. In Group A the degree of residual neuromuscular blockade was assessed by clinical criteria (CC) only; in Group B by CC and manual evaluation of the response to TOF nerve stimulation; and in Group C by CC, manual evaluation of the response TOF and DBS stimulation. Immediately after arrival at the recovery room, mechanical twitch was recorded using TOF stimulation. The mean TOF ratios were 0.53 in Group A, 0.67 in Group B and 0.81 in Group C. The incidence of a TOF ratio of less than 0.7 was 83.3% in Group A, 56.7% in Group B and 6.7% in Group C. Thus, the diagnosis of significant residual neuromuscular blockade improved by using double burst nerve stimulation ($DBS_{3\cdot2}$) (Ueda[38], 1990).

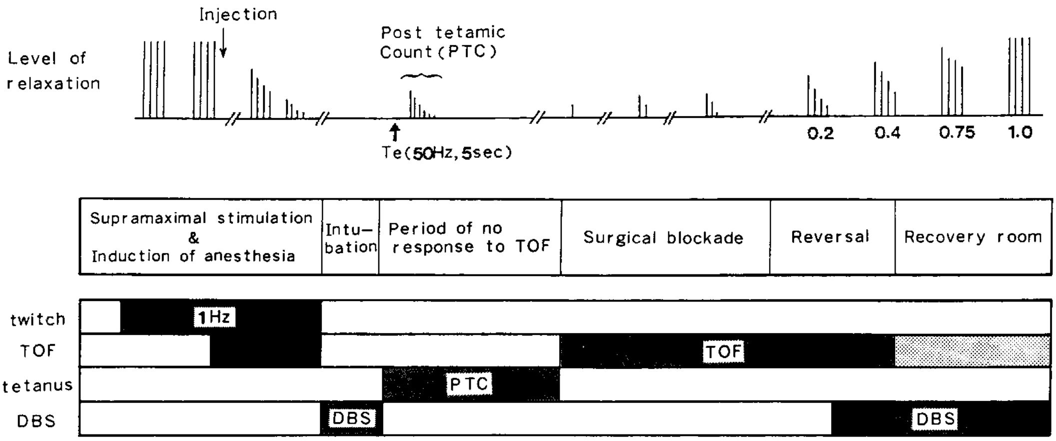


Fig. 13. Diagramatic illustration of when to use the different patterns of nerve stimulation during the course of anesthesia, at Copenhagen University and Kurume Universiy Hospital (Viby-Mogensen 1984, 1990; Ueda 1988, 1990).

neostigmine itself might induce neuromuscular blockade.

d. After operation

The manual evaluation of the response to TOF stimulation is of value in the adjustment of individual dose regimens for neuromuscular blocking drugs during anesthesia in order to avoid overdose and to secure reversibility. However, the postoperative absence of visual and tactile fade in the TOF response does not exclude the possibility of residual neuromuscular blockade. Consequently, the DBS method is applied when fade is no longer felt in the TOF response. This increases the possibility of ensuring that the patient's residual neuromuscular blockade has reached the level of TOF > 0.75. Of course, the clinical signs of adequate recovery should always be evaluated before extubation is performed.

In our department, the use of $DBS_{3\cdot2}$ enabled the doctors with no special interest in neuromuscular monitoring and less than one year's training in anesthesia to recognized significant residural block and thus reduced the incidence of postoperative neuromuscular blockade[38] (fig. 12).

The time when each of the different patterns of stimulation should be selected are shown in figure 13.

V. Indication for monitoring with a nerve stimulator

Because of the wide variation in patient response to a given dose of muscle relaxant, it would be prudent to use monitor whenever relaxants are given, and this is what actually is happening today in an increasing number of departments. If it is not possible to use the sophisticated MMG or EMG, a nerve stimulator should at least be used in the following situations[40].

a. patients with neuromuscular disease like myasthenia gravis or myasthenic syndrome (monitoring may not reliable in the patients with motor neuron lesions)[41,42].
b. Patients with severe renal or hepatic dysfunction, or both.
c. Patients with severe heart disease or bronchial asthma, in whom achievement of reversal through an anti-cholinesterase agent might induce problems.
d. Patients with severe pulmonary disease and grossly obese or elderly.
e. Patients whose general condition is poor.
f. Patients who are scheduled to undergo prolonged surgical procedure.
g. Patients in whom relaxation is to be obtained by the continuos infusion of neuromuscular blocking drugs[43].

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