ASSESSMENT OF THE DATEX RELAXOGRAPH DURING ANAESTHESIA AND ATRACURIUM-INDUCED NEUROMUSCULAR BLOCKADE

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Accurate assessment of neuromuscular function requires the stimulation of a motor nerve and the recording of the evoked mechanical or electromyographic response (EMG). Measurement of the evoked tension in muscle involves problems with transducer fixation and overload, and immobilization of the arm (Ali and Savarese, 1976). In general, these systems are cumbersome and difficult to set up in clinical practice. The advantages of measuring the EMG are that a response may be obtained from muscles which are not accessible for mechanical recording and it may be used in paediatric patients. Traditionally, the recording of the EMG required the use of a preamplifier and storage oscilloscope and, as a result, its use was restricted. With modern microprocessor technology it is now possible to detect, analyse, digitize and record the EMG without the need for a storage oscilloscope.

The Datex Relaxograph is a neuromuscular transmission analyser which utilizes the integration of the EMG response. It is a modified form of the neuromuscular transmission monitor (NTM) of the Datex Anaesthesia Brain Monitor (ABM) and is now marketed as a separate unit (fig. 1). We have been using this machine and have compared its results with those provided simultaneously with a force transducer.

SUMMARY

The Datex Relaxograph is a recently introduced electromyographic monitor of neuromuscular transmission. It has been assessed in patients requiring neuromuscular blockade and the results compared with those obtained simultaneously with a force transducer. There was a good correlation between the two methods of measurement for both twitch height and train-of-four ratio (correlation coefficients 0.93 and 0.97, respectively). The Datex Relaxograph proved easy to use in the clinical setting.

MATERIALS AND METHODS

Apparatus

The Datex Relaxograph uses small disposable pre-gelled silver–silver chloride surface electrodes for nerve stimulation and EMG recording. The two stimulating electrodes may be positioned over the median, ulnar or posterior tibial nerves. As a result of the differential amplification utilized by the monitor, only one recording electrode is required on the appropriate muscle, ideally over the motor point of the muscle stimulated. When the active electrode is placed over the thenar or hypothenar eminence, it may be advantageous to place the indifferent electrode at the tip of the first or fifth finger, respectively, although it can be positioned elsewhere on the hand if the patient is small or large ECG electrodes are used. In order to decrease stimulus artefact, the fifth electrode (ground electrode) is positioned between the stimulating and the recording electrodes and the EMG response is gated; that is, the electronic integration lasts for 10 ms, starting 3 ms after the
nerve is stimulated. The signal detected by the
analyser is processed by an amplifier, a rectifier
and an electronic integrator. The results are
displayed, sampled and held for a variable period
in the memory of the computer. The machine uses
a fully isolated constant current stimulator which
produces train-of-four (TOF) stimuli, with a
pulse width of 100 μs and a frequency of 2 Hz
every 20 s. The stimulus output is a rectangular
wave with a current range of 0–70 mA and the
machine calibrates automatically by searching for
the optimum signal levels before setting the
supramaximal level. The calibration sequence
usually takes less than 20 s. As it is both
potentially painful and easily affected by patient
movement, it must be initiated after the patient
is anaesthetized, but before neuromuscular trans-
mission is blocked. After locating the supramaxi-
mal stimulus for the patient (to set the 100% reference values) the time-elapsed clock is reset automatically and starts counting.

Every 20 s the monitor calculates the percentage
of first twitch amplitude compared with the
reference (T1), and the train-of-four (TOF) ratio
(the ratio of last twitch height to first height). These values are shown on two digital displays.

When less than four responses are elicited, the
TOF ratio is replaced by a number of dots,
representing the responses that can be recorded.
The machine also incorporates a silent hard-copy
printer which includes the results of the automatic
calibration procedure and error messages. The
printer has two speeds: one for recording every
response of the train-of-four and the other for
maximally compressed trend recording, giving
only the first and fourth responses.

If neuromuscular blocking drugs have been
given to the patient before calibration, the
instrument can be used in an uncalibrated mode
and will measure TOF ratios.

There is also backup power for the calibration
memory so that the machine can be unplugged
from its power supply for up to 15 min without
the need to recalibrate.

Patients and anaesthesia

Twenty patients were studied: all required
surgical relaxation for a variety of procedures.
None had existing neuromuscular disorders. All
were premedicated with either temazepam
10–20 mg by mouth or papaveretum 10–20 mg
and hyoscine 0.2–0.4 mg i.m.
The five electrodes of the Datex Relaxograph were attached after cleaning the skin thoroughly with alcohol. The stimulating electrodes were applied over the ulnar nerve and the recording electrodes over the thenar eminence. The ground electrode was placed between the stimulating and recording electrodes. A force transducer (Gould-Statham UC3) was then attached to the thumb of the same hand and strapped into position. The arm was fixed in a splint. The output from the Relaxograph was recorded on one channel of a pen recorder (Gould 220) and the amplified signal from the force transducer was displayed on the second channel. Thus, the electromyographic and mechanical responses to the same stimulus could be compared simultaneously (fig. 2).

Anaesthesia was induced with thiopentone 4–5 mg kg\(^{-1}\) and maintained with 67% nitrous oxide in oxygen and increments of fentanyl 0.1–0.2 mg. Evoked mechanical and electromyographic responses were allowed to stabilize and control values were obtained before the administration of atracurium 0.5 mg kg\(^{-1}\). Supplements of atracurium 0.1–0.3 mg kg\(^{-1}\) were given as required. Halothane 0.5–1% was added to the inspired gases in some cases. Neuromuscular blockade was antagonized in all patients with neostigmine 2.5 mg (plus atropine 1.2 mg).

A further five patients were studied to assess the degree of stability of the Datex Relaxograph. All were young and fit and required intubation of the trachea for routine dental surgery. The Relaxograph was attached in the same manner as before, but without the addition of the force transducer. Anaesthesia was induced with thiopentone 4–5 mg kg\(^{-1}\) and maintained with 67% nitrous oxide in oxygen plus 1–2% halothane. After calibration of the Relaxograph, the value of the supramaximal stimulus was noted and suxamethonium 1 mg kg\(^{-1}\) was administered to facilitate tracheal intubation. At the end of the procedures (operating time 25–90 min) the instrument was recalibrated and the second supramaximal stimulus noted.

**RESULTS**

An example of the recordings obtained simultaneously from both the Relaxograph and the force transducer is given in figure 2, showing the onset and recovery of neuromuscular blockade. The results of 1078 consecutive measurements of first twitch (T1) from the Relaxograph and from the force transducer are shown in figure 3. The best fitted straight line was calculated by the method of least squares regression. The correlation coefficient was calculated.

![Graph showing correlation between force transducer T1 and EMG T1](https://example.com/graph.png)

**Fig. 3.** Results from 1078 measurements of first twitch (T1) from the force transducer and the Datex Relaxograph. The best fitted straight line was calculated by least squares regression. The 95% tolerance limits are also shown. \(Y = 1.05 + 1.03X; r^2 = 87\%\).
FIG. 4. Results from 683 measurements of train-of-four (TOF) ratio. The regression line and 95% tolerance limits are shown. $Y = 1.69 + 0.914X; r^2 = 93.7\%$.

tity was 0.933. Figure 4 shows the results from 683 simultaneous recordings of TOF ratio. The correlation coefficient was 0.968. Ninety-five percent tolerance limits are shown for the results on both graphs. For TOF ratio, the Relaxograph tended to underestimate the degree of blockade as compared with the force transducer. This was most marked when neuromuscular transmission was least impaired.

The additional five patients, who received suxamethonium, had all regained full neuromuscular function after 30 min (as seen by TOF ratio returning to 100%). In all five, the supramaximal stimulus remained the same after recalibration.

DISCUSSION

There are many persuasive arguments for trying to measure the degree of neuromuscular blockade produced by neuromuscular blockers. The variation in individual response to these drugs is considerable. Katz (1967) found that, following the administration of tubocurarine 0.1 mg kg$^{-1}$, twitch height was unaffected in 6% of patients while 7% showed 100% twitch depression. Similar results have been described with other myoneural blockers (Norman, 1982). Another advantage is that the need for incremental doses can be easily noted by the anaesthetist. Monitoring of neuromuscular blockade will also allow the anaesthetist to determine whether the administration of anticholinesterases is necessary, and to predict the circumstances where they are likely to produce a rapid or slow antagonism of blockade.

Many methods have been suggested to quantify the degree of neuromuscular blockade (Ali and Savarese, 1976). More than 25 years ago, Churchill-Davison and Christie (1959) proposed that nerve stimulators be used. The only satisfactory way to monitor neuromuscular function is by stimulation of an accessible peripheral motor nerve and the measurement of the evoked response in the skeletal muscle innervated by that nerve. Since the adductor pollicis brevis is the only muscle producing adduction of the thumb which is supplied by the ulnar nerve (Merton, 1954), this ulnar adductor method most closely resembles an experimental nerve–muscle preparation (Ali, 1985) and is most often used.

EMG recording has several advantages over the measurement of tension (Epstein and Epstein, 1973; Lee et al., 1977; Lam, Cass and Ng, 1981). Once the electronic systems were developed, machines that record and process the evoked EMG could be made compact and easy to use. This development was foreseen more than 20 years ago (Katz, 1965). The problems in the use of a force transducer can be avoided: the need for absolute immobility with adequate fixation, and overload and preload adjustment on certain systems (Epstein and Epstein, 1973). The EMG monitor is not affected by changes in muscle contractility and has a more rapid response (Viby-Mogensen, Jorgensen and Ording, 1979). The criticism that systems for assessing the degree of neuromuscular blockade are too clumsy and difficult to use in clinical practice may no longer be applicable to the newer generation of electromyographic monitors (Lam, Cass and Ng, 1981).

The Datex Relaxograph is compact and of modular design. It fits comfortably on a standard British anaesthetic machine. Only five electrodes have to be placed on the patient’s arm. We found that paediatric ECG electrodes were adequate in most patients, although they were often trimmed. In obese patients the position of the stimulating electrodes was critical if the machine was to find the supramaximal stimulus current. If these had to be
repositioned, the time in the anaesthetic room was increased and, as the repositioning had to be done after induction of anaesthesia, such adjustment was inconvenient.

There are also potential disadvantages involved in the use of EMG monitors. Stability may be a problem in some cases, the exact cause of which remains unclear. Fixation of the hand may still be desirable with these machines as changes in the relative positions of recording and stimulating electrodes may alter the measured evoked response. The effect of other drugs, in addition to the neuromuscular blockers, has never been investigated thoroughly and the effects of changes in pH, blood-gas tensions and electrolyte concentrations remain to be defined. The greatest effect, however, may be caused by changes in electrode impedance which increase with time and with changes in temperature. In five control patients, the supramaximal stimulus value remained stable after recovery from suxamethonium. It should be noted, however, that these procedures were of short duration (less than 90 min) and were not associated with the opening of body cavities with subsequent major heat loss or poor peripheral perfusion.

We found the Datex Relaxograph gave a reliable assessment of neuromuscular function. Correlation with a well-proven mechanical system was good. Others have studied the relationship between EMG analysers and force transducers, with varying results (Ali, Utting and Gray, 1971; Lee et al., 1977; Lam, Cass and Ng, 1981). Shanks and Jarvis (1980) stated that, while the adductor pollicis muscle and the adjacent interosseous muscles are supplied by the ulnar nerve and while the mechanical twitch measurement of thumb adduction approaches the single nerve–muscle preparation, the compound EMG obtained from surface electrodes can never be as precise. They concluded, however, that evoked EMG measurements would appear to provide a more reliable index of blockade than the mechanical twitch response. Their data suggested that either EMG amplitude or the rectified, integrated signal would be equally suitable in the assessment of neuromuscular blockade. It is likely that the relationship between electromyographic and mechanical responses varies for different neuromuscular blockers and we chose to use only atracurium in an effort to avoid this potential error. The relationship has also been shown to vary according to which muscle or muscle group is stimulated (Katz, 1973).

In conclusion, we have assessed the Datex Relaxograph in clinical use. It produces accurate and coherent information about the state of muscle relaxation and it is convenient to operate.

REFERENCES

DATEX RELAXOGRAPH 1451


