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Monitoring neuromuscular block by acceleromyography: comparison of the Mini-Accelograph with the Myograph 2000

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SUMMARY

The precision of the compact Mini-Accelograph (M-A) was compared with the Myograph 2000 (MYO). Neuromuscular block resulting from atracurium was measured simultaneously by the MYO and the M-A applied to contralateral thumbs. During onset, the M-A frequently underestimated the extent of block (maximal at approximately 50% twitch depression). The M-A control train-of-four (TOF) ratio was characteristically > 1.0 and remained greater than the MYO ratio during the onset of atracurium. During recovery, the difference between the MYO and the M-A was maximal at approximately 50% twitch depression, but the M-A frequently overestimated the extent of block. The mean differences between the MYO and the M-A were small in respect of the recovery index (RI) and the TOF. However, the limits of agreement were unacceptably wide for both TOF and RI. When the MYO TOF was 0.7, the corresponding M-A TOF varied between 0.4 and 1.0. The M-A was more susceptible to drift than the MYO. (Br. J. Anaesth. 1994; **72**: 411–414)

KEY WORDS

Monitoring: neuromuscular function. Neuromuscular block: atracurium.

Measurement of the force of muscular contraction (mechanomyography) is accepted generally as a reliable research method for measuring the extent of neuromuscular block during anaesthesia. However, this technique has several practical disadvantages when there is a requirement for a simple method of monitoring neuromuscular block in routine clinical practice. Mechanomyography is dependent critically on the maintenance of a constant preload, necessitating meticulous fixation of the thumb in relation to the transducer. Several mechanometric devices are available commercially, but their use is not commonplace for routine monitoring of neuromuscular block.

Recently, acceleromyography has been introduced in an attempt to simplify routine neuromuscular monitoring. The aim of this study was to compare a new, compact acceleromyograph, the Mini-Accelograph (Biometer), with the Myograph 2000 (Biometer), a mechanomyograph that is well established as a research tool.

PATIENTS AND METHODS

We have compared the Mini-Accelograph (M-A) and the Myograph 2000 (MYO) in 13 adults undergoing elective lower limb surgery during both onset and offset of neuromuscular block. Ethics Committee approval and patient informed consent were obtained. All patients were ASA I or II and none had neuromuscular disease or was taking medication known to influence neuromuscular transmission.

After oral premedication with temazepam 20 mg and metoclopramide 10 mg, anaesthesia was induced with thiopentone 3–5 mg kg^{-1} and maintained with 1–2% enflurane and nitrous oxide in oxygen via a laryngeal mask airway. Ventilation was spontaneous initially and mechanical ventilation was commenced when neuromuscular block had been induced.

Both arms were placed in the abducted position on padded arm boards and each patient was monitored with both the MYO and the M-A concurrently. The arms were insulated to minimize heat loss and the hands were taped in such a manner as to deny any movement to the fingers. The transducers of the MYO and the M-A were allocated randomly to the dominant or non-dominant hand.

The transducer of the MYO was fixed to the thumb to measure the force of contraction of the adductor pollicis and a 300-g preload was applied. The acceleration transducer of the M-A was taped to the flexor aspect of the contralateral thumb which was free to move. Identical nerve stimulators (Myotest, Biometer) were attached to the skin overlying the ulnar nerves at the wrists, using the rubberized electrodes supplied, after identical skin preparation. The M-A is designed to display the train-of-four (TOF) responses on the patient's vital signs monitor via a channel occupied normally by an invasive pressure signal. For the purposes of the study, the output from the M-A was displayed on an S&W vital signs monitor connected to a multichannel chart recorder (Gould) which displayed also the signals from the MYO, permitting simultaneous

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measurement of the force of contraction of the adductor pollicis of one hand and acceleration of the thumb of the contralateral hand. It had been established previously that there was negligible drift in the amplifier of the S&W monitor.

When stable anaesthesia had been established for 15–20 min, the current supplied by the Myotest stimulators was adjusted to produce supramaximal stimulation of both ulnar nerves and the stimulators were set to deliver TOF (supramaximal stimuli at 2 Hz at 12-s intervals).

The deflections displayed by the chart recorder were adjusted to a nominal 100 % which represented the control value. When the amplitude was stable, atracurium was given in a single dose sufficient to produce approximately 95 % twitch depression. Mechanical ventilation was commenced and normocapnia was maintained.

At completion of surgery, residual neuromuscular block was antagonized with neostigmine 40 $\mu g\ kg^{-1}$ and glycopyrronium. Simultaneous monitoring with the MYO and the M-A continued until the MYO TOF ratio exceeded 0.7 and the first response of the TOF had achieved a sustained plateau, at which time anaesthesia was discontinued.

The following indices of neuromuscular block were used to compare the MYO and the M-A at several, specified points during the onset and offset of atracurium. Both the TOF ratio and single twitch depression (the first response of the TOF) were compared.

Onset. (1) Time taken to achieve maximum depression of the first response of the TOF; (2) the TOF ratio when the first response of the MYO TOF was depressed by 50 %; and (3) the extent of maximum neuromuscular block.

Recovery. (1) The recovery index (RI), the time taken for the first response of the TOF to recover from 75 % twitch depression to 25 % twitch depression; (2) the TOF ratio at 50 %, 25 % and 10 % depression of T1 and when the MYO TOF ratio was 0.7; and (3) the magnitude of the drift of the two recordings during the entire period of measurement (the extent to which the first response of the TOF differed from the control value, before administration of atracurium, after maximum recovery had been permitted).

During analysis of the recovery indices, an established correction was made to allow for drift in the respective recordings [1].

Statistical analysis

The data were analysed by the method described by Bland and Altman [2] for determining the extent of agreement between two different methods of measuring a single, physiological response. The extent to which the methods agree can be estimated by calculating the mean of the differences between the two measurements (bias) and the SD of the differences. The "limits of agreement" represent the range within which 95 % of the differences fall and equals the bias ± 2 SD if the data are distributed normally. Providing that differences between these limits of agreement are not of clinical importance, the two methods can be used interchangeably.

RESULTS

Onset of neuromuscular block

The onset of neuromuscular block was characteristically less rapid when measured by accelerometry. The difference between the two methods of measurement was generally small at the outset, increased progressively to a maximum at approximately 50 % block and subsequently decreased as block approached 100 %. Comparing the mean MYO and M-A values, the M-A underestimated the extent of block in eight patients and overestimated the extent of block in two patients. When mean depression of T1 was 50 %, the mean difference between the methods (MYO − M-A) was −0.13 and the limits of agreement were −0.6 to +0.3 (table I).

There was little difference between mean maximum block measured by the MYO and the M-A (mean difference −0.006; limits of agreement −0.05 to +0.03) (table I).

There were significant differences in the control TOF ratios before atracurium. The control TOF ratio measured with the M-A was greater than 1.0 in all patients (median 1.1; range 1.0–1.31). Examination of the paper chart recording revealed that the amplitude of the first response of the TOF was invariably smaller than the subsequent three responses until neuromuscular block had been established. The corresponding MYO control TOF ratio was significantly less (median 1.0; range 0.93–1.02) ($P = 0.0001$, Mann–Whitney U test).

During the onset of atracurium, the extent of TOF fade measured by the M-A was less than that measured by the MYO at 50 % and 75 % twitch depression and the limits of agreement were unacceptably wide. At 50 % and 75 % twitch depression the mean difference or bias was −0.25 (MYO–M-A). This may be a consequence of the "reverse fade" seen in the control M-A TOF responses.

Recovery from neuromuscular block

The magnitude of the drift during the period of measurement was greater in the M-A (mean drift −20.6 %; range 54–0 %) than the MYO (mean drift −5.7 %; range −37 to +12.5 %). If the limits of acceptable drift were set arbitrarily at 10 %, this was exceeded in eight M-A recordings and three MYO recordings.

The general pattern of the relation between the MYO and the M-A values was similar to that observed during onset of block: the discrepancy was small at the extremes of block and was maximal at approximately 50 % twitch depression (table II). However, in contrast with the situation during onset of neuromuscular block, the M-A *overestimated* the block in seven patients and made an underestimate in two patients.

The individual differences in RI between the MYO and the M-A were large and the limits of agreement were −340 to +320 s. The small, mean difference (−10.4 s) tended to conceal the extent and variability of the magnitude of the differences because the discrepancy occurred in both directions, that is there was no *systematic* bias.

TABLE I. *Mean differences, SD of the differences and limits of agreement between the Myograph 2000 (MYO) and the Mini-Accelograph (M-A) estimates of T1 depression when the mean of the two methods was 50% during onset and recovery, and at maximum block*

	Mean difference (MYO − M-A)	SD of the differences	Limits of agreement
"True" T1/T0 = 0.5 (Onset)	−0.13	0.23	−0.59 to +0.33
Maximum block (T1/T0)	−0.006	0.02	−0.05 to +0.03
"True" T1/T0 = 0.5 (Recovery)	0.09	0.19	−0.29 to +0.47

TABLE II. *Mean differences, SD of the differences and limits of agreement between the Myograph 2000 (MYO) and the Mini-Accelograph (M-A) estimates of T1 depression during recovery when the MYO T1 depression was 50%, 25% and 10%*

	Mean difference (MYO − M-A)	SD of the differences	Limits of agreement
T1/T0 (MYO) = 0.5	−0.07	0.11	−0.29 to +0.15
T1/T0 (MYO) = 0.75	−0.005	0.14	−0.28 to +0.27
T1/T0 (MYO) = 0.9	+0.01	0.14	−0.27 to +0.29

The individual differences between the TOF ratios measured by the MYO and the M-A were large. There was no systematic bias, but the limits of agreement were unacceptably wide throughout the period of recovery of neuromuscular function. When the MYO TOF ratio was 0.7, the limits of agreement were −0.3 to +0.3, indicating that the corresponding TOF ratio, measured simultaneously using the M-A, may vary between 0.4 and 1.0.

DISCUSSION

We have demonstrated that there is some agreement between the MYO and the M-A, but the limits of agreement are unacceptably wide for some of the measurements. Two previous studies, from the department which developed the Accelograph, have compared acceleromyography with a mechanomyographic method of measuring the TOF ratio during recovery from neuromuscular block [3, 4]. Onset was not investigated and only the TOF data were presented. Unfortunately, these studies used the linear regression approach to analyse the data. Linear regression is an inappropriate method of analysing the extent of the agreement between two different methods of measuring a single physiological response [2]. A significance test applied to the regression line is able to demonstrate only that the two methods are related; it provides no information about the extent to which the methods are in agreement or disagreement. A correlation coefficient indicates only the strength of the linear relation between any two variables; a large value for r clearly does not indicate that the two variables are in close agreement.

Examination of the scattergram presented in the first study [3] indicates that there is considerable scatter of the data. For example, when the mechanomyographic TOF ratio was 0.7, the spread of the corresponding acceleromyometric ratios extended from approximately 0.48 to 0.88. When the mechanomyographic TOF ratio had increased to 0.9, the corresponding accelometric ratio deviated upwards from the line of identity and approached 1.2 in one patient.

In the second study, May, Kirkegaard Nielsen and Werner [4] demonstrated a large r value for the linear relation between acceleromyometric and mechanomyographic measurements in six patients, indicating proportionality. The slope of the line appeared to vary with time. Technical error was assessed by measurement of residuals, but it was conceded that each residual correlated significantly with the value of the residual of the previous reading so that the P value was underestimated.

Because neuromuscular monitoring is performed normally over a considerable period of time, a method which is not susceptible to drift would be particularly desirable in neuromuscular research. Unfortunately, it appears that the M-A is prone to excessive drift in comparison with the MYO. This drift is important only when considering the first response of the TOF; it does not affect the TOF ratio and may be of little importance in routine, clinical use when "single twitch" depression is of less value than the TOF response.

A consistent finding was a tendency for the difference between the MYO and the M-A measurements to be maximum at approximately 50% block. This pattern has not been described previously in relation to the comparison of two methods of measuring neuromuscular block. When any two methods of measuring neuromuscular block are compared, the initial measurements necessarily indicate 0% block and are, therefore, in close agreement. As block progresses, any inherent disagreement between the methods of measurement would be expected to increase progressively. If sufficient neuromuscular blocking drug has been administered, profound block is achieved and any method of recording a TOF response documents 100% block. Thus, any differences between two methods of measuring neuromuscular block are constrained to a minimum at both extremes and would be expected to achieve their maximum at approximately 50% block.

Considering the depression of the first response of the TOF, the M-A appeared to underestimate neuromuscular block during onset and overestimate block during offset, in comparison with the MYO. This might be considered to represent an error in the direction of safety. The TOF ratio was diminished to a lesser extent using the acceleromyographic method but it is impossible to separate the influence of the

initial, control "reverse fade" because of the characteristic weakness of the first acceleromyographic response to TOF stimulation.

The rate of spontaneous recovery from neuromuscular block is described commonly as the time taken for the first response of the TOF to recover from 25% to 75% of the pre-relaxant control value (RI). Although the mean difference between the recovery indices was small because the bias was not in a consistent direction, the limits of agreement were as wide as ± 6 min. We suggest that this may be important, even in a non-research setting.

The wide variability in the M-A TOF ratio during recovery from neuromuscular block was of particular interest. In comparison with the MYO, the M-A underestimated the TOF ratio as frequently as it was overestimated, but the limits of agreement were wide, such that a TOF ratio of 0.7 measured with a force transducer might be associated with an acceleromyographic estimate of between 0.4 and 1.0 (limits of agreement). The lower value might provoke an unnecessary second dose of neostigmine. In contrast, and of more concern, a mechanomyographic TOF ratio of 0.5, indicating residual impairment of spontaneous ventilation [5], might be associated with an optimistic ratio of 0.8 if the M-A were the sole method of measurement.

In conclusion, the Mini-Accelograph appears to be easier to use than the Myograph. In routine, clinical use it may be less susceptible to operator error and to inadvertent movement of the transducer in relation to the thumb. However, we suggest that the discrepancies between the two methods of measurements indicate that the two methods cannot be used interchangeably. Further work is needed to define the place of acceleromyography in clinical practice.

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REFERENCES

1. Beemer GH, Bjorksten AR, Dawson PJ, Dawson RJ, Heenan PJ, Robertson BA. Determinants of the reversal time of competitive neuromuscular block by anticholinesterases. *British Journal of Anaesthesia* 1991; **66**: 469–475.
2. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; **1**: 307–310.
3. Viby-Mogensen J, Jensen E, Werner M, Kirkegaard Nielsen H. Measurement of acceleration: a new method of monitoring neuromuscular function. *Acta Anaesthesiologica Scandinavica* 1988; **32**: 45–48.
4. May O, Kirkegaard Nielsen H, Werner MU. The acceleration transducer—an assessment of its precision in comparison with a force displacement transducer. *Acta Anaesthesiologica Scandinavica* 1988; **32**: 239–243.
5. Brand JB, Cullen DJ, Wilson NE, Ali HH. Spontaneous recovery from non-depolarizing neuromuscular blockade: correlation between clinical and evoked responses. *Anesthesia and Analgesia* 1977; **56**: 55–58.