Comparison of a new piezoelectric train-of-four neuromuscular monitor, the ParaGraph, and the Relaxometer mechanomyograph

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The ParaGraph is a new device for monitoring neuromuscular function using a piezoelectric motion sensor. In 20 patients, monitoring of neuromuscular block produced by cisatracurium 0.1 mg kg⁻¹ was compared using the ParaGraph and a Relaxometer 2 mechanomyograph. The ParaGraph was quick to set up, and easy to operate and interpret. There were no significant differences in the time to 100% depression of T1/T0, time to 25% recovery of T1/T0 or time to recovery of T1/T0 from 25% to 75%, measured by the two monitors. When the difference between the two monitors was plotted against the average of the two measurements, the limits of agreement for T1/T0 (–42.95, +153.98%) and the train-of-four ratio, T4/T1 (–0.28, +0.21) were too wide to allow the values given by the two monitors for individual patients to be used interchangeably.

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The mechanomyograph measures the force of muscle contraction in response to electric stimulation of a motor nerve. The main limitations to its clinical use are: it is rather bulky; it takes time to set up, adjust and operate; it requires a preload; and it is sensitive to changes in fixation. Instead of measuring force displacement, the ParaGraph (Vital Signs, NJ, USA) uses a new method for monitoring neuromuscular block, a piezoelectric film sensor. When the sensor is exposed to motion, an electric signal proportional to the bending movement of the thumb is generated, which is analysed, displayed and recorded.

The aim of this study was to evaluate the effectiveness of the ParaGraph for neuromuscular monitoring compared with the Relaxometer 2 mechanomyograph (Groningen University, Holland).

Patients and methods

The study was planned in accordance with the recommendations outlined in ‘Good Clinical Research Practice’ (GCRP) and was approved by the Karl-Franzens University Ethics Committee. All patients gave written informed consent. We excluded those with a history of neuromuscular disease, small joint arthritis or receiving treatment with drugs thought to interfere with neuromuscular transmission. None of the female participants was pregnant or breast feeding. We studied 20 patients, aged 18–59 yr, ASA I–II, undergoing elective surgical procedures in the supine position, lasting 1–3 h. Anaesthesia was induced with fentanyl 100–150 µg and propofol 2–3 mg kg⁻¹ i.v. until the eyelash reflex was obtunded. Anaesthesia was maintained with propofol 75–100 µg kg⁻¹ min⁻¹ by infusion, 60% nitrous oxide in oxygen, and fentanyl 50–100 µg supplements. Ventilation was adjusted to maintain end-tidal carbon dioxide in the range 4.7–5.3 kPa. Arterial pressure was recorded non-invasively every 5 min.

After induction, both arms were positioned comfortably on arm boards and were restrained by straps. The thumbs were the only unrestrained digits. The two monitors were allocated alternately to the left or right hand to balance the effect of dominance of one hand. The Relaxometer (MMG) evaluated neuromuscular block at the adductor pollicis muscle using a force transducer. The ulnar nerve was stimulated at the wrist (pulse width 200 µs, square wave)
The ParaGraph TOF neuromuscular monitor

The sensor cable assembly of the ParaGraph was attached to the other arm (Fig. 1). The piezoelectric sensor is a thin polyvinylidene fluoride polymer in a protective adhesive pad. The sensor pad was aligned with the ideal plane of flexion of the distal metacarpal joint of the thumb. The hydrogel stimulating electrode pad was placed just proximal to the patient’s wrist over the ulnar nerve. The stimulating current was increased manually until maximal twitch height was reached, and then it was increased by 10 mA to give supramaximal stimulation (pulse width 200 μs, square wave) with TOF stimuli (2 Hz for 2 s) at 20-s intervals.

The determined supramaximal current was maintained throughout the procedure.

The first twitch of the TOF (T1/T0) measured by the ParaGraph was monitored using the ParaPhrase computer interface. On each occasion the ParaGraph was read first followed immediately by the MMG. Artefact readings were filtered by discarding all measurements that suggested an increase on the previous reading of more than 15% and those recorded during inflation of the arterial pressure cuff. After a stable control response (variation of less than ±2% in T1 for 3 min) from both monitors had been achieved, cisatracurium 0.1 mg kg⁻¹ i.v. (2×ED₉₅) was administered, and further 0.05 mg kg⁻¹ increments were given each time the height of T1/T0 reached 25% using the MMG. For 30 min before the end of surgery, no further cisatracurium was administered, and neuromuscular block was allowed to recover spontaneously.

The paired t test was used for evaluating the differences between the two monitors. Data are expressed as mean (sd). P<0.05 was considered statistically significant.

Results

In 10 patients, TOF ratio before administration of cisatracurium, monitored using the ParaGraph, showed ‘reverse fade’ (T4>T1). The mean of the maximum TOF ratio in these patients was 1.05 (range 1.01–1.09). No patient showed reverse fade when monitored with the MMG. After stabilization and administration of cisatracurium, the height of T1/T0 and TOF ratio, using both methods, started to decrease at the same rate.

There was no significant difference in onset time (time to 100% depression of T1/T0), Dur_{25} (time to 25% recovery of T1/T0) or interval_{25–75} (time of recovery of T1/T0 from 25% to 75%) measured using the ParaGraph (mean 5.73 (sd 2.83), 39 (9.33) and 18.7 (7.67) min, respectively), compared with the MMG (5.65 (2.79), 37.8 (9.42) and 18.8 (13.66) min, respectively).

During recovery from neuromuscular block, the differ-
ence between the height of T1/T0 using the ParaGraph and the MMG was plotted against the average of the two measurements using Bland and Altman analysis. Bias (mean of the difference between the two monitors) was 5.52%, and the limits of agreement (bias±1.96 SD, in which 95% of the differences between the two monitors lie) were −42.95, +53.98% (Fig. 2). The bias of the value for TOF ratio between the ParaGraph and MMG was −3.5. Limits of agreement for TOF ratio (−0.28, +0.21) were narrower than those for the height of T1/T0 (Fig. 3).

Recovery of TOF ratio to 0.8 using the MMG occurred when the ParaGraph reading was 0.71 (0.14). This value was reached simultaneously by the two monitors in 50% of patients. When the TOF ratio using the MMG was 0.8, the ParaGraph reading was in the range 0.8–0.9 in two patients, 0.7–0.8 in three patients, 0.6–0.7 in three patients and <0.6 in two patients.

Discussion
The ParaGraph is a new neuromuscular monitor. It is easy to use; fixation of the hand can be reduced to a minimum and it does not require the use of a preload. The sole requirement is a freely moving thumb and this is achieved by simply restraining the other four digits by straps. Attachment of the transducer and the stimulating electrodes was easy, taking only a few seconds.

A possible explanation for the TOF reverse fade recorded by the ParaGraph is that, despite the period of stabilization before administration of cisatracurium, the non-relaxed thumb might not return to exactly the same position after each stimulus; as the MMG applies a preload on the thumb, this might prevent reverse fade.

The limits of agreement of the TOF ratio in our study were comparable with those reported by Kern and co-workers (-0.24, +0.27). The recovery threshold of T4/T1=0.8 was reached simultaneously by the two monitors in 74% of patients, while in our study T4/T1=0.8 was reached simultaneously in only 50% of patients.

The shortest acceptable interval between successive TOF stimulations to prevent interference with the release of acetylcholine at the neuromuscular junction is 10 s. However, as the response of a muscle, particularly in the curarized state, might still be frequency dependent, the difference in frequency of stimulation by the mechanomyographs used in our study (12 s) and that by Kern and co-workers (20 s) compared with the ParaGraph (20 s) could explain the difference in the results obtained in the two studies.

In summary, the ParaGraph is a simple, clinical neuromuscular monitoring tool as it is small in size, quick to set up, and easy to operate and interpret. However, the wide limits of agreement of the height of T1/T0 (−42.95, +53.98%) and TOF ratio (−0.28, +0.21) between the two monitors does not allow the values given by the two monitors for individual patients to be used interchangeably.

References