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A new multifunction nerve stimulator

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Summary

A new peripheral nerve stimulator for monitoring neuromuscular transmission during relaxant use is described and evaluated. Performance was according to specification and the characteristics are suitable for reproducible monitoring. Useful facilities are a display of the stimulating current, and a rapid check of battery state.

Key words

Equipment; nerve stimulator.

Assessment of the degree of neuromuscular block by motor nerve stimulation has frequently been advocated to allow judgement of relaxant dosage and reversal,[1–3] but often the characteristics of the stimulation for routine use have not been specified. This is surprising since several factors such as pulse duration,[4] the type of stimulus delivered,[5] and the electrode type and nerve chosen[6] can influence the consistency of response.

In contrast to American practice, until recently only a few types of stimulator have been available in the United Kingdom, and these were not able to give patterns of stimulus such as the 'train of four' which can be useful in the assessment of recovery.[7,8] A Danish device with more comprehensive features has been described recently by Viby-Mogensen.[9] We have assessed the electrical and clinical characteristics of a new stimulator that is now available in the UK.

Description

The Bard Biomedical Model 750 is a battery-powered device with a digital display of the maximum current delivered during the stimulus pulse. It measures about 18 × 8 × 8 cm and weighs 430 g, so it can be hand-held or placed at the patient's head during use.

The output pulse is said to last for 200 μseconds and the current can be varied by a linear slide control. Two output sockets are available, for use with either surface electrodes or needle electrodes. Each output pulse is accompanied by an audible tone. The output pulse can be delivered in the following patterns: a single pulse; one pulse/second; one pulse every 5 seconds; one pulse every 10 seconds; four pulses in 2 seconds – the 'train of four'; a 'train of four' repeated at 12-second intervals; a tetanic rate of 50 pulses/second; a tetanic rate of 100 pulses/second.

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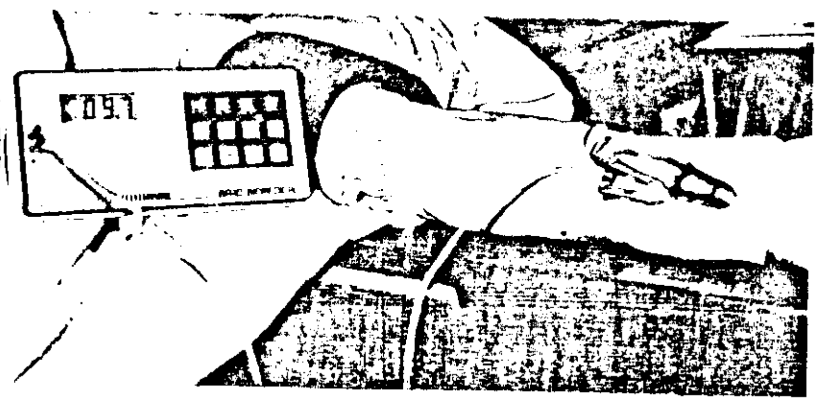

Fig. 1. The device in use.

Each pattern is selected by a key on a board next to the digital display (Fig. 1). There are also keys for on, off, reset to standby, and to display the battery voltage.

Methods

The outputs were connected to resistive loads ranging from 5 Ω to 50 kΩ. The voltage across the load resistance was recorded with a transient recorder (Datalab DL 901) and reproduced on a potentiometric pen recorder (Servoscribe RE511) for measurement of the maximum voltage and impulse duration. Peak current was read from the digital display of the device. To time the stimulus intervals, an ultraviolet recording oscillograph (Bell and Howell 5-137) was used with a paper speed of 500 cm/second. Current drawn from the battery during different types of use was measured with a digital multimeter.

The stimulating current at a constant output setting was noted in two groups of patients, each of four subjects, during routine monitoring throughout anaesthesia for abdominal surgery. In the first group 23-gauge 25 mm disposable needles were used as subcutaneous electrodes, placed over the ulnar nerve just proximal to the wrist. In the second group, the skin was rubbed with a swab coated in 70% isopropyl alcohol and dried, and a pre-gelled silver/silver chloride electrode set (Bard PNS dual electrode) was applied to the same site. The stimulator output was adjusted to a value greater than that necessary for a maximal response, and then the relaxant was given. The stimulator output current was noted throughout the procedure, at 5 or 10 minute intervals, to assess possible changes in output current as a result of changes in electrode resistance.

Results

A schematic diagram of the device is shown in Fig. 2. The output from the pulse generator is shaped to give a very asymmetric biphasic signal and passed through an isolating transformer to a potential divider to control the stimulus size. The current in the output circuit is measured through a second isolating transformer and shown to the nearest 0.1 mA on the digital display.

A typical output waveform is shown in Fig. 3. The large amplitude wave is followed by a slow, low amplitude wave of opposite polarity. The error in timing of this waveform, and of the various stimulus intervals relative to the specified time, is given in Table 1 as a percentage of the specified value and compared with the tolerance given in the manufacturer's specification. All of these values were within the specified tolerance. However, although the battery current at 'standby' was the specified 12 mA, the drain during 100 Hz tetanus into a 5 kΩ load was 45 mA, compared with a stated value of 27 mA ± 10%.

The peak current through the load resistance can be calculated from the peak voltage and the value of the resistance ($I = V/R$). The display gives a value that is about 3 mA less than the calculated value, over most of the current range. (Fig. 4).

The values for current and voltage with different values of load resistance are shown in Fig. 5, for both high and low outputs. As expected

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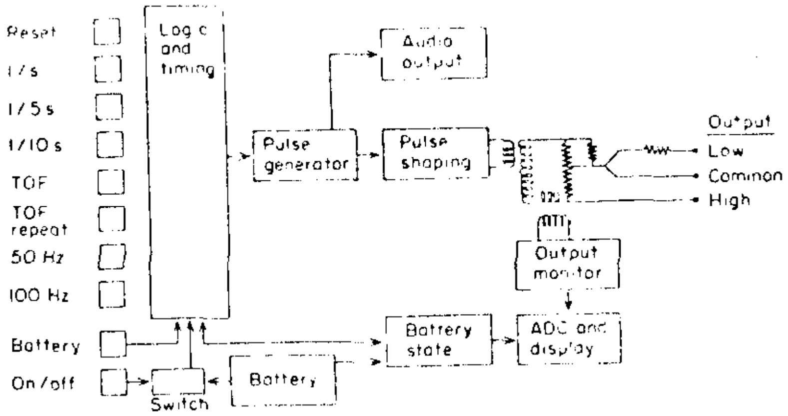

Fig. 2. Schematic diagram of circuit. TOF = train of four; ADC = analogue to digital converter.

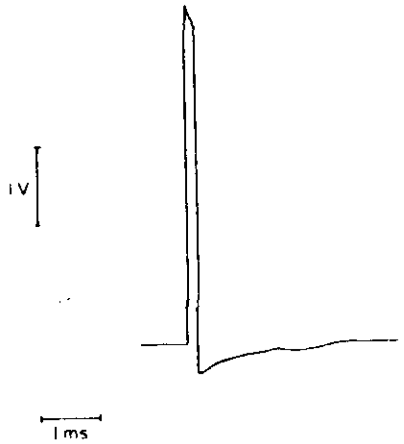

Fig. 3. Typical output waveform. Low output, 200 Ω load.

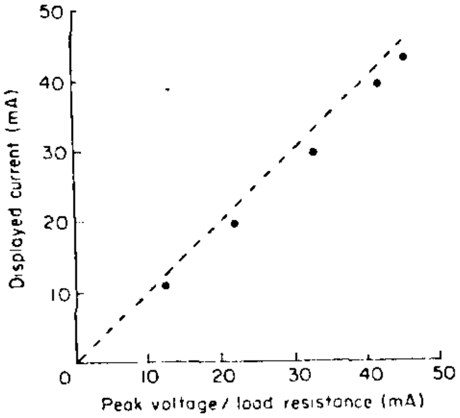

Fig. 4. Relationship between displayed current and value derived from peak voltage and load resistance. The interrupted line is the line of identity.

Table 1. Percentage deviation of timing from specification, with specification tolerances. (*TOF* = *train of four*)

	Deviation	Tolerance
Waveform duration	+5%	±10%
1 Pulse/second	+1%	± 5%
1 Pulse/5 second	+1%	± 5%
1 Pulse/10 second	+1%	±10%
TOF repeat	+6%	±10%
TOF	+2%	± 5%
50 Hz	+2%	± 5%
100 Hz	+2%	± 5%

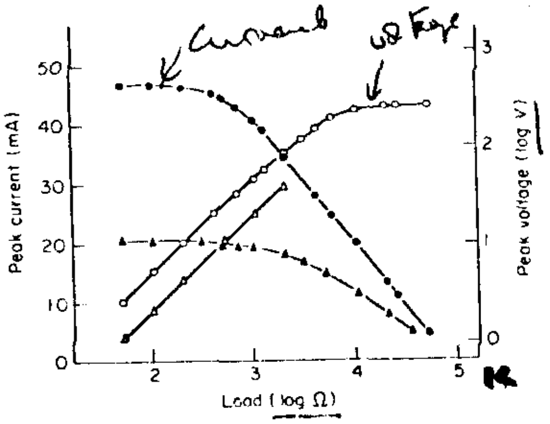

Fig. 5. Relationship between output current (closed symbols) and voltage (open symbols) for high (●, ○) and low (▲, △) outputs with load resistance. The voltage and resistance scales are logarithmic.

from the circuit configuration, the outputs are proportional. Until the load exceeds 2.5 kΩ, the output current is constant, and the voltage therefore increases as the load resistance in-

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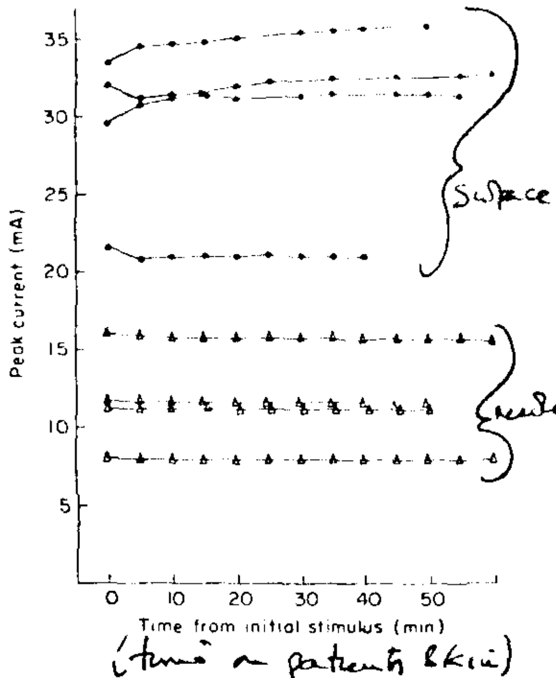

Fig. 6. Peak current through skin electrodes (●) and needle electrodes (△) during clinical monitoring.

creases. Above 2.5 kΩ, voltage and current change reciprocally, indicating that the output power remains constant, until a maximum voltage of 250 V is reached. Further increase in applied load, to values greater than would be encountered in practice, results in a reduction of output current only.

Figure 6 shows how the current changes with time during clinical monitoring. The conductivity of the skin electrode system progressively increases, whereas the needle electrode current remains very constant.

Discussion

Monitoring neuromuscular transmission when blocking agents are used in anaesthesia is useful for two reasons. First, the response to the agent can differ greatly between individuals and assessment of the response to an initial dose can prevent overdosage. Second, adequate reversal can be assessed without the need for patient cooperation. In a recent study of patients given relaxants but not monitored with a nerve stimulator, about 40% were subsequently found to be inadequately reversed.[10]

However, the response to nerve stimulation can vary depending on the type of stimulus, the pattern of stimulation, and the means of delivery, which can cause clinical confusion. For example, the muscles of the face are less sensitive to relaxants than those of the hand, and hand muscles appear more sensitive if surface electrodes are used for stimulation.[5,6]

The stimulus should be short and have one predominant polarity. A long stimulus can lead to repetitive excitation of the nerve.[4] Stimulators that deliver a constant current despite changes in electrode resistance have been shown to give more uniform results.[1] For example, a unipolar stimulus could result in polarisation of the electrodes (particularly if the current density is great as with needle electrodes) and this could alter the delivered current, unless a constant current stimulator were used. We did not find any change in the stimulus current with time, using needle electrodes, although the device was not working in the 'constant current' part of its output range. The asymmetric biphasic current pattern may prevent polarisation and changes in electrode resistance. Using skin electrodes, we found an initial decrease in resistance after application, probably because the skin became soaked with the conductive gel of the electrode. Both electrode types would give satisfactory results for clinical purposes. The display of the stimulus current was valuable clinically to detect electrode disconnexion or disturbance. The stimulus waveform is satisfactory for routine monitoring.[11]

Interpretation of the results of nerve stimulation depends upon the pattern of delivery of the stimuli. In the presence of a non-depolarising blocking agent, the response to frequent stimuli will 'fade' unless a single stimulus is given at 10-second intervals or greater.[12] The response to this form of stimulation is the most 'resistant' to tubocurarine type block and can be used to ensure satisfactory surgical relaxation. The fade seen at higher frequencies has been used as a more sensitive index of residual curarisation, using the train of four or 50 Hz tetanus patterns.

However, the two phenomena of fade and tetanic depression are independent, with fade developing more slowly than twitch depression.[13] Thus the stimulus pattern of 1 Hz is useful to monitor the initial effects of a dose of relaxant, and to assess facilitation of transmission after tetanic stimulation. However, the presence of fade will limit the value of stimuli at 5-second

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intervals. Fade of contraction during tetanic stimulation at 100 Hz can be misleading, particularly in the assessment of completeness of recovery, since fade at this frequency occurs in anaesthetised subjects who have not been given relaxants.[14] However, 100 Hz tetanus is more effective in facilitation of the response to a single stimulus in the presence of tubocurarine.[15] Nevertheless, the 100 Hz and 1, 5 second patterns of stimuli are probably of little use in routine clinical circumstances.

In other respects, this device is a useful, compact and accurate stimulator, with the valuable feature of a display of delivered current.

The Bard Biomedical Peripheral Nerve Stimulator is marketed by C.R. Bard, Pennywell Industrial Estate, Sunderland, England SR4 9EW. Price £200 + VAT.

Acknowledgment

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