ELECTROSTIMULATION OF THE SMALL AND THE LARGE BOWEL IN DOGS*

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Electrical stimulation of various muscles of the body has been used successfully, particularly in certain types of cardiac arrhythmias. In the case of the heart the problem is simplified by the fact that the myocardium behaves as a syncitium, and the electrocardiogram provides an aid in the assessment of the effect of electrical stimulation.

There are various conditions in which electrical stimulation of the intestines could be envisaged as therapeutic means, although this method of treatment has enjoyed only limited popularity. This is not entirely due to the fact that the heart is considered a more vital organ, but also because the technical problems inherent with bowel stimulation are more numerous and complex.

Katona *et al.*[1] have shown that bowel constriction can be produced in the intestinal segments of animals by using direct electrical stimulation with electrodes in the lumen of the duodenum and the rectum. Square wave impulses were found to be most efficient at a frequency of 50 - 100 cycles/second.

Sperling[2] treated 3 patients suffering from paralytic ileus with stimuli applied externally to the skin.

Bilgutai *et al.*[3] described an electronic apparatus for gastro-intestinal stimulation which they used on over 40 patients. For gastric stimulation, the active electrode was incorporated into nasogastric tubes with the tip lying in the antral region. In other cases, the rectal route was used or intramural electrodes extending through the abdominal wall were employed. The optimal electrical parameters were found to be 50 pulses/second, with an impulse duration of 5 - 10 milliseconds for 5 seconds' duration at 1 - 5-minute intervals.

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TABLE I. COMPARISON OF RESULTS OF VARIOUS AUTHORS

Authors	*Positive electrode*	*Negative electrode*	*Frequency (c.p.s.)*	*Pulse duration (m sec.)*	*Amplitude*	*Duration of train (min.)*	*Interval*	*Time of first bowel activity (hours)*
Katona *et al.*[1] (1959)	1. Lumen of duodenum 2. Rectum	Body	50–100	—	30–40	30	30	—
Sperling[2] (1959)	External	—	—	—	—	30	60	—
Bilgutai *et al.*[3] (1963)	1. Gastric 2. Rectal 3. Direct on bowel	Body	50	5–10	1–10	5–10	60	16
De Villiers *et al.*[4] (1963)	1. Jejunum 2. Ileus	Bipolar	40–70	5–7	4–5	6–8 (sec.)	—	—
Caldwell[5] (1963)	Sphincter	Sphincter	25–200	0·1–1	—	—	—	—
Cardiovascular research, Witwatersrand University (1965)	Ileum	Ileum	10–100	6	1–5	—	—	—
		Range:	10–200	0·1–10	1–40			

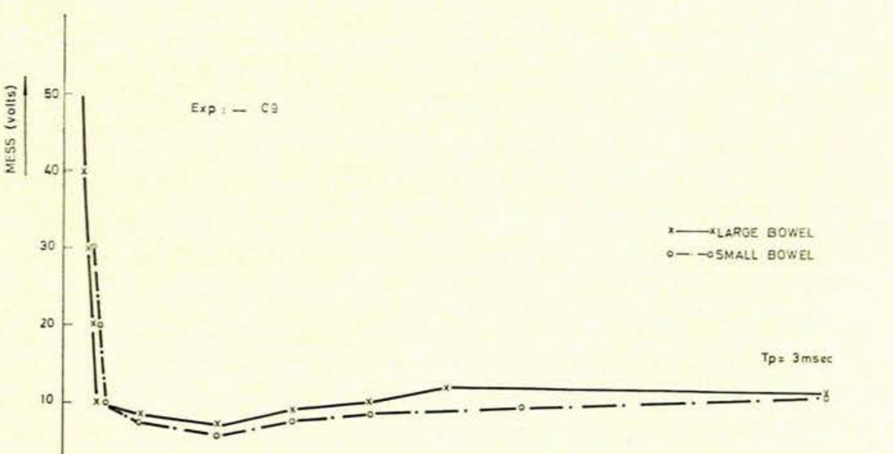

Fig. 1. The minimum effective stimulus strength.

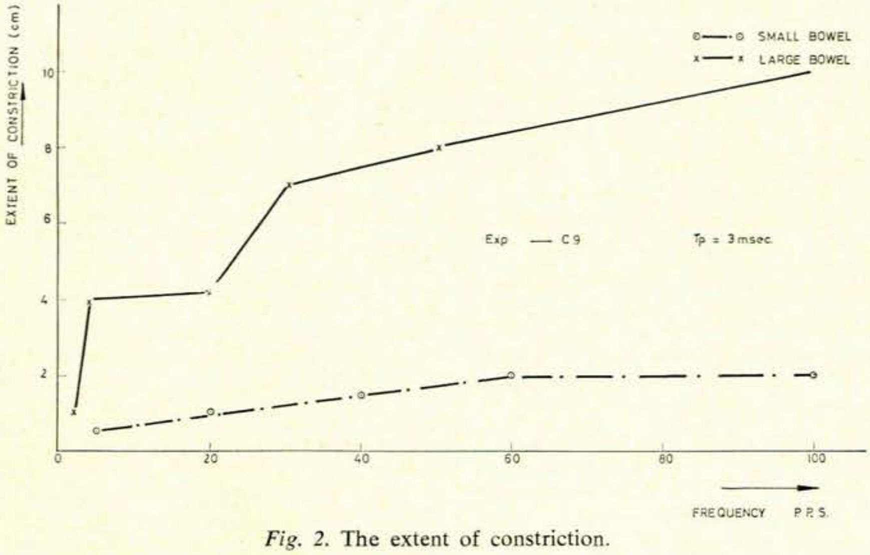

Fig. 2. The extent of constriction.

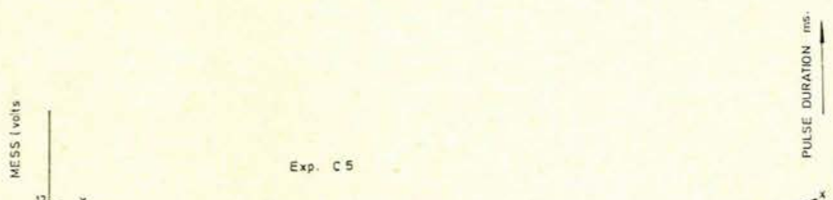

Fig. 3. Group of curves for various pulse durations.

De Villiers *et al.*[4] obtained similar results regarding the electrical parameters from their animal experiments.

Caldwell[5] electrically reversed anal sphincter incompetence.

At the University of the Witwatersrand, the findings of the abovementioned authors were confirmed on animals.[6]

Table I shows a comparison of the results mentioned. From this table it can be seen that a wide range of electrical parameters has been tried and found effective for stimulation.

The purpose of the present set of experiments was to ascertain how the various parameters, such as frequency of impulses and duration of impulses, affected the minimum effective stimulus strength (MESS) and the extent of constriction.

MATERIAL AND METHODS

Anaesthesia was induced in 10 dogs with pentothal and maintained with Fluothane. Laparotomy was performed and 2 Elema myocardial electrodes were sutured in various positions onto the surface of the bowel regions under investigation. A Disa Multistim pulse generator was used to provide the pulses. The output impedance of this apparatus in the 'constant voltage' configuration is less than 3 ohms. The range of frequency and pulse duration of the apparatus are 0·1 - 1,000 pulses per second and 0·02 - 1,000 milliseconds, respectively.

The MESS (Fig. 1) and extent of constriction (Fig. 2) versus frequency curves were obtained as follows. The approximate shapes of the curves were first determined. They had a steep initial negative slope, reaching a minimum, followed by a slight rising slope. With a preselected pulse duration, the repetition frequency was set to one impulse per second and the output was increased to 50 volts (maximum output of stimulator). At this stimulation frequency and voltage no response was registered. The frequency was thereafter slowly increased until a response was observed. The intensity of the response was visually estimated. With the slow increase of frequency, there was an initial gradual constriction followed by a faster *en masse* constriction. The stimulation was interrupted at the beginning of this faster response, and the frequency setting was read. The voltage setting was then called the MESS for that particular frequency. The extent of constriction was the length of constricted bowel (in centimetres), one or two seconds after the interruption of stimulation. This extent of constriction was stable until relaxation of the bowel began about 10 - 20 seconds later. The same procedure was repeated for 40, 30, 20 and 10 volts, and at the points where the influence of frequency was more marked more points were taken. This procedure gave us the initial part of the curve. The remainder of the curve was established by choosing a given frequency and increasing the voltage until the above-described response was observed. Separate curves were obtained for pulse durations of 0·5, 0·7, 1·0, 3·0, 10·0 and 30·0 milliseconds.

RESULTS

The lowest MESS was at a frequency between 20 and 25 pulses/second for all the experiments and for both the small and the large bowel. The two types of bowel behaved very similarly as regards MESS, but the extent of constriction was about 5 times greater with large bowel.

A group of curves was obtained for the various pulse durations (Fig. 3). The similarity of the curves can be illustrated in the normalized form (Fig. 4), where the normalization was performed in respect of the minimum of each curve.

The MESS versus pulse duration at any frequency was very similar to the classical strength-duration curve (Fig. 5).

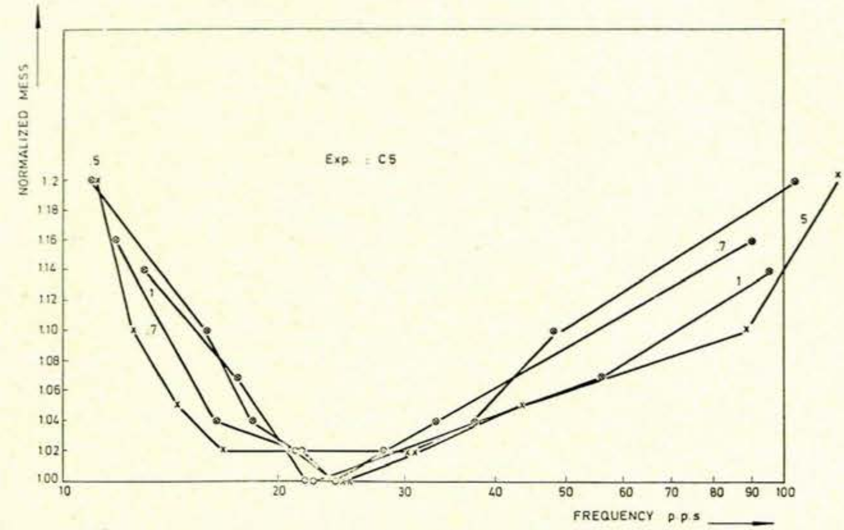

Fig. 4. Normalized curve.

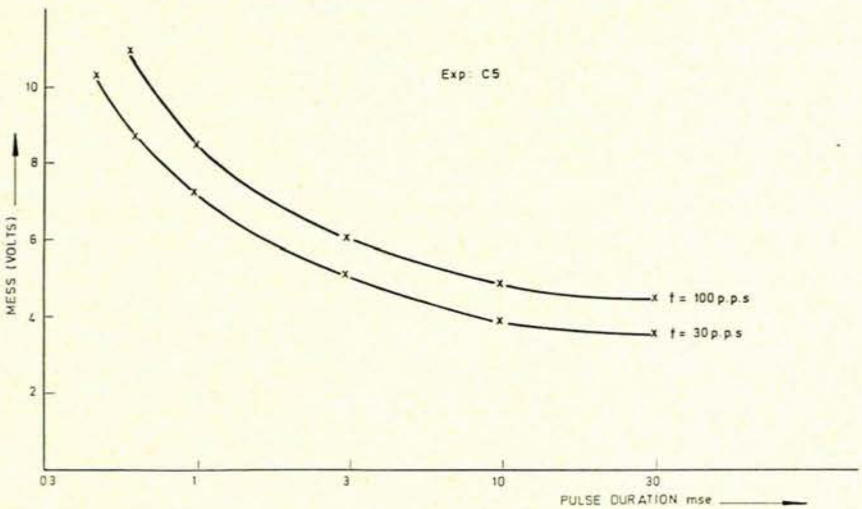

Fig. 5. Strength duration curve.

CONCLUSIONS

It is evident from the above results that, using the electrodes that were commercially available, there was a definite frequency where the minimum efficient stimulation strength was the least. This frequency was found to be between 20 and 25 pulses/second in our series of experiments. It was also found that the extent of bowel constriction due to stimulation increased with frequency, reaching 80% of its maximal constriction by about 50 pulses/second. A suitable frequency can thus be chosen for a particular situation. For example, if an implanted bowel stimulator is to be built, the smallest electrical energy consumption is desirable. For this purpose, 20 pulses/second are suitable. In cases where the extent of bowel constriction is more important, frequency values in excess of 50 pulses/second should be chosen.

SUMMARY

The behaviour of the small and large bowel subjected to pulsed electrical stimulation was studied. A wide range of pulse durations and frequencies of the stimulating impulses was used. The minimum effective stimulus strength (MESS) and the extent of constriction were measured for the various pulse durations and frequency values. It was found that the MESS was the lowest at about 20 cycles/second and the extent of constriction did not increase appreciably when the frequency was elevated above 50 cycles/second. These results suggest that 20 cycles/second should be used when the physical size of the stimulator is of greater importance and 50 cycles/second should be used where the extent of bowel constriction is more important.

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