ten patients, an endobronchial tube could not be satisfactorily placed in two additional patients with large aneurysms. Use of right double-lumen endobronchial tubes might improve the success rate. We consider the use of endobronchial tubes during resections of thoracic aneurysms to be a significant contribution to the surgical treatment of this disease.

REFERENCES

1. Bjork, V. O., and Carlens, E.: The prevention of spread during pulmonary resection by the use of a double-lumen catheter, J. Thorac. Surg. 20: 151, 1950.
2. Edwards, E. M., and Hatch, D. J.: Experiences with double-lumen tubes, Anaesthesia 20: 461, 1965.
3. Nilsson, E., Slater, E. M., and Greenberg, J.: The cost of the quiet lung: Fluctuations in Pa_{O_2} when the Carlens tube is used in pulmonary surgery, Acta Anaesth. Scand. 9: 49, 1965.
4. Seed, R. F.: The cost of the quiet lung? Proc. Roy. Soc. Med. 60: 750, 1967.
5. Zimberg, Y. H., and Lynch, C. G.: Controlled operative atelectasis, Ann. Thorac. Surg. 5: 325, 1968.
6. Elebute, E. A., Masood, A., Faulkner, C. S., Yu, P. N., and Schwartz, S. I.: The effects of acute and chronic atelectasis on pulmonary hemodynamics, J. Thorac. Cardiovasc. Surg. 52: 292, 1966.

Comparison of Three Clinical Peripheral-nerve Stimulators

WILLIAM T. ROSS, JR., M.D.*

Epstein recently reported his observations of the electromechanical response of muscle to peripheral nerve stimulation with the Block-Aid Monitor nerve stimulator.[1] He noted that this nerve stimulator delivers a biphasic stimulus. This is, in effect, paired stimuli of opposite polarity, separated by 4 to 5 msec. This interval is of the same order of magnitude as the neuromuscular refractory period. In a subsequent report,[2] Epstein also showed that the mechanical twitch tension developed by muscle in response to paired stimuli applied to a peripheral nerve is dependent upon the interval between the two stimuli of the pair. He further showed that nondepolarizing muscle relaxants and anticholinesterases alter the neuromuscular refractory period, and that this alteration of the refractory period has a marked effect on twitch tension produced by paired stimuli of a given pair interval. From the information in these two reports, a stimulator used clinically to evaluate twitch tension in the presence of agents which alter the neuromuscular refractory period should have the following stimulus characteristics: 1) The stimulator should produce a single square-wave stimulus pulse; 2) The stimulus pulse should be of short duration (less than 0.3 msec); 3) The output voltage should be sufficient to deliver a supramaximal stimulus. With these characteristics in mind it seemed reasonable to examine the stimulus pulses delivered by several clinical peripheral-nerve stimulators.

MATERIALS AND METHODS

Three commercially-available clinical peripheral-nerve stimulators were studied: 1) The Block-Aid Monitor (Burroughs-Wellcome & Co., Inc., Tuckahoe, New York); 2) The Meditron Nerve Locator–Stimulator (Crescent Engineering & Research Co., 5440 North Peck Road, El Monte, California); 3) The Churchill-Davidson Peripheral Nerve Stimulator (R. G. Wakeling & Co., Ltd., Medical Electronics, Holly Road, Twickingham, Middlesex, England).

Fresh batteries were used in each nerve stimulator examined. Output of the stimu-

* Resident, Department of Anesthesiology, University of Virginia Hospital, Charlottesville, Virginia.

Presented at the Fourth Annual Southeastern Anesthesia Residents' Conference, Charlottesville, Virginia, May 10, 1969. Supported in part by research training grant #1-T1-GM01548-03, Public Health Service.

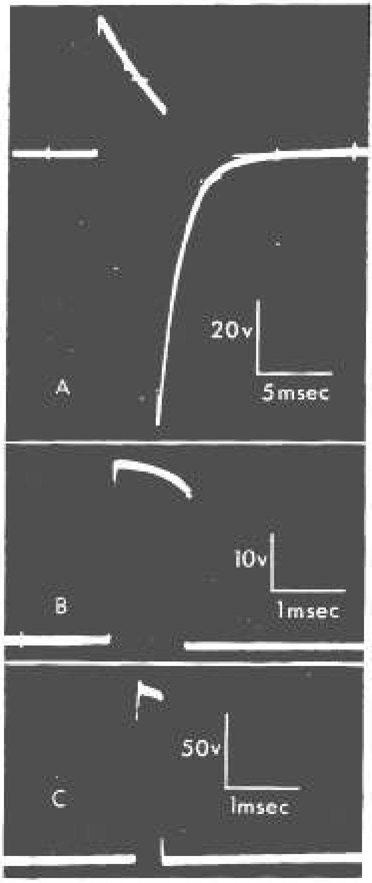

FIG. 1. Output waveforms of peripheral-nerve stimulators with a load resistance of 5,000 ohms: *a*, Block-Aid Monitor; *b*, Meditron Peripheral Nerve Locator-Stimulator; *c*, Churchill-Davidson Peripheral Nerve Stimulator.

lators was displayed on a Tektronix Model 515 oscilloscope. Waveforms produced by each stimulator were observed at maximum output with load resistances of 5,000 ohms, 1,000 ohms, 500 ohms and 100 ohms. The effects of load resistance on output voltage and waveform characteristics are shown in table 1. Representative waveforms were obtained with a load resistance of 5,000 ohms and the oscilloscope display photographed (fig. 1).

RESULTS

Each stimulator produced the same waveform whether operating in the single-twitch or in the tetanus mode.

The Block-Aid Monitor (fig. 1*a*) delivered a paired bipolar stimulus with approximately 5 msec between the two pulses of opposite polarity. The total duration of this waveform is approximately 8 msec. The maximum voltage of the stimulus pair was 32 volts for the initial pulse and 60 volts for the second pulse, with 5,000-ohms load resistance. Decreasing the load resistance reduced the output voltage of the stimulator in proportion to the load resistance. Load resistance did not affect the frequency of tetany nor the shape of the waveform. The rate of tetanic stimulation was 25 stimuli/sec.

The Meditron Nerve Locator-Stimulator (fig. 1*b*) delivered a single pulse that approximated a square wave. Duration of the pulse is 1 msec. Maximum voltage produced was 30 volts, with 5,000 ohms load resistance. Decreasing the load resistance resulted in little change in voltage or waveform characteristics between 5,000 ohms and 1,000 ohms. However, below 1,000 ohms the pulse voltage and duration were markedly reduced. Below 1,000 ohms the frequency of tetanic stimulation rose from 30/sec to 90/sec at 100 ohms load resistance.

The Churchill-Davidson Peripheral Nerve Stimulator (fig. 1*c*) delivered a single square-wave stimulus of .40 msec duration. Maximum voltage produced was 112 volts, with 5,000 ohms load resistance. Decreasing the load resistance resulted in a proportional decrease in stimulus voltage but did not affect the pulse width or frequency of tetanus. The rate of tetanic stimulation was 45/sec.

Table 1. Effects of Output Loading on Stimulus Characteristics of Peripheral-nerve Stimulators

Stimulator	Waveform	Load Resistance (ohms)	Stimulus Duration (msec)	Maximum Voltage (volts)	Frequency of Tetanus (per sec)	Power Source
Block-Aid Monitor	Bipolar paired	5,000	8	$S_1 = 32$ $S_2 = 60$	35	Alkaline cells
		1,000		$S_1 = 9.5$ $S_2 = 15$		
		500		$S_1 = 4.5$ $S_2 = 7.0$		
		100		$S_1 = 1.0$ $S_2 = 1.4$		
Meditron	Unipolar square wave	5,000	1.0	30	30	Alkaline battery
		1,000	1.0	28	30	
		500	0.9	25	35	
		100	0.5	14	90	
Churchill-Davidson	Unipolar square wave	5,000	0.4	112	45	Mercury battery
		1,000		32		
		500		16		
		100		3.5		

(S_1—First pulse of stimulus pair; S_2—Second pulse of stimulus pair)

Discussion

Of three stimulators only one produced a stimulus less than 1 msec in duration. Two stimulators each delivered a square-wave stimulus; the third did not. The output voltages of two stimulators were reduced proportionally by loading of the output; in the third output voltage was reduced in a nonlinear fashion at low load resistances. It should be noted that a load resistance of 1,000 ohms is commonly encountered in clinical practice. This, therefore, may make the loading of the Meditron Nerve Locator-Stimulator less important under usual clinical circumstances.

The effect of battery aging on the output of the Block-Aid Monitor has been reported.[3] It should be noted that the power sources of the Block-Aid Monitor and Meditron Stimulator are alkaline cells. The output of these cells falls much less rapidly as the cells are exhausted than does that of a mercury cell, so that alkaline cell failure is not easily appreciated. Of the three nerve stimulators tested, only one is powered by a mercury cell.

Summary and Conclusions

Clinically available peripheral-nerve stimulators are essentially low-power devices which are affected in varying degrees by loading the output. This fact serves to emphasize that, although they are clinically useful, the control of output obtainable with laboratory-type stimulators is not available.

References

1. Epstein, R. A., Wyte, S. R., Jackson, S. H., and Sitter, S.: The electromechanical response to stimulation by the Block-Aid Monitor, Anesthesiology 30: 43, 1969.
2. Epstein, R. A., Jackson, S. H., and Wyte, S. R.: The effects of nondepolarizing relaxants and anticholinesterases on the neuromuscular refractory period of anesthetized man, Anesthesiology 31: 69, 1969.
3. Heisterkamp, D. V., and Cohen, P. J.: Technical note concerning the Block-Aid Monitor, Anesthesiology 29: 1210, 1968.