Impedance—time functions in the white rat with chronic body electrode implants¹

Douglas P. Ferraro, Michael P. Silver and Arthur G. Snapper
V. A. HOSPITAL, NEW YORK CITY

Abstract

Four male albino rats were implanted with chronic body shock electrodes. Impedance measurements were made at a low impressed voltage over a 38-day period following implantation. Impedance was found to increase significantly as a function of time since implantation, although the absolute magnitude of the rise varied among animals.

Introduction

Delivery of shock "punishment" to animals from chronic body electrode implants may circumvent some of the problems encountered with the use of conventional grid shock to the feet (Azrin, 1959). One advantage of implanted electrodes is that they make possible a greater degree of control and specification of the shock stimulus actually received by the animal than can be achieved with grid shock. To realize this advantage, however, it is necessary to know the impedance characteristics of the organism. The latter have been studied in the pigeon by Azrin (1960) and more systematically in the same species by Sidley & Schoenfeld (1963). Silver et al (1964), using chronic body implants in the white rat, have found that impedance remains fairly constant over a wide range of impressed voltages and increases somewhat at low voltages. A redetermination of their first measurements by the latter workers indicated that impedance in the rat increases with age of implant, and that the greatest increase occurs at low voltages. Such changes in impedance might be attributed, among other factors, to the destruction of tissue by repeated pulsing, especially when high voltages are employed; or to processes which progress with time (e. g., the formation of scar tissue). No specific redetermination data are given in that study, however, so that the actual function relating impedance changes to age of implant could not be derived. The present experiment sought to clarify the time course of changes in impedance in the rat following electrode implantation. To minimize any confounding effects which might be introduced by tissue damage, a low value was chosen for the impressed voltage used in the impedance measurements.

Method

The subjects were four Charles River Caesarean delivery male albino rats about 110 days old at time of implantation. The method of implantation used was similar to that employed by Silver et al (1964). In general, the method involves passing insulated wire subcutaneously from a connector socket mounted on the skull to the rats' shoulders. For the present study, two No. 40 gauge stainless steel wires insulated by polyethylene

tubing served as the electrode lead wires. The actual electrodes were the lead wire tips, separated by 3/8 in, and formed by cutting the polyethylene tubing to expose the last 1/8 in of each wire. The electrodes were positioned immediately behind the right shoulders of the rats. A shielded transformer supplied 60 cycle AC across a precision 10K ohm resistor in series with both the animal and a 1K ohm precision resistor. Impressed voltage was calibrated on an oscilloscope. The voltage drop across the 1K ohm resistor was read from the oscilloscope and used to calculate impedance by Ohm's law.

The impressed voltage was 2.76 v root mean square, this being the lowest voltage at which distortion of the AC wave form did not occur. No behavioral reactions to shock were observed in the rat at this voltage. The shock source was left on continuously while taking measurements until a reliable reading could be made from the oscilloscope. It usually took about 5 sec. to adjust the oscilloscope and obtain the reading, although in some few instances variations in signal magnitude occurred, and as long as 20 sec. were needed. The cause of the occasional variations in signal magnitude was not determined.

The initial measurements were made immediately after the animals were implanted and while still under nembutal anesthesia. Sixteen succeeding measurements were taken once a day over a 37-day period (Days 1, 2, 3, 5, 6, 10, 12, 13, 14, 17, 19, 23, 26, 28, 30, and 37 days after implantation). During these measurements the animals were not under anesthesia and were free to move about in the experimental chamber while being shocked.

Results and Discussion

Impedance rises slowly with age of implant. The functions in Fig. 1 show that this increase is approximately linear, although the impedances in Rat 6 and Rat 8 seem close to asymptote by the 38th day. Individual animals differ in the absolute increase in impedance from Day 1 to Day 38: Rat 6, 13K ohms; Rat 7, 16.5K ohms; Rat 8, 5.8K ohms; Rat 9, 9.8K ohms. However, with each animal's data ranked individually, the overall increase in impedance for the four rats was found to be significant ($\chi^2_r = 52.35$; $df = 16$; $p < .001$) using a Friedman two-way analysis of variance (Siegel, 1956). The data obtained on the first day were included in the statistical analysis, since Silver et al (1964) have shown that anesthesia is not an important variable affecting impedance. As mentioned above, the latter workers have

Fig. 1. Impedance changes in four male white rats as a function of days since implantation of chronic body electrodes. The first day's measurement for all rats was taken under nembutal anesthesia. All other measurements were obtained without anesthesia.

also suggested that the increase in impedance with time is greatest at low voltages. Therefore, impedance changes with time greater than those reported here might not be expected when working in a voltage range which is more "aversive" to the rat. None the less, these data indicate that, during the course of an experiment in aversive control, changes in shock voltage may be necessary to maintain the specified induced electric current flow in the rat.

As can be seen from Fig. 1, there is also some variation among rats in the general level of impedance. Although differences in procedures and in electrode sizes make comparisons between absolute impedances difficult, the present levels are similar in magnitude to those reported for the rat by Hendry & Hendry (1963), and by Silver et al (1964) at low voltages.

The present data confirm and extend the data relating impedance to age of implant reported by Silver et al (1964). In contrast to the rat, however, age of implant does not seem to be an important variable with chronic implants in the pigeon. Azrin (1960) found no systematic

changes in impedance with the latter organism over an extended period of exposure to a punishment schedule; and Sidley & Schoenfeld (1963), also using pigeons and Azrin's implantation technique, found no differences, over a voltage range of from 4 to 80 v peak to peak, between implants prepared 3 hours prior to measurement and implants prepared 15 months earlier. Aside from species differences, the implant technique used with rats differs from that used to obtain the pigeon impedance data in several details, including electrode size, electrode material, and area of implant (in the pigeon the electrodes are tied to the pubis bones). It is difficult to say which of these may account for the progressive trend in impedance over time observed in the rat.

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Note

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