A Fused Monitor Cable—Protection Against Electrical Shock and Burns

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Accidental electrical shocks and skin burns of patients through monitor electrodes may occur when one of two or more electrical devices connected to the patient develops a fault. A typical pair of electrical devices consists of an Operating Room Monitor (EKG/EEG) and an electrocautery machine. The absence of proper connection from the patient-grounding plate to the cautery machine may cause skin burns under the EKG and EEG electrodes. Current sufficient to cause burns passes through the cautery blade, through the patient's body, EKG electrode, and the cable to a virtual ground. This virtual ground is formed by a "protective" diode network attached to the EKG amplifier input terminals. If the electrode cable is long, it may, by virtue of its large capacitance-to-ground, absorb harmful high-frequency currents through the electrodes even without being connected to the amplifier. With no connection from the cautery machine to the grounding plate, and a 15-foot monitor cable disconnected from the amplifier, sparking under dry electrodes applied to the well-depilated moist skin of anesthetized dogs has been observed.† An occasional catastrophic defect in an electrocautery machine may render the grounding plate "hot" with 117-volt 60-Hz current, which then may pass through EKG, EEG or grounding electrodes to ground. Such accidents have caused ventricular fibrillation in patients.

Certain types of amplifier input circuits are less vulnerable to these accidents than others. An example of this is the Offner type R preamplifier, in which the input is chopper–transformer-coupled to the active circuitry where 15 volts dc and 7 volts 400 Hz are the maximum internally available voltages. However, a large number of monitors which may be described as "accident-prone" are being used.

Accidental electrical shocks and skin burns may be avoided by using properly fused monitor cables. In association with a fuse manufacturer we developed a new model of fuse ‡ to meet the following specifications: 1) current to blow, 40 milliamperes; 2) when blown, no arcing with 2,000 volts RMS at 1 megahz applied across the fuse; 3) distinctive appearance to permit distinguishing it from other fuses.

The current-to-blow value was selected because currents up to 30 milliamperes have been measured passing through EKG electrodes when the electrocautery was being used properly. Since current of 50 milliamperes § of low-frequency power through electrodes on the body surface is considered to be below the minimum current dangerous to the heart, a fuse value of 40 milliamperes seems practical. Furthermore, this value (40 milliamperes, nominally a 1/32-ampere fuse rating) is the minimum possible at this time in the particular construction required here. Because of the no-arcing requirement the fuse element must disintegrate over a long pathway (25 mm). Before the present fuse was developed the smallest-value fuse available in this type of construction was 1/16 ampere.

Fuses with much lower ratings (1/500 or 1/200 ampere) are also available. The fuse element consists of a very fine filament (diameter in millionths of an inch) stretched

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† These experiments were carried out by the author and Dr. Steven R. Wyte while Dr. Wyte was a resident in Anesthesiology at the Columbia-Presbyterian Medical Center.

‡ These fuses may be purchased from Closter Prototypes, 3 Laurence Court, Closter, New Jersey 07624.

§ Kouwenhoven, William B.: personal communication, 10 Jan. 1969.

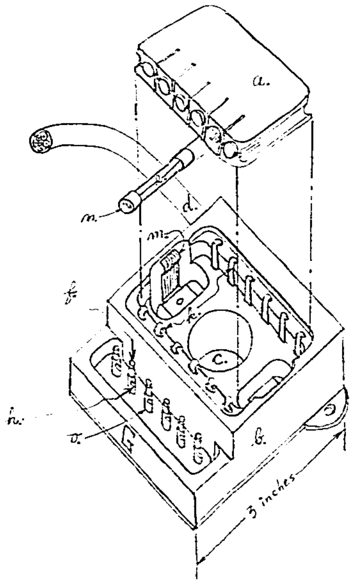

FIG. 1. Sketch showing "six-pack" separate from cable "block." *a,* plastic "six pack" containing five fuses, with the sixth (*e*) pushed out. *b,* cable "block" which accepts "six pack" of fuses. This plastic "block" also has provisions for attachment of electrode lead wires. *c,* thumb hole for pushing out "six pack." *d,* cable. *e,* fuse shown in line with its hole in the "six pack"; this is a special fuse, gold plated for coding purposes. *f,* clip for attachment of electrode lead wire. Pushing down with finger in direction of *f* arrow opens slot *h,* allowing bared end of lead wire to be inserted. *k,* gold-plated beryllium copper contacts which make connection to ends of fuses when six pack is inserted. *m,* retaining spring clip for six pack. *n,* gold-plated end of special fuse (both ends gold-plated). *o,* the "ground" connection clip marked by engraved "G" on end of block; the two EEG connections are each marked "E"; the ECG connections are self-evident.

across a narrow, 1½-mm gap. Because of the possibility of arcing with high voltage it has to be used in series with a high-voltage 1/16 or 1/32 ampere fuse. This arrangement was impractical in the operating room: annoying and expensive "false blows," resulted wherever electrocautery was used. However, our experience with such a dual-fuse system in an intensive care facility has been satisfactory. If no electrocautery or other power-producing device is to be used, a single 1/500 ampere fuse would probably provide satisfactory protection against accidental voltages up to 250 volts. The new 1/32-ampere fuse is gold-plated on the ends, which are visible when used in the present system. Thus, the operator of the monitor can readily determine that the proper fuses are being used.

The wire between the electrode and the fuse should have a low capacitance to ground. Experience with fuses placed directly at the electrodes taught that replacement after blowing was too difficult. Usually some of the electrodes are inaccessible. It is also inconvenient to locate the blown fuse during the surgical procedure.

A "six-pack" fuse holder (fig. 1) has been developed. The six-pack is snapped into a recess in a plastic "block" (fig. 2) placed at the patient end of the monitor cable.¶ Vinyl

¶ The fused cable is available from Closter Prototypes.

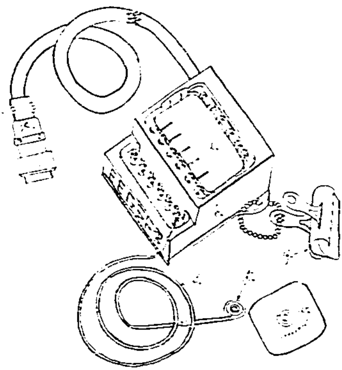

FIG. 2. Sketch showing complete fused cable system as used with the E.F.M. Operating Room Monitor. *p,* cable connector to match monitor input. *q,* spring clip (2¼ inches long) for attachment to sheet (bedclothes). *s,* electrode lead. *t,* snap end on electrode lead to match particular paste-on electrode (*w*). The electrode lead may have any kind of connector to match any desired type of electrode.

insulated flexible wires (24-gauge) lead from the patient electrodes to the spring-loaded pushbutton clamps on the "block," which in turn are connected to the fuses. The unshielded wires have a sufficiently low capacitance even when six feet long to avoid harmful electrocautery current flow after a fuse is blown.

The fuse block may be fastened to the bed sheet with an attached heavy-duty pinch clamp. When a fuse blows during use, no attempt is made to locate or replace individual fuses. The "six-pack" fuse holder is easily replaced. If only three of the six monitor leads are being used, the same "six pack" may be simply turned over to provide three new fuses. Fuse testing and replacement are performed by supporting personnel, using a special resistance–continuity meter built for the purpose.

Several such fused cables have been in daily use in the Presbyterian Hospital operating rooms for more than a year.

CASE REPORTS

Reversal of Chloral Hydrate-associated Cardiac Arrhythmia by a Beta-adrenergic Blocking Agent

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Beta-adrenergic receptor blocking agents represent a new class of pharmacologic agents which have been used experimentally in treatment of a wide variety of disorders. At the present time one such agent, propranolol, is available for use in the therapy of idiopathic hypertrophic aortic stenosis, pheochromocytoma, and cardiac arrhythmias. Other beta receptor blocking agents are currently under clinical investigation. Since 1966 we have been using one, alprenolol (Aptine) in the treatment of cardiac arrhythmias. Successful treatment of a rare arrhythmia with this agent forms the basis of this report.

REPORT OF A CASE

A 48-year-old white man who weighed 258 pounds was admitted to the hospital emergency room at 9 PM in a comatose state 30 minutes after ingestion of approximately 18 g chloral hydrate. He had a history of an old myocardial infarction. During the attempted passage of a gastric tube the patient vomited, aspirated gastric contents, and became cyanotic. Cardiac arrest occurred. An endotracheal tube was inserted and external cardiac massage was begun immediately. The pattern on the electrocardioscope was that of ventricular fibrillation. At 9:15 PM the patient was given 88 mEq sodium bicarbonate intravenously and the heart was defibrillated. This produced on the oscilloscope (a direct-writer was not available) what was interpreted as sinus rhythm at a pulse rate of 130 to 150 beats/min, with frequent PVC's. Blood pressure was 130/100 mm Hg. At 9:25 PM the patient was given lidocaine, 60 mg, with subsequent reduction in frequency of PVC's, which lasted about 20 minutes, after which they became more frequent and multifocal. The blood pressure dropped to the 80–100 mm Hg systolic and at times was unobtainable. At 9:50 PM the patient was given an additional 80 mg lidocaine and 44 mEq sodium bicarbonate, which produced marked reduction in PVC's and a blood pressure of 120/80 mm Hg. The patient was not breathing spontaneously, and the endotracheal tube was attached to a positive-pressure ventilator. At 10:25 PM the vital signs were stable with blood pressure was 130/80 mm Hg; pulse rate 120 beats/min. The cardioscope was detached from the patient and preparations were made to transfer him to the Intensive Care Unit. The immediately subsequent events are obscure, but the personnel attending the patient reported that his

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