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Intraoperative Defibrillator Failure

G. BASHEIN, M.D., PH.D.,* AND DONALD B. WILLIAMS, M.D.†

We wish to describe a cascade of three defibrillator failures that could have been prevented by changes in operating procedure or equipment design.

REPORT OF A CASE

A 62-year-old woman presented for emergency coronary artery bypass grafting. After an uneventful anesthetic induction, the scrub nurse passed the sterile defibrillator cable to the anesthesiologist, who connected the cable to the defibrillator (Model 640, Physio-Control Corp., Redmond, Washington) but found that it would not charge for testing. A second, identical defibrillator was borrowed from the adjacent operating room, connected to the original cable, and charged to approximately five joules. Then the unit was switched off, causing it to discharge through its internal "dump" resistor, completing our usual test procedure.

Surgery proceeded without incident until the aortic cross-clamp was removed, when vigorous ventricular fibrillation developed. Defibrillation was attempted with the second unit, but it too would not charge. A second sterile cable was brought onto the operative field and connected successively to the second and first defibrillators, but neither of these would charge. A third, identical defibrillator was borrowed, but it too would not charge when connected to either cable. While waiting for another defibrillator to arrive, various combinations of defibrillators, internal and external cable sets, wall plugs, and extension cords were tried, all without success.

A fourth defibrillator (Life Pack 6[®], Physio-Control Corp.) came with no internal cable, nor would it accept the available internal cables. Four unsuccessful defibrillation attempts were made with 400 joule shocks applied externally just lateral to the sterile field (two of these after the pericardial sac was filled with saline solution).

Finally, when a fifth defibrillator arrived with its own internal cable, the first shock of 10 joules produced normal sinus rhythm. Total fibrillation time was 27 min on full cardiopulmonary bypass at normothermia. The remainder of the operation and recovery were uneventful. The patient's peak creatine phosphokinase MB fraction postoperatively was 4 units/l (normal in our laboratory: ≤ 6 units/l), indicating that no significant myocardial damage occurred.

Subsequent investigation disclosed that the first cable had been steam autoclaved, despite a large red placard stating "Gas Sterilize Only." An earlier model of this cable set had been approved by the manufacturer for steam sterilization, and confusion arose because our inventory of cables contains both the current and the old models. Apparently, the autoclaving caused a short circuit in the cable connector, which, in turn, caused the fuse in the charging circuit of each defibrillator to blow when charging was attempted with the faulty cable connected. The fuse in question is of the "slo-blo" variety, so that the second defibrillator tested successfully because it was only briefly charged and then discharged, but it failed in actual use when the charging was sustained slightly longer. Unfortunately, the faulty cable happened to be the first one connected to the third defibrillator, so that it too failed.

DISCUSSION

Because of the design of this unit, we did not recognize that the source of the problem was in the cable connector. We then attached the faulty cable to two additional defibrillators, rendering them inoperative. The fuses on this unit are located inside the case and are not accessible for inspection or replacement by the user in the event of difficulty. There is no external indication when the charging circuit fuse has blown and the pilot lamp continues to function normally. Although this may appear to be a serious design flaw in this particular unit (which no longer is manufactured), the current voluntary standard for defibrillators‡ makes no statement that

* Assistant Professor, Department of Anesthesiology.

† Assistant Professor, Division of Cardiothoracic Surgery, Department of Surgery.

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Address reprint requests to Dr. Bashein.

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‡ American National Standard for Cardiac Defibrillator Devices. Arlington, Virginia, Association for the Advancement of Medical Instrumentation Publication No. ANSI/AAMI DF2-1981, 1981.

fuses should be accessible to the user or that the instrument should have a blown fuse indicator. § Furthermore, none of the defibrillators evaluated in a recent review ¶ have either user-accessible fuses or a blown-fuse indicator. **

Nevertheless, our original problem would not have propagated from unit to unit if we had replaced the cable when the first unit failed to charge. We strongly recommend the practice of replacing the cable first, or else replacing the entire defibrillation apparatus whenever a failure is encountered. We also recommend that defibrillators intended for use in any surgical suite or emergency room have sterile internal cables stored with them, since open-chest defibrillation may have to be employed outside the usual cardiac surgery setting.

This episode also raises important questions regarding proper testing of defibrillators intended for intraoperative use. The only method to test the entire defibrillator/cable apparatus is to discharge the defibrillator into a test load having an indicator to show the energy delivered. †† Ideally, such a test should be performed at the start of each operation, requiring that several test loads be kept sterile, because of the necessary aeration time following ethylene oxide sterilization. However, the testing process itself causes wear and tear on the capacitor, switches and relay contacts that could shorten the time between failures. †† Furthermore, testing presents a small hazard to operating room personnel, and no amount of testing will forestall unpredictable failures. †† A bulletin from the manufacturer (Routine defibrillator testing by clinical personnel. Physio-Control® Technical Paper No. 2, September, 1979) recommends a daily charge/discharge cycle into a test load at 50 joules (to minimize wear and tear) and a weekly full energy

charge/discharge test, in addition to a full engineering maintenance check every 3 months.

We consider it impractical to inventory enough test loads to perform a sterile test before each operation. Furthermore, our operating room defibrillators are tested almost daily by actual use. Therefore, we have adopted an alternative method suggested in the authoritative publication *Health Devices*, †† which is to test-charge the capacitor to 5–10 joules at the beginning of each operation and then turn off the defibrillator to discharge it through the internal dump resistor. Although this procedure does not verify continuity of the cable, nor does it verify proper operation of the discharge circuit and relay, we believe that it strikes a reasonable balance between the problems prevented by testing and those created by testing. Because the defibrillator plays such a critical role in cardiac surgery, we believe that a replacement unit and sterile cable set must be kept immediately available.

In summary, three cardiac defibrillators failed in succession because a short circuit developed in a cable that inadvertently was steam autoclaved. Because the patient was sustained on full cardiopulmonary bypass, no apparent injury occurred. However if ventricular fibrillation had occurred off bypass, major organ injury or death could have resulted. The original problem would not have propagated from unit to unit if we had replaced the entire apparatus when a failure first was encountered. Improved equipment design would have given us a clue as to the source of the problem and allowed us to replace the blown fuse. Although preoperative firing into a test load also would have alerted us to the problem, exhaustive testing protocols are impractical to implement in the operating theater. Instead, we prefer to rely on keeping a spare unit and cable set immediately available.

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†† Anonymous: Defibrillator testing: Too much of a good thing. *Health Devices* 5:192–193, 1976.

§ We have communicated a suggestion to this effect to the Defibrillator Committee of the Association for the Advancement of Medical Instrumentation.

¶ Anonymous: Line powered defibrillators. *Health Devices* 12:291–314, 1983.

** Personal communication: T. Hernandez, Emergency Care Research Institute.