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Clinical Paper

Electrical exposure risk associated with hands-on defibrillation☆

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ABSTRACT

Background: The use of hands-on defibrillation (HOD) to reduce interruption of chest compression after cardiac arrest has been suggested as a means of improving resuscitation outcomes. The potential dangers of this strategy in regard to exposing rescuers to electrical energy are still being debated. This study seeks to determine the plausible worst-case energy-transfer scenario that rescuers might encounter while performing routine resuscitative measures.
Methods: Six cadavers were acquired and prepared for defibrillation. A custom instrumentation-amplifier circuit was built to measure differential voltages at various points on the bodies. Several skin preparations were used to determine the effects of contact resistance on our voltage measurements. Resistance and exposure voltage data were acquired for a representative number of anatomic landmarks and were used to map rescuers' voltage exposure. A formula for rescuer-received dose (RRD) was derived to represent the proportion of energy the rescuer could receive from a shock delivered to a patient. We used cadaver measurements to estimate a range of RRD.
Results: Defibrillation resulted in rescuer exposure voltages ranging from 827 V to ~200 V, depending on cadaver and anatomic location. The RRD under the test scenarios ranged from 1 to 8 J, which is in excess of accepted energy exposure levels.
Conclusions: HOD using currently available personal protective equipment and resuscitative procedures poses a risk to rescuers. The process should be considered potentially dangerous until equipment and techniques that will protect rescuers are developed.

1. Introduction

Defibrillators have played an integral role in cardiopulmonary resuscitation (CPR) since the 1950s. They were first demonstrated in 1899 by Prévost and Batelli and first applied to humans in 1947.[1] Defibrillation can correct certain cardiac arrhythmias, the primary one being ventricular fibrillation. When triggered, the defibrillator creates a short burst of electricity that follows a capacitive discharge curve. Modern defibrillators create biphasic discharge curves that compensate for chest wall impedance to lower the total energy used while maintaining efficacy. Rapid and early defibrillation remains a mainstay of treatment for ventricular fibrillation and has been shown to increase survival after cardiac arrest.[2]

High-quality chest compressions also improve survival rates.[2] Brief interruptions in compressions for rhythm and pulse checks have a deleterious effect on patient outcomes.[2] Delays in chest compressions may impair resuscitation outcomes, and high-quality chest compressions are more effective than other advanced interventions.[3–10] By extension, continuous compressions during defibrillation are thought to generate continuous cerebral and coronary perfusion in humans, which maximizes the success of defibrillation.

The resuscitation guidelines issued by the American Heart Association in 2010 sparked interest in delineating the true risks of hands-on defibrillation (HOD) during cardiac arrest.[2] Hoke and associates sought reports of adverse events related to defibrillation and determined that life-threatening events from accidental electric shock during a medical procedure are rare.[11] Lloyd and

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colleagues set out to measure the voltage experienced by medical care providers engaged in active chest compressions during defibrillation while wearing medical gloves.[7] None of the providers felt a shock. The investigators determined that the average amount of current leaking through a resuscitator's body was below several recommended safety standards. The study was limited by the use of nitrile gloves, which can block the flow of electricity; therefore, the potential danger to providers is still not known if there is a break in the integrity of the gloves, or the provider is not wearing gloves. Worse, recent studies suggest that many gloves lack the dielectric strength necessary to protect rescuers who perform HOD.[12,13]

Current guidelines still recommend withholding chest compressions during defibrillation to prevent the accidental electrocution of rescuers, though recent articles have postulated that the leakage current during defibrillation is low enough to support the idea of HOD[7]; others suggest the conclusions are too far reaching and call for a greater understanding of the risk.[14] However, leakage current does not adequately convey the total risk of defibrillation. Any rescuer in contact with a patient during defibrillation will share a portion of the energy delivered. Energy values greater than 1 J reportedly have the ability to cause ventricular fibrillation.[15] Since total energy delivered, voltage, and the resistance of the patient and rescuer will determine the amount of energy transferred (complete discussion in Supplemental Data: Section 1 [26,27]), we sought to better understand the interplay of these variables on rescuer risk. We introduce the concept of the rescuer-received dose (RRD) of defibrillation as a more accurate measure to describe defibrillation risk. Our specific goal was to determine whether the practice of HOD is safe for rescuers.

Supplementary material related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2014.06.023.

2. Methods

2.1. Study design

This is a cross-sectional study of voltage measurements from cadavers during high-voltage defibrillation. Eight cadavers were obtained from the Maryland State Board of Anatomy and were neither frozen nor embalmed. The cadavers' body mass index (BMI) ranged from 12 to 29 kg/m^2. This research protocol was approved by the institutional review board at the University of Maryland School of Medicine.

2.2. Data collection

2.2.1. Resistance measurements

Resistance measurements were taken from eight cadavers and two of the investigators, using a calibrated multi-meter (Fluke Corp., Everett, WA) connected to NovaPlus V2560 (Irving, TX) monitoring electrodes placed 40 cm apart on the chest. A variety of preparations were used to measure resistance differences: intact skin, abraded skin, saline, 1/10 saline (simulating sweat), sterile water, ultrasound gel, and needle probes. The resistances were measured to ensure that the subsequent voltages measured during defibrillation were accurate and not altered by a voltage divider effect. Details of our resistance preparations and measurements are presented in Supplemental Data: Section 2.

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The minimum consistent resistance reading was recorded after a 5 s sampling period. If outliers were recorded, the meter was re-zeroed and another 5 s sampling was obtained. Results were rounded to the nearest significant digit. When unstable measurements were identified, the electrode sites were re-prepped to ensure accurate measurement.

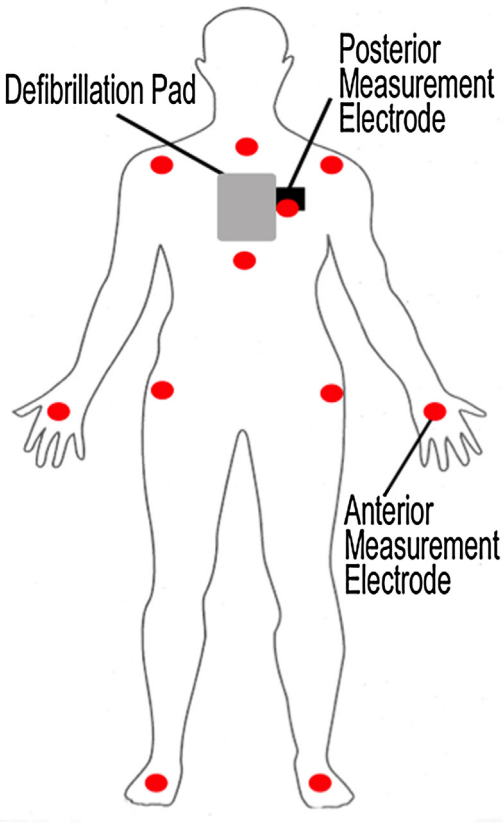

Fig. 1. The red dots denote anatomic sites that the defibrillation voltage measurements were obtained. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

2.2.2. Voltage measurements

Six of the eight cadavers were available for defibrillation and were placed on tables, with care being taken to ensure they were not grounded. Adult defibrillation pads (Physio-Control, Redmond, WA) were applied using standard anterior-to-posterior technique on all cadavers. The posterior electrodes were placed contiguous and lateral to the posterior defibrillation pads. Anterior measurement electrodes were placed at diverse anatomic landmarks as shown in Fig. 1. Measurement electrodes were placed using the abraded skin technique described in Supplemental Data: Section 2. Voltages were acquired at all anatomic sites for each cadaver, and presented in Fig. 2. All voltages were measured with respect to the posterior electrode. Selecting the posterior electrode as a common reference point for all measurements allows easy calculation of voltages between any two anatomic sites and subsequent estimation of electrical hazard for contact between any two anatomic sites.

One of the two inputs of the measurement circuit was connected to the posterior defibrillation pad; the other input was connected anteriorly to each measurement electrode in sequence. An Agilent U1620A 200-MHz oscilloscope (Agilent Technologies, Santa Clara, CA) was connected to the measurement circuit. Probes measured the differential and common-mode voltage at the circuit outputs. The measurement circuit ground and the oscilloscope ground were both connected directly to a grounded outlet.

A Physio-Control Lifepack 20 (Physio-Control, Redmond, WA) defibrillator was charged to 360 J, and the cadaver was defibrillated