# Airborne Defibrillation . . . The Sequel

■ Russell R. Waggoner, RN, BSN; Denise A. Landis, RN, MSA; Kris Nelson, RN; Dale K. Dedrick, MD

DEFIBRILLATION HAS PLAYED A significant role in interventional cardiology since the early 1970's. Concern for safety has become more important as the defibrillators have been utilized in diverse environments, including fixed-wing and rotary-wing aircraft.

The safety of airborne defibrillation is an extremely important issue as increasing numbers of civilian fixed-wing and rotary-wing air medical programs transport medically unstable patients from one hospital to a tertiary level care center.

## History of Defibrillation

Although used as early as 1899, defibrillators did not come into common usage until the 1970's. At that time, the major trend was the use of the alternating current (AC) defibrillators, with the direct current (DC) secondary.

The first ten years brought many changes in the type and quality of defibrillators. In 1983, a study found that a number of defibrillators in use at that time lacked basic safety and modern design features found on battery-powered units.[1]

Alternating current line-powered defibrillators have since become obsolete due to their inefficient/ineffective delivery of a monophasic electric wave which produces the optimum wave for defibrillation. Direct current defibrillators have a better track record in terms of safety, quality, and ability to successfully depolarize the heart out of ventricular fibrillation.

Today's defibrillators are DC line-powered or DC battery-powered. The two DC line-powered defibrillators reviewed by the University of Michigan Hospitals in 1987 were the LIFEPAK® 7 defibrillator and also the Airshields Porta Fib III®. These two were tested due to their ability to defibrillate in either the DC line-powered or battery-powered mode.

The LIFEPAK 7 and LIFEPAK 5 defibrillators have identical output characteristics. The two DC battery-powered defibrillators used primarily in the air medical industry are the LIFEPAK 5 defibrillator and the LIFEPAK 10 defibrillator/monitor, which are DC battery-powered only.

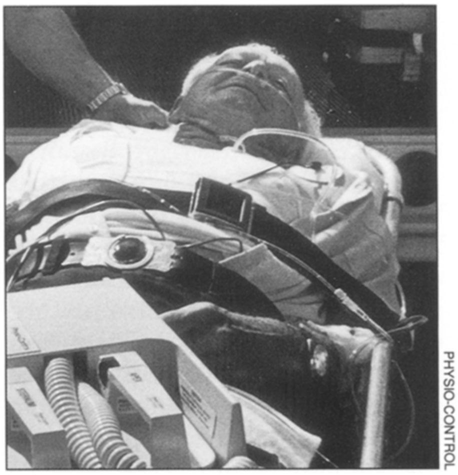
Two accessories utilized with DC battery-powered defibrillators are the R2® and the Physio-Control FAST-PATCH®. These accessories allow the patient to be defibrillated without direct contact and increase the distance between the patient and the person defibrillating.

## Factors Influencing Defibrillation

Factors that influence defibrillation can be discussed in reference to the paddles (paddle location, size, type, contact pressure), transthoracic resistance (TTR), and amount of delivered energy or current.

### *Paddle Location*

Paddles deliver the current for defibrillation. When the electrode paddles are placed too close together, a substantial amount of current shunts between the electrodes and an insufficient amount reaches the heart. Wider spacing of the paddles in the anterior-apical position allows a sufficient amount of current to reach and depolarize the ventricle.[2,3]



**A defibrillator is used to successfully depolarize a patient's heart out of ventricular fibrillation.**

Some controversy exists as to the "best" placement of the paddles/electrodes for defibrillation (anterolateral vs. anteroposterior approach). Studies indicate the following: anterolateral paddles are as effective as anteroposterior paddles for the elective cardioversion of atrial arrhythmias. There was no demonstrable advantage to using paddles larger than the standard size.[4] With the use of self-adhesive preapplied electrode pads, it has been found that the pads are equally effective when used in the apex-anterior or apex-posterior position.[5]

*Paddle Size*

Proper paddle size for optimum defibrillation is under debate. Kerber et al. used large (13 cm) and small (8.5 cm) paddles on two groups of patients. In this study they found that both groups received shocks of similar energy levels, but the patients shocked with one or two large paddles had significantly lower TTR. At any given energy level, use of larger paddles lowered TTR, increased current flow and improved the likelihood of achieving defibrillation.[6] The American Heart Association's (AHA) recommendation for adults is to have the equivalent area of circular paddles of 10 to 13 cm in diameter.[7] At the present time, manufacturers of the self-adhesive electrode pads are following the AHA's guideline.

*Contact Pressure*

Paddle contact pressure is another factor that influences defibrillation. Electrode-chest contact pressure influences transthoracic resistance when hand-held paddle electrodes are used.[6] It is recommended that firm pressure of about 11 kgs (25 lbs) per paddle be used. The paddle-chest contact pressure is directly proportional to the amount of delivered energy. Greater pressure improves the paddle-chest contact and lowers impedance.[3] With firm paddle contact pressure the TTR was 25% lower than with light paddle contact pressure, thus increasing current flow.[6]

*Transthoracic Resistance (TTR)*

Transthoracic resistance is related to body weight, paddle contact pressure, chest size, serial shocks, and the phase of ventilation. The relationship between TTR and body weight is weak.[6] If the energy selected is low and therefore marginal for defibrillation, a high TTR might result in inadequate current flow. This would result in failure to defibrillate a heavy, big-chested subject.[6]

Transthoracic resistance is more clearly related to chest width.[8] Ewy et al. studied patients undergoing elective cardioversion with anteroposterior paddles and found a relationship between TTR and anteroposterior chest diameter.[8] With serial shocks, the TTR does decrease with a second same-energy shock, but the magnitude of this decline is small, and the resultant increase in peak current flow only 4%.

A substantial increase in current flow can be obtained more reliably and quickly by selecting a higher energy for a second defibrillation attempt.[6] The relationship of transthoracic resistance and the phase of ventilation is minimal at full expiration.[7] Concurrently, the conduction of delivered current is greatly reduced when conducted through bones or pleural effusions.[2]

*The ability to place the pads accurately is not only beneficial to successful defibrillation of the patient, but allows more peace of mind for the caregiver.*

*Peak Current*

One of the last considerations is peak current. In a circuit comprised of a patient attached to a monitor/defibrillator, the current depends upon the voltage delivered from the paddles/pads and the impedance or resistance to flow in both the patient and the defibrillator. Peak current is measured in amperes (A); impedance is measured in ohms.

When calibrating defibrillators, the industry uses a patient impedance of 50 ohms, so what is indicated off the machine is the energy expected to be delivered to the patient. Fifty ohms is a figure that is at the lower end of the scale to maximize the current flow and the potential current leakage through the system. Measured impedance in patients varies between 15 and 143 ohms, with an average of 67 to 80 ohms.[2,5,6] The industry utilizes 1,000 ohms for the impedance (or resistance) of the operator.

*Air Medical Safety*

Prior to the University of Michigan Hospitals' (UMH's) study of defibrillation in emergency helicopter transport, the only published study of the performance of electrical defibrillators in aircraft was conducted in 1977, when the United States Air Force (USAF) School of Aerospace Medicine studied the Physio-Control LIFEPAK 5 cardioscope, defibrillator, and battery charger (Physio-Control Corporation, Redmond, Washington).[9] This report was based upon in-flight testing aboard a C-130, a large fixed-wing aircraft whose cabin and avionics are quite different from a small helicopter. The USAF air medical evacuation routinely defibrillates in the C-130, C-141, and C-9 fixed-wing aircraft.

The UMH procedure measured transient leakage current by discharging defibrillators into a 50 ohm test load (patient). Alternately, each paddle was connected by a 1000 ohm resistor (operator) to ground. Peak current was measured by dividing the peak voltage by 1000 ohm.

This procedure is a worst-case scenario which duplicates the condition where a person is touching a paddle during discharge and simultaneously touches a good electrical ground. It is important to remember that the 50 ohm test load to simulate a patient is at the low end of patient resistance and hence allows maximum current to flow from the defibrillator. The 1000 ohm load used to simulate an operator/person who could be in contact with the electrode is at the low end of expected operator resistance, again allowing maximum current flow.[10]

The tests were conducted using the LIFEPAK 7 defibrillator and Airshields Porta Fib III. The results were very similar when they were compared in the line-powered and battery-powered modes.[10] In this study measurements were taken directly from each of the defib paddles. At maximum energy, the highest peak current measured was 6 milliamp (mAmp) with the defibrillator on-line. With the defibrillator in the battery-powered mode, the highest peak current was measured at 1.5 mAmp.

Together with a time duration of 1 millisecond, the results fall well below the recommended safe value of 50 mAmp peak current and a time duration of 10 milliseconds.[1] The measured currents were similar to those found by Emergency Care Research Institute (ECRI) in their evaluation of defibrillators.[1] The maximum they found was 27 mAmp.

To provide better perspective, the peak current delivered to a patient during a discharge of 360 joules is about 100 amperes, or about 70,000 times larger than UMH measured in the worst case battery-powered discharge![5,10]

During their tests, Physio-Control's experience with the LIFEPAK 5 defibrillator and the LIFEPAK 10 defibrillator/monitor were similar to the tests performed by the UMH study.[11] The only difference found was that the LIFEPAK 10 defibrillator/monitor's peak current leakage was less than the LIFEPAK 5 defibrillator.

In the clinical situation, body tissue resistance could greatly decrease the current flow between the paddle site and the stretcher. This margin for error is further increased by the use of self-adhesive preapplied electrode pads for monitoring and/or defibrillation, such as R2 pads or Physio-Control's FAST-PATCH.

The number of advantages to utilizing these pads for safe, airborne defibrillation far outnumber the disadvantages. The operator is removed farther from the patient, thus increasing the resistance or impedance even more than if it was just the operator and the patient with the operator completing the circuit by touching the patient during defibrillation.

Current is delivered via the cable(s) directly to the patient, so contact paddle pressure is not a problem, and arcing from too much gel or sliding defibrillation pads is avoided. These pads can be preapplied, therefore alleviating hasty application of hand-held paddles that may not be placed in the correct position.

The ability to place the pads accurately in a calm, prearrest circumstance is not only beneficial to successful defibrillation of the patient, but allows more peace of mind for the caregiver. These pads can be placed effectively on the acutely diaphoretic patient with appropriate preparation (dry skin, using Tinc-o-ben® around the outside border).

It is recommended that the pads be used in the apex-anterior placement. The pads offer the same conduction in either the apex-anterior or apex-posterior position, but the apex-anterior approach allows for both easier placement on a critically ill patient and easier detection of displacement were it to occur.

The biggest advantage of these pads is to prevent a delay in administering the initial shock. The earlier the initial shock is delivered in ventricular fibrillation, the better the success in reestablishing an organized perfusing rhythm.

In terms of delivered energy, the most important thing to remember is that maximum energy is not needed to achieve successful defibrillation. A shock of 150 to 200 joules is adequate for the first two or three attempts in almost all cases.[2,3]

There are a few disadvantages to using preapplied pads. It is difficult to obtain an accurate chest x-ray with pads in place, and a full 12-lead EKG cannot be taken. The number of shocks that can be delivered through one set of pads is unknown; however, in one reported case, 24 of 27 delivered shocks were successful using one set of pads.[5]

The last area of concern for airborne defibrillation deals with aircraft, whether rotor wing or fixed wing. The issue of safety regarding electronic avionics and the navigational equipment on board both types of aircraft is directly related to Federal Aviation Administration (FAA) standards. If the avionics conform to the FAA standards, all electronic avionics and navigational equipment will have a common ground in the aircraft.

The airframe of both rotor-wing and fixed-wing aircraft are grounded; therefore the airframe acts as a ground whether the aircraft is airborne or on the ground. No difference exists between touching the ground in an aircraft and standing on the ground in the hospital setting when defibrillating a patient.

## Summary

The greatest potential error occurring during attempted cardiac resuscitation is to delay administering the initial shock.[2] Defibrillation with current equipment can be performed without hesitation whether the rotary or fixed-wing aircraft is in flight or on the ground.

Despite cramped quarters and sensitive electrical equipment, defibrillation can be safely performed in all types of rotary and fixed-wing aircraft currently in use for emergency medical transports. ■

*Russell Waggoner, RN, BSN; Denise Landis, RN, MSA; and Kris Nelson, RN, work for Survival Flight, Section of Emergency Services, University of Michigan Hospitals (Ann Arbor, MI).*

*Dale Dedrick, MD, works for the Section of Orthopedic Surgery, Department of Surgery, University of Michigan (Ann Arbor, MI).*

## References

1. Health Devices 1983; 12:298.
2. Weaver WE: Optimal results with defibrillators. *Cardiovasc Med* 1985; 10:55-60.
3. Kerber RE: External defibrillation: new technologies. *Ann Emerg Med* 1984; 13:794-797.
4. Kerber RE, Jensen SR, Grayzel J, et al: Elective cardioversion: Influence of paddle-electrode location and size on success rates and energy requirements. *N Engl J Med* 1981; 305:658-662.
5. Kerber RE, Martins JB, Kelly DW, et al: Self-adhesive preapplied electrode pads for defibrillation and cardioversion. *J Am Coll Cardiol* 1984; 3:815-820.
6. Kerber RE, Grayzel J, Hoyt R: Transthoracic resistance in human defibrillation. *Circulation* 1981; 63:676-682.
7. Textbook for ACLS, American Heart Association, 1983, 2nd ed., 1987.
8. Ewy GA, Ewy MD, Silverman J: Determinants of human transthoracic resistance to direct current discharge (abstr). *Circulation* 46 (suppl II): II-150, 1972.
9. US Air Force School of Aerospace Medicine, Biomed Systems Branch: Test and Evaluation Report on the LifePak 5 DC Defibrillator/Synchronizer Module, December 1977.
10. Dedrick DK, Darga A, Landis D, et al: Defibrillation safety in emergency helicopter transport. *Ann Emerg Med* 1989; 18:125-127.
11. Physio-Control, Ed Perkins, Technical Support Specialist, November, 1990.