Pediatric Defibrillation: A Window of Opportunity

Scott DeBoer, RN, MSN, CEN, CCRN, CFRN
Michael Seaver, RN, BA, NREMT-P

The goal of this presentation is to familiarize nurses with issues surrounding pediatric defibrillation. After you study this information, you will be able to —

- Explain how defibrillation affects a heart in ventricular fibrillation.
- Identify the two types of waveforms delivered by defibrillators.
- Recognize at least two concerns regarding the use of automatic external defibrillators (AEDs) in the pediatric population.

"Defibrillators are the tool to deal with 'hearts too good to die.'"— Beck, 1947

It's hard to recall life before defibrillators. However, in the scheme of medical developments, defibrillators are a relatively new invention. The first human defibrillation was just 55 years ago. During an operation to repair a congenital chest defect, Dr. Charles Beck's pediatric patient suffered what appeared to be a ventricular fibrillation (VF) cardiac arrest. It wasn't confirmed for some 35 minutes when an ECG could be obtained. Emergency medications were given and, finally, a defibrillator from Beck's laboratory was brought into the operating room. The first shock was administered. Amazingly, after several shocks and more than 45 minutes into the code, the rhythm converted to normal sinus and the child went on to make a full recovery.[1,2]

That was just the beginning. Now we have several defibrillation options. We can attempt it from the inside or from the outside. Inside defibrillation can be delivered with an implanted automatic internal cardioverter/defibrillator (AICD), transesophageal defibrillation, or through open-chest internal-cardiac defibrillation. Defibrillation from the outside is a matter of manual versus automatic methods, using either a conventional defibrillator or an AED. Despite the common misconception, defibrillation does not "jump start" the heart. What's really happening is the shock completely "stuns" or depolarizes the myocardium, which is followed by a brief period of asystole. If sufficient stores of high-energy phosphates remain in the myocardium, the intrinsic cardiac automaticity can "restart" the heart.[3]

Kids Never Go VF — or Do They?

So if adult cardiac arrest victims go into VF very often, what about children? Though some have suggested that the importance of defibrillation should be downplayed during pediatric advanced life support (PALS) training,[4] ongoing research seems to indicate otherwise. Until recently, it was commonly believed that children rarely go into VF; rather, they typically suffer asystole as the result of a respiratory emergency. This belief has lead to emphasizing "phone fast" instead of "phone first" in cases of pediatric arrest. While it is true that the majority of pediatric cardiac arrests are bradyasystolic in origin,[5-9] many more children than previously thought are initially in VF. The "phone fast" concept suggests that, unlike with adults, a minute of CPR should be performed before calling 911.[10,11] This paradigm may need rethinking in light of the expanding opportunity for pediatric defibrillation.

Studies have indicated that at least 6% to 18% of pediatric terminal cardiac rhythms are VF.[5-9] And even more important, if children are in VF, the chances of discharge from a medical center are significantly better (24%) than if the child is bradyasystolic (8.4%).[5] It's true that fewer children are found in VF/ventricular tachycardia (VT) than their adult counterparts, but this fact must be balanced with the greatly improved survival and neurological outcomes with VF/VT versus asystole.[5,10] VF has been associated with a good outcome in the pediatric population, indicating that effective treatment of VF/VT through pediatric defibrillation may indeed represent a tremendous "window of opportunity" to improve survival in children.[5,8]

Now that we've made the case for defibrillation, let's talk joules (j). When caring for children, the dose of medication or delivery of defibrillation energy is calculated on the basis of weight. In pediatrics, defibrillation attempts starting at 2 j/kg followed by 4 j/kg was established in 1975 as a guideline for treating pediatric VF arrest.[12] Here's an easy way to remember these guidelines. Pick up the paddles and count them. When you're holding the paddles in your hands, how many are there? Two – and 2 j/kg is the initial recommended defibrillation energy you'll need. If the first shock is unsuccessful, then simply remember that 2 x 2 = 4. The second, and all subsequent shocks, should be at 4 j/kg.

Next comes the use of pediatric versus adult paddles. Studies in paddle size have shown that adult paddles may be used in children age 1 year (about 10 kg) and older.[13] An important consideration, regardless of paddle and patient size, is to ensure that the paddles or pads do not touch each other. Such contact could result in electrical flow between the paddles and insufficient current being delivered to the heart.[14]

Nuts and Bolts

To make sense of the whole defibrillator picture, one must absorb a bit of terminology. Monophasic or biphasic waveforms? Biphasic defibrillators deliver shocks with lower peak currents than monophasic shocks of the same energy. For example, a 360 j monophasic shock provides some 65 amps of peak current, while a 360 j biphasic shock offers about 40 amps of peak current. Keep in mind that it's the peak current, not the energy delivered, that's most closely associated with damage to the heart from a defibrillation shock. Biphasic waveforms have shown a 21% to 31% absolute improvement in rate of defibrillation achieved with three or fewer shocks and a strong trend toward return of spontaneous circulation.[15]

Since 1988, internal cardioverter/defibrillators have used biphasic waveforms. In 1996, the first AED with biphasic technology was introduced.[15,16] And although the American Heart Association (AHA) has not made a formal position statement, this organization describes the effectiveness of biphasic waveform technology as a "standard-of-care" intervention.[17,18] At present, most manufacturers are currently using biphasic waveform technology in their automatic and manual defibrillators.[15-19]

But when it comes to a child, should we use monophasic or biphasic defibrillation? The AHA recommends a monophasic energy dose of 2 j/kg to 4 j/kg, and when using alternative waveforms, a dose that has been shown an equivalent survival rate.[17] The US Food and Drug Administration (FDA) has determined that requiring clinical studies of pediatric patients was not warranted.

Manual defibrillators with biphasic waveform technology include operating instructions for pediatric use. Maintaining the same energy levels, biphasic shocks will average 30% to 40% less peak current than the monophasic waveform. Simply put, defibrillators that use biphasic waveforms provide a "kinder,

gentler" shock, with the same or better results.[15,17-21] Research studies have used swine models to simulate biphasic defibrillation in children, and the results of these studies appear quite promising with regard to the efficacy and safety of biphasic defibrillation in children.[20,22] Numerous adult studies have demonstrated that low-energy biphasic waveform defibrillation may be as effective as or superior to high-energy monophasic waveform therapy and with less energy of dysfunction. It's therefore possible, although not demonstrated, that with a biphasic waveform, lower energies than currently practiced with monophasic devices may be effective for children.[16,17,20]

Time Is of the Essence

Cardiac defibrillation was initially practiced only by physicians, but later by nurses, respiratory therapists, and paramedics. In the 1980s, defibrillation was made more accessible to the general public with the introduction of AEDs.[23] In addition to education for medical professionals during advanced cardiac life support (ACLS) and PALS courses,[14,24] individuals outside of the hospital setting are also being trained to use these devices. Emergency medical services workers at the basic emergency medical technician level, police, and fire personnel are now saving lives with AEDs.

Support for the use of AEDs is clear. Most adults in cardiac arrest are initially in VF.[5,25] The only "cure" for a VF cardiac arrest is defibrillation. The sooner a person in VF is defibrillated, the likelihood of conversion of the rhythm with a good neurological outcome rises. Time is extremely critical with a 7% to 10% drop in survival rates for every minute that the VF persists.[18,26]

AEDs, unlike conventional defibrillators, are easy to use. Sixth-grade students have been taught to use them properly with no previous training.[27] AEDs are now being taught in community CPR and first aid classes and can be found in many areas where large groups of people congregate. Airports, airplanes, and even casinos have made the news as a result of having an AED available. Some researchers have predicted that in the near future, AEDs may become a common household item for persons at high risk for sudden cardiac arrest. Even now, with a physician's order, you can purchase an AED for your home. Public-access defibrillation has the potential to be the single greatest advance in the treatment of sudden cardiac arrest.[14]

Vital "Pedi" Adjustments

If a manual defibrillator is not immediately available for a pediatric patient, can an AED be used? When AEDs were first introduced, they were intended only for adults. But what about a child in VF/VT? Imagine a youngster at play who receives a sharp blow to the chest. If the insult occurs during a vulnerable phase of the cardiac cycle, this can disrupt the electrical activity, especially during the relative refractory phase, similar to an "R-on-T" premature ventricular contraction.[28] No matter what the age, quick access to defibrillation is essential. Despite the relatively uncommon occurrence of VF or pulseless ventricular tachycardia (VT) in children,[6,28,29,30] the difference that the availability of a pediatric defibrillator could make to the child is staggering.

The current AHA recommendation regarding the use of adult AEDs on children is that the child be at least 8 years old or weigh greater than 25 kg or 55 pounds.[14] Despite this recommendation, the youngest child documented to have been shocked with an adult biphasic AED was 39 months old with cardiomyopathy who suffered a witnessed VF arrest. The child was defibrillated by his mother with the initial adult AED energy dose of 150 j (9 j/kg) and was awake and crying 10 minutes later. He was later discharged from the hospital with no cardiac damage from the event.[31]

This unique case notwithstanding, routine use of adult AEDs (without pediatric modifications) cannot be recommended. An AED, designed for adults, may incorrectly "think" that the pediatric rhythm is appropriate for a defibrillatory shock. In response, Philips Medical Systems obtained FDA approval for a pediatric adapter for its adult HeartStart AED.[32] Although the FDA recently approved the first pediatric adapter for an adult AED, the AHA currently classifies the Philips pediatric AED adapter as "indeterminate" in its recommendations.[11,14,24] This classification describes an intervention that, while it can be recommended for use, reviewers must acknowledge that research quality and/or quantity falls short of supporting a final class decision.[24] Despite the AHA's position on pediatric AEDs, some clinicians believe the current prohibition of the use of AEDs in the young pediatric patient means that these patients do not receive the equivalent level of care for older children and adults.[8]

Safety First: Concerns About the Pediatric AED

Concerns regarding pediatric AED use are essentially fourfold, the first three coming directly from the AHA:

1. Analysis of pediatric vs. adult cardiac rhythms and subsequent shock/no shock determination: The defibrillation algorithms for AEDs were developed based on adult cardiac rhythms. Remember that baseline heart rates in infants and young children are faster than those of adults. So if an AED were to determine that a shock was "advised" based on rate alone, this might be deadly for a child. There are several different manufacturers of AEDs, which likely have different shock/no shock algorithms.[33,34] However, the FDA-approved Philips HeartStart AED pediatric adapter is capable of identifying pediatric cardiac rhythms for a shock/no-shock decision with a sensitivity exceeding the 1997 AHA performance standards.[22,33,35-37] On the near horizon is the planned release of a Medtronic Physio-Control pediatric adapter as well.[38]

2. The amount of energy delivered: Another concern of the AHA is safety of the amount of energy delivered with each "shock." Adult AEDs currently deliver "shocks" in one of two ways. Some AEDs deliver biphasic energy at a consistent level of 150 j, regardless of the number of attempts at defibrillation. Other AEDs deliver biphasic energy in amounts that rise with a second and third "shock," remaining constant at the third level of energy for any subsequent energy deliveries. Obviously,

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