Pediatric AEDs: Children Are Not Just Little Adults

(Why Having a Pediatric-specific AED Does Matter)

Overview

When the American Heart Association's "Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care" was published three years ago, Automatic External Defibrillator (AED) use in children under the age of eight was not recommended. At that time, study results had demonstrated an AED's ability to accurately detect Ventricular Fibrillation (VF) for all ages under eight, however there were limited data regarding an AED's ability to distinguish shockable vs. non-shockable tachyarrhythmias in the infant and young child age groups. The latter concern relates to the possibility that sinus tachycardia (ST) or supraventricular tachycardia (SVT) in pediatric patients may be mistaken for shockable rhythms by an AED with an arrhythmia analysis program originally developed for evaluating adult arrhythmias.[1]

Cardiac arrest also represents only a small portion of the pediatric arrest cases, typically considerably less than 10%. The more common causes are asphyxiation or poisoning which are not initially treatable with defibrillation. Thus, an important factor in successful resuscitation is the ability of the rescuer to retain all aspects of the Chain of Survival, not just how to use an AED.

More recently, AED use in children under eight has been shown to be safe and effective [2][3][4]. In July of 2003, the American Heart Association provided an update which included the results of two studies demonstrating high sensitivity[1] for VF[2] and high specificity for non-shockable rhythms, primarily for children ages one to eight.[1] The update provided the evidence for the following recommendations:

- AED use in children (ages one to eight) is a Class I recommendation for VF and pulseless VT.
- AED use in the infant age group (under age one) is not recommended due to insufficient data on safety and efficacy. This will be clarified as future studies are completed.

[1] Sensitivity measures the ability of the AED to detect shockable rhythms.
[2] Specificity measures the ability of the AED to detect non-shockable rhythms.

- CPR is recommended for the first minute followed by AED application.

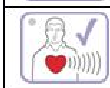
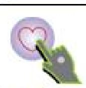
The use of AEDs in pediatric patients means that after cardiac arrest, it is no longer necessary to delay defibrillation of pediatric victims until the arrival of an EMT trained in advanced life support and the use of a manual defibrillator. Reduced time from the onset of cardiac arrest to the delivery of shock has been shown to be positively correlated with the rate of survival from cardiac arrest in adults.

It is a common notion with clinicians to “treat the patient, not the device being used to treat the patient.” This simple notion is particularly applicable to pediatric emergencies, since cardiac arrest represents only a small subset of all pediatric arrest cases. ZOLL Medical Corporation has taken just such a “treat the patient” approach to pediatric defibrillation by providing the only AED that:

- Is able to automatically detect whether the patient is a child by the type of pad used.
- Provides prompting for airway, ventilation, and circulation to treat the 90% of pediatric patients NOT in cardiac arrest.
- Uses an ECG analysis algorithm specifically designed for children’s ECG.
- Uses an optimized biphasic defibrillation waveform, unfiltered by attenuation resistors. The ZOLL Rectilinear Biphasic Waveform (RBW) is the only waveform that has been approved for use by the FDA to claim superiority to another biphasic waveform.

Prompting for Airway, Ventilation and Circulation

The ZOLL AED Plus is the only AED which provides prompting for the full Chain of Survival as shown in the chart below:

		AED Plus	Physio CR Plus	Philips On Site	Cardiac Science PowerHeart
	Check Response	✓	✗	✗	✗
	Call for Help	✓	✓	✗	✗
	Airway Support	✓	✗	✗	✗
	Check Circulation	✓	✗	✗	✗
	Attach Pads	✓	✓	✓	✓
	Stand Clear	✓	✓	✓	✓
	Shock / No Shock	✓	✓	✓	✓
	Instant CPR Feedback	✓	✗	✗	✗

As a subset of pediatric arrest cases, cardiac arrest due to ventricular defibrillation or tachycardia is typically considerably less than 10%. The more common causes are asphyxiation or poisoning which are not initially treatable with defibrillation. Thus, an important factor in successful resuscitation is the ability of the rescuer to retain all aspects of the Chain of Survival, including checking the airway and providing ventilations first before analyzing the ECG for possible need for defibrillation.

In recently completed studies presented at the National Association of EMS Physicians (NAEMSP) conference in Tucson, AZ in January, 2004, the benefits of full Chain of Survival prompting was shown.[6][7]
The studies compared the proportion of the steps of Chain of Survival performed by rescuers using the AED Plus with three other standard AEDs:

- Physio Medtronic Lifepak CR Plus
- Philips HeartStart OnSite

- Cardiac Science PowerHeart

45 people were tested:

- None ever trained on how to use an AED
- All trained in CPR in the last 1-to-5 years
- All "unsuspecting." Came to test site without being told research had to do with CPR, AEDs, or cardiac arrest

The test subjects were tested for performing the following steps:

1. Check responsiveness of victim
2. Seek help from EMS
3. Open **A**irway
4. Check **B**reathing
5. Give two ventilating breaths
6. Check **C**irculation
7. Remove clothing from victim's chest
8. Attach AED electrodes to victim's chest

Results:

AED	Number of Test Subjects	Steps Complete	Percent Complete	P-Value
Physio Lifepak CR Plus	11	3.5 ± 1.4	44%	0.017*
Cardiac Science PowerHeart	11	3.4 ± 1.9	43%	0.032*
Philips HeartStart On Site	12	3.8 ± 1.3	48%	0.038*
ZOLL AED Plus	11	5.0 ± 1.3	**63%**	

* Two-sided comparison with ZOLL AED Plus. P indicates statistical significance when less than 0.05. All comparisons are therefore statistically significant.

Conclusions:

- *“AEDs are easy to use, while CPR and the ABCs remain difficult to perform. Based on adherence to the Chain of Survival guidelines, however, those who used the ZOLL device performed significantly better than those who used the other devices.”* [6]
- *“… AED devices that provide support prompts for the Chain of Survival may help to achieve higher survival rates for out-of-hospital cardiac arrest.”* [6]
- *“New Chain of Survival prompts, designed for untrained laypersons, significantly increase the number of Chain of Survival steps performed by such persons when compared to presently available AEDs in the setting of simulated Out-of-Hospital Cardiac Arrest.”* [7]

ECG Analysis Algorithm Designed Specifically for the Pediatric Population

Children differ from adults as to the types and characteristics of shockable and non-shockable ECG rhythms. The lower incidence of VF in children indicates that they are more likely to have non-shockable rhythms than are adults [4]. It is important to correctly classify non-shockable high rate pediatric rhythms such as sinus tachycardia (ST), supraventricular tachycardia (SVT), and accelerated ventricular rhythms when presented to an AED used on a child. Adult-based AED arrhythmia analysis algorithms may have difficulty correctly classifying these high rate pediatric rhythms as non-shockable since the characteristics of the non-shockable pediatric rhythms overlap the shockable criteria used in the adult based algorithms. For instance, the defined heart rates of shockable ventricular tachycardia for those adult AEDs without specific pediatric criteria are defined as > 120BPM in one device and > 150BPM in two other devices.

ZOLL Medical Corporation has developed a dedicated pediatric AED arrhythmia analysis algorithm for use in the AED PLUS which correctly distinguishes shockable versus non-shockable pediatric rhythms. The AED PLUS detects the use of either pediatric or adult therapy pads and automatically adjusts the arrhythmia analysis processing for the appropriate patient type. The ZOLL AED Plus, when it has automatically switched to pediatric mode, performs a complex rhythm analysis (the criteria for which are shown in appendix A) and requires a heart rate for tachycardias of at least 200 BPM to be considered shockable.

Since SVT is a prominent pediatric arrhythmia, special efforts were made to gather a significant number of SVT rhythms during development of the ZOLL pediatric ECG algorithm. Adult-based algorithms typically consider high rate SVT as a shockable rhythm. However, small children can have perfusing rhythms at these same rates and should not be shocked. These non-shockable rhythms in the database included abnormal ventricular and supraventricular rhythms with rates up to 300 BPM, which are often found in infants and young children. Performance of the ZOLL pediatric arrhythmia algorithm on this database exceeded the performance recommendations of the AHA [5] published for adult AED arrhythmia processing algorithms. The use of separate processing algorithms provides the means to retain a high rate SVT in adults as a shockable rhythm while providing for pediatric SVT to be classified as non-shockable.

Although it is subject to the specifics of a given database, the ZOLL analysis algorithm demonstrated superior performance as compared to the performance reported in other pediatric AED studies that were based on the evaluation of adult-based algorithms on pediatric ECG signals.[2][3]

Comparative Reported Sensitivity of Pediatric Advisory Algorithms

Rhythms	AHA Goal	ZOLL	AED A	AED B
Shockable:				
Coarse VF	> 90 % sensitivity	100 % (42/42)	94.3% (50/53)	98.6 (71/72)%
Rapid VT	> 75 % sensitivity	93.9 % (77/82)	70% (21/30)	Insufficient data (3 shockable VTs only)
Non-shockable:				
NSR	> 99 % specificity	100 % (208/208)	100% (374/374)	99.2 (792/798)%
SVT (Heart rates 152 – 302 BPM)	> 95 % specificity	99.4 % (160/161)	Insufficient Data	Insufficient Data

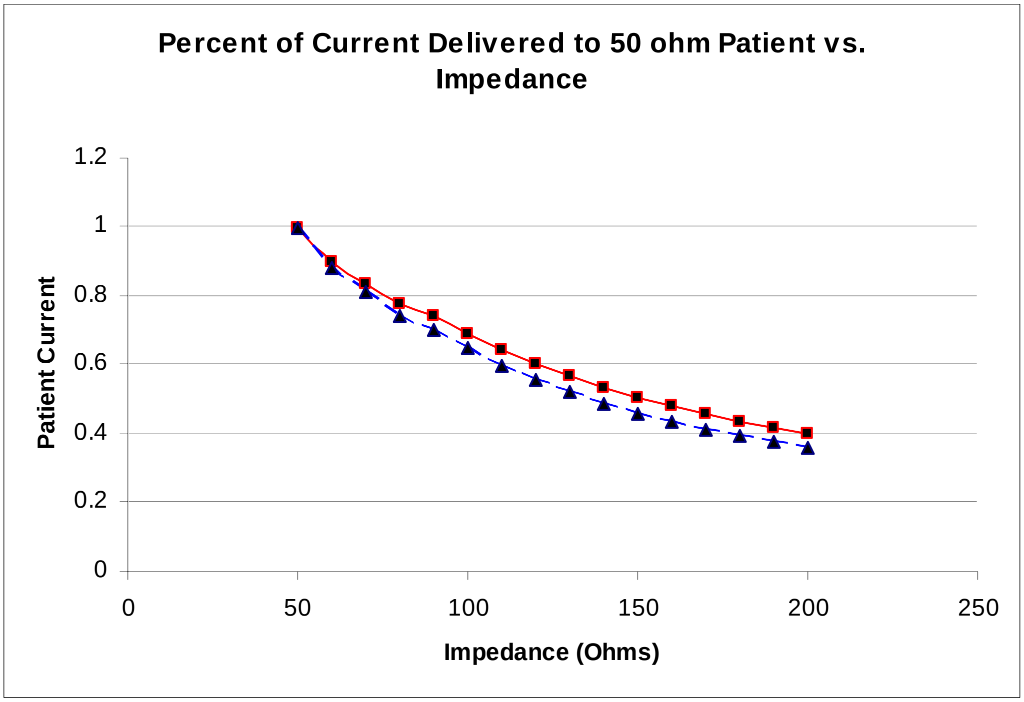
Contrary to the previous pediatric AED studies [2][3], shockable and non-shockable VT rhythms were more prominent than VF in our data collection. The database contained 122 records of shockable and non-shockable VT as compared to 42 records of VF. The ability of the dedicated pediatric algorithm to detect these rhythms and recommend the appropriate therapy is a significant improvement over adult-based algorithms. The increased sensitivity in the detection of shockable VT's will reduce the time to cardioversion and return to spontaneous circulation. The increased specificity in the detection of non-shockable VT's will avoid unnecessarily shocking a pediatric patient not needing defibrillation therapy.

Biphasic Defibrillation Optimized for Children

Contrary to what you might expect based on common sense alone, pediatric patients, while having a smaller thoracic circumference, actually have higher defibrillation impedances. Published work by Atkins has shown that average impedances of pediatric patients are 90 ohms [4], approximately 20 ohms higher than adult patients. This is due primarily to the smaller area of pediatric electrodes. As a result, impedance compensation methods actually become more important in the pediatric population.

Other AEDs which use circuits to attenuate the energy delivered to pediatric patients (the bulge that you see on the wires of their pediatric pads) put resistors in between the defibrillator and the patient. This has two negative effects:

1. The AED has no ability to distinguish between the resistors in the wire and the impedance of the patient and, as a result, the AED's ability to compensate for patient impedance – an important part of a waveform's efficacy – is compromised.
2. In some AED pediatric systems, a resistor that shunts current away from the child is used to attenuate the energy. This method has the negative affect that as patient impedance increases, proportionally more and more current is steered away from the patient – exactly the opposite of what biphasic defibrillation impedance compensation methods are attempting to accomplish. The figure below shows the amount of current delivered to a pediatric arrest patient as a function of the patient's impedance compared to how much would have been delivered to a patient with 50 ohms. The two curves are for commercially available AED pediatric defibrillation systems. As can be seen, in the figure, 40% of the current is lost to the patient for an impedance of 100 ohms – a typical one in the pediatric population, and nearly half of the current is not delivered to the patient for an impedance of 150 ohms for both AEDs.



Conclusions:

An AED designed to specifically treat the pediatric patient can provide significant benefits to the pediatric arrest patient, with better CPR skill performance by rescuers, faster treatment of the preponderance of presenting pediatric clinical conditions, better accuracies in ECG analysis, and better optimized biphasic defibrillation.

Appendix A: AED Pediatric Rhythm Definitions

Shockable Rhythm Definitions	
Ventricular Fibrillation (VF) - 1	Uncoordinated ventricular depolarizations. Minimum of 5 complexes with an average > 0.2 mVpp. during a 3 second window.
Rapid Ventricular Tachycardia (VT) - 2	Absence of P waves. Rate > 200 beats per minute (R-R interval <= 300 milliseconds). QRS Complex width > 160 milliseconds. Includes monomorphic or polymorphic VT, and ventricular flutter. Minimal (or no) isoelectric activity.

Non-shockable Rhythm Definitions	
Normal Sinus Rhythm (NSR) - 3	Complexes are sinus in origin. Does not satisfy the criteria of supraventricular arrhythmias.
Supraventricular Tachycardia (SVT) - 4	Complexes show a supraventricular origin. Rate > 180 bpm. QRS duration < 120 milliseconds. R-R interval variability < 20%.
Supraventricular Arrhythmias (ABN) - 4	Other supraventricular arrhythmias that do not qualify as NSR or SVT with or without AV block and bundle-branch block **(BBB)**. Includes Atrial Fibrillation **(AF)**, Atrial Flutter **(AF)**, Junctional Rhythms, Sinus Rhythm & Arrhythmia **(SA)** with or without Premature Atrial **(PAC)**, Premature Junctional **(PJC)**, or Premature Ventricular **(PVC)** Contractions. Complex width < 160 ms.
Idioventricular Rhythms (ABN) - 4	Ventricular complexes only, no supraventricular complexes. Monomorphic or polymorphic. Rate < 100 beats per minute. At least 1 complex > 0.3 mVpp.
Asystole (ASY) - 5	Absence of consistent electrical activity of at least 0.1 mVpp amplitude.

Intermediate Rhythm Definitions	
Fine VF (FVF) - 6	Uncoordinated ventricular depolarizations with a minimum of 5 complexes with an average > 0.1 mVpp and < 0.2 mVpp.
Intermediate VT (OVT) - 7	QRS duration > 160 milliseconds. Absence of P waves, or AV dissociation if P waves present, Ventricular complexes only. Rate < 200 bpm and > 100 bpm (the idioventricular rate). Includes monomorphic and polymorphic VT.

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