ACFASP Scientific Review

Infant AED

American Red Cross Advisory Council on First Aid, Aquatics, Safety and Preparedness

Overall Recommendation including any Standard, Guideline or Option:

Standards: Minimally trained witness defibrillation programs are effective in reducing mortality in infants from birth through childhood from sudden cardiac arrest. (Class II)

Guidelines: None

Options: None

Questions to be addressed:

Should an Automated External Defibrillator (AED) be Used on an Infant in Cardiac Arrest?

Introduction/Overview:

Ventricular fibrillation (VF) is the primary cause of sudden cardiac death in adults. While VF is less common among children, as many as one quarter of pediatric out-of-hospital arrests are from VF[1, 2], with a similar number from in-hospital cardiac arrests.[3] Importantly up to 14% of case of VF in children will occur in those less than one year of age.[4] Importantly, survival and survival with good neurological outcome are significantly better when VF is the presenting rhythm compared to asystole.[1, 5, 6]

Prompt defibrillation is crucial for survival of patients with VF.[7, 8] Estimates from adult out-of-hospital arrests suggest that survival decreases as much as 10% for each minute defibrillation is not performed.[9, 10] Automated external defibrillators (AEDs) have been successfully used to improve time to defibrillation and survival in many settings[11-15]

The American Heart Association (AHA) and the European Resuscitation Council recommend the use of AEDs for pediatric patients > 1 year of age for out-of-hospital arrests, and training on the use of AEDs is part of the AHA courses on pediatric basic and advanced life support. [16] The American Academy of Pediatrics Committee on Pediatric Emergency Medicine and Section of Cardiology and Cardiac Surgery recently released a technical report on AEDs and recommended their use for infants. [17, 18] AEDs that deliver energy dosages that are attenuated for children are preferred; however, using AEDs that deliver adult energy dosages are acceptable if there is no other AED available.

The specific question to be addressed here is whether the use of AEDs should be extended to infants (i.e. those < 12 months of age). The primary concerns about the use of AEDs in infants and children have revolved around (1) concern for the accuracy of AEDs in detecting arrhythmias in children and (2) the safety of the large energy dose delivered.

Summary of Scientific Foundation:

1. **Accuracy of AEDs for Infants Children.**

There are several studies that have evaluated the accuracy of AEDs for detecting arrhythmias in children. Checcin et al. evaluated the adult algorithm from the ForeRunner AED (Agilent, Heartstream) in children < 12 years-old.[19] Many of the heart rhythms analyzed were collected prospectively, but some of the rhythms were retrospectively acquired and then tested against the AED algorithm. There were 74 total patients < 1 year old. The sensitivity of the AED for VF in infants (i.e. appropriately recognizing VF and recommending a shock) ranged between 93 to 100%. The sensitivity for rapid ventricular tachycardia (VT) ranged from 50 to 100%, although there were only 6 patients studied. Importantly the specificity for nonshockable rhythms (i.e. not recommending a shock where a shock is not warranted, such as sinus tachycardia) was 100% in the 208 rhythms evaluated.

In a similar study by Atkinson et al., heart rhythms were collected from infants and children from the intensive care unit, electrophysiology laboratory and operating room.[20] Samples from the rhythms collected were analyzed against the adult AED algorithm from the Lifepak 500 (Medtronic Physio-Control Corporation). The study included 96 infants. The sensitivity for VF was 100% in 39 samples. The specificity of nonschockable rhythms was also > 95% with the AED only recommending a shock in 7 of the 810 nonshockable rhythms. Of note, 6 of the 7 rhythms occurred in one child that was < 1 month of age.

In a recent study by Atkins et al., a pediatric algorithm was tested against an adult algorithm from the Zoll AED. [21] Heart rhythms were collected during electrophysiology studies and then tested against the AED algorithm. There were 31 infants in the study. The results are not broken down by age group, but the sensitivity for of the AED algorithm for VF ranged from 100% (pediatric algorithm) to 97.6% (adult algorithm), and the sensitivity for rapid VT ranged from 94.9% (pediatric algorithm) to 98.7% (adult algorithm). Additionally, the pediatric algorithm had a specificity of 100% for not recommending a shock for sinus rhythm and asystole, and specificity of 99.6% for supraventricular tachycardia. This was slightly superior to the adult algorithm which had a specificity for supraventricular tachycardia of 87.1%. Importantly, the Zoll AED automatically uses the pediatric algorithm if the pediatric pads are applied.

There have also been a few case reports on the use of AEDs in infants. One describes the successful use of a Phillips HeartStart Home Defibrillator (Phillips Medical Systems) with pediatric pads.[22] The AED appropriately recognized VF and delivered 50J, which successfully defibrillated the infant. The authors state that there was no evidence of significant injury to the child. An additional case report describes a 8.6 kg child that was defibrillated with a M-series defibrillator that was modified by Zoll to work as an AED and shock with an appropriate weight based dose.[23] The AED correctly identified the heart rhythm and provided three shocks which eventually terminated the VF.

2. **Safety of AEDs in Infants and Children.**

The optimal energy dose for defibrillation in infants and children, both from an efficacy and safety standpoint, is not known. The longstanding recommendation from the American Heart Association to defibrillate at 2 - 4 J/kg is based on one retrospective study of 27 children.[24] Dr. Gutgesell and colleges demonstrated that most children successfully defibrillated were defibrillated at 2 J/kg with the remainder of those successfully defibrillated at up to 4 J/kg. While this study was certainly a landmark one to demonstrate an effective dose for defibrillation, it failed to demonstrate what energy dose would be safe to deliver to children. AEDs deliver 150 to 200 J of energy for the first shock without pediatric pads and 50 J with pediatric pads, and most infants weigh < 12 kg. Thus, the doses delivered by the AED will be considerably larger than the recommended doses by the American Heart Association.

Data from animal studies do not provide a consistent dose that may be extrapolated to pediatric patients in order to determine a safe dose. Babbs et al. demonstrated in dogs that histological evidence for myocardial damage was seen at a median dose of 30 J/kg, which was significantly higher than the median dose for successful defibrillation of 1.5 J/kg.[25] Rats, however, only survived 5 hours on average after a shock of 40 J/kg, but survived > 24 hours after a shock of 4 J/kg.[26] There are some data to suggest that the infant myocardium may be more tolerant of higher energy doses. In newborn piglets, there was not histological evidence of myocardial damage until cumulative energy doses of ≥ 150 J/kg.[27] These energy doses are more than those reported in adult and older children animal models,[28-30] and may be related to the lower thoracic impedance found in smaller children. Importantly, these studies suggest that there is a large margin of effective doses (i.e. beyond 4 J/kg) before toxic doses are achieved.

Standard defibrillators and AEDs currently manufactured today deliver biphasic energy, whereas the previously described studies were of defibrillators that deliver monophasic energy. This distinction is important because defibrillation with biphasic energy results in less myocardial damage at a given energy dose, and may result in more effective defibrillation at a lower energy dose [29, 31-35] Tang et al. demonstrated in a piglet model that 50 J shocks of biphasic energy (up to 3 shocks) could successfully defibrillate all subjects, including those weighing as low as 3.8 kg.[36] Hemodynamic status and myocardial function was depressed initially after resuscitation, but returned to normal is all animals by 4 hours post-resuscitation. Berg et al. randomized piglets to weight based monophasic defibrillation (2-4 J/kg) or biphasic energy (50-81 J/kg) in a VF model (insert reference). Subjects randomized to the biphasic energy required fewer shocks for defibrillation and had as good or better myocardial function after resuscitation compared to those randomized to monophasic energy.[35] In an additional study by Berg et al., piglets were randomized to sequential biphasic of energy 200/300/360 verses 50/75/86 after 7 minutes of untreated VF.[30] This study was to simulate the difference of using a standard defibrillation doses from and AED to doses received using pediatric pads with and AED. In this study, subjects receiving the lower energy dose had fewer elevations in cardiac enzymes, less depression of ventricular function, and improved survival with good neurological outcome at 24 hours post-arrest.

There are very limited human data to describe the safe defibrillation dose in infants and children. The case reports describing the use of AEDs on infants are described above. Additionally, Atkins and Jorgenson reported on the use of an AED with pediatric pads in 27 patients, of which 8 had VF (age 4.5 months to 10 years).[37] The AED successfully terminated VF in all cases and 5 survived to hospital discharge. Gurnett and Atkins reported the use of an AED on a 9 year old child, which successfully defibrillated at 150 J without apparent toxicity to the child.[38] Rossano et al. reviewed the energy doses used for defibrillation in 57 cases of VF, 14% of which were infants.[4] Most of the children in this study received energy doses at or near the doses recommended for adults. In the study, weight was estimated based on the age of the patient. When doing this 24% of the shocks were appropriate (2-4 J/kg), 51% were moderately high (4-6 J/kg), and 33% were high (>6 J/kg). There was no relation between energy dose delivered and survival. This study suggests that there are probably more important factors for survival of VF (e.g. prompt defibrillation) than energy dose.

3. Recommendation:

The American Academy of Pediatrics supports the recommendation of using AEDs in infants. There is limited clinical evidence from clinical studies to support this recommendation. The recommendation is primarily by expert opinion with the limited human and animal data listed above.

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