Cardiac Arrest in Children and Young Adults: We Are Making Progress

Running title: Atkins; Cardiac arrest: We are making progress

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Thirty years ago, sudden cardiac arrest (SCA) in children and young people was called a rare event.\textsuperscript{1,2} Etiologies were thought to be primarily respiratory and resuscitation efforts were directed at restoring ventilation or oxygenation. Most studies were limited by incomplete data collection including in-hospital and out-of hospital arrest, and small study size. Outcomes were so dismal that resuscitation was considered futile by some\textsuperscript{3,4}. In 1995, Mogayzel et al\textsuperscript{5} published a ground-breaking article on ventricular fibrillation in children ages 5-18. They documented that ventricular fibrillation occurred at some time during a resuscitation in 19% of cardiac arrests in children in the Seattle/King County area and 17% were discharged with good neurologic outcomes, compared to 2% of those with asystole. This study coincided with the availability of automated external defibrillators (AEDs) in the community, and led to a re-consideration of the need for early assessment of rhythm in pediatric cardiac arrest and development of AEDs with pediatric modifications. Over the last 20 years, there has been increasing documentation of cardiac arrest in children.\textsuperscript{6-9} A major shortcoming in most of these studies is inclusion of all non-traumatic causes cardiac arrest when incidence is calculated. This has been a major deficiency in pediatric cardiac arrest literature as most include non-cardiac etiologies such as suffocation, drowning, drug overdose.\textsuperscript{6,7,10} Inclusion of multiple etiologies in the incidence data rendered them difficult to interpret when attempting to establish the appropriateness of CPR techniques, screening and prevention programs, treatment algorithms, and especially outcomes.

Meyer et al. have made a significant contribution to our understanding of cardiac arrest in children and young adults < 35 years of age.\textsuperscript{11} The investigators specifically evaluated cardiac etiologies and calculated incidence and outcomes of cardiac arrest in their target population over the 30 year period from 1980 to 2009. The definitions used to select the patient population are most consistent with those of adult studies focusing on SCA, and do not include sudden infant
death syndrome (SIDS,) respiratory etiologies or other non-traumatic causes of cardiac arrest.

The investigators based the assessment of cardiac etiologies on a review of the emergency medical systems (EMS) documentation, defibrillator recordings, hospital records when available, autopsy reports and death certificates. Etiologies were sub-classified into the specific cardiac etiologies that affect young people: electrical, cardiomyopathy, congenital heart disease, and atherosclerotic coronary artery disease, other and unspecified. The strengths of this study include the complete, population-based, long-term data collection that has characterized the King County EMS agency. The thorough assessment of etiology provides significant validity and utility to the data.

The most important messages of this study are the calculation of incidence of true SCA stratified by age, and documentation of improved outcomes in all age groups over the 30-year study period. SCA is more common than expected in this population with an average incidence of 2.28/100,000 person-years. Incidence increases with age, with the highest in the 25-35 year group at 4.40/100,000 person-years. The most encouraging information is that survival has markedly improved over the 30 year period, although incidence, age distribution, etiology, and response times were not different. Importantly, this study provides relative frequencies of the cardiac etiologies. Primary electrical disorders and cardiomyopathies, associated with the best survival, are the two most common cardiac etiologies. Additionally, cardiac arrest associated with exercise has better outcomes, although the authors acknowledge that this group is not comparable to studies evaluating competitive athletes.

How do we respond to this new information? The authors suggest that the data promote the development of primary prevention programs for this population. This typically involves a screening program using ECGs or echocardiograms for large populations. The literature is
extensive and highly controversial. In Italy, all competitive athletes are required to have ECGs prior to competition. Although reported to be highly successful at preventing sudden death, other large-scale screening programs have not been effective.\textsuperscript{12-16} Currently the American Heart Association does not recommend screening programs, citing lack of sensitivity, cost and manpower requirements as major barriers. A National Heart Lung and Blood Institute panel concluded that current evidence was insufficient to generate recommendations, but rather outlined the questions which require answers.\textsuperscript{17} The first of these is an accurate estimate of the true incidence of cardiac arrest, which this study provides and suggests that the incidence may justify population-based screening. The panel also recommended pilot programs to clarify the best screening strategies, (specific testing methods and selective versus universal screening), and ascertain clinical impact and outcome.

Several recent studies add additional information to fill evidence gaps. Zeltser et al\textsuperscript{18} report the results from a state-funded screening program in Texas using health questionnaires, physical examinations, electrocardiography and limited echocardiograms. Health questionnaires were of limited value. Of 2506 students screened, 11 were identified as being potentially at risk for SCA. Interobserver agreement was 100\% for electrocardiography, (all ECGs were interpreted by pediatric electrophysiologists), but only79\% for echocardiography. Surprisingly, only 67\% of those with abnormal initial screening tests sought follow-up evaluation. Leslie et al\textsuperscript{19} published a simulation study and cost-benefit analysis of history, physical examination and ECG screening. The study was limited to two groups considered at higher risk for SCA: competitive athletes ages 8–14 years and children initiating stimulant therapy for attention deficit disorder. The algorithms were constructed for children at age 8 years initiating stimulants for ADHD and those age 14 years beginning competitive athletics. Cardiac diagnoses were limited
to hypertrophic cardiomyopathy, Wolff-Parkinson-White syndrome and long QT syndrome. The investigators concluded that cost was high relative to health benefits. The reduction in sudden death was $5.7 \times 10^{-5}$ and life expectancy increased by 0.8-1.6 days/screened individual. The incremental cost per life year saved was $91-$204,000. Another small study evaluated the accuracy of 53 experienced pediatric cardiologists to interpret 18 ECGs obtained from normal children or those with known cardiac disease placing them at risk for SCA. The average number of correct interpretations was 12 (69%). Inappropriate exercise (participation or restriction) guidance was given to approximately 20% of the patients. This demonstrates the difficulty of screening programs for heart disease since the tests do not have a simple yes/no answer, but rather are often dependent on operator skill and experience.

Concern has been voiced about the impact of false positive screening with overutilization of additional testing. However, false negative tests are also a problem. Several of the at-risk diseases are “silent” without ECG or echocardiographic abnormalities, including several electrical abnormalities and atherosclerotic coronary artery disease, the most common cause of death in the 25-35 year old group. Others are easily missed or require expert consultation including long QT and arrhythmogenic right ventricular dysplasia. Although screening programs could be beneficial, we must recognize that we need improved standards and even the best programs will have considerable limitations.

This study by Meyer et al does demonstrate that we can improve survival from cardiac arrest by enhancing systems which are already in place. The combination of a population motivated to provide bystander CPR and a well-organized, effective EMS system resulted in marked improvement of survival over this 30 year period. This time period, especially since 2005, also coincides with improved scientific basis for CPR and post-resuscitation care.\textsuperscript{21}
Survival doubled in the pediatric population in the 5 years after the 2005 CPR guidelines were instituted compared to the 5 years just prior to this. But these results are not typical. The Resuscitation Outcomes Consortium (ROC) recorded overall survival of only 6.4% in a pediatric population.\textsuperscript{6} Nichol et al described a broad range of survival from 8% to 40% within the multiple EMS agencies participating in the ROC.\textsuperscript{22} We can improve cardiac arrest outcomes and communities, and agencies should be accountable for their outcomes and work to achieve results comparable to these.

This investigation by Meyer et al is characteristic of most pediatric resuscitation studies: retrospective analysis of database information. Common methodologies include simulation/mannequin or small cohort studies. There are almost no prospective human trials of pediatric CPR, resuscitation techniques or post-resuscitation care. CPR guidelines, including the changes in 2005 that are associated with the improved outcomes in this study, are primarily developed by extrapolation from adult studies. Yet, virtually every article, including this one, begins with a statement about the devastating nature of SCA in young people. The victims are often thought to be healthy, and the magnitude of years of life lost is substantial, resulting in a shattering effect on the family and community when a young person suffers SCA. However, the presumed rarity of these events, multi-factorial nature of the events and the need for large multi-center trials has hindered the conduct of studies compared to adult trials. The data presented in this report establishes that these events are not rare. As this study demonstrates, high survival rates can be achieved and good neurologic outcomes are possible.\textsuperscript{23,24} The Pediatric Emergency Care Applied Research Network funded by Emergency Medical System for Children (EMSC) of the Maternal Child Health Bureau has developed a successful model to support such studies and is conducting a large trial of post-cardiac arrest hypothermia therapy in children.\textsuperscript{25}
resuscitation community should be supported to develop well-designed pediatric trials and urge funding agencies to support them. SCA in the young is a public health problem that can be approached in ways that lead to improved outcomes.

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**References:**


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