The Impact of Integrating Emergency Dispatch Systems with Public Automated External Defibrillator Locations:

A Systematic Review of the Literature and an Original Research Study Design

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Abstract

Background: Out-of-hospital cardiac arrest, most commonly due to heart disease, kills as many as 450,000 people each year in the United States. Devices called automated external defibrillators can detect if this condition is due to an abnormal heart rhythm, and if so, can deliver a timed electrical shock. Though the use of defibrillators by the public is known to be both safe and effective, the impact of their integration into the 9-1-1 system remains unclear.

Objective: To systematically review evidence on the effect that incorporating public defibrillator locations into the 9-1-1 dispatch system has on survival rates from out-of-hospital cardiac arrest, and to design a research study to evaluate this relationship.

Methods: To systematically review the evidence, this author searched the MEDLINE, CINAHL, EMBASE, and The Cochrane Library (January 1, 2000 to May 1, 2011) using MeSH terms such as “automated external defibrillator” and “emergency medical services.” Additional articles were identified through a bibliography search of selected articles. To design an original research study, this author used both the results of the systematic evidence review and previous studies conducted in the medical literature to specifically address public defibrillator integration.

Results: The initial systematic review of the evidence yielded 128 citations. After review of the abstracts, 6 articles were identified for full text review. After applying inclusion and exclusion criteria, all of the articles were excluded. Manual review of two selected bibliographies revealed an additional article selected for a full text review; it was subsequently excluded. The systematic evidence review resulted in no articles meeting inclusion criteria for data analysis, leading this author to design a research study to answer the clinical question.

The proposed study design is a multiphase before-after cohort occurring over 60 consecutive months in Orange County, NC. The study population includes all patients with out-of-hospital cardiac arrest from a cardiac etiology over 18 years of age treated by EMS. Phase 1 will serve as a lead-in period to bring the EMS agency up to full implementation of the 2005 AHA guidelines over 12 months. Phase 2 will be a baseline control period over 24 months. Phase 3
will serve as an intervention period with an integrated emergency dispatch system in addition to the 2005 AHA guidelines over 24 months. Primary outcome will be survival to discharge.

**Conclusion:** In the context of evaluating the impact that incorporating public defibrillator locations into the emergency dispatch system has on survival to discharge from out-of-hospital cardiac arrest, the medical literature suffers from a lack of evidence. The studies identified through the literature search did not completely address this issue; thusly, no inference can be made about causality at this time. Further research is required to determine the effect that an integrated 9-1-1 system has on survival.
A Systematic Review of the Medical Literature
Introduction

Purpose

The integration of publically located automated external defibrillators (AEDs) with the 9-1-1 emergency dispatch center and EMS systems is poorly studied. Existing reports suggest that integration between EMS systems and public AEDs is limited\(^1,2\). For example, in North Carolina in 2002, only 19% of all AED locations were known to EMS systems and only 1 of 100 counties had AED locations incorporated into computer aided 9-1-1 dispatch systems\(^1\).

The purpose of this paper is to perform a systematic review of the literature to evaluate if the integration of registered public AED databases with the 9-1-1 emergency dispatch system improves survival from out-of-hospital cardiac arrest (OHCA). I plan to answer the question: Does the incorporation of public AED location databases with the emergency dispatch system in addition to full AHA compliance improve survival to discharge rates from out-of-hospital cardiac arrest as compared to systems operating with full AHA implementation only? Knowing this answer will help EMS systems determine if such integration would be possible and necessary to enhance the current level of care they provide.

Background

Cardiac arrest is the cessation of normal circulation of the blood due to failure of the heart to contract effectively\(^3\), leading to sudden unconsciousness. When this occurs in a setting away from the hospital, it is referred to as out-of-hospital cardiac arrest (OHCA), something that happens to as many as 450,000 people each year\(^4\). The normal electrical rhythm of the heart flows from top to bottom in a manner that allows blood to pass through each part then out to the
rest of the body. If this normal rhythm is disturbed, resulting in something known as an
arrhythmia, cardiac arrest and eventually cardiac death can occur.

One lethal arrhythmia, known as ventricular fibrillation or simply VF, leads to an overall quivering of the myocardium instead of a coordinated contraction. When this life-threatening arrhythmia occurs, AEDs can be used to increase the chances of resuscitation from cardiac arrest. AEDs are small, easy to use devices that can be employed by the trained and untrained alike when someone is found to be unconscious from suspected OHCA\(^5\). AEDs are able to detect if a person is in VF, and if so, deliver a timed electrical shock to allow the heart to regain a normal rhythm.

Unfortunately, the public has no way of knowing if any particular location has an AED, or where it is precisely located. While many instances of OHCA occur at private residences instead of highly traveled public places, one study shows that VF and other shockable rhythms occur more frequently in public areas, suggesting that AEDs are best placed in these areas and not in private homes\(^6\).

**Cardiac Arrest**

As previously mentioned, OHCA occurs to nearly half a million people each year in the United States. Both the incidence and mortality of OHCA varies significantly from one geographic region to another\(^7\). Nichol and colleagues report evidence supporting the fact that health disparities have a dramatic impact on cardiac arrest. For instance, Dallas, TX has the highest incidence and mortality rates of OHCA, 159.0 and 153.2 per 100,000 respectively, whereas areas like Portland, OR have less than half those rates at 77.5 and 71.4 respectively\(^7\).
Over 280,000 of the 450,000 cases of cardiac arrest each year are caused by coronary heart disease (CHD), which affects over 17 million American adults and results in over 1 million heart attacks each year\textsuperscript{8,9}. The prevalence of CHD hints at the impact it has on the American way of life, even the entire nation and its economy. CHD was responsible for almost 2 million short-stay hospitalizations in the past year alone, with almost half a million bypass surgeries. In all, CHD leads to an estimated $177 billion each year in both direct and indirect cost\textsuperscript{8}. Other causes of cardiac arrest include cardiac abnormalities such as cardiomyopathy and congestive heart failure.

Although cardiac arrests are usually sudden with little or no warning, many risk factors exist and are similar to those associated with CHD. Smoking, diabetes, and a lack of physical activity have all been shown to increase one’s risk of heart disease. Perhaps the largest risk factor is age, something that most physicians agree serves as a red flag, mainly because the incidence of CHD and the presence of other risk factors tend to increase as we age. Decreasing one’s risk by exercising, smoking cessation, and having a healthy diet all help prevent cardiac arrest. Blood pressure and cholesterol control can also serve as therapeutic ways to decrease risk.

**Automated External Defibrillators**

When someone enters cardiac arrest, bystanders can apply an AED to the chest of the victim and the device will determine if it should deliver an electric shock or “defibrillation.” The purpose of defibrillation is to stop the chaotic electrical activity of an arrhythmia, allowing the heart to “reset” itself. This is different from cardiopulmonary resuscitation (CPR) in that CPR focuses mainly on the mechanical operation of the heart, i.e. contractions. In some systems, AED use has been shown to double the survival to discharge rate in OHCA when combined with
bystander CPR as compared to CPR alone. Knowing the history of AEDs, how they work, and how they are used is important, but this will not be addressed in detail here.

Time to first defibrillation is the single most important predictor of survival, meaning the quicker an AED is utilized for a person in OHCA, the better their chances of living. Survival drops 7-10% for each minute that a person in arrest goes without defibrillation. Additionally, prior research has shown that only approximately 8% of individuals who suffer OHCA will survive to hospital discharge.

The geographic placement of AEDs is unknown. In recent years, public buildings and athletic facilities, as well as airports and casinos, have begun to mount AEDs in public places for use by the lay public. Some have suggested that planners use fire extinguisher placement as a rough template for where to put an AED, but this has been shown to be problematic and too costly. A better solution could be to place AEDs in areas with a known history of having cases of OHCA, areas also known as being at “high-risk” of having an event. Investigators have attempted to identify these high-risk locations for OHCA. While the majority of OHCAs occur in private residences, locations with high population density (e.g. apartment complexes, nursing homes) and locations with high traffic volume (e.g. shopping malls, sports facilities, public transportation stations) may be public sites of primary importance for AED placement.

**Public-Access Defibrillation**

*Public access defibrillation* (PAD) is a concept that provides for the placement of AEDs in frequently traveled public places where bystanders are more likely to encounter someone in cardiac arrest. These places include shopping malls and apartment complexes, which due to their high traffic volume are more likely to be a location with an OHCA. Unfortunately, lay responders frequently are unaware that an AED is nearby and available.
The success of PAD programs hinges on both the knowledge and attitude of the public towards AEDs. Schober and colleagues have shown that in Amsterdam, the public is largely unaware of the availability of public accessible defibrillators. That same study revealed that 64% knew what a defibrillator is used for when asked, but only 6% spontaneously mentioned its use as something that should be done in a suspected cardiac arrest. Despite this, other studies have shown that the usage rate of AEDs by their owners in public locations has remained high at about 13%, and AEDs were frequently taken to suspected cases of OHCA.

Weisfeldt and colleagues report that bystander application of an AED prior to EMS arrival is associated with an increase in survival from 9% to 24%. Other studies also indicate that defibrillation by the lay public is efficient, safe, and cost-effective. However, the life-saving capability of AEDs is for naught if the public does not know where the machine is located. An AED may be just around the corner but unless the lay responder knows this, the device is useless. Almost all cardiac arrests necessitate a 9-1-1 call; if the 9-1-1 center had knowledge of AED locations, then lay responders could be directed to the nearest AED for use during an OHCA.

**Chain of Survival**

In 1992, the *American Heart Association* (AHA) adopted a resuscitation process known as the chain of survival, its goal being to save more lives during cardiovascular emergencies. The process is as follows: recognize an emergency, call 9-1-1, begin CPR, and use an AED. Their axiom of “early access, early CPR, early defibrillation” serves as a reminder of the importance of these three simple steps during an emergency. The goal of PAD programs is to increase the supply of AEDs available to the public for this very reason, leading to higher rates of early defibrillation. Gold and colleagues have shown that the longer an individual in cardiac
arrest goes without defibrillation, the lower their odds of survival\textsuperscript{20}. If PAD programs are able to accurately identify key locations at high-risk for having a cardiac arrest, placement of AEDs can be carried out and the public informed.

**Identification of High-Risk Areas**

Effective geographic placement of AEDs is a critical step in having a successful PAD program. The PAD trial in 2004 identified high-risk areas as those with at least 250 adults over 50 years of age present for at least 16 hours per day, or have a history of at least 1 witnessed sudden cardiac arrest every 2 years\textsuperscript{21}. Since 2005, the AHA has recommended strategic deployment of AEDs in these areas, with unguided placement often resulting in an inadequate supply of AEDs\textsuperscript{22}. In other words, unguided placement with a limited supply of devices would put defibrillators in areas where they are less needed, leaving fewer devices in high-risk areas.

The determination of AED placement in residential areas has proven to be more elusive, with demographic analysis taking the place of population density. Where the desired effect is to reach those at highest risk in a community, demographic analysis may be a useful method when determining placement of AEDs in residential areas beyond what population density analysis may provide. Research shows that age, education, and income are useful characteristics when identifying both public and residential high-risk areas\textsuperscript{23}. Folke and colleagues point out that no single characteristic should be used solely to determine the exact placement of an AED. Interestingly, the demographic factors that identify a neighborhood as being high-risk are the same risk factors that lead to poor outcomes, such as lowest education level and highest mean age\textsuperscript{23}. 
The 2005 American Heart Association Guidelines

The 2005 update of the *AHA Guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care (ECC)* resulted in a new emphasis being placed on three areas: chest compressions, strict control of ventilation, and postresuscitation support\(^{24}\). The changes included a 30:2 compression-to-ventilation ratio instead of 15:2, the use of airway impedance devices to avoid hyperventilation, and the induction of hypothermia in indicated cases. The goal of each area is to increase survival from OHCA using the best evidence available.

Evidence shows that a full and sequential implementation of the 2005 guidelines dramatically increases survival to discharge rates in cases of OHCA\(^{25,26,27}\). Hinchey and colleagues reported an increase in overall survival from 4.2% at baseline to 11.5% at full implementation. Sayre and colleagues describe a 54% increase in survival (from 6.1% to 9.4%); post-guidelines patients had 1.8 greater odds of survival as compared to pre-guidelines patients. Lick and colleagues describe an even larger increase in survival rate from 8.5% to 19%. These results show that a phased full implementation of the 2005 AHA guidelines can significantly increase survival to discharge from OHCA.

**What We Need to Know**

In summary, evidence suggests that in order to maximize survival from OHCA, an emergency system needs to do the following: fully implement the 2005 AHA guidelines, identify areas at high-risk for having cardiac arrest events, and develop an efficient PAD program that places AEDs in public high-risk places. What we do not know is if going the extra step of registering all public AEDs with EMS and the 9-1-1 dispatch system will further improve survival.
Methods

Focus

The focus of this systematic review is to answer the following question: Does the incorporation of public AED location databases with the emergency dispatch system in addition to full AHA compliance improve survival to discharge rates from out-of-hospital cardiac arrest (OHCA) as compared to systems operating with full AHA implementation only? Past studies have focused primarily on the effectiveness of AEDs in treating cardiac arrest and what locations would most likely benefit from having an AED. Although these factors are important, simply placing AEDs in areas of high population density or where there is heavy pedestrian traffic does not give us the full picture of how these machines could impact patient outcomes.

This paper will not be reviewing literature that explains how AEDs work, how they are used, their use by the public, or what geographic areas would benefit most from their placement. All of the literature mentioned previously, though crucial in nature, does not precisely answer the key question of this paper. Emergency medical services communication systems, also known as the 9-1-1 dispatch system, operates on software that is not uniformly or universally combined with registered AED location databases in a manner that allows the emergency dispatcher to alert a 9-1-1 caller to the closest public AED. It is the impact that this relationship has on patient outcomes that is the focus of this paper.
Eligibility Criteria

The nature of the question limits the ability to randomize, as a 9-1-1 caller cannot be randomized to either a dispatch center with an integrated AED system or one that is not integrated. Such randomization would not be ethical, as it would deny someone of the life-saving treatment of an AED in an emergency situation. However, it is possible that other investigators could develop a design that would allow for randomization while preserving ethical standards. Cohort studies by their nature require an investigator to identify a group of individuals who have been exposed to some factor, who are then followed to determine if any of the group develops some outcome; they offer causal data and are good for outcomes with high mortality. Case control studies seek to identify some exposure that is associated with some outcome that has already occurred; they are relatively inexpensive and short in duration. Both cohort studies and case-control studies could be useful in finding an answer to this paper’s question.

For the purposes of this paper, descriptive studies – such as ecological studies – and observational studies – such as cohort and case-control studies – with an objective measure of the effects of an integrated 9-1-1 dispatch system on OHCA survival will be included. Articles that describe case series studies or studies that do not report public access to defibrillation or do not measure survival to discharge rates will be excluded from this paper. Studies will also be excluded if conducted in an area where public access defibrillation is absent or if the outcome being measured is not survival to discharge. Table 1 below is a summary of both the inclusion and exclusion criteria.
### Study Design:

<table>
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<tr>
<th>Included</th>
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<tr>
<td>• Observational – Cohort and Case-Control studies help to determine exposure-outcome relationship</td>
<td>• RCTs – due to difficulty of randomizing 9-1-1 callers to either an integrated or non-integrated dispatcher</td>
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<tr>
<td>• Descriptive – Ecological studies use data already available</td>
<td>• Case series – OHCA is not a new phenomenon</td>
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### Population:

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<tr>
<td>• All adults suffering from OHCA due to a cardiac etiology.</td>
<td>• Cardiac arrest resulting from either trauma or drug-related causes.</td>
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### Intervention:

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<tr>
<td>• A 9-1-1 dispatch system incorporated with known locations of public AEDs</td>
<td>• Any intervention other than access to an integrated system</td>
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### Comparison:

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<td>• <strong>Group 1</strong> – Control group where 9-1-1 callers have access to a system fully compliant to AHA guidelines only</td>
<td>• Any control group that does not fully implement AHA guidelines, or is not solely AHA compliant</td>
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<td>• <strong>Group 2</strong> – Study group where 9-1-1 callers have access to a fully AHA compliant system that is also integrated with known public AED locations</td>
<td>• Any study group that is not fully AHA compliant and integrated</td>
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### Outcome Measured:

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<tr>
<td>• Survival to discharge</td>
<td>• Any outcome other than survival to discharge</td>
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**Time Frame:**

- At least 3 years of data for both groups
- Less than 3 years of data for each group

*Table 1. Eligibility criteria.*

**Search Strategy**

I conducted a systematic review of the literature regarding known automated external defibrillator locations and their integration with emergency medical services communication systems. I searched all articles limited to English language published from January 1, 2000 to May 1, 2011. I searched the MEDLINE and CINAHL databases in addition to the Cochrane Library using the following phrase: “(automated external defibrillator OR defibrillator, automated external) AND (emergency medical service communication systems OR emergency medical services/organization and administration).” I also searched the EMBASE database using the following phrase: “(automated external defibrillator OR defibrillator, automated external) AND (emergency medical services).” The above search phrase was exploded by the MEDLINE search engine to include both MeSH terms and text terms. Additional candidate articles were identified by reviewing bibliographies of selected articles from the search.

**Key Words**

<table>
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<th>Automated external defibrillator or Defibrillator, automated external</th>
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<tr>
<td>Emergency medical services</td>
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<td>Emergency medical service communication systems</td>
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<td>Emergency medical services/organization and administration</td>
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*Table 2. Key words for database search.*
Data Extraction

I reviewed the abstracts of candidate articles from the initial search to assess their relevance to my study question for possible inclusion or exclusion. Ideally, there would be a reviewer in addition to this writer; however, this writer will serve as the sole reviewer. I then reviewed the full text of those articles that appeared to meet the initial inclusion criteria. The following data were then extracted from each article: study design, study population, description of the intervention and comparison, comparability of the subjects, outcomes (description of patient survival), potential for bias, a description of both the internal and external validity, and an assessment of the overall quality. The internal and external validity assessment was made according to *U.S. Preventive Services Task Force* (USPSTF) guidelines and can be seen in *Table 3 and 4*, respectively, below. A summary of overall quality can be seen in *Table 5* below.
### Internal Validity

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<td>- Accurate ascertainment of cases; nonbiased selection of cases/controls with exclusion criteria applied equally.</td>
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<tr>
<td>- Initial assembly of comparable groups and their maintenance throughout.</td>
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<td>- Measurements are equal, reliable, and valid.</td>
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<td>- Measurement of exposure accurate and applied equally to each group.</td>
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<td>- Appropriate attention to potential confounding variables.</td>
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<tr>
<td>- Clear definition of interventions.</td>
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<tr>
<td>- Adjustment for potential confounders in analysis.</td>
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<th>Ratings:</th>
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<td><strong>Good</strong> – Meets all criteria; nonbiased selection of case and control participants (if applicable); comparable groups are assembled and maintained throughout; reliable and valid measurement instruments are used and applied equally to groups; interventions are spelled out clearly; appropriate attention to confounders in analysis.</td>
</tr>
<tr>
<td><strong>Fair</strong> – Recent, relevant, without major apparent selection; attention to some but not all important confounding variables; generally comparable groups assembled initially; measurement instruments are acceptable and generally applied equally.</td>
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| **Poor** – Major selection bias; inattention to confounding variables; groups assembled initially are not close to being
comparable or maintained; unreliable or invalid measurement instruments are used or not applied equally among groups.

Table 3. Criteria for assessing internal validity²⁸.

External Validity

Criteria:

- **Study population** – The degree to which the people who were involved as subjects in the study constitute a special population; the following features may cause experience in study to be different from what would be observed in the general population.
  
  - **Demographics:** age, gender, ethnicity, education, and income of study participants.
  
  - **Co-morbidities:** the frequency of co-morbid conditions in the study population.
  
  - **Refusal rate:** among eligible study subjects; a high rate makes enrollees in study unrepresentative.
  
  - **Adherence:** features of the study that make participants comply with study intervention.

- **Situation** – The degree to which the clinical experience in the situation in which the study was conducted is likely to be reproduced in other settings.

- **Providers** – The degree to which the providers in the study have the skills and experience likely to be available in general settings.
### Ratings:
- **Good** – The study differs minimally from the US primary care population/situation/providers and only in ways that are unlikely to affect the outcome; it is highly probable (>90%) that the clinical experience with the intervention observed in the study will be attained in the US primary care setting.

- **Fair** – The study differs from the US primary care population/situation/providers in a few ways that have the potential to affect the outcome in a clinically important way; it is only moderately probable (50%-89%) that the clinical experience with the intervention in the study will be attained in the US primary care setting.

- **Poor** – The study differs from the US primary care population/situation/providers in many ways that have a high likelihood of affecting the clinical outcomes; the probability is low (<50%) that the clinical experience with the intervention observed in the study will be attained in the US primary care setting.

*Table 4. Criteria for assessing external validity*

### Overall Quality

#### High Quality:
- Good internal and external validity.

#### Moderate:
- Good internal validity with at least fair external validity or at least fair internal and external validity.

#### Low Quality:
- Either fair internal validity with poor external validity or poor internal validity.

*Table 5. Overall quality of studies based on both the internal and external validity.*
Results

Search Results

The initial MEDLINE search yielded 128 citations. After review of the abstracts, 122 were excluded for reasons including: wrong study design, patient survival was not the measured outcome, measured outcome was not survival to discharge, and there was no abstract or full viewable text. The remaining 6 full text articles were reviewed in their entirety.

The EMBASE, CINAHL, and Cochrane searches yielded a total of 68 citations, of which 66 were excluded for reasons similar to those listed above; the remaining 2 full text articles were
duplicates and already identified in the MEDLINE search. After applying inclusion and exclusion criteria to the full text articles, all 6 articles were excluded in the review. Four full text articles were excluded because they did not measure the specified outcome of survival to discharge and two articles were excluded because they did not address the 9-1-1 dispatch system.

After manual review of two selected bibliographies of papers that most closely addressed the clinical question, 62 additional citations were identified and their abstracts reviewed. Of these, 1 study was found and reviewed in its entirety. This article was subsequently excluded because it did not measure any specified intervention. In total, all 7 articles selected for a full text review were excluded.

**Figure 1. Results of literature search.**

194 citations initially identified through literature search, 62 through bibliography search

249 citations rejected after review of abstract*
Fig. 1 – Flow of articles.

*Reasons for exclusion of abstracts included: wrong study design (181), patient survival was not the measured outcome (6), measured outcome was not survival to discharge (34), and there was no abstract or full viewable text (28).

#Reasons for exclusion of full articles included: did not measure the specified outcome of survival to discharge (4), did not address the 9-1-1 dispatch system (2), or did not measure any specified intervention (1).

Limitations

This systematic review describes only the current availability of evidence published in the last ten years in English. Despite using carefully predefined review and selection methodology, this paper is still susceptible to the fact that only data that has been published and made available to the public can be reviewed. I did not include any ongoing trials or unpublished data. The possibility exists that this writer may have not identified studies through the literature search, which potentially limits the comprehensive nature of the literature search.

Conclusion
Given this review, what can be said about the current research regarding the impact that an integrated emergency dispatch system has on OHCA survival? First and foremost, the literature suffers from a lack of observational or descriptive studies that directly address the above question. Virtually every investigation to date deals with either the placement of AEDs in public areas or the effect of public defibrillation on outcomes. To their credit, Myers and colleagues were the only investigators to address the issue of unregistered public AEDs and the importance of informing EMS of AED locations to direct 9-1-1 callers to the nearest public AED\(^1\). The next wave of research in this area must attempt to answer the question of whether or not an AED integrated emergency dispatch system leads to increased survival from OHCA. For now, no inference can be made about causality and we therefore must remain uncertain whether or not such an integrated system would lead to increased survival rates.

Secondly, much of the literature on this topic comes from large, urban areas that are not easily generalized to smaller or rural areas. Large urban areas by default have many more public locations whereby an AED can be placed for public use during an emergency. Many of the tools and procedures that were analyzed may not be as easily implemented in rural counties or areas of low population density. Just as future initiatives need to be tested prospectively, so too must they be studied in both urban and rural populations. Lastly, much of the literature seems to suggest a more limited role for EMS. Future focus should be placed on developing EMS as a more expansive entity capable of knowing not only where events happen, but also where emergency equipment is located in relation to those events.

Despite these limitations, existing evidence from previous studies have made important strides toward the goal of improving survival from cardiac arrest. First, numerous studies have shown the effectiveness of fully implementing the 2005 AHA guidelines\(^25,26,27\), which is an important step toward maximizing efficiency in the EMS system. Second, many investigators
discuss the need to develop and refine PAD programs\textsuperscript{6,17,18}. Random placement of AEDs does not work, and often times results in areas that need the most not having any; instead, identification of high-risk areas should guide placement to ensure that optimal public benefit is achieved\textsuperscript{14,15}. Lastly, identifying pools of unregistered AEDs is crucial when compiling a location database that would eventually be incorporated into the dispatch system\textsuperscript{1}.

As previously stated, a lack of data on the subject prevents this writer from making a definite conclusion regarding the potential impact of an integrated emergency dispatch system. It is not known if such integration would confer any benefit at all beyond that which is already gained by full implementation of AHA guidelines, but this is precisely why the following question needs to be answered: Does incorporating known locations of AEDs with the 9-1-1 emergency dispatch system increase a person’s chances of surviving cardiac arrest?

What follows in the next part of this paper is a research study, designed by this writer, which will advance the medical community’s current understanding of emergency care and help elucidate the role that public-access defibrillation plays in EMS. Furthermore, the findings of my study will provide evidence that other public health leaders can use to improve their systems to better serve the community.
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critical care; council on cardiovascular nursing; council on clinical cardiology; and quality of care and outcomes research interdisciplinary working group. Circulation. 2008;117(17):2299.


An Original Design of a Research Study

Introduction

Purpose

For my research study, I plan to address the gaps in knowledge that corresponds to the lack of findings in the systematic literature review. The systematic review was valuable in one key area, namely that it pointed the medical community’s limited understanding regarding the efficacy of public access defibrillation (PAD) and its integration with emergency medical services. This writer, and the medical community as a whole, is not able to make an evidence-based determination on this topic due to a lack of available data. The ultimate goal will be to
effectively increase knowledge and identify the true benefit of an integrated public
defibrillation/9-1-1 dispatch system.

**Emergency Medical Services**

Emergency medical services, or EMS, is a critical component in the treatment of any patient having an *out-of-hospital cardiac arrest* (OHCA). Of all unexpected cardiac deaths that occur annually, EMS treats roughly 60% \(^1\). Patients requiring bystander cardiopulmonary resuscitation (CPR) and/or defibrillation are usually hemodynamically unstable and often require advanced care by EMS providers to restore and maintain spontaneous circulation \(^2\). An integral part of the *American Heart Association’s* (AHA) chain of survival is the recognition of an emergency and calling 9-1-1 to initiate the emergency response system.

**Steps Necessary to Implement the 2005 American Heart Association Guidelines**

The 2005 update to the AHA’s guidelines featured many changes, but the three areas most affected were the CPR compression-ventilation rates, hyperventilation, and post-resuscitation measures. First, the compression-ventilation ratio has been changed from 15:2 to 30:2, placing an even greater emphasis on circulating the oxygenated blood that already exists in the circulatory system. If a bystander responds to a suspected victim or cardiac arrest and is not trained in CPR, then the bystander should provide compression-only CPR without rescue breaths \(^3\); however, trained responders that feel comfortable to do so should provide both compressions and rescue breathing at the 30:2 ratio. This change in CPR can be introduced as
either a part of continuing medical education that is required of all emergency medical personnel or a separate, special training session. Alternatively, off-the-shelf training materials provided by the AHA can take the place of a training program and still be effective⁴.

Second, tighter controls on ventilation rates have been instituted to decrease hyperventilation. Hyperventilation has been shown to decrease survival due to the resulting increase in intrathoracic pressure, which decreases coronary perfusion in cardiac arrest patients⁵. One way to combat this is by using an oral airway in conjunction with a nonrebreather mask to give two quick breaths per round of CPR, with endotracheal intubation attempted after 3 rounds of CPR⁶. The use of impedance threshold devices also serves to prevent unnecessary air from entering the chest during CPR, which helps to increase blood return to the heart and improves short-term survival⁷,⁸.

Lastly, the induction of therapeutic hypothermia by EMS as a means of postresuscitation support cools the body to improve neurological outcomes. One study shows that the induction of hypothermia by means of rapid infusion of up to 2L of 4°C normal saline by EMS is feasible and an effective method of lowering core body temperature⁹. Other studies have shown that therapeutic hypothermia is beneficial to patients suffering from cardiac arrest¹⁰, leading to improved neurological outcomes following the return of spontaneous circulation¹¹,¹². A summary of the recommended AHA guidelines for induced hypothermia can be seen in Figure 1.

**Figure 1. Summary of induced hypothermia**¹³

**Induction:**
- Cool patients to between 32-34°C for at least 24 hours
- Median time to target body temperature is approx. 8 hours
- IV cold fluids (0.9% saline or Ringer’s lactate)
- Cold packs (groin, armpit, neck/head)
- Optional → surface cooling with cold mat
**Focused Clinical Question**

<table>
<thead>
<tr>
<th><strong>Research Design:</strong></th>
<th>Observational before-after cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focused Question:</strong></td>
<td>Does incorporating known public locations of AEDs with the 9-1-1 emergency dispatch system increase a person's chances of surviving out-of-hospital cardiac arrest?</td>
</tr>
<tr>
<td><strong>Population:</strong></td>
<td>All patients with out-of-hospital cardiac arrest from a cardiac etiology over 18 years of age</td>
</tr>
<tr>
<td><strong>Intervention:</strong></td>
<td>A 9-1-1 dispatch system incorporated with known locations of public AEDs</td>
</tr>
</tbody>
</table>

**Maintenance:**
- Cooling blankets that circulate cold-water or air
- Continue cold or wet blankets on torso
- Optional → intravascular cooling catheters (femoral or subclavian vein)

**Rewarming:**
- Remove cold blankets and stop infusion of cold fluids
- Rewarm patient at a rate of between 0.25-0.50°C per hour
Comparison: An EMS system that has fully implemented the 2005 AHA guidelines for CPR and emergency care versus a fully AHA implemented EMS plus a 9-1-1 dispatch system incorporated with public AED locations

Primary Outcome: Survival to hospital discharge

Secondary Outcome: Survival to admission, presence of a pulse upon Emergency Department arrival, and return of spontaneous circulation

Time Frame: Sixty (60) consecutive months

Table 1. Focused clinical question for the proposed study. AED – automated external defibrillator. EMS – emergency medical services. AHA – American Heart Association.

Materials and Methods

Focus

The aim of this research is to determine whether incorporating public AED locations into the 9-1-1 dispatch structure of EMS agencies that have fully implemented the 2005 AHA guidelines for CPR and emergency cardiovascular care improves survival from OHCA as compared to full AHA implementation only. For this study, I will build on previous studies
conducted in the medical literature, utilizing basic tools and measures from those studies with modifications to specifically address public AED integration.

**Setting**

This study will take place in Orange County, North Carolina, which is a county of approximately 133,000 residents\textsuperscript{14}. The county EMS service receives more than 11,000 calls to 9-1-1 annually\textsuperscript{15}. The EMS system consists of 33 paramedics and 21 emergency medical technicians (EMTs), as well as fire fighters and other first responders. The Orange County emergency services network not only partners with EMS and fire departments, but it also includes law enforcement and social services that provide assistance to Orange County residents\textsuperscript{14}. All advanced life support (ALS) providers receive initial didactic training in accordance with state law, and must undergo annual continuing medical education requirements to maintain certification.

**Study Design**

This study will be a 3-phase before-after cohort design occurring over 60 consecutive months. During the first phase lasting for 12 months, county EMS agencies will the trained in 2005 AHA guidelines. This will consist of three main areas (Table 2): 1) new CPR with minimal interruptions during chest compressions and a 30:2 compression-ventilation ratio, 2) the use of oral airway and impedance threshold devices to better prevent hyperventilation, and 3) the induction of therapeutic hypothermia in eligible patients who remain unresponsive after return of
spontaneous circulation (ROSC) (see Figure 1). County EMS administrators will be required to perform monthly quality assurance measures to ensure compliance, and if their responder compliance rate falls below 95% they will be given performance feedback with ways to bring them up to said limit.

The adoption and implementation of the 2005 AHA guidelines in phase 1 will be carried out using training sessions provided by the medical director and county training officer at the beginning of the phase and every three months for a total of four sessions. The initial session will involve all paramedics and EMTs in a weekend didactic and clinical training session given by the medical director. Each of the remaining sessions will be a one-day review provided by the county training officer.

Phase 2 will last for 24 months after the completion of phase 1 and will serve as a baseline or control phase. During this time, all EMS agencies and personnel will be in full compliance of the 2005 AHA guidelines and all patients will be treated accordingly with continued quality assurance and performance feedback to the EMS personnel. Phase 2 will also involve the identification of all publically available AEDs in the county, which will result in a database that will be incorporated into the emergency dispatch system at the conclusion of the 24 months. Finally, phase 3 will last for 24 months and will involve the use of an integrated public AED/emergency dispatch system in addition to the treatments implemented in phase 1. Table 2 summarizes this study design.

**Study Population**

The study population will be all adult patients with out-of-hospital cardiac arrests occurring within Orange County, NC. Included patients will be aged at least 18 years and will have received emergency care from EMS regardless if they were ultimately transported to the
hospital, meaning patients who have their resuscitation efforts terminated before transport will also be included. Exclusion criteria will include non-cardiac or traumatic causes of arrest as determined by official cause of death, obvious death (defined as the presence of mortal wounds such as decapitation or the presence of rigor mortis), and patients with a legal and valid do-not-resuscitate (DNR) order made available to EMS. This study will have to be approved by the institutional review board of the University of North Carolina.

**Outcome Measurement and Data Analysis**

The primary outcome will be survival to hospital discharge. Secondary outcomes will be survival to hospital admission, presence of a pulse upon Emergency Department arrival, and return of spontaneous circulation. Study data will be collected from the EMS electronic patient care reporting system entered immediately after the patient encounter. Additional data and survival outcomes will be manually gathered from hospital records by trained personnel performing data review after the event has occurred. Data will also be collected by review of 9-1-1 records to determine usage rates of publicly accessible AEDs.

In order to assess the effects of having an integrated 9-1-1 dispatch system, the intervention and control groups will be compared with respect to survival to discharge rates and will be evaluated using Pearson’s chi-square analysis ($X^2$). Adjusted odds ratios (OR) comparing phase 3 to the baseline control phase will be determined by linear or logistic regression models, which will control for confounding variables including: age, gender, ethnicity, initial cardiac rhythm, EMS/9-1-1 response interval, arrest location, bystander-witnessed arrest, and bystander CPR. All analyses will be performed on an intention-to-treat (ITT) basis.
Phase 1: Lead-in (12 months)

- New CPR
  - Minimal interruptions in chest compressions
  - Compression-ventilation ratio of 30:2

- Airway
  - Use of oral airway devices
  - Use of impedance threshold devices
  - De-emphasized early intubation

- Therapeutic hypothermia
  - Unresponsive patients with ROSC
  - Induction carried out by EMS

Phase 2: Control (24 months)

- Serves as a baseline with full implementation of AHA guidelines only.

- Investigation of all publically available AEDs in the county.

Phase 3: Intervention (24 months)

- Serves as a comparison for the control phase.

- Intervention
  - Full implementation of AHA guidelines and incorporation of public AED locations into the emergency dispatch system


Results
Descriptive analysis of both the phase 2 baseline control group and the phase 3 intervention group – including age, gender, ethnicity, initial cardiac rhythm, EMS/9-1-1 response interval, arrest location, defibrillation prior to EMS arrival, bystander-witnessed arrest, and advanced management – would be included here [Table 3]. This would be followed by the primary and secondary survival outcomes from each of the study groups [Table 4].

**Primary Outcome of Interest**

This topic will be assessed through the descriptive analysis in Table 4. The results will be difficult to predict. However, I believe the results will be positive; similar to past studies that showed improved survival with full implementation of the 2005 AHA guidelines, I expect to see improved survival with incorporation of public AED locations into EMS agencies already practicing those guidelines. A statistically significant increase should be expected in the primary outcome of survival to hospital discharge among adult patients with out-of-hospital cardiac arrest. It will be difficult to predict the exact magnitude of this suspected relationship. I believe the potential improvement in OHCA survival will be close to but not as dramatic as the effect of fully implementing the 2005 AHA guidelines.

**Secondary Outcomes of Interest**

This topic will also be assessed through the descriptive analysis in Table 4. The results will be difficult to predict, but I believe there will be as large an improvement in these measures as that predicted in the primary outcome. I suspect that any improvement in primary outcome that the intervention group sees would be accompanied by a commensurate improvement in secondary outcome measures.

**Discussion**
Out-of-hospital cardiac arrest is a life-threatening event that affects people of all races and walks of life. However, it can safely and effectively be treated by both the lay public and emergency trained professionals alike. Devices called automated external defibrillators, or AEDs, are able to detect if a person’s heart has an abnormal rhythm that can be corrected with a timed electrical shock, which the devices deliver. When combined with bystander CPR, AEDs can double the survival rates for persons having an out-of-hospital cardiac arrest\textsuperscript{16}, which is the basis behind the concept of public access defibrillation (PAD).

Knowledge and public awareness of PAD appear to be important components of any effective public health policy aimed at improving survival from cardiac arrest. The American Heart Association’s (AHA) chain of survival is dependent on the public’s ability to at least recognize an emergency and hopefully know how to provide basic life saving skills, such as CPR and the use of an AED. The systematic evidence review (SER) was valuable in that it identified a key area for which little is known and virtually no data or evidence exists. This fact, along with studies from related topics, was instrumental in creating my research design.

The SER made me aware that the medical community was lacking in knowledge regarding the potential impact of incorporating public AED locations into the emergency dispatch system and the effect it would have on OHCA survival. Therefore, it is evident that we must increase the information available by carrying out studies such as the one described by this writer in this paper. The process of obtaining this information is time consuming and many logistical and fiscal barriers remain challenges to overcome.

**Strengths and Limitations**

[39]
My research design suggests an effective way of determining whether incorporating public AED locations into the 9-1-1 dispatch system will make a difference in survival rates from OHCA. The strengths of this study design include a clear, focused clinical question. Given the growing number of people living with heart disease, cardiac arrest will continue to be an issue of concern among medical experts and the public. Therefore, the clinical question is clear and relevant and the design of the study is appropriate.

All adult patients with out-of-hospital cardiac arrest from a cardiac etiology will be treated by standard of care alone – which includes full implementation of the 2005 AHA guidelines – to determine baseline survival rates. This will be compared to patients with the same condition that will be treated with standard of care plus a fully integrated emergency dispatch system to determine if such integration improves those survival rates. The exclusion of non-cardiac or traumatic causes of arrest, obvious death, and patients with a legal and valid DNR will strengthen the study.

The limitations of this study include the relatively small sample size. With an overall population of about 133,000 in Orange County, NC and an OHCA incidence of 0.55 per 1,000 (Rea, 2004), I expect just 75 cases annually. This means there will only be about 150 cases in both the control group and the intervention group. Although the study will be powered to find statistically significant differences, the small numbers will be difficult to generalize to larger EMS agencies or the entire population. The external validity will be satisfactory, but will not approach that of a large multi-center randomized controlled trial.

Conclusion
There exists the possibility that an emergency dispatch system integrated with public AED locations could improve survival from out-of-hospital cardiac arrest beyond the current standard of care. Future studies should take a look at the role that public defibrillation plays in prehospital emergency care, specifically in the area of survival to discharge and how an integrated system might affect this measure. Prior to recommending that all county EMS agencies incorporate a comprehensive database of public AED locations into their 9-1-1 dispatch system, studies should be conducted in a manner consistent with that which is contained within this paper to better elucidate this topic.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Phase 2 (Control) (n=x)</th>
<th>Phase 3 (Intervention) (n=x)</th>
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<tbody>
<tr>
<td>Mean age (yrs)</td>
<td></td>
<td></td>
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### Table 3. Characteristics of included patients with out-of-hospital cardiac arrest where resuscitation was attempted.

<table>
<thead>
<tr>
<th>Male sex (%)</th>
<th>Ethnicity</th>
<th>Initial cardiac rhythm</th>
<th>EMS response interval</th>
<th>Arrest location</th>
<th>Defibrillated prior to EMS arrival</th>
<th>Bystander-witnessed arrest</th>
<th>Advanced management</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Black</td>
<td>VF/VT</td>
<td>Defibrillator to scene ≤10 min</td>
<td>Residential</td>
<td>Yes</td>
<td>Yes</td>
<td>On-scene</td>
</tr>
<tr>
<td></td>
<td>White</td>
<td>Asystole</td>
<td>Defibrillator to scene ≤5 min</td>
<td>Public</td>
<td>No</td>
<td>No (EMS only)</td>
<td>Receiving hospital</td>
</tr>
<tr>
<td></td>
<td>Hispanic</td>
<td>PEA</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Other</td>
<td></td>
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</tbody>
</table>

VF/VT – ventricular fibrillation/ventricular tachycardia. PEA – pulseless electrical activity. EMS – emergency medical services.
<table>
<thead>
<tr>
<th>Admission to hospital (%)</th>
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<tbody>
<tr>
<td>Pulse on hospital arrival (%)</td>
<td></td>
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<tr>
<td>Return of spontaneous circulation (%)</td>
<td></td>
</tr>
</tbody>
</table>

*Table 4. Survival outcome measures for both the control group and intervention group.*

REFERENCES


13. Neumar RW, Nolan JP, Adrie C, et al. Post-cardiac arrest syndrome: Epidemiology, pathophysiology, treatment, and prognostication A consensus statement from the international liaison committee on resuscitation (american heart association, australian and new zealand council on resuscitation, european resuscitation council, heart and stroke foundation of canada, InterAmerican heart foundation, resuscitation council of asia, and the resuscitation council of southern africa); the american heart association emergency cardiovascular care committee; the council on cardiovascular surgery and anesthesia; the council on cardiopulmonary, perioperative, and critical care; the council on clinical cardiology; and the stroke council. *Circulation*. 2008;118(23):2452.

