# PREDICTING THE MAXIMAL EFFECT OF PUBLIC ACCESS DEFIBRILLATION: WHY MOST PUBLIC ACCESS DEFIBRILLATION PROGRAMS WILL NOT SAVE LIVES

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## ABSTRACT

**Context**: Many agencies are promoting widespread availability of automated external defibrillators (AED) in public places despite a lack of evidence for the best locations for public access defibrillation (PAD). **Objective**: To identify high-risk cardiac arrest locations to guide the optimal distribution of AEDs in a wide variety of communities. **Design, Setting, and Patients**: A prospective cohort study of adult, out-of-hospital cardiac arrests of presumed cardiac etiology within the 20 communities of the Ontario Prehospital Advanced Life Support (OPALS) study from July 1, 1995 to June 30, 2000. The property assessment roll identified the specific property type for each cardiac arrest address and the total number of sites, per location type, within the study boundary. **Main Outcome Measures:** Measures of the potential utility of PAD for each of 26 location categories, including the number of PAD programs needed to treat one cardiac arrest, and the potential PAD use per site in years. **Results**: Overall, 7,667 (99.5%) of 7707 cardiac arrests had valid address information. Private residences comprised 85% of the arrest locations and the remaining 15% were public locations. Potential PAD venues include (location-specific cardiac arrest rates per site, the number of PAD programs needed to treat one cardiac arrest during a five-year period and the potential PAD use per site in years): casinos (14, 0.07, 0.4); non-acute hospitals (1, 1, 5); nursing/retirement homes (1, 1, 5); penal institutions (0.3, 4, 18); indoor shopping malls (0.2, 5, 26); and hotels (0.1, 9, 46). All other remaining locations had poor utility scores. **Conclusions**: Most cardiac arrests occur in private residences. It appears that only a few locations may be amenable to efficient placement of PAD. All communities considering public placement of AEDs should identify high-risk sites to guide the rational deployment of these devices.

**Key words: cardiac arrest, public access, defibrillation, survival**

## INTRODUCTION

Out-of-hospital cardiac arrest remains the leading cause of death in the western world, despite years of ongoing study. Each year, roughly 250,000 sudden out-of-hospital deaths occur in the United States.[1] In most centers, less than 5% of these patients will survive to hospital discharge.[2] To date, researchers have shown that only early cardiopulmonary resuscitation (CPR) and early defibrillation improve cardiac arrest survival.[3,4,5] It follows that emergency medical services (EMS) should work to improve the delivery of these two modalities. Methods used to improve bystander CPR rates have included mass CPR training, targeted training of high-risk populations, and dispatch-assisted CPR instructions. To address the issue of early defibrillation, EMS experts developed the concept of public access defibrillation (PAD). Their rationale was that increasing the availability of automated external defibrillators (AEDs) may lead to more rapid defibrillation which, in turn, would result in improved survival. The American Heart Association (AHA) defines the spectrum of PAD providers as follows: 1) traditional first responders (fire and police); 2) non-traditional first-responders (security personnel, flight attendants, lifeguards); 3) trained citizen-responders such as friends and families of high risk cardiac patients; and 4) minimally trained citizen-responders, such as bystanders who witness a cardiac arrest in a public location where an AED is available.[6]

The effectiveness of PAD is unknown and is the subject of an ongoing multi-center PAD trial.[7] Little research has been done to establish high-risk locations to guide the optimal placement of AEDs within the community.[8,9,10,11] Recent reports indicate that the vast majority of cardiac arrests occur in private residences and that only about 15% occur in public locations.[8,12,13] Thus, current PAD programs target only a small part of the cardiac arrest problem. Despite this, thousands of AEDs already exist in public locations. Widespread implementation of PAD before its effectiveness is proven is largely expensive and has the potential to divert attention and resources away from other programs.

We believe that decisions to place AEDs in public locations should be guided by a thorough understanding of the rates and demographics of cardiac arrest in our communities. Thus, the purpose of this study was to identify an objective measure to determine high-risk locations for which PAD may be beneficial. Specifically, we sought to determine the cardiac arrest rate per site for each type of location in order to determine the number of PAD programs that would be necessary in each location category to treat one cardiac arrest in a five-year period. This will allow EMS and public health decision makers to make rational choices regarding the implementation of PAD programs in their communities.

## METHODS

### Study Design and Setting

This prospective cohort study is a component of the Ontario Prehospital Advanced Life Support (OPALS) study. The OPALS Study is a multi-phase before and after controlled clinical trial designed to assess the impact of advanced life support (ALS) on a variety of prehospital patient presentations, including cardiac arrest, trauma, respiratory distress, and chest pain. Complete details of the OPALS methodology are described in earlier publications.[14,15] The current study includes 20 urban/suburban centers within 11 base-hospital regions in the province of Ontario, Canada. Centers have a combined population of approximately 2.8 million and individual study community populations range from 16,000 to 750,000. In the study sites, EMS responds to approximately 1,700 cardiac arrests each year. This represents an annual incidence of 60 arrests per 100,000 persons which is consistent with the mean rate published in a review of cardiac arrest studies.[16] Emergency medical technicians (EMTs) providing a basic life support level of care with defibrillation (BLS-D) or advanced life support (ALS) with intubation, intravenous fluid and drug administration responded to all medical emergencies within the study area. Fire fighters also provided basic CPR, oxygen administration and defibrillation with automated defibrillators under local tiered-response agreements. All centers had 911 emergency telephone services during the study.

**Study Subjects**

Patients included all out-of-hospital cardiac arrests occurring before arrival of EMS personnel for whom providers attempted resuscitation. We excluded children less than 16 years of age, obvious deaths as defined by the Ontario ambulance act, traumas and other medical cases clearly of non-cardiac etiology. We also excluded cases that were EMS-witnessed from this analysis, as public access defibrillation programs are applicable only in the situation where the patient arrests before defibrillator-equipped personnel are available at the scene. The OPALS study had full research ethics committee approval.

**Outcome Measures**

The primary outcome measure was the utility of PAD for each location category. This was defined as the number of PAD programs needed to treat one cardiac arrest event in a five-year period. A PAD program was defined as the placement of one or more AEDs at an individual site. Secondary measures included the utility of PAD for witnessed ventricular fibrillation or ventricular tachycardia (VF/VT) arrests and the expected frequency of PAD use, measured in years, for each site within a location category.

**Data Collection**

Since 1994, all cardiac arrest encounters have been entered from a standardized provincial ambulance call report into the OPALS database following the Utstein style.[17] A central computerized ambulance response information system provided all dispatch information. As address information is not a component of the main OPALS dataset, the address of each cardiac arrest was primarily determined by linking call report run numbers to the provincial dispatch database. Occasionally, the address field was not complete and address information was determined from the call report. We then linked individual addresses to the Municipal Property Assessment Corporation (MPAC) roll to identify the unique property type code for each address. We collapsed the 174 property type codes identified in the property roll into a set of 26 location categories that the provincial base hospital ACR working group had defined *a priori*.

We defined the boundaries for each of the 20 study communities using a set of Universal Transverse Mercator (UTM) points that represent one-$km^2$ grids. Conversely, the property roll identifies property data with the federal postal coding system, which uses 6-digit polygons for geographical representation. A consulting firm used software to digitize each study community's UTM boundaries as a separate mapping layer and overlay this on the digitized postal code map. We were then able to identify the centroids of each postal code polygon contained within the UTM boundaries. This allowed us to define each of the study communities by a set of postal codes. Finally, we linked the MPAC roll to the postal code list for each community to identify the frequency of each property type within each community.

**Data Analysis**

Simple descriptive statistics were used to identify demographic, clinical and EMS characteristics of cardiac arrest patients. Frequencies of cardiac arrest and the number of sites per location category were determined. The ratio of these two numbers provided the number of cardiac arrests per site and is referred to as the location-specific cardiac arrest 'rate' for simplicity. A utility score was computed as the inverse of this location-specific cardiac arrest rate and represented the number of PAD programs needed to treat one cardiac arrest in a five-year period. In addition, the number of PAD programs needed to treat one witnessed VF/VT arrest in a five-year period was determined by multiplying the cardiac arrest rate for each location by the witnessed VF/VT rate for that location's arrest population, and then computing the inverse of the witnessed VF/VT cardiac arrest rate. Finally, multiplying the utility score by the length of the study period (five years) provided the expected frequency in years with which an individual site within a given location category could expect to have a cardiac arrest event. Data entry and statistical analyses were performed using the SAS System Version 8.01 (SAS Institute Inc., Cary, North Carolina).

**Economic Evaluation**

A cost effectiveness analysis compared the total costs and life expectancy of treating patients with a cardiac arrest with and without a defibrillator on site by location. Eighteen of the 26 location types were considered based on incidence of cardiac arrests: casinos, non-acute hospitals, shopping centres, nursing homes, penal institutions, hotels, golf courses, restaurants, airports/railway stations, marinas, schools, single stores, medical offices, office buildings, stadium, community facilities, factories, sports fields.

To calculate the specific incremental cost effectiveness ratio, for each location the following needed to be estimated: 1) the average number of cardiac arrests per annum; 2) the proportion of patients who die on site, die during hospitalization and survive to discharge without an on-site defibrillator by gender and age; 3) the benefit in terms of survival from access to an on-site defibrillator; 4) the cost of a defibrillator; and 5) the life expectancy and treatment costs of patients by survival status, gender and age at cardiac arrest.

Data on the first two data elements was available directly from the OPALS study.[3,4] The benefit of on-site defibrillators was incorporated by increasing the proportion of patients who survive to discharge based on additional analysis of survival rates from the OPALS study (RR of survival = 3.2).[4]

The cost of an on-site defibrillator (the cost of materials and training costs) was obtained direct from manufacturers. Assuming a five year lifespan of the materials, amortization of these costs over their lifespan resulted in an annual cost estimate for an onsite defibrillator of $1319.01.

A decision analysis model was created to estimate age and sex specific costs and life expectancies for individuals surviving cardiac arrests (Figure E1). Survival estimates and disease progression probabilities were derived from the Weinstein model and costs were based on observed health resource utilization of incident coronary heart disease for a representative sample of the Canadian population.[28,29,30] Both future life expectancy and costs were discounted at a rate of 5% (Table E1).

Monte Carlo simulation estimated the uncertainty surrounding the estimated incremental cost effectiveness ratios.[31] Cost effectiveness was assessed by estimating incremental cost effcetiveness ratios and through creation of cost effectiveness acceptability curves.[32]

## RESULTS

During the five-year study period from July 1, 1995 to June 30, 2000, EMS providers treated 8,494 eligible cardiac arrest patients within the OPALS Study communities. The 787 EMS-witnessed arrests were excluded. An additional 40 cases were excluded, as the location of arrest was not available. Table 1 displays the patient and EMS characteristics and survival rates for the 7,667 (99.5%) study patients who had valid address information during this period. The patients were more often male and had a mean age of 69 years. Bystanders witnessed about half of all cardiac arrests, few patients received bystander CPR (16%), and 37% had an arrest rhythm of VF/VT. There were 18 (0.2%) cases where the arrest occurred at a location (casino) already equipped with PAD. The 90$^{th}$ percentile for the defibrillation response interval of call received to vehicle stopped was 7.8 minutes. The overall survival to hospital discharge for patients during this period was 4.0%. The survival rate in casinos was 42.9%.

Table 2 lists the breakdown of the frequencies of cardiac arrests and the rate of witnessed VF/VT by location. We have further grouped the locations into large and small residential and public locations (Figure 1). The vast majority of cases occurred in patients' homes: 56% in single-residential dwellings, 23% in multi-residential dwellings, and 6% in nursing homes. All other sites accounted for only a small proportion (15%) of the total number of cardiac arrests. The more frequent public locations included single stores/strip malls, streets/highways/roads, recreation/assembly/community facilities, office buildings and indoor shopping malls. All other public locations accounted for less than 1% of arrests. Public locations typically had larger witnessed VF/VT rates than residential dwellings and nursing homes.

Table 2 also identifies the total number of sites for each location category. There were over one million properties identified in the OPALS study communities (1,188,197), which represent 29% of all properties located within the province of Ontario (4,105,164). Places of residence accounted for 87% of all properties. Aside from residential properties, the most frequent property types were factory or industrial-use, farms, and retail stores or store blocks. All other properties accounted for less than one percent of the total number of properties. The property data does not include streets, roads, or highways, as these locations are not enumerated in a property assessment roll. The 'other' category primarily represents vacant land parcels.

Table 3 provides measures of the potential utility of PAD by identifying the rates of cardiac arrest per site for each of the locations, the corresponding number of PAD programs that would need to be placed in order to treat one cardiac arrest and one witnessed VF/VT arrest during a five-year period, and how often each PAD program would be used to treat a cardiac arrest in the study community (Figure 2). Casinos, by far, had the highest rate of cardiac arrest, with 14 per site during the study period. Non-acute hospitals (without an emergency department) and nursing homes each had one cardiac arrest per site. All other location categories had an arrest rate of less than one.

The number of PAD programs needed to treat one cardiac arrest for casinos is 0.07. That is, by placing AEDs in each of the two casinos within the OPALS study communities one would expect to treat numerous cardiac arrests during a five-year period. We could expect a PAD use every 0.07 x 5 years = 0.35 years (four months) in each casino. In comparison, the number of PAD programs needed to treat one cardiac arrest for schools is 49. That is, 49 PAD programs are necessary to treat just one cardiac arrest during a five-year period. Alternatively, we could expect that each school with a PAD program would have an AED use once every 245 years (49 x 5). The other venues with moderate utility for PAD include non-acute hospitals and nursing homes. Penal institutions, indoor shopping malls and hotels had low utility scores, reflecting a larger number of PAD programs necessary to treat one arrest in a five-year period. All other remaining locations had poor utility scores.

An incremental cost effectiveness ratio was calculated for on-site availability of a defibrillator for each of the eighteen location types (Table E2). There were three situations in which a defibrillator would be considered cost effective based on a willingness to pay threshold of $50,000 per life year gained, namely, casinos, non-acute hospitals and nursing homes. The

ICER for casinos was $5427 per life year (p(<50,000)> 0.99), it was $30750 (p(<50,000)=0.99) for non-acute hospitals and $45926 for nursing homes (p(<50,000)=0.67) (Figure E2). For only one other location was the probability of being cost effective greater than 0.01%: shopping malls (p=0.02).

## DISCUSSION

The OPALS study is the largest study of prehospital cardiac arrest yet conducted. The current study shows that only a small proportion of cardiac arrests occur in public locations and that the vast majority of arrests occur in private residences, presently unsuitable for PAD. In light of the widespread interest in PAD programs, we identified a utility measure to determine which public locations would be amenable to PAD. Using the rates of cardiac arrest per site for each location category, the utility score represented the number of PAD programs necessary to treat one cardiac arrest in a five-year period for each type of location. The cardiac arrest rate is high in casinos, with one arrest occurring every four months in each casino, giving casinos a very favorable utility score. Patients collapsing in those venues were often witnessed by bystanders and found to have an initial rhythm of VF/VT, factors likely to dramatically improve the chances of survival should electrical counter-shock be immediately available. Unfortunately, the utility scores for all other location categories were far below that of casinos. Non-acute care hospitals and nursing homes each had one cardiac arrest per five-year period, but the low witnessed-VF/VT rate diminished their utility score, making them only 'moderate-yield' PAD locations. There were many locations with a very low rate of cardiac arrest. Few, if any locations beyond casinos had a utility score that would justify the anticipated costs of widespread PAD program implementation.

The results of the cost effectiveness analysis confirmed these conclusions. The incremental cost per life year gained appears very favourable for implementing a PAD program in casinos and non-acute hospitals and moderately favourable for implementation in nursing homes. However, for all other locations, implementation is highly cost ineffective and scarce public resources would be better invested elsewhere.

The concept of public use of defibrillators has been discussed for almost two decades. However, it was not until the landmark *casino study*[18] was published that considerable attention was gained within the scientific community and media headlines began to take interest in PAD as a novel approach to the treatment of out-of-hospital cardiac arrest. Investigators found PAD to be remarkably effective in the casino setting. Overall survival was 38%, 74% for those patients receiving defibrillation within three minutes of their witnessed collapse and 49% for those who received their first shock after three minutes. More recently, these authors have established the cost-effectiveness of PAD in this setting when compared to an existing EMS system.[19] In addition, other small observational studies have shown improvement in survival in selected high-risk locations such as aboard airlines, in airports and at cricket grounds.[20,21,22] Such high risk locations represent only a small proportion of all public settings.

These studies of uniquely high-risk populations, especially the casino, more likely reflect the ‘efficacy’ of PAD in ideal circumstances rather than the ‘effectiveness’ of the intervention in the average community. The casino authors themselves cautioned that cardiac arrests were unusually high in gaming facilities compared to other public locations. Furthermore, because of the extensive monitoring by security personnel and video cameras, detection and response was much more rapid than would occur in other public settings.[18] It is anticipated that these arrests have a more favorable prognosis owing to the high witnessed-VF/VT rate (61%). The casino likely represents the ideal conditions available for effective use of PAD.

One must be very cautious in extending the results of the casino study to conclude that PAD will be suitable and effective in other public locations. Recent observational studies have had mixed results. A small Helsinki study placed AEDs in all public sites with at least one cardiac arrest per year. However, they failed to show a benefit for PAD since in 65% of cases, lay responders did not use the available AED due to dispatch problems or arrival of EMS prior to AED use.[23] On the other hand, an Italian study showed tripling of survival with PAD. However, there were no cases of a lay responder utilizing any of the fixed public AED devices. Instead, targeted mobile PAD providers, such as fire, police and public assistance personnel provided defibrillation in all cases.[11]

Researchers and EMS administrators are hoping for a definitive answer to the question of effectiveness in the large-scale multi-center randomized-controlled PAD trial currently underway in Canada and the United States.[7] Twenty four centers have randomized approximately 1000 distinct community units, including apartment buildings, gated communities, sports venues, seniors centers and shopping malls to receive either CPR alone or CPR plus AED. An additional prospective observational study is underway in the United Kingdom where defibrillators are located in public places determined to have the highest frequency of cardiac arrest and where staff were willing to be trained.[24]

Until science provides a more definitive answer regarding the impact of PAD, opinion and consensus are likely to drive the effort to determine populations and locations that are most suitable for this intervention. The AHA defined suitable locations for PAD as those sites that: 1) have a high frequency of cardiac arrest events such that there is greater than a 50% probability of at least one AED use within the five-year period; and 2) are unable to attain EMS response intervals of 911 call to defibrillatory shock of less than five-minutes.[25]

Though we agree that cardiac arrest rates and traditional EMS response intervals are necessary to determine optimal placement of PAD programs, we feel that the person-years concept does not identify all of the factors unique to each public location that will ultimately determine whether a particular setting is appropriate for PAD. Based on our results, we suggest the following four steps to assist with PAD implementation decisions. First, calculate the overall frequency of cardiac arrest per location category. Since only 15% of out-of-hospital cardiac arrests occur in public locations, there will be few public locations with a sufficient volume of cardiac arrest events to warrant widespread use of PAD. Second, determine the number of sites per location category. Exceedingly high numbers of sites within a location category will drive down the rate of cardiac arrest per site, making it much more difficult to target sufficient numbers of cardiac arrest patients within certain location categories. Third, identify the patient demographics of the location category. Specifically, age, sex, witnessed status, initial rhythm, and other risk and prognostic indices that affect not only the likelihood of an arrest occurring, but also whether the arrest would be amenable to defibrillation. Fourth, evaluate the geographical demographics of the location category. Traditional EMS response intervals, building size, layout, and other potential barriers to patient access may require a more extensive PAD program with multiple AEDs in different locations. All of these factors will determine suitable locations for PAD programs and the ultimate effectiveness of this intervention for improving survival.

Other studies have attempted to estimate the potential effectiveness of implementing a PAD program by identifying appropriate sites for PAD. A recent British Medical Journal article presented a retrospective analysis of the Heartstart Scotland data and predicted limited impact of PAD on survival when locating PAD in ‘suitable’ and ‘possibly suitable’ sites.[26] However, the categorization of location suitability was largely subjective, based on consensus rather than on data underscoring the frequencies and rates of cardiac arrest for each of the location types. In addition, this study over-estimates PAD’s potential impact on survival because of the assumption of an AED being available at the scene of every cardiac arrest.[27] A more compelling analysis by Becker estimated that between eight and 32 lives could be saved in five years with the strategic placement of 276 AEDs in 172 higher-incidence sites.[8] Finally, a Pittsburgh study noted that there were no identifiable high-risk public locations other than nursing homes and dialysis centers.[10] The disparity in these findings demonstrates the importance of utilizing a uniform measure of potential PAD utility to ensure the appropriate placement of AEDs within each individual community.

The investigation has several limitations. First, we designed the study to present a predictive model of the utility of PAD based on a review of observational data. Though we can estimate the impact of PAD in our population, we are unable to make definitive statements on the effectiveness of PAD. Second, the study did not include any large metropolitan centers. Thus, we are unable to make conclusions about the potential utility of PAD in cities with populations larger than 750,000. This limitation is apparent in our inability to confirm previous studies’ positive findings regarding the utility of PAD in airport settings. This discrepancy results from the fact that no large international airports are located within our study communities and adds further weight to the argument that community-specific analyses are important. Third, there is a very small possibility that the property assessment role has misclassified some cardiac arrest locations. As we were not able to access separate property databases for each year of study, a small number of properties may have new classifications in the property roll as a result of property transactions occurring subsequent to the cardiac arrest event.

Public locations represent only a small part of the cardiac arrest problem, and few public locations may be amenable to PAD. Strategic placement of PAD programs in only those locations with the highest utility may lead to clinically important survival benefits, but for a very small proportion of arrests. The premise behind using the utility score to identify potential PAD locations is that there are simply too many individual sites and extraordinary costs associated with starting a PAD program in every location. We have based the measure on cardiac arrest rates and amenable patient factors, and from this, we can allocate PAD programs to the highest utility sites taking into account program resources. Every agency considering PAD should identify the site-specific utility to guide the deployment of AEDs in their community. In addition, EMS systems should consider alternative means to improve cardiac arrest outcomes in the majority 'low-yield' PAD venues. Scientists, EMS leaders and public health managers should continue to investigate new techniques for improving survival for victims of cardiac arrest.

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Table E1: Life Expectancies and Costs by Outcome after Cardiac Arrest

| **Outcomes** | **Discounted Costs** | **Discounted Life Expectancy** |
|---|---:|---:|
| Died before hospital | $97.66 | 0 |
| Died in hospital | $3988.66 | 0.082 |
| Discharged alive (range given : data are age and gender specific) | $22131.01 to $23845.26 | 4.703 to 5.078 |

Table E2: Cost Effectiveness Results for PAD Programs by Location

| Site Type | Number of Sites | Number of Arrests per Site per Year | Incremental Cost | Incremental Effects (Life Years) | ICER | Probability Cost Effective | Maximum Number of Defibrillators to be Cost Effective |
|---|---|---|---|---|---|---|---|
| Casino | 2 | 2.8 | $8635 | 1.5911 | $542 | 1.00 | 54.8 |
| Non-acute hospital | 42 | 0.2 | $1551 | 0.0505 | $30750 | 0.99 | 1.7 |
| Nursing home | 460 | 0.199 | $1466 | 0.0319 | $45926 | 0.67 | 1.1 |
| Indoor shopping mall | 394 | 0.039 | $1415 | 0.0209 | $67690 | 0.02 | <1 |
| Penal institution | 21 | 0.057 | $1368 | 0.0106 | $128783 | 0 | <1 |
| Hotel | 604 | 0.022 | $1363 | 0.0095 | $143530 | 0 | <1 |
| Golf course | 156 | 0.012 | $1349 | 0.0065 | $205990 | 0 | <1 |
| Recreation/ assembly/ community facility | 3206 | 0.010 | $1349 | 0.0066 | $205407 | 0 | <1 |
| Restaurant/ bar | 1410 | 0.007 | $1337 | 0.0038 | $347954 | 0 | <1 |
| Airport/ heliport/ bus station | 83 | 0.014 | $1336 | 0.0036 | $368606 | 0 | <1 |
| Water/ boat/ marina | 240 | 0.004 | $1332 | 0.0028 | $478647 | 0 | <1 |
| School/ college/ university | 1770 | 0.004 | $1329 | 0.0022 | $598210 | 0 | <1 |
| Single store/ stripmall | 14956 | 0.003 | $1326 | 0.0014 | $925784 | 0 | <1 |
| Medical office | 2399 | 0.003 | $1325 | 0.0014 | $955614 | 0 | <1 |
| Office building | 7276 | 0.003 | $1325 | 0.0013 | $990511 | 0 | <1 |
| Stadium/ fairground | 238 | 0.001 | $1322 | 0.0007 | $1910193 | 0 | <1 |
| Sports field/ park | 3139 | 0.001 | $1320 | 0.0003 | $4104539 | 0 | <1 |
| Factory/ industrial/ railway/ dockyard | 17261 | 0.001 | $1320 | 0.0003 | $4323180 | 0 | <1 |

Figure E1: Design of Decision Model

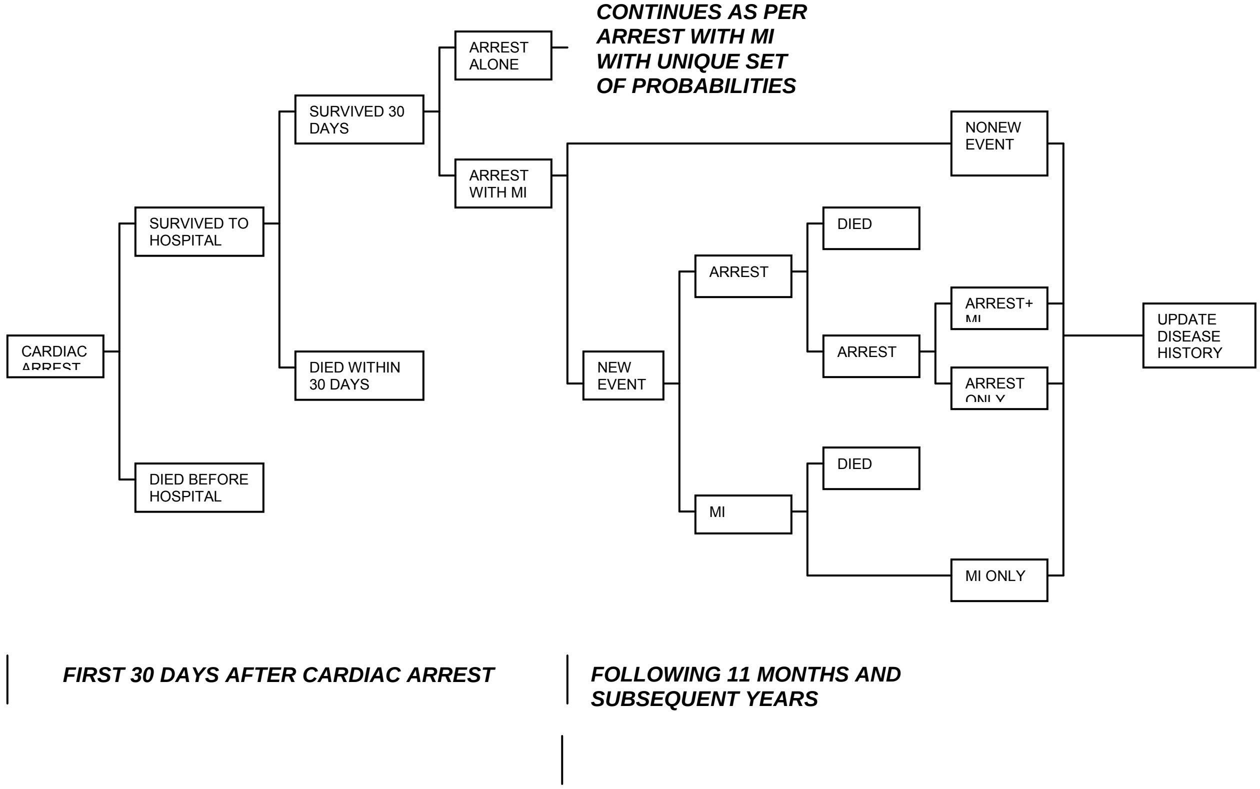


Figure E2: Cost Effectiveness Acceptability Curves for Casinos, Non-acute Hospitals and Nursing Homes

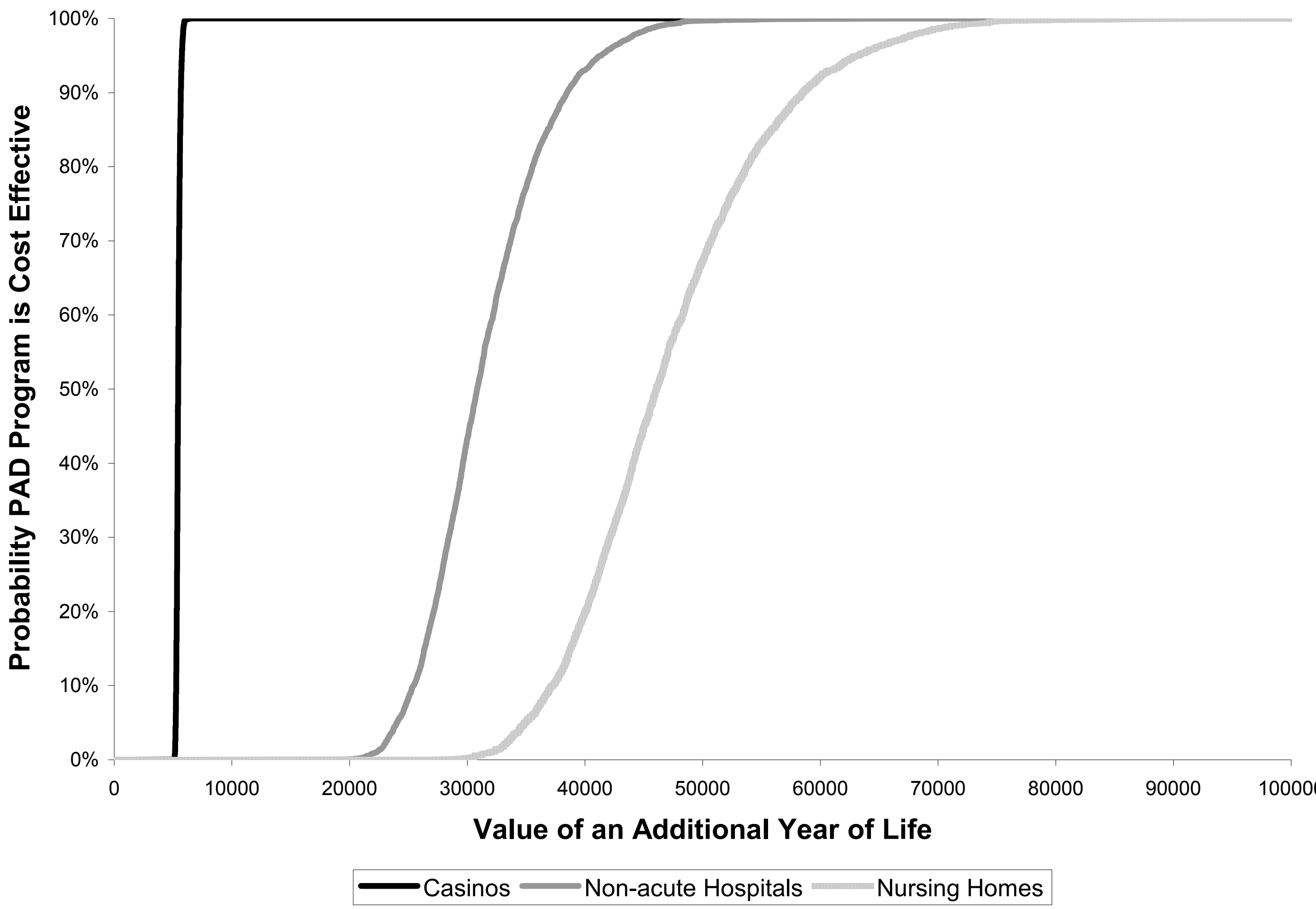


**Table 1. Demographic, clinical, and emergency medical services characteristics for the 7667 study subjects during the five-year study period.**

| | Patients (N=7,667) | |
|---|---|---|
| Mean age (SD) | 68.8 | (13.9) |
| [Age range] | | [16-102] |
| Male sex (%) | 5152 | (67.2) |
| Population size (%) | | |
| <30,000 | 279 | (3.6) |
| 30,000 to 99,999 | 1591 | (20.8) |
| 100,000 to 199,999 | 1687 | (22.0) |
| 200,000 to 499,999 | 2737 | (35.7) |
| ≥500,000 | 1373 | (17.9) |
| Bystander-witnessed arrest (%) | 3718 | (48.5) |
| Initial rhythm (n=7,431; %) | | |
| Ventricular fibrillation or tachycardia | 2746 | (37.0) |
| Pulseless electrical activity | 1597 | (21.5) |
| Asystole | 3125 | (42.1) |
| Bystander CPR (%) | 1255 | (16.4) |
| Fire/police CPR (; %) | 2951 | (38.7) |
| Defibrillated (%) | 3305 | (43.1) |
| PAD response (%) | 18 | (0.2) |
| Fire first EMS vehicle on scene (%) | 3738 | (49.2) |
| Defibrillation response interval (n=7,593) | | |
| Mean (min; SD) | 5.4 | (2.1) |
| $90^{th}$ percentile (min) | 7.8 | |
| Response eight min or less (%) | 6938 | (91.4) |
| Return of spontaneous circulation (%) | 1144 | (14.9) |
| Admitted alive to hospital (%) | 818 | (10.7) |
| Discharged alive from hospital (%) | 305 | (4.0) |

**Table 2. Frequency of cardiac arrest, witnessed VF/VT rate and number of property sites by location category during the five-year study period.**

| | Patients (N=7,667) | | Wit VF/VT (N=1,908) | | Sites (N=1,188,197) |
|---|---|---|---|---|---|
| | ***n*** | **(%)*** | ***n*** | (%)** | ***n*** |
| 1. Single residential dwelling | 4321 | (56.4) | 936 | (21.7) | 872811 |
| 2. Multi-residential dwelling | 1745 | (22.8) | 341 | (19.5) | 159519 |
| 3. Nursing/Retirement home | 457 | (6.0) | 48 | (10.5) | 460 |
| 4. Single store/Strip mall | 230 | (3.0) | 112 | (48.7) | 14956 |
| 5. Street/Highway/Road[ŧ] | 204 | (2.7) | 90 | (44.1) | --- |
| 6. Recreation/Assembly/Community facility | 165 | (2.2) | 119 | (72.1) | 3206 |
| 7. Office building | 96 | (1.3) | 50 | (52.1) | 7276 |
| 8. Indoor shopping mall | 77 | (1.0) | 45 | (58.4) | 394 |
| 9. Hotel | 65 | (0.8) | 31 | (47.7) | 604 |
| 10. Factory/Industrial/Railway/Dockyard | 56 | (0.7) | 23 | (41.1) | 17261 |
| 11. Restaurant/Bar | 48 | (0.6) | 30 | (62.5) | 1410 |
| 12. Non-acute hospital | 42 | (0.5) | 9 | (21.4) | 42 |
| 13. Medical office/clinic | 41 | (0.5) | 16 | (39.0) | 2399 |
| 14. School/College/University | 36 | (0.5) | 19 | (52.8) | 1770 |
| 15. Casino | 28 | (0.4) | 17 | (60.7) | 2 |
| 16. Sports field/Park | 14 | (0.2) | 4 | (28.6) | 3139 |
| 17. Other | 12 | (0.2) | 4 | (33.3) | 85454 |
| 18. Golf course | 9 | (0.1) | 6 | (66.7) | 156 |
| 19. Penal institution | 6 | (0.1) | 1 | (16.7) | 21 |
| 20. Water/Boat/Marina | 5 | (0.1) | 4 | (80.0) | 240 |
| 21. Airport/Heliport/Rail/Bus station | 4 | (0.1) | 2 | (50.0) | 83 |
| 22. Construction site [t] | 3 | (<0.1) | 0 | (0) | --- |
| 23. Farm | 2 | (<0.1) | 0 | (0) | 16720 |
| 24. Stadium/Fairground | 1 | (<0.1) | 1 | (100.0) | 238 |
| 25. Mine/Quarry | 0 | (0) | 0 | (0) | 36 |
| 26. Nursing outpost | 0 | (0) | 0 | (0) | 0 |

*percentages represent proportion of total cardiac arrests

**percentages represent rate of witnessed VF/VT for each location category

[t]The number of construction sites active during the study period is unknown.

[ŧ]The number of streets, highways and roads is not estimable.

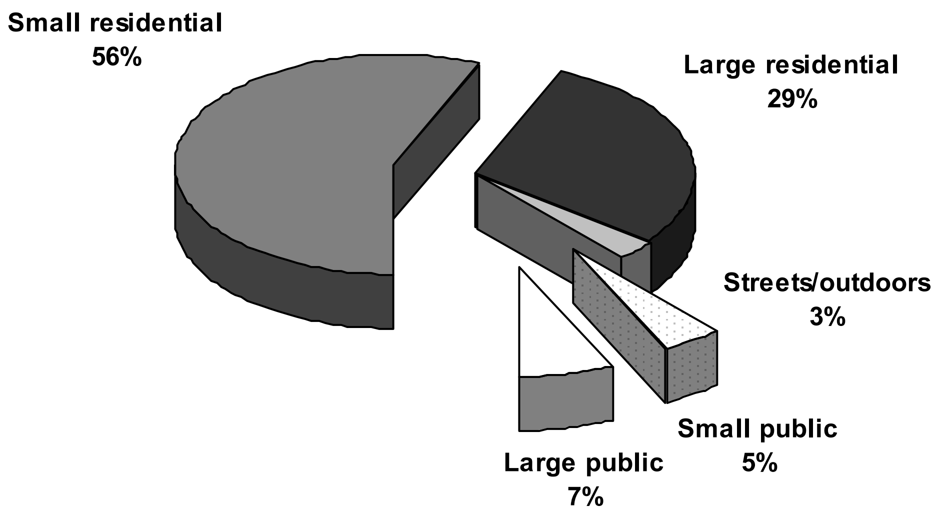
**Table 3. Utility measures PAD for each location category over a five-year period.**

| Location (total cases) | Cardiac arrests per site | PAD programs needed to treat one arrest | PAD programs needed to treat one wit VF/VT arrest |
|---|---|---|---|
| Casino (n=28) | 14.00 | 0.07 | 0.12 |
| Non-acute hospital (n=42) | 1.00 | 1 | 5 |
| Nursing home (n=457) | 0.99 | 1 | 10 |
| Penal institution (n=6) | 0.29 | 4 | 21 |
| Indoor shopping mall (n=77) | 0.20 | 5 | 9 |
| Hotel (n=65) | 0.11 | 9 | 19 |
| Golf course (n=9) | 0.06 | 17 | 26 |
| Recreation/Assembly/Community Facility (n=165) | 0.05 | 19 | 27 |
| Airport/Heliport/Rail/Bus station (n=4) | 0.05 | 21 | 42 |
| Restaurant/Bar (n=48) | 0.03 | 29 | 47 |
| Water/Boat/Marina (n=5) | 0.02 | 48 | 60 |
| School/College/University (n=36) | 0.02 | 49 | 93 |
| Medical office/Clinic (n=41) | 0.02 | 59 | 150 |
| Single store/Strip mall (n=230) | 0.02 | 65 | 135 |
| Office building (n=96) | 0.01 | 76 | 146 |
| Multi-residential dwelling (n=1745) | 0.01 | 91 | 468 |
| Single residential dwelling (n=4321) | <0.01 | 202 | 933 |
| Sports field/Park (n=14) | <0.01 | 224 | 785 |
| Stadium/Fairground (n=1) | <0.01 | 238 | 238 |
| Factory/Industrial/Railway/Dockyard (n=56) | <0.01 | 308 | 750 |
| Other (n=12) | <0.01 | 7121 | 21634 |
| Farm (n=2) | <0.01 | 8360 | --- |
| Mine/Quarry (n=0) | 0 | --- | --- |
| Nursing outpost (n=0) | --- | --- | --- |
| Construction site (n=3)* | --- | --- | --- |
| Street/Highway/Road (n=204)[t] | --- | --- | --- |

*The number of construction sites active during the study period is unknown, thus, cardiac arrest rates cannot be determined.

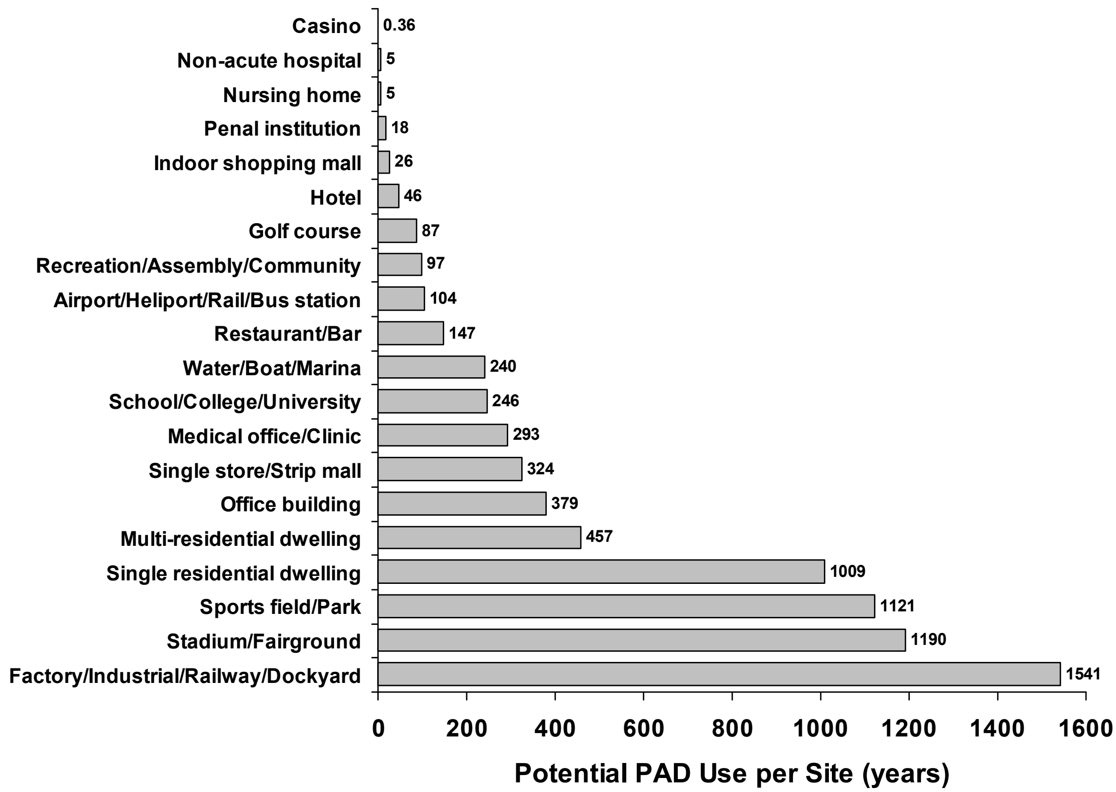
[t] The number of streets, highways and roads is not estimable, thus, cardiac arrest rates cannot be determined.

**Figure 1. The breakdown of cardiac arrest locations over a five-year period grouped into small and large residential and public venues***




***Small residential:** single residential dwelling; **Large residential:** multi-residential dwelling, nursing home; **Streets/outdoors:** street/highway/road, farm, water/boat, other vacant land parcel; **Small public:** construction site, medical office/clinic, nursing outpost, single store/strip mall, sports field/park, golf course, restaurant/bar; **Large public:** airport/heliport/rail/bus, factory/industrial/railway/dockyard, hotel, non-acute hospital, indoor shopping mall, penal institution, school/college/university, mining site/quarry, office building, recreation facility, stadium/fairground, casino.

**Figure 2. Number of years for one expected PAD use per site.**



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