Optimizing the Placement of Automated External Defibrillators in Marin County, CA — A Location-Allocation Analysis

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Abstract

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This study evaluated the spatial and temporal coverage of public automated external defibrillators (AEDs) in Marin County, California, from 2019 to 2024 to determine whether existing AEDs were optimally located to maximize Out-of-hospital cardiac arrest (OHCA) coverage and to identify additional placement opportunities. We defined coverage as the proportion of OHCAs occurring within 100 meters of an AED and differentiated between *expected coverage* (ignoring AED availability) and *actual coverage* (accounting for AED accessibility at the time of arrest). Using registry data on 321 publicly available AEDs and geocoded OHCA events, we found no significant difference between *expected* and *actual coverage*, suggesting temporal accessibility was not a major limiting factor. However, by incorporating 20 candidate AED sites identified through location-allocation modeling, OHCA coverage significantly improved by 2.93 percentage points (from 7.01% to 9.94%, $p < 0.05$), representing a 42% relative increase. This suggests that spatial distribution—not temporal availability—is the key for improved coverage in Marin County, and strategic placement of a limited number of additional AEDs could meaningfully enhance public access to defibrillation.

Introduction

Heart disease has been the leading cause of death in the United States since the 1950's, with now about 250,000 deaths due to out of hospital cardiac arrests (OHCAs), annually[1]. Arrests labeled with this acronym occur outside hospital settings, which could include locations such as residential areas, plazas, roadways, and others outside of healthcare. Prompt response times from emergency medical services (EMS) teams are crucial for life-saving intervention measures — like cardiopulmonary resuscitation (CPR) or automated external defibrillator (AED) use — to retain peak effectiveness for patient survival. The reality of EMS response times consistently landing within the window of peak intervention effectiveness (3-5 minutes after arrest) is not currently what we are observing[2]. Instead, researched EMS units are reporting an average of 8-12 minute response times[3].

A key factor to OHCA survival *prior* to EMS arrival is the provision of prevention efforts by bystanders who may have witnessed or happened upon the arrest. Bystander CPR and AED use are two methods of OHCA intervention with the most reported and researched success[4]. Every minute that a patient goes without bystander defibrillation, the survival rate decreases by 7-10%, when compared to those who received immediate intervention[1]. This decay of survival likelihood only continues as time elapses between the event occurring and EMS arrival [5,6,7]. Despite this compelling evidence, the percentage of OHCA patients receiving AED defibrillation from bystanders has been estimated to only be around 4-7%[8,9].

Efforts have been made to increase this percentage, including placing AEDs in public locations to widen the availability of access. This solution gained momentum in the late 1990s and early 2000s, through public access defibrillation (PAD) programs[10]. PAD programs improved access by placing AEDs at publicly accessible locations where OHCAs may be more likely to occur. PAD programs also stressed training bystanders for AED use, creating AED registries, and routine maintenance of AEDs.

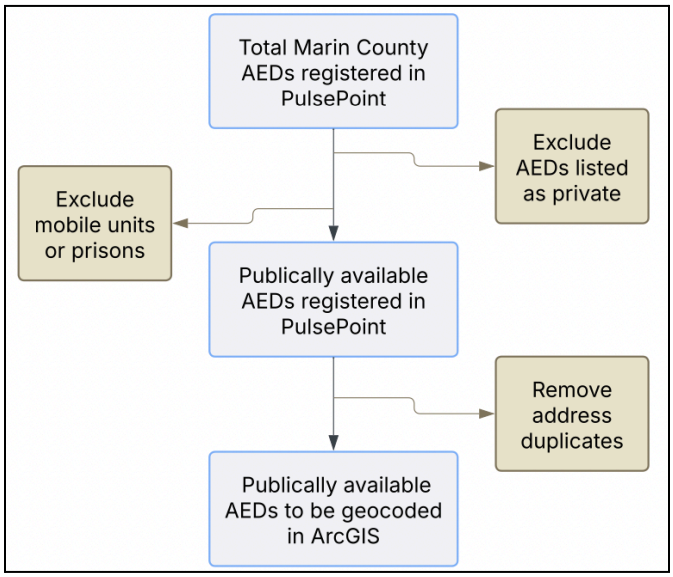
To learn why AED location matters, researchers have investigated the true accessibility of reportedly "public" AED locations and found that many AEDs had been placed in locations not readily accessible by the general public, due to limited business hours or spatial inaccessibility[2]. Over the years researchers have developed mathematical models and other methods to guide the placement of AEDs in hopes of increasing rates of actual bystander AED use[11,12,13]. These modeling methods can consider the temporal and spatial availability of candidate AED locations and use density analyses to identify optimal locations for additional devices with the aim of improving rates of AED use in the community.

Marin County, a coastal region in California, has a life expectancy that exceeds the national average by 9 years[14]. However, life expectancy alone is not sufficient evidence of perfect health for all Marin County residents. With health conditions like cancer and cardiovascular disease leading causes of death nationwide, even regions like Marin County, despite strong health metrics, struggle to prevent potentially avoidable deaths. Starting in 2020 the Marin County Department of Health and Human Services (HHS) began promoting PulsePoint, a free mobile application that acts as a registry for publicly available AEDs, which alerts app-owning individuals to nearby OHCAs and the location of the nearest AED[15]. For applications like PulsePoint to function at full capacity, and for bystanders to maximize a patient's chances of survival, the essential cardiac arrest intervention supplies must be strategically located, easily accessible, and clearly identifiable.

This study assessed whether the publicly available AEDs in Marin County are optimally located for maximum OHCA coverage and, if not, sought to identify the best placement to achieve this goal. The primary aim was to determine the already-present proportion of OHCAs that occurred within 100 meters of a publicly accessible AED and whether temporal factors affected this coverage proportion. We analyzed the spatial distribution of OHCAs in relation to the locations of registered public AEDs, assessing the effectiveness of current AED placement strategies. We identified AED candidate locations to improve public access to emergency

defibrillation devices using data from 2019-2024 to evaluate the extent to which coverage for OHCAs in Marin County could be improved by incorporating candidate AED locations identified through spatiotemporal optimization methods.

Figure 1. Flowchart of the approach to data cleaning for PulsePoint data



Methods

Study design

We conducted a retrospective, registry-based study using OHCA data collected in Marin County from the years 2019-2024. AED data included public and private AED locations reported to PulsePoint in Marin County, totaling 378 AEDs, 321 of which were reported as publicly available (**Figure 1)**. We excluded AEDs in hospital settings, in private residences, and within mobile units or a prison. Multiple AEDs at one geographic location were considered duplicates and only unique address values were retained. It is not required to publicly report AED locations and, noting this, it is understood that the reported AED locations may underestimate the true number of AEDs in Marin County.

The outcome measure, coverage, was defined in two ways, following previous work in this field[12-14]: *expected coverage*—an AED within 100m of an OHCA—and *actual coverage*—an AED within 100m *that is accessible at the time* of the OHCA. The availability of AEDs is dependent on the operational hours of the location where they are stored. Hours of operation for each AED were categorized as either business hours (8am-5pm) or extended hours (open within and beyond business hours). The timestamp of each OHCA was included in the data and used to classify OHCAs as occurring within or outside of the set business hours. The buffer distance of 100m around each OHCA was chosen as it is the standard distance used in studies of spatiotemporal placement of AEDs[14]. It takes into account the speed at which a bystander would most likely be moving to retrieve the AED, as well as how far they could reach while being able to return to the patient within a three-minute period.

Study setting

Marin County is a coastal county with a population of 250,000+ located in the northwestern part of the San Francisco Bay Area[16]. Its citizens' health is overseen by the Marin County HHS Department which includes the Marin EMS Agency[17].

Study subjects

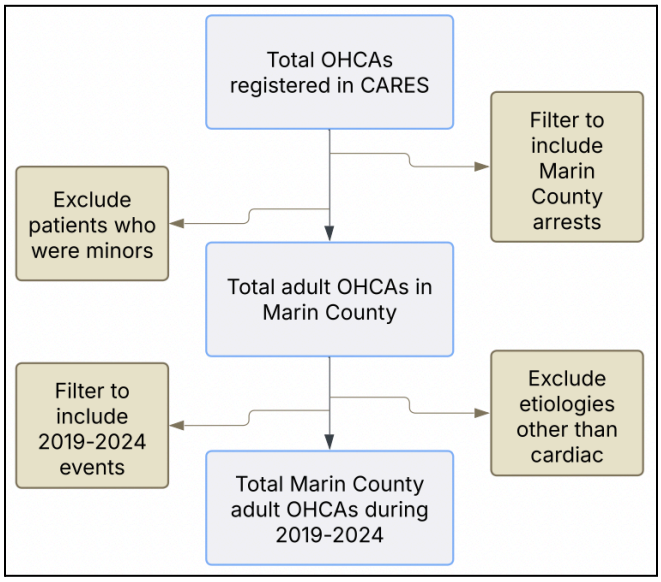
The subjects in this study were those who, within the geographic bounds of Marin County, received resuscitation attempts by EMS services after experiencing an OHCA during the years 2019-2024 (**Figure 2**). Subjects were collected from a repository, Cardiac Arrest Registry to Enhance Survival (CARES)[18], a CDC-established data source that collects information on patients who experienced a non-traumatic cardiac arrest outside of a hospital setting, where resuscitation was attempted. It is maintained by Physio-Control, Inc., which links 911 call center data, EMS data, and hospital data. The registry excludes events in which patients were dead upon arrival and therefore focuses on events where patient survival is a possibility.

Subjects were considered eligible if they were 18 years of age or older and experienced an OHCA with an etiology recorded as "Cardiac (Presumed)". Other etiologies included in the

CARES registry were “Asphyxiation” or “Overdose” and these cases were excluded as this analysis focused on events with a cardiac etiology. In total, during 2019-2024, there were 785 eligible OHCAs in the CARES registry for Marin County.

The CARES database included data, entered manually or via electronic records, on demographics, location of event, end of event status, and bystander intervention information. The data regarding AED location was provided by Marin EMS’s PulsePoint data and included variables such as AED address details and whether the AED is private or public.

Figure 2. Flowchart of the approach to data cleaning for CARES data



Candidate locations for future AED placement were chosen through Google Maps, and, to ensure extended hour availability, using filtering tools to return only locations open 24/7 in Marin County. This list of candidate locations included gas stations, convenience stores, lodging facilities, fast food establishments, pharmacies, and 24/7 gyms; and comprised 98 locations. Google Takeout is a free service that lets users export a copy of saved Google data, including saved location of candidates, to a computer or another storage location for backup or archiving purposes. We used this service to transport saved candidate locations found on Google Maps into a file format for ArcGIS geocoding.

Statistical Analysis

We calculated two OHCA coverage measures. The *expected coverage* was the proportion of OHCAs that had an AED within an 100m radius. The *actual coverage* was the proportion of OHCAs that had an AED within an 100m radius that was categorized as available at the time of the OHCA. From these percentages, the *coverage loss* was calculated by subtracting the *actual coverage* from the *expected coverage* and dividing by the *expected coverage*. This *coverage loss* measure was used to quantify gaps that can be attributed to AED temporal availability factors.

We used the *actual coverage* findings as a baseline to examine how mathematical modeling/placement could improve *actual coverage* of OHCAs in Marin County. We used a list of candidate locations and, based on the Maximal Covering Location Problem (MCLP)[19], identified AED placement locations that improved the current *actual coverage* of OHCAs in Marin County. The MCLP is used by researchers who want to prioritize coverage in their Location-Allocation analysis, as it is one of seven “problem types” that can be chosen from[20]. The Location-Allocation tool takes two main inputs: the facilities (AEDs) and the demand points (OHCAs). MCLP is a setting within the analysis, frequently used for locating fire/EMS facilities, that works to ensure as many demand points as possible are allocated to solution facilities within the impedance cutoff (100m).

This previously-developed mathematical optimization model was used to determine the best AED locations by aiming to *maximize coverage* based on OHCA incidence and location[14]. The model incorporates whether a cardiac arrest event is covered or not by spatial buffer (100m), whether an AED is to be placed in the candidate location or not, whether a cardiac arrest is within 100 meters of a candidate location, the number of locations where AEDs are placed, the number of OHCA locations, and the number of candidate locations.

The number of candidate locations a researcher wants inputted into this model can be chosen through the ArcGIS Location Allocation tool. To cover a multitude of possible future scenarios, we conducted analyses of the potential coverage gain given AED placements at the top 5, 10, 15, 20,…n candidate locations until adding more locations no longer increased the coverage percentage[14]. We then compared the *actual coverage* percentage under the potential and existing AED placement scenarios. To compare the proportions of OHCA covered under each scenario, we used a 2-sample, chi-square test for equality of proportions, with a null hypothesis of no difference in proportions. A p-value was labeled significant if it was less than 0.05.

Table 1. Summary statistics on demographics for OHCAs in Marin County (CARES: 2019-2024)

Characteristic	Count * (N = 785)	Characteristic (continued)	Count (N = 785)
Age	69 (15)	*Recreation area*	27 (3.4%)
Sex		*Beach/Ocean/Lake/River*	2 (0.3%)
Male	559 (72%)	*School/College/University*	2 (0.3%)
Female	215 (28%)	*Swimming Pool*	2 (0.3%)
Race		*Wilderness area*	2 (0.3%)
American Indian or Alaska Native	2 (0.3%)	*Fire Department*	1 (0.1%)
Asian	26 (3.3%)	*Transport Center*	1 (0.1%)
Black or African American	42 (5.4%)	*Unspecified place*	1 (0.1%)
Hispanic or Latino	52 (6.6%)	Time of Day of Arrest	
Native Hawaiian or Pacific Islander	10 (1.3%)	*Business Hours (8am-5pm)*	397 (51%)
White	569 (72%)	*Outside Business Hours*	388 (49%)
Other	84 (11%)	Arrest Witnessed By	
Arrest Location		*Lay Person/Family Member*	310 (39%)
Residence/Assist. Living	572 (73%)	*Not Witnessed*	360 (46%)
Medical Practitioner Office	5 (0.6%)	*Healthcare Provider*	108 (14%)
Street/highway	46 (5.9%)	*Other*	7 (0.9%)
Health Club/Gym	4 (0.5%)	Was an AED Used Prior to EMS Arrival?	
Residential institution	4 (0.5%)	*Yes*	118 (16%)
Commercial establishments	32 (4.1%)	*No*	636 (84%)
Public Building	3 (0.5%)	*Other*	4 (0.5%)

** Mean (SD); n (%)*

Results

OHCA Descriptive Data

A large majority of OHCAs (73%) in Marin County were recorded to have happened in a residential setting, with other frequently recorded locations being on the street, in commercial establishments, and in recreation areas (**Table 1**). Marin County's predominantly White population is reflected in the 72% of OHCAs that were reported to be White patients[17]. The proportion of Black or African American OHCA patients was 5.4% although the population that identified as Black or African American in Marin County was 2.9%[16]. The proportion of patients who were reportedly Hispanic or Latino is lower than the population proportion of Hispanic or Latino residents (6.6% vs 19.6%).

Table 2. Summary statistics on demographics for OHCAs in Marin County within each year of arrest (CARES: 2019-2024)

Characteristic	2019 N = 95[1]	2020 N = 137[1]	2021 N = 147[1]	2022 N = 144[1]	2023 N = 139[1]	2024 N = 123[1]
Age	69 (17)	69 (16)	70 (14)	69 (16)	70 (14)	67 (15)
Sex						
Female	26 (27%)	41 (30%)	42 (29%)	43 (30%)	27 (21%)	36 (29%)
Male	69 (73%)	96 (70%)	105 (71%)	101 (70%)	101 (78%)	87 (71%)
Unknown	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.8%)	0 (0%)
Race						
American Indian or Alaska Native	0 (0%)	0 (0%)	0 (0%)	1 (0.7%)	0 (0%)	1 (0.8%)
Asian	5 (5.3%)	6 (4.4%)	4 (2.7%)	2 (1.4%)	6 (4.3%)	3 (2.4%)
Black or African American	4 (4.2%)	12 (8.8%)	5 (3.4%)	8 (5.6%)	8 (5.8%)	5 (4.1%)
Hispanic or Latino	4 (4.2%)	8 (5.8%)	8 (5.4%)	9 (6.3%)	9 (6.5%)	14 (11%)
Native Hawaiian or Other Pacific Islander	0 (0%)	0 (0%)	4 (2.7%)	2 (1.4%)	3 (2.2%)	1 (0.8%)
White	68 (72%)	100 (73%)	104 (71%)	99 (69%)	103 (74%)	95 (77%)
Other/Unk	14 (15%)	11 (8.0%)	22 (15%)	23 (16%)	10 (7.2%)	4 (3.3%)
Arrest Witnessed By						
Healthcare Provider	18 (19%)	13 (9.5%)	16 (11%)	21 (15%)	20 (14%)	20 (16%)
Lay Person/Family Member	38 (40%)	62 (45%)	61 (41%)	54 (38%)	51 (37%)	44 (36%)
Not Witnessed	38 (40%)	62 (45%)	69 (47%)	67 (47%)	66 (47%)	58 (47%)
Time Category						
Business Hours	41 (43%)	78 (57%)	67 (46%)	65 (45%)	80 (58%)	66 (54%)
Outside Business Hours	54 (57%)	59 (43%)	80 (54%)	79 (55%)	59 (42%)	57 (46%)
Was an AED Used Prior to EMS Arrival?						
No	84 (92%)	117 (87%)	122 (85%)	105 (76%)	106 (79%)	102 (87%)
Other	1 (1.1%)	1 (0.7%)	0 (0%)	1 (0.7%)	1 (0.7%)	0 (0%)
Yes	6 (6.6%)	16 (12%)	21 (15%)	32 (23%)	28 (21%)	15 (13%)

[1] *Mean (SD); n (%)*

A large percentage of OHCAs in Marin County went unwitnessed by others, the number remaining consistently close to 40-45% over the years (**Table 2**). Of those that were witnessed, about 72% were witnessed by a lay person or family member. Overall, 16% of all OHCAs received the use of an AED prior to EMS arrival. By year, actual bystander use of an AED prior to the arrival of EMS increased from 6.6% to 23% during 2019 through 2022 before dropping to 13% in 2024. Of the 200+ public AEDs listed in the Marin County PulsePoint registry, 77% were open beyond the 8am-5pm business hours (**Figure 3**). Marin County's reported public AEDs were most often found in schools (12%), businesses (6.9%), government offices (5.9%), and gyms/libraries (4.9%).

Current Coverage Analysis

ArcGIS software was used to geocode the locations of existing AEDs and OHCAs across Marin County (**Figure 4**). Of the OHCAs from 2019-2024, 7.13% met the requirements for *expected coverage* from the existing public AEDs (**Table 3**). When we changed the coverage type to *actual coverage,*incorporating temporal factors*,* we found that 7.01% of the OHCAs were

Figure 3. AED count in top five different Marin County location types, stratified by hours of availability

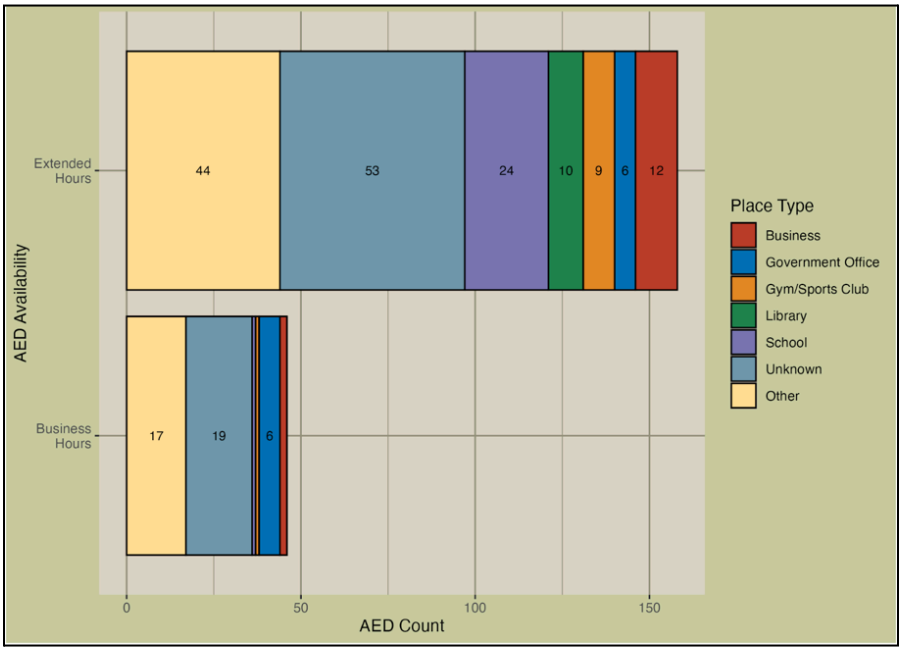
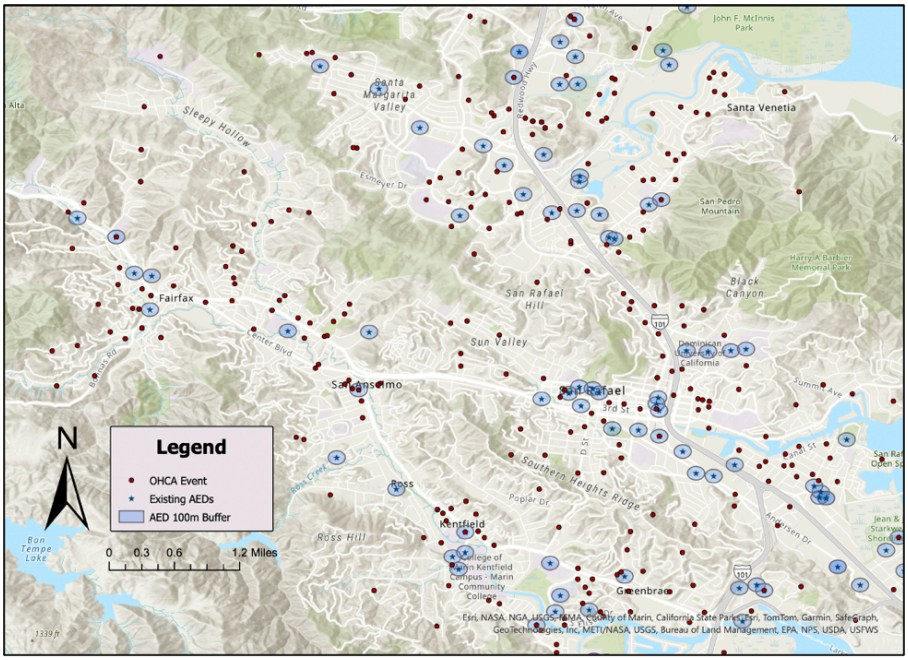


Figure 4. Focused map of San Rafael area, Marin County, CA, displaying current actual OHCA coverage



Map with the blue stars representing each existing AED in Marin County, and the blue circular buffers representing the 100m distance from each AED. Any OHCAs (red dots) contained within the buffer zones are considered "actually covered"

actually covered by AEDs in Marin County. The coverage loss, or *expected* minus *actual* AED coverage divided by the *expected* value, was 1.68%. This means that the *actual coverage* achieved was about 1.68% less than what was anticipated. This is a very small difference in proportion, suggesting minimal coverage loss due to temporal factors. The 2-sample test for equality of proportions confirmed that the coverage loss was not significant (p = 0.99; confidence interval -2.5%, 2.8%) .

Location-Allocation Analysis

To target arrests that were not covered by existing AEDs in Marin County, those that were found to be *actually covered* in the current coverage analysis were removed from the dataset. This left 752 OHCA points available for the ArcGIS allocation analysis. The ArcGIS Location-Allocation tool identified the nearest "n" candidate AEDs with the Maximal Coverage setting and added them to the map as "chosen" locations (**Figure 5:** starred map features).

The *actual coverage*, once additional AED placements were added, only reached a significant level of difference when a total of 20 candidate locations were "chosen" in the Location-Allocation analysis (p-value < 0.05) (**Table 4**). The *actual coverage* for OHCAs under the additional 20 candidate locations increased from 7.01% to 9.94% coverage.

Table 3. Comparison of expected vs. actual OHCA coverage by AEDs, with p-value from proportion test

Coverage	OHCAs Covered (n (%))	OHCAs Not Covered (n (%))	Proportion Difference (95% CI)	p-value[1]
Expected	56 (7.13%)	729 (92.87%)	ref	
Actual	55 (7.01%)	730 (92.99%)	0.001 (-0.025, 0.028)	0.99

1. p-value from a 2-sample test for equality of proportions

Table 4. Comparison of OHCA coverage: baseline AED sites vs. additional candidate sites (2-sample proportion tests, 95% CI)

Chosen Candidates	OHCAs Covered	OHCA Coverage (%)	Difference in Count	Difference in Proportion (95% CI)	p-value[1]
0	55	ref	ref	ref	ref
5	63	8.03	8	0.0102 (−0.0375, 0.0172)	0.503
10	68	8.66	13	0.0166 (−0.0444, 0.0113)	0.260
15	73	9.30	18	0.0229 (−0.0513, 0.0054)	0.117
20	78	9.94	23	0.0293 (−0.0581, −0.0005)	0.046
25	78	9.94	23	0.0293 (−0.0581, −0.0005)	0.046
30	78	9.94	23	0.0293 (−0.0581, −0.0005)	0.046

1. p-value from a 2-sample test for equality of proportions with 95% confidence intervals

Discussion

In an analysis of Marin County OHCA data from 2019-2024, we found that the difference in current coverage between *expected* and *actual coverage* was small. However, coverage percentage significantly increased by 2.93% once 20 new candidate locations were added to the Location-Allocation analysis (p-value: <0.05). The proportion of OHCAs covered by AEDs increased by approximately 42% (9.94 /7.01 = 0.42) compared to the original coverage level. While the absolute increase was only 2.93 percentage points, the relative improvement was substantial, indicating a meaningful growth in bystander access to AEDs for cardiac arrest events.

The current coverage analysis shows that temporal factors of AED availability in OHCAs in Marin County were not influential in explaining the low coverage, as Marin County already has 77% of its existing AEDs available past business hours. We found no significant difference between the *expected* versus *actual coverage,* unlike previous research on this topic[12,13]. In a Toronto study, the difference was found to be around 4%, which is most likely due to the fact that other research locations have less robust temporal availability of AEDs. A Sun et al. study in Toronto found that 73% of their current AEDs were not in locations with extended hours of operation[12].

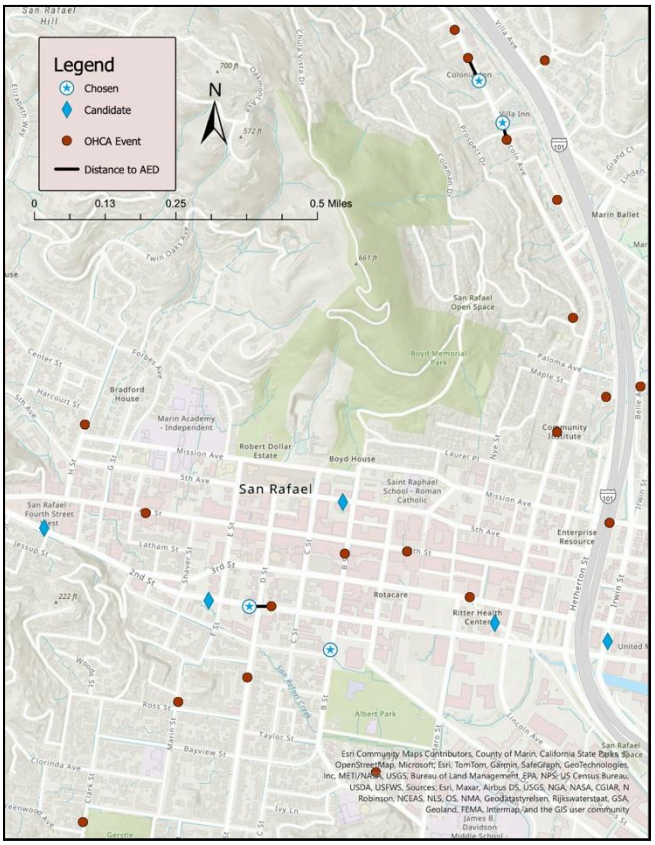
Using location-allocation analysis, we found that there was a significant improvement in coverage only once 20 new AEDs were added to the Marin County landscape from the candidate list. Once the first five candidate locations were added into the analysis, the count of OHCAs covered increased by eight events. As the count of candidate sites increased beyond 5, the count of covered OHCAs then increased by five with each addition of five candidate sites. This trend plateaued once significance was reached at 20 candidate sites, with 78 covered arrests-- an arrest count that was sustained as the chosen candidate count continued to increase past 20. At this plateau, the coverage percentage increased from the actual coverage found in the primary analysis (7.01%) by 2.93%. The improvement in coverage was lower than in previous research using candidate locations and MCLP for this field of interest[12,13]. However, this may be attributed to the population density differences between the study locations. Toronto is a densely populated urban environment, whereas Marin County houses a smaller population over a larger land area. The top five cities within Marin County that housed the most AEDs were

San Rafael (seen in **Figure 5**), Mill Valley, Novato, Tiburon, and Corte Madera. Cities with the lowest percentage (below 1% of the total) of AEDs were Tomales and Marshall. These facts align with the population densities in these cities, in that cities with a higher density generally contain more AEDs.

According to a 2018 study, neighborhood characteristics including proportion of people living alone, the proportion of white people, and the proportion with a high-school degree or higher, were associated with greater bystander AED use[7]. Marin County is predominantly white (84% of population) and college-educated (59% of population)[16]. As expected, the proportion of all OHCA patients in Marin County who received bystander AED was 6.5%, at the high end of the range of 4-7% observed nationally[8,9].

Our location-allocation analysis specified that all existing AEDs in Marin County be included in the analysis as permanent fixtures. Other research papers have done a similar analysis, save the fact that they relocated existing AEDs in addition to adding candidate locations. This process has previously been shown to be an effective intervention plan, however it is ultimately not the route that our analysis took, due to complications that Toronto researchers described in their paper; reasons such as the desire of host businesses to keep their AEDs and confusion of future bystanders who relied on previous AED locations[22].

Figure 5. A closer look over the San Rafael area of Marin County, CA using the Location-Allocation analysis



Map with the blue stars representing each "chosen" AED from the list of candidate sites, and the black lines representing the 100m distance from each AED. Any OHCAs (red dots) connected to an AED are considered "actually covered".

We found that an additional 20 AED sites placed in Marin County at locations with extended hours would result in the most efficient placement of new devices for optimal coverage as well as cost-effectiveness of the purchasing of new AEDs. AEDs can cost health departments $1,200 to $3,000 per unit, a total of *at least* $24,000 for 20 new AEDs; at most: $60,000. Each additional five candidate locations chosen adds a $6,000-$15,000 fee to the placement of these devices; choosing a candidate count with minimum cost/maximum coverage is important to the funding and budgetary side of EMS and HHS AED work.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, this analysis did not incorporate pedestrian walkways or account for actual travel paths to reach a nearby AED. Instead, it used road networks in Marin County to measure proximity between OHCAs and the nearest AED. This is a limitation because straight-line, on-road, distances may overestimate the actual distance or time required to access an AED, particularly in areas where pedestrian walkways would present fewer barriers or a more direct pathway to the event. As a result, the coverage estimates may understate the practical accessibility of AEDs in real-world scenarios, where individuals must navigate the sidewalks, crosswalks, buildings, or traffic to reach a device.

A second limitation is that the analysis was based on AED locations reported in the PulsePoint AED registry, which is not a complete inventory of all AEDs within Marin County. There may be unreported AEDs that were not included in the dataset due to the housing facility not reporting their AED in the PulsePoint registry. This limitation underscores a potential underestimation of existing AED coverage and availability and may impact the accuracy of the spatial optimization recommendations by omitting devices that are already present but not documented.

There are also limitations when considering the collection method of the race variable in the CARES dataset, which was collected and recorded by the EMS professionals who responded to the arrests. The EMS professionals were tasked with assigning race/ethnicity as reported by the patient, the patient's family, or the patient's healthcare provider. It is understandable that often the patient was not alert enough to report their own race, requiring the EMS worker to use family or provider information. This method, where the patient themselves is not recording their own race, is a fallible method of identification and presents this research with limitations surrounding the validity of the reported race variable when not reported by the patient.

The location-allocation geocoding process was unable to identify a point of interest (POI) for 33 (3%) OHCA addresses, preventing these events from being included in the analysis. This is a limitation because it reduced the sample size of cardiac arrest events used to assess AED coverage and spatial optimization. The missing events may have had distinct geographic locations, such as a pedestrian walkway or outdoor hiking trail, and their exclusion could bias the findings if these excluded OHCAs systematically differed from those that were successfully geocoded. It is also prudent to note that the time span where OHCA data was collected includes the years of the COVID-19 pandemic. This could bias the finding to overestimate the number of OHCAs due to hospitals limiting patient intake during the pandemic.

Future Implications

The spatial optimization analysis demonstrated that significant increases in OHCA coverage were not achieved until at least 20 additional AEDs were added, with little gain in coverage beyond that point. This finding underscores the need for strategic placement of new devices, rather than simply increasing quantity in the community. For health departments and EMS agencies operating under budgetary constraints, this type of analysis provides a data-driven recommendation for finding the optimal number and placement of new AEDs, offering a pathway to maximize both public health impact and fiscal responsibility.

Future efforts could further explore the coverage incorporating information on pedestrian walkways as a mode of travel. Efforts could also focus on the potential to integrate AED placement strategies with public education and training initiatives aimed at increasing awareness of, and confidence in, AED use, particularly in neighborhoods with lower likelihoods of bystander intervention. Additionally, consideration of other public candidate locations, such as transit stations or recreational facilities, could further refine spatial placement strategies beyond the business/extended hours availability approach taken in this analysis.

Finally, these findings may inform broader policy discussions around AED legislation, including requirements for AED access in certain types of facilities, like gyms, convenience stores, or other businesses open during extended hours. By demonstrating the relationship between AED availability and bystander use, this study supports a more targeted and cost-effective approach to improving out-of-hospital cardiac arrest outcomes.

Conclusions

Our analyses found the current placement of AEDs in Marin County, CA, to meet the estimated typical percentage of OHCA patients receiving AED defibrillation from bystanders (4-7%) and, temporally, the devices to be predominantly available beyond 8am-5pm business hours[8,9]. Utilizing the Location-Allocation analysis in ArcGIS, we identified 20 new AED sites

that, once equipped, would significantly increase the OHCA coverage percentage by 2.93%, increasing the coverage by 42% relative to the original coverage. Any additional sites would not significantly increase the coverage and any fewer would not be a significant increase from the current coverage.

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