UNIVERSITY OF CALIFORNIA SAN DIEGO

Modeling the Potential Impact of a Community Bystander CPR Training Program in San Diego County, California

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in

Master of Public Health (Epidemiology)

by

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The Thesis of Jihui Zhao is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

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LIST OF ABBREVIATIONS

AED	Automated External Defibrillator
AHA	American Heart Association
AOR	Adjusted Odds Ratio
BCPR	Bystander Cardiopulmonary Resuscitation
CARES	Cardiac Arrest Registry to Enhance Survival
CI	Confidence Interval
CPC	Cerebral Performance Category
CPR	Cardiopulmonary Resuscitation
EMS	Emergency Medical Service
HC	Howard County
OHCA	Out-of-Hospital Cardiac Arrest
OR	Odds Ratio
QALY	Quality-Adjusted Life-Year
ROSC	Return of Spontaneous Circulation
RR	Relative Risk
SD	Standard Deviation

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ABSTRACT OF THE THESIS

Modeling the Potential Impact of a Community Bystander CPR Training Program in San Diego County

by

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Objective: Out-of-hospital cardiac arrest (OHCA) remains a significant public health concern, with high incidence and mortality rates. Bystander cardiopulmonary resuscitation (BCPR) can significantly improve survival and neurological outcomes. We aim to estimate the potential impact of the San Diego County "Revive and Survive San Diego" initiative, a community BCPR training program started in 2024 with the goal to train 1 million San Diegans in hands-only CPR.

Methods: We adapted a decision tree model simulating health outcomes among a population with OHCA eligible for BCPR. The model was parameterized with the San Diego County Cardiac Arrest Registry to Enhance Survival (CARES) database from 2020-2023, which receives input from participating large healthcare agencies. Based on a systematic review, we assume community BCPR training increases the proportion of OHCA patients who receive BCPR by 41% and the chances of survival if BCPR is received by 59%. We estimate 5-year impacts on BCPR, deaths, life-years, and quality-adjusted life-years (QALYs). We also examined potential secondary benefits, such as increased organ donation.

Results: Analysis suggests 8,445 (95% CI 7884-9006) OHCA cases eligible for BCPR will be tracked in CARES within the 5-year period after finishing the training for 1 million residents. The model forecasts the implementation of the initiative will result in an absolute increase of 1,709 (95% CI 1139-2347) BCPR events, leading to 467 (95% CI 185-896) lives and 1,773 (95% CI 685-3314) QALYs saved compared to current interventions over five years.

Conclusions: The "Revive and Survive San Diego" initiative could substantially improve OHCA outcomes. However, future research must focus on tailoring interventions to promote health equity across diverse populations and exploring secondary benefits like increased organ donation.

INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) remains a significant public health concern in the United States, characterized by a high incidence and mortality rate.[1,2] OHCA is defined as the loss of functional cardiac mechanical activity in association and systemic circulation that occurs outside of a hospital setting.[3] According to the 2023 Cardiac Arrest Registry to Enhance Survival (CARES) Report, which is a web-based data management system established in 2004 for participating communities to report and compare their OHCA data, there were 139,822 OHCA cases nationwide in 2023, with only 14,261 (10.2%) surviving hospital discharge.[2,4] Even for those who do survive, many may suffer from anoxic brain damage due to the cessation of cerebral blood flow to brain tissue during cardiac arrest, potentially requiring long-term nursing home admission or resulting death.[5,6] OHCA survivors may experience further complications, such as organ dysfunction and psychological distress, including anxiety and depression.[7,8]

Bystander CPR for OHCA

Bystander CPR (BCPR) is defined as the administration of conventional CPR (either or both ventilation and chest compressions) by an individual who has been trained in basic life support, excluding 9-1-1 responder witnessed, nursing home, or healthcare facility arrest.[9–11] Studies indicated that BCPR could significantly increase the chances of survival and favorable outcomes, including the presence of the return of spontaneous circulation (ROSC), which is the restart of a sustained perfusing cardiac activity after the cardiac arrest, and good neurological outcomes, and the absence of aforementioned adverse health outcomes, for OHCA patients by 2 to 4-fold.[5,12–15] Reported by the American Heart Association (AHA), the overall BCPR rate for OHCA cases treated by emergency medical services (EMS) in the United States in 2022 was 40.0%. This rate varied significantly across states, from a low of 22.8% in Connecticut to a high

of 73.2% in Alaska. In California, the BCPR rate of 41% was slightly above the national average but lower than many other states, such as Washington (51.7%), Oregon (56.9%), and Vermont (48.7%), indicating substantial room for improvement.[2]

Community-based Bystander CPR Intervention

As the national BCPR rate (39.5% in 2013 vs. 41.2% in 2023) and survival of OHCAs (10.9% in 2013 vs. 10.2% in 2023) have not substantially improved in decades, community-based CPR interventions have been developed.[10,16] These interventions have the goal of increasing rates of BCPR or using bystander-automated external defibrillator (AED), a portable device designed to treat cardiac arrest through an electric current via external electrode pads, among the lay population.[17] A wide range of community-based initiatives, including providing CPR training to the general public and mandating CPR instruction for students and drivers obtaining licenses, have been undertaken in some high-income countries to achieve the intended goal. Other approaches involve distributing self-instructed CPR kits in schools, disseminating CPR training programs through various media platforms, and messaging trained laypersons or first responders when CPR assistance is needed nearby at the scene of a cardiac emergency.[18,19] Most interventions showed better bystander CPR rates and survival rates associated with the implementation.[18,19] Complementing the community-based CPR initiatives, interventions at the health system level are often implemented concurrently. These include strengthening EMS systems and adopting advanced life support protocols in hospitals, expanding ambulance fleets, providing high-performance CPR training to EMS personnel and hospital staff, facilitating early emergency cardiac catheterization procedures, and utilizing therapeutic hypothermia techniques.[18,19] A systematic review and meta-analysis found that the implementation of community-based BCPR interventions, either with or without remediation in health systems, can

effectively increase not only the BCPR rate (odds ratio (OR) 2.26; 95% confidence interval (CI) 1.74-2.94) but additionally among those with receive BCPR the survival to discharge or 30-day survival rate (OR 1.59; 95% CI 1.20-2.10) compared to without the community bystander CPR intervention.[18] Among 16 prior studies included in the systematic review and meta-analysis, community-based CPR training (n = 12), community-based AED training (n = 9), and dispatched-assisted CPR (n = 8) were the most common and showed a greater improvement in favorable outcomes, including BCPR rate and survival rate.[18] Therefore, community-based BCPR interventions, particularly CPR and AED training, and dispatched-assisted CPR, are promoted by the American Heart Association based on the benefits they can potentially bring to the public.[18,19]

Potential Population Impact and Cost-effectiveness of Community-based Bystander CPR Interventions

Despite several studies showing the potential impact of community bystander CPR programs on increasing BCPR rates and survival, few studies have evaluated the population impact and cost-effectiveness of these programs. In 2011, Howard County (HC), Maryland launched a 10-year community outreach program to provide BCPR training.[20] The goal was to train 3% of the county's population, or around 11,000 residents, annually. The estimated yearly cost to operate this program was $65,000, spending on salary for full-time community CPR specialists, presentation supplies, CPR manikins, transportation, hand-outs, and miscellaneous costs.[20] By the end of the decade-long program, approximately 110,000 residents would have received CPR training, with a projected total cost of roughly $650,000.[20] A study examining this program projected that, after 10 years of implementation, it would save 7 additional lives (65 in base case vs. 72 with intervention) and 29 quality-adjusted life-years (QALYs) (208 in base case vs. 237 with intervention), while QALY refers to a metric that quantifies the additional number

of years a person lives as a result of a healthcare intervention, adjusted for the quality of those years.[20,21] The cost-effectiveness analysis, accordingly, revealed that each life and QALY saved would cost $93,376 and $22,539, respectively, in the 10-year period of program implementation.[20] This program provided valuable real-world data on the potential reach and cost considerations when implementing community-based BCPR training initiatives.

San Diego County "Revive and Survive" Initiative

San Diego County, California is the 9th largest county in California by total area and has a population of 3.27 million people.[22] In 2024, San Diego County initiated the implementation of a new BCPR training initiative called "Revive and Survive San Diego" to supplement its existing BCPR measures, which include ongoing BCPR training, dispatcher-assisted CPR, and a robust public access defibrillation program.[23–25] This initiative will be under a "train-the-trainer" model, aiming to train 1 million San Diegans (around 30%) to perform high-quality hands-only CPR and teach other untrained individuals BCPR with the assistance of various community partners, such as local fire departments, hospitals, and non-profit organizations.[23] However, there is currently limited information on how impactful this type of community-wide training initiative may be in the San Diego region specifically. Therefore, the objective of our study is to project the potential 5-year and 10-year impacts of implementing this San Diego-specific BCPR training program for the county.

Chapter 1 METHODS

Model

We built a decision tree model of OHCA outcomes to simulate the potential impact of the "Revive and Survive San Diego" initiative on population-level OHCA outcomes in the county. The model (Figure 1) is based on a previously published OHCA model and simulates all possible health outcomes of OHCA patients who are eligible for BCPR, which is our target population. The model (Figure 1) depicts that all OHCA cases eligible for BCPR either receive BCPR from laypersons or do not. Regardless of whether BCPR is performed, the patient can either have the ROSC or remain without restored circulation, resulting in death. For OHCA cases achieving ROSC, there is a probability of having either a good or poor neurological outcome, or death. Neurological outcomes are determined by the cerebral performance category (CPC) score, where CPC 1-2 indicates a good outcome and CPC 3-4 a poor outcome.[20,26] A good neurological outcome, or CPC 1-2, means the individual is neurologically intact or has a moderate disability but can independently perform activities of daily living. In contrast, a poor outcome, or CPC 3-4, signifies severe neurological disability requiring supportive care or an unresponsive, unconscious state lacking environmental awareness.[26]

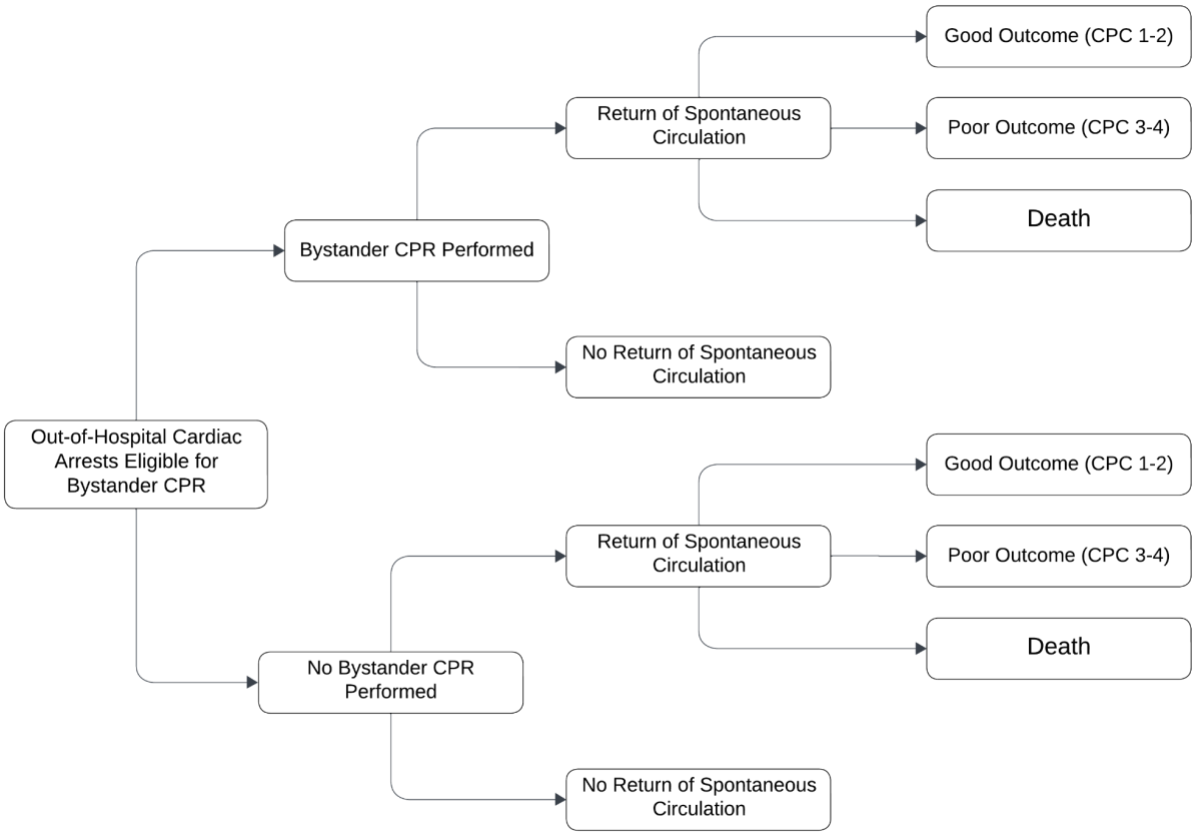

Figure 1. Adapted decision tree model of OHCA patient outcomes.[1]

Parameters

Table 1 summarizes all parameter values used in the analysis, including their sources and intervals for sensitivity analysis. Many parameters (listed in Table 2) were obtained from the 2020-2023 San Diego County Cardiac Arrest Registry to Enhance Survival (CARES) Report, while the CARES system had many more health agencies joining and covered approximately 86% of 9-1-1 incidents within San Diego County starting in 2020. For parameters obtained from the CARES Reports, we utilized the mean values, either numerical or proportional, across the four-year period from 2020 to 2023. Although the CARES Reports include data on all types of OHCA cases, we restricted our target population to those eligible for BCPR, as individuals

[1] *CPR* = cardiopulmonary resuscitation, *CPC* = Cerebral Performance Category.

ineligible for BCPR would not benefit from the county's intervention. The term "eligible for BCPR" refers to OHCA patients who are readily accessible to laypersons intending to perform CPR, excluding cases witnessed by 9-1-1 responders, nursing home residents, and healthcare facility patients.

We assumed that the initiative would increase both the quantity and quality of BCPR, based on findings from a recent systematic review and meta-analysis by Simmon et al.[18] The meta-analysis reported an adjusted odds ratio (AOR) of 2.26 (95% CI 1.74-2.94) for increased odds of receiving BCPR and an AOR of 1.59 (95% CI 1.20-2.10) for increased odds of survival among those who received BCPR with community-based interventions.[18] We converted these AORs into relative risks (RRs) of 1.41 (95% CI 1.28-1.50) and 1.59 (95% CI 1.20-2.10), respectively, using established statistical methods and use these values to calculate the outcome probabilities with the intervention in the decision tree model.[20]

The other parameters utilized in the analysis, such as life expectancy and quality-adjusted life years (QALYs) - the generic metric that values health utilities based on both quantity and quality of life for individuals - for survivors with different neurological statuses following cardiac arrest, were derived from published literature sources.[21,27,28]

Table 1. Model parameters and sources.[2]

Parameters	Point value	Sampling distribution and intervals for the sensitivity analysis	Sources
Number of OHCA cases eligible for BCPR each year	1,689	Uniform, minimum = 1575 maximum = 1803	San Diego CARES 2020-2023
OHCA cases receiving BCPR at baseline, %	49.13	Uniform, minimum = 45.05 maximum = 53.20	San Diego CARES 2020-2023
RR of receiving BCPR with a community intervention	1.41	Lognormal, mean = 1.41 SD = 0.02	Simmon et al.[18]
ROSC for BCPR cases, %	28.72	Uniform, minimum = 22.97 maximum = 34.47	San Diego CARES 2020-2023
ROSC for no BCPR cases, %	20.94	Uniform, minimum = 17.80 maximum = 24.07	San Diego CARES 2020-2023
BCPR survivors with CPC 1-2/CPC 3-4 at baseline, %	33.58/5.22	Uniform, minimum = 28.51/2.70 maximum = 38.65/7.73	San Diego CARES 2020-2023
No BCPR survivors with CPC 1-2/CPC 3-4 at baseline, %	25.50/4.44	Uniform, minimum = 20.51/2.13 maximum = 30.50/6.76	San Diego CARES 2020-2023
RR of survival with BCPR with a community intervention	1.59	Lognormal, mean = 1.59 SD = 0.06	Simmon et al.[18]
Life expectancy for survivors with CPC 1-2	5.6 years	Not sampled	Merchant et al.[27], Rea et al.[28]
Life expectancy for survivors with CPC 3-4	1 year	Not sampled	
QALY score for CPC 1-2	0.75	Not sampled	Merchant et al.[27], Rea et al.[28]
QALY score for CPC 3-4	0.39	Not sampled	

[2] *OHCA* = out-of-hospital cardiac arrest, *BCPR* = bystander cardiopulmonary resuscitation, *CARES* = Cardiac Arrest Registry to Enhance Survival, *RR* = risk ratio, *ROSC* = return of spontaneous circulation, *CPC* = cerebral performance category, *QALY* = quality-adjusted life-year.

Table 2. CARES data summary. [3]

Parameter	2020		2021		2022		2023		Mean (2020-2023)
	n	%	n	%	n	%	n	%	n/%
Total Non-Traumatic OHCA	2097	——	2142	——	2299	——	2133	——	——
Overall Survival	203	9.7%	200	9.3%	188	8.2%	188	8.8%	9.0%
Overall CPC 1 or 2	174	8.3%	169	7.9%	150	6.5%	158	7.4%	7.5%
Overall CPC 3 or 4	29	1.4%	31	1.4%	38	1.7%	30	1.4%	1.5%
Total Eligible for BCPR	1602	——	1657	——	1803	——	1693	——	1689
Total Receiving BCPR	734	45.8%	794	47.9%	894	49.6%	901	53.2%	49.1%
ROSC for BCPR	239	32.6%	267	33.6%	230	25.7%	207	23.0%	28.7%
BCPR Discharged Alive	87	11.9%	90	11.3%	89	10.0%	96	10.7%	10.9%
BCPR CPC 1 or 2 among those with ROSC	80	33.5%	79	29.6%	75	32.6%	80	38.6%	33.6%
BCPR CPC 3 or 4 among those with ROSC	7	2.9%	11	4.1%	14	6.1%	16	7.7%	5.2%
Total Not Receiving BCPR	868	54.2%	863	52.1%	909	50.4%	792	46.8%	50.9%
ROSC for No BCPR	203	23.4%	204	23.6%	172	18.9%	141	17.8%	20.9%
No BCPR Discharged Alive	61	7.0%	56	6.5%	51	5.6%	46	5.8%	6.2%
No BCPR CPC 1 or 2 among those with ROSC	50	24.6%	47	23.0%	41	23.8%	43	30.5%	25.5%
No BCPR CPC 3 or 4 among those with ROSC	11	5.4%	9	4.4%	10	5.8%	3	2.1%	4.4%

[3] *OHCA* = out-of-hospital cardiac arrest, *BCPR* = bystander cardiopulmonary resuscitation, *ROSC* = return of spontaneous circulation, *CPC* = cerebral performance category.

Primary Analysis

Preliminary analysis and sensitivity analyses were conducted in MATLAB R2024a.[29] We simulated two scenarios: one representing the baseline status quo, where the rate of BCPR remained unchanged, and another assuming an increased rate of BCPR resulting from the "Revive and Survive San Diego" Initiatives. Subsequently, we ran simulations for both scenarios over a 5-year period and compared the following outcomes between the intervention and baseline scenarios: BCPR rates, numbers of OHCA patients who die and survive, numbers surviving with CPC 1-2 and CPC 3-4, life-years, and QALYs. For our analysis, we assumed that the number of individuals eligible for BCPR remained constant, using the mean value from the 2020-2023 period, throughout the 5 years following the implementation of the initiative.

Sensitivity Analysis

To incorporate parameter uncertainty, we performed a multivariate probabilistic uncertainty analysis where we sampled 10,000 parameter sets from uncertainty distributions. The sampling intervals of CARES-retrieved parameters for the sensitivity analysis (shown in Table 1) were calculated based on the largest percent difference between the mean value across 2020-2023 and the estimate in a single year. For each parameter, we determined the maximum deviation from the mean value across the years of data by calculating the absolute differences between the maximum value and the mean, as well as the minimum value and the mean. We then selected the larger of these two deviations and calculated the percent difference of this larger deviation relative to the mean; and at the end, we used this largest percent difference to define the sampling interval for the parameter, or specifically, sampling values from the calculated percent difference above the mean to the percent difference below the mean. This sampling method ensures the sampling interval encompasses the largest observed year-to-year variability in the data, thereby capturing all potential uncertainties in the parameter value.

For each of these 10,000 parameter sets, we run our baseline and intervention scenarios and calculate the mean and 95% CI of the outcomes.

Organ Donation from OHCA Patients

To identify OHCA patients in CARES who donated organs and address the potential impacts of the initiative on saving more lives through organ donations, we performed a probabilistic matching of patient records between the CARES Report and organ donor information from Lifesharing - an organ donation organization in San Diego County - for the years 2020-2023. The matching process utilized the date of admission, age, and gender, and was further confirmed using the date of discharge/death.[27] Through this record matching, we used data from the CARES Report to identify the number of organ donors, number of organs donated, and number of OHCA patients who were registered as organ donors but did not ultimately donate.

Chapter 2 RESULTS

Based on the San Diego County CARES data from 2020-2023, there are an average of 1,689 OHCA cases eligible for BCPR each year. The distributions of the population by health outcomes for the no-intervention and intervention scenarios are shown in Table 3.

Assuming the number of OHCA cases eligible for BCPR remains constant yearly, we predict there will be 8,445 (95% CI 7884-9006) such cases across the five-year period after the 1 million San Diego residents are completely trained. Table 4 shows the 5-year cumulative numbers of all health outcomes stratified by BCPR recipient status at baseline and with the intervention scenario.

Table 5 presents a summarized result of the 5-year cumulative population outcomes. At baseline, without the Revive and Survive initiative, our model projected 4,149 (95% CI 3676-4647) BCPR events, 7,714 (95% CI 7169-8266) deaths, 732 (95% CI 583-899) survivors, 629 (95% CI 499-777) patients with CPC 1-2, and 102 (95% CI 61-149) patients with CPC 3-4 at hospital discharge over the 5-year period. The total life-years and QALYs were estimated to be 3,627 (95% CI 2884-4467) and 2,684 (95% CI 2131-3309), respectively. In contrast, with the implementation of the Revive and Survive initiative, the model predicts 5,858 (95% CI 5008-6798) BCPR events, 7,234 (95% CI 6536-7913) deaths, 1,211 (95% CI 836-1718) survivors, 1,046 (95% CI 719-1489 patients with CPC 1-2, and 165 (95% CI 88-273) patients with CPC 3-4 at hospital discharge over the same 5-year period. The total life years and QALYs were projected to increase to 6,022 (95% CI 4150-8562) and 4,457 (95% CI 3068-6339), respectively.

Overall, our model predicted that the “Revive and Survive San Diego” initiative would result in an absolute increase of 1,709 (95% CI 1139-2347) BCPR events, 467 (95% CI 185-896)

additional lives saved, 416 (95% CI 161-778) more patients with good neurological outcomes, and 63 (95% CI 14-140) more patients with poor neurological outcomes at hospital discharge compared to the status quo. Additionally, the initiative was projected to help save 2,395 (95% CI 926-4470) life years, a 66.0% increase, and gain 1,773 (95% CI 685-3314) QALYs, a 66.1% rise, over the 5-year period after the initiative is completely implemented.

Table 3. Proportion of each health outcome.[4]

Health Outcome	Without initiative	With initiative
	Proportion of the population (%)	**Proportion of the population (%)**
BCPR, ROSC, CPC 1-2	4.7	10.6
BCPR, ROSC, CPC 3-4	0.7	1.7
BCPR, ROSC, Death	8.6	7.6
BCPR, No ROSC	35.0	49.4
No BCPR, ROSC, CPC 1-2	2.7	1.6
No BCPR, ROSC, CPC 3-4	0.5	0.3
No BCPR, ROSC, Death	7.5	4.5
No BCPR, No ROSC	40.2	24.3

[4] *BCPR* = bystander cardiopulmonary resuscitation, *ROSC* = return of spontaneous circulation, *CPC* = cerebral performance category.

Table 4. 5-year cumulative number and 95% CI of each health outcome.[5]

Health Outcome	Without initiative		With initiative	
	n	**95% CI**	**n**	**95% CI**
BCPR, ROSC, CPC 1-2	400	290-529	897	651-1188
BCPR, ROSC, CPC 3-4	62	31-100	138	69-225
BCPR, ROSC, Death	729	549-936	644	432-898
BCPR, No ROSC	2957	2536-3417	4169	3576-4818
No BCPR, ROSC, CPC 1-2	229	167-304	139	95-194
No BCPR, ROSC, CPC 3-4	40	19-64	24	11-40
No BCPR, ROSC, Death	630	501-776	381	281-498
No BCPR, No ROSC	3397	2996-3834	2052	1649-2494

[5] *BCPR* = bystander cardiopulmonary resuscitation, *ROSC* = return of spontaneous circulation, *CPC* = cerebral performance category.

Table 5. Summary of 5-year cumulative population outcomes in San Diego County.[6]

Parameter	Without initiative		With initiative		Net difference	
	n	95% CI	n	95% CI	n	95% CI
Number OHCA eligible for BCPR	8445	7884-9006	8445	7884-9006	—	——
Number BCPR	4149	3676-4647	5858	5008-6798	1709	1139-2347
Number of people who die	7714	7169-8266	7234	6536-7913	-479	-896-(-185)
Number of people who survive OHCA	732	583-899	1211	836-1718	479	185-896
Number surviving with CPC 1-2	629	499-777	1046	719-1489	416	161-778
Number surviving with CPC 3-4	102	61-149	165	88-273	63	14-140
Total life years	3627	2884-4467	6022	4150-8562	2395	926-4470
Total QALYs	2684	2131-3309	4457	3068-6339	1773	685-3314

The following figures (Figures 2,3, and 4) present the potential improvement of cumulative BCPRs, life saved, and QALYs that can be increased by the intervention of the "Revive and Survive San Diego" initiative in the future 10-year time horizon, respectively. By 10 years after the intervention, the model predicts 3,418 more BCPRs performed, 958 lives saved, and 3,507 QALYs saved in San Diego County compared to without the initiative.

[6] *OHCA* = out-of-hospital cardiac arrest, *BCPR* = bystander cardiopulmonary resuscitation, *CPC* = cerebral performance category, *QALY* = quality-adjusted life-year.

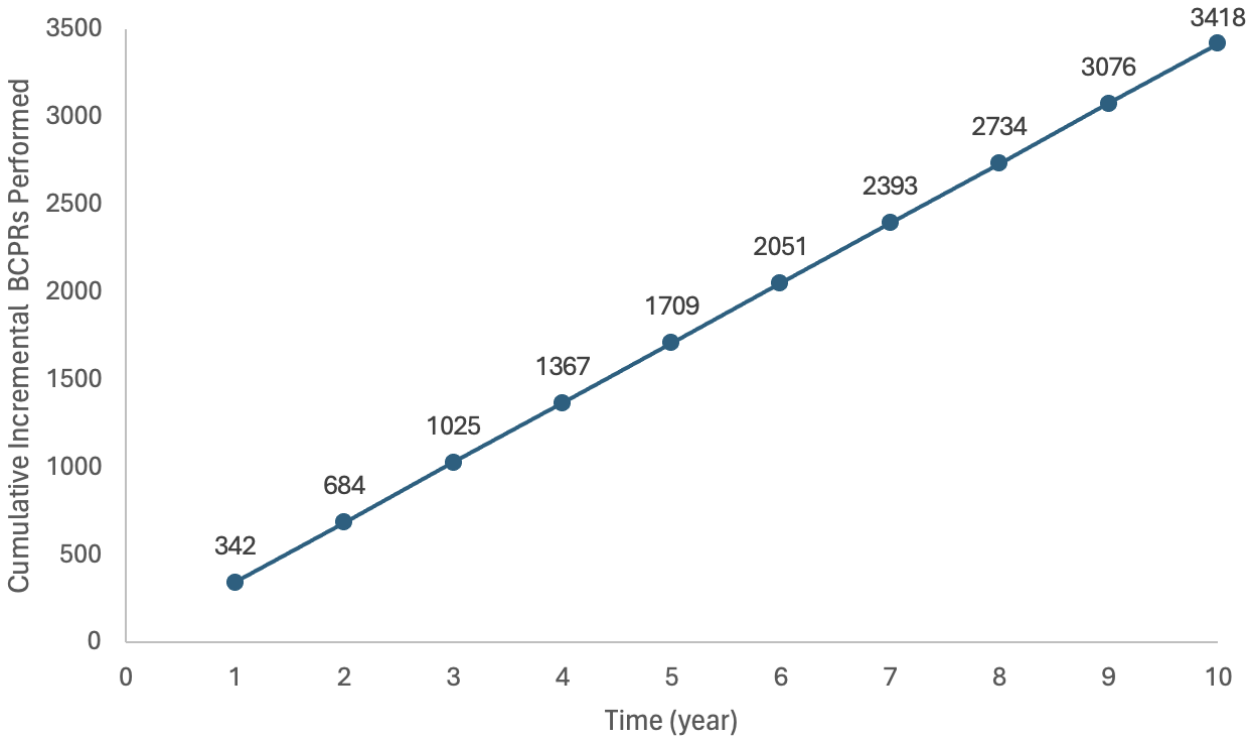

Figure 2. Cumulative incremental BCPRs performed with the community-based BCPR intervention compared to no intervention over time.[7]

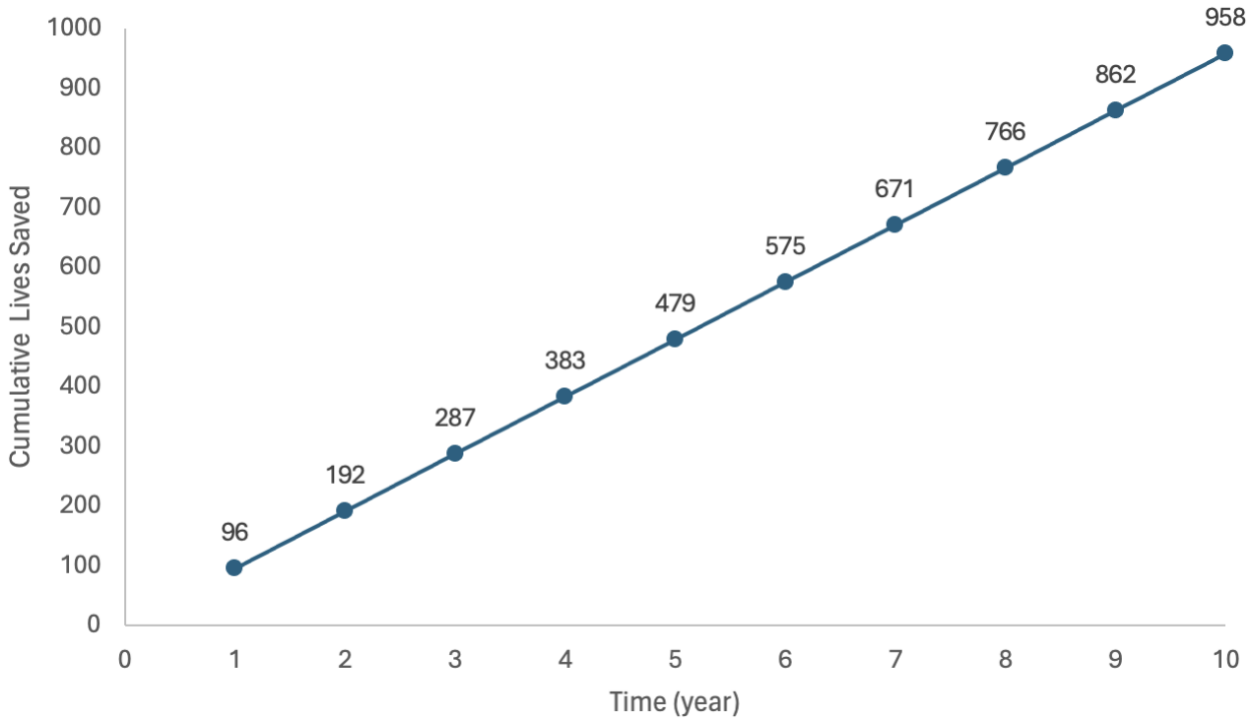

Figure 3. Cumulative lives saved by the intervention compared to no intervention over time.

[7] *BCPR* = bystander cardiopulmonary resuscitation.

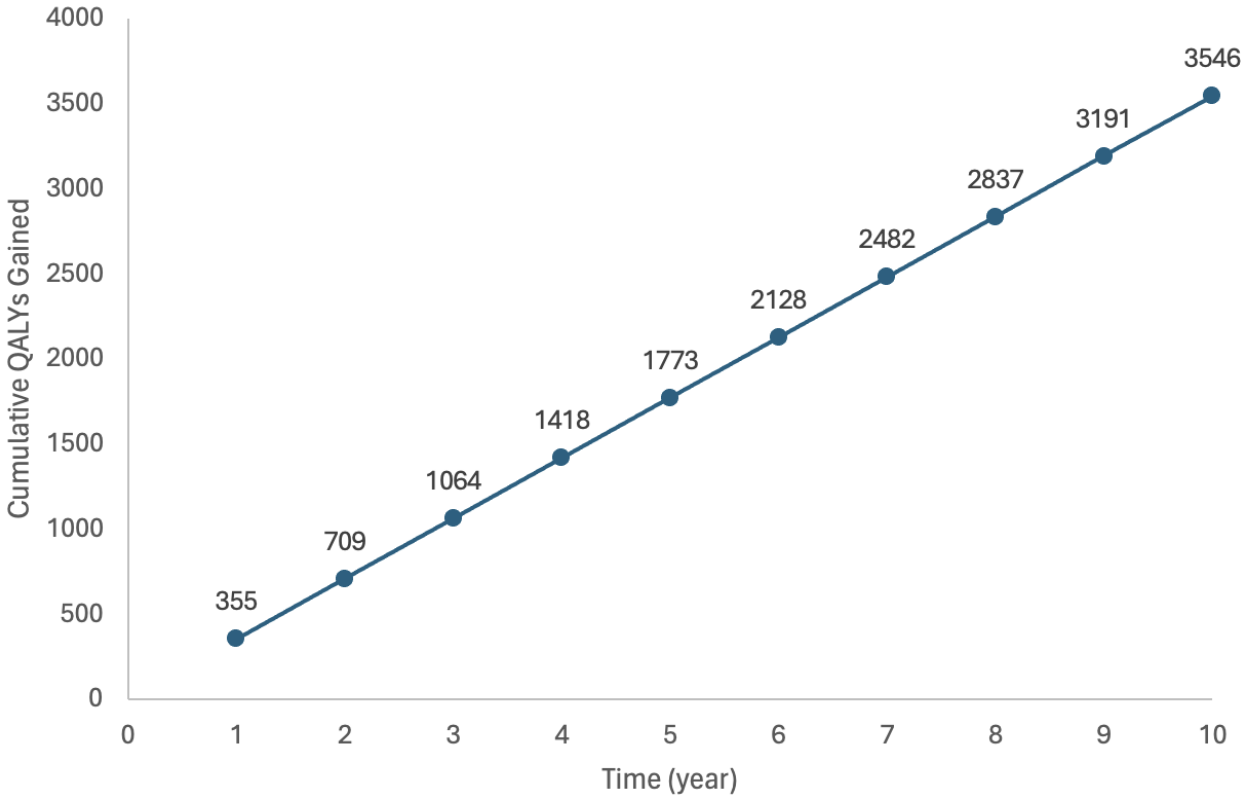

Figure 4. Cumulative QALYs gained with the intervention compared to no intervention over time.[8]

Table 6 shows a summary of the organ donation data provided by the county from 2020 to 2023. From 2020 to 2023, the number of organ donors among OHCA patients within the CARES registry was 8, 9, 5, and 17, respectively, with the corresponding number of organs donated each year of 17, 14, 15, and 28. In 2020 and 2022, all CARES patients listed as organ donors successfully donated their organs. However, in 2021 and 2023, there were 3 and 5 registered organ donors, respectively, who failed to donate their organs.

[8] *QALY* = quality-adjusted life-year.

Table 6. Summary of organ donation data among CARES patients with OHCA in San Diego County.[9]

Number	2020	2021	2022	2023
Organ donors among CARES patients with OHCA	8	9	5	17
Total number of organs donated among CARES patients with OHCA	17	14	15	28
CARES patients listed as organ donors but didn't donate their organs	0	3	0	5

[9] *CARES* = Cardiac Arrest Registry to Enhance Survival, *OHCA* = out-of-hospital cardiac arres

Chapter 3 DISCUSSION

The results of our analysis demonstrate the potential impact of implementing the "Revive and Survive San Diego" community-based BCPR training initiative. Over a 5-year period, the program is projected to increase the number of OHCA cases receiving BCPR by 1,709, resulting in an additional 479 lives saved, and 1,773 QALYs gained compared to the current interventions.

The projected positive impacts of our initiative are highly encouraging. While the "Revive and Survive San Diego" initiative aimed to reach around 30% of the county's population (1 million residents) for BCPR training, similar to the 30% target shown in the Howard County (HC) study that served as the basic model for our analysis, San Diego County had more favorable baseline parameters.[20] Specifically, the San Diego CARES data reported a higher baseline BCPR rate (49.1% vs. 33.4% in HC) and a higher proportion of BCPR survivors with good neurological outcomes (9.5% vs. 8.0% in HC).[20] These advantageous starting points suggest the San Diego initiative has the potential to save even more lives and accrue greater QALY gains than projected in the HC study. Nonetheless, continuous real-world monitoring during and after the implementation will be crucial to accurately assess the actual impact of the initiative via reliable and viable measures and make timely modifications if necessary.

The supplemental organ donation data underscores an additional potential benefit of increased BCPR rates. Chest compression, as the major part of the hands-only CPR taught under the new initiative, can effectively maintain the circulation of blood and preserve the organs.[30] Previous studies have suggested that organs donated by patients who die after OHCA have similar viability to those from other donors.[31–33] With more OHCA cases receiving life-saving interventions, there may be more viable organ donors, enabling more lives to be saved through

transplantation. However, this secondary benefit requires further dedicated research into how community-based BCPR intervention increases the number of individuals eligible for organ donations and/or the number of organs they donate, as well as if the intervention will change the number of registered organ donors who didn't donate their organs later.

A key strength of this analysis is the utilization of local data from the San Diego County CARES database, which provides a more accurate representation of the local OHCA population and baseline parameters compared to using national or state-level data. Additionally, the adaptation of a previously published decision tree model increases the credibility of the modeling approach and allows for comparisons with other similar studies. Moreover, the incorporation of findings from a recent systematic review and meta-analysis on the impact of community-based CPR interventions provides a strong evidence base for the relative risk estimates used in the model. Furthermore, the analysis evaluated multiple comprehensive outcome measures, including BCPR events, lives saved, neurological outcomes, life years saved, and QALYs, providing a comprehensive insight into the potential impact of the intervention.

Some limitations should be acknowledged in our study. Firstly, the analysis relied on some parameter values obtained from various published literature sources, which may not be fully generalizable to our target population - the OHCA patients that are eligible for BCPR in San Diego. For instance, the life expectancy and QALY values for OHCA survivors with different neurological outcomes were derived from studies conducted in other geographic regions or healthcare settings. Potential differences in patient characteristics, treatment protocols, or environmental factors could limit the direct applicability of these parameter estimates. Additionally, the assumption of a static incidence of OHCA cases over the study period may not accurately reflect potential changes in the underlying population demographics, risk factor

prevalence, or other contributing factors that could influence the OHCA rate over time. Failure to account for such temporal variations could lead to an over- or underestimation of the projected outcomes.

Our analysis focuses only on outcomes among individuals tracked in the CARES database, which only covers 86% of 9-1-1 incidents within the county. Additional benefits could occur among people with OHCA not covered in the CARES database, and therefore our analysis likely underestimates the potential benefit of the intervention. However, we believe the CARES database is not generalizable to the population not covered in CARES, and so therefore we could not extrapolate our results to this population. Future work examining the OHCA characteristics among the non-CARES population would provide data for the extension of the model to this group.

It is also important to note that the analysis did not fully consider the potential secondary benefits of the intervention, including organ donation, given the lack of data on the impact of community-based BCPR interventions on organ donation outcomes. Further research should be conducted to explore the impact of community-based BCPR interventions on organ donation. Key questions to be investigated include whether the percentage of viable organs from victims who received BCPR differs from those who didn't, and whether the proportion of organ donors among OHCA patients increases as the intervention is implemented, compared to the status quo.

Last but not least, one of our study's most significant limitations is its failure to adequately address potential health disparities in the implementation and impact of the "Revive and Survive San Diego" initiative. The analysis did not examine differences in OHCA outcomes across various ethnic, socioeconomic, and geographic groups, nor did it consider whether the

CARES database, which excludes 14% of 9-1-1 incidents, might introduce systematic bias by underrepresenting certain communities. The study also didn't explore how bystander CPR efforts might need to be tailored for different areas, such as rural regions, or whether interventions are being appropriately targeted to communities with the poorest outcomes. Furthermore, it didn't investigate the role of community partners in making the initiative culturally appropriate and accessible. This oversight in addressing health equity concerns is a critical gap, as it could significantly affect the initiative's effectiveness and fairness across San Diego County's diverse population.

CONCLUSION

This study suggests that implementing the "Revive and Survive San Diego" community-based CPR training program could substantially improve population-level OHCA outcomes in San Diego County. Specifically, the projected increases in BCPR rates, lives saved, and QALYs gained are driven by the evidence-based mechanisms through which community-based BCPR interventions enhance both the quantity and quality of BCPR delivery. These improvements underscore the potential of the initiative to alleviate the burden of OHCA while concurrently promoting better health outcomes and quality of life for survivors.

While the analysis has inherent limitations, such as the assumption of a static OHCA incidence rate and limited generalizability, the results provide compelling evidence to support the implementation of this community-based CPR training initiative. Further monitoring and evaluation of the program's implementation and outcomes would be valuable to refine the estimates and ensure optimal resource allocation and program effectiveness.

Empowering the general public with CPR skills through initiatives like "Revive and Survive San Diego" can potentially save lives and improve the quality of life for OHCA survivors, ultimately contributing to the overall well-being of the community at local, state, and federal levels, or even globally.

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