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Rapid response systems

Strategic placement of automated external defibrillators (AEDs) for cardiac arrests in public locations and private residences

S. Ball[a,b,*], A. Morgan[a], S. Simmonds[b], J. Bray[a,c], P. Bailey[a,b], J. Finn[a,b,c,d]

Abstract

Aim: The aim of our study was to determine whether businesses can be identified that rank highly for their potential to improve coverage of out-of-hospital cardiac arrests (OHCAs) by automated external defibrillators (AEDs), both in public locations and private residences.

Methods: The cohort comprised 10,422 non-traumatic OHCAs from 2014 to 2020 in Perth, Western Australia. We ranked 115 business brands (across 5,006 facilities) for their potential to supplement coverage by the 3,068 registered public-access AEDs in Perth, while accounting for AED access hours.

Results: Registered public-access AEDs provided 100 m coverage of 23% of public-location arrests, and 4% of arrests in private residences. Of the 10 business brands ranked highest for increasing the coverage of public OHCAs, six brands were ranked in the top 10 for increased coverage of OHCAs in private residences. A public phone brand stood out clearly as the highest-ranked of all brands, with more than double the coverage-increase of the second-ranked brand. If all 115 business brands hosted AEDs with 24–7 access, 57% of OHCAs would remain without 100 m coverage for public arrests, and 92% without 100 m coverage for arrests in private residences.

Conclusion: Many businesses that ranked highly for increased coverage of arrests in public locations also rank well for increasing coverage of arrests in private residences. However, even if the business landscape was highly saturated with AEDs, large gaps in coverage of OHCAs would remain, highlighting the importance of considering other modes of AED delivery in metropolitan landscapes.

Keywords: Out-of-hospital cardiac arrest, Defibrillator, AED, Proximity, Public, Private

Introduction

Bystander use of automated external defibrillators (AEDs) is estimated to double the chance of survival from out-of-hospital cardiac arrest (OHCA).[1,2] However, the use of an AED prior to paramedic arrival depends critically on bystanders having fast access to an AED. For pedestrian-based access, it has been proposed that AEDs should ideally be within 100 m of the OHCA patient, consistent with the American Heart Association recommendation of defibrillation occurring within three minutes of the patient arresting.[3–6]

Governments, funding bodies and emergency medical services have the potential to play an important role in filling gaps in AED coverage, either by direct purchase and installation of AEDs, or by advocating other organisations to do so. At the same time, the significant cost of AEDs (currently approximately AUD$2000 per unit) means that any such investment needs to be highly strategic, so that AEDs are available when and where they are most needed.

In recent years, spatial analysis methods have been developed to compare different location types for their potential to supplement existing coverage of cardiac arrests by public-access AEDs.[5,7–10] While arrests in public locations have been a focus of previous research on AED coverage,[5,8,10] arrests in private residences are an important consideration due to their much higher incidence.[10–12] The aim of our study was to determine whether businesses can be identified that would simultaneously rank highly for the potential to improve AED coverage of arrests in public locations and private homes, in the context of a large Australian city.

* Corresponding author at: Prehospital, Resuscitation and Emergency Care Research Unit (PRECRU), School of Nursing, Curtin University, GPO Box U1987, Perth, WA 6845, Australia.

E-mail address: stephen.ball@curtin.edu.au (S. Ball).

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Methods

This study was a retrospective analysis of OHCA cases attended by St John Western Australia (SJ-WA) in metropolitan Perth, Western Australia. We calculated the coverage that would have been provided by selected business brands as potential hosting sites of AEDs, in relation to cardiac arrests in public locations and private residences. Metropolitan Perth covers 6416 km^2, with a population of 2.07 million in 2016.[13,14] SJ-WA is the sole provider of emergency road ambulance services in Perth.

Our cohort comprised non-traumatic OHCA cases from 1 Jan 2014 to 31 Dec 2020. OHCA records were sourced from the SJ-WA OHCA Database - a state-wide database of all OHCA cases attended by SJ-WA, coded according to the Utstein guidelines.[15] The Database is managed by the Prehospital, Resuscitation and Emergency Care Research Unit at Curtin University.[16] We excluded patients younger than one year, due to minimum age guidelines for AED usage.[17] We also excluded cases from location types that were neither public locations or private residences – e.g. medical centres, prisons, caravan parks, hotels, and residential aged care facilities. The data extracted for each case included the geographic coordinates of the incident, time of emergency call, patient age and sex, whether the arrest was witnessed, bystander CPR (cardiopulmonary resuscitation), bystander AED use, initial arrest rhythm, and ambulance response time. Thirty-day survival was determined using data from the WA Death Registry;[18] Metropolitan Cemeteries Board database,[19] and SJ-WA electronic patient care records. We stratified the cohort into OHCA cases in public locations and private residences.

We used a method developed by Sun et al.[5] for Toronto, Canada, to rank different businesses as candidate sites for public-access AEDs. Specifically, Sun et al ranked businesses according to their ability to provide 100 m coverage of OHCA cases; while taking into account coverage by existing AEDs, and hours-of-access in relation to the timing of each arrest. This process assumes all facilities (i.e., individual sites/outlets/premises) for each business brand in question would host an AED, enabling a simple, reliable message for bystanders (e.g., "All facilities of Brand X have a defibrillator").

Candidate businesses were modelled on categories presented by Sun et al.[5] as banks, cafés (coffee shops), parking lots, restaurant chains, recreational facilities (sports centres and gymnasiums), libraries, liquor/beer stores, petrol stations (gas stations), pharmacies, retail stores, public schools, supermarkets (grocery stores), and convenience stores. While automatic teller machines (ATMs) ranked very highly for Sun et al.[5] we excluded ATMs on the basis that ATM location data in Perth were extremely unreliable, possibly related to declining numbers of ATMs in Australia. This unreliability was evident as large discrepancies in the ATMs listed by bank websites versus third-party ATM registers, with subsequent on-ground checks showing discrepancies with both electronic data sources. In addition to the categories in Sun et al.[5] we included bakeries, gambling outlets, higher education campuses, hotels, post offices, transport stations, and public telephones. We restricted the list of candidate businesses to brands with 10 or more facilities in metropolitan Perth.

Lists of individual business facilities, including geographic coordinates (longitude and latitude) and hours-of-access, were developed by searching the Australian Business Register,[20] Yellow Pages online business phone directory,[21] Google Search,[22] and directly contacting businesses by email or telephone. These data were sourced March-May 2021. For each facility, hours-of-access were recorded for each day of the week. For locations based on street address (i.e., where geographic coordinates were unavailable), we determined geographic coordinates by matching address details with the Australian Geocoded National Address File,[23] or manually querying Google Maps. While coordinates were variously sourced in WGS84 and GDA94 datums, the discrepancy between these datums is less than 1 m.[24]

Data on existing AEDs (including geographic coordinates and hours of access) were sourced in March 2021 from SJ-WA, using its register of public-access AEDs, which supplies AED location data to registered users of the St John First Responder App,[25] and to call-takers in the SJ-WA State Operations Centre. Records are nominated for inclusion in this register when members of the public notify SJ-WA of the location of an AED in the community. Approval for use of that information is subsequently sought by SJ-WA from each AED's owner.

Using ArcMap v10.6,[26] we projected geographic coordinates of OHCA cases, existing AED locations, and business facilities into map coordinates (i.e., Eastings and Northings, measured in metres), on Zone 50 of the Map Grid of Australia 1994.[27] We imported all data into Microsoft Access 2016, and developed syntax in Visual Basic for Applications to determine coverage of OHCA cases by existing AEDs, and by each candidate business. Each OHCA case was classified as having existing coverage (binary variable) if there was at least one existing AED within 100 m 'coverage radius', whose hours-of-access overlapped the timing of the arrest. Coverage was based on straight-line distance. Similarly, each OHCA case was classified as having coverage by each brand in question, if there were one or more facilities of that business within 100 m. However, business coverage was optionally based on (1) known business hours in relation to the timing of the arrest, or (2) assumed 24–7 AED availability (e.g., as if an AED was placed directly outside each facility).

Our primary basis for ranking businesses was supplementary 100 m business-hours coverage of public-location OHCAs, where 'supplementary' refers to coverage additional to existing AEDs, and 'business-hours coverage' refers to AED availability being restricted to the business hours of each facility. We also determined 'supplementary 100 m 24–7 coverage' - the coverage provided on the assumption of 24–7 AED availability for candidate businesses. While our primary ranking was for arrests in public locations, we also calculated coverage metrics and rankings for arrests in private residences.

To assess the sensitivity of rankings to the threshold distance used to model AED coverage, we ran alternative scenarios of 200 m and 500 m coverage radius, as applied to coverage by both existing AEDs and candidate businesses.

As with Sun et al.,[5] in addition to reporting supplementary coverage, we also report the Total Coverage by each business (i.e., ignoring coverage by existing AEDs), as well as Coverage Loss, and Coverage Efficiency. Coverage Loss is the percentage loss in OHCA coverage due to AED availability being restricted to business hours, (24–7 coverage minus business hours coverage) / 24–7 coverage; while Coverage Efficiency, which relates to the 'return on investment', is the number of OHCA cases covered per individual facility per year, (OHCA cases covered / number of facilities / year).

The study was approved by the Curtin University Human Research Ethics Committee (HR128/2013–61) and SJ-WA Research Advisory Group.

Results

A total of 10,422 OHCA cases met our inclusion criteria (Fig. 1): 1,064 in public locations and 9,358 in private residences. Table 1 summarises patient characteristics. The study area contained 3,068 registered public-access AEDs, 1,037 having 24–7 access. Fig. 2 shows the distribution of OHCAs and existing AEDs across the study area.

We initially identified 5,717 individual business facilities in metropolitan Perth. After removing data on duplicate facilities, and business brands with fewer than 10 facilities, our list of candidate AED sites comprised 5,006 facilities among 115 brands, in 19 business categories. While we started with 20 categories, the 'convenience store' category was excluded due to there being no brands in Perth with 10 or more facilities.

Table 2 shows the retrospective OHCA coverage by existing AEDs, as well as the coverage possible if all 5,006 business facilities hosted an AED with 24–7 access. Based on 100 m coverage, 57.4% of public OHCAs and 91.7% of OHCAs in private residences would remain without coverage despite all 5,006 business outlets hosting an AED. Even based on 200 m coverage, 40.5% of public OHCAs and 73.9% of OHCAs in private residences would remain without coverage.

Table 3 and Table A1 show the ranking of businesses by supplementary 100 m business-hours coverage of public OHCA cases. Telstra Air public phones ranked highest, with supplementary coverage (additional to coverage by existing AEDs) of 56 public OHCA cases, more than double that of the second-ranked brand (Lotterywest, supplementary coverage of 25 public OHCA cases). The 10 highest-ranked brands also included one gambling brand, three restaurant brands, one supermarket brand, one petrol station brand and two liquor brands.

In general, business brands with good supplementary coverage of public locations also provided good coverage of OHCAs in private residences (Table 3, Table A1). Of the 10 business brands ranked highest for increasing the supplementary coverage of public OHCAs, six brands were ranked in the top 10 for increased coverage of OHCAs in private residences. However, some businesses ranked highly for coverage of OHCAs in private residences despite having relatively low coverage of public OHCAs – e.g., Caltex/Ampol petrol stations ranked 5th for supplementary business-hours coverage of OHCAs in private residences, but 16th for public arrests.

Rankings were generally similar for business-hours and supplementary 24–7 coverage (Table 3, Table A1). For arrests in public locations, the 10 brands ranked highest by 100 m supplementary business-hours coverage were in the top 13 brands for supplementary 24–7 coverage.

Coverage loss (Table 3, Table A2) shows the percentage loss of supplementary OHCA coverage when each brand was switched from 24-7 coverage to business-hours coverage. In the 10 highest-ranked brands by 100 m supplementary business-hours coverage of public OHCA cases, coverage loss ranged from 0.0% to 49.0%.

The ranking of many businesses was highly robust to the threshold distance modelled (Table A1). The notable exception was 'Government Schools', which, for supplementary 24–7 coverage of public OHCAs ranked 29th by 100 m coverage, but 8th by 200 m coverage, and 1st by 500 m coverage. The business rankings for OHCAs in private residences were also generally robust to threshold distances; but again, Government Schools was the notable exception.

Table 3 and Table A3 show the coverage efficiency of each business, as the number of new OHCA cases covered (supplementary to coverage by existing AEDs) per business facility per year. Some of the businesses that ranked highly by coverage efficiency were

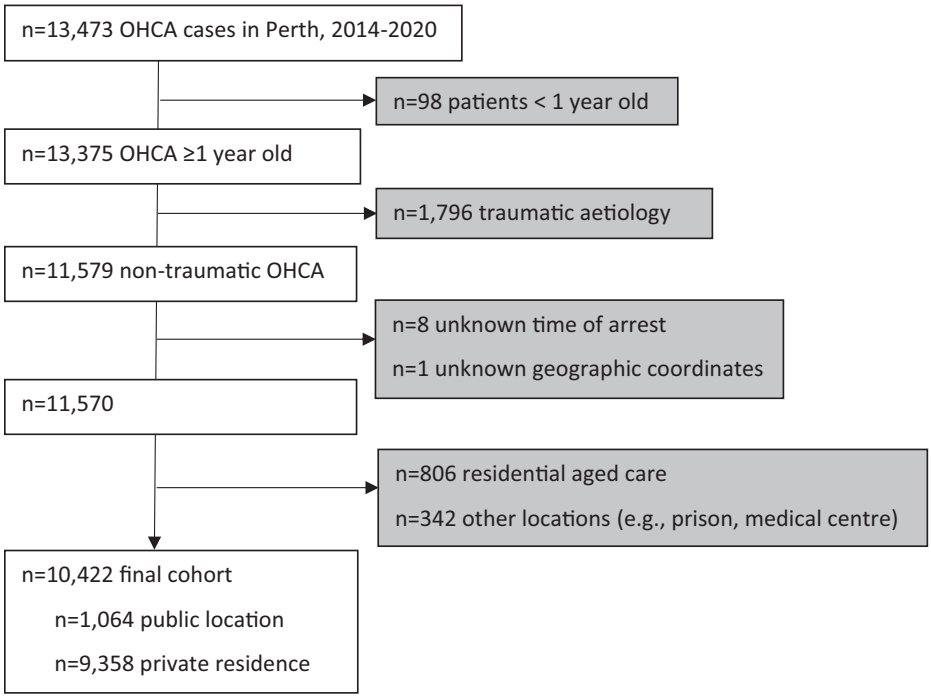

Fig. 1 – Cohort selection. Boxes shaded grey indicate exclusions.

Table 1 – Characteristics of 10,422 OHCA patients in this study, stratified by location type.

Characteristic	Public Location *n* = 1,064	Private Residence *n* = 9,358
Age in years (median, IQR)	58 (45–70)	68 (53–80)
Sex (%)		
male	876 (82.3)	6,089 (65.1)
female	188 (17.7)	3,269 (34.9)
Calendar year (%)		
2014	155 (14.6)	1184 (12.7)
2015	151 (14.2)	1368 (14.6)
2016	137 (12.9)	1333 (14.2)
2017	144 (13.5)	1387 (14.8)
2018	165 (15.5)	1347 (14.4)
2019	173 (16.3)	1373 (14.7)
2020	139 (13.1)	1366 (14.6)
Aetiology (%)		
Presumed cardiac	905 (85.1)	8,304 (88.7)
Respiratory	85 (8.0)	232 (2.5)
Overdose/poisoning	68 (6.4)	455 (4.9)
Malignancy	6 (0.6)	367 (3.9)
Witness status (%)		
Unwitnessed	464 (43.6)	6803 (72.7)
Bystander-witnessed	535 (50.3)	2003 (21.4)
EMS-witnessed	65 (6.1)	552 (5.9)
Bystander CPR (%)	697 (65.5)	3082 (32.9)
Bystander AED shock (%)	154 (14.5)	16 (0.2)
EMS response time in mins (median, IQR)	8.6 (6.4–11.2)	8.5 (6.5–10.8)
Initial arrest rhythm (%)		
Shockable	458 (43.0)	940 (10.0)
Non-shockable	601 (56.5)	8390 (89.7)
Unknown	5 (0.5)	28 (0.3)
EMS resuscitation attempt (%)	780 (73.3)	4043 (43.2)
Survived to 30 days (%)	274 (25.8)	391 (4.2)

IQR = Interquartile range; CPR = Cardiopulmonary resuscitation; AED = automatic external defibrillator; EMS = Emergency Medical Service.

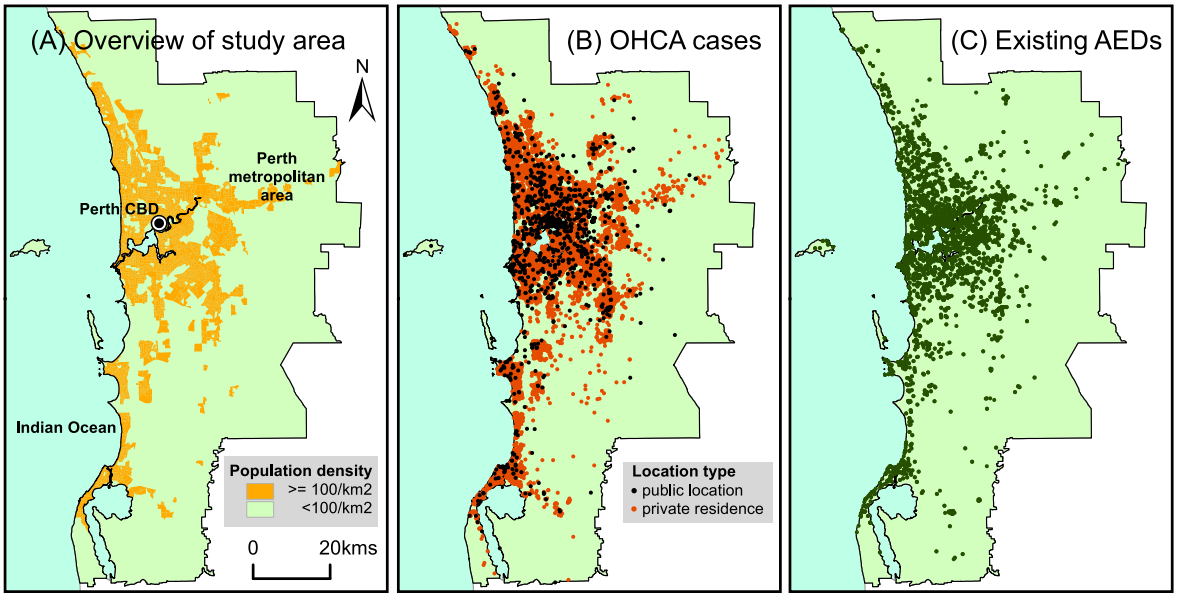

Fig. 2 – Map of study area - metropolitan Perth, Western Australia. Fig. 2A shows regions where population density exceeds 100 people / km^2 (includes 97% of the Perth population);[13,14] 2B shows the location of out-of-hospital cardiac arrest (OHCA) cases between 2014 and 2020, stratified by location type (NB: point locations have been spatially jittered by several hundred metres to protect privacy); 2C shows the location of registered public-access automated external defibrillators (AEDs), as of March 2021.

Table 2 – Retrospective coverage of OHCA cases in Perth, 2014–2020, by automated external defibrillators (AEDs). Two scenarios are presented: (a) coverage based on registered public-access AEDs as of March 2021 (restricted to the hours-of-access of each AED), and (b) coverage by registered AEDs (as of March 2021), supplemented with 'saturation' (including 24–7 access) of all n = 5,006 business facilities in this study. Coverage statistics are stratified by OHCA cases in public locations and private residences, and data presented for three coverage models (100 m, 200 m and 500 m).

	OHCA cases in Public Locations		OHCA cases in Private Residences	
Threshold distance	Coverage by existing AEDs	Coverage supplemented by saturation of 5,006 business facilities	Coverage by existing AEDs	Coverage supplemented by saturation of 5,006 business facilities
100 m	244 (22.9%)	453 (42.6%)	336 (3.6%)	776 (8.3%)
200 m	439 (41.3%)	633 (59.5%)	1,153 (12.3%)	2,446 (26.1%)
500 m	754 (70.9%)	895 (84.1%)	4,647 (49.7%)	7,308 (78.1%)
Total cases	1,064	1,064	9,358	9,358

ranked low in number of OHCA cases covered, and vice versa (Table 3, Table A1 and Table A3).

Tables A4, A5 and A6 respectively show the total coverage provided by each business (i.e., ignoring coverage by existing AEDs), total coverage loss, and total coverage efficiency. Tables A7-A12 show coverage statistics analysed at the level of the 19 business categories.

Discussion

While there has been a large investment in public-access AEDs in Perth, with more than 3000 AEDs registered to March 2021, there remain large opportunities for increased coverage of public OHCA cases, with 77% of cases further than 100 m (and 59% further than 200 m) of the nearest registered AED. For OHCA cases in private residences there are even greater opportunities, with 96% of cases further than 100 m (and 88% further than 200 m) of the nearest registered AED.

Similar to previous research,[5] we identified a strong ranking of businesses as potential sites for hosting AEDs. Clearly business brands with a large number of facilities have a numerical advantage for covering many OHCA cases, and such businesses generally ranked highly in OHCA coverage. Based on supplementary 100 m business-hours coverage of OHCA cases, Telstra Air public phones stood out clearly as the highest-ranked of all brands with more than double the coverage-increase of the second-ranked brand (Lotterywest) for OHCAs in both public locations and private residences. If all 337 Telstra Air public phones in Perth hosted an AED, the 100 m coverage of public-location arrests is expected to increase from 23% to 28%, and from 4% to 5% for OHCA cases in private-residence. The small size of these increases is important to note, in that the highest-ranked brand would achieve only a modest improvement in overall coverage. Thus, if businesses are to provide the basis for ongoing improvements in AED coverage, a large range of brands need to be considered.

We found a large opportunity for improvement in AED coverage of cardiac arrests in private residences. Coverage by existing AEDs was very low for arrests in private residences (100 m coverage of 4%, 200 m coverage of 12%). However, with arrests in private residences being nearly nine times more frequent than arrests in public locations in our cohort, it is important to look for businesses that are ranked highly for increased AED coverage in both location types. Fortunately, a number of such businesses were evident.

Our study shows the value of comparing alternative distance thresholds for modelling AED coverage. For many businesses, this affords increased confidence that their high ranking is robust. Alternatively, for specific businesses that are sensitive to this parameter, further enquiry may be justified. Notably, Government Schools, the most numerous business in our dataset (with 465 individual facilities) was highly ranked at 200 m and 500 m, but not at 100 m. With previous research showing that the probability of AED use can extend well beyond 100 m (albeit with reduced probability of use)[28,29] it is important to flag businesses that cover many OHCAs at longer distances.

Our results add to the body of literature that shows that hours-of-access is an important factor in AED coverage,[5,6,30–32] with many businesses in Perth having coverage loss (i.e., when AED access was restricted to business hours) in the range of 25–50% for public-location arrests, and 50–75% for private residences. This highlights that for many business brands, there may be large gains in pursuing externally mounted 24–7 AEDs. However, it may be important to also consider possible risks of vandalism and theft of such AEDs, and examine mitigation methods.

Even with complete saturation of all 115 brands hosting AEDs with 24–7 access, 57% of public OHCA cases in Perth would remain without 100 m AED coverage, and 40% without 200 m coverage. This approach, of modelling system saturation has been previously applied by Siddiq et al. in Toronto[33] and highlights the challenges of achieving AED coverage across a broad metropolitan area. Further to these challenges for public-location arrests, greater challenges exist for arrests in private residences, whereby, even with 24–7 saturation of all 115 businesses, 92% of cases would remain without 100 m coverage, and 74% without 200 m coverage. Ultimately, for providing coverage of more sparsely-dispersed cardiac arrests, it may be necessary to explore models of AED delivery other than fixed-location AEDs – e.g., vehicle-based and drone-based AEDs.[34–37] Furthermore, the development of smaller low-cost AEDs may increase the prospect of widespread personal ownership of highly portable AEDs.[38]

The high levels of variation between business brands we observed in OHCA coverage efficiency has important implications. In the scenario of a finite investment of AEDs being allocated across businesses, it may be strategic to pursue a combination of brands

Table 3 – Comparison of businesses in Perth, in supplementary coverage of OHCA cases by AEDs. The primary ranking is by 100 m business-hours coverage of public-location OHCAs, with the 30 highest-ranked businesses shown here (see Tables A1-A3 for full list of 115 businesses). Also shown is coverage for OHCAs in private residences. Coverage is reported as the number of OHCA cases, with the ranking for each variable in brackets, and bold text showing businesses in the 10 highest-ranked businesses for each variable. Coverage Efficiency refers to the number of OHCA cases covered per AED per year (that are not covered by existing AEDs), and Coverage Loss refers to the percentage of coverage that is lost in restricting AED coverage to business hours.

				100 m coverage of OHCA cases in Public Locations					100 m coverage of OHCA cases in Private Residences				
				Cases covered		Coverage efficiency		Cov. loss	Cases covered		Coverage efficiency		Cov. loss
1° rank	Business brand	Business category	Facilities	bus. hrs	24–7	bus. hrs	24–7		bus. hrs	24–7	bus. hrs	24–7	
1	Telstra Air public phone	Public phone	**337 (3)**	**56 (1)**	**56 (1)**	0.24 (18)	0.24 (34)	**0.0 (1)**	**149 (1)**	**149 (1)**	**0.63 (1)**	**0.63 (2)**	**0.0 (1)**
2	Lotterywest	Gambling facility	**344 (2)**	**25 (2)**	**49 (2)**	0.10 (55)	0.20 (45)	49.0 (60)	**23 (3)**	**56 (2)**	0.10 (44)	0.23 (33)	58.9 (54)
3	TAB agency	Gambling facility	**112 (7)**	**23 (3)**	**30 (3)**	0.29 (11)	**0.38 (10)**	23.3 (47)	**20 (4)**	**29 (5)**	0.26 (12)	0.37 (13)	31.0 (31)
4	IGA	Supermarket	**146 (5)**	**22 (4)**	**25 (5)**	0.22 (23)	0.24 (32)	12.0 (41)	**27 (2)**	**36 (3)**	0.26 (11)	0.35 (14)	25.0 (26)
5	Subway	Restaurant chain	**130 (6)**	**18 (5)**	**28 (4)**	0.20 (27)	0.31 (20)	35.7 (55)	5 (22)	9 (20)	0.05 (56)	0.10 (69)	44.4 (41)
6	McDonalds	Restaurant chain	75 (12)	**16 (6)**	**16 (7)**	**0.30 (9)**	0.30 (22)	**0.0 (1)**	**13 (6)**	13 (14)	0.25 (14)	0.25 (29)	**0.0 (1)**
7	KFC	Restaurant chain	48 (27)	**13 (7)**	**16 (7)**	**0.39 (3)**	**0.48 (4)**	18.8 (43)	4 (31)	5 (37)	0.12 (35)	0.15 (53)	20.0 (25)
8	BWS	Liquor store	**102 (9)**	**13 (7)**	**15 (9)**	0.18 (30)	0.21 (40)	13.3 (42)	6 (20)	**18 (7)**	0.08 (49)	0.25 (27)	66.7 (58)
9	Bottlemart	Liquor store	58 (20)	**12 (9)**	**15 (9)**	**0.30 (10)**	0.37 (12)	20.0 (44)	**12 (7)**	**18 (7)**	**0.30 (8)**	**0.44 (9)**	33.3 (32)
10	BP	Petrol station	**86 (10)**	**12 (9)**	12 (12)	0.20 (26)	0.20 (47)	**0.0 (1)**	8 (14)	11 (15)	0.13 (34)	0.18 (43)	27.3 (28)
11	Hungry Jacks	Restaurant chain	58 (20)	11 (11)	12 (12)	0.27 (16)	0.30 (23)	8.3 (36)	9 (12)	11 (15)	0.22 (18)	0.27 (24)	18.2 (23)
12	Wilson Parking	Parking lot	36 (37)	10 (12)	11 (15)	**0.40 (1)**	**0.44 (5)**	9.1 (37)	7 (17)	8 (22)	**0.28 (10)**	0.32 (19)	12.5 (20)
13	Australia Post	Post office	**194 (4)**	9 (13)	**22 (6)**	0.07 (72)	0.16 (54)	59.1 (73)	**12 (7)**	**30 (4)**	0.09 (47)	0.22 (35)	60.0 (55)
14	TAB outlet (stand-alone)	Gambling facility	65 (18)	9 (13)	14 (11)	0.20 (27)	0.31 (20)	35.7 (55)	7 (17)	14 (12)	0.15 (29)	0.31 (20)	50.0 (43)
15	Dome Café	Café	44 (29)	9 (13)	10 (16)	0.29 (12)	0.32 (18)	10.0 (38)	3 (36)	7 (28)	0.10 (43)	0.23 (34)	57.1 (53)
16	Caltex/Ampol	Petrol station	**104 (8)**	8 (16)	9 (18)	0.11 (52)	0.12 (68)	11.1 (39)	**16 (5)**	**16 (10)**	0.22 (19)	0.22 (36)	**0.0 (1)**
17	Pharmacy 777	Pharmacy	50 (26)	8 (16)	9 (18)	0.23 (19)	0.26 (30)	11.1 (39)	**10 (10)**	**16 (10)**	**0.29 (9)**	**0.46 (8)**	37.5 (36)
18	7-Eleven	Petrol station	41 (32)	8 (16)	8 (20)	0.28 (15)	0.28 (26)	**0.0 (1)**	5 (22)	5 (37)	0.17 (27)	0.17 (46)	**0.0 (1)**
19	City of Perth Parking	Parking lot	32 (47)	8 (16)	8 (20)	**0.36 (5)**	0.36 (13)	**0.0 (1)**	**11 (9)**	11 (15)	**0.49 (3)**	**0.49 (6)**	**0.0 (1)**
20	Puma	Petrol station	52 (24)	8 (16)	8 (20)	0.22 (20)	0.22 (37)	**0.0 (1)**	8 (14)	8 (22)	0.22 (19)	0.22 (36)	**0.0 (1)**
21	Muzz Buzz	Café	30 (52)	7 (21)	7 (26)	**0.33 (7)**	0.33 (17)	**0.0 (1)**	5 (22)	9 (20)	0.24 (15)	0.43 (11)	44.4 (41)
22	Thirsty Camel	Liquor store	42 (30)	6 (22)	12 (12)	0.20 (24)	**0.41 (7)**	50.0 (61)	4 (31)	8 (22)	0.14 (31)	0.27 (22)	50.0 (43)
23	Shell	Petrol station	69 (17)	6 (22)	6 (29)	0.12 (44)	0.12 (67)	**0.0 (1)**	5 (22)	5 (37)	0.10 (40)	0.10 (65)	**0.0 (1)**
24	Coles	Supermarket	73 (13)	5 (24)	8 (20)	0.10 (61)	0.16 (56)	37.5 (57)	5 (22)	8 (22)	0.10 (42)	0.16 (51)	37.5 (36)
25	Liquorland	Liquor store	61 (19)	5 (24)	7 (26)	0.12 (51)	0.16 (53)	28.6 (49)	5 (22)	6 (31)	0.12 (37)	0.14 (55)	16.7 (21)
26	Red Rooster	Restaurant chain	57 (22)	4 (26)	8 (20)	0.10 (59)	0.20 (46)	50.0 (61)	9 (12)	11 (15)	0.23 (17)	0.28 (21)	18.2 (23)
27	Government School	Government School	**465 (1)**	4 (26)	6 (29)	0.01 (83)	0.02 (98)	33.3 (50)	8 (14)	**20 (6)**	0.02 (68)	0.06 (78)	60.0 (55)
28	Cellarbrations	Liquor store	72 (15)	4 (26)	5 (35)	0.08 (66)	0.10 (82)	20.0 (44)	**10 (10)**	**17 (9)**	0.20 (25)	0.34 (16)	41.2 (39)
29	Commonwealth Bank	Bank	45 (28)	4 (26)	5 (35)	0.13 (42)	0.16 (55)	20.0 (44)	1 (52)	6 (31)	0.03 (66)	0.19 (41)	83.3 (67)
30	Bakers Delight	Bakery	52 (24)	4 (26)	4 (41)	0.11 (52)	0.11 (76)	**0.0 (1)**	1 (52)	4 (43)	0.03 (67)	0.11 (62)	75.0 (64)

(each with high coverage efficiency) that collectively cover a large number of OHCA cases. However, this would need to be balanced against the challenge of achieving public awareness across a larger number of brands. From the perspective of an individual business brand, coverage efficiency may help manage expectations about the likelihood of each AED being used.

This study has several limitations. While existing AED coverage was modelled in terms of SJ-WA's register of public-access AEDs, we acknowledge that there may be other AEDs in the community that afford some additional level of coverage. For simplicity, we modelled circular coverage areas around AEDs, whereas it is possible to model more realistic walking-routes based on road/path networks.[39] We did not distinguish cardiac arrests based on demographic and arrest characteristics, other than stratifying by arrests in public locations versus private residences. We treated proximity as a binary variable – whereby an OHCA case was considered to have AED coverage if one or more AEDs were within a threshold distance of the arrest, regardless of the distance within or beyond that threshold. A potential direction for future research is to use a distance-weighted approach to modelling AED coverage,[4,9] ideally based on empirical estimates of the relationship between AED use and proximity to OHCA.[28,29] Finally, a range of practical constraints may affect decisions to invest in AEDs in specific businesses, but were outside the scope of this study.

Conclusions

We identified a strong ranking of businesses as candidate host sites of AEDs in Perth, Western Australia, for their potential to supplement existing AED coverage of out-of-hospital cardiac arrests. Many businesses were identified that ranked highly for increased coverage of arrests in both public locations and private residences. Even under the scenario of all 115 business brands hosting AEDs with 24–7 access across all facilities, 57% of arrests in public locations, and 92% of arrests in private residences would remain without 100 m coverage. This highlights the importance of considering other modes of AED delivery in metropolitan landscapes.

CRediT authorship contribution statement

S. Ball: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Funding acquisition. **A. Morgan:** Conceptualization, Methodology, Validation, Investigation, Data curation, Writing – original draft, Writing – review & editing. **S. Simmonds:** Methodology, Writing – review & editing. **J. Bray:** Conceptualization, Methodology, Writing – review & editing, Funding acquisition. **P. Bailey:** Conceptualization, Writing – review & editing, Funding acquisition. **J. Finn:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: SS and PB are employed by SJ-WA; and SB and JF hold adjunct appointments with SJ-WA.

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Appendix A. Supplementary data

Supplementary data to this article (Tables A1-A12) can be found online at https://doi.org/10.1016/j.resplu.2022.100237.

Author details

[a]*Prehospital, Resuscitation and Emergency Care Research Unit (PRECRU), School of Nursing, Curtin University, Bentley, WA 6102, Australia* [b]*St John Western Australia, Belmont, WA 6104, Australia* [c]*Department of Epidemiology and Preventive Medicine, Monash University, Victoria 3004, Australia* [d]*Emergency Medicine, The University of Western Australia, Crawley, WA 6009, Australia*

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