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## Clinical paper

# Association between location of out-of-hospital cardiac arrest, on-scene socioeconomic status, and accessibility to public automated defibrillators in two large metropolitan areas in Canada and France



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### Abstract

**Aim:** To compare walking access times to automated external defibrillators (AEDs) between area-level quintiles of socioeconomic status (SES) in out-of-hospital cardiac arrest (OHCA) cases occurring in 2 major urban regions of Canada and France.

**Methods:** This was an international, multicenter, retrospective cohort study of adult, non-traumatic OHCA cases in the metropolitan Vancouver (Canada) and Rhône County (France) regions that occurred between 2014 and 2018. We calculated area-level SES for each case, using quintiles of country-specific scores (Q5 = most deprived). We identified AED locations from local registries. The primary outcome was the simulated walking time from the OHCA location to the closest AED (continuous and dichotomized by a 3-minute 1-way threshold). We fit multivariate models to analyze the association between OHCA-to-AED walking time and outcomes (Q5 vs others).

**Results:** A total of 6,187 and 3,239 cases were included from the Metro Vancouver and Rhône County areas, respectively. In Metro Vancouver Q5 areas (vs Q1-Q4), areas, AEDs were farther from (79 % over 400 m from case vs 67 %,  $p < 0.001$ ) and required longer walking times to (97 % above 3 min vs 91 %,  $p < 0.001$ ) cases. In Rhône Q5 areas, AEDs were closer than in other areas (43 % over 400 m from case vs 50 %,  $p = 0.01$ ), yet similarly poorly accessible (85 % above 3 min vs 86 %,  $p = 0.79$ ). In multivariate models, AED access time  $\geq 3$  min was associated with decreased odds of survival at hospital discharge in Metro Vancouver (odds ratio 0.41, 95 % CI [0.23–0.74],  $p = 0.003$ ).

**Conclusions:** Accessibility of public AEDs was globally poor in Metro Vancouver and Rhône, and even poorer in Metro Vancouver's socioeconomically deprived areas.

**Keywords:** Out-of-hospital cardiac arrest, Automated external defibrillator, AED, Access to urgent care, Socioeconomic inequities

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## Introduction

Approximately 80,000 cases of out-of-hospital cardiac arrest (OHCA) occur annually in Canada and France.<sup>1–2</sup> Predictors of survival rely on a complex chain of care<sup>3</sup> including response time intervals by lay responders<sup>4</sup> and use of bystander-applied automated external defibrillators (AEDs).<sup>5</sup>

However, few jurisdictions have implemented structured, evidence-based, systematic plans for AED deployments. Whereas governments align other communal resources with population density and historical usage (e.g. fire hydrants and stations, schools), AED placement has largely been left to private community groups. This may lead to inequities across communities, given that certain communities may have fewer resources to obtain AEDs. Further compounding the situation is that communities with poor socioeconomic status (SES) have been shown to have higher incidence of OHCA and lower rates of bystander intervention.<sup>6–7</sup>

Systematic AED placement to optimize geographical positioning may reduce both time intervals until defibrillation and inequities in socioeconomic health outcomes.<sup>8–12</sup> However, there is a paucity of data detailing the relationship between SES and AED accessibility. Previous studies have primarily focused on crude numbers of AEDs in given census tracts,<sup>12–13</sup> instead of assessing case-level access. Further, due to differences in community composition, cityscapes, and road networks in different areas of the world, relationships between SES and AED accessibility may vary significantly depending on community characteristics. Therefore, we sought to explore associations between the geospatial distribution of OHCA, on-scene SES, and spatial accessibility of AEDs. In addition, we examined the association between the OHCA-to-closest-AED walking time and outcomes. We studied 2 large metropolitan areas in Canada and France, to explore differences between community settings.

## Methods

### Study design

We conducted an international, multicenter, retrospective cohort study of adult, non-traumatic, Emergency Medical Services (EMS)-attended OHCA cases that occurred in either the Vancouver metropolitan area, “Metro Vancouver” (British Columbia, Canada), or Rhône County (France) between January 1st, 2014, and December 31st, 2018.

### Settings

British Columbia (BC) covers 944,735 km<sup>2</sup> and includes 5 million inhabitants, mostly located in urban areas, of which Metro Vancouver is the largest (2,883 km<sup>2</sup>), with a population of 2.5 million (population density of 854/km<sup>2</sup>). BC has the second-highest overall poverty rate in Canada: approximately 20 % of Metro Vancouver’s population lives under the national poverty line.<sup>14–16</sup> OHCA medical care is directed by the provincial BC Emergency Health Services (BCEHS). This care consists of a 3-tiered response, including First Responder (FR) firefighter units (trained in basic life support [BLS]), Primary Care Paramedics (also trained in BLS), and Advanced Care Paramedics (trained in advanced life support [ALS]).<sup>17–18</sup>

Rhône County covers 2,715 km<sup>2</sup> with a population of 1.9 million (density of 685/km<sup>2</sup>). It comprises the Lyon metropolitan area, the

region’s biggest urban area (second overall in France), with 1.3 million people spread over 534 km<sup>2</sup> (2,621/km<sup>2</sup>). In some districts in the Lyon metropolitan area, 30 % of inhabitants live in poverty.<sup>19</sup> OHCA medical care consists of a 2-tiered response, including firefighter units (trained in BLS) and physician-staffed mobile medical teams providing ALS.<sup>20</sup>

### Definitions and variables

The Metro Vancouver and Rhône regions contribute cases to the *Canadian Resuscitation Outcomes Consortium* (CanROC) and the *Registre Électronique des Arrêts Cardiaques* (RéAC), respectively. These nationwide, population-based, Utstein-style prospective registries contain consecutive EMS-assessed OHCA cases covering approximately 70 million people combined.<sup>21–22</sup> Every OHCA assessed by a paramedic team or mobile medical team is eligible for inclusion in CanROC and RéAC, respectively.<sup>23</sup> The 2 registries are engaged in a mutual, international, homogenized registry called ReACanROC, which has previously been described.<sup>24</sup> CanROC and RéAC report survival and neurological outcomes at hospital discharge and 30 days, respectively. ReACanROC uses an aligned dataset to ensure proper comparability. For the present study, we used the ReACanROC variable homogenization methods.

### AED registries

BCEHS is the provincial agency responsible for EMS organization and prehospital medical care in British Columbia. It maintains a provincial AED registry, integrated into the BCEHS computer-aided dispatch system. New AEDs can be added to the registry by contacting BCEHS or through the crowd-sourced PulsePoint mobile-phone app (<https://www.pulsepoint.org>; Supplementary Fig. 1).

In France, ARLOD (*Association pour le Recensement et la Localisation des Défibrillateurs*, <https://www.arlod.fr>) is a national public association responsible for holding AED-related data (Supplementary Fig. 1). At the time of the study period, AED registration was voluntary. A recent law made this census mandatory.

### SES data

In BC, area-level socioeconomic status (SES) was defined at the census-tract level (called the “dissemination area” [DA], incorporating 2016 Canadian census data), using values of the metropolitan *Institut National de Santé Publique du Québec* (INSPQ) deprivation index<sup>25</sup> (see Supplementary Methods).

In France, area-level SES was assessed at the census-block level, based on the smallest infra-urban level for which French census data are available, the *Ilots Regroupés pour l’Information Statistique* (IRIS),<sup>26</sup> which groups areas of 1,800–5,000 inhabitants with homogenous housing. Every IRIS’s SES was calculated using the French version of the European Deprivation Index,<sup>27</sup> based on 2015 census data.

### Geographical data

We defined OHCA location by the scene address, as recorded by emergency call centers, and we defined AED location by address of placement, as recorded in local registries. Each address was geocoded into WGS84 coordinates (longitude/ latitude) using QGIS 3.0 (QGIS).

OHCA cases and AEDs were classified according to the corresponding census tract they were located in (DA in Metro Vancouver and IRIS in Rhône). OHCA cases were categorized into quintiles based on SES,

with Q1 representing the highest SES and Q5 representing the lowest.

To illustrate the geographic distribution of OHCA and AEDs, we calculated the direct Euclidean distance (the direct distance between 2 points, without considering geographical obstacles) between each OHCA and its closest AED. To further analyze real-life accessibility, we computed walking paths based on the road network between each OHCA location and its closest AED.

### Outcomes

The primary outcome was walking time from the OHCA location to the closest defibrillator, using simulated walking paths. Secondary outcomes included associations between case-to-defibrillator distance (continuous and dichotomized by a > 400 m threshold) and survival and favourable neurological status (cerebral performance category < 3) at hospital discharge (for Metro Vancouver) and at 30 days (for Rhône).

### Analyses

We conducted geographical analyses with QGIS 3.0 (QGIS) and calculated walking paths with ArcMap's 10.8.1 (ESRI, CA) Network Analyst extension. Statistical analyses were performed using R (3.6.2),<sup>28</sup> at a bilateral alpha risk of 0.05 for p-values. All p-values regarding access to AEDs were adjusted for multiple testing with a Bonferroni adjusted threshold of 0.003. For all SES-based group comparisons, we compared Q5 with all other quintiles combined.

### General Characteristics

We described the general characteristics and outcomes of the study population in proportions (among cases with non-missing data) for categorical variables and with median and interquartile range (IQR) for continuous variables.

### AED Accessibility

We used 2 models to analyze accessibility to AEDs based on current guidelines on AED placement.<sup>29</sup> First, we identified the direct Euclidean distance from each OHCA to the closest AED, using 5 evenly spaced categories (0–100 m, 100–200 m, 200–300 m, 300–400 m, over 400 m). Second, based on simulated walking paths, we calculated the road network-based walking time between the OHCA and the closest AED. We considered AEDs that could be retrieved within 6 minutes (based on historical EMS response times in Metro Vancouver<sup>30–31</sup> round trip by foot as “accessible” (possible AED application prior to EMS arrival) and thus specifically examined AEDs that were within a 3-minute, 1-way walking distance. We computed 3 incremental, 1-way, 1-minute brisk walking distances, at a speed of 1.4 m/s (the QGIS default speed). For visual comparability purposes, to graphically homogenize spatial units between Canada and France, we divided Metro Vancouver and Rhône into 1 km<sup>2</sup> tiles.

### Differences by SES

To examine between-group SES-based differences, we compared Q5 to Q1–Q4 combined, individually for both regions, using the Kruskal-Wallis test for continuous variables and Chi<sup>2</sup> test for categorical variables. We calculated the correlation between walking time and SES to illustrate global AED accessibility. We calculated OHCA case density (cases/10,000 inhabitants/study period) at the DA/IRIS level in each region, per SES quintile, to account for potential discrepancies in cases' distribution.

### AED accessibility and outcomes

We calculated the association between AED 1-way accessibility time and outcomes using multivariate logistic regression models, after adjustment for age, sex, location type, area-level SES, type of territory (urban vs rural), witnessed by bystander, and bystander-attempted cardiopulmonary resuscitation (CPR).

### Ethics

RéAC and CanROC were reviewed and approved by their respective research ethics boards at creation, as was ReACanROC (France: *Commission Nationale Informatique et Libertés* [CNIL], approval no.DT-2020–015; Canada: Toronto Research Ethics Board, approval no.20–122). In both registries, OHCA case inclusion met the requirements of waived consent.

## Results

### General characteristics

During the study period, the Metro Vancouver and Rhône regions had 6,187 and 3,239 OHCA cases, respectively (Supplementary Fig. 2). Patient characteristics are shown in Table 1 (Metro Vancouver) and Table 2 (Rhône).

In Metro Vancouver, patients were predominantly male (70 %), with a median age of 65 years (IQR [51–79]). OHCA occurred mainly during the daytime (61 %), at home (76 %), and in urban areas (77 %). Cases were homogeneously distributed across quintiles of deprivation. A bystander witnessed the OHCA in 40 % of cases, bystander CPR was attempted in 53 % of cases, and an AED was applied prior to EMS arrival in 4 % of cases. When applied, the AED delivered a shock in 58 % of cases. Initial cardiac rhythm was non-shockable in most cases (81 %). Median time from call to first EMS unit arrival at the scene was 6 minutes (IQR<sup>5–8</sup> and to the first ALS unit arrival, 9 minutes (IQR<sup>7–11</sup>).

In Rhône, patients were predominantly male (65 %), with a median age of 71 years (IQR [57–82]). Again, OHCA occurred mainly during the daytime (62 %), at home (74 %), and in urban areas (74 %). Unlike in Metro Vancouver, however, most cases were located in Q5 areas (34 %); bystander-witnessed OHCA (59 % of cases) and AED application (7 %) tended to be more common, yet bystander CPR (45 %) tended to be less common. When applied, the AED delivered a shock in 23 % of cases. The first EMS-assessed cardiac rhythm was more frequently non-shockable (93 %). Median time from call to the first EMS unit arrival at the scene was 8 minutes (IQR<sup>5–12</sup> and to the first ALS unit arrival, 18 minutes (IQR<sup>13–23</sup>).

Return of spontaneous circulation (ROSC) was present at hospital arrival in 32 % of cases in Metro Vancouver and 21 % in Rhône. Using the metrics present in each registry, in Metro Vancouver, 12 % of patients survived at hospital discharge, and in Rhône, 5.1 % achieved 30-day survival. Favourable neurological status was present in 8.2 % of Metro Vancouver patients and 3.7 % of Rhône patients.

### AED accessibility

In Metro Vancouver and Rhône, the median OHCA-to-AED distance was 923 m (IQR [470–1,529]) and 795 m (IQR [410–1,555]), respectively. Most AEDs were located more than 400 m from case location (67 % and 55 %, respectively), with median 1-way walking times of

**Table 1 – General characteristics upon quintiles of socio-economic deprivation, Vancouver metropolitan area (Canada).**

|  | Total population | Missing values | Q1<br>n = 1235 | Q2<br>n = 1053 | Q3<br>n = 1081 | Q4<br>n = 1110 | Q5<br>n = 1107 | p-value | Q1-Q4<br>n = 4479 | Q5<br>n = 1107 | p-value |
|--|------------------|----------------|----------------|----------------|----------------|----------------|----------------|---------|-------------------|----------------|---------|
| <b>Patient</b>                             |                  |                |                |                |                |                |                |         |                   |                |         |
| Age, mean (SD), years                      | 65 [51;79]       | 157 (3)        | 66 [51;79]     | 67 [53;79]     | 65 [51;79]     | 68 [53;80]     | 64 [48;79]     | 0.001   | 66 [52;79]        | 64 [48;79]     | 0.002   |
| <b>Sex</b>                                 |                  |                |                |                |                |                |                |         |                   |                |         |
| Male, No.(%)                               | 4315/6156 (70)   | 31 (0)         | 885/1229 (72)  | 739/1050 (70)  | 748/1072 (70)  | 760/1108 (69)  | 778/1101 (71)  | 0.48    | 3132/4459 (70)    | 778/1101 (71)  | 0.81    |
| Female, No.(%)                             | 1841/6156 (30)   | 31 (0)         | 344/1229 (28)  | 311/1050 (30)  | 324/1072 (30)  | 348/1108 (31)  | 323/1101 (29)  | 0.48    | 1327/4459 (30)    | 323/1101 (29)  | 0.81    |
| <b>Scene location</b>                      |                  |                |                |                |                |                |                |         |                   |                |         |
| Home, private, No.(%)                      | 4668/6165 (76)   | 22 (0)         | 867/1230 (70)  | 818/1050 (78)  | 854/1075 (79)  | 895/1108 (81)  | 918/1103 (83)  | < 0.001 | 3434/4463 (77)    | 918/1103 (83)  | < 0.001 |
| Street, No.(%)                             | 441/6165 (7)     | 22 (0)         | 93/1230 (8)    | 60/1050 (6)    | 71/1075 (7)    | 57/1108 (5)    | 77/1103 (7)    | < 0.001 | 281/4463 (6)      | 77/1103 (7)    | < 0.001 |
| Public area, No.(%)                        | 699/6165 (11)    | 22 (0)         | 200/1230 (16)  | 125/1050 (12)  | 114/1075 (11)  | 103/1108 (9)   | 76/1103 (7)    | < 0.001 | 542/4463 (12)     | 76/1103 (7)    | < 0.001 |
| <b>Type of territory</b>                   |                  |                |                |                |                |                |                |         |                   |                |         |
| Urban, No.(%)                              | 4780/6187 (77)   | 0 (0)          | 947/1235 (77)  | 776/1053 (74)  | 845/1081 (78)  | 839/1110 (76)  | 912/1107 (82)  | < 0.001 | 3407/4479 (76)    | 912/1107 (82)  | < 0.001 |
| Rural, No.(%)                              | 1407/6187 (23)   | 0 (0)          | 288/1235 (23)  | 277/1053 (26)  | 236/1081 (22)  | 271/1110 (24)  | 195/1107 (18)  | < 0.001 | 1072/4479 (24)    | 195/1107 (18)  | < 0.001 |
| <b>Time of arrest</b>                      |                  |                |                |                |                |                |                |         |                   |                |         |
| Daytime (8am-8 pm), No.(%)                 | 3694/6095 (61)   | 92 (1)         | 786/1218 (65)  | 632/1034 (61)  | 636/1071 (59)  | 656/1092 (60)  | 627/1093 (57)  | 0.009   | 2710/4415 (61)    | 627/1093 (57)  | 0.02    |
| Night (8 pm-8am), No.(%)                   | 2401/6095 (39)   | 92 (1)         | 432/1218 (35)  | 402/1034 (39)  | 435/1071 (41)  | 436/1092 (40)  | 466/1093 (43)  | 0.009   | 1705/4415 (39)    | 466/1093 (43)  | 0.02    |
| <b>Bystander</b>                           |                  |                |                |                |                |                |                |         |                   |                |         |
| Presence of a bystander, No.(%)            | 2429/6019 (40)   | 168 (3)        | 561/1203 (47)  | 439/1021 (43)  | 415/1057 (39)  | 414/1079 (38)  | 372/1078 (35)  | < 0.001 | 1829/4360 (42)    | 372/1078 (35)  | < 0.001 |
| Bystander-attempted CPR, No.(%)            | 3246/6064 (53)   | 123 (2)        | 682/1210 (56)  | 572/1034 (55)  | 564/1054 (54)  | 595/1094 (54)  | 531/1083 (49)  | 0.001   | 2413/4392 (55)    | 531/1083 (49)  | 0,001   |
| <b>PAD</b>                                 |                  |                |                |                |                |                |                |         |                   |                |         |
| <b>Distance to closest PAD (m), No.(%)</b> |                  |                |                |                |                |                |                |         |                   |                |         |
| < 100                                      | 271/6187 (4)     | 0 (0)          | 87/1235 (7)    | 43/1053 (4)    | 30/1081 (3)    | 25/1110 (2)    | 25/1107 (2)    | < 0.001 | 185/4479 (4)      | 25/1107 (2)    | < 0.001 |
| [100–200[                                  | 587/6187 (9)     | 0 (0)          | 174/1235 (14)  | 80/1053 (8)    | 97/1081 (9)    | 75/1110 (7)    | 52/1107 (5)    | < 0.001 | 426/4479 (10)     | 52/1107 (5)    | < 0.001 |
| [200–300[                                  | 587/6187 (9)     | 0 (0)          | 160/1235 (13)  | 108/1053 (10)  | 81/1081 (7)    | 97/1110 (8)    | 53/1107 (5)    | < 0.001 | 446/4479 (10)     | 53/1107 (5)    | < 0.001 |
| [300–400[                                  | 612/6187 (10)    | 0 (0)          | 143/1235 (12)  | 82/1053 (8)    | 104/1081 (10)  | 94/1110 (8)    | 104/1107 (9)   | < 0.001 | 423/4479 (9)      | 104/1107 (9)   | < 0.001 |
| ≥ 400                                      | 4130/6187 (67)   | 0 (0)          | 671/1235 (54)  | 740/1053 (70)  | 769/1081 (71)  | 819/1110 (74)  | 873/1107 (79)  | < 0.001 | 2999/4479 (67)    | 873/1107 (79)  | < 0.001 |
| <b>PAD access time (min), No.(%)</b>       |                  |                |                |                |                |                |                |         |                   |                |         |
| < 1  | 84/6187 (1)      | 0 (0)          | 30/1235 (2)    | 15/1053 (1)    | 12/1081 (1)    | 5/1110 (0)     | 7/1107 (0)     | < 0.001 | 62/4479 (1)       | 7/1107 (0)     | < 0.001 |
| [1–2[                                      | 130/6187         | 0 (0)          | 52/1235        | 19/1053        | 18/1081        | 10/1110        | 6/1107         | < 0.001 | 99/4479           | 6/1107         | < 0.001 |

**Table 1 (continued)**

|                                       | Total population  | Missing values | Q1                    | Q2                   | Q3                    | Q4                    | Q5                    | p-value | Q1-Q4                 | Q5                    | p-value |
|---------------------------------------|-------------------|----------------|-----------------------|----------------------|-----------------------|-----------------------|-----------------------|---------|-----------------------|-----------------------|---------|
|                                       | N = 6187          |                | n = 1235              | n = 1053             | n = 1081              | n = 1110              | n = 1107              |         | n = 4479              | n = 1107              |         |
|                                       | (2)               |                | (4)                   | (2)                  | (2)                   | (1)                   | (0)                   |         | (2)                   | (0)                   |         |
| [2–3]                                 | 292/6187<br>(5)   | 0 (0)          | 78/1235<br>(6)        | 43/1053<br>(4)       | 47/1081<br>(4)        | 54/1110<br>(5)        | 25/1107<br>(2)        | < 0.001 | 222/<br>4479 (5)      | 25/1107<br>(2)        | < 0.001 |
| ≥ 3                                   | 5681/6187<br>(92) | 0 (0)          | 1075/<br>1235<br>(87) | 976/<br>1053<br>(93) | 1004/<br>1081<br>(93) | 1041/<br>1110<br>(94) | 1069/<br>1107<br>(97) | < 0.001 | 4096/<br>4479<br>(91) | 1069/<br>1107<br>(97) | < 0.001 |
| PAD application prior to EMS, No. (%) | 216/6021<br>(4)   | 166 (3)        | 66/1200<br>(5)        | 49/1028<br>(5)       | 31/1051<br>(3)        | 29/1087<br>(3)        | 19/1073<br>(2)        | < 0.001 | 175/<br>4366 (4)      | 19/1073<br>(2)        | < 0.001 |
| Defibrillation prior to EMS, No. (%)  | 124/215<br>(58)   | 1 (0)          | 37/66<br>(56)         | 33/48<br>(69)        | 18/31<br>(58)         | 18/29<br>(62)         | 10/19<br>(53)         | 0.65    | 106/174<br>(61)       | 10/19<br>(53)         | 0.65    |
| <b>Cardiac arrest</b>                 |                   |                |                       |                      |                       |                       |                       |         |                       |                       |         |
| OHCA case density, median [IQR]*      | 19 [0;36]         | 0 (0)          | 17 [0;29]             | 18 [0;33]            | 19 [0;36]             | 20 [0;39]             | 24 [12;43]            | < 0.001 | 18 [0;34]             | 24 [12;43]            | < 0.001 |
| First assessed rhythm, No. (%)        |                   |                |                       |                      |                       |                       |                       |         |                       |                       |         |
| Shockable                             | 1136/6004<br>(19) | 183 (3)        | 286/<br>1188<br>(24)  | 218/<br>1015<br>(21) | 188/<br>1045<br>(18)  | 199/<br>1093<br>(18)  | 169/<br>1077<br>(16)  | < 0.001 | 891/<br>4341<br>(21)  | 169/<br>1077<br>(16)  | < 0.001 |
| <b>EMS</b>                            |                   |                |                       |                      |                       |                       |                       |         |                       |                       |         |
| Time intervals, mean (SD), min        |                   |                |                       |                      |                       |                       |                       |         |                       |                       |         |
| First unit vehicle time interval      | 6 [5;8]           | 464 (7)        | 6 [5;8]               | 7 [5;8]              | 6 [5;8]               | 7 [5;8]               | 6 [5;8]               | 0.002   | 6 [5;8]               | 6 [5;8]               | 0.006   |
| ALS unit vehicle time interval        | 9 [7;11]          | 7 (0)          | 9 [7;12]              | 10 [7;12]            | 9 [7;11]              | 9 [7;12]              | 8 [7;11]              | < 0.001 | 9 [7;12]              | 8 [7;11]              | < 0.001 |
| First epinephrine administration      | 19 [16;24]        | 221 (5)        | 19 [16;24]            | 20 [17;24]           | 20 [16;24]            | 20 [16;23]            | 18 [16;23]            | < 0.001 | 20 [16;24]            | 18 [16;23]            | < 0.001 |
| First unit at scene, No. (%)          |                   |                |                       |                      |                       |                       |                       |         |                       |                       |         |
| BLS                                   | 5609/6094<br>(92) | 93 (2)         | 1124/<br>1218<br>(92) | 952/<br>1034<br>(92) | 978/<br>1070<br>(91)  | 1018/<br>1092<br>(93) | 1013/<br>1093<br>(93) | 0.59    | 4072/<br>4414<br>(92) | 1013/<br>1093<br>(93) | 0.68    |
| ALS                                   | 485/6094<br>(8)   | 93 (2)         | 94/1218<br>(8)        | 82/1034<br>(8)       | 92/1070<br>(9)        | 74/1092<br>(7)        | 80/1093<br>(7)        | 0.59    | 342/<br>4414 (8)      | 80/1093<br>(7)        | 0.68    |
| ALS at scene, No. (%)                 | 5918/6095<br>(97) | 92 (1)         | 1175/<br>1218<br>(96) | 994/<br>1034<br>(96) | 1037/<br>1071<br>(97) | 1062/<br>1092<br>(97) | 1076/<br>1093<br>(98) | 0.02    | 4268/<br>4415<br>(97) | 1076/<br>1093<br>(98) | 0.003   |
| CPR attempted, No. (%)                | 4203/5017<br>(84) | 1170<br>(19)   | 829/<br>1022<br>(81)  | 717/854<br>(84)      | 739/878<br>(84)       | 774/890<br>(87)       | 748/880<br>(85)       | 0.01    | 3059/<br>3644<br>(84) | 748/880<br>(85)       | 0.47    |
| <b>Outcomes</b>                       |                   |                |                       |                      |                       |                       |                       |         |                       |                       |         |
| Dead at scene, No. (%)                | 3577/6184<br>(58) | 3 (0)          | 697/<br>1235<br>(56)  | 597/<br>1053<br>(57) | 616/<br>1080<br>(57)  | 646/<br>1110<br>(58)  | 658/<br>1105<br>(60)  | 0.51    | 2556/<br>4478<br>(57) | 658/<br>1105<br>(60)  | 0.30    |
| ROSC at hospital arrival, No. (%)     | 2002/6187<br>(32) | 0 (0)          | 413/<br>1235<br>(33)  | 352/<br>1053<br>(33) | 355/<br>1081<br>(33)  | 351/<br>1110<br>(32)  | 343/<br>1107<br>(31)  | 0.88    | 1471/<br>4479<br>(33) | 343/<br>1107<br>(31)  | 0.29    |
| Alive at hospital discharge, No. (%)  | 691/5990<br>(12)  | 197 (3)        | 166/<br>1196<br>(14)  | 134/<br>1019<br>(13) | 119/<br>1048<br>(11)  | 130/<br>1079<br>(12)  | 96/1077<br>(9)        | 0.004   | 549/<br>4342<br>(13)  | 96/1077<br>(9)        | < 0.001 |
| CPC 1–2 at discharge, No. (%)         | 479/5825<br>(8)   | 362 (6)        | 121/<br>1157<br>(10)  | 80/973<br>(8)        | 90/1030<br>(9)        | 96/1057<br>(9)        | 68/1055<br>(6)        | 0.02    | 387/<br>4217 (9)      | 68/1055<br>(6)        | 0.006   |

ALS: advanced life support; BLS: basic life support; CPC: cerebral performance category; CPR: cardio-pulmonary resuscitation; EMS: emergency medical services; IQR: interquartile range; PAD: public automated defibrillator; ROSC: return of spontaneous circulation.

\* case density: OHCA cases/10,000 inhabitants.

**Table 2 – General characteristics upon quintiles of socio-economic deprivation, Rhône (France).**

|  | Total population<br>N = 3239 | Missing values | Q1<br>n = 676 | Q2<br>n = 374 | Q3<br>n = 447 | Q4<br>n = 516 | Q5<br>n = 1115 | p-value | Q1-Q4<br>n = 2013 | Q5<br>n = 1115 | p-value |
|--|------------------------------|----------------|---------------|---------------|---------------|---------------|----------------|---------|-------------------|----------------|---------|
| <b>Patient</b>                             |                              |                |               |               |               |               |                |         |                   |                |         |
| Age, mean (SD), years                      | 71 [57;82]                   | 0 (0)          | 73 [60;83]    | 70 [58;83]    | 72 [58;82]    | 72 [58;82]    | 69 [54;81]     | 0.01    | 72 [58;82]        | 69 [54;81]     | < 0.01  |
| <b>Sex</b>                                 |                              |                |               |               |               |               |                |         |                   |                |         |
| Male, No.(%)                               | 2109/3239 (65)               | 0 (0)          | 433/676 (64)  | 259/374 (69)  | 295/447 (66)  | 334/516 (65)  | 702/1115 (63)  | 0.26    | 1321/2013 (66)    | 702/1115 (63)  | 0.15    |
| Female, No.(%)                             | 1130/3239 (35)               | 0 (0)          | 243/676 (36)  | 115/374 (31)  | 152/447 (34)  | 182/516 (35)  | 413/1115 (37)  | 0.26    | 692/2013 (34)     | 413/1115 (37)  | 0.15    |
| <b>Scene location</b>                      |                              |                |               |               |               |               |                |         |                   |                |         |
| Home, private, No.(%)                      | 2363/3201 (74)               | 38 (1)         | 523/668 (78)  | 248/369 (67)  | 345/442 (78)  | 393/513 (77)  | 818/1103 (74)  | < 0.001 | 1509/1992 (76)    | 818/1103 (74)  | < 0.001 |
| Street, No.(%)                             | 329/3201 (10)                | 38 (1)         | 46/668 (7)    | 38/369 (10)   | 40/442 (9)    | 58/513 (1)    | 124/1103 (11)  | < 0.001 | 182/1992 (9)      | 124/1103 (11)  | < 0.001 |
| Public area, No.(%)                        | 77/3201 (2)                  | 38 (1)         | 17/668 (3)    | 11/369 (3)    | 14/442 (3)    | 10/513 (2)    | 24/1103 (2)    | < 0.001 | 52/1992 (3)       | 24/1103 (2)    | < 0.001 |
| <b>Type of territory</b>                   |                              |                |               |               |               |               |                |         |                   |                |         |
| Urban, No.(%)                              | 2404/3238 (74)               | 1 (0)          | 291/676 (43)  | 190/374 (51)  | 301/447 (67)  | 468/516 (91)  | 1059/1115 (95) | < 0.001 | 1250/2013 (62)    | 1059/1115 (95) | < 0.001 |
| Rural, No.(%)                              | 834/3238 (26)                | 1 (0)          | 385/676 (57)  | 184/374 (49)  | 146/447 (33)  | 48/516 (9)    | 56/1115 (5)    | < 0.001 | 763/2013 (38)     | 56/1115 (5)    | < 0.001 |
| <b>Time of arrest</b>                      |                              |                |               |               |               |               |                |         |                   |                |         |
| Daytime (8am-8 pm), No.(%)                 | 2023/3239 (62)               | 0 (0)          | 430/676 (64)  | 226/374 (60)  | 281/447 (63)  | 325/516 (63)  | 692/1115 (62)  | 0.88    | 1262/2013 (63)    | 692/1115 (62)  | 0.76    |
| Night (8 pm-8am), No.(%)                   | 1216/3239 (38)               | 0 (0)          | 246/676 (36)  | 148/374 (40)  | 166/447 (37)  | 191/516 (37)  | 423/1115 (38)  | 0.88    | 751/2013 (37)     | 423/1115 (38)  | 0.76    |
| <b>Bystander</b>                           |                              |                |               |               |               |               |                |         |                   |                |         |
| Presence of a bystander, No.(%)            | 1900/3239 (59)               | 0 (0)          | 387/676 (57)  | 237/374 (63)  | 262/447 (59)  | 310/516 (60)  | 638/1115 (57)  | 0.25    | 1196/2013 (59)    | 638/1115 (57)  | 0.25    |
| Bystander-attempted CPR, No.(%)            | 1459/3239 (45)               | 0 (0)          | 313/676 (46)  | 183/374 (49)  | 204/447 (46)  | 201/516 (39)  | 495/1115 (44)  | 0.03    | 901/2013 (45)     | 495/1115 (44)  | 0.87    |
| <b>PAD</b>                                 |                              |                |               |               |               |               |                |         |                   |                |         |
| <b>Distance to closest PAD (m), No.(%)</b> |                              |                |               |               |               |               |                |         |                   |                |         |
| < 100                                      | 223/3239 (7)                 | 0 (0)          | 17/676 (3)    | 30/374 (8)    | 22/447 (5)    | 57/516 (1)    | 90/1115 (8)    | < 0.001 | 126/2013 (6)      | 90/1115 (8)    | 0.01    |
| [100–200[                                  | 459/3239 (14)                | 0 (0)          | 46/676 (7)    | 40/374 (11)   | 82/447 (18)   | 106/516 (21)  | 171/1115 (15)  | < 0.001 | 274/2013 (14)     | 171/1115 (15)  | 0.01    |
| [200–300[                                  | 442/3239 (14)                | 0 (0)          | 69/676 (10)   | 37/374 (10)   | 63/447 (14)   | 95/516 (19)   | 164/1115 (15)  | < 0.001 | 264/2013 (13)     | 164/1115 (15)  | 0.01    |
| [300–400[                                  | 342/3239 (11)                | 0 (0)          | 51/676 (8)    | 31/374 (8)    | 69/447 (15)   | 58/516 (11)   | 131/1115 (12)  | < 0.001 | 209/2013 (10)     | 131/1115 (12)  | 0.01    |
| ≥ 400                                      | 1773/3239 (55)               | 0 (0)          | 493/676 (73)  | 236/374 (63)  | 211/447 (47)  | 200/516 (39)  | 559/1115 (50)  | < 0.001 | 1140/2013 (57)    | 559/1115 (50)  | 0.01    |

**Table 2 (continued)**

|                                       | Total population<br>N = 3239 | Missing values | Q1<br>n = 676 | Q2<br>n = 374 | Q3<br>n = 447 | Q4<br>n = 516 | Q5<br>n = 1115 | p-value | Q1-Q4<br>n = 2013 | Q5<br>n = 1115 | p-value |
|---------------------------------------|------------------------------|----------------|---------------|---------------|---------------|---------------|----------------|---------|-------------------|----------------|---------|
| <b>PAD access time</b>                |                              |                |               |               |               |               |                |         |                   |                |         |
| (min), No.(%)                         |                              |                |               |               |               |               |                |         |                   |                |         |
| < 1                                   | 77/3239 (2)                  | 0 (0)          | 8/676 (1)     | 11/374 (3)    | 3/447 (1)     | 22/516 (4)    | 30/1115 (3)    | < 0.001 | 44/2013 (2)       | 30/1115 (3)    | 0.79    |
| [1–2[                                 | 170/3239 (5)                 | 0 (0)          | 13/676 (2)    | 17/374 (5)    | 24/447 (5)    | 47/516 (9)    | 60/1115 (5)    | < 0.001 | 101/2013 (5)      | 60/1115 (5)    | 0.79    |
| [2–3[                                 | 210/3239 (6)                 | 0 (0)          | 20/676 (3)    | 27/374 (7)    | 35/447 (8)    | 49/516 (10)   | 74/1115 (7)    | < 0.001 | 131/2013 (7)      | 74/1115 (7)    | 0.79    |
| ≥ 3                                   | 2782/3239 (86)               | 0 (0)          | 635/676 (94)  | 319/374 (85)  | 385/447 (86)  | 398/516 (77)  | 951/1115 (85)  | < 0.001 | 1737/2013 (86)    | 951/1115 (85)  | 0.79    |
| PAD application prior to EMS, No. (%) | 231/3239 (7)                 | 0 (0)          | 50/676 (7)    | 38/374 (10)   | 22/447 (5)    | 25/516 (5)    | 73/1115 (7)    | 0.01    | 135/2013 (7)      | 73/1115 (7)    | 0.92    |
| Defibrillation prior to EMS, No.(%)   | 53/231 (23)                  | 0 (0)          | 9/50 (18)     | 14/38 (37)    | 4/22 (18)     | 7/25 (28)     | 11/73 (15)     | 0.08    | 34/135 (25)       | 11/73 (15)     | 0.13    |
| <b>Cardiac arrest</b>                 |                              |                |               |               |               |               |                |         |                   |                |         |
| OHCA case density, median [IQR]*      | 15 [19;23]                   | 0 (0)          | 14 [8;24]     | 12 [6;22]     | 16 [8;23]     | 14 [9;20]     | 19 [11;26]     | < 0.001 | 14 [8;22]         | 19 [11;26]     | < 0.001 |
| <b>First assessed rhythm, No.(%)</b>  |                              |                |               |               |               |               |                |         |                   |                |         |
| Shockable                             | 219/3087 (7 %)               | 152 (5 %)      | 44/656 (7 %)  | 27/356 (8 %)  | 19/425 (4 %)  | 42/483 (9 %)  | 77/1062 (7 %)  | 0.15    | 132/1920 (7 %)    | 77/1062 (7 %)  | 0.76    |
| <b>EMS</b>                            |                              |                |               |               |               |               |                |         |                   |                |         |
| Time intervals, mean (SD), min        |                              |                |               |               |               |               |                |         |                   |                |         |
| First unit vehicle time interval      | 8 [5;12]                     | 843 (26)       | 10 [7;14]     | 10 [6;13]     | 8 [5;11]      | 8 [5;11]      | 8 [5;10]       | < 0.001 | 9 [5;12]          | 8 [5;10]       | < 0.001 |
| ALS unit vehicle time interval        | 18 [13;23]                   | 793 (24)       | 20 [15;26]    | 20 [14;25]    | 17 [13;23]    | 16 [12;22]    | 16 [13;21]     | < 0.001 | 18 [14;25]        | 16 [13;21]     | < 0.001 |
| First epinephrine administration      | 22 [17;29]                   | 307 (14)       | 24 [19;30]    | 23 [18;30]    | 21 [16;28]    | 21 [16;29]    | 21 [16;27]     | < 0.001 | 23 [17;30]        | 21 [16;27]     | 0.007   |
| First unit at scene, No.(%)           |                              |                |               |               |               |               |                |         |                   |                |         |
| BLS                                   | 2350/2446 (96)               | 793 (24)       | 500/520 (96)  | 250/258 (97)  | 326/343 (95)  | 369/389 (95)  | 835/865 (97)   | 0.50    | 1445/1510 (96)    | 835/865 (97)   | 0.37    |
| ALS                                   | 96/2446 (4)                  | 793 (24)       | 20/520 (4)    | 8/258 (3)     | 17/343 (5)    | 20/389 (5)    | 30/865 (3)     | 0.50    | 65/1510 (4)       | 30/865 (3)     | 0.37    |
| ALS at scene, No. (%)                 | 2446/2446 (100)              | 793 (24)       | 520/520 (100) | 258/258 (100) | 343/343 (100) | 389/389 (100) | 865/865 (100)  | X       | 1510/1510 (100)   | 865/865 (100)  | X       |
| CPR attempted, No.(%)                 | 3215/3239 (99)               | 0 (0)          | 669/676 (99)  | 370/374 (99)  | 443/447 (99)  | 513/516 (99)  | 1110/1115 (99) | 0.56    | 1995/2013 (99)    | 1110/1115 (99) | 0.24    |
| <b>Outcomes</b>                       |                              |                |               |               |               |               |                |         |                   |                |         |
| Dead at scene, No.(%)                 | 2476/3239 (76)               | 0 (0)          | 552/676 (82)  | 290/374 (78)  | 324/447 (72)  | 392/516 (76)  | 842/1115 (76)  | 0.005   | 1558/2013 (77)    | 842/1115 (76)  | 0.25    |
| ROSC at hospital arrival, No.(%)      | 669/3239 (21)                | 0 (0)          | 110/676 (16)  | 74/374 (20)   | 105/447 (23)  | 108/516 (21)  | 242/1115 (22)  | 0.05    | 397/2013 (20)     | 242/1115 (22)  | 0.36    |
| Alive at 30 days, No.(%)              | 166/3239 (5)                 | 0 (0)          | 26/676 (4)    | 19/374 (5)    | 23/447 (5)    | 21/516 (4)    | 63/1115 (6)    | 0.43    | 89/2013 (4)       | 63/1115 (6)    | 0.15    |
| CPC 1–2 at 30 days, No.(%)            | 119/3219 (4)                 | 20 (1)         | 19/673 (3)    | 16/372 (4)    | 16/444 (4)    | 16/514 (3)    | 40/1106 (4)    | 0.75    | 67/2003 (3)       | 40/1106 (4)    | 0.77    |

ALS: advanced life support; BLS: basic life support; CPC: cerebral performance category; CPR: cardio-pulmonary resuscitation; EMS: emergency medical services; IQR: interquartile range; PAD: public automated defibrillator; ROSC: return of spontaneous circulation.

\* case density: OHCA cases/10,000 inhabitants.

11 minutes (IQR<sup>6–18</sup>) and 9 minutes (IQR<sup>5–19</sup>), respectively. Access to most AEDs (92 % and 86 % of cases, respectively) required a 1-way walk of > 3 minutes (Fig. 1).

Among the prespecified 1 km<sup>2</sup> tiles in Metro Vancouver and Rhône, the proportions of OHCA within a 1-way 1-minute trip to an AED were 1 % and 2 %, respectively, and the proportions within a 1-way 3-minute trip to an AED were 8 % and 14 %, respectively (Fig. 2, A & B). Therefore, the majority of AEDs were not accessible in < 3 minutes in either study area (Fig. 2, C & D).

### Differences by deprivation quintiles

The geographical distribution of deprivation indices can be seen in Supplementary Fig. 3. The deprivation score was missing in 8 % of total cases (n = 712), resulting in 601 missing quintiles (10 %) in Metro Vancouver and 111 (3 %) in Rhône.

In Metro Vancouver, in the most deprived areas (Q5) compared to the others (Q1–Q4), patients were younger (median age 64 years, IQR [48–79] vs 66 years, IQR [52–79]), and OHCA occurred more frequently at home (83 % vs 77 %), less frequently in public locations (7 % vs 12 %), and predominantly in urban areas (82 % vs 76 %) (all p < 0.001) (Table 1). In Q5 areas, bystanders less frequently witnessed the OHCA (35 % vs 42 %), attempted less CPR (49 % vs 55 %), and applied fewer AEDs (2 % vs 4 %) than in Q1–Q4 areas (all p < 0.001). In Q5 areas, AEDs were more frequently located > 400 m from case location (79 % vs 67 %), and more required ≥ 3 minutes for a 1-way brisk walk than in Q1–Q4 areas (97 % vs 91 %) (all p < 0.001). First EMS-assessed cardiac rhythm was mainly non-shockable (84 % in Q5 vs 79 % in Q1–Q4, p < 0.001). There was no difference in proportions of sustained ROSC achieved in Q5 areas as compared to Q1–Q4 (39 % vs 41 %, p = 0.20), but both survival at hospital discharge and favourable neurological status were lower in Q5 than Q1–Q4 areas (9 % vs 13 % and 6 % vs 9 %, respectively, p = 0.006). Detailed AED walking access times by quintiles of deprivation are synthesized in Supplementary Table 1.

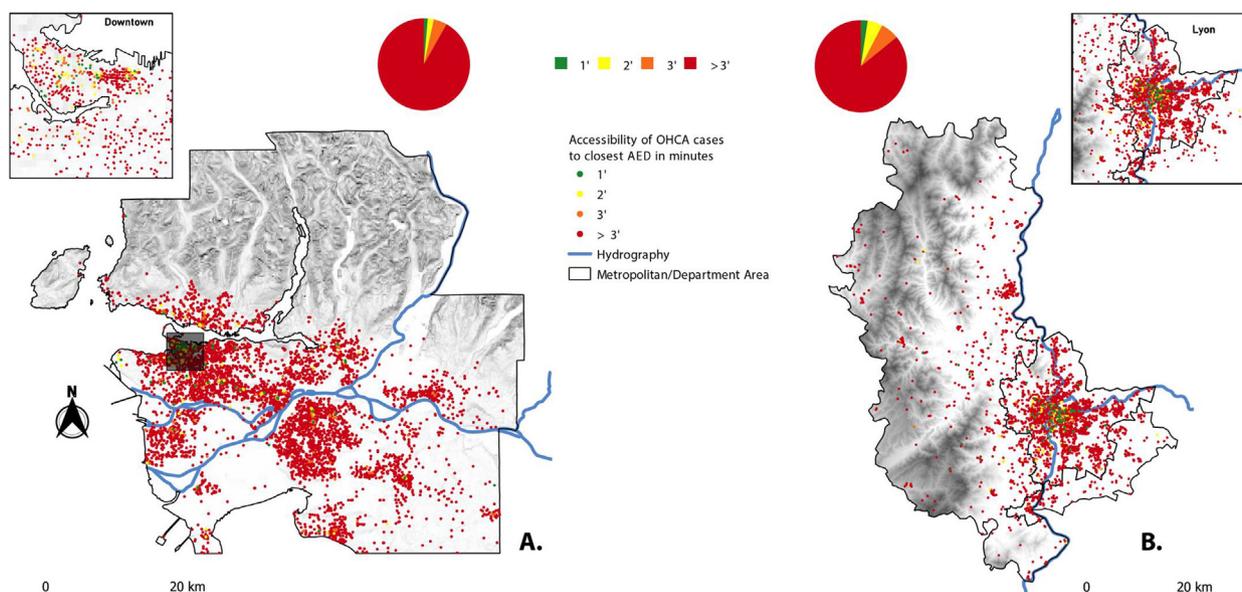
In Rhône, patients in Q5 were younger than those in Q1–Q4 (median age 69 years, IQR [54–81] vs 72 years, IQR [58–82]), and OHCA occurred less frequently at home (74 % vs 76 %), more frequently on the street (11 % vs 9 %), and more often in urban areas (95 % vs 62 %) (all p < 0.001). We did not detect a difference in bystander-witnessed cases (57 % vs 59 %), bystander CPR (44 % vs 45 %), bystander AED application (7 % vs 7 %), or shock delivery (15 % vs 25 %) (all p ≥ 0.13). AEDs in Q5 areas were more frequently located < 400 m from case location than in the other areas (50 % vs 43 %, p = 0.01) but were not accessible within a shorter walking time (>3 minutes in 85 % vs 86 %, p = 0.79). We detected no difference in rates of sustained ROSC achieved (25 % in Q5 vs 24 % in Q1–Q4, p = 0.31) and no difference in 30-day survival or favourable neurological status (6 % in Q5 vs 4 % in Q1–Q4 and 4 % vs 3 %, respectively, all p ≥ 0.15). Detailed AED walking access times by quintiles of deprivation are synthesized in Supplementary Table 1.

In both regions, OHCA case density was higher in low-SES areas (Q5 vs Q1–Q4, Rhône: 19/10,000 vs 14; Metro Vancouver: 24/10,000 vs 18, all p < 0.001), with density increasing continuously with deprivation in Metro Vancouver (Table 1 and Table 2).

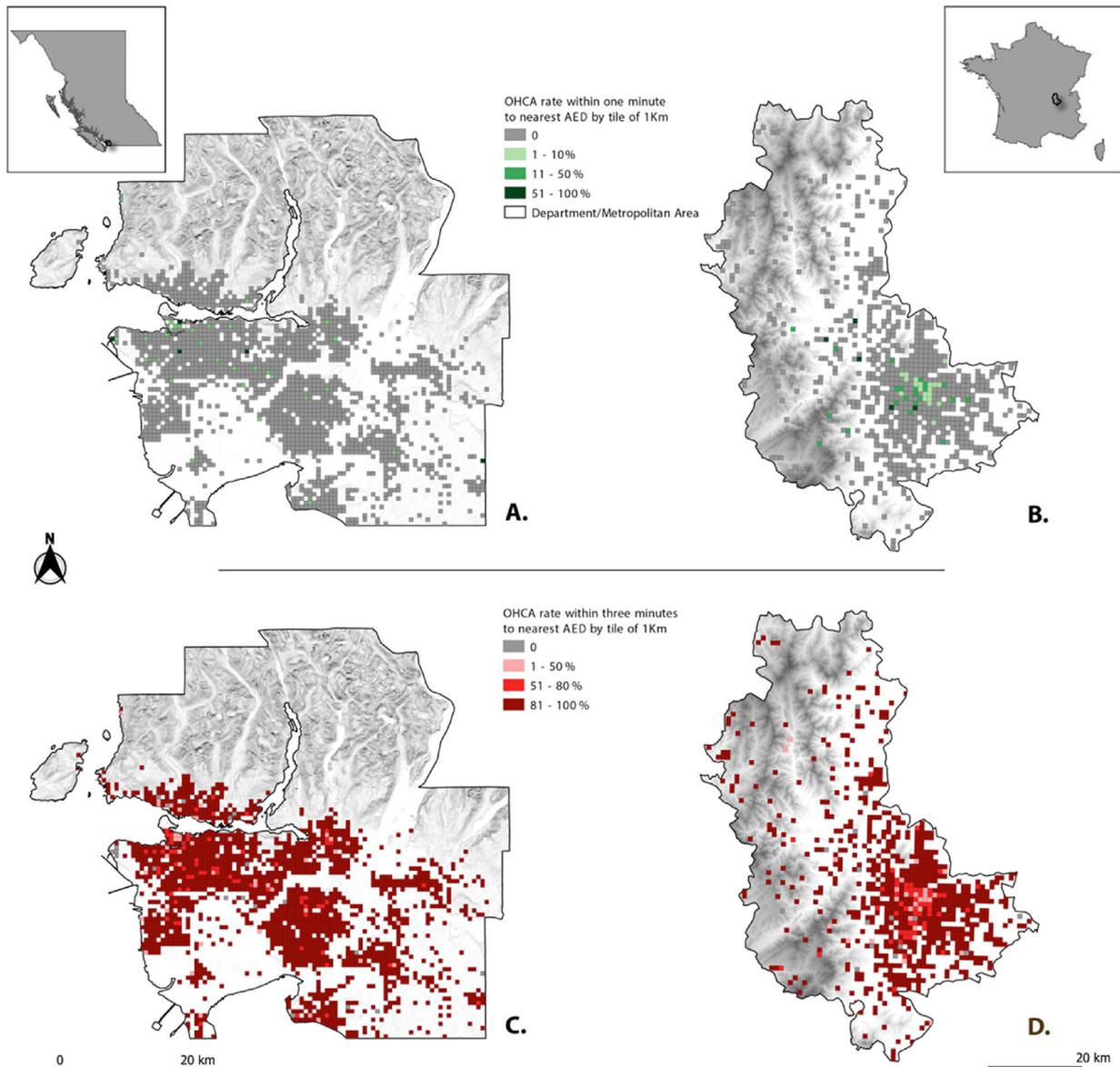
### AED accessibility and outcomes

In Metro Vancouver, univariate models demonstrated that AED access time of ≥ 3 minutes was associated with a lower probability of ROSC at hospital arrival (OR 0.39, 95 % CI [0.24, 0.64]) and survival at hospital discharge (OR 0.19, 95 % CI [0.10, 0.36]) (all p < 0.001). In multivariate models, 1-way access time of ≥ 3 minutes was associated with lower survival at hospital discharge (OR 0.41, 95 % CI [0.23, 0.74], p = 0.003) but not with ROSC (Table 3 and Supplementary Table 2).

Even though the observed effects were similar in Rhône, AED access time was not significantly associated with any outcome in either univariate or multivariate analyses (Table 3 and Supplementary Table 2).



**Fig. 1 – Spatial distribution of OHCA represented by walking access time in Metro Vancouver (A) and Rhône County (B).**



**Fig. 2 – Proportion of time-distant OHCA cases to nearest AED by tile of 1 km<sup>2</sup> in Metro Vancouver (A, C) and Rhône County (B, D).**

## Discussion

We examined a large, international population of adult, non-traumatic, EMS-assessed OHCA, with geographical AED data. We found significant associations between AED accessibility, geographic and socioeconomic features of each region, and outcomes. These data demonstrate that AED placement efforts have resulted in inadequate (and potentially inequitable) AED access. Our study highlights the need for the systematic deployment of AEDs to achieve the greatest benefit and decrease outcome differences between communities.

We compared the most deprived areas with more affluent areas in urban regions of 2 countries. Some findings were congruent between the regions, such as less frequent bystander involvement in the most deprived areas. However, the geographic distribution of AEDs and OHCA, as well as distances to the closest AED, highlighted differences between them. In Rhône, the most deprived areas were

located downtown, where a high number of AEDs were concentrated, and where OHCA case density was higher than in less deprived areas. In contrast, in Metro Vancouver, less deprived areas had more AEDs (concentrated in urban areas), and case density was lower than in more deprived areas. Hence, AED location might reflect socio-geographic configurations in Rhône, whereas Metro Vancouver showed evidence of persistent inequities in AED placement. In France, a government-regulated AED placement strategy has been in place since 2007, whereas in BC, AED placement is left to community initiatives. This difference in strategy could explain our findings.

The OHCA-to-AED retrieval time interval was > 6 minutes in the majority of cases in both regions. These results are consistent with previous work.<sup>32</sup> Although studies have found varying AED accessibility,<sup>29</sup> previous work has evaluated optimisation strategies to shorten AED retrieval times.<sup>9–11,33–35</sup> Comparing regions in different countries highlights the need to understand geographic differences.

**Table 3 – Predictors of survival at hospital discharge/30 days, uni- and multivariate models.**

|                                   | Survival          |         |                   |         |                   |         |                   |         |
|-----------------------------------|-------------------|---------|-------------------|---------|-------------------|---------|-------------------|---------|
|                                   | Vancouver metro   |         |                   |         | Rhône county      |         |                   |         |
|                                   | Univariate        |         | Multivariate      |         | Univariate        |         | Multivariate      |         |
|                                   | OR [95 %CI]       | p-value |
| Age, years (ref: 65; step: 5)     | 0.92 [0.89; 0.94] | < 0.001 | 0.88 [0.86; 0.90] | < 0.001 | 0.87 [0.84; 0.90] | < 0.001 | 0.87 [0.83; 0.90] | < 0.001 |
| Sex: male                         | 1.60 [1.23; 2.09] | < 0.001 | 1.28 [1.03; 1.59] | 0.03    | 1.53 [1.06; 2.22] | 0.02    | 1.29 [0.88; 1.90] | 0.19    |
| Scene location: home              | 0.20 [0.16; 0.25] | < 0.001 | 0.31 [0.25; 0.38] | < 0.001 | 0.39 [0.28; 0.54] | < 0.001 | 0.55 [0.39; 0.78] | 0.001   |
| Quintile of deprivation (ref: Q1) |                   |         |                   |         |                   |         |                   |         |
| Q2                                | 0.93 [0.67; 1.28] | 0.54    | 1.19 [0.90; 1.58] | 0.21    | 1.34 [0.73; 2.46] | 0.34    | 0.95 [0.50; 1.81] | 0.89    |
| Q3                                | 0.79 [0.57; 1.11] | 0.07    | 1.08 [0.81; 1.43] | 0.59    | 1.29 [0.72; 2.31] | 0.39    | 1.22 [0.66; 2.23] | 0.53    |
| Q4                                | 0.86 [0.62; 1.19] | 0.23    | 1.28 [0.97; 1.69] | 0.08    | 1.05 [0.59; 1.90] | 0.86    | 0.91 [0.47; 1.75] | 0.77    |
| Q5                                | 0.61 [0.43; 0.87] | < 0.001 | 0.93 [0.69; 1.26] | 0.66    | 1.47 [0.92; 2.35] | 0.11    | 1.31 [0.76; 2.25] | 0.33    |
| Type of territory: urban          | 1.36 [1.03; 1.80] | 0.005   | 1.33 [1.05; 1.67] | 0.02    | 1.04 [0.71; 1.51] | 0.85    | 0.95 [0.60; 1.52] | 0.84    |
| Presence of a bystander           | 5.22 [4.07; 6.70] | < 0.001 | 5.42 [4.39; 6.69] | < 0.001 | 5.44 [3.31; 8.95] | < 0.001 | 4.47 [2.66; 7.51] | < 0.001 |
| Bystander-attempted CPR           | 2.20 [1.73; 2.80] | < 0.001 | 1.43 [1.17; 1.74] | < 0.001 | 3.89 [2.67; 5.66] | < 0.001 | 2.65 [1.78; 3.94] | < 0.001 |
| PAD access time,min (ref: < 1)    |                   |         |                   |         |                   |         |                   |         |
| [1–2[                             | 0.40 [0.16; 1.00] | 0.01    | 0.47 [0.22; 1.04] | 0.06    | 0.98 [0.36; 2.69] | 0.97    | 1.09 [0.38; 3.15] | 0.88    |
| [2–3[                             | 0.35 [0.16; 0.76] | < 0.001 | 0.51 [0.26; 1.01] | 0.05    | 0.45 [0.15; 1.35] | 0.15    | 0.48 [0.15; 1.52] | 0.22    |
| ≥ 3                               | 0.19 [0.10; 0.36] | < 0.001 | 0.41 [0.23; 0.74] | 0.003   | 0.53 [0.23; 1.25] | 0.15    | 0.53 [0.21; 1.32] | 0.17    |

CPR: cardio-pulmonary resuscitation; PAD: public automated defibrillator; ROSC: return of spontaneous circulation.

An "X" is displayed for the interaction term in the univariate column as an interaction cannot be univariate.

For example, in Rhône, AEDs were located at shorter Euclidean distances from cases in low-SES areas than in areas with higher SES; however, they were not accessible within shorter walking times. When compared to Metro Vancouver, where longer Euclidean distance was associated with longer walking times, these findings suggest differences in the underlying complexity of road networks.

Studies have demonstrated a clear association between SES and the density of AEDs.<sup>33–35</sup> Data from Metro Vancouver support the external validity of these findings in similar Anglo-American EMS systems. A nationwide study of 51 French regions described a disconnect between AED density and the proportion of the population trained in BLS, with variation in both metrics; although no specific analysis was performed, region-level SES may be a hidden component of such inequities.<sup>36</sup>

AED accessibility was associated with outcomes in Metro Vancouver, although it did not reach significance in Rhône. Longer AED retrieval time also appeared to be associated with a lower likelihood of survival in Metro Vancouver, consistent with previous studies.<sup>37</sup> These findings emphasize the need for rapid and efficient access to public AEDs.<sup>34,38–40</sup> Nevertheless, these associations war-

rant cautious interpretation as outcomes depend on a complex chain of survival in which the organization and efficiency of EMS systems and in-hospital practices play important roles.<sup>3,41</sup>

Overall, our results illustrate the broad geographic variability in OHCA and AED distribution, hence the need for local adaptation of AED placement strategies. In Metro Vancouver, programs should address the AED deficiencies of low-SES areas; in Rhône, as placement seems equitable, populations in low-SES areas would benefit from educational interventions to achieve more frequent use of AEDs.<sup>42</sup>

## Limitations

First, the observational design was limited to conclusions of associations, and confounders may have affected the results. Second, AED accessibility was simulated, based on available data and using public, open-source algorithms, which might not equate to real-life stressful situations. We computed AED access time intervals based on the best-case scenario (i.e., bystander retrieves closest AED with-

out delay). This model did not account for bystander reaction time interval or difficulties locating the closest AED. The values of parameters used in the models can appear arbitrary, but the study's main justification was to illustrate differences in distribution and on-foot accessibility of public AEDs between regions and to highlight inequities within and across regions. The use of identical parameters and criteria in both regions therefore ensures sufficient comparability to address the objectives. Third, some AEDs may have been inaccessible at the time of the OHCA.<sup>37,43</sup> This may have resulted in errors in the AED registries used. Fourth, our models did not account for area-level population and AED density, which may differ between areas that have different SES levels. Fifth, country-specific differences in data may have introduced error. However, we used the ReACanROC methodology<sup>24</sup> to homogenize datasets, and SES was divided into quintiles to create a relative scale within each region. The remaining variability in our results most likely relates to population-based, geographic, and broad organizational predictors.

## Conclusion

On-foot accessibility to AEDs was poor in 2 large metropolitan areas in France and Canada, and this was negatively associated with survival in Canada. Predictors of AED accessibility differed between the countries and appeared to relate to variability in geospatial distribution of low-SES areas, AED placement, and OHCA cases.

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## Data sharing/data availability

Requests for access to data must be sent by email to the corresponding author. Data sharing can be granted after analysis of each request by the ReACanROC steering committee and relevant ethical boards.

## CRedit authorship contribution statement

**Matthieu Heidet:** Conceptualization, Methodology, Resources, Writing – original draft, Writing – review & editing, Software, Data curation, Supervision. **Julie Freyssenge:** Conceptualization, Methodology, Resources, Writing – original draft, Writing – review & editing, Data curation. **Clément Claustre:** Methodology, Resources, Writing – original draft, Writing – review & editing, Software, Data curation, Formal analysis. **John Deakin:** Writing – review & editing. **Jennie Helmer:** Writing – original draft, Writing – review & editing. **Bruno Thomas-Lamotte:** Writing – review & editing, Data curation. **Mathys Wohl:** Writing – review & editing,

Software, Formal analysis. **Li Danny Liang:** Writing – review & editing. **Hervé Hubert:** Writing – review & editing, Data curation, Supervision. **Valentine Baert:** Writing – review & editing, Data curation. **Christian Vilhelm:** Writing – review & editing, Data curation. **Laurie Fraticelli:** Conceptualization, Methodology, Writing – review & editing. **Éric Mermet:** Writing – review & editing, Software. **Axel Benhamed:** Writing – review & editing. **François Revaux:** Writing – review & editing, Data curation. **Éric Lecarpentier:** Writing – review & editing, Supervision. **Guillaume Debatty:** Writing – review & editing. **Karim Tazarourte:** Writing – review & editing, Supervision. **Sheldon Cheskes:** Writing – review & editing, Supervision. **Jim Christenson:** Conceptualization, Writing – review & editing, Resources, Supervision. **Carlos El Khoury:** Conceptualization, Writing – review & editing, Resources, Supervision. **Brian Grunau:** Conceptualization, Methodology, Writing – review & editing, Data curation, Resources, Supervision.

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## Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.resuscitation.2022.10.016>.

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## REFERENCES

- Truong C. Registry Analyses [Internet]. CanROC. [cited 2020 May 9]. Available from: <http://canroc.org/observational-studies/>.
- Luc G, Baert V, Escutnaire J, Genin M, Vilhelm C, Di Pompéo C, et al. Epidemiology of out-of-hospital cardiac arrest: A French national incidence and mid-term survival rate study. *Anaesth Crit Care Pain Med* 2019;38:131–5.
- Sasson C, Rogers MAM, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. *Circ Cardiovasc Qual Outcomes* 2010;3:63–81.
- Vukmir RB. Survival from prehospital cardiac arrest is critically dependent upon response time. *Resuscitation* 2006;69:229–34.
- Holmberg MJ, Vognsen M, Andersen MS, Donnino MW, Andersen LW. Bystander automated external defibrillator use and clinical outcomes after out-of-hospital cardiac arrest: A systematic review and meta-analysis. *Resuscitation* 2017;120:77–87.
- Fosbøl EL, Dupre ME, Strauss B, Swanson DR, Myers B, McNally BF, et al. Association of neighborhood characteristics with incidence of out-of-hospital cardiac arrest and rates of bystander-initiated CPR: implications for community-based education intervention. *Resuscitation* 2014;85:1512–7.
- Buick JE, Ray JG, Kiss A, Morrison LJ. The association between neighborhood effects and out-of-hospital cardiac arrest outcomes. *Resuscitation* 2016;103:14–9.
- Boutillier JJ, Brooks SC, Janmohamed A, Byers A, Buick JE, Zhan C, et al. Optimizing a Drone Network to Deliver Automated External Defibrillators. *Circulation* 2017;135:2454–65.
- Chan TCY. Rise and Shock: Optimal Defibrillator Placement in a High-rise Building. *Prehosp Emerg Care* 2017;21:309–14.
- Sun CLF, Karlsson L, Torp-Pedersen C, Morrison LJ, Folke F, Chan TCY. Spatiotemporal AED optimization is generalizable. *Resuscitation* 2018;131:101–7.
- Cheskes S, McLeod SL, Nolan M, Snobelen P, Vaillancourt C, Brooks SC, et al. Improving access to automated external defibrillators in rural and remote settings: a drone delivery feasibility study. *JAMA* 2020;9. <https://doi.org/10.1161/JAMA.120.016687>.
- Leung KHB, Brooks SC, Clegg GR, Chan TCY. Socioeconomically equitable public defibrillator placement using mathematical optimization. *Resuscitation* 2021;166:14–20.
- Dicker B, Garrett N, Wong S, McKenzie H, McCarthy J, Jenkin G, et al. Relationship between socioeconomic factors, distribution of public access defibrillators and incidence of out-of-hospital cardiac arrest. *Resuscitation* 2019;138:53–8.
- Social-indicators-profile-city-of-vancouver.pdf [Internet]. [cited 2021 Nov 29]. Available from: <https://vancouver.ca/files/cov/social-indicators-profile-city-of-vancouver.pdf>.
- Roundtable 7: The Income Gap and Poverty Reduction [Internet]. Vancouver City Planning Commission. [cited 2021 Nov 29]. Available from: <http://vancouverplanning.ca/a-city-for-all/summit-report/roundtable-reports/roundtable-7-income-gap-poverty-reduction/>.
- Yu J, Dwyer-Lindgren L, Bennett J, Ezzati M, Gustafson P, Tran M, et al. A spatiotemporal analysis of inequalities in life expectancy and 20 causes of mortality in sub-neighbourhoods of Metro Vancouver, British Columbia, Canada, 1990–2016. *Health Place* 2021;72:102692.
- Panchal AR, Bartos JA, Cabañas JG, Donnino MW, Drennan IR, Hirsch KG, et al. Part 3: Adult Basic and Advanced Life Support: 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* 2020;2020:142. <https://doi.org/10.1161/CIR.0000000000000916>.
- Symons P, Shuster M. International EMS Systems: Canada. *Resuscitation* 2004;63:119–22.
- Rhône-Alpes, une région riche en dépit d'inégalités territoriales - Insee Analyses Rhône-Alpes - 29 [Internet]. [cited 2021 Nov 29]. Available from: <https://www.insee.fr/fr/statistiques/1285869#titre-bloc-7>.
- Adnet F, Lapostolle F. International EMS Systems: France. *Resuscitation* 2004;63:7–9.
- Hubert H, Tazarourte K, Wiel E, Zitouni D, Vilhelm C, Escutnaire J, et al. Rationale, Methodology, Implementation, and First Results of the French Out-of-hospital Cardiac Arrest Registry. *Prehospital Emergency Care* 2014;18:511–9.
- Morrison LJ, Nichol G, Rea TD, Christenson J, Callaway CW, Stephens S, et al. Rationale, development and implementation of the Resuscitation Outcomes Consortium Epistry—Cardiac Arrest. *Resuscitation* 2008;78:161–9.
- Idris AH, Bierens JJLM, Perkins GD, Wenzel V, Nadkarni V, Morley P, et al. 2015 Revised Utstein-Style Recommended Guidelines for Uniform Reporting of Data From Drowning-Related Resuscitation: An ILCOR Advisory Statement. *Circulation: Cardiovascular Quality and Outcomes*. 2017;10:e000024.
- Heidet M, Hubert H, Grunau BE, Cheskes S, Baert V, Fraticelli L, et al. Rationale, development and implementation of the ReACanROC registry for out-of-hospital cardiac arrests in France and Canada. *Emerg Med J* 2021.
- Deprivation Index [Internet]. INSPQ. [cited 2020 May 9]. Available from: <https://www.inspq.qc.ca/en/information-management-and-analysis/deprivation-index>.
- Définition - IRIS | Insee [Internet]. [cited 2019 Mar 15]. Available from: <https://www.insee.fr/fr/metadonnees/definition/c1523>.
- Pornet C, Delpierre C, Dejardin O, Grosclaude P, Launay L, Guittet L, et al. Construction of an adaptable European transnational

- ecological deprivation index: the French version. *J Epidemiol Community Health* 2012;66:982–9.
28. R Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2019 [Internet]. Available from: .
  29. Part 4: The Automated External Defibrillator. *Circulation*. 2000 Aug 22;102(suppl\_1):I–60
  30. Grunau B, Kawano T, Dick W, Straight R, Connolly H, Schlamp R, et al. Trends in care processes and survival following prehospital resuscitation improvement initiatives for out-of-hospital cardiac arrest in British Columbia, 2006–2016. *Resuscitation* 2018;125:118–25.
  31. Heidet M, Fraticelli L, Grunau B, Cheskes S, Baert V, Vilhelm C, et al. ReACanROC: Towards the creation of a France-Canada research network for out-of-hospital cardiac arrest. *Resuscitation* 2020;152:133–40.
  32. Levy MJ, Seaman KG, Millin MG, Bissell RA, Jenkins JL. A poor association between out-of-hospital cardiac arrest location and public automated external defibrillator placement. *Prehosp Disaster Med* 2013;28:342–7.
  33. Hansen CM, Lippert FK, Wissenberg M, Weeke P, Zinckernagel L, Ruwald MH, et al. Temporal trends in coverage of historical cardiac arrests using a volunteer-based network of automated external defibrillators accessible to laypersons and emergency dispatch centers. *Circulation* 2014;130:1859–67.
  34. Dahan B, Jabre P, Karam N, Misslin R, Bories MC, Tafflet M, et al. Optimization of automated external defibrillator deployment outdoors: An evidence-based approach. *Resuscitation* 2016;108:68–74.
  35. Lin BC, Chen CW, Chen CC, Kuo CL, Fan IC, Ho CK, et al. Spatial decision on allocating automated external defibrillators (AED) in communities by multi-criterion two-step floating catchment area (MC2SFCA). *Int J Health Geograph* 2016;15.
  36. Karam N, Narayanan K, Bougouin W, Benameur N, Beganton F, Jost D, et al. Major regional differences in Automated External Defibrillator placement and Basic Life Support training in France: Further needs for coordinated implementation. *Resuscitation* 2017;118:49–54.
  37. Karlsson L, Hansen CM, Wissenberg M, Hansen SM, Lippert FK, Rajan S, et al. Automated external defibrillator accessibility is crucial for bystander defibrillation and survival: A registry-based study. *Resuscitation* 2019;1:30–7.
  38. Ringh M, Hollenberg J, Palsgaard-Moeller T, Svensson L, Rosenqvist M, Lippert FK, et al. The challenges and possibilities of public access defibrillation. *J Intern Med* 2018;283:238–56.
  39. Moon S, Bobrow BJ, Vadeboncoeur TF, Kortuem W, Kisakye M, Sasson C, et al. Disparities in bystander CPR provision and survival from out-of-hospital cardiac arrest according to neighborhood ethnicity. *Am J Emerg Med* 2014;32:1041–5.
  40. Ahn KO, Shin SD, Hwang SS, Oh J, Kawachi I, Kim YT, et al. Association between deprivation status at community level and outcomes from out-of-hospital cardiac arrest: a nationwide observational study. *Resuscitation* 2011;82:270–6.
  41. Nichol G, Detsky AS, Stiell IG, O'Rourke K, Wells G, Laupacis A. Effectiveness of emergency medical services for victims of out-of-hospital cardiac arrest: a metaanalysis. *Ann Emerg Med* 1996;27:700–10.
  42. Owen DD, McGovern SK, Murray A, Leary M, del Rios M, Merchant RM, et al. Association of race and socioeconomic status with automatic external defibrillator training prevalence in the United States. *Resuscitation* 2018;127:100–4.
  43. Malta HC, Mads W, Peter W, Huth RM, Morten L, Knudsen LF, et al. Automated External Defibrillators Inaccessible to More Than Half of Nearby Cardiac Arrests in Public Locations During Evening, Nighttime, and Weekends. *Circulation* 2013;128:2224–31.