Variation in Community and Ambulance Care Processes for Out-of-Hospital Cardiac Arrest During the COVID-19 Pandemic: A Systematic Review and Meta-Analysis

Yoshio Masuda  
Yong Loo Lin School of Medicine, National University of Singapore

Seth Teoh  
Yong Loo Lin School of Medicine, National University of Singapore

Jun Wei Yeo  
Yong Loo Lin School of Medicine, National University of Singapore

Darren Tan  
Yong Loo Lin School of Medicine, National University of Singapore

Shir Lynn Lim  
National University Heart Centre Singapore

Marcus Ong  
Singapore General Hospital

Audrey Blewer  
Duke University

Andrew Ho  (andrew.ho@duke-nus.edu.sg)  
Singapore General Hospital

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Abstract

Bystander cardiopulmonary resuscitation (BCPR) and early defibrillation can double the chance of survival from out-of-hospital sudden cardiac arrest (OHCA). We investigated the effect of COVID-19 on the pre-hospital chain of survival. We searched five bibliographical databases for articles that compared prehospital OHCA care processes during and before the COVID-19 pandemic. Random effects meta-analyses were conducted, and meta-regression with mixed-effect models and subgroup analyses were conducted where appropriate. The search yielded 966 articles; 20 articles were included in our analysis. OHCA at home was more common during the pandemic (OR=1.38, 95% CI 1.11-1.71, p=0.0069). BCPR did not differ between COVID-19 and Pre-COVID-19 populations (OR=0.94, 95% CI 0.80-1.11, p=0.4631), although bystander defibrillation was significantly lower during the COVID-19 period (OR=0.65, 95% CI 0.48-0.88, p=0.0107). EMS call-to-arrival time was significantly higher in COVID-19 populations (SMD=0.27, 95% CI 0.13-0.40, p=0.0006). Resuscitation duration did not differ significantly between pandemic and pre-pandemic timeframes. The COVID-19 pandemic significantly affected prehospital processes for OHCA. These findings may inform future interventions, particularly to consider interventions to increase BCPR and improve the pre-hospital chain of survival.

1. Introduction

Out-of-hospital cardiac arrest (OHCA) is a time-critical medical emergency, in which clinical outcomes are thoroughly dependent on a well-organized "chain of survival". [1, 2] This prehospital component of the "chain of survival" involves timely and seamless bystander cardiopulmonary resuscitation (BCPR), the use of automated external defibrillators (AED), as well as treatment by emergency medical services (EMS). However, the unprecedented coronavirus disease 2019 (COVID-19) pandemic had a poorly understood impact on EMS resources and was believed to have disrupted the prehospital "chain of survival" particularly layperson or bystander response. [5, 6] There is tremendous scientific and public health interest in how community and EMS-related processes were altered since these confer larger survival impact relative to advanced hospital-based interventions, and the benefits of the latter are confined to those who had received timely prehospital interventions. [7] Understanding the impact of the COVID-19 pandemic on OHCA care processes is key to planning of future public health programs and policies to improve OHCA outcomes in the post-pandemic era and pandemic-preparedness. Studies that assessed the impact of the pandemic on the prehospital "chain of survival", particularly early bystander response, have reported inconsistent findings. [8, 9] Marijon et al reported a decrease in BCPR possibly because bystanders were more hesitant to perform CPR on possible COVID-19 cases. [10] This was particularly worrying since BCPR with early defibrillation may double a victim's chances of survival. [11] This observation, however, was not found in other studies [12, 13], prompting a review of the current literature on BCPR before and during the pandemic and on related variables such as OHCA at home, witnessed OHCA, and bystander AED use. EMS care processes in the pre-hospital "chain of survival" are also key factors contributing to improved outcomes in OHCA, including EMS resuscitation attempts and duration, EMS call to arrival times, and the use of various advanced life support measures such as endotracheal intubation, supraglottic airway devices, amiodarone, epinephrine, and mechanical CPR. These factors are critical in the pre-hospital management of OHCA patients before accessing advanced care. [14] Previously, Lim et al suggested that EMS call to arrival times during the pandemic may have risen due to challenges such as increased personal protective equipment (PPE) requirements. [3] However, the impact of the pandemic on EMS care processes is unclear.

Therefore, this systematic review and meta-analysis aimed to consolidate the existing data on how community and EMS processes have changed during the COVID-19 pandemic. We hypothesized that OHCA increased in the home and BCPR rates decreased during the pandemic. Furthermore, we postulated that EMS call to arrival times increased during the pandemic.

2. Methods

This systematic review and meta-analysis adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. [15] It is pending confirmation in the International Prospective Register of Systematic Reviews (PROSPERO).

2.1 Search Strategy

The search strategy was developed in consultation with a medical information specialist at NUS, Singapore. We utilized the MeSH term "heart arrest" and the non-MeSH terms "sudden cardiac arrest, sudden cardiac death, out of hospital cardiac arrest, out-of-hospital cardiac arrest, cardiac arrest, OHCA, OOHCA, Covid-19, Coronavirus, SARS-CoV-2". An exhaustive literature search was performed in five bibliographic databases from inception to May 3rd, 2021: PubMed, EMBASE, Web of Science, Scopus and The Cochrane Central Register of Controlled Trials (CENTRAL) in The Cochrane Library. References of relevant articles were hand-searched to identify additional relevant studies. The search strategy is available in the Appendix I.

2.2 Selection Criteria

The inclusion criteria were: (A) patients with OHCA during the COVID-19 pandemic; (B) articles that reported any of the following characteristics and outcomes: OHCA at home, unwitnessed OHCA, BCPR, AED use, EMS resuscitation attempted, resuscitation duration, EMS call to arrival time, use of endotracheal intubation, use of supraglottic airway, use of amiodarone, use of epinephrine, use of mechanical CPR; and (C) articles that compared the above mentioned outcomes prior to and during the pandemic. We ensured that there was no overlapping or repeated data from the included studies.
The exclusion criteria were: (A) all articles not written in the English language; (B) all articles that did not utilize a historical control (comparing outcomes prior to and during the pandemic); (C) case reports; (D) case series with fewer than five patients; and (E) conference abstracts and posters.

The web-based platform Rayyan QCRI was utilized to perform article deduplication, screening and assessment for final eligibility. [16] Two authors (Y.M and S.E.T) performed the literature search and evaluated the eligibility of studies independently. Disagreements were resolved after consensus with the senior author, A.F.W.H.

2.3 Data Extraction and Quality Assessment

Three authors (Y.M, S.E.T, D.J.H.T) independently extracted data from included studies to a spreadsheet. Any conflicts with data collection were arbitrated after consensus with a senior author, A.F.W.H. We extracted the following data - (A) study characteristics including first author details, year of publication, study origin, study design and population, time periods and sample sizes of (i) Pre-COVID-19 (ii) COVID-19; (B) patient characteristics including age and gender; (C) community processes-related outcomes such as OHCA incidence at home, unwitnessed OHCA events, BCPR, and AED use; and (D) EMS processes-related outcomes such as EMS resuscitation attempted, resuscitation duration, EMS call to arrival time, endotracheal intubation and supraglottic airway, amiodarone and epinephrine, and use of mechanical CPR. If the data presented were missing or unclear, we contacted the corresponding author by email for clarification.

The methodological quality of the included studies was assessed by two authors (Y.M and S.E.T) independently using the Newcastle-Ottawa Scale (NOS). The scale included eight items, and possible scores ranged from zero to nine. Studies with a score of seven or more were considered high quality.

2.4 Statistical Analysis

Meta-analyses were conducted for the community processes (OHCA location at home, unwitnessed OHCA, BCPR and AED use), as well as EMS processes of OHCA patients (EMS resuscitation attempted, resuscitation duration, EMS call to arrival time, endotracheal intubation and supraglottic airway, amiodarone and epinephrine, and mechanical CPR).

Data analyses were performed using the meta 4.18-0 and metafor 2.4-0 packages with R 3.6.3 (R Foundation for Statistical Computing, Vienna, Austria). Random-effects models were used in conjunction with the Sidik-Jonkman estimator and Mantel-Haenszel method to estimate the pooled effects of COVID-19, as substantial between-study heterogeneity was present. Forest plots displayed individual and pooled odds ratios (OR) and 95% confidence intervals (95% CI) for the binary outcomes: OHCA at home, unwitnessed OHCA, BCPR, AED use, EMS resuscitation attempted, endotracheal intubation and supraglottic airway, amiodarone and epinephrine, and mechanical CPR. For the continuous outcomes (resuscitation duration and EMS call to arrival time), forest plots displayed individual and pooled standardized mean difference (SMD) and 95% CI. Two-tailed statistical significance was set at p-value $\leq 0.05$. The $I^2$ statistic was used to quantify statistical heterogeneity. [17] This statistic indicates whether variation is more likely due to chance or study heterogeneity, with $I^2$ values of 25%, 50%, and 75% indicating low, moderate, and high heterogeneity respectively. Whenever there was substantial statistical heterogeneity ($I^2 > 50$%), we evaluated for outliers by performing a set of case deletion diagnostics to identify influential studies and subsequent leave-one-out sensitivity analyses. To account for possible moderators that might contribute to statistical heterogeneity, we performed univariate meta-regression with mixed-effects models and subgroup analyses for the outcome of BCPR. Publication bias was evaluated via visual evaluation of funnel plots and Egger's regression.

3. Results

3.1 Literature Retrieval

The database search yielded a total of 966 articles. After removal of duplicates, 546 abstracts were screened and subsequently 122 reports were sought for retrieval, of which 14 articles could not be retrieved. The resultant 108 full-texts were reviewed, and 20 were identified as meeting the selection criteria. The study selection process and reasons for exclusion were illustrated in the PRISMA-P 2020 Flow Diagram (Fig. 1).

3.2 Characteristics of Studies and Risk of Bias

The 20 included studies originated from ten countries (France, Italy, Australia, Korea, United States of America, Spain, Netherlands, United Kingdom, Singapore and Sweden). All studies included were retrospective cohort study design.

There were a total of 67815 patients with OHCA across the studies, of which 38855 patients were evaluated in the Pre-COVID-19 period and 28960 patients were evaluated in the COVID-19 period. Study sample sizes ranged from 101 to 19303 patients. The study characteristics were summarized in Table 1.
| Study                  | Location           | Study Design# | Study Population                                                                 | Time Period                  | Sample Size | Age (Years), Mean (SD) | Male Gender, N (%) |
|-----------------------|--------------------|---------------|----------------------------------------------------------------------------------|-----------------------------|-------------|------------------------|-------------------|
| Baert et al, 2020     | France             | Registry-based study | Adult and pediatric cases of presumed medical etiology (EMS-treated NR; Received resuscitation NR) | (i) March 1 – April 31, 2019 | (i) 1620     | (i) 69.0 (17.0)         | (i) 1071/1620 (66.1%) |
|                       |                    |               |                                                                                  | (ii) March 1 – April 31, 2020 | (ii) 1005    | (ii) 68.0 (17.0)        | (ii) 676/1005 (67.3%) |
| Baldi et al, 2020     | Lombardy, Italy    | Registry-based study | Adult and pediatric cases regardless of etiology (EMS-treated NR; Received resuscitation NR) | (i) February 21 – April 20, 2019 | (i) 321      | (i) 77.3 (14.2)         | (i) 188/321 (58.6%)  |
|                       |                    |               |                                                                                  | (ii) February 21 – April 20, 2020 | (ii) 490     | (ii) 77.0 (14.1)        | (ii) 321/490 (65.5%)  |
| Ball et al, 2020      | Victoria, Australia| Registry-based study | Adult cases regardless of etiology; EMS-treated and received resuscitation       | (i) March 16 – May 12, 2017–2019 | (i) 1218     | (i) 65.7 (19.3)         | (i) 845/1218 (69.4%) |
|                       |                    |               |                                                                                  | (ii) March 16 – May 12, 2020 | (ii) 380     | (ii) 67.7 (19.4)        | (ii) 250/380 (65.8%)  |
| Cho et al, 2020       | Daegu, South Korea | Registry-based study | Adult cases of presumed medical etiology; EMS-treated and received resuscitation | (i) February 17 – March 31, 2018 | (i) 158      | (i) 72.8 (15.3)         | (i) 103/158 (65.2%)  |
|                       |                    |               |                                                                                  | (ii) February 17 – March 31, 2020 | (ii) 171     | (ii) 72.0 (13.5)        | (ii) 108/171 (63.2%)  |
| Elmer et al, 2020     | Pennsylvania, USA  | Registry-based study | Adult cases regardless of etiology; EMS-treated (Received resuscitation NR)       | (i) January – February 2016–2020 | (i) 12252    | (i) 63.0 (19.0)         | (i) 7700/12252 (62.8%) |
|                       |                    |               |                                                                                  | (ii) March 1 – May 25, 2020  | (ii) 683     | (ii) 64.0 (19.0)        | (ii) 430/683 (63.0%)  |
| Lai et al, 2020       | New York City, USA | Non-registry-based study | Adult cases regardless of etiology; EMS-treated and received resuscitation | (i) March 1 – April 25, 2019 | (i) 1336     | (i) 68.0 (19.0)         | (i) 752/1336 (56.3%) |
|                       |                    |               |                                                                                  | (ii) March 1 – April 25, 2020 | (ii) 3989    | (ii) 72.0 (18.0)        | (ii) 2183/3989 (54.7%) |
| Marijon et al, 2020   | Paris, France      | Registry-based study | Adult cases of non-traumatic etiology; EMS-treated (Received resuscitation NR)   | (i) Weeks 12–17, 2012–2019  | (i) 3052     | (i) 68.5 (18.0)         | (i) 1826/3052 (59.8%) |
|                       |                    |               |                                                                                  | (ii) March 16 – April 26, 2020 | (ii) 521     | (ii) 69.7 (17.0)        | (ii) 334/521 (64.1%)  |
| Ortiz et al, 2020     | Spain              | Registry-based study | Adult and pediatric cases regardless of etiology; EMS-treated (Received resuscitation NR) | (i) April 1–30, 2017 and February 1 – March 31, 2018 | (i) 1723     | (i) 65.6 (16.9)         | (i) 1210/1723 (70.2%) |
|                       |                    |               |                                                                                  | (ii) February 1 – April 30, 2020 | (ii) 1446    | (ii) 64.4 (16.5)        | (ii) 1028/1446 (71.1%) |
| Paoli et al, 2020     | Province of Padua, Italy | Non-registry-based study | Adult and pediatric cases regardless of etiology; EMS-treated (Received resuscitation NR) | (i) March 1 – April 30, 2019 | (i) 206      | (i) 77.0 (14.0)         | (i) NR              |
|                       |                    |               |                                                                                  | (ii) March 1 – April 30, 2020 | (ii) 200     | (ii) 79.0 (17.0)        | (ii) NR              |
| Study                     | Location                                  | Study Design* | Study Population                                                                 | Time Period                  | Sample Size | Age (Years), Mean (SD) | Male Gender, N (%) |
|--------------------------|-------------------------------------------|---------------|----------------------------------------------------------------------------------|------------------------------|-------------|------------------------|---------------------|
| Sayre et al, 2020 [21]   | Seattle and King County, USA              | Registry-based study | Adult and pediatric cases regardless of etiology; EMS-treated (Received resuscitation NR) | (i) January 1 – February 25, 2019 (ii) February 26 – April 15, 2020 | (i) 530 (ii) 537 | (i) NR (ii) NR | (i) NR (ii) NR |
| Seimeraro et al, 2020 [30] | Bologna, Italy                           | Registry-based study | Adult cases regardless of etiology; EMS-treated and received resuscitation       | (i) January 1 – June 30, 2019 (ii) January 1 – June 30, 2020 | (i) 563 (ii) 624 | (i) 82.7 (13.4) (ii) 82.7 (13.4) | (i) 284/563 (50.4%) (ii) 318/624 (51.0%) |
| Chan et al, 2021 [22]    | 27 States and multiple Counties, USA     | Registry-based study | Adult cases of non-traumatic etiology; EMS-treated (Received resuscitation NR)  | (i) March 16 – April 30, 2019 (ii) March 16 – April 30, 2020 | (i) 9440 (ii) 9863 | (i) 62.2 (19.2) (ii) 62.6 (19.6) | (i) 5922/9440 (62.7%) (ii) 6040/9863 (61.2%) |
| de Koning et al, 2021 [31]| Hollands-Midden, The Netherlands         | Registry-based study | Adult cases regardless of etiology; EMS-treated (Received resuscitation NR)      | (i) March 16 – April 27, 2019 (ii) March 16 – April 27, 2020 | (i) 45 (ii) 56 | (i) 70.0 (12.0) (ii) 70.0 (14.0) | (i) 31/45 (68.9%) (ii) 32/56 (57.1%) |
| Fothergill et al, 2021 [13] | London, UK                              | Registry-based study | Adult and pediatric cases regardless of etiology; EMS-treated (Received resuscitation NR) | (i) March 1 – April 30, 2019 (ii) March 1 – April 30, 2020 | (i) 1724 (ii) 3122 | (i) 68.0 (20.0) (ii) 71.0 (19.0) | (i) 1069/1724 (62.0%) (ii) 1839/3122 (58.9%) |
| Glober et al, 2021 [23]  | Indiana (Marion County), USA              | Registry-based study | Adult cases of non-traumatic etiology; EMS-treated (Received resuscitation NR)  | (i) January 1 – June 30, 2019 (ii) January 1 – June 30, 2020 | (i) 884 (ii) 1034 | (i) 61.5 (18.1) (ii) 59.7 (18.5) | (i) 544/884 (61.5%) (ii) 622/1034 (60.2%) |
| Lim et al, 2021 [3]      | Singapore                                 | Registry-based study | Adult cases regardless of etiology; EMS-treated (Received resuscitation NR)      | (i) January 1 – May 31, 2018 – 2019 (ii) January 1 – May 31, 2020 | (i) 1280 (ii) 1400 | (i) 71.3 (17.1) (ii) 72.3 (17.8) | (i) 818/1280 (63.9%) (ii) 882/1400 (63.0%) |
| Mathew et al, 2021 [24]  | Detroit, USA                              | Registry-based study | Adult cases of non-traumatic etiology; EMS-treated and received resuscitation   | (i) March 10 – April 30, 2019 (ii) March 10 – April 30, 2020 | (i) 180 (ii) 291 | (i) 58.5 (19.8) (ii) 64.5 (18.1) | (i) 93/180 (51.7%) (ii) 165/291 (56.7%) |
| Nickles et al, 2021 [25] | Detroit (Macomb, Oakland, and Wayne Counties), USA | Registry-based study | Adult and pediatric cases of non-traumatic etiology; EMS-treated (Received resuscitation NR) | (i) January 1 – May 31, 2019 (ii) January 1 – May 31, 2020 | (i) 1162 (ii) 1854 | (i) NR (ii) NR | (i) 662/1162 (57.0%) (ii) 1083/1854 (58.4%) |
### Study Designs for All Included Studies Were Multicentered and Retrospective in Nature

All studies achieved a score from seven to nine on the Newcastle-Ottawa Scale, signifying high quality and low risk of bias for selection (Supplemental Table 1).

### 3.2.1 Community Processes

#### 3.2.1.1 OHCA Location at Home

Fifteen studies accounted for the outcome of OHCA at home. [3, 8, 10, 12, 13, 18–27] Amongst these, Ortiz et al reported the lowest percentage (60.5%) of patients with OHCA at home in the Pre-COVID-19 period, while Nickles et al reported the lowest percentage (64.2%) for the COVID-19 period. [20, 25] In contrast, Fothergill et al reported the highest percentage of patients with OHCA at home in both Pre-COVID-19 and COVID-19 time periods (85.5%, 92.9% respectively). [13] With the exception of four studies [12, 23–25], which showed a higher percentage of patients with OHCA at home before as compared to during the pandemic, a trend was observed where the percentage of patients with OHCA at home was higher in the COVID-19 period as compared to the pre-pandemic period (Table 2).
| Study               | Time Period | OHCA at Home, N (%) | Unwitnessed OHCA, N (%) | Bystander CPR, N (%) | AED Use, N (%) |
|---------------------|-------------|---------------------|-------------------------|---------------------|---------------|
|                     |             |                     |                         |                     |               |
| Baert et al, 2020   | Pre-COVID-19| 1156/1512 (76.5%)   | 585/1620 (36.1%)        | 889/1620 (54.9%)    | 1319/1620 (81.4%) |
|                     | COVID-19    | 819/971 (84.3%)     | 357/1005 (35.5%)        | 500/1005 (49.8%)    | 737/1005 (73.3%) |
| Baldi et al, 2020   | Pre-COVID-19| 267/321 (83.2%)     | 147/321 (45.8%)         | 87/321 (27.1%)      | NR            |
|                     | COVID-19    | 442/490 (90.2%)     | 261/490 (53.3%)         | 89/490 (18.2%)      | NR            |
| Ball et al, 2020    | Pre-COVID-19| 965/1218 (79.2%)    | 574/1218 (47.1%)        | 889/1218 (73.0%)    | 84/1218 (6.9%)  |
|                     | COVID-19    | 342/380 (90.0%)     | 179/380 (47.1%)         | 299/380 (78.7%)     | 15/380 (3.9%)  |
| Cho et al, 2020     | Pre-COVID-19| 112/158 (70.9%)     | 70/158 (44.3%)          | 50/158 (31.6%)      | 30/158 (19.0%) |
|                     | COVID-19    | 121/171 (70.8%)     | 41/171 (24.0%)          | 87/171 (50.9%)      | 22/171 (12.9%) |
| Elmer et al, 2020   | Pre-COVID-19| NR                 | 8772/12252 (71.6%)      | 4125/12252 (33.7%)  | 1744/12252 (14.2%) |
|                     | COVID-19    | NR                 | 466/683 (68.2%)         | 246/683 (36.0%)     | 104/683 (15.2%) |
| Lai et al, 2020     | Pre-COVID-19| NR                 | 982/1336 (73.5%)        | 441/1336 (33.0%)    | NR            |
|                     | COVID-19    | NR                 | 2909/3989 (72.9%)       | 1359/3989 (34.1%)   | NR            |
| Marijon et al, 2020 | Pre-COVID-19| 2336/3042 (76.8%)  | 1021/2908 (35.1%)       | 1165/1822 (63.9%)   | 33/1092 (3.0%)  |
|                     | COVID-19    | 460/510 (90.2%)    | 206/500 (41.2%)         | 239/500 (47.8%)     | 2/500 (0.4%)   |
| Ortiz et al, 2020   | Pre-COVID-19| 1042/1714 (60.8%)  | 392/1723 (22.8%)        | 788/1723 (45.7%)    | 173/1723 (10.0%) |
|                     | COVID-19    | 988/1446 (68.3%)   | 309/1446 (21.4%)        | 538/1446 (37.2%)    | 113/1441 (7.8%) |
| Paoli et al, 2020   | Pre-COVID-19| NR                 | 42/59 (71.2%)           | 15/60 (25.0%)       | NR            |
|                     | COVID-19    | NR                 | 39/52 (75.0%)           | 10/55 (18.2%)       | NR            |
| Sayre et al, 2020   | Pre-COVID-19| 155/227 (68.3%)    | NR                      | 106/227 (46.7%)     | NR            |
|                     | COVID-19    | 150/207 (72.5%)    | NR                      | 94/207 (45.4%)      | NR            |
| Study                        | Time Period | OHCA at Home, N (%) | Unwitnessed OHCA, N (%) | Bystander CPR, N (%) | AED Use, N (%) |
|------------------------------|-------------|---------------------|-------------------------|---------------------|---------------|
| Semeraro et al, 2020 [30]   | Pre-COVID-19| NR                  | NR                      | 29/110* (26.4%)     | NR            |
|                             | COVID-19    | NR                  | NR                      | 30/95 (31.6%)       | NR            |
| Chan et al, 2021 [22]       | Pre-COVID-19| 6590/9440 (69.8%)   | 5313/9440 (56.3%)       | 4418/9440 (46.8%)   | 766/9440 (8.1%) |
|                             | COVID-19    | 7385/9859 (74.9%)   | 5812/9861 (58.9%)       | 4690/9839 (47.7%)   | 565/9862 (5.7%)  |
| de Koning et al, 2021 [31]  | Pre-COVID-19| NR                  | NR                      | NR                  | NR            |
|                             | COVID-19    | NR                  | NR                      | NR                  | NR            |
| Fothergill et al, 2021 [13] | Pre-COVID-19| 1474/1723 (85.5%)   | 240/683* (35.1%)        | 359/683* (52.6%)    | 61/683* (8.9%) |
|                             | COVID-19    | 2899/3122 (92.9%)   | 361/1135 (31.8%)        | 718/1135 (63.3%)    | 47/1135 (4.1%) |
| Glober et al, 2021 [23]     | Pre-COVID-19| 642/884 (72.6%)     | NR                      | 430/884 (48.6%)     | NR            |
|                             | COVID-19    | 727/1034 (70.3%)    | NR                      | 532/1034 (51.5%)    | NR            |
| Lim et al, 2021 [3]         | Pre-COVID-19| 943/1280 (73.7%)    | 690/1280 (53.9%)        | 772/1280 (60.3%)    | 142/1280 (11.1%) |
|                             | COVID-19    | 1081/1400 (77.2%)   | 533/1400 (38.1%)        | 729/1400 (52.1%)    | 131/1400 (9.4%) |
| Mathew et al, 2021 [24]     | Pre-COVID-19| 133/180 (73.9%)     | 94/180 (52.2%)          | 73/180 (40.6%)      | NR            |
|                             | COVID-19    | 201/291 (69.1%)     | 161/291 (55.3%)         | 117/291 (40.2%)     | NR            |
| Nickles et al, 2021 [25]    | Pre-COVID-19| 800/1162 (68.8%)    | NR                      | 580/1161 (50.0%)    | NR            |
|                             | COVID-19    | 1191/1854 (64.2%)   | NR                      | 847/1854 (45.7%)    | NR            |
| Sultanian et al, 2021 [26]  | Pre-COVID-19| 710/930 (76.3%)     | 396/930 (42.6%)         | 532/930 (57.2%)     | 273/930 (29.4%) |
|                             | COVID-19    | 784/1016 (77.2%)    | 445/1016 (43.8%)        | 575/1016 (56.6%)    | 287/1016 (28.2%) |
| Uy-Evanado et al, 2021 [27] | Pre-COVID-19| 145/231 (62.8%)     | 109/231 (47.2%)         | 142/231 (61.5%)     | 12/231 (5.2%)  |
|                             | COVID-19    | 210/278 (75.5%)     | 138/278 (49.6%)         | 141/278 (50.7%)     | 4/278 (1.4%)   |

*OHCA, out-of-hospital cardiac arrest; CPR, cardiopulmonary resuscitation; AED, automatic external defibrillator; NR, not reported; N, number; *Among those in whom resuscitation was attempted by the Emergency Medical Services*
Meta-analysis showed that the odds of patients undergoing OHCA at home was significantly higher in the COVID-19 period as compared to the Pre-COVID-19 period (OR = 1.38, 95% CI 1.11–1.71, p = 0.0069, $I^2 = 90\%$) (Fig. 2A).

### 3.2.1.2 Unwitnessed OHCA

Fifteen studies accounted for the number of unwitnessed OHCA events. [3, 8–10, 12, 13, 18–20, 22, 24, 26–29] Ortiz et al reported the lowest percentage of unwitnessed OHCA cases in both Pre-COVID-19 (22.8%) and COVID-19 time periods (21.4%). [20] Meanwhile, Lai et al reported the highest percentage for the Pre-COVID-19 period (73.5%) and Paoli et al reported the highest percentage for the COVID-19 period (75%) (Table 2). [9, 29] Meta-analysis showed that there was no difference in unwitnessed OHCA events between the COVID-19 and Pre-COVID-19 time periods (OR = 0.94, 95% CI 0.80–1.12, p = 0.4776, $I^2 = 88\%$) (Fig. 2B).

### 3.2.1.3 BCPR

Nineteen studies accounted for BCPR rates. [3, 8–10, 12, 13, 18–30] In the Pre-COVID-19 period, Paoli et al reported the lowest percentage for BCPR among patients (25%) while Ball et al reported the highest percentage (73%). [19, 29] In the COVID-19 period, Paoli et al and Baldi et al both reported the lowest percentage for BCPR among patients (18.2%) while Ball et al reported the highest percentage (78.7%) (Table 2). [8, 19, 29] Meta-analysis showed that there was no difference in BCPR between the COVID-19 and Pre-COVID-19 time periods (OR = 0.94, 95% CI 0.80–1.11, p = 0.4631, $I^2 = 88\%$) (Fig. 2C).

### 3.2.1.4 AED use

Eleven studies accounted for AED use. [3, 10, 12, 13, 18–20, 22, 26–28] The percentage of the population with AED use ranged from 0.4–81.4% across intervals of both Pre-COVID-19 and COVID-19 time periods. Apart from Elmer et al [28], a trend of higher percentage of population with AED use was observed in the pre-pandemic period as compared to in the COVID-19 period. Across intervals of both Pre-COVID-19 and COVID-19 time periods, almost all studies reported a percentage AED use of 29.4% or less. Only Baert et al reported relatively higher percentages for the Pre-COVID-19 and COVID-19 time periods (81.4% and 73.3% respectively) (Table 2). [18] Meta-analysis showed that the odds of OHCA patients using AED was significantly lower in the COVID-19 period as compared to the Pre-COVID-19 period (OR = 0.65, 95% CI 0.48–0.88, p = 0.0107, $I^2 = 75\%$) (Fig. 2D).

### 3.2.2 EMS Processes

#### 3.2.2.1 EMS Resuscitation Attempted

Eight studies accounted for the outcome of EMS resuscitation attempted. [3, 8, 9, 12, 13, 19, 29, 30] Apart from Lai et al [9], all other studies reported a higher percentage of population with EMS resuscitation attempted in the Pre-COVID-19 period as compared to in the COVID-19 period (Table 3).
Table 3
Summary of Emergency Medical Services Processes of Care

| Study              | Time Period | EMS Resuscitation Attempted, N (%) | Resuscitation Duration (Minutes), Mean (SD) | EMS Call to Arrival Time (Minutes), Mean (SD) | Supraglottic Airway, N (%) | Endotracheal Intubation, N (%) | Mechanical CPR, N (%) | Amiodarone, N (%) | Epinephrine, N (%) |
|--------------------|-------------|-----------------------------------|--------------------------------------------|---------------------------------------------|---------------------------|-----------------------------|-----------------------|-------------------|-------------------|
| Baert et al, 2020  | Pre-COVID-19| NR                                | NR                                         | NR                                          | 22.0 (13.0)               | NR                          | NR                    | NR                | 1100/1619 (67.9%) |
|                    | COVID-19    | NR                                | NR                                         | NR                                          | 23.0 (18.0)               | NR                          | NR                    | NR                | 620/1004 (61.8%) |
| Baldi et al, 2020  | Pre-COVID-19| 222/321 (69.2%)                   | NR                                         | NR                                          | 12.0 (4.5)                | NR                          | NR                    | NR                | 23/138* (16.7%)   |
|                    | COVID-19    | 314/490 (64.1%)                   | NR                                         | NR                                          | 15.3 (6.7)                | NR                          | NR                    | NR                | 9/138* (6.5%)     |
| Ball et al, 2020   | Pre-COVID-19| 1218/2599 (46.9%)                 | 18.3 (19.3)                                | NR                                          | 8.8 (3.6)                 | NR                          | NR                    | NR                | 177/1218 (14.5%) |
|                    | COVID-19    | 380/935 (46.9%)                   | 17.5 (19.3)                                | NR                                          | 10.2 (3.6)                | NR                          | NR                    | NR                | 188/1218 (15.4%) |
| Cho et al, 2020    | Pre-COVID-19| 248/540 (45.9%)                   | 13.3 (5.2)                                 | NR                                          | 87/158 (55.1%)            | NR                          | NR                    | NR                | 23/158 (14.6%)   |
|                    | COVID-19    | 230/527 (43.6%)                   | 19.7 (7.5)                                 | NR                                          | 89/171 (52.0%)            | NR                          | NR                    | NR                | 16/171 (9.4%)    |
| Elmer et al, 2020  | Pre-COVID-19| NR                                | NR                                         | NR                                          | 904/12252 (7.4%)          | 2760/12252 (22.5%)         | NR                    | NR                | 6/158 (3.8%)     |
|                    | COVID-19    | NR                                | NR                                         | NR                                          | 89/683 (13.0%)            | 127/683 (18.6%)            | NR                    | NR                | 63/171 (36.8%)   |
| Lai et al, 2020    | Pre-COVID-19| 1336/2302 (58.0%)                 | 35.1 (20.6)                                | 4.9 (3.7)                                  | 193/1336 (14.4%)          | 1011/1336 (75.7%)          | NR                    | 143/1336 (10.7%) |
|                    | COVID-19    | 3989/6709 (59.5%)                 | 32.3 (23.4)                                | 5.9 (5.5)                                  | 1385/3989 (34.7%)         | 1915/3989 (48.0%)          | NR                    | 231/3989 (5.8%) |
| Marijon et al, 2020| Pre-COVID-19| NR                                | NR                                         | NR                                          | 10.0 (3.5)                | NR                          | NR                    | NR                | 3516/3989 (88.1%)|
|                    | COVID-19    | NR                                | NR                                         | NR                                          | 10.9 (4.0)                | NR                          | NR                    | NR                | NR                |
| Ortiz et al, 2020  | Pre-COVID-19| NR                                | NR                                         | NR                                          | 13.0 (8.2)                | 103/1560 (6.6%)            | 1224/1560 (78.5%)        | NR                | NR                |
|                    | COVID-19    | NR                                | NR                                         | NR                                          | 15.0 (9.7)                | 168/1423 (11.8%)           | 858/1423 (60.3%)         | NR                | NR                |
| Paoli et al, 2020  | Pre-COVID-19| 48/90 (53.3%)                     | NR                                         | NR                                          | 15.0 (6.0)                | NR                          | NR                    | NR                | NR                |
|                    | COVID-19    | 45/114 (39.5%)                    | NR                                         | NR                                          | 16.7 (7.5)                | NR                          | NR                    | NR                | NR                |
| Study                      | Time Period | EMS Resuscitation Attempted, N (%) | Resuscitation Duration (Minutes), Mean (SD) | EMS Call to Arrival Time (Minutes), Mean (SD) | Supraglottic Airway, N (%) | Endotracheal Intubation, N (%) | Mechanical CPR, N (%) | Amiodarone, N (%) | Epinephrine, N (%) |
|----------------------------|-------------|-----------------------------------|---------------------------------------------|-----------------------------------------------|--------------------------|--------------------------------|----------------------|------------------|------------------|
| Sayre et al, 2020 [21]    | Pre-COVID-19 | NR                                | NR                                         | NR                                            | NR                       | NR                             | NR                   | NR               | NR               |
|                           | COVID-19     | NR                                | NR                                         | NR                                            | NR                       | NR                             | NR                   | NR               | NR               |
| Semeraro et al, 2020 [30] | Pre-COVID-19 | 110/563 (19.5%)                   | NR                                         | 9.7                                           | NR                       | NR                             | NR                   | NR               | NR               |
|                           | COVID-19     | 95/624 (15.2%)                    | NR                                         | 9.3                                           | NR                       | NR                             | NR                   | NR               | NR               |
| Chan et al, 2021 [22]     | Pre-COVID-19 | NR                                | 23.1                                        | 8.8                                           | NR                       | NR                             | NR                   | NR               | NR               |
|                           | COVID-19     | NR                                | 26.2                                        | 9.3                                           | NR                       | NR                             | NR                   | NR               | NR               |
| de Koning et al, 2021 [31]| Pre-COVID-19 | NR                                | NR                                         | 6.0                                           | NR                       | NR                             | NR                   | NR               | NR               |
|                           | COVID-19     | NR                                | NR                                         | 7.1                                           | NR                       | NR                             | NR                   | NR               | NR               |
| Fothergill et al, 2021 [13]| Pre-COVID-19 | 683/1724 (39.6%)                  | NR                                         | 7.5                                           | NR                       | NR                             | NR                   | NR               | 562/683* (82.3%) |
|                           | COVID-19     | 1135/3122 (36.4%)                 | NR                                         | 10.3                                          | NR                       | NR                             | NR                   | NR               | 994/1135 (87.6%) |
| Glober et al, 2021 [23]   | Pre-COVID-19 | NR                                | NR                                         | 6.1                                           | 379/884 (42.9%)          | NR                             | NR                   | NR               | NR               |
|                           | COVID-19     | NR                                | NR                                         | 6.3                                           | 725/1034 (70.1%)         | NR                             | NR                   | NR               | NR               |
| Lim et al, 2021 [3]       | Pre-COVID-19 | 1260/1280 (98.4%)                 | NR                                         | 6.2                                           | NR                       | NR                             | NR                   | NR               | NR               |
|                           | COVID-19     | 1365/1400 (97.5%)                 | NR                                         | 6.5                                           | NR                       | NR                             | NR                   | NR               | NR               |
| Mathew et al, 2021 [24]   | Pre-COVID-19 | NR                                | NR                                         | NR                                            | NR                       | NR                             | NR                   | NR               | NR               |
|                           | COVID-19     | NR                                | NR                                         | NR                                            | NR                       | NR                             | NR                   | NR               | NR               |
| Nickles et al, 2021 [25]  | Pre-COVID-19 | NR                                | NR                                         | NR                                            | NR                       | NR                             | NR                   | NR               | NR               |
|                           | COVID-19     | NR                                | NR                                         | NR                                            | NR                       | NR                             | NR                   | NR               | NR               |
| Sultanian et al, 2021 [26]| Pre-COVID-19 | NR                                | 12.7                                        | NR                                            | NR                       | NR                             | NR                   | 94/930 (10.1%)     | 683/930 (73.4%)  |
|                           | COVID-19     | NR                                | 13.0                                        | NR                                            | NR                       | NR                             | NR                   | 110/1016 (10.8%)   | 770/1016 (75.8%) |
3.2.2.2 EMS Call to Arrival Time

Sixteen studies accounted for the outcome of EMS call to arrival time. [3, 8–10, 12, 13, 18–20, 22, 23, 26, 27, 29–31] Mean duration of EMS call to arrival time ranged from 4.9 minutes to 23 minutes across the Pre-COVID-19 and COVID-19 time periods. Apart from Semeraro et al [30], a trend of longer mean duration of EMS call to arrival time was observed in the COVID-19 period as compared to the Pre-COVID-19 period (Table 3). Meta-analysis showed that there was a significant difference in EMS call to arrival time between the COVID-19 and Pre-COVID-19 time periods (SMD = 0.27, 95% CI 0.13–0.40, p = 0.0006, $I^2 = 94\%$) (Fig. 3B).

3.2.2.3 Resuscitation Duration

Only three studies accounted for resuscitation duration. [9, 19, 22] Apart from Chan et al [22], all other studies reported a longer mean duration of resuscitation in the Pre-COVID-19 period as compared to in the COVID-19 period (Table 3). Meta-analysis showed that there was no difference in resuscitation duration between the COVID-19 and Pre-COVID-19 time periods (SMD = 0.02, 95% CI -0.43–0.48, p = 0.8537, $I^2 = 98\%$) (Fig. 3C).

3.2.2.4 Endotracheal Intubation and Supraglottic Airway

Seven studies accounted for the use of endotracheal intubation [9, 12, 20, 23, 28], while five studies accounted for the use of supraglottic airway. [9, 12, 20, 23, 28] All relevant studies reported a higher percentage of endotracheal intubation use in the Pre-COVID-19 period as compared to in the COVID-19 period. In contrast, almost all studies (except Cho et al [12]) reported a higher percentage of supraglottic airway use in the COVID-19 period as compared to the Pre-COVID-19 period (Table 3). Meta-analysis showed that the odds of using endotracheal intubation on OHCA patients was significantly lower in the COVID-19 period as compared to the Pre-COVID-19 period (OR = 0.48, 95% CI 0.27–0.85, p = 0.0195, $I^2 = 97\%$) (Fig. 4A). Meanwhile, the odds of using supraglottic airways on OHCA patients was significantly higher in the COVID-19 period as compared to the Pre-COVID-19 period (OR = 2.04, 95% CI 1.09–3.82, p = 0.0344, $I^2 = 91\%$) (Fig. 4B).

3.2.2.5 Amiodarone and Epinephrine

Four studies accounted for the use of amiodarone [8, 9, 19, 26], while seven studies accounted for the use of epinephrine. [8, 9, 12, 13, 18, 19, 26] Apart from Lai et al [9], all other studies reported a higher percentage of amiodarone use in the COVID-19 period relative to the Pre-COVID-19 period. The trend was not as obvious in epinephrine usage; four studies [8, 12, 13, 26] reported a higher percentage of epinephrine use during the COVID-19 period as compared to the Pre-COVID-19 period, while three studies reported an inverse occurrence (Table 3). Meta-analysis showed that there was no difference in OHCA patients receiving amiodarone in the COVID-19 period and in the Pre-COVID-19 period (OR = 0.91, 95% CI 0.46–1.81, p = 0.6901, $I^2 = 90\%$) (Fig. 5A). Similarly, there was no difference in OHCA patients receiving epinephrine in the COVID-19 period and in the Pre-COVID-19 period (OR = 1.28, 95% CI 0.48–3.41, p = 0.5576, $I^2 = 93\%$) (Fig. 5B).

3.2.2.6 Mechanical CPR

Only two studies accounted for the use of mechanical CPR. [8, 19] Baldi et al reported a higher percentage of mechanical CPR use in the Pre-COVID-19 period as compared to the COVID-19 period while Ball et al reported the converse (Table 3). [8, 19] Meta-analysis showed that there was no difference in the use of mechanical CPR for OHCA patients in the COVID-19 period and in the Pre-COVID-19 period (OR = 0.64, 95% CI 0.0008–536.8771, p = 0.5551, $I^2 = 83\%$) (Fig. 5C).

| Study                        | Time Period | EMS Resuscitation Attempted, N (%) | Resuscitation Duration (Minutes), Mean (SD) | EMS Call to Arrival Time (Minutes), Mean (SD) | Supraglottic Airway, N (%) | Endotracheal Intubation, N (%) | Mechanical CPR, N (%) | Amiodarone, N (%) | Epinephrine, N (%) |
|------------------------------|-------------|-----------------------------------|--------------------------------------------|---------------------------------------------|---------------------------|-------------------------------|----------------------|------------------|------------------|
| Uy-Evanado et al, 2021 [27]  | Pre-COVID-19 | NR                               | NR                                         | 6.6 (2.0)                                   | NR                        | NR                            | NR                   | NR               | NR               |
| COVID-19                     | NR          | NR                               | 7.6 (3.0)                                  | NR                                          | NR                        | NR                            | NR                   | NR               | NR               |

Meta-analysis showed that the odds of EMS resuscitation attempted on OHCA patients was significantly lower in the COVID-19 period as compared to the Pre-COVID-19 period (OR = 0.84, 95% CI 0.73–0.97, p = 0.0247, $I^2 = 68\%$) (Fig. 3A).
3.3 Sensitivity Analyses

3.3.1 Leave-One-Out Analyses

After visual inspection of forest plots for potential sensitivity analyses were performed using influential diagnostic plots and Baujat plots. Applying this approach on each outcome of community and EMS processes, none of the estimates were substantially changed in direction or statistical significance. However, the magnitude of effect was increased in six outcomes: 18.5% for EMS call to arrival time, 600% for resuscitation duration, 18.75% for endotracheal intubation, 20.6% for supraglottic airway, 27.5% for amiodarone and 30.5% for epinephrine. The revised estimates on sensitivity analyses were: OHCA at home (OR = 1.44 [95%CI 1.16–1.79, p = 0.0031, I² = 87%] after excluding Nickles et al), unwitnessed OHCA (OR = 0.99 [95%CI 0.86–1.15, p = 0.9214, I² = 70%] after excluding Lim et al), BCPR (OR = 0.98 [95%CI 0.83–1.14, p = 0.7582, I² = 85%] after excluding Marjon et al), AED use (OR = 0.61 [95%CI 0.45–0.84, p = 0.0064, I² = 66%] after excluding Elmer et al), EMS resuscitation attempted (OR = 0.80 [95%CI 0.71–0.90, p = 0.0034, I² = 0%] after excluding Lai et al), EMS call to arrival time (SMD = 0.22 [95%CI 0.12–0.32, p = 0.0003, I² = 94%] after excluding Cho et al), resuscitation duration (SMD = -0.10 [95%CI -0.57–0.38, p = 0.2355, I² = 30%] after excluding Chan et al), endotracheal intubation (OR = 0.57 [95%CI 0.36–0.89, p = 0.0236, I² = 96%] after excluding Glover et al), supraglottic airway (OR = 2.46 [95%CI 1.54–3.92, p = 0.0087, I² = 86%] after excluding Cho et al), amiodarone (OR = 1.16 [95%CI 0.90–1.51, p = 0.1278, I² = 0%] after excluding Lai et al), and epinephrine (OR = 0.89 [95%CI 0.60–1.31, p = 0.4643, I² = 88%] after excluding Cho et al) (Supplemental Fig. 2–34).

3.3.2 Subgroup Analyses: BCPR

In order to account for possible moderators that might contribute to statistical heterogeneity, subgroup analyses were conducted for the outcome of BCPR based on categorical variables, namely, publication year and study location. None of the permutations yielded a statistically significant difference. Statistical heterogeneity remained high in all subgroup analyses. We did not conduct subgroup analyses for all other outcomes due to the inadequate data (Supplemental Table 3).

3.3.3 Meta-Regression: BCPR

Meta-regression with a mixed-effects model was performed for the outcome of BCPR to examine if the observed heterogeneity could be contributed by possible moderators such as sample size, mean age, proportion of males, proportion of patients with OHCA at residential location, GDP per country, GDP per state and population density of study region (km²). Univariate meta-regression did not reveal any statistically significant moderators. We did not conduct meta-regression for other outcomes due to the inadequate data (Supplemental Table 4).

3.4 Publication Bias

A funnel plot was generated based on the outcome BCPR which had the highest number of studies, revealing no asymmetry, hence suggesting the absence of publication bias (Supplemental Fig. 1). This was congruent with a non-significant Egger's regression test (p = 0.62).

4. Discussion

In this study, we elucidated several salient findings. First, there was a significant increase in OHCA occurring at home and a significant decrease in bystander AED use during the COVID-19 pandemic. Second, there was no difference in BCPR rates during the pandemic as compared to before. Third, the pandemic was associated with changes to EMS processes including a significant decrease in attempted EMS resuscitation, a significant increase in EMS call to arrival times, a significant decrease in endotracheal intubation, and a significant increase in supraglottic airway use.

The increase in OHCA at home is consistent with stay-at-home and social distancing measures worldwide during the COVID-19 pandemic. [32] As more people are enforced to stay or work from home [33], OHCA at home rates have consequently increased. Importantly, this finding also highlights that witness rates for OHCA incidence are similar during the pandemic as compared to before. This is necessary to consider for future prehospital interventions as subsequent measures should be targeted at the accessibility of services and devices and less at the detection of OHCA in the chain of survival. [34] This finding is supported by a statistically significant decrease in bystander AED use during the COVID-19 pandemic, which could be attributed to an increase of OHCA occurring at home. [35, 36] The lack of AED availability in homes may principally explain this observation, along with inaccessibility of AEDs installed in public buildings due to the sudden closure of non-essential businesses and services by government policies. [35] Accordingly, new perspectives for current AED guidelines may be warranted as the pandemic has highlighted that current AED policies are inadequate at decreasing OHCA at home rates. More strategic placements of AEDs should be carried out to maximize access from individual homes, with particular emphasis on rural areas where AED accessibility is relatively more limited. [35, 37] Given the potentially long-lasting lifestyle changes from the COVID-19 pandemic, the rising rates of OHCA at home should be urgently addressed.

Interestingly, we found no statistical difference in BCPR during the pandemic as compared to before. This is in contrast to previous literature, which suggested that observed decreases in BCPR resulted from fear of COVID-19 disease transmission from patient to bystanders or hesitancy among family members towards performing CPR for OHCA at home due to psychological and emotional reasons. [3, 10, 38] This result could be explained by an attitude-behavior gap whereby family members at home perform CPR despite such hesitancy. [39] Moreover, it could also be attributed to certain recommendations that CPR is not an aerosol-generating procedure [40–42], thus, decreasing the likelihood for COVID-19 to be transmitted. A recent study with swine models validates such findings, where the authors found that chest compressions alone did not cause significant aerosol generation...
in the swine model. [43] However, our findings should be interpreted with caution as an analysis on BCPR rates for home versus non-home arrests could not be performed due to paucity of data. Furthermore, this result should be interpreted in light of significant statistical heterogeneity unexplained by the sociodemographic, economic status, and geographical location of the sample population in each study. It is possible that BCPR varied with sociocultural factors such as the fear of engaging in CPR which were not reflected in the above variables. Although no differences were found in BCPR before and after COVID-19, this does not mean that campaigns or interventions encouraging CPR during the pandemic should cease, which should instead be carefully tailored to each country’s unique response to the pandemic at the societal and individual levels. [44, 45]

The decrease in EMS resuscitation attempts was significant, contrary to a previous review. The COVID-19 pandemic directly led to a severe strain on ambulance resources, changes in EMS workflows, and sicker OHCA patients, possibly leading to fewer patients qualifying for EMS resuscitation in an attempt to redirect scarce resources and maximize lives saved when crisis standards of care are enforced. [19, 46] Additionally, protocol changes could have exacerbated the decrease in EMS resuscitation attempts during the pandemic. For example, in Detroit, EMS protocols were amended to include the termination of resuscitation in suspected COVID-19 cases after ten minutes of resuscitation without return of spontaneous circulation. [24] The scarcity of resources is also consistent with the increase in EMS call to arrival times, which could be attributed to PPE requirements during the pandemic and increased ambulance travel distance for OHCA patients at home. [12] Cho et al reported an emphasis on high-level PPE, consistent with an exaggerated increase in EMS call to arrival time and did not modify the significance of the effect size when excluded during leave-one-out analysis. [12] Finally, a decrease in endotracheal intubation was accompanied by an increase in supraglottic airway use, likely reflecting the perceived risks of COVID-19 transmission in endotracheal intubation. [47] Certain protocol revisions could have also contributed to the increase in intubation use, as these guidelines recommended the use of supraglottic airways over endotracheal intubation. [23] While the overload of healthcare systems is to be expected during a pandemic, this should not come at the cost of worsening outcomes for non-COVID illnesses including OHCA. More needs to be done to find a balance in resource allocation when saving lives affected by COVID-19 or other non-COVID life-threatening diseases. Better preparation and predefined protocols are needed for emergency care systems to operate under resource-scarce crisis situations.

These findings hold implications for future pre-hospital interventions. A growing body of evidence demonstrates significant changes to OHCA characteristics during the COVID-19 pandemic which impact public health and urgently need to be addressed. [3, 18] Efforts to manage the effects of the pandemic, which may be the chief priority for public health institutions, should not come at the cost of worsening outcomes for non-COVID illnesses including OHCA. Future pre-hospital OHCA measures should also be targeted at the accessibility of services and devices and less at the detection of OHCA in the chain of survival. Systematic placement of AEDs should be carried out to maximize access from individual homes, with particular emphasis on rural areas where AED accessibility is relatively more limited. [35, 48] Although no differences were found in BCPR before and after COVID-19, this does not mean that campaigns or interventions encouraging CPR during the pandemic should cease, which should instead be carefully tailored to each country’s unique response to the pandemic at the societal and individual levels. [37] The negative changes to EMS processes associated with the pandemic are worrying and suggest that better preparation and predefined protocols are needed for emergency care systems to operate under resource-scarce crisis situations, including the stockpiling and effective use of PPE. [49] A clear transition from non-crisis to crisis resource allocation coupled with clear public health messaging will likely be beneficial. Additionally, a centralized public EMS system may improve coordination between different stakeholders during the COVID-19 pandemic and reduce OHCA mortality rates. [50, 51] However, more investigation is needed in this field. Further research is also needed to investigate measures for minimizing COVID-19 transmission during resuscitation, such as supraglottic airway use and mechanical CPR, as well as the barriers to implementing them during the pandemic.

The results of this study were robust to sensitivity analyses and incorporated data from several large OHCA registries from various countries. No publication bias was detected on visual inspection and statistical analysis. However, the findings of this study should be interpreted in the context of known limitations. All included studies were observational cohort studies comparing the COVID-19 period to a historical control. Hence, results were vulnerable to confounding and should be interpreted carefully. Moderate to high statistical heterogeneity was encountered during analyses. Heterogeneity in the definition of the COVID-19 and pre-COVID-19 periods may have led to varying estimates of effect size, depending on local epidemiology. Moreover, differences in study characteristics such as demographics, surveillance, and data collection processes likely further accounted for observed heterogeneity. All included studies originated from first-world countries that comprised populations with higher income and higher socio-economic status. Hence, study results may be limited in terms of generalizability despite providing key insights into OHCA during the COVID-19 pandemic.

However, this study is, to our knowledge, one of the first few systematic reviews and meta-analyses to examine the impact of the COVID-19 pandemic on community and EMS care processes. It represents a global body of literature that may inform future prehospital interventions and guide the interpretation of changes in OHCA characteristics during the COVID-19 pandemic.

5. Conclusion

BCPR rates remained unchanged before and during the COVID-19 pandemic, while outcomes of OHCA in the home and bystander AED increased. Ambulance processes remained largely unchanged, although EMS resuscitation attempts decreased and call to arrival times increased slightly. These findings may inform future interventions, particularly to consider interventions to increase BCPR and improve the pre-hospital chain of survival for future implementation.

Declarations
Data Availability Statement

The data presented in this study are available in Supplementary Materials – Appendix I, Supplemental Figures, Supplemental Tables and Supplemental Data.

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Author Contributions

Conceptualization, A.F.W.H; Methodology, Y.M, S.E.T, A.F.W.H; Validation, A.F.W.H; Formal Analysis, Y.M, S.E.T, A.F.W.H; Investigation, Y.M, S.E.T, A.F.W.H; Resources, Y.M, S.E.T, D.J.H.T; Data Curation, Y.M, S.E.T, D.J.H.T; Writing - Original Draft Preparation, Y.M, S.E.T, J.W.Y, A.F.W.H; Writing - Review and Editing, Y.M, S.E.T, J.W.Y, S.L.L, M.E.H.O, A.L.B, A.F.W.H; Visualization, A.F.W.H; Supervision, A.L.B, A.F.W.H; Project Administration, Y.M, A.F.W.H.

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Conflicts of Interest

The authors declare no conflict of interest.

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**Figures**
Figure 1

PRISMA-P Flowchart for Study Selection
Figure 2

Forest Plots for Community Processes - (A) OHCA at home (B) Unwitnessed OHCA (C) Bystander CPR (D) AED Use

AED, automated external defibrillator; CPR, cardiopulmonary resuscitation; OHCA, out-of-hospital cardiac arrest

Figure 3

Forest Plots for EMS Processes - (A) EMS Resuscitation Attempted (B) EMS Call to Arrival Time (C) Resuscitation Duration
Figure 4

Forest plots for EMS Processes - (A) Endotracheal Intubation (B) Supraglottic Airway
EMS, emergency medical services

Figure 5

EMS Processes - (A) Amiodarone (B) Epinephrine (C) Mechanical CPR
CPR, cardiopulmonary resuscitation; EMS, emergency medical services

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