Epidemiology and Outcome of Out-of-Hospital Cardiac Arrests during the COVID-19 Pandemic in South Korea: A Systematic Review and Meta-Analyses

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Purpose: To evaluate the effect of coronavirus disease 2019 (COVID-19) on out-of-hospital cardiac arrest (OHCA) outcomes in South Korea, we conducted systematic review and meta-analysis.

Materials and Methods: MEDLINE, Embase, KoreaMed, and Korean Information Service System databases were searched up to June 2022. We included observational studies and letters on OHCA during the COVID-19 pandemic and compared them to those before the pandemic. Epidemiologic characteristics, including at-home OHCA, bystander cardiopulmonary resuscitation, unwitnessed arrest, use of an automated external defibrillator (AED), shockable cardiac rhythm, and airway management, were evaluated. Survival and favorable neurological outcomes were extracted. We conducted a meta-analysis of each characteristic and outcome.

Results: Six studies including 4628 OHCA patients were included in this study. The incidence of at-home OHCA significantly increased and the AED use decreased during the COVID-19 pandemic compared to before the pandemic [odds ratio (OR), 1.29; 95% confidence interval (CI), 1.08–1.55; I^2=0% and OR, 0.74; 95% CI, 0.57–0.97; I^2=0%, respectively]. Return of spontaneous circulation after OHCA, survival, and favorable neurological outcomes during and before the pandemic did not differ significantly (OR, 0.90; 95% CI, 0.71–1.13; I^2=37%; OR, 0.74; 95% CI, 0.43–1.26; I^2=72%; OR, 0.77; 95% CI, 0.43–1.37; I^2=70%, respectively).

Conclusion: During the COVID-19 pandemic in South Korea, the incidence of at-home OHCA increased and AED use decreased among OHCA patients. However, survival and favorable neurological outcomes did not significantly differ from before the pandemic. This insignificant effect of the pandemic on OHCA in South Korea could be attributed to the slow increase in patient count in the early days of the pandemic.

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Key Words: Out-of-hospital cardiac arrest, COVID-19, survival, South Korea

INTRODUCTION

Given the prolonged persistence of the coronavirus disease 2019 (COVID-19) pandemic, significant medical resources

have been acquired and applied for care of patients with CO-VID-19.[1,2] In the early phase of the pandemic, which was marked by inadequate information and preparedness against the emerging pathogen, patients without COVID-19 received poor medical service and environment, a potential indirect effect of the pandemic, leading to potential gaps in medical care between patients with and without COVID-19.[3-5] Furthermore, the public healthcare system was disrupted by increasing illness severity and mortality among patients with COVID-19 before the availability of a vaccine or medication.[4,6,7] Apart from the social distancing measures and self-quarantine requirements that resulted in a change in daily life activities, delays in proper management and the characteristic epidemiologic state of acute diseases also had an effect on patients with acute illness. Previous studies on out-of-hospital cardiac arrest (OHCA)

have reported an increase occurring at home, a decrease in the use of bystander cardiopulmonary resuscitation (CPR) and automated external defibrillators (AEDs), and an increase in OHCA patients with nonshockable rhythm due to an increase in COVID-19 patients with respiratory failure who cause cardiac arrest.[8-11] Administering appropriate care in the emergency department to such patients was delayed due to several circumstances, including overcrowding in medical institutions, shortage of medical resources and personnel, increased workload for paramedics, and delays in reaching the site of OHCA occurrence.[8-11] Eventually, the loose chain of survival for OHCA led to poor survival and unfavorable neurological outcomes.[8,9]

Several meta-analyses have already compared the epidemiological characteristics and outcomes of OHCA during the COVID-19 pandemic to those reported before the pandemic.[8-11] The results of the first and most current meta-analyses were comparable for most factors.[8,11] However, these meta-analyses did not consider an important factor. These were undertaken regardless of the pandemic phase or the region, although the environment and system for emergency care and service in the later phase of the pandemic differed from those in the earlier phase that was unsystematic and collapsing. For instance, before and after vaccination, before and after the peak surge of COVID-19 cases, and before and after changing the strategy for the use of medical resources varied by location; hence, the results of prior meta-analyses could not be generalized.[12] As a result, a detailed meta-analysis that reflects regional characteristics and outcomes of OHCA is required.

Therefore, we determined that comparing the same medical system and medical resources during and before the pandemic is critical for the meta-analysis, and hence, this study focused on studies from South Korea. The findings of this study will establish the epidemiologic characteristics of OHCA in South Korea and assess the outcomes.

MATERIALS AND METHODS

Reporting guidelines and protocol registration
This study complied with the Preferred Reporting Items for Systematic reviews and Meta-analyses and the Meta-analysis of Observational Studies in Epidemiology guidelines for reporting information from observational studies.[12,13] We prospectively registered the review protocol in the OSF Registry (https://doi.org/10.17605/OSF.IO/UGE9D).

Search strategy
Two experienced reviewers (J.H.K. and C.A.) systematically searched five electronic databases, including local databases (MEDLINE, Embase, Cochrane Library, KoreaMed, and Korean Information Service System) for studies on the epidemiology and outcome of OHCA during COVID-19 pandemic, which included those reported before the pandemic and through June

2022. We included medical subject headings (MeSH), Embase subject headings, and other relevant keywords in our search strategy. We combined the MeSH terms and free terms related to "out-of-hospital cardiac arrest" and "COVID-19." Supplementary Table 1 (only online) summarizes the search strategy in detail.

Study selection
Two reviewers (J.H.K. and C.A.) independently screened the titles, abstracts, and the type of each of the identified articles, excluding irrelevant studies. First, we eliminated duplicate studies. Studies were considered duplicates if their titles, authors, and publication years were the same. We then excluded all articles meeting the following criteria: reviews, case reports, case series, editorials, comments, or meta-analyses; animal studies; irrelevant populations; and inappropriate controls. In case the two reviewers disagreed about the study selection, the third reviewer (M.N.) intervened, and differences were discussed until consensus was achieved. Finally, we included studies which evaluated the epidemiologic factors and outcomes of patients with OHCA during COVID-19 and compared them to those reported before the pandemic. We also excluded studies that 1) included patients aged <18 years, 2) provided no comparison or outcomes, and 3) were non-original articles. We subsequently reviewed the full text of potentially relevant articles that met the inclusion criteria.

Data extraction
The two reviewers independently extracted the following information from the included studies: authors, year of publication, location of study, information about the medical institution, population, age, sex, OHCA at home, bystander CPR, unwitnessed state, AED usage, shockable cardiac rhythm, airway management, paramedic related factors, etiology, and CPR time. In addition, we extracted the study outcomes including return of spontaneous circulation (ROSC), survival to hospital admission, survival to hospital discharge, and favorable neurological outcome. Discrepancies between reviewers were resolved by consensus.

Quality assessment in individual studies
The Newcastle-Ottawa Scale is a quality assessment tool used to evaluate non-randomized studies based on an eight-point score divided across three domains.[14] Each report is scored with a number of stars for three domains: 1) selection (maximum of four stars), 2) comparability (maximum of two stars), and 3) outcome (maximum of three stars). Two reviewers (J.H.K. and C.A.) independently assessed the included six studies; any unresolved disagreements between reviewers were resolved by discussion with the third author.

Statistical analysis
This meta-analysis investigated the epidemiological charac-

Table 1. Baseline Characteristics of Included Studies

	Cho (2020)[15]	Ahn (2021)[16]	Lee (2021)[17]	Lim (2021)[18]	Chung (2022)[19]	Lim (2022)[20]
Location and institution	Daugu, multicenter	Daugu, multicenter	Daejeon, multicenter	Busan, multicenter	Seoul, single center	Multicenter registry
Study period						
Before pandemic	Feb 18–Mar 31, 2018	Feb 18–Apr 17, 2018	Feb 1–Oct 31, 2019	Nov 1, 2019–Jan 31, 2020	Jan 1–Dec 31, 2019	Jan 1–Jun 30, 2016, 2017, 2018, and 2019
During pandemic	Feb 18–Mar 31, 2020	Feb 18–Apr 17, 2020	Feb 1–Oct 31, 2020	Nov 1, 2020–Jan 31, 2021	Mar 1, 2020–Feb 29, 2021	Jan 1–Jun 30, 2020
Population						
Before pandemic	158	145	492	891	129	628
During pandemic	171	152	538	1063	101	160
Age, yr						
Before pandemic	74.3 (61.8–82.2)	74.0 (61.5–82.0)	NR	70.07±15.06	71.2±14.6	NR
During pandemic	74.0 (62.0–80.8)	76.0 (66.0–81.8)	NR	71.05±14.98	68.2±17.8	NR
Male						
Before pandemic	103 (65.2)	91 (62.8)	NR	577 (64.76)	79 (61.2)	490 (78.0)
During pandemic	108 (62.2)	102 (67.1)	NR	647 (60.87)	65 (64.4)	135 (84.4)
OHCA at home						
Before pandemic	NR	112 (77.2)	NR	592 (66.44)		0 (0)*
During pandemic	NR	127 (83.6)	NR	761 (71.59)		0 (0)*
Bystander						
Before pandemic	50 (31.6)	94 (64.8)	NR	541 (60.72)	66 (51.2)	401 (63.9)
During pandemic	87 (50.9)	92 (60.5)	NR	636 (59.83)	50 (49.5)	101 (63.1)
Unwitnessed						
Before pandemic	70 (44.3)	81 (55.9)	NR	477 (53.5)	58 (45.5)	248 (39.5)
During pandemic	41 (24.0)	82 (53.9)	NR	597 (56.2)	41 (40.6)	62 (38.8)
AED use						
Before pandemic	30 (19.0)	2 (1.4)	NR	97 (10.89)		NR
During pandemic	22 (12.9)	2 (1.3)	NR	91 (8.56)		NR
Shockable cardiac rhythm						
Before pandemic	19 (12.0)	24 (16.6)	NR	71 (7.97)	18 (14.0)	241 (38.4)
During pandemic	15 (8.8)	20 (13.2)	NR	127 (11.95)	21 (20.8)	67 (41.9)
Intubation						
Before pandemic	23 (14.8)	NR	NR	47 (5.27)	NR	NR
During pandemic	16 (9.6)	NR	NR	13 (1.22)	NR	NR
Supraglottic airway device use						
Before pandemic	87 (56.1)	NR	NR	638 (71.6)	NR	NR
During pandemic	59 (53.6)	NR	NR	952 (89.56)	NR	NR
Mechanical CPR						
Before pandemic	NR	NR	NR	272 (30.53)	NR	NR
During pandemic	134 (78.4)	NR	NR	474 (44.59)	NR	NR
Response time						
Before pandemic	NR	7.0 (5.0–9.9)	NR	NR	NR	NR
During pandemic	NR	6.0 (5.0–7.0)	NR	NR	NR	NR
Transport time						
Before pandemic	NR	7.0 (4.0–10.0)	NR	NR	NR	NR
During pandemic	NR	7.0 (4.0–11.0)	NR	NR	NR	NR
Etiology of OHCA						
Before pandemic	NR	NR	NR	NR	90 (69.8)	NR
During pandemic	NR	NR	NR	NR	66 (59.4)	NR

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Table 1. Baseline Characteristics of Included Studies (continued)

	Cho (2020)[15]	Ahn (2021)[16]	Lee (2021)[17]	Lim (2021)[18]	Chung (2022)[19]	Lim (2022)[20]
CPR duration						
Before pandemic	NR	20.0 (12.0–28.8)	NR	NR	NR	NR
During pandemic	NR	21.0 (14.0–26.0)	NR	NR	NR	NR
TTM						
Before pandemic	NR	NR	NR	NR	3 (12.5)	NR
During pandemic	NR	NR	NR	NR	7 (31.8)	NR
ROSC						
Before pandemic	49 (31.0)	33 (11.1)	53 (10.8)	271 (30.42)	24 (18.6)	NR
During pandemic	39 (22.8)	25 (17.2)	70 (13.0)	291 (27.38)	22 (21.8)	NR
Survival to hospital admission						
Before pandemic	NR	NR	NR	201 (22.56)	NR	NR
During pandemic	NR	NR	NR	196 (18.44)	NR	NR
Survival to hospital discharge						
Before pandemic	14 (8.9)	15 (10.3)	NR	70 (7.86)	NR	132 (21.0)
During pandemic	8 (4.7)	7 (4.6)	NR	58 (5.46)	NR	43 (26.9)
Favorable neurological outcome						
Before pandemic	9 (5.7)	14 (9.7)	NR	54 (6.06)	7 (29.2)	105 (16.7)
During pandemic	5 (2.9)	5 (3.3)	NR	38 (3.57)	9 (40.9)	34 (21.3)

NR, not reported; OHCA, out-of-hospital cardiac arrest; AED, automated external defibrillator; CPR, cardiopulmonary resuscitation; TTM, target temperature management; ROSC, return of spontaneous circulation.
Values are presented as mean±standard deviation, median (interquartile range), or number (%).
*Population of this study experienced OHCA in public locations.

teristic and outcomes of OHCA during the COVID-19 pandemic comparing to before the pandemic. For dichotomous variables, we calculated the pooled odds ratio (OR) with a 95% confidence interval (CI) using a random-effects model. We estimated the proportion of inter-study inconsistency using the I^2 statistic to assess heterogeneity, considering I^2 values of 25%, 50%, and 75% as low, moderate, and high heterogeneity, respectively. We performed the meta-analysis using the statistical analysis software R (version 4.0.0, The R Foundation for Statistical Computing, Vienna, Austria), using the packages "meta" (version 4.11-0) and "metaphor" (version 2.1-0); a *p* value<0.05 was considered statistically significant. Each comparison was conducted using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) analysis (GRADEpro Guideline Development Tool, McMaster University, USA). We did not assess for publication bias, given the small number of included studies.

RESULTS

In total, 419 studies were identified from the database search, and 368 papers remained after removing duplicates. Subsequently, 351 studies were excluded for irrelevance after assessing the titles and abstracts; 17 relevant studies remained, which were subjected to full-text retrieval. From those, we excluded 11 studies due to irrelevant population (n=5), irrelevant control (n=4), irrelevant outcome (n=1), and duplicated data [n=1; Supplementary Table 2 (only online)]. Finally, we conducted the meta-analysis and systematic review including six eligible studies with 4628 patients with OHCA.[15-20] Table 1 shows the baseline characteristics of included studies and Fig. 1 presents the study selection flowchart.

Quality assessment
When assessing the quality of articles according to the Newcastle-Ottawa Scale, only one had a score of 6. Of the remaining studies, two scored 7 and three scored 8 (Supplementary Table 3, only online).

Epidemiological characteristics of OHCA during the pandemic vs. before the pandemic
Except for the study by Chung, et al.,[19] the OHCA population during the pandemic was larger in four studies. Except for the study by Lim, et al.,[18] five studies included patients from the initial period immediately after the first reported case of COVID-19 in South Korea (Fig. 2).

The pooled OR for at-home OHCA was significantly higher during the pandemic than before the pandemic (OR, 1.29; 95% CI, 1.08–1.55; I^2=0%) (Fig. 3A). Bystander CPR did not differ between the during-pandemic and before-pandemic periods (OR, 1.09; 95% CI, 0.81–1.47; I^2=69%) (Fig. 3B). Unwitnessed OHCA did not significantly differ between the during-pandemic and before-pandemic periods (OR, 0.83; 95% CI, 0.59–1.16; I^2=76%) (Fig. 3C). Bystander AED use was significantly lower during the pandemic than before the pandemic (OR, 0.74: 95%
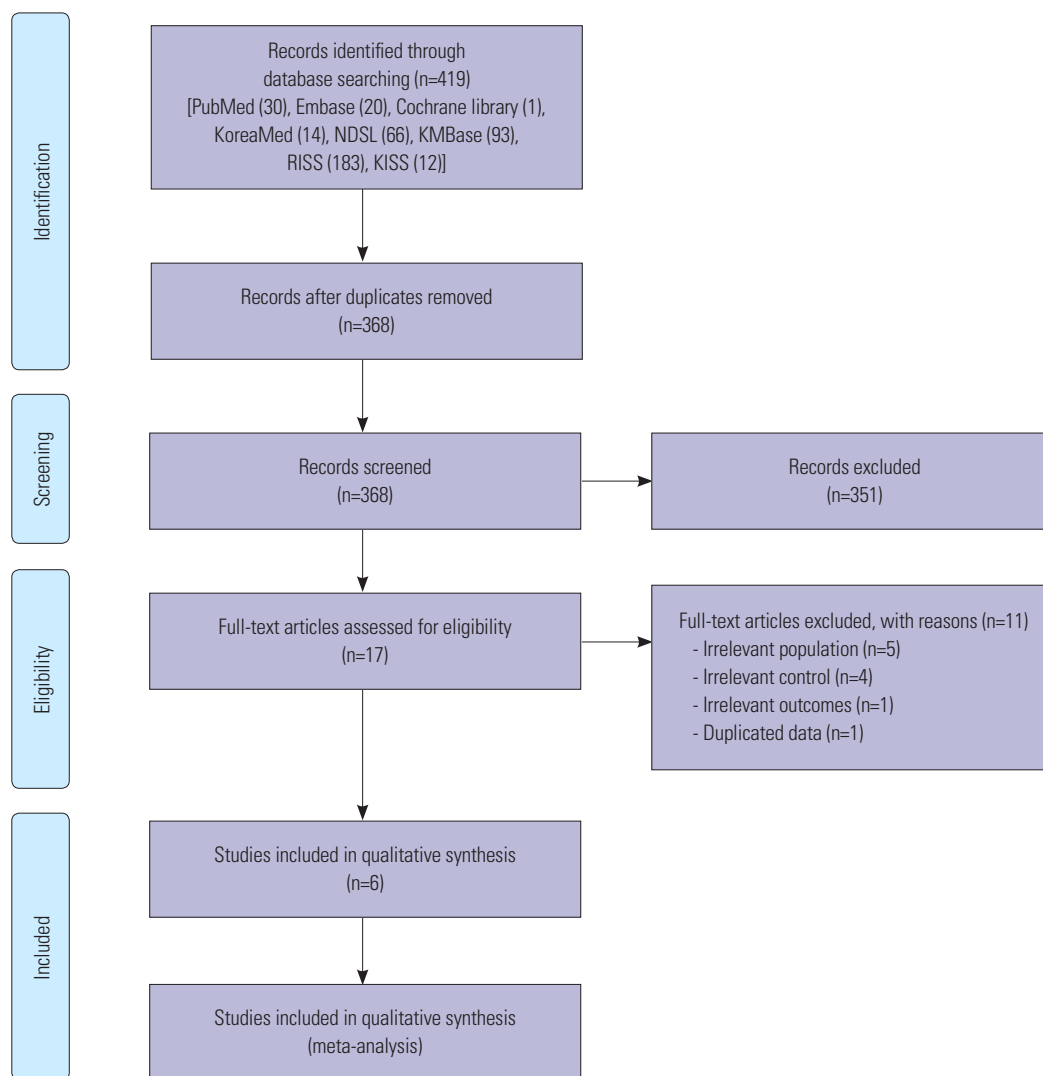
Fig. 1. Flow diagram for the identification of relevant studies.

CI, 0.57–0.97; I^2=0%) (Fig. 3D). Shockable rhythm did not differ between the during-pandemic and before-pandemic periods (OR, 1.17; 95% CI, 0.87–1.59; I^2=47%) (Fig. 3E).

A significantly smaller number of patients underwent endotracheal intubation (ETI) during the pandemic compared to before the pandemic (OR, 0.36; 95% CI, 0.14–0.97; I^2=78%) (Fig. 3F). Supraglottic airway (SGA) device use did not differ between the during-pandemic and before-pandemic periods (OR, 1.22; 95% CI, 0.16–9.26; I^2=98%) (Fig. 3G).

Clinical outcome of OHCA during the pandemic vs. before the pandemic

ROSC after OHCA did not differ between the during-pandemic and before-pandemic periods (OR, 0.90; 95% CI, 0.71–1.13; I^2=37%) (Fig. 3H). Survival to discharge did not differ between the during-pandemic and before-pandemic periods (OR, 0.74; 95% CI, 0.43–1.26; I^2=72%) (Fig. 3I). We found no difference in favorable neurological outcomes between the during-pandemic and before-pandemic periods (OR, 0.77; 95% CI, 0.43–1.37;

I^2=70%) (Fig. 3J).

Level of evidence

The results of this study were assigned low or very low level of evidence in each epidemiological characteristics and outcomes according to the evidence profile using the GRADE framework (Supplementary Table 4, only online). Analysis of observational studies was the main reason for the low level of evidence.

DISCUSSION

Unlike previous reports, our meta-analysis focused on the effect of the COVID-19 pandemic on OHCA in South Korea. Several previous meta-analyses have considered all during-pandemic data as one group, and compared those with data from before the pandemic.[8-11] A limitation of these studies was their inability to represent the regional differences in the medical care environment, which was addressed by our meta-analysis
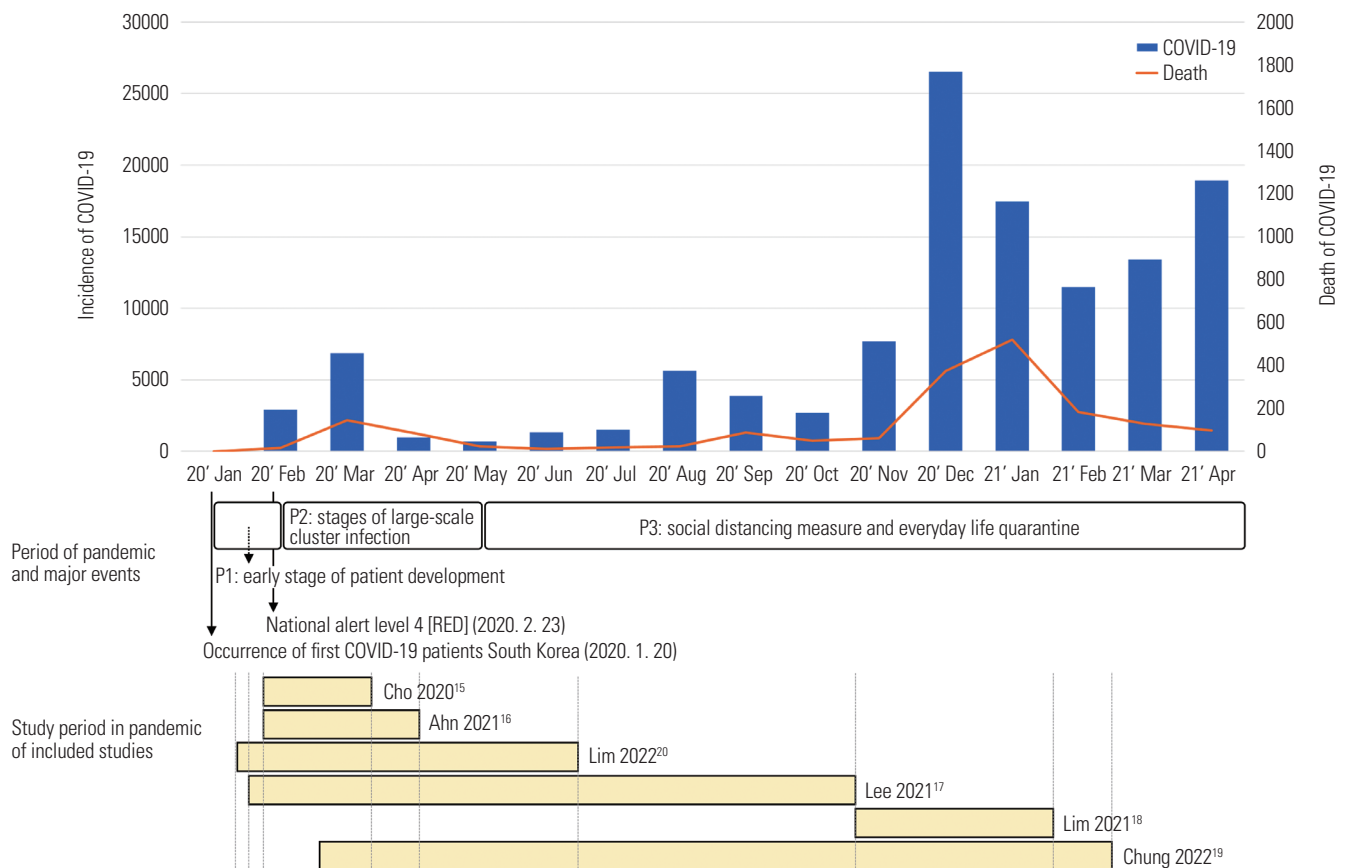
Fig. 2. Incidence and mortality of patients with COVID-19, major events during the pandemic in South Korea, and the study period of the included studies.

as we focused only on data from South Korea. For instance, the incidence and mortality of COVID-19 in South Korea increased only moderately in the early phase compared to those in other countries, owing to favorable medical conditions.[21] Considering that global data inclusion leads to high inter-study heterogeneity, to ensure accurate analysis and to better represent the characteristics of the emergency medical service response system, the prognosis of OHCA patients, and the emergency medical system established in response to the COVID-19 pandemic in South Korea, we performed a meta-analysis including reports only from South Korea.

The Korean Association of Cardiopulmonary Resuscitation annually provides records of patients experiencing cardiac arrest (Supplementary Fig. 1, only online). Although the most recent data facilitated identifying the total number of patients with OHCA and rates of survival, home isolation, bystander CPR, and defibrillation at the beginning of the pandemic in 2020, this information was limited and other factors could not be validated. Therefore, we assessed for additional variables by a meta-analysis of published research papers providing detailed statistics. This meta-analysis showed significantly increased incidence of at-home OHCA, decreased bystander use of AEDs, and decreased intubation during the COVID-19 pandemic in South Korea. In contrast, we observed no significant changes in the use of SGA devices, unwitnessed arrests, shock-

able rhythm, and bystander CPR. Furthermore, ROSC, survival until discharge, and favorable neurological outcomes did not differ significantly.

Lim, et al.[8] were the first to compare the outcomes of OHCA during and before the COVID-19 pandemic. Their study included studies from several countries, including the United States, Europe, and Australia. OHCA incidence had increased during the pandemic; and particularly, the incidence of at-home OHCA increased, attributable to the need for social distancing and reduced outdoor activity.[8] The early days after the outbreak in South Korea witnessed inadequate medical response and preparedness, similar to other countries.[22,23] In this study, however, we observed an unexpected trend in the incidence of shockable rhythm. Due to an increased influx of patients with OHCA experiencing respiratory failure due to COVID-19,[24-26] previous studies had reported a decreased incidence of shockable rhythm compared to before the pandemic.[27,28] However, in this meta-analysis, we found no significant differences in this regard. The decrease in the rate of shockable rhythm in Europe and the United States could be attributed to the dramatic increase in the number of patients at the early phase of the pandemic, as well as the increase in the number of confirmed patient arrests due to a collapsing medical system. The aforementioned factors could have resulted in delayed paramedic response to OHCA incidents or delayed arrival of critically ill pa-
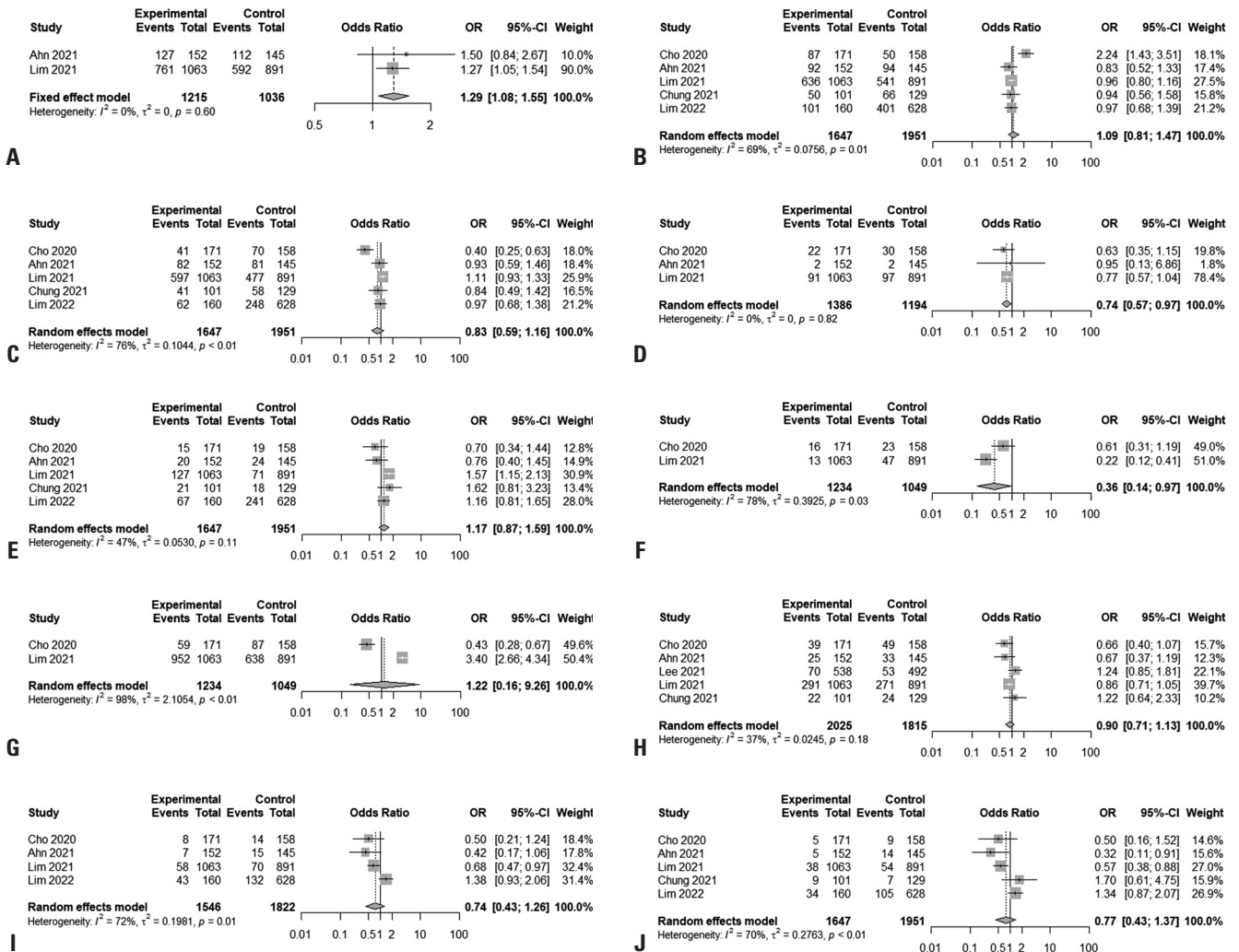
Fig. 3. A forest plot comparing the during-COVID-19-pandemic and before-pandemic periods in South Korea. (A) OHCA at home, (B) bystander CPR, (C) unwitnessed arrest, (D) AED use, (E) shockable cardiac rhythm, (F) intubation, (G) supraglottic airway device use, (H) ROSC, (I) survival to discharge, and (J) favorable neurological outcome.

tients to the medical facility with aggravated underlying pathophysiology.[8,29] Given a relatively lower COVID-19 caseload with stringent isolations policy in the early phase of the pandemic in South Korea compared to that in other countries, we hypothesized that the epidemiological features and outcomes of patients would differ.

Lim, et al.[8] found an increased use of SGA devices and decreased use of ETI in prehospital airway management during the pandemic. Conversely, a recent other meta-analysis showed that ETI use has increased to pre-pandemic proportions.[11] In the early phase of the pandemic, airway treatment recommendations avoided intubation to help aerosol-led COVID-19 infection.[30] However, a recent study showed that intubation by experienced healthcare providers was associated with a low incidence of COVID-19 infection,[31,32] and recent meta-analyses likely reflect this trend. Our meta-analysis showed a significant decrease in intubation use; however, we did not observe a significant difference in the use of SGA devices. However, only two

of the included studies compared intubation results, and the heterogeneity was substantial. Therefore, identifying the overall trend of airway management during the COVID-19 pandemic in South Korea is challenging, and additional analysis are needed.

Regarding OHCA outcomes during the pandemic, our findings in South Korea differed from those reported in previous studies. Other studies highlighted a decrease in survival rate and favorable neurological outcomes for OHCA. However, we found no significant difference in outcomes, including ROSC, survival, and favorable neurological outcomes, in South Korea. The national statistics data evaluating prehospital data indicated a slight decline in survival in 2020 (Supplementary Fig. 1, only online); however, meta-analyses showed no significant change. This observation may imply that the pandemic had a relatively lesser effect on the outcome of OHCA in South Korea compared to other regions worldwide. This difference could be attributed to varying timing and trends in the occurrence of

OHCA and public health system collapse compared to other countries.

It should not be overlooked that during a pandemic, awareness and altered responses to OHCA can be skewed. A pandemic is a type of disaster, and resources are focused as much as possible on those who can survive with limited medical resources. Resuscitative care was provided to as many people as possible prior to the pandemic; however, during the pandemic, resuscitative care focused on patients with a high probability of resuscitation. The characteristics of the two populations may differ. For example, during a pandemic, resuscitation may be easily terminated or not even started, particularly in patients with a low chance of ROSC. These people would be excluded from statistics, which could have an impact on the overall outcome of this meta-analysis.

Predicting a pandemic breakout is challenging; however, in recent years, unexpected infectious diseases are occurring more frequently, which has an impact on the healthcare system. Although COVID-19 was completely unknown, it led to an initial collapse of the healthcare system and adversely affected the course of treatment and outcomes for many critical diseases. In South Korea, the number of confirmed COVID-19 cases did not initially increase as quickly as it did in other countries, and the number of cases increased dramatically only later, allowing for the strengthening of the emergency medical system in the meantime. The medical system collapse seen during the COVID-19 pandemic should not be disregarded as a one-time event, and efforts should be made to systematize the medical system to prevent it from collapsing as a result of a pandemic caused by emerging and reemerging pathogens.

This study had several limitations. First, it was restricted to data only from South Korea. Hence, the total number of studies included was small, and the period of the pandemic varied in each study. In addition, despite the fact that there was an increase in at-home cardiac arrest, only two studies were included, and even those studies were not representative as they did not overlap the study period. Furthermore, although several epidemiologic factors and outcomes were compared across studies, interpreting the results of each variable was challenging since not all variables were analyzed in each study. Second, due to a lack of included studies, we were unable to conduct additional analyses, such as subgroup analysis or meta-regression, to reduce the heterogeneity of each meta-analysis. Some factors in the meta-analysis had only two studies, making it difficult to conduct additional analysis. Third, the latest pandemic situation was not considered. In early 2022, South Korea had the highest number of daily confirmed COVID-19 cases and deaths. However, only data up to February 21, 2021 were included, with the study by Chung, et al.[19] being the most recent one. Hence, the most recent OHCA outcomes and characteristics were not examined in this study. Fourth, analyses based on published studies are restricted in their ability to reflect the complete trend. Negative research findings are not always

disclosed, eliminating the inclusion of such data in the study. Therefore, future studies should compare the outcomes based on more comprehensive national data.

In conclusion, during the COVID-19 pandemic in South Korea, two studies found an increased tendency for home cardiac arrest, as well as a decreasing trend in the use of AED, among the rapidly increasing number of COVID-19 patients in the early phase of the pandemic. In addition, survival and favorable neurological outcomes of OHCA during the pandemic did not significantly differ compared to before the pandemic. In contrast to the deterioration of OHCA outcomes in the United States and Europe, which experienced medical system collapse and dramatic increase in the number of COVID-19 cases at the beginning of the pandemic, the caseload increased relatively slowly in South Korea during the same period, implying that the effect of the COVID-19 pandemic on OHCA was not significant. However, since there is insufficient evidence to support this, more investigation in South Korea is required.

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AUTHOR CONTRIBUTIONS

Conceptualization: Chiwon Ahn. Data curation: Jae Hwan Kim and Chiwon Ahn. Formal analysis: all authors. Funding acquisition: Chiwon Ahn. Investigation: Jae Hwan Kim and Chiwon Ahn. Methodology: Myeong Namgung and Chiwon Ahn. Project administration: Chiwon Ahn. Resources: all authors. Software: Jae Hwan Kim and Chiwon Ahn. Supervision: Chiwon Ahn. Validation: all authors. Visualization: Jae Hwan Kim. Writing—original draft: Jae Hwan Kim and Chiwon Ahn. Writing—review & editing: all authors. Approval of final manuscript: all authors.

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REFERENCES

1. Blumenthal D, Fowler EJ, Abrams M, Collins SR. COVID-19-implications for the health care system. N Engl J Med 2020;383:1483-8.
2. Ciotti M, Ciccozzi M, Terrinoni A, Jiang WC, Wang CB, Bernardini S. The COVID-19 pandemic. Crit Rev Clin Lab Sci 2020;57:365-88.
3. Lange SJ, Ritchey MD, Goodman AB, Dias T, Twentyman E, Fuld J, et al. Potential indirect effects of the COVID-19 pandemic on use of emergency departments for acute life-threatening conditions-United States, January-May 2020. Am J Transplant 2020;20:2612-7.
4. Kansagra AP, Goyal MS, Hamilton S, Albers GW. Collateral effect of COVID-19 on stroke evaluation in the United States. N Engl J Med 2020;383:400-1.

5. Kim JH, Ahn C, Namgung M. Comparative evaluation of the prognosis of septic shock patients from before to after the onset of the COVID-19 pandemic: a retrospective single-center clinical analysis. J Pers Med 2022;12:103.

6. National Bureau of Economic Research. Effects of state COVID-19 closure policy on non-COVID-19 health care utilization [accessed on 2022 July 30]. Available at: https://www.nber.org/papers/w27621.

7. Rachamin Y, Senn O, Streit S, Dubois J, Deml MJ, Jungo KT. Impact of the COVID-19 pandemic on the intensity of health services use in general practice: a retrospective cohort study. Int J Public Health 2021;66:635508.

8. Lim ZJ, Ponnapa Reddy M, Afroz A, Billah B, Shekar K, Subramaniam A. Incidence and outcome of out-of-hospital cardiac arrests in the COVID-19 era: a systematic review and meta-analysis. Resuscitation 2020;157:248-58.

9. Masuda Y, Teoh SE, Yeo JW, Tan DJH, Jimian DL, Lim SL, et al. Variation in community and ambulance care processes for out-of-hospital cardiac arrest during the COVID-19 pandemic: a systematic review and meta-analysis. Sci Rep 2022;12:800.

10. Teoh SE, Masuda Y, Tan DJH, Liu N, Morrison LJ, Ong MEH, et al. Impact of the COVID-19 pandemic on the epidemiology of out-of-hospital cardiac arrest: a systematic review and meta-analysis. Ann Intensive Care 2021;11:169.

11. Bielski K, Szarpak A, Jaguszewski MJ, Kopiec T, Smereka J, Gasecka A, et al. The influence of COVID-19 on out-hospital cardiac arrest survival outcomes: an updated systematic review and meta-analysis. J Clin Med 2021;10:5573.

12. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ 2009;339:b2700.

13. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. JAMA 2000;283:2008-12.

14. Wells GA, Shea B, O'Connell D, Peterson J, Welch V, Losos M, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-nalyses [accessed on 2022 July 30]. Available at: https://www.ohri.ca/programs/clinical_epidemiology/oxford.asp.

15. Cho JW, Jung H, Lee MJ, Lee SH, Lee SH, Mun YH, et al. Preparedness of personal protective equipment and implementation of new CPR strategies for patients with out-of-hospital cardiac arrest in the COVID-19 era. Resusc Plus 2020;3:100015.

16. Ahn JY, Ryoo HW, Cho JW, Kim JH, Lee SH, Jang TC. Impact of the COVID-19 outbreak on adult out-of-hospital cardiac arrest outcomes in Daegu, South Korea: an observational study. Clin Exp Emerg Med 2021;8:137-44.

17. Lee NJ, Yang JC, Moon JD. Collateral damage of emergency medical services due to COVID-19. Korean J Emerg Med Ser 2021;25:189-200.

18. Lim D, Park SY, Choi B, Kim SH, Ryu JH, Kim YH, et al. The comparison of emergency medical service responses to and outcomes of out-of-hospital cardiac arrest before and during the COVID-19 pandemic in an area of Korea. J Korean Med Sci 2021;36:e255.

19. Chung H, Namgung M, Lee DH, Choi YH, Bae SJ. Effect of delayed transport on clinical outcomes among patients with cardiac arrest during the coronavirus disease 2019 pandemic. Australas Emerg Care 2022;25:241-6.

20. Lim KT, Ahn KO, Park JH, Park CH, Lim J, Lee K. Bystander cardiopulmonary resuscitation in public locations before and after the coronavirus disease 2019 pandemic in the Republic of Korea. Am J Emerg Med 2022;56:271-4.

21. Oh J, Lee JK, Schwarz D, Ratcliffe HL, Markuns JF, Hirschhorn LR. National response to COVID-19 in the Republic of Korea and lessons learned for other countries. Health Syst Reform 2020;6:e1753464.

22. Choi JY. COVID-19 in South Korea. Postgrad Med J 2020;96:399-402.

23. COVID-19 National Emergency Response Center, Epidemiology & Case Management Team, Korea Centers for Disease Control & Prevention. Contact transmission of COVID-19 in South Korea: novel investigation techniques for tracing contacts. Osong Public Health Res Perspect 2020;11:60-3.

24. Renzi S, Landoni G, Zangrillo A, Ciceri F. MicroCLOTS pathophysiology in COVID 19. Korean J Intern Med 2020 Sep 9 [Epub]. Available at: https://doi.org/10.3904/kjim.2020.336.

25. Lindner D, Fitzek A, Bräuninger H, Aleshcheva G, Edler C, Meissner K, et al. Association of cardiac infection with SARS-CoV-2 in confirmed COVID-19 autopsy cases. JAMA Cardiol 2020;5:1281-5.

26. Zhang L, Yan X, Fan Q, Liu H, Liu X, Liu Z, et al. D-dimer levels on admission to predict in-hospital mortality in patients with COVID-19. J Thromb Haemost 2020;18:1324-9.

27. Lai PH, Lancet EA, Weiden MD, Webber MP, Zeig-Owens R, Hall CB, et al. Characteristics associated with out-of-hospital cardiac arrests and resuscitations during the novel coronavirus disease 2019 pandemic in New York city. JAMA Cardiol 2020;5:1154-63.

28. Marijon E, Karam N, Jost D, Perrot D, Frattini B, Derkenne C, et al. Out-of-hospital cardiac arrest during the COVID-19 pandemic in Paris, France: a population-based, observational study. Lancet Public Health 2020;5:e437-43.

29. de Graaf C, Donders DNV, Beesems SG, Henriques JPS, Koster RW. Time to return of spontaneous circulation and survival: when to transport in out-of-hospital cardiac arrest? Prehosp Emerg Care 2021;25:171-81.

30. Orser BA. Recommendations for endotracheal intubation of COVID-19 patients. Anesth Analg 2020;130:1109-10.

31. Dhillon RS, Rowin WA, Humphries RS, Kevin K, Ward JD, Phan TD, et al. Aerosolisation during tracheal intubation and extubation in an operating theatre setting. Anaesthesia 2021;76:182-8.

32. Brown J, Gregson FKA, Shrimpton A, Cook TM, Bzdek BR, Reid JP, et al. A quantitative evaluation of aerosol generation during tracheal intubation and extubation. Anaesthesia 2021;76:174-81.

Supplementary Table 1. Search Strategy (Searched on June 14, 2022)

Database	Search terms	n
PubMed	("coronavirus"[MeSH Terms] OR "coronavirus" [Title/Abstract] OR "COVID-19"[Title/Abstract] OR "novel coronavirus 2019"[Title/Abstract] OR "SARS-CoV"[Title/Abstract] OR "SARS-CoV-2"[Title/Abstract] OR "2019-nCoV"[Title/Abstract] OR "sars covid 19"[Title/Abstract] OR "sars-covid-2"[Title/Abstract] OR (("severe acute respiratory syndrome"[MeSH Terms] OR ("severe"[All Fields] AND "acute"[All Fields] AND "respiratory"[All Fields] AND "syndrome"[All Fields]) OR "severe acute respiratory syndrome"[All Fields]) AND "coronavirus related"[Title/Abstract]) AND ("Out-of-Hospital Cardiac Arrest"[MeSH Terms] OR "Heart Arrest"[MeSH Terms] OR "Ventricular Fibrillation" [MeSH Terms] OR "OHCA"[All Fields] OR "resuscitation"[All Fields] OR "cardiac arrest"[All Fields] OR "pulseless electrical activity"[All Fields] OR "asystole" [All Fields]) AND ("Korea" [All Fields] OR "South Korea" [All Fields])	30
Embase	('coronavirus infection'/exp OR coronavirus infection OR coronavirus disease 2019 OR covid 19 OR (novel AND coronavirus AND 2019) OR sars cov OR 2019 ncov OR severe acute respiratory syndrome) AND (('out of hospital' AND 'arrest') OR 'heart arrest' OR (cardiac AND arrest) OR 'ohca')) AND (korea OR (south AND korea))	20
Cochrane library	('COVID-19' OR 'novel coronavirus' OR 'SARS-COVID-2' OR 'severe acute respiratory syndrome coronavirus 2' OR 'severe acute respiratory failure novel coronavirus-related') AND ('out-of-hospital cardiac arrest' OR 'heart arrest' OR 'OHCA' OR 'cardiac arrest') AND korea OR south korea	1
KoreaMed	(("arrest"[ALL]) OR ("OHCA"[ALL]) OR ("resuscitation"[ALL])) AND (("COVID"[ALL]) OR ("corona"[ALL]) OR ("pandemic"[ALL]))	14
NDSL	(main text) corona*|COVID*|pandemic| AND (main text) resuscitation|arrest|OHCA| AND Publication data: 2019-present	66
KMBase	(([ALL=arrest] OR [ALL=OHCA] OR [ALL=resuscitation]) AND ([ALL=COVID] OR [ALL=corona] OR [ALL=pandemic])) AND Publication data: 2019-present	93
RISS	Title: corona|COVID|pandemic| <AND> title : resuscitation|arrest|OHCA|	183
KISS	arrest AND corona	12
Total		79

Supplementary Table 2. List of Excluded References after Full-Text Review

| No.	Title	First author	Journal (year)	Main reason for exclusion
1	Is there an association between metformin use and clinical outcomes in diabetes patients with COVID-19?	Do JY	Diabetes Metab (2021)	Populations did not fulfill
2	Association between chronic kidney disease or acute kidney injury and clinical outcomes in COVID-19 patients	Kang SH	J Korean Med Sci (2020)	Populations did not fulfill
3	Clinical characteristics and risk factors for fatality and severity in patients with coronavirus disease in Korea: a nationwide population-based retrospective study using the Korean Health Insurance Review and Assessment Service (HIRA) database	Lee SG	Int J Environ Res Public Health (2020)	Populations did not fulfill
4	Predicting unexpected deterioration of high-risk hospitalized patients during the COVID-19 pandemic: a multicenter cohort study	Kim SH	Resuscitation (2021)	Populations did not fulfill
5	Impact of the COVID-19 pandemic on patient delay and clinical outcomes for patients with acute myocardial infarction	Choi H	J Korean Med Sci (2022)	Populations did not fulfill
6	Effect of sex on clinical outcomes in patients with coronavirus disease: a population-based study	Cho KH	J Clin Med (2020)	Control group was not eligible for comparison with intervention groups
7	Impact of personal protective equipment on out-of-hospital cardiac arrest resuscitation in coronavirus pandemic	Ko HY	Medicina-Kaunas (2021)	Control group was not eligible for comparison with intervention groups
8	External validation of multimodal termination of resuscitation rules for out-of-hospital cardiac arrest patients in the COVID-19 era	Chung H	Scand J Trauma Resusc Emerg Med (2021)	Control group was not eligible for comparison with intervention groups
9	Confirmation of COVID-19 in out-of-hospital cardiac arrest patients and postmortem management in the emergency department during the COVID-19 outbreak	Kim C	Infection and Chemotherapy (2020)	Control group was not eligible for comparison with intervention groups
10	Effect of designating emergency medical centers for critical care on emergency medical service systems during the COVID-19 pandemic: a retrospective observational study	Park HA	J Clin Med (2022)	Outcome did not fulfill
11	Effect of delayed transport on clinical outcomes among patients with cardiac arrest during the coronavirus disease 2019 pandemic	Chung H	Korean Soc Emerg Med (2021)	Duplicated data was shared with other study

Supplementary Table 3. Newcastle-Ottawa Quality Assessment Scale of Included Studies

Items\studies	Cho 2020[15]	Ahn 2021[16]	Lee 2021[17]	Lim 2021[18]	Chung 2022[19]	Lim 2022[20]
Selection (4)						
1)	1	1	1	1	1	1
2)	1	1	1	1	1	1
3)	1	1	1	1	1	1
4)	0	1	0	1	0	0
Comparability (2)						
1)-a, 1)-b	1	1	0	1	2	1
Outcome (3)						
1)	1	1	1	1	1	1
2)	1	1	1	1	1	1
3)	1	1	1	1	1	1
Total (9)	7	8	6	8	8	7

Supplementary Table 4. GRADE of Each Comparison

Participant (studies) follow-up	Certainty assessment						Summary of findings				
	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Overall certainty of evidence	Study event rates (%)		Relative effect (95% CI)	Anticipated absolute effects	
							With before the COVID-19 pandemic	With during the COVID-19 pandemic		Risk with before the COVID-19 pandemic	Risk difference with during the COVID-19 pandemic
OHCA at home											
2251 (2 observational studies)	Not serious	Not serious	Not serious	Not serious	None	⊕⊕◯◯ Low	704/1036 (68.0)	888/1215 (73.1)	OR 1.29 (1.08 to 1.55)	680 per 1,000	53 more per 1,000 (from 17 more to 87 more)
Bystander CPR											
3598 (5 observational studies)	Not serious	Serious	Not serious	Not serious	None	⊕◯◯◯ Very low	1152/1951 (59.0)	966/1647 (58.7)	OR 1.09 (0.81 to 1.47)	590 per 1,000	21 more per 1,000 (from 52 fewer to 89 more)
Unwitnessed arrest											
3598 (5 observational studies)	Not serious	Serious	Not serious	Not serious	None	⊕◯◯◯ Very low	934/1951 (47.9)	823/1647 (50.0)	OR 0.83 (0.59 to 1.16)	479 per 1,000	46 fewer per 1,000 (from 127 fewer to 37 more)
AED usage											
2580 (3 observational studies)	Not serious	Not serious	Not serious	Not serious	None	⊕⊕◯◯ Low	129/1194 (10.8)	115/1386 (8.3)	OR 0.74 (0.57 to 0.97)	108 per 1,000	26 fewer per 1,000 (from 43 fewer to 3 fewer)
Shockable cardiac rhythm											
3598 (5 observational studies)	Not serious	Serious	Not serious	Not serious	None	⊕◯◯◯ Very low	373/1951 (19.1)	250/1647 (15.2)	OR 1.17 (0.87 to 1.59)	191 per 1,000	25 more per 1,000 (from 21 fewer to 82 more)
Intubation											
2283 (2 observational studies)	Not serious	Serious	Not serious	Not serious	None	⊕◯◯◯ Very low	70/1049 (6.7)	29/1234 (2.4)	OR 0.36 (0.14 to 0.97)	67 per 1,000	42 fewer per 1,000 (from 57 fewer to 2 fewer)
Supraglottic airway											
2283 (2 observational studies)	Not serious	Very serious	Not serious	Not serious	None	⊕◯◯◯ Very low	725/1049 (69.1)	1011/1234 (81.9)	OR 1.22 (0.16 to 9.26)	691 per 1,000	41 more per 1,000 (from 427 fewer to 263 more)
ROSC											
3840 (5 observational studies)	Not serious	Serious	Not serious	Not serious	None	⊕◯◯◯ Very low	430/1815 (23.7)	447/2025 (22.1)	OR 0.90 (0.71 to 1.13)	237 per 1,000	19 fewer per 1,000 (from 56 fewer to 23 more)
Survival to discharge											
3368 (4 observational studies)	Not serious	Serious	Not serious	Not serious	None	⊕◯◯◯ Very low	231/1822 (12.7)	116/1546 (7.5)	OR 0.74 (0.43 to 1.26)	127 per 1,000	30 fewer per 1,000 (from 68 fewer to 28 more)
Ravorable neurological outcome											
3598 (5 observational studies)	Not serious	Serious	Not serious	Not serious	None	⊕◯◯◯ Very low	189/1951 (9.7)	91/1647 (5.5)	OR 0.77 (0.43 to 1.37)	97 per 1,000	21 fewer per 1,000 (from 53 fewer to 31 more)

CI, confidence interval; OR, odds ratio.
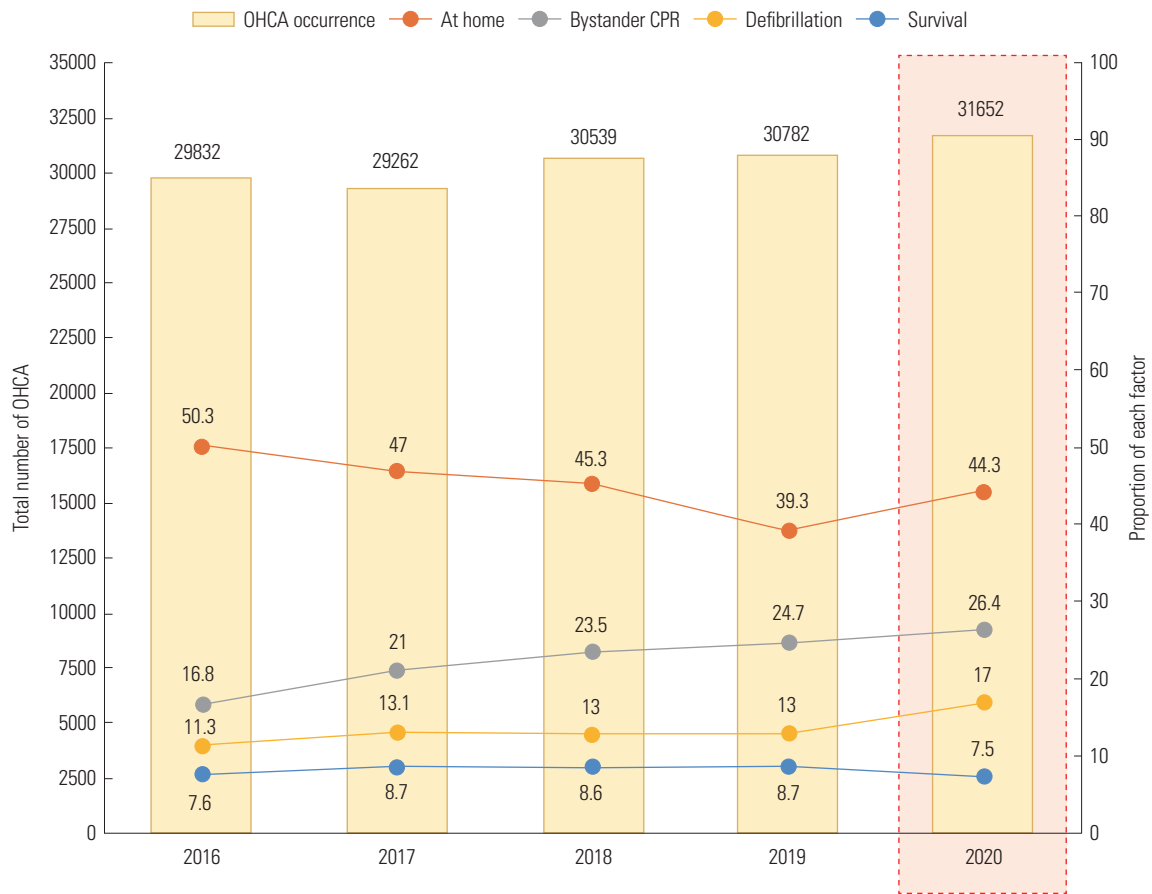
Supplementary Fig. 1. Graph showing the annual total number of OHCA and other factors from the Korean Association of Cardiopulmonary Resuscitation (2016–2020).