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Review

# The impact of the SARS-CoV-2 pandemic on in-hospital cardiac arrest: A systematic review and meta-analysis

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**Abstract**

**Background**: There is an emerging concern regarding the indirect effect the Covid-19 pandemic has had on the care provided to patients. New resuscitation guidance including the donning of Personal Protective Equipment before commencing resuscitation efforts, the avoidance of bag-mask ventilation, limiting the number of responders and stopping resuscitation efforts earlier could have led to worse outcomes following in-hospital cardiac arrest (IHCA) when compared to the non-pandemic period. The primary objective was to understand the impact of the pandemic on patient outcomes following IHCA by comparing the pandemic and non-pandemic periods.

**Methods**: Our systematic search was conducted on the 13th of September 2022 in three databases: Medline, Embase and Central. Randomised or non-randomised clinical trials and observational studies were included. The search was repeated on 31st December 2023 and there were no new studies appropriate for inclusion which had been published in the interim. The patient population consisted of adult patients who suffered IHCA due to any cause. The primary outcome was survival to hospital discharge (SHD). The secondary outcomes were return of spontaneous circulation (ROSC) and length of resuscitation.

**Results**: We identified 1873 studies, 9 were included in our qualitative analysis. SHD was reported in 8 studies with no difference between the two periods (OR 0.69; 95% CI 0.47–1.03) along with resuscitation (MD: 0.74; 95% CI: −0.67 to 2.14; $p = 0.153$. ROSC was included in all studies and showed significant difference between the two periods (OR 0.75; 95% 0.60–0.95)

**Conclusion**: Although SHD was similar between the two periods, ROSC was significantly lower during the pandemic with longer resuscitation times highlighting a substantial impact of the pandemic on patient outcomes.

**Keywords**: In-hospital cardiac arrest, Covid-19, Survival, ROSC, CPR

## Introduction

The direct effect of the Coronavirus 19 (COVID-19) disease on morbidity and mortality is well known, however there is an emerging concern regarding the indirect effect the pandemic has had on the care provided to patients.[1–3]

In terms of in-hospital cardiac arrest (IHCA), survival to hospital discharge was between 13% and 22% before the pandemic, however during pandemic surge periods the available literature data varies.[4] Early publications presented low survival rates following IHCA.[5–9] However, a systematic review which incorporated 3 studies and 1432 patients in total, showed no statistical difference in survival rates between the COVID-19 and the pre-pandemic period.[10] Since

*Abbreviations*: CI, confidence interval, COVID-19, coronarvirus-19, CPR, cardiopulmonary resuscitation, DOI, Digital Object Identifier, ICU, intensive care unit, IHCA, in-hospital cardiac arrest, IQR, interquartile range, MD, mean dierence, OR, odds ratio, PPE, personal protective equipment, PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses, ROB, risk of bias, ROBINS-I, Risk of Bias in Non-randomized Studies – of Interventions, ROSC, return of spontaneous circulation, SD, standard deviation, SHD, survival to hospital discharge, UK, United Kingdom, USA, United States of America

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this systematic review, new studies have been published with larger patient populations showing an adverse effect of the pandemic on the outcomes of IHCA irrespective of COVID-19 status of the patient.[11–13] This suggests that the effect of the pandemic may have indirectly adversely affected patient outcomes, even if they did not have COVID-19 disease. This systemic review and meta-analysis interrogates data from a significantly larger sample size than prior works (182,980 patients) in order to improve confidence and accuracy in our conclusions regarding IHCA outcomes during the pandemic when compared to pre-pandemic times.

Evidence suggests that the 'Chain of Survival', denoting early recognition, early cardiopulmonary resuscitation (CPR), rapid defibrillation and post-cardiac arrest care can improve chances of survival and recovery for patients who suffer cardiac arrest.[14] The question that these authors try to address is as follows: Was our widely adopted, protocol-driven approach to managing IHCAs less successful during the pandemic?

New resuscitation guidance for COVID-19 was published by many medical associations with the aim of protecting healthcare staff when responding to a cardiac arrest. Although the recommendations differed internationally, they broadly included: the donning of Personal Protective Equipment (PPE) before commencing resuscitation, the avoidance of bag-mask ventilation to avoid aerosol formation, limiting the number of responders, reducing the amount of equipment that is taken to the scene, and an earlier team decision to abandon resuscitation efforts if the outcome was unlikely to be favourable.[15,16]

Measures mandating more time delay before starting CPR could have weakened the Chain of Survival leading to worse outcomes following IHCA when compared to the pre-pandemic period.

The primary objective of this systematic review and meta-analysis was to assess differences in survival outcomes following IHCA by comparing data from the pandemic and pre-pandemic periods.

## Methods

We report our systematic review and meta-analysis based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 guideline (see in the "Supplementary material S1"),[17] following the recommendation of the Cochrane Handbook.[18] The protocol of the study was registered on PROSPERO (CRD42022360959) and was adhered to throughout.

### *Eligibility criteria*

The research question was formulated using the Population, Intervention, Comparator, and Outcomes (PICO) framework as follows: P – patients who suffered in-hospital cardiac arrest, I- in-hospital cardiac arrest during the COVID-19 pandemic, C – in- hospital cardiac arrest during the pre-pandemic period, O – survival to hospital discharge, ROSC, resuscitation length.[19] Randomised or non-randomised clinical trials and observational studies were included; conference abstracts, case reports, case series were excluded from our systematic review and meta-analysis. The patient population consisted of patients who suffered in-hospital cardiac arrest due to any cause. The primary outcome was survival to hospital discharge. The secondary outcomes were return of spontaneous circulation and length of resuscitation, which was measured from the time that basic resuscitation efforts began until ROSC or declaration of death.

### *Information sources, search strategy and selection process*

Our systematic search was conducted on the 13th September 2022 and repeated on the 31st of December 2023 in three databases: MEDLINE (via PubMed), Embase and Cochrane Central Register of Controlled Trials (CENTRAL). The selection process was performed by two independent review authors (A.F-Gy.) and (A.S.) using reference manager software (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia, 2023). Removal of the duplicates was made both automatically and manually. Disagreements were solved by a third reviewer (BK).

### *Data collection process*

From the eligible articles data were collected by two authors (A.F-Gy. and A.S.) independently into a standardised data collection sheet (Microsoft Excel for Mac, Microsoft, 2022). The accuracy of data was validated by a third reviewer (BK).

### *Data items*

The following data were extracted from each eligible article: title; first author; the year of publications; Digital Object Identifier (DOI); study site; study period; study design; recruitment period; gender; age; and initial rhythm ratios in the populations; location of arrest, return of spontaneous circulation (ROSC), survival to hospital discharge (SHD), total resuscitation time. Odds ratios (ORs) with confidence intervals (CIs) and medians with interquartile range (IQR) were extracted as measures of effect.

### *Study risk of bias assessment*

The ROBINS-I tool (Risk of Bias in Non-randomized Studies – of Interventions) was used to assess the quality of studies in accordance with the recommendation of the Cochrane Collaboration[20] Robvis application was used to visualise risk-of-bias assessments.[21] Two authors (A.F-Gy.) and (A.S.) independently evaluated the studies for risk of bias (ROB). Any disagreements were discussed and resolved by a third reviewer (B.K.).

### *Synthesis method*

The odds ratio with 95% CI was used for the effect measure of SHD (primary outcome) and ROSC (secondary outcome), while mean differences (MD) were used for resuscitation length (secondary outcome). To calculate the odds ratio, the total number of patients in each group and those with the event of interest were extracted from each study, while for continuous outcomes we used the between group mean differences and standard deviations (SD) to calculate the effect measure. We used random effect models with the Mantel-Haenszel method and the Hartung-Knapp adjustment.[22,23] To estimate $\tau^2$ we used the Paule-Mandel method and the Q profile method for calculating the confidence interval of $\tau^2$. A funnel plot of the logarithm of effect size and comparison with the standard error for each trial was used to evaluate publication bias where sample size made it possible. Statistical heterogeneity across studies was assessed by means of the Cochrane Q test, and the $I^2$ statistic values. Outlier and influence analyses were carried out following the recommendations of Harrer et al. and Viechtbauer and Cheung.[23,24] Forest plots were used to graphically summarise results. We also reported the prediction intervals (i.e., the expected range of effects of future studies) of results following the recommendations of IntHout et al.[25] All the analyses were carried out using the R 4.1.3 ((R Core Team 2021)) using the packages 'meta' and 'dmetar'.[26,27]

## Results

### *Search and selection*

A total of 1873 studies were identified in the three databases during our systematic search. After automatic duplicate removal, 1575 papers were screened, and finally, 45 full-text studies were assessed for eligibility. 36 papers were excluded because they did not adhere to the correct study design and did not focus on the appropriate patient population, leaving 9 papers for qualitative and quantitative analysis. The selection process is shown in Fig. 1.

### *Risk of bias*

The assessment for each domain and the graphical presentation of ROB are presented in Fig. 2. Overall, ROB was "low" in 6 studies and "moderate" in 3 studies. Within the ROB assessment domains, the "low" risk of bias was observed in most domains.

### *Characteristics of the included studies*

Due to the nature of the subject, all the nine studies are retrospective cohorts. They mainly originate from developed countries, and many of them are multicentre studies. There are three papers from the USA,[7,11,13] and the others are from the United Kingdom (UK), Germany, Sweden, Singapore, Hong Kong and Pakistan.[12,28–32] All studies that were included made a comparison between IHCAs that occurred during a 'non-pandemic' period and a 'pandemic' period. Two papers from the same group in the United States of America (USA) further distinguish the 'pandemic' periods into discrete 'pre-surge', 'surge', and 'post-surge' periods.[11,13] Detailed characteristics of the included studies are described in Table 1.

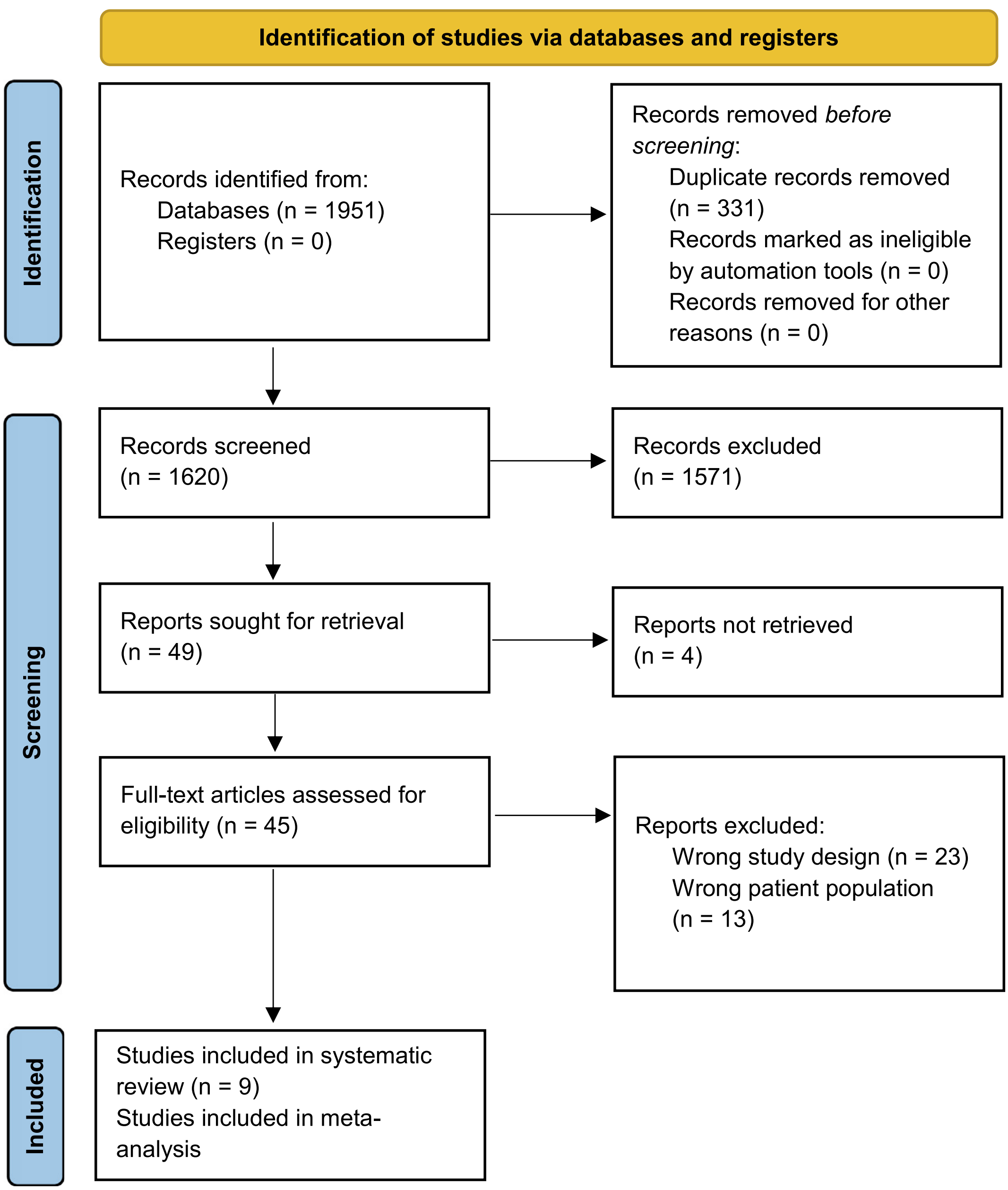



**Fig. 1 – PRISMA 2020 flowchart representing the study selection process.**[17]

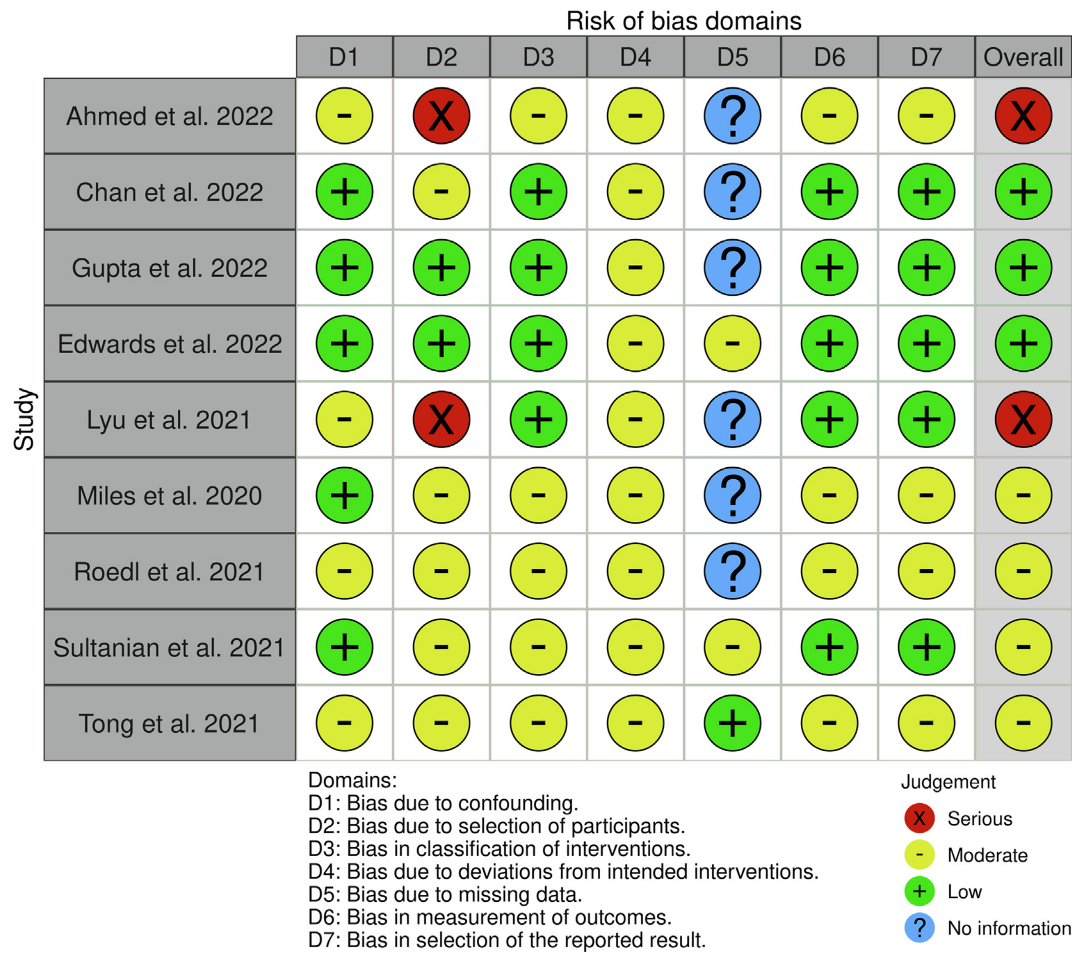



**Fig. 2 – ROB assessment and overall risk of each type of bias using ROBINS-I tool in observational prognostic studies.[20]**

### *Characteristics of the patients*

Detailed characteristics of patients with IHCA are summarised in Table 2. Baseline characteristics of patients suffering IHCA during the COVID-19 pandemic were similar to those of non-pandemic periods except in studies conducted in Singapore and the UK, where patients were younger in the COVID-19 pandemic cohort.[12,30] The total number of patients included in our analysis is 182,980.

Overall shockable rhythm was slightly lower during the pandemic with the exception of the trial conducted by Roedl et al, where shockable rhythm was more likely during the COVID-19 period.[28]

The rate of COVID-19 infection among IHCA patients was investigated in 6 studies. Less than 30% of patients had COVID-19 infection during their arrest in all studies except one; Miles et al. In their trial 79% of the patients had COVID-19 disease.[11,13,28,29,31,7]

### *Primary outcome – survival to hospital discharge*

A total of 7 studies were eligible for analyses covering 86,137 patients.[11,12,30–32,7] Five of them, three conducted in the USA, one in Pakistan and one in Singapore, observed a significantly lower survival to hospital discharge rate during the pandemic versus non-pandemic periods.[7,11,13,30,32] Two studies, both from the USA, found that patients suffering IHCA during surge time had a lower survival rate compared to patients during non-surge or pre-pandemic periods.[11,13]

Although both in UK and Hong Kong the number of patients surviving hospital discharge was lower during the pandemic, statistically the difference was not significant.[12,31]

In our meta-analysis we found marginally significant difference in survival to hospital discharge between the pandemic and non-pandemic periods, 19.5% vs. 24.7% respectively (OR: 0.69; 95% CI: 0.47–1.03; $p = 0.064$, Fig. 3).

### *Secondary outcomes – return of spontaneous circulation and resuscitation length*

We identified 9 studies reporting ROSC with a total of 87,394 patients. Out of 9 studies 2 found a statistically non-significant reduction in ROSC rates,[28,29] whereas 7 observed significantly lower rates of ROSC during the pandemic.[7,11–13,30–32] Our analysis shows a significant difference in ROSC between the pandemic and non-pandemic periods, 58% vs. 63% respectively (OR: 0.75; 95% CI: 0.6–0.95; $p = 0.023$, Fig. 4).

Resuscitation length was measured only in 3 studies involving 17,987 patients.[12,28,31] Our analyses showed no significant difference in resuscitation length between the pandemic and

**Table 1 – Characteristics of included studies.**[7,11–13,28–32]

| First author, year | Study setting | Study type | Study design | Pandemic period MM/YYYY | Non-pandemic period MM/YYYY | Total number of patient | Number of patients in the pandemic group | Number of patients in the pre-pandemic group |
|---|---|---|---|---|---|---|---|---|
| Ahmed et al. 2022[32] | Pakistan | Single centre | Cross-sectional | 08/2019–02/2020 | 03/2020–08/2020 | 77 | 32 | 45 |
| Chan et al. 2022*[13] | United States of America | Multicentre | Retrospective | 01/03–15/05/2020 | 01/03–15/05/2015–19 | 61,586 | 5949 | 20,510 |
| Gupta et al. 2022#[11] | United States of America | Multicentre | Retrospective | 01/07–15/08/2020; 06/10–31/12/2020 | 01/07–15/08/2015–19; 06/10–31/12/2015–19 | 102,635 | 3480; 6279 | 11410; 21,060 |
| Edwards et al. 2022[12] | United Kingdom | Multicentre | Retrospective | 01/03–31/05/2020 | 01/03–31/05/2016–19 | 16,474 | 2269 | 14,970 |
| Lyu et al. 2021[30] | Singapore | Single centre | Retrospective | 01/03–31/05/2020 | 01/03–31/05/2019 | 27 | 17 | 10 |
| Miles et al. 2020[7] | United States of America | Single centre | Retrospective | 01/03–15/05/2020 | 01/01–31/12/2019 | 242 | 125 | 117 |
| Roedl et al. 2021[28] | Germany | Single centre | Retrospective | 27/02–28/05/2020 | 27/02–28/05/2019 | 177 | 93 | 84 |
| Sultanian et al. 2021[29] | Sweden | Multicentre | Retrospective | 16/03–20/07/2020 | 01/01–16/03/2020 | 1080 | 548 | 532 |
| Tong et al. 2021[31] | Hong Kong | Multicentre | Retrospective | 27/01/2020–26/01/2021 | 27/01/2019–26/01/2020 | 629 | 267 | 362 |

* Only 1st surge period included (01/03–15/05/2020 vs. 01/03–15/05/2015–19).
# Only 2nd and 3rd surge periods included (01/07–15/08/2020; 06/10–31/12/2020 vs. 01/07–15/08/2015–19; 06/10–31/12/2015–19).

**Table 2 – Demographics of the included studies.**[7,11–13,28–32]

| First author, year | Sex Female % | | Age mean ± SD/ median (IQR) | | IHCA on ICU % | | Shockable rhythm % | | Covid-19 infected patients % |
|---|---|---|---|---|---|---|---|---|---|
| | Pandemic period | Non-pandemic period | Pandemic period | Non-pandemic period | Pandemic period | Non-pandemic period | Pandemic period (VF, pVT %) | Non-pandemic period (VF, pVT %) | |
| Ahmed et al. 2022[32] | 37.5 | 46.7 | NA | NA | NA | NA | 3.1, 0 | 3.8, 2.3 | NA |
| Chan et al. 2022*[13] | 39.4 | 41.3 | 64.6 ± 15.2 | 65.2 ± 15.3 | 46.5 | 47 | 7.0, 7.5 | 7.6, 9.5 | 25.3 |
| Gupta et al. 2022#[11] | 40.5; 39.3 | 40.7; 40.9 | 64 ± 15.4; 65.5 ± 15.2 | 64.6 ± 15.7; 65.2 ± 15.5 | 48.6; 47.7 | 48.1; 47.3 | 7.1, 7; 7, 6.8 | 9.7, 7.9; 9.2, 7.5 | 22; 28.3 |
| Edwards et al. 2022[12] | 36.1 | 39.9 | 66.5 ± 17 | 71.4 ± 16.3 | 20.3 | 18.7 | 13.1, 6.6 | 12.8, 5.7 | NA |
| Lyu et al. 2021[30] | 33.6 | 35.2 | 65 ± 12.8 | 70.8 ± 12.7 | NA | NA | NA | NA | NA |
| Miles et al. 2020[7] | 34 | 42 | 67 (57–76) | 66 (56–77) | 33 | 60 | 3 | 9 | 79 |
| Roedl et al. 2021[28] | 35 | 29.1 | 68 (57–78) | 72 (57–78) | 56 | 37 | 29 | 18 | 13 |
| Sultanian et al. 2021[29] | 36.1 | 38.6 | 67.8 ± 18.9 | 70.1 ± 18.2 | 9.5 | 10.9 | 23.8 | 28 | 16.1 |
| Tong et al. 2021[31] | 34 | 42 | 77 (66–85) | 76 (66–85) | 15^ | 13^ | 7 | 9 | 0 |

*ICU=intensive care unit, IHCA=in-hospital cardiac arrest, IQR=interquartile range, NA=no value available, SD=standard deviation, VF=ventricular fibrillation, pVT=pulseless ventricular tachycardia.*

* Only 1st surge period included (01/03–15/05/2020 vs. 01/03–15/05/2015–19).

\# Only 2nd and 3rd surge periods included (01/07–15/08/2020; 06/10–31/12/2020 vs. 01/07–15/08/2015–19; 06/10–31/12/2015–19).

^ Monitored area.

non-pandemic period (MD: 0.74; 95% CI: −0.67 to 2.14; $p$ = 0.153, Fig. 5).

## Discussion

This is the largest study in terms of patient population analysing the available data on the outcomes of patients who suffered IHCA comparing the two periods, regardless of whether or not they had COVID-19 disease. In this review we aimed to examine the indirect effects of the pandemic on the delivery of day-to-day emergency care and resuscitation in hospitals during this extraordinary time.

### *Survival to hospital discharge (primary endpoint)*

In our meta-analysis, there was marginally significant difference in SHD. However, this finding needs further attention. Gupta et al found that there was a significant difference in SHD when comparing the surge periods with the same period in the pre-pandemic years. A similar pattern was also seen with the secondary outcome of ROSC. Gupta et al. concluded from this that there was likely an impact from the hospitals being overwhelmed with admissions and having insufficient number of inpatient beds and critical care staff to look after dedicated critically ill patients at this time. This theory is upheld by their data collection in the 'post-surge' periods which showed rates of SHD and ROSC which were comparable with the 'pre-pandemic' periods.[11] Another of the papers from the USA also found significant decreases in SHD during the first surge of the COVID-19 pandemic which returned to normal in the 'post-surge' period.[13] This finding was the case even when patients known or suspected to have COVID-19 disease were excluded from the study, which indicates there was a contribution from organisational changes that were made, rather than purely the clinical course of COVID-19 disease.

Two of the papers in the meta-analysis showed no significant difference in SHD in the non-pandemic period compared with the pandemic period.[12,31] One of these was a multi-centre study in Hong Kong which included 630 cardiac arrest patients, none of whom had COVID-19 disease. This finding could be hailed as an indicator that SHD was not altered in centres that did not experience a surge period. The other paper is a registry data study from the UK. The possible reason why these results are different from the other: they only looked at the first wave of the pandemic, which in the UK was significantly smaller than the second in terms of patients occupying beds in hospitals.[33] Having noted this, Edwards and her team then stratified the data into hospitals with a low, medium or high burden of COVID-19 disease (defined by number of confirmed cases admitted to ICU per 10,000 admissions). In hospitals with a high burden of COVID-19 disease, there was a significant reduction in SHD obviously affected by the disease itself as well and the overwhelming workload of admitting and treating patients was near average in hospitals that did not experience surges.[12] This is a key finding, as it suggests that changes to resuscitation protocols, redeployment of staff and the donning and doffing of PPE do not have an impact on the survival of patients who suffer IHCA in and of themselves. But when these changes coincide with very high numbers of acute admissions, these factors begin to have a clear detrimental impact. Conversely, it is certainly encouraging to note that if there is a difference in rates of survival, it seems to relate only to the time periods when hospitals were over bedded, and not to the entire pandemic period.

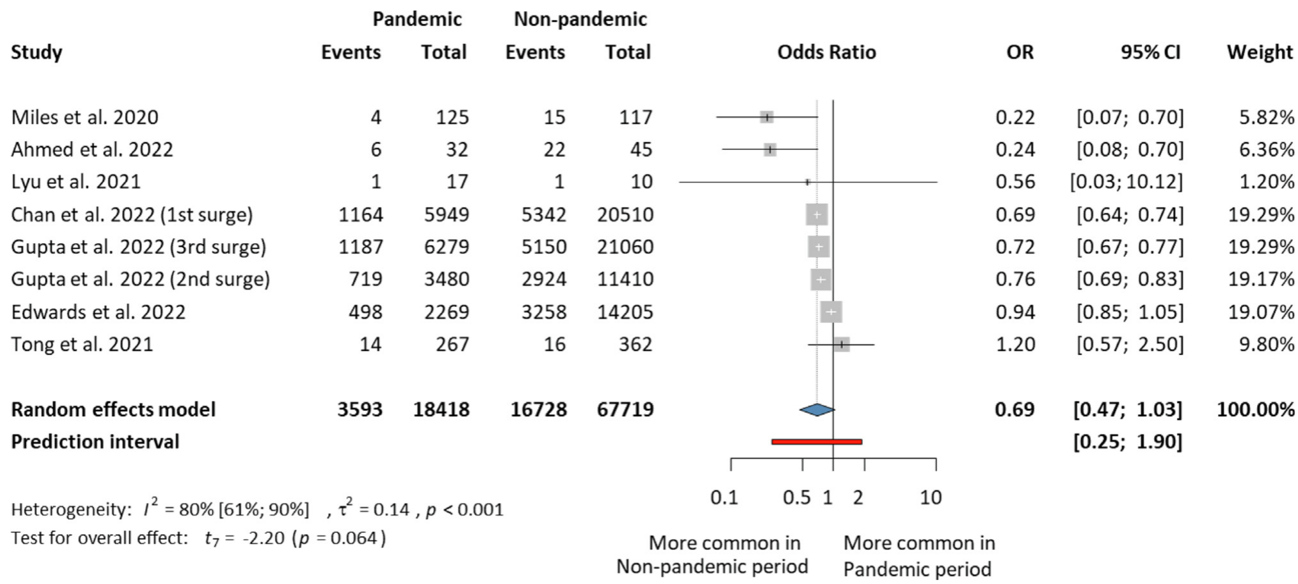



**Fig. 3 – Forest plot showing meta-analysis results for survival to hospital discharge (primary outcome).**

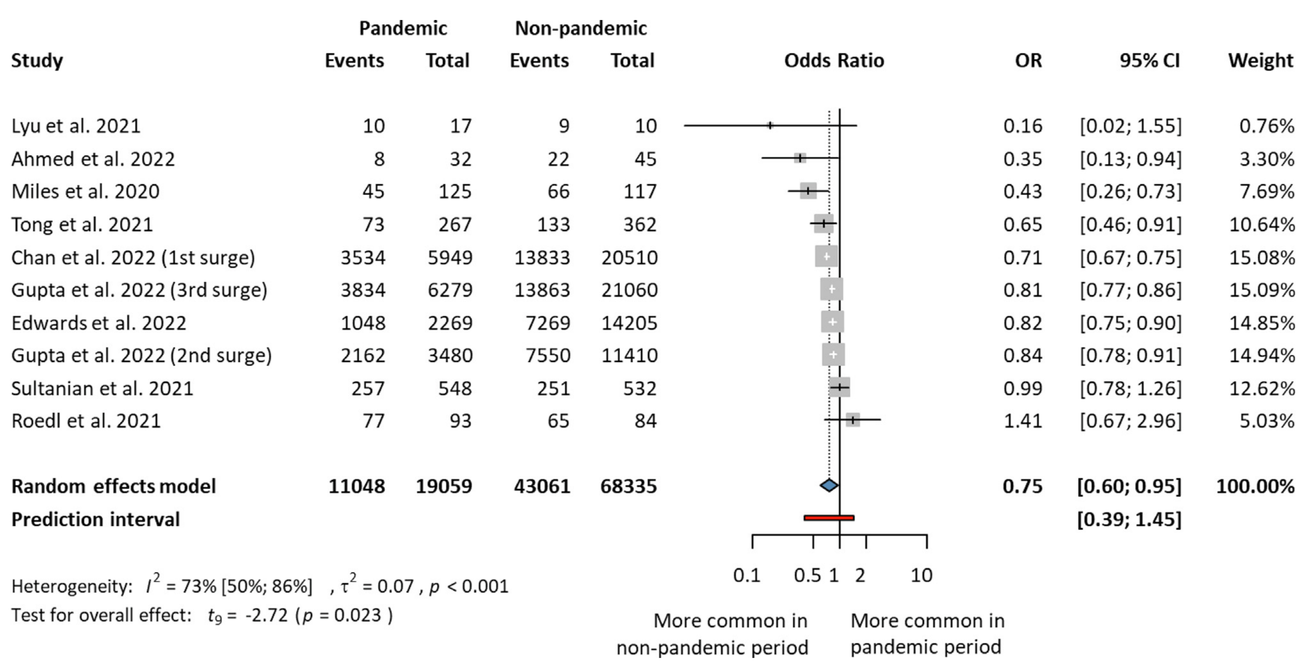



**Fig. 4 – Forest plot showing meta-analysis results for ROSC (secondary outcome).**

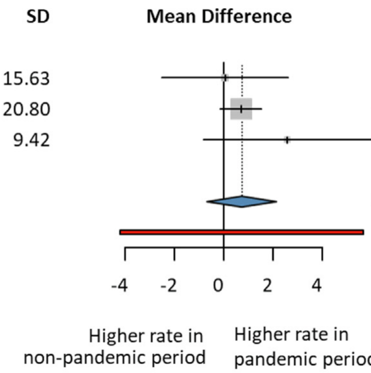
### *Rates of ROSC (secondary endpoint)*

Regarding our secondary outcomes, there were significantly lower rates of ROSC during the pandemic period. This was a special characteristic of whole study population, not only patients who had or were suspected to have COVID-19 disease.

There are many reasons assumed by the authors of the analysed papers for this observed decline in ROSC, which in developed countries showed a gradual improvement for many years up until the COVID-19 pandemic.[34] One possible answer is the changes that were made to the life support algorithms, an example of which is cited above. It is obvious that a resuscitation team who is having to fully don PPE before entering the room of a patient in cardiac arrest, will have a delay in commencing full and effective CPR when compared to normal practice prior to the pandemic. Of course, there was a pertinent need to protect staff; this should remain a priority. Nonetheless, as a healthcare community we have an opportunity to review the evidence of the effectivity of full PPE clothing for all resuscitation team and weigh up whether a similar approach would be needed in future pandemics, or if adjustments should be made. The other impact to making a fundamental change to resuscitation guidelines is that the healthcare providers will be less familiar to the changes especially as they may have had less time and

| Study | Pandemic N | Pandemic Mean | Pandemic SD | Non-pandemic N | Non-pandemic Mean | Non-pandemic SD | MD | 95% CI | Weight |
|---|---|---|---|---|---|---|---|---|---|
| Tong et al. 2021 * | 267 | 22.40 | 16.40 | 362 | 22.35 | 15.63 | 0.05 | [-2.49; 2.59] | 8.98% |
| Edwards et al. 2022 | 2362 | 17.00 | 18.60 | 14819 | 16.30 | 20.80 | 0.70 | [-0.12; 1.52] | 86.03% |
| Roedl et al. 2021 * | 93 | 9.23 | 13.54 | 84 | 6.64 | 9.42 | 2.58 | [-0.83; 5.99] | 4.99% |
| **Random effects model** | **2722** | | | **15265** | | | **0.74** | **[-0.67; 2.14]** | **100.00%** |
| **Prediction interval** | | | | | | | | **[-4.20; 5.68]** | |

Heterogeneity: $I^2$ = 0% [0%; 90%], $\tau^2$ < 0.01, $p$ = 0.494
Test for overall effect: $t_2$ = 2.25 ($p$ = 0.153)




If a study is indicated with * , then its mean and/or standard deviation is estimated from median, quartiles or minimum, maximum values. See raw data and methods.

**Fig. 5 – Forest plot showing meta-analysis results for length of resuscitation (secondary outcome).**

resources to fully train staff with the new guidelines. This may have led to a worsening of the human factor elements of a team resuscitation effort with all the drawbacks of wearing full PPE: difficult communication among team members, reaching fatigue and discomfort faster, and reduced visibility and hearing due to the use of hoods or visors.

### *Length of resuscitation effort (secondary endpoint)*

Although resuscitation length was longer during the COVID-19 pandemic according to two papers, our meta-analysis found it to be a non-significant increase.[12,28] The relationship between ROSC and length of resuscitation effort is a complex one. Generally, we should expect that the longer a resuscitation effort continues, the higher the likelihood is of achieving ROSC.[35] This is a favourable trend which is sadly not reflected in neurological outcomes and long term survival rates.[35,36] However, during the COVID-19 pandemic we found that resuscitation attempts were less successful at achieving ROSC, despite resuscitation attempts being of a comparable length of time. Many of the factors explored above, when considering the ROSC outcomes, could also contribute to this, the most obvious one perhaps being that there was a delay in starting resuscitation due to the team donning PPE outside the patient's bedspace. To mitigate this, all three papers measured resuscitation length from the time that basic resuscitation efforts began, rather than the time cardiac arrest was declared.

### *Outreach for the future*

As society moves on from the COVID-19 pandemic, policy makers and health leaders are keen to prioritise 'pandemic preparedness' in their manifestos. In order to do this, it is imperative to closely analyse the effects of the changes that were made in haste to hospital protocols globally during these surges, so that we can better understand their positive and negative impacts and plan for the future. The likelihood of the world facing another global pandemic is unfortunately high. A highly virulent, contagious viral pandemic remains one of the greatest threats to humanity. The significance of these results is to review the outcomes to changes to practice that were made out of necessity, with very little time. However, in this time of relative stability, we have an opportunity to learn, and to be better prepared. We recommend a careful inquiry into the evidence behind each of these protocol changes, with the aim of amending what can be safely modified for any subsequent pandemic. This will allow us to deliver the highly effective cardiac arrest care we have become accustomed to giving, meanwhile keeping our healthcare staff safe from infection with strong evidence-based precautions.

### *Limitations*

One of the limitations of our meta-analysis is that the 'pandemic' periods that were included in the studies are quite variable in their length and their timing throughout 2020, capturing some surge periods where there was a very noticeable sudden increase in hospital and ICU admissions, as well as some periods when hospitals had more manageable numbers of admissions. This makes it challenging to make direct comparisons about the pandemic itself as it was a global event which struck different countries at different times and with different severity. Furthermore, no randomised trials exist due to the nature of the topic hence only observational studies were included. Since we used the raw extracted data, instead of results of multivariate models, our results are burdened with the common biases of observational studies.

Another limitation that we have is that only three of our included papers did subgroup analyses between patients who did and did not have COVID-19 disease.[11,28,29] When this is done it is very useful as it allows us to differentiate how much of the results we see are a pathological problem, and how much they are a systems/resources problem. Many of our studies were registry studies from databases which did not reliably collect data on COVID-19 status. This is further compounded by different testing capabilities being available at different times. The corresponding benefit of registry studies however is the very large population sizes, and the reduction in selection bias, allowing us to draw more accurate conclusions and make generalisations accordingly.

A further limitation is regarding resuscitation time. No data was included about 'low flow time' or 'no flow time', prior to the resuscitation effort starting. This means there is no way to quantify the delay that was presumably incurred by the donning of PPE by the resuscitation team.

## Conclusion

In our meta-analysis, there was no change in survival to hospital discharge after in-hospital cardiac arrest during the COVID-19 pandemic when compared to the pre-pandemic period. However, the wide confidence intervals cannot rule out a clinically important lower survival rate during the pandemic. We found that rates of ROSC were significantly lower during the COVID-19 pandemic, however resuscitation times as well as efforts were comparable between the two periods, underlying the enthusiasm and commitment of the medical personnel.

## Ethical approval

No ethical approval was required for this systematic review with meta-analysis, as all data were already published in peer-reviewed journals. No patients were involved in the design, conduct, or interpretation of our study.

## Consent for publication

Not applicable.

## Availability of data and materials

The datasets used in this study can be found in the full-text articles included in the systematic review and meta-analysis.

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## CRediT authorship contribution statement

**Alexa Fekete-Győr:** Writing – original draft, Visualization, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Anna Seckington:** Writing – original draft, Investigation, Data curation. **Boldizsár Kiss:** Writing – review & editing, Writing – original draft, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Bettina Nagy:** Writing – review & editing. **Ádám Pál-Jakab:** Writing – review & editing. **Dénes Zsolt Kiss:** Writing – review & editing. **Péter Fehérvári:** Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Formal analysis, Data curation. **Endre Zima:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.resplu.2024.100756.

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