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COVID-19 in cardiac arrest and infection risk to rescuers: a systematic review

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Abstract

Background: There may be a risk of COVID-19 transmission to rescuers delivering treatment for cardiac arrest. The aim of this review was to identify the potential risk of transmission associated with key interventions (chest compressions, defibrillation, cardiopulmonary resuscitation) to inform international treatment recommendations.

Methods: We undertook a systematic review comprising three questions: 1) aerosol generation associated with key interventions; 2) risk of airborne infection transmission associated with key interventions; and 3) the effect of different personal protective equipment strategies. We searched MEDLINE, Embase, Cochrane Central Register of Controlled Trials, and the World Health Organisation COVID-19 database on 24th March 2020. Eligibility criteria were developed individually for each question. We assessed risk of bias for individual studies, and used the GRADE process to assess evidence certainty by outcome.

Results: We included eleven studies: two cohort studies, one case control study, five case reports, and three manikin randomised controlled trials. We did not find any direct evidence that chest compressions or defibrillation either are or are not associated with aerosol generation or transmission of infection. Data from manikin studies indicates that donning of personal protective equipment delays treatment delivery. Studies provided only indirect evidence, with no study describing patients with COVID-19. Evidence certainty was low or very low for all outcomes.

Conclusion: It is uncertain whether chest compressions or defibrillation cause aerosol generation or transmission of COVID-19 to rescuers. There is very limited evidence and a rapid need for further studies.

Review registration: PROSPERO CRD42020175594
Introduction

The World Health Organization (WHO) declared a Severe Acute Respiratory Syndrome Coronavirus two (SARS-CoV-2) pandemic on 11 March 2020. As of 4th April 2020, over one million individuals are reported to have been infected with Coronavirus Disease 2019 (COVID-19), of which over 55,000 have died. Data from China highlight the potential risk to healthcare workers when undertaking aerosol generating procedures (AGP) in COVID-19 patients.

The WHO has categorised cardiopulmonary resuscitation (CPR) as an aerosol generating procedure, requiring the wearing of respirator masks and other personal protective equipment (PPE). In contrast, some national guidance describes chest compressions and defibrillation as non-aerosol generating procedures. The discordance between WHO and national guidance may reflect differences in terminology, specifically WHO uses the term cardiopulmonary resuscitation to incorporate chest compressions, defibrillation and associated airway manoeuvres. Nevertheless, a 2012 review on Severe Acute Respiratory Syndrome (SARS) transmission identified uncertainty about the aerosol generating potential of chest compressions and defibrillation.

Current resuscitation guidelines highlight the importance of rescuer safety. Delaying the delivery of chest compressions and defibrillation for up to several minutes for healthcare workers to don personal protective equipment (PPE) will reduce the likelihood of patient survival. In contrast, the delivery of aerosol generating procedures to a patient infected with COVID-19 may place healthcare workers at risk. Driven by concern amongst the clinical community as to the optimum approach in cardiac arrest, the International Liaison Committee on Resuscitation (ILCOR) identified the urgent need for a review of current evidence to inform international resuscitation treatment recommendations in patients with known or suspected COVID-19.

Methods

We undertook a systematic review to explore three key questions relating to the transmission of COVID-19 in relation to chest compressions, defibrillation and CPR (box one). In view of the urgent need for evidence to inform international policy, the review was completed in four-days. Our review was prospectively registered with PROSPERO (CRD42020175594) and is written in accordance with the PRISMA statement.

Our first two research questions examined the association between key resuscitation interventions (chest compressions, defibrillation, CPR) and aerosol generation and airborne
transmission of infection. Our third question examined the effect of different personal protective equipment systems (supplementary information).

Search strategy
The information specialist iteratively developed the search strategy in consultation with other project team members and drawing on the strategy developed for a previous review. We undertook a single search to encompass all three review questions. We searched MEDLINE (OVID interface), Embase (OVID interface), Cochrane Central Register of Controlled Trials, and the Database of publications on coronavirus disease (COVID-19) developed by the World Health Organisation, all from inception to 24th March 2020. We updated the search using the WHO COVID-19 database on 6th April 2020. Our full record of searches is included in the supplementary information.

In addition, we used the Science Citation Index (Web of Science) to identify additional citations from a relevant Canadian review published in 2011. We also assessed the reference lists of three relevant reviews. Finally, we identified additional citations through consultation with subject experts.

Study eligibility
We assessed study inclusion using pre-defined study criteria based on the research question (see supplementary information). For all questions, we included randomised controlled trials and non-randomised studies (e.g., interrupted time series, controlled before-and-after studies, cohort studies). For questions one and two, we additionally included case reports and case-series. For questions one and three we included cadaver studies, and for question three included manikin studies.

For all studies, we required that the study be set in the context of a cardiac arrest, with delivery of chest compressions and/or defibrillation and/or CPR by any individual (healthcare worker or lay person). For infection transmission, we included all types of infection (viral/bacterial/fungal) with presumed airborne transmission. We imposed no date or language restrictions provided there was an English language abstract.

Article selection
On search completion, we used EndNote X9 software to systematically identify and remove duplicate citations. Titles/abstracts were reviewed independently by two reviewers from the team (two of STP/AG/AM), and obviously irrelevant citations excluded. We subsequently sourced full-text papers, with eligibility independently assessed by two reviewers (AG/AM) against pre-specified criteria. At each stage, disagreements were discussed and reconciled or referred to a third reviewer for adjudication (KC).

Data extraction and analysis
A single reviewer from the team (one of STP/AG/KF/OO) extracted data from eligible full-text papers using a piloted data extraction form. Accuracy was assessed by a second reviewer. We extracted key data from each study relevant to the specific research question, including details of population, exposure, intervention/comparator, outcome and type of infection. Disagreements between reviewers were resolved by consensus, or consultation with a third reviewer (KC). Where a publication was eligible for inclusion for more than one research question, data were extracted into a single data extraction form record.

Risk of bias assessment and assessment of certainty of evidence
A single reviewer from the team (one of STP/AG/KF/OO) assessed risk of bias of full-text papers using quality assessment tools that were appropriate for each study design. We used the modified Cochrane Collaboration Risk of Bias tool for randomised controlled trials; the Evidence Partners tool for case-control studies and cohort studies, and the Murad tool for case reports and case series. Assessment accuracy was evaluated by a second reviewer (one of STP/AG/KF/OO). We used the GRADE system to assess certainty of evidence per outcome (outcomes for each question are listed in box one).

Data analysis
We anticipated that identified studies would be heterogeneous. We assessed studies for clinical, methodological, and statistical heterogeneity. Where not precluded by heterogeneity, we intended to consider pooling data in a meta-analysis using a random-effects model. In the likely event that a meta-analysis was precluded, we planned a narrative synthesis.

Results

Searches of databases and other sources identified 749 citations. Following removal of duplicates and screening of titles/abstracts, we retrieved 38 full-text papers of which 11 were eligible for inclusion in the review (see Figure 1). The electronic supplement includes characteristics of included studies, and a list of reasons for excluding studies at full text review.

Of the 11 papers, we included two studies for question one, eight for question two, and three for question three. Both papers included in question one were also included in question two. We included five case reports, three observational studies, and three manikin randomised controlled trials. None of the included papers described a patient with COVID-19. Study risk of bias assessments and GRADE tables are included in the electronic supplement.

Question one - aerosol generation
We did not find any direct evidence that chest compressions or defibrillation either did or did not generate aerosols. We included data from two case reports providing indirect evidence of aerosol generation. In both cases, a healthcare worker contracted an infection from patients undergoing CPR, which the report authors attribute to aerosol generation. In both cases, patients underwent prolonged resuscitation attempts that likely incorporated ventilation. Neither patient is reported as receiving defibrillation. In one case, the healthcare worker is described as wearing appropriate PPE. Evidence certainty was categorised as very low.

**Question two - transmission of infection**

We did not find any direct evidence that chest compressions or defibrillation either are or are not associated with transmission of infection. We included indirect evidence from eight studies: two retrospective cohort studies, one case-control study, and five case reports. Studies are summarised in Table one.

In the two cohort studies, the authors compared SARS infection transmission in individuals who were exposed and not exposed to specific interventions. Both studies were undertaken in Canada and examined SARS transmission. In one study of 697 healthcare workers, only nine individuals were exposed to chest compressions and four were exposed to defibrillation. In the other study of 43 healthcare workers, eight individuals were exposed to CPR and defibrillation. Neither study identified a statistically significant association between these exposures and infection transmission. Key study limitations were the lack of clear definition of exposures and inability to account for multiple exposures.

In the case-control study, 51 healthcare workers with probable SARS were compared with 477 healthcare workers without infection. There was a correlation between giving chest compressions and tracheal intubation, indicating that often healthcare workers who were exposed to one were often exposed to the other. A multivariate analysis suggested that exposure to chest compressions was associated with an increased odds of probable SARS infection (odds ratio 4.52, 95% confidence interval 1.08 to 18.81). However, the omission of tracheal intubation in the multivariate model may mean the reported risk is primarily driven by tracheal intubation or other airway manoeuvres (e.g. bag-mask ventilation) associated with chest compressions. Questionnaires that collected details of exposure were completed one to four months after exposure, and so may be subject to recall bias.

In the five case reports, the reported transmissions were: Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome (MERS), tuberculosis, novel bunyavirus, designated Severe Fever with Thrombocytopenia Syndrome (SFTS) virus, and Panton-Valentine leucocidin. The use of PPE varied across reports. In none of the cases was delivery of defibrillation described. In all cases, the patients appear to have received airway manoeuvres alongside chest compressions. In one case report, a nurse
wearing full PPE delivered chest compressions to a patient with SARS for 15-minutes and subsequently developed symptoms of infection. However, based on timings presented in the study it is likely the nurse was also present in the room during airway manoeuvres.

All studies and reports may be subject to recall bias, both in relation to the PPE worn and the procedures undertaken. Evidence certainty was assessed as very low.

**Question three- personal protective equipment strategies**

For question three, we included three manikin RCTs that recruited 104 participants.\(^{22,29,30}\) One study was individually randomised,\(^{30}\) and the other two were crossover RCTs.\(^{22,29}\) All studies simulated chest compression or CPR delivery. Two studies compared different types of respirator\(^{22,29}\) and one study compared different types of gown.\(^{30}\) Characteristics of included studies and results are shown in table two.

The outcome of infection transmission was not evaluated in any study.

No studies examined infection rates with different types of PPE.

The outcome of PPE effectiveness was evaluated in one randomised crossover trial that examined the performance of different N95 (or higher-level) mask types (cup-type, fold-type, valve-type) during chest compressions (see Table 2).\(^{29}\) The primary outcome was the adequate protection rate (APR) defined as the proportion of participants achieving a good fit. During chest compression delivery, the APR differed between study arms (cup-type: 44.9% (SD 42.8) v fold-type: 93.2% (SD 21.7) v valve-type 59.5% (SD 41.7), \(P<0.001\) for difference between groups). For all mask types, APR was lower during chest compression delivery than at baseline.

The outcome of CPR quality was evaluated in three studies, two studies reported time taken to deliver key interventions,\(^{28,30}\) and one study by Shin and colleagues (2017), examined CPR quality\(^{29}\) with and without PPE (see Table 2).\(^{22,30}\) In one study, delivery of pre-hospital paediatric life support (including bag mask ventilation, defibrillation, tracheal intubation, and drug administration) was quickest in individuals not wearing PPE (Control: 261 seconds (SD 12) v Conventional air-purifying respirators 275 seconds (SD 9) v air-purifying respirator-hood 286 seconds (SD 13), \(p<0.0001\)).\(^{28}\) In firefighters, the type of gown used, alongside other PPE, influenced time to commence chest compressions (standard gown: 71 seconds (95% CI 66–77) v modified gown 59 seconds (95% CI 54–63) v no gown 39 seconds (95% CI 34–43), \(p<0.001\)).\(^{30}\) In the trial by Shin,\(^ {29}\) there was no difference in CPR quality between groups.

Discussion
In this systematic review of 11-studies, we identified evidence that chest compressions may generate aerosols and are associated in some circumstances, with transmission of infection to rescuers. However, in all cases, it is likely there was simultaneous exposure to airway manoeuvres, such that the isolated effect of either chest compressions or defibrillation could not be reliably identified. Evidence from manikin studies showed that the donning of PPE delays the initiation of treatment. Furthermore, PPE may, in many cases, be less effective during chest compressions because of the risk of mask slippage, highlighting the need for careful donning and ongoing monitoring of effectiveness.

Our findings are broadly similar to those of a Canadian review completed in 2012 which found no statistically significant association between SARS transmission and chest compression delivery (odds ratio 1.4, 95% confidence interval 0.2 to 11.2) or SARS transmission and defibrillation (odds ratio 2.5, 95% confidence interval 0.1 to 43.9). This finding was based on data from three observational studies.\textsuperscript{24, 25, 27} Whilst we included the same studies in this review, we decided that it was not methodologically appropriate to pool data between studies because of the likelihood that healthcare workers were exposed to multiple aerosol generating procedures and owing to the very low rates of disease transmission. For example, in one study, only one healthcare worker was infected in both the chest compression exposed and defibrillation exposed groups. Our confidence in any pooled estimates would be very low.

Since completing the review, we identified via ongoing literature scanning a retrospective cohort study of 72 healthcare workers (28 infected with COVID-19; 44 not infected) that met inclusion criteria for question two.\textsuperscript{31} Healthcare workers experienced multiple potential exposures as part of their clinical duties. Single non-infected individual was exposed to CPR. The risk of COVID-19 transmission in individuals exposed to CPR was not significant (relative risk 0.63, 95% confidence interval 0.06 to 7.08). Whilst this additional study does not alter the findings of our review, it highlights the rapid publication of much needed new data about COVID-19.

Our finding that there is no direct evidence that chest compressions and defibrillation either are or are not aerosol generating procedures is important. However, this absence of evidence should not be interpreted as providing evidence that these procedures are not aerosol generating.

From a physiological perspective, the generation of aerosols by chest compressions is clinically plausible, because changes in thoracic pressure during chest compressions generate airflow and small exhaled tidal volumes.\textsuperscript{32} Evidence from the physiotherapy literature shows that manual chest physiotherapy techniques do generate aerosols.\textsuperscript{33} In contrast, for defibrillation,\textsuperscript{32} the mechanism for aerosol generation during defibrillation is
less clear. However, tonic muscle spasms caused by defibrillation could conceivably generate a small amount of airflow.

For policy makers, there is a need to balance the known risk of treatment delays if PPE is donned before chest compressions and defibrillation are delivered, against the unknown, but potential, risk of COVID-19 transmission to rescuers. This risk may also extend beyond the rescuer, with additional risk of onward transmission to other healthcare workers, patients, and the wider community. The known risk associated with treatment delay relate to the time taken to don PPE and the challenges of delivering effective treatment whilst wearing PPE. Importantly, we found evidence that delivery of chest compressions may reduce the effectiveness of face masks.

This review highlights the urgent need for research to identify and quantify aerosol generation associated with chest compressions and defibrillation. This could be undertaken using observations in clinical settings, or cadaver or animal models. Such work is essential to better understand the potential risk to the rescuer when undertaking these procedures.

The aim of this review was to identify the available evidence relating to aerosol generation, infection transmission and protection afforded by personal protective equipment. Beyond this specific focus, interpretation of the evidence to guide clinical practice guidelines will need careful consideration of the prevalence of COVID-19 in specific settings, the likelihood that the resuscitation provider has already been exposed (e.g. close household contact), the availability of personal protective equipment, the time taken to train staff in its use, and the values and preferences of the wider community where any guidance will be implemented. In addition the balance of risks and benefits for specific interventions will vary; for example, early defibrillation for a witnessed cardiac arrest compared with cardiopulmonary resuscitation for cardiac arrest secondary to refractory hypoxia. As identified in this review, cardiopulmonary resuscitation is also a complex intervention comprising ventilation, chest compressions, drug therapy and defibrillation, which become difficult to separate out without reducing overall clinical effectiveness. Finally, with over one million out of hospital cardiac arrests each year around the world and the critical importance of the community’s willingness to commence chest compressions and defibrillation, long term unintended consequences of restrictive policies need to be considered and necessitate clear communication strategies with local communities.

Our review has three key limitations. Firstly, in order to provide an urgent review of evidence to meet the needs of the international resuscitation community, we were unable to undertake simultaneous independent data extraction and risk of bias assessments. Instead, we performed single assessments followed by independent accuracy assessments. Secondly, for expediency, we undertook a single search to cover all three questions. If more time had been available, we might have considered an individual search strategy for each
question which may have increased search sensitivity. To mitigate this, we undertook citation tracking of key papers to identify citations not identified in the search. Thirdly, the available evidence was typically at high risk of bias and indirect, which limits the inferences that can be drawn. This is reflected in our assessment that evidence certainty for all outcomes was low or very low.

In conclusion, we identified very limited evidence that does not enable us to estimate the risk of chest compressions or defibrillation in relation to aerosol generation and COVID-19 transmission from the patient to the rescuer. In developing practice recommendations, guideline writers must balance an unknown potential infection risk to rescuers against the known risk to the patient from treatment delays.

Declaration of conflicts of interest:
JN is Editor-in-Chief of Resuscitation and receives payment from the publisher Elsevier. JS and GDP are Editors of Resuscitation and receive payment from the publisher Elsevier. JS is chair of the ILCOR ALS Task Force, and GDP is co-chair of ILCOR. KC, STP, AG, KF, OO, RC, AM and PM have no conflicts of interest to declare.

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Box one: research questions

| Research question one |
|-----------------------|
| In individuals in any setting, is delivery of 1) chest compressions, 2) defibrillation or 3) cardiopulmonary resuscitation associated with aerosol generation? |

| Research question two |
|-----------------------|
| In individuals in any setting wearing any/no personal protective equipment, is delivery of 1) chest compressions, 2) defibrillation or 3) cardiopulmonary resuscitation associated with transmission of infection? |

| Research question three |
|-------------------------|
| In individuals delivering chest compressions and/or defibrillation and/or CPR in any setting, does wearing of personal protective equipment compared with wearing any alternative system of personal protective equipment or no personal protective equipment affect infection with the same organism as the patient, personal protective equipment effectiveness, or quality of CPR? |
Table 1. Results for question two, investigating the association between chest compressions, defibrillation, and cardiopulmonary resuscitation with transmission of infection

| Study, Design/setting | Population | PPE worn by rescuers? | Exposure | Infection-transmitted | Risk of infection in unexposed | Risk of infection in exposed |
|-----------------------|------------|------------------------|----------|-----------------------|--------------------------------|------------------------------|
| Raboud et al 2010     | Retrospective cohort 20 hospitals, Canada | 624 HCWs who provided care to 45 laboratory confirmed SARS patients | Not recorded | Chest compression and defibrillation (and 32 other activities) | SARS | No chest compression: 25/615 (4%) No defibrillation: 25/620 (4%)† | Chest compression: 1/9 (11%) | Defibrillation: 1/4 (25%) |
| Loeb et al 2004       | Retrospective cohort 2 hospitals, Canada | 32 nurses entering rooms with SARS patients | Variable | CPR and defibrillation (and 30 other activities) | SARS | No CPR (but other exposures): 8/29 (28%) No defibrillation (but other exposures): 8/30 (27%)† | CPR: 0/3 | Defibrillation: 0/2 |
| Liu et al 2009        | Case control 1 hospital, China | 477 HCWs (51 case/ 426 control) | Variable | Chest compression (and 27 other factors) | SARS | 11% (numerator and denominator not reported)† | 5/15 (33%) |
| Case reports          |            |                        |          |                       |                                |                              |
| Chalumeau et al 2005  | Case report Hospital, France | 15 HCWs- performed CPR on the index patient | None | CPR | Panton-Valentine leukocidin-producing S. aureus pneumonia | 1/15 (6.7%) Case was in the physician who performed tracheal intubation |
| Christian et al 2004  | Case report Hospital, Canada | 9 HCWs- performed CPR on the index patient | Full | CPR | SARS | 1/9 (11%)- 5 tested; 4 refused Additional ICU nurse (delivered compressions only for 10-15min) developed symptoms with indeterminate SARS serologic findings |
| Kim et al 2015        | Case report Hospital, Korea | 7 HCWs- performed CPR on the index patient | Variable | CPR | Novel bunyavirus, designated SFTS virus | 4/7 (57.1%) |
| Knapp et al 2016      | Case report Pre-hospital, Germany | 3 HCWs- performed CPR on index patient | Variable | CPR | TB | 2/3 (66.7%) |
| Nam et al 2017        | Case report Hospital, Korea | 6 HCWs involved in CPR | Full | CPR | MERS | 1/6 (16.7%) |

† - Multiple other exposures. CPR- Cardiopulmonary defibrillation. SARS-Severe acute respiratory syndrome. TB- Tuberculosis. MERS- Middle East Respiratory Syndrome. ICU- Intensive Care Unit
Table 1. Results of studies included in research question 3: comparison of personal protective equipment strategies effect on infection, PPE effectiveness, and quality of CPR

| Study                  | Design/ setting       | Population (clinical) | Procedure                                      | Intervention and comparator                                                                 | Outcomes measured                                                                 |
|------------------------|-----------------------|-----------------------|------------------------------------------------|---------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Schumacher et al 2013  | Manikin RCT (crossover) | 16 paramedics         | Paediatric cardiac arrest (airway management, defibrillation, drug administration)-paediatric manikin | Intervention group 1: Conventional air-purifying respirators (APR)  
Intervention group 2: Modern loose-fitting air-purifying respirator-hoods (PAPR-hood)  
Comparator: no PPE | Treatment duration:  
Control: 261 seconds (SD 12)  
APR: 275 seconds (SD 9)  
PAPR-hood: 286 seconds (SD 13)  
P<0.0001 for difference between groups. |
| Shin et al 2017        | Manikin RCT (crossover) | 30 healthcare workers | Simulated chest compressions with real-time feedback- adult manikin | Intervention group 1: cup-type respirator mask preformed into a cup shape  
Intervention group 2: fold-type respirator mask that is flexible and 3-folded  
Intervention group 3: valve-type respirator mask similar to the fold-type respirator with valve | Adequate protection rate (%) during chest compressions:†  
Cup-type: 44.9% (SD 42.8)  
Fold-type: 93.2% (SD 21.7)  
Valve-type 59.5% (SD 41.7%)  
P<0.001 for difference between groups.  
Compression quality similar between groups |
| Watson et al 2008      | Manikin RCT Canada     | 58 firefighters        | Simulated CPR-manikin                          | Intervention Group 1: Standard gown plus N95 respirator, gloves and eye protection  
Intervention group 2: Modified gown and an N95 respirator, gloves and eye protection  
Comparator: No gown, but PPE included an N95 respirator, gloves and eye protection | Time to chest compressions (seconds):  
Standard gown: 71 (95% CI 66–77)  
Modified gown: 59 (95% CI 54–63)  
No gown: 39 (95% CI 34–43)  
P<0.001 for difference between groups. |

RCT - Randomised Controlled Trial; SD - Standard Deviation; PPE- Personal protective equipment; 95% CI- 95% confidence interval  
† Fit factor calculated as concentration of particles outside respirator divided by concentration inside respirator (maximum value - 200)-fit factor > 100 considered adequate protection  
‡ Modified gown comprises re-tied neck ties waist ties that are tied at front.
Records identified through database searching (n = 688)

Records after duplicates removed (n = 545)

Records screened (n = 545)

Full-text articles assessed for eligibility (n = 38)

Studies included in qualitative synthesis (n = 11)

Full-text articles excluded, with reasons (n = 27)
- Non-eligible study design, e.g., review (n = 6)
- Non-eligible exposure (n = 14)
- No relevant outcome (n = 4)
- No comparator group (n = 3)

Studies included in quantitative synthesis (n = 0)

Additional records identified through other sources
- Expert consultation (n = 3)
- Citation searching (n = 60)

Records excluded (n = 507)
Supplementary information

Title
COVID-19 in cardiac arrest and infection risk to rescuers: a systematic review

Contents

1. Search strategy (full record of search)
2. Full details of the study eligibility criteria
3. List of studies excluded at full text review
4. Quality assessment of included studies
5. GRADE tables
1. **Search strategy (full record of search)**

**Medline (Ovid)**

Search date: 24/03/2020
Database: Ovid MEDLINE(R) ALL <1946 to March 23, 2020>

Search Strategy:

1. exp cardiopulmonary resuscitation/ (17618)
2. heart arrest/ (28725)
3. out-of-hospital cardiac arrest/ (4046)
4. electric countershock/ (14654)
5. defibrillators/ (1774)
6. (cardiopulmonary resuscitation or defibrillat* or CPR or chest compression* or ((cardiac or cardiopulmonary) adj arrest)).ti,ab,kf. (70049)
7. 1 or 2 or 3 or 4 or 5 or 6 (91442)
8. exp Health personnel/ (505028)
9. exp police/ (5056)
10. exp firefighters/ (1000)
11. (health care worker* or healthcare worker* or health care provider* or healthcare provider* or physiotherap* or dentist* or nurse* or doctor* or physician* or health personnel or medical personnel or hospital personnel or hospital worker* or staff or healthcare professional* or health care professional* or care giver* or caregiver* or paramedic* or therapist* or bystander* or police* or firefighter* or layperson* or laypeople or public).ti,ab,kf. (1497414)
12. 8 or 9 or 10 or 11 (1743878)
13. cadaver/ (40334)
14. manikins/ (4981)
15. (cadaver* or manikin* or mannequin*).ti,ab,kf. (63603)
16. 13 or 14 or 15 (80361)
17. 12 or 16 (1819209)
18. occupational exposure/ (53787)
19. air microbiology/ (7553)
20. infectious disease transmission/ (9010)
21. infection control/ (23324)
22. exp cross infection/ (58476)
23. Disease Outbreaks/ (78245)
24. Aerosols/ (29986)
25. ((aerosol* or cough* or droplet* or infection* or infectious or disease*) adj3 (generat* or induc* or stimulat* or produc*or creat* or respirable range* or dispers* or transmission or transmitted or transmit or spread* or disseminat* or count* or precaution* or control* or inhibit* or prevent* or reduc*)).ti,ab,kf. (437175)
26. cross infection.ti,ab,kf. (2969)
27. 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 (642342)
28. 17 and 27 (91209)
29. Infectious Disease Transmission, Patient-to-Professional/ (3835)
30. 28 or 29 (93257)
Supplementary information

31 7 and 30 (184)
32 human influenza/ (48279)
33 exp Influenza A virus/ (42980)
34 SARS virus/ (2899)
35 Severe Acute Respiratory Syndrome/ (4470)
36 exp coronavirus/ (11425)
37 exp Coronavirus Infections/ (9723)
38 Middle East Respiratory Syndrome Coronavirus/ (968)
39 exp tuberculosis/ (190319)
40 exp pneumonia/ (90583)
41 (influenza* or H1N1 or tuberculosis or pneumonia or pneumococcus or severe acute respiratory syndrome or SARS or MERS or avian flu or swine flu or rhinovirus or acute respiratory infection*).ti,ab,kf. (450916)
42 (((corona* or corono*) adj1 (virus* or viral* or virinae*)) or coronavirus* or coronovirus* or coronavirinae* or Coronavirus* or Coronovirus* or Wuhan* or Hubei* or Huanan or "2019-nCov" or 2019nCoV or nCoV2019 or "nCoV-2019" or "COVID-19" or COVID19 or "CORVID-19" or CORVID19 or "WN-CoV" or WNCov or "HCoV-19" or HCoV19 or CoV or "2019 novel**" or Ncov or "n-cov" or "SARS-CoV-2" or "SARSCoV-2" or "SARS-CoV2" or "SARS-CoV2" or SARS-CoV19 or "SARS-CoV-19" or "SARSCoV-19" or "SARS-CoV-19" or Ncovor or Ncorona* or Ncorono* or NcovWuhan* or NcovHubei* or NcovChina* or NcovChinese*).ti,ab,kf. (17835)
43 Rhinovirus/ (3680)
44 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 (544638)
45 7 and 17 and 44 (141)
46 31 or 45 (307)

Embase (Ovid)

Search date: 24/03/2020
Database: Embase Classic+Embase <1947 to 2020 Week 12>
Search Strategy:

1 *resuscitation/ (56156)
2 *heart arrest/ (26461)
3 *cardiopulmonary arrest/ (1142)
4 *out of hospital cardiac arrest/ (5817)
5 *defibrillation/ (4586)
6 exp *external defibrillator/ (706)
7 (cardiopulmonary resuscitation or defibrillat* or CPR or chest compression* or ((cardiac or cardiopulmonary) adj arrest)).ti,ab,kw. (112209)
8 1 or 2 or 3 or 4 or 5 or 6 or 7 (154423)
9 exp *health care personnel/ (518538)
10 exp *police/ (3765)
11 *fire fighter/ (1532)
12 (health care worker* or healthcare worker* or health care provider* or healthcare provider* or physiotherap* or dentist* or nurse* or doctor* or physician* or health personnel or medical personnel or hospital personnel or hospital worker* or staff or...
healthcare professional* or health care professional* or care giver* or caregiver* or paramedic* or therapist* or bystander* or police* or firefighter* or layperson* or laypeople or public).ti,ab,kw. (1968709)

13 9 or 10 or 11 or 12 (2263394)
14  *cadaver/ (5746)
15  exp *manikin/ (382)
16  (cadaver* or manikin* or mannequin*).ti,ab,kw. (84125)
17  14 or 15 or 16 (86517)
18  13 or 17 (2343670)
19  *airborne infection/ (795)
20  *hospital infection/ (19842)
21  *virus transmission/ (12660)
22  *bacterial transmission/ (2301)
23  *disease transmission/ (9518)
24  *aerosol/ (24924)
25  ((aerosol* or cough* or droplet* or infection* or infectious or disease*) adj3 (generat* or induc* or stimulat* or produc*or creat* or respirable range* or dispers* or transmission or transmitted or transmit or spread* or disseminat* or count* or precaution* or control* or inhibit* or prevent* or reduc*)).ti,ab,kw. (588510)
26  19 or 20 or 21 or 22 or 23 or 24 or 25 (644165)
27  18 and 26 (88591)
28  8 and 27 (240)
29  exp *influenza virus/ (16773)
30  exp *influenza/ (51692)
31  *parainfluenza virus infection/ (258)
32  *severe acute respiratory syndrome/ (4499)
33  exp *coronavirus/ (6085)
34  exp *Coronavirus Infection/ (6335)
35  *Middle East respiratory syndrome/ (536)
36  *tuberculosis/ (88342)
37  *lung tuberculosis/ (50737)
38  *drug resistant tuberculosis/ (1185)
39  *streptococcus pneumoniae/ (15862)
40  *pneumonia/ (49217)
41  *respiratory syncytial pneumovirus/ (6459)
42  (influenza* or H1N1 or tuberculosis or pneumonia or pneumococcus or severe acute respiratory syndrome or SARS or MERS or avian flu or swine flu or rhinovirus or acute respiratory infection*).ti,ab,kw. (565099)
43  (((corona* or corona*) adj1 (virus* or viral* or virinae*)) or coronavirus* or coronovirus* or coronovirus* or coronovirinae* or Coronavirus* or Coronavirus* or Wuhan* or Hubei* or Huanan or "2019-nCoV" or 2019nCoV or nCoV2019 or "nCoV-2019" or "COVID-19" or COVID19 or "CORVID-19" or CORVID19 or "WN-CoV" or WNCov or "HCoV-19" or HCoV19 or CoV or "2019 novel*" or Ncov or "n-cov" or "SARS-CoV-2" or "SARSCoV-2" or "SARSCoV2" or "SARS-CoV2" or SARSCov19 or "SARS-Cov19" or "SARS-CoV19" or "SARS-Cov-19" or SARS-Cov19 or Ncovaor or Ncorono* or Ncorono* or NcovWuhan* or NcovHubei* or NcovChina* or NcovChinese*).ti,ab,kw. (20813)
44  *rhinovirus/ (2144)
Supplementary information

45  29 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 (639389)
46  8 and 18 and 45 (357)
47  28 or 46 (568)
48  limit 47 to (conference abstract or conference paper or "conference review") (294)
49  47 not 48 (274)

Cochrane Central Register of Controlled Trials (Cochrane Library via Wiley)

Search date: 25/03/2020

| ID | Search                  | Hits  |
|----|-------------------------|-------|
| #1 | [mh "cardiopulmonary resuscitation"] | 1019  |
| #2 | [mh "heart arrest"]     | 1053  |
| #3 | [mh ^"out-of-hospital cardiac arrest"] | 364   |
| #4 | [mh ^"electric countershock"] | 858   |
| #5 | [mh ^defibrillators]     | 81    |
| #6 | ("cardiopulmonary resuscitation" or defibrillat* or CPR or (chest next compression*)) or ((cardiac or cardiopulmonary) next arrest)):ti,ab,kw | 8632  |
| #7 | #1 or #2 or #3 or #4 or #5 or #6 | 9168  |
| #8 | [mh "health personnel"] | 8364  |
| #9 | [mh police]             | 65    |
| #10| [mh firefighters]       | 37    |
| #11| ("health care" next worker*) or (healthcare next worker*) or ("health care" next provider*) or (healthcare next provider*) or physiotherap* or dentist* or nurse* or doctor* or physician* or "health personnel" or "medical personnel" or "hospital personnel" or (hospital next worker*) or staff or (healthcare next professional*) or ("health care" next professional*) or (care next giver*) or caregiver* or paramedic* or therapist* or bystander* or police* or firefighter* or layperson* or laypeople or public):ti,ab,kw | 137610|
| #12| #8 or #9 or #10 or #11  | 138631|
| #13| [mh ^cadaver]           | 580   |
| #14| [mh ^manikins]          | 839   |
| #15| (cadaver* or manikin* or mannequin*):ti,ab,kw | 4097  |
| #16| #13 or #14 or #15      | 4097  |
| #17| #12 or #16             | 141620|
| #18| [mh ^"occupational exposure"] | 502   |
| #19| [mh ^"air microbiology"] | 65    |
| #20| [mh ^"infectious disease transmission"] | 106   |
| #21| [mh ^"infection control"] | 523   |
| #22| [mh "cross infection"] | 1241  |
| #23| [mh ^"disease outbreaks"] | 192   |
| #24| [mh ^aerosols]          | 2039  |
| #25| ((aerosol* or cough* or droplet* or infection* or infectious or disease*) near/3 (generat* or induc* or stimulat* or produc* or creat* or (respirable next range*) or dispers* or transmission or transmitted or transmit or spread* or disseminat* or count* or precaution* or control* or inhibit* or prevent* or reduc*)):ti,ab,kw | 103502|
Supplementary information

#26 "cross infection":ti,ab,kw 1218
#27 #18 or #19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 106205
#28 #17 and #27 11540
#29 [mh ^"Infectious Disease Transmission, Patient-to-Professional"] 59
#30 #28 or #29 11559
#31 #7 and #30 72
#32 [mh ^"human influenza"] 2595
#33 [mh "Influenza A virus"] 836
#34 [mh ^"SARS virus"] 9
#35 [mh ^"Severe Acute Respiratory Syndrome"] 33
#36 [mh coronavirus] 11
#37 [mh "Coronavirus Infections"] 12
#38 [mh ^"Middle East Respiratory Syndrome Coronavirus"] 1
#39 [mh tuberculosis] 557
#40 [mh pneumonia] 3428
#41 (influenza* or H1N1 or tuberculosis or pneumonia or pneumococcus or "severe acute respiratory syndrome" or SARS or MERS or "avian flu" or "swine flu" or rhinovirus or ("acute respiratory" next infection*)):ti,ab,kw 29310
#42 (((corona* or corono*) near/1 (virus* or viral* or virinae*)) or coronavirus* or coronavirus* or coronavirinae* or Coronavirus* or Coronavirus* or Wuhan* or Hubei* or Huanan or "2019-nCoV" or 2019nCoV or nCoV2019 or "nCoV-2019" or "COVID-19" or COVID19 or "CORVID-19" or CORVID19 or "WN-CoV" or WNCoV or "HCoV-19" or HCoV19 or CoV or "2019 novel*" or Ncov or "n-cov" or "SARS-CoV-2" or "SARSCoV-2" or "SARSCoV2" or "SARS-CoV2" or SARSCov19 or "SARS-CoV-19" or SARS-CoV19 or "SARS-CoV-19" or "SARS-CoV-19" or Ncovor or Ncorona* or Ncorono* or NcovWuhan* or NcovHubei* or NcovChina* or NcovChinese*):ti,ab,kw 412
#43 [mh ^Rhinovirus] 144
#44 #32 or #33 or #34 or #35 or #36 or #37 or #38 or #39 or #40 or #41 or #42 or #43 29660
#45 #7 and #17 and #44 39
#46 #31 or #45 106

Trials: 105

Database of publications on coronavirus disease (COVID-19) developed by WHO
https://www.who.int/emergencies/diseases/novel-coronavirus-2019/global-research-on-novel-coronavirus-2019-ncov

Search date: 25/03/2020, updated 06/04/2020

Search:
resuscitation 0 (2 found during update, excluded by two reviewers STP/AG)
heart arrest 0
cardiac arrest 0
cardiopulmonary arrest 0
defibrillator 0
Supplementary information

defibrillators 0
defibrillation 0
defibrillate 0
CPR 0 (1 found during update, excluded by two reviewers STP/AG)
chest compression 0
chest compressions 0

Forward citation searching
Science Citation Index (WoS)
Search date: 23 March 2020

Citation searches on CADTH review and related PloS ONE article 60

Reference checking

The following reviews were checked:

CADTH. Aerosol-Generating Procedures and Risk of Transmission of Acute Respiratory Infections: A Systematic Review. 2011
https://www.cadth.ca/media/pdf/M0023__Aerosol_Generating_Procedures_e.pdf

Tran K, Cimon K, Severn M, Pessoa-Silva CL, Conly J. Aerosol generating procedures and risk of transmission of acute respiratory infections to healthcare workers: a systematic review. PLoS ONE 2012;7(4):e35797. https://dx.doi.org/10.1371/journal.pone.0035797

Alhazzani W, Moller MH, Arabi YM, Loeb M, Gong MN, Fan E, et al. Surviving Sepsis Campaign: guidelines on the management of critically ill adults with Coronavirus Disease 2019 (COVID-19). Intensive Care Med 2020; http://dx.doi.org/10.1007/s00134-020-06022-5

Expert consultation

One additional study identified:
Raboud J, Shigayeva A, McGeer A, Bontovics E, Chapman M, Gravel D, et al. Risk factors for SARS transmission from patients requiring intubation: a multicentre investigation in Toronto, Canada. PLoS One 2010;5(5):e10717. http://dx.doi.org/10.1371 journal.pone.0010717
### 2. Full details of the study eligibility criteria

| Question one | Include | Exclude |
|--------------|---------|---------|
| Question one | Population - Individuals in any setting | Animals |
| | Exposure - Delivery of: | Computer models |
| | 1) Chest compressions | Manikin studies |
| | 2) Defibrillation | Non-primary research-reviews, editorials etc |
| | 3) CPR (all CPR-interventions that include chest compressions) | Guidelines |
| | Delivery may be by human or mechanical chest compression device to patient or cadaver. | Non-English language |
| | Outcome - Aerosol generation (reported to be associated with exposure) | |
| | May be described as presence or absence or quantitatively (e.g. count per metre-cubed) | |
| | Study design | |
| | Randomized controlled trials (RCTs) and non-randomized studies (non-randomized controlled trials, interrupted time series, controlled before-and-after studies, cohort studies, case reports/series, cadaver studies) are eligible for inclusion. Unpublished studies (e.g., conference abstracts, trial protocols) | |

| Question two | Include | Exclude |
|--------------|---------|---------|
| Question two | Population - Individuals in any setting | Animals |
| | Exposure - Delivery of: | Computer models |
| | 1) Chest compressions | Manikin studies |
| | 2) Defibrillation | |
### Supplementary information

| Question three | Population - Individuals delivering chest compressions and/or defibrillation and/or CPR in any setting |
|----------------|--------------------------------------------------------------------------------------------------|
|                | Intervention - Wearing of personal protective equipment                                           |
|                | Comparator - Wearing any alternative system of personal protective equipment or no personal protective equipment |
|                | Includes wearing normal clothing/ no PPE                                                           |
|                | Outcome - Infection with the same organism as patient (can be any infection)                       |
|                | PPE effectiveness- example mask slippage, areas of exposure                                       |
|                | Quality of CPR- chest compression depth, chest compression rate, no-flow time, flow-time, time to key interventions (start CPR, defibrillation) |
|                | Study design                                                                                        |

| Study design   | Randomized controlled trials (RCTs) and non-randomized studies (non-randomized controlled trials, interrupted time series, controlled before-and-after studies, cohort studies, case reports/series). |

| Outcomes       | Transmission of any viral or bacterial or fungal infection- must be reported transmission or reports of no transmission (in studies with comparator group). |

| Quality of CPR  | chest compression depth, chest compression rate, no-flow time, flow-time, time to key interventions (start CPR, defibrillation) |

| Study design   | Randomized controlled trials (RCTs) and non-randomized studies (non-randomized controlled trials, interrupted time series, controlled before-and-after studies, cohort studies, case reports/series). |

| Non-primary research- reviews, editorials etc | Guidelines |
| Non-English language | Guidelines |
| Non-primary research- reviews, editorials etc | Guidelines |
| Studies of hazmat suits | Studies without a control group |
### Supplementary information

| Randomized controlled trials (RCTs) and non-randomized studies (non-randomized controlled trials, interrupted time series, controlled before-and-after studies, cohort studies) cadaver studies, simulation studies. |  |
### 3. List of studies excluded at full text review

| Excluded studies                                                                 | Reason                                      |
|----------------------------------------------------------------------------------|---------------------------------------------|
| 1. Abrahamson, S. D., et al. (2006). "Using simulation for training and to change protocol during the outbreak of severe acute respiratory syndrome." Critical Care (London, England) 10(1): R3. | Study design - narrative review              |
| 2. Al-Dorzi, H. M., et al. (2016). "The critical care response to a hospital outbreak of Middle East respiratory syndrome coronavirus (MERS-CoV) infection: an observational study." Annals of Intensive Care 6: 11. | Intervention – not cardiac arrest           |
| 3. Alraddadi, B. M., et al. (2019). "Noninvasive ventilation in critically ill patients with the Middle East respiratory syndrome." Influenza and Other Respiratory Viruses 13(4): 382-390. | Intervention – not cardiac arrest           |
| 4. Arabi, Y. M., et al. (2014). "Clinical Course and Outcomes of Critically Ill Patients With Middle East Respiratory Syndrome Coronavirus Infection." Annals of Internal Medicine 160(6): 389-+. | Study design – epidemiological               |
| 5. Blenkhar, J. I., et al. (1990). "Prevention of transmission of infection during mouth-to-mouth resuscitation." Resuscitation 19(2): 151-157. | Intervention – not cardiac arrest           |
| 6. Chuang, H. L., et al. (2007). "Impact of enhanced infection control procedures on clinical outcome following resuscitation attempts." Journal of Hospital Infection 67(3): 258-263. | Intervention – not cardiac arrest           |
| 7. Hassaniazad, M., et al. (2016). "Preventive measures for Crimean-Congo hemorrhagic fever in healthcare workers; how high is the chance of transmission?" Acta Medica Mediterranea 32(SpecialIssue5): 2017-1024. | Study design – not case study                |
| 8. Hui, D. S. (2013). "Severe acute respiratory syndrome (SARS): lessons learnt in Hong Kong." Journal of Thoracic Disease 5: S122-S126. | Study design - narrative review              |
| 9. Lightsey, D. M., et al. (1992). "A human immunodeficiency virus-resistant airway for cardiopulmonary resuscitation." American Journal of Emergency Medicine 10(1): 73-77. | Outcome – no eligible outcomes              |
| 10. Lufkin, K. C. and E. Ruiz (1993). "Mouth-to-mouth ventilation of cardiac arrested humans using a barrier mask." Prehospital & Disaster Medicine 8(4): 333-335. | Outcome – no eligible outcomes              |
|   | Study Description                                                                                                                                  | Intervention/Outcome | Reference                                                                 |
|---|----------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|---------------------------------------------------------------------------|
| 11| MacIntyre CR, Wang Q, Cauchemez S, Seale H, Dwyer DE, Yang P, Shi W, Gao Z, Pang X, Zhang Y, Wang X, Duan W, Rahman B, Ferguson N, (2011) A cluster randomized clinical trial comparing fit-tested and non-fit-tested N95 respirators to medical masks to prevent respiratory virus infection in health care workers. Influenza Other Respir Viruses 5: 170-179 | Intervention – not cardiac arrest |                                                                 |
| 12| MacIntyre CR, Wang Q, Seale H, Yang P, Shi W, Gao Z, Rahman B, Zhang Y, Wang X, Newall AT, Heywood A, Dwyer DE, (2013) A randomized clinical trial of three options for N95 respirators and medical masks in health workers. Am J Respir Crit Care Med 187: 960-966 | Intervention – not cardiac arrest |                                                                 |
| 13| MacIntyre CR, Wang Q, Rahman B, Seale H, Ridda I, Gao Z, Yang P, Shi W, Pang X, Zhang Y, Moa A, Dwyer DE, (2014) Efficacy of face masks and respirators in preventing upper respiratory tract bacterial colonization and co-infection in hospital healthcare workers. Prev Med 62: 1-7 | Intervention – not cardiac arrest |                                                                 |
| 14| Milton DK, Fabian MP, Cowling BJ, Grantham ML, McDevitt JJ, (2013) Influenza virus aerosols in human exhaled breath: particle size, culturability, and effect of surgical masks. PLoS Pathog 9:e1003205 | Intervention – not cardiac arrest |                                                                 |
| 15| Piegeler, T., et al. (2016). "Evaluation of six different airway devices regarding regurgitation and pulmonary aspiration during cardio-pulmonary resuscitation (CPR) - A human cadaver pilot study." Resuscitation 102: 70-74. | Outcome – no eligible outcomes |                                                                 |
| 16| Radonovich LJ Jr., Simberkoff MS, Bessesen MT, Brown AC, Cummings DAT, Gaydos CA, Los JG, Krosche AE, Gibert CL, Gorse GJ, Nyquist AC, Reich NG, Rodriguez-Barradas MC, Price CS, Perl TM, Res Pi, (2019) N95 Respirators vs Medical Masks for Preventing Influenza Among Health Care Personnel: A Randomized Clinical Trial. JAMA 322: 824-833 | Intervention – not cardiac arrest |                                                                 |
| 17| Rule, A. M., et al. (2018). "Healthcare personnel exposure in an emergency department during influenza season." PLoS ONE [Electronic Resource] 13(8): 15. | Intervention – not cardiac arrest |                                                                 |
| 18| Sietsema, M. and L. M. Brosseau (2018). "Are quantitative fit factors predictive of respirator fit during simulated healthcare activities?" Journal of Occupational & Environmental Hygiene 15(12): 803-809. | Comparator - no comparator group |                                                                 |
|   | Authors                          | Title                                                                 | Study Design                  | Intervention/Comparator                  |
|---|----------------------------------|-----------------------------------------------------------------------|-------------------------------|------------------------------------------|
|19 | Thompson, K. A., et al. (2013)   | "Influenza Aerosols in UK Hospitals during the H1N1 (2009) Pandemic - The Risk of Aerosol Generation during Medical Procedures." | Intervention – not cardiac arrest |
|20 | Tran K, Cimon K, Severn M, Pessoa-Silva CL, Conly J, (2012) | Aerosol generating procedures and risk of transmission of acute respiratory infections to healthcare workers: a systematic review. | Study design – systematic review |
|21 | Twu SJ, Chen TJ, Chen CJ, Olsen SJ, Lee LT, Fisk T, Hsu KH, Chang SC, Chen KT, Chiang IH, Wu YC, Wu JS, Dowell SF, (2003) | Control measures for severe acute respiratory syndrome (SARS) in Taiwan. | Intervention – not cardiac arrest |
|22 | Watson, C. M., et al. (2011)     | "Simulated pediatric resuscitation use for personal protective equipment adherence measurement and training during the 2009 influenza (H1N1) pandemic." | Comparator - no comparator group |
|23 | Watson, L., et al. (2008)       | "The "delay effect" of donning a gown during cardiopulmonary resuscitation in a simulation model." | Comparator - no comparator group |
|24 | Weber, R. T., et al. (2019)     | "Environmental and Personal Protective Equipment Contamination during Simulated Healthcare Activities." | Intervention – not cardiac arrest |
|25 | Wong, E. and K. K. Ho (2006)    | "The effect of severe acute respiratory syndrome (SARS) on emergency airway management." | Intervention – not cardiac arrest |
|26 | Yam LY, Chen RC, Zhong NS, (2003) | SARS: ventilatory and intensive care. | Study design - narrative review |
|27 | Yu, I. T., et al. (2007)        | "Why did outbreaks of severe acute respiratory syndrome occur in some hospital wards but not in others?" | Outcome – not transmission to individual delivering compressions |
4. **Quality assessment of included studies**

Quality assessment of included case reports and case-series

| Study       | Selection | Ascertainment | Causality | Reporting | Comments |
|-------------|-----------|---------------|-----------|-----------|----------|
| Christian et al 2004 | Yes       | No            | No        | NA        | Yes      | Yes       | No additional health care activities other than CPR were recorded. The study assumes that CPR was the activity that caused transmission even though nurses |
| Study                  | Did HCWs wear protective clothing? | Was RT-PCR testing done for antibodies? | Did HCWs receive RT-PCR testing? | Did emergency physician receive RT-PCR testing? | Emergency physician involvement during CPR? |
|-----------------------|------------------------------------|----------------------------------------|---------------------------------|-----------------------------------------------|---------------------------------------------|
| Knapp et al 2016      | Yes                                | Yes                                    | Yes                             | NA                                           | Emergency physician was only involved in CPR during care of patient |
| Kim et al 2015        | Yes                                | No                                     | Yes                             | NA                                           | Unlikely that CPR was the only clinical activity. There is therefore some uncertainty over the type of exposure and whether transmission can be attributed to CPR. |
| Chalumeau et al 2005  | Yes                                | Yes                                    | No                              | NA                                           | The study demonstrated that the same strain of Staph. aureus infected both the index case and the physician. It is most likely that the transmission occurred during CPR. |
| Nam et al 2017        | Yes                                | Yes                                    | No                              | NA                                           | The study demonstrated the transmission of |
infection from Case B to Case C (the HCW). There was CCTV footage showing the most likely period during which the transmission occurred.

Quality assessment of included case control studies

| Study       | 1. Can we be confident in the assessment of exposure? | 2. Can we be confident that cases had developed the outcome of interest and controls had not? | 3. Were the cases (those who were exposed and developed the outcome of interest) properly selected? | 4. Were the controls (those who were exposed and did not develop the outcome of interest) properly selected? | 5. Were cases and controls matched according to important prognostic variables or was statistical adjustment carried out for those variables? | Comments |
|-------------|------------------------------------------------------|-----------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|----------|
| Liu et al 2009 | Probably yes                                         | Definitely yes                                                                              | Probably no                                                                                     | Definitely yes                                                                              | Probably yes                                                                              | Potential recall bias as HCW were asked about the type of patient contact. 2 cases were excluded that are believed to have contracted the infection outside of the hospital. Unclear how contracting of disease was confirmed for the other cases. |
Supplementary information

Quality assessment of included cohort studies

| Tool for evaluating the methodological quality of cohort studies |
|---------------------------------------------------------------|
| Study | 1. Was selection of exposed and non-exposed cohorts drawn from the same population? | 2. Can we be confident in the assessment of exposure? | 3. Can we be confident that the outcome of interest was not present at start of study? | 4. Did the study match exposed and unexposed for all variables that are associated with the outcome of interest or did the statistical analysis adjust for these prognostic variables? | 5. Can we be confident in the assessment of the presence or absence of prognostic factors? | 6. Can we be confident in the assessment of outcome? | 7. Was the follow up of cohorts adequate? | 8. Were co-interventions similar between groups? | Comments |
|-------|-----------------------------------------------------------------|-------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| Rabaoud et al 2010 | Probably yes | Probably yes | Definitely yes | Probably no | Probably yes | Definitely yes | Definitely yes | Probably no | HCWs were interviewed as part of a public health investigation into the transmission of SARS-CoV. No record available when HCWs were interviewed. Interviews were used to identify additional HCWs who may have been in contact with the |
Supplementary information

| Study             | Selection bias | Selection bias | Reporting bias | Other sources of bias | Performance bias | Detection bias | Attrition bias | Comments                                                                 |
|-------------------|----------------|----------------|----------------|-----------------------|------------------|----------------|----------------|--------------------------------------------------------------------------|
| Loeb et al 2004   | Probably yes   | Probably yes   | Definitely no   | Definitely no         | Probably no      | Definitely yes | Definitely yes | Only 3 CPRs and 2 Defibrillations, unclear whether HCWs had different PPE to those involved in other activities and got infected |
| Schumacher et al 2013 | Unclear       | Unclear        | Unclear        | Low                   | High             | High           | Low            | Fully crossed RCT design so imbalances at baseline not a concern. Very limited reporting of methods. |
| Shin et al 2017   | Low            | High           | Low            | Low                   | Unclear          | Unclear        | Low            | Fully crossed RCT design so imbalances at baseline not a concern.        |
| Watson et al 2008 | Unclear        | Unclear        | High           | High                  | High             | Unclear        | Unclear        | Small numbers of participants, not a crossover trial so high risk of imbalance at baseline. Baseline characteristics by group not reported. |

Quality assessment of included randomised controlled trials

Cochrane Risk of Bias Domains

| Study             | Selection bias | Selection bias | Reporting bias | Other sources of bias | Performance bias | Detection bias | Attrition bias | Comments                                                                 |
|-------------------|----------------|----------------|----------------|-----------------------|------------------|----------------|----------------|--------------------------------------------------------------------------|
| Schumacher et al 2013 | Unclear       | Unclear        | Unclear        | Low                   | High             | High           | Low            | Fully crossed RCT design so imbalances at baseline not a concern. Very limited reporting of methods. |
| Shin et al 2017   | Low            | High           | Low            | Low                   | Unclear          | Unclear        | Low            | Fully crossed RCT design so imbalances at baseline not a concern.        |
| Watson et al 2008 | Unclear        | Unclear        | High           | High                  | High             | Unclear        | Unclear        | Small numbers of participants, not a crossover trial so high risk of imbalance at baseline. Baseline characteristics by group not reported. |
Supplementary information

5. **GRADE tables**

- Research question one: In individuals in any setting (population), is delivery of 1) chest compressions, 2) defibrillation or 3) cardiopulmonary resuscitation (exposures) associated with aerosol generation (outcome)?
- Research question two: In individuals in any setting wearing any/ no personal protective equipment (population), is delivery of 1) chest compressions, 2) defibrillation or 3) cardiopulmonary resuscitation (exposures) associated with transmission of infection (outcome)?
- Research question three: In individuals delivering chest compressions and/or defibrillation and/or CPR in any setting (population), does wearing of personal protective equipment (intervention) compared with wearing any alternative system of personal protective equipment or no personal protective equipment (comparator) affect infection with the same organism as the patient, personal protective equipment effectiveness, or quality of CPR (outcomes)?

| Certainty assessment | Nr of patients | Effect | Certainty | Importance |
|----------------------|----------------|--------|-----------|------------|
|                       | Nr of studies  | Study design | Risk of bias | Inconsistency | Indirectness | Imprecision | Other considerations | intervention | comparison | Relative (95% CI) | Absolute (95% CI) |          |          |
| Research question 1- aerosol generation | 2 observational studies | serious a | not serious | serious b | not serious | none | | | | | | | VERY LOW | CRITICAL |
| Research question 2- transmission of infection | 8 observational studies | very serious c | not serious | serious d | not serious | none | | | | | | | VERY LOW | CRITICAL |
| Research question 3- Infection with same organism as patient | 0 | - | | | | | | | | | | | CRITICAL |
| Research question 3- personal protective equipment effectiveness | 3 randomised trials | serious e | not serious | serious f | not serious | none | | | | | | | LOW | CRITICAL |
| Research question 3- quality of CPR | 3 randomised trials | very serious g | not serious | serious h | not serious | none | | | | | | | VERY LOW | IMPORTANT |

CI: Confidence interval

**Explanations**

a. Only evidence type was case reports
b. Did not describe COVID-19 (based on other infections)
Supplementary information

c. Evidence from studies with very serious risk of bias and from case reports
d. Data from randomised controlled trial with serious risk of bias
e. Data based on manikin studies
f. Data from randomised controlled trials with very serious risk of bias