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Guidelines

SARS-CoV-2 routes of transmission and recommendations for preventing acquisition: joint British Infection Association (BIA), Healthcare Infection Society (HIS), Infection Prevention Society (IPS) and Royal College of Pathologists (RCPath) guidance

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droplet transmission
aerosol transmission
infectious disease transmission

Executive summary

The pandemic of the coronavirus disease 2019 (COVID-19), caused by novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), emerged amid uncertainty about the dynamics of transmission and the possible management options for COVID-19 patients. This resulted in confusion for healthcare workers (HCWs) and hospital managers who often received conflicting advice on how to organise care and manage infected individuals without increasing the risk of transmission to HCWs and other patients. Advice for the public has also been confusing and apparently sometimes contradictory, which sometimes resulted in overuse of Personal Protective Equipment (PPE) in the general population as well as in healthcare workers. As evidence from the first wave has emerged, we are now in a position to summarise it and provide guidance on how to prevent SARS-CoV-2 transmission whilst preserving essential resources. This article is the first of two guidance documents produced jointly by the Healthcare Infection Society, British Infection Association, Infection Prevention Society and Royal College of Pathologists. This guidance article describes routes of SARS-CoV-2 transmission, which will allow the public and healthcare professionals to understand how SARS-CoV-2 transmission occurs. By determining how likely transmission can occur via a given route, we can extrapolate the evidence for infection prevention and control (IPC) and apply this knowledge to optimise protection from SARS-CoV-2 infection. At the time of writing (April 2021), new variants of SARS-CoV-2 emerged, raising concerns whether the virus could make current vaccines ineffective. The evidence strongly suggests that these variants have a transmission potential higher than the original virus thus, strict adherence to IPC measures is still required in breaking the chain of SARS-CoV-2 transmission. Further review may be required as more evidence about these variants becomes available.

On review of the evidence, the COVID-19 Rapid Guidance Working Party considers the different transmission routes as follows:

droplet transmission: *probable*
transmission via fomites: *possible*
airborne transmission: *possible* (in some circumstances, e.g., aerosol generating procedures (AGPs)
transmission via ocular surface: *possible*
vertical transmission: *unlikely*
transmission from different body fluids (other than respiratory secretions and saliva): *unlikely*
transmission from blood transfusion and transplantation organs: *unlikely*

The Working Party concludes that transmission most often occurs following close contact, especially where PPE is not worn, as reflected in high transmission rates between family members, friends, and co-workers. At the moment it is not possible to determine the distance or the duration over which transmission can occur, although these vary depending on circumstances (e.g. the shorter the distance, the shorter the duration of contact will be required, but also on environmental and other factors). Transmission from COVID-19 patients to HCWs in hospitals is low, except in a small number of cases where HCWs cared for undiagnosed COVID-19 patients and did not use appropriate PPE. Even in these cases, transmission usually occurs during AGPs. Transmission in care homes appears to be very high and anecdotal evidence suggests that there were difficulties in obtaining appropriate PPE and observing social distancing during the pandemic. The published literature is not comprehensive enough to make recommendations for this setting. However, considering there is no IPC guidance specific for care homes, we suggest that staff in these institutions follow the recommendations for persons working in health and care settings listed below and that they explore aspects specific to their local institutions to address the barriers which prevent them in doing so, e.g. inability to maintain social distancing. The rationale for the above conclusions and the following recommendations is provided in Section Review of evidence.

Recommendations

General recommendations which apply to all settings, including social settings:

GR1: Adhere to regulations currently imposed by your government. Specific guidance may be available from your government.

GR2: Maintain the recommended minimum distance, as advised by your government, at all times.

GR3: Use a face covering in enclosed spaces to protect yourself and others.

GR4: Reduce the time of contact with anyone outside your household to a minimum.

GR5: To avoid transmission from fomites, decontaminate your hands frequently using soap and water, and when this is not possible, use alcohol-based hand rub.

Good practice point: Follow World Health Organization advice on how to handwash (https://www.who.int/gpsc/5may/How_To_HandWash_Poster.pdf) and how to handrub (https://www.who.int/gpsc/5may/How_To_HandRub_Poster.pdf)

GR6: Avoid touching your face and eyes with your hands as transmission via ocular surface is possible.

GR7: Evidence suggests that a high proportion of transmissions occur as a result of close contact between family members, friends, and co-workers. Adhere to the above recommendations when in contact with anyone outside your household or support network.

GR8: Available evidence suggests that transmission without close contact or outside is unlikely. Continue maintaining your locally determined distance (which is 2m within the UK) and using face covering in indoor settings. There is no evidence which suggests that respirator masks (e.g. N95, FFP2/3) offer additional protection outside the healthcare settings.

Good practice point: To protect yourself and others, follow WHO advice and avoid 3Cs: **C**losed spaces, **C**rowds, **C**lose contact.

Specific recommendations for persons working in health and care settings:

HR1: You must adhere to regulations imposed by your trust/employer.

HR2: Where there is ongoing transmission, for contact with patients and other healthcare staff, use a fluid-resistant face mask, and adhere to general recommendations listed above.

HR3: For care of patients suspected or confirmed to have COVID-19, in addition to the above, use fluid resistant surgical face mask and adhere to contact and droplet precautions. No other precautions are necessary.

HR4: Risk of SARS-CoV-2 transmission from body fluids (faeces, urine, ocular excretions, and sexual body fluids) is unlikely, use contact precautions and appropriate PPE (including fluid resistant surgical face mask type IIR) and do not use additional precautions (e.g., filtering respiration mask) unless carrying out AGPs. Your employer may make a decision to provide respirator masks for procedures other than AGPs, based on local circumstances.

HR5: Whilst blood and body fluids are not a likely source of SARS-CoV-2 infection, there remains a risk of infection with other pathogens to HCWs and via them to other patients. Use PPE (gloves, plastic aprons, eye protection) as appropriate when there is a risk of exposure to blood, body fluids or any items contaminated with these products and clean your hands immediately after glove removal.

HR6: Literature suggests that most SARS-CoV-2 transmissions from patients to HCWs occurred when HCW did not use protection during AGPs on patients not suspected of having COVID-19. Consider using filtering respiration mask (FFP3) designed for filtering fine airborne particles for any AGPs regardless of a patient's COVID-19 status when local assessment suggests risk of SARS-CoV-2 circulating in the community or local setting.

HR7: Vertical transmission is unlikely. Studies have reported avoiding caesarean delivery where possible and mothers being advised to use a surgical mask.

Summary of recommendations is provided in Table I.

Recommendations for managers in health and care settings:

MR1: Adhere to current national guidelines for IPC, including those specific to COVID-19 as well as general ones for preventing infectious diseases.

MR2: Consider exploring potential factors for SARS-CoV-2 transmission specific to your setting, e.g., inability to maintain social distancing and managing apparently asymptomatic cases.

Lay summary

The COVID-19 pandemic has had far reaching implications for health, economics and society. One of the many areas affected has been the ability of healthcare professionals to stop the spread of the infection in health and care settings both in hospital and in the community such as a dental surgery. With research being published since the emergence of the outbreak we now have a much better understanding of how to help prevent the spread of the infection. This document was co-produced by a multiprofessional group that includes clinicians, nurses, academics, and a member of the public. It provides the current evidence with recommendations to help frontline health professionals and managers. The timing of this guidance is important, it is vital that people are aware what has been proven to work. We are aware that new evidence will come along which may contradict or add to some of our recommendations, however this is an important start in giving health providers and managers evidence-based recommendations for limiting the spread of infection. The document contains explanation, evidence and a glossary of terms (Appendix 1). If you simply want to look at the recommendations, please see the executive summary section. Along with this document we are publishing materials for patients, carers and members of the public because it is vital that we all have access to guidance and understand our individual role in reducing COVID-19 spread in hospitals and community.

Introduction

The coronavirus disease 2019 (COVID-19) global pandemic, first detected in Wuhan, China has affected more than 130 million people [1]. The disease is caused by novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which together with its close relative SARS-CoV belongs to a B lineage of beta-coronaviruses. The virus is also related to MERS-CoV virus from C lineage which was responsible for the outbreaks of Middle East Respiratory syndrome (MERS).

The first wave of the pandemic occurred amid uncertainty about the dynamics of SARS-CoV-2 transmission and the possible management options for COVID-19 patients. This resulted in confusion for HCWs and hospital managers who often received conflicting advice on how to organise care and manage infected individuals without increasing the risk of transmission to HCWs and other patients. As the evidence has emerged, we are now in a position to summarise it and provide guidance to healthcare professionals on how to prevent healthcare associated COVID-19 disease when subsequent waves or localised outbreaks occur.

This guidance will be produced in two parts, each covering a different question relating to prevention of COVID-19 in health and care settings. This article is the first working party report and describes routes of SARS-CoV-2 transmission. Understanding the likelihood of transmission occurring via different routes is important, so individuals can take appropriate precautions to protect themselves and others.

Guideline development team

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Table I
Summary of recommendations for persons working in healthcare settings

	Casual contact — no patient care	Care for non-COVID-19 patients	Care for suspected or confirmed COVID-19 patients
Precautions	Social distancing	Standard precautions: hand hygiene, respiratory hygiene, sharps safety, environmental & equipment safety, safe injections, PPE, occupational safety, social distancing*	Standard precautions, contact precautions & droplet precautions
Patient management	Patient to wear face covering	Patient to wear face covering (as per local policies)	Patient placed in isolation/single room or as far away from others as possible (and at least 2m within the UK) Patient to wear fluid resistant surgical face mask when in contact with others
PPE if no contact with body fluids			
Face protection	Face covering	Fluid resistant surgical face mask	Fluid resistant surgical face mask type
Gloves	None	None	Single use, double gloving not necessary
Clothes/body protection	Bare below elbow	Bare below elbow	Bare below elbow, apron tied at neck and waist
Eye protection	None	None	Face shield
Head protection	None	None	None
Foot/shoe protection	None	None	None
PPE if in contact with body fluids			
Face protection	n/a	Fluid resistant surgical face mask	Fluid resistant surgical face mask
Gloves		Single use, double gloving not necessary	Single use, double gloving not necessary
Clothes/body protection		Bare below elbow, apron (if risk of contamination) tied at neck and waist	Bare below elbow, apron (if risk of contamination) tied at neck and waist
Eye protection		Face shield (if risk of splashes)	Face shield (if risk of splashes)
Head protection		None	None
Foot/shoe protection		None	None
PPE if AGPs performed			
Face protection	n/a	Filtering respiration mask FFP3	Filtering respiration mask FFP3
Gloves		Single use, covering the cuffs of the gown	Single use, covering the cuffs of the gown
Clothes/body protection		Long sleeved gown	Long sleeved gown
Eye protection		Goggles	Goggles
Head protection		None	None
Foot/shoe protection		None	None

* **Note**: social distancing is now a part of standard precautions.

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Disclosure of potential conflict of interest

- No authors reported any conflict of interest (Appendix 2)

Relationship of authors with sponsor

BIA, HIS, IPS and RCPath commissioned the authors to undertake the Working Party Report. The authors are members of the societies. AB and MAM are employed by HIS as guideline developers. Further information is provided in Appendix 2.

Responsibility for guidance

The views expressed in this publication are those of the authors and have been endorsed by BIA, HIS, IPS and RCPath, and following rapid consultation.

Working party report

What is the working party report?

The report is the first in a pair of guidance documents covering key aspects of preventing transmission of SARS-CoV-2 in health and care settings. The guidance also reviews the evidence for transmission dynamics of SARS-CoV-2 virus outside these settings. The diagnosis and management of COVID-19 disease in general are outside the remit of this guidance.

The Working Party recommendations have been developed systematically through multi-disciplinary discussions based on currently available evidence from published and pre-print sources. They should be used in the development of local protocols for all relevant health and care settings such as hospitals, nursing/care homes, primary care and dental practices.

Why do we need a working party report for this topic?

The first wave of COVID-19 pandemic occurred amid uncertainty as to how it could be prevented and controlled. New outbreaks are still occurring, and many countries are currently experiencing subsequent waves. Concerns whether the virus has an ability to spread efficiently via certain routes still remain. We now have sufficient evidence from the first wave, which gives us an opportunity to develop an evidence-based guidance for preventing and controlling future outbreaks.

What is the purpose of the working party Report's recommendations?

The main purpose is to inform clinicians, managers, and policy makers about the dynamics of transmission of SARS-CoV-2 and to provide evidence-based recommendations to prevent and control its spread in health and care settings. This document highlights current gaps in knowledge, which will help to direct future areas of research.

What is the scope of the guidance?

The scope of the guidance is to provide advice for the optimal provision of an effective and safe healthcare service during the time when COVID-19 remains a health threat. This guidance was developed with acute healthcare settings in mind but may be useful in other health and care settings such as dental practices and care homes.

What is the evidence for this guidance?

Topics for this guidance were derived from the initial discussion of the Working Party and review questions were designed in accordance with the PECO (P=population, E=exposure, C=comparator, O=outcome) framework for investigating the likelihood of developing a certain condition after exposure to an event [2]. To prepare these recommendations, the Working Party collectively reviewed relevant evidence from published and pre-print sources. Methods, which were in accordance with National Institute for Health and Care Excellence (NICE) manual for developing guidelines, are described fully below.

Who developed this guidance?

The Working Party included infectious diseases/microbiology clinicians, academic IPC experts, systematic reviewers, and a lay representative.

Who is this guidance for?

Any healthcare practitioner, manager and policy maker may use this guidance and adapt it for their use. It is anticipated that users will mostly include clinical staff and IPC teams. Some parts of this guidance may also be beneficial to patients, carers and public.

How is the guidance structured?

To provide rapid advice, this guidance is produced as two separate articles, each covering a different question. Each will comprise an introduction, a summary of the evidence, and recommendations graded according to the available evidence.

How frequently is the guidance reviewed and updated?

New evidence will be reviewed within one year to determine whether this guidance needs updating.

Aim

The aim of this guidance was to assess the current evidence for all aspects relating to dynamics and routes of transmission of SARS-COV-2 and preventing its transmission in hospitals and other care settings.

Methodology

Evidence search and appraisal

Topics for this guidance were derived from the initial discussions of the COVID-19 Rapid Guidance Working Party Group. In addition, HIS invited all members to propose topics. To prepare these recommendations, the Working Party collectively reviewed relevant evidence from published and pre-print sources. Methods were followed in accordance with the NICE manual for guideline development with modifications that allowed a rapid review process (described below). The modifications included systematically searching two electronic databases, including fewer members for the Working Party with one lay member, and quality assessment being conducted by one reviewer and checked by a second person.

Data sources and search strategy

Two electronic databases (Medline and EMBASE) were searched for articles published between 1st January and 11th May 2020; search terms were constructed using relevant MeSH and free text terms (Appendix 3). Additional hand searching was conducted in the following databases: WHO Chinese database, CNKI, China Biomedical Literature Service, Epistemonikos COVID-19 L·OVE platform, EPPI Centre living systematic map of the evidence, CORD-19, COVID-END, and the HIS's COVID-19 resources to identify pre-print and articles in press. Reference lists of identified reviews and included papers were scanned for additional studies. The searches were restricted to human-to-human transmission and the presence of the virus in the environment. No language restrictions were set.

The Working Party considered the updating the review in the light of new evidence emerging rapidly. However, a number of articles related to this question were published daily, making this update unfeasible. The Working Party is aware of a number of publications which have not been included in the above evidence review, particularly those in relation to the current debate about aerosol transmission. The Working Party decided to include a separate section where relevant papers not identified by a systematic search but obtained from other various sources, (e.g., experts highlighting key research papers, Working Party members informed of the articles being published, and the articles identified from the searches ran for other COVID-19 related questions) were included. All other methodological aspects of data handling remained the same for this evidence.

Study eligibility and selection criteria

The members of the Rapid Guidance Working Party determined criteria for study inclusion. Any article presenting primary data relevant to human-to-human transmission of SARS-CoV-2, as well as relevant laboratory studies and environmental surveys, was included. Search results were downloaded to EndNote database and screened for relevance. One reviewer reviewed the title, abstracts, and full texts. A second reviewer checked at least 10% of the excluded studies at each sifting stage. Disagreements were first discussed between the two reviewers and if consensus was not reached, a third reviewer was consulted. The results are shown in the PRISMA diagram in Appendix 4.

Data extraction and quality assessment

Included epidemiological studies were appraised for quality using checklists recommended in the NICE guideline development manual. Environmental and laboratory studies were not appraised for quality. Critical appraisal and data extraction were conducted by one reviewer, and at least 10% was checked by the second. The results are available in Appendix 5. Data from the included studies were extracted to create the summary of findings, study description and data extraction tables (Appendix 6). Data were stratified into the type of transmission and either aggregated or otherwise described narratively. Where data were aggregated, meta-analyses were not conducted because the scope of this guidance was to establish whether transmission could take place via certain routes. These data should not be used as an indicator of the frequency at which these transmission events occurred because this was not the intended scope of this document. The list of the studies excluded at full text sift with a reason for this decision is provided in (Appendix 7).

Rating of evidence and recommendations

Summary of findings tables were presented to the Working Party, and recommendations were prepared according to the nature and applicability of the evidence regarding the likelihood of transmission via a certain route. The likelihood of transmission via different routes was assessed using the criteria recommended by Shah *et al.* (2020) [3] for classifying the possibility of vertical transmission. This classification system was adapted to reflect other routes of transmission by creating five mutually exclusive categories:

- **Confirmed infection** — strong epidemiological evidence and proof that infection occurred via the route in question: e.g. the affected person had positive SARS-CoV-2 polymerase chain reaction (PCR) test AND possibility of infection via alternative routes was excluded
- **Probable infection** — strong evidence suggestive of infection, but lack of confirmatory proof that infection occurred via the route in question: e.g. the affected person had a positive PCR or symptoms suggestive of infection AND strong epidemiological evidence suggestive that the infection occurred via the route in question
- **Possible infection** — evidence that is suggestive of infection but is incomplete: e.g. the affected person had a positive PCR or symptoms suggestive of infection AND weak epidemiological evidence suggestive that the infection occurred via the route in question OR strong non-epidemiological evidence that viable virus (i.e. virus that

was shown to infect cells in culture) was detected in samples related to a route in question

- **Unlikely infection** – little evidence for infection occurring via the route in question but cannot be completely ruled out: e.g. the affected person had a positive PCR test or symptoms suggestive of infection AND weak epidemiological evidence to support that infection occurred via the route in question OR the person had negative PCR or no symptoms AND evidence for likely exposure via route in question OR weak non-epidemiological evidence that virus (viable or PCR) is detected in samples related to the route in question
- **Confirmed no infection** – strong evidence with proof that infection did not occur after exposure via the route in question: e.g. negative PCR AND strong evidence that exposure via a certain route occurred OR strong non-epidemiological evidence that virus (viable or PCR) is not detected in samples related to the route in question.

The strength of the evidence was defined by GRADE (Grading of Recommendations Assessment, Development and Evaluation) tables (Appendix 8) and using the ratings 'high', 'moderate', 'low' and 'very low' to construct the evidence statements, that reflected the Working Party Group's confidence in the evidence. The strength of recommendation was adopted from GRADE and reflects the strength of each evidence statement. In instances where no evidence was identified from searches, the statement 'No evidence was found in studies published so far...' indicates that no studies have assessed this as an outcome. Where there was no evidence or a paucity of evidence, good practice recommendations were made by expert experience and consensus via videoconferences. All disagreements were resolved by discussion and voting by members of the Working Party.

Consultation process

Feedback on draft guidance was received from the HIS Guidelines Committee and through rapid consultation with relevant stakeholders. The draft report was placed on the HIS website for 7 days along with the HIS standard comment form. The availability of the draft was advertised via email and social media. Stakeholders were invited to comment on format, content, local applicability, patient acceptability, and recommendations. The Working Party reviewed stakeholder comments, and collectively agreed revisions (Appendix 9). All reviews received from individuals with a conflict of interest or those who did not provide a declaration were excluded.

Results

The search identified a total of 1765 articles. After excluding duplicate and irrelevant studies and checking reference lists for related citations, a total of 130 were included (Appendix 4) [4–133]. As mentioned above, due to the large number of papers being published daily, the decision was made not to update the search results before publication as this would significantly delay the guidance being available to readers. However, there were seven articles [134–140], which were published after the search date and during the data extraction process that were felt to be of significant clinical importance. Further 55 articles [141–195] were identified and recommended by experts and via other searches and were included in this guidance after the first draft was written. These are included as the additional literature in Section Additional literature published after the initial search.

Due to the large number of articles describing SARS-CoV-2 transmission, the decision was made not to include studies which focused on SARS-CoV, MERS-CoV and other betacoronaviruses. Any evidence from such studies, thought to be relevant to this guidance was provided as Supporting information but not included in evidence synthesis.

Of the included studies there were 169 case studies/series [5–16,20–28,30–61,63,65,68–80,82–91,94–104,106–133,135–140,142,143,147–149,155,157,158,162–195], 23 environmental surveys [4,17,18,29,62,64,66,67,81,93,105,134,141,144,145,150–154,156,159–161], and three laboratory experiments [19,92,146]. Twenty seven of these studies described the possibility of SARS-CoV-2 transmission via air [17,18,26,29,64,67,81,92,134,141–147,149–161], eleven via droplets [30,51,59,82,142,143,147,149,155,157,158], eleven via fomites [8,17–19,29,66,67,81,92,93,134] and 32 via the vertical route [5,10,12,14,15,22,24,31,35,39,42,46,52,54–56,58,71,73,75,94,97,113–115,117,119–121,124,133,136]. Other studies described the possibility of the SARS-CoV-2 virus being transmitted via faeces [148], presence of virus in faecal matter (n=33) [4,13,21,25,31,36,38,45,50,53,62,59,68,69,72,88–91,93,95,96,101,104,105,108,111,112,122,125,126,129–131], urine (n=11) [15,31,38,53,68,72,91,96,130,131,133], ocular secretions (n=9) [11,20,85,87,102,106,110,127,132] and sexual body fluids (n=3) [21,44,79]. Two studies also described the chance of transmission via the ocular surface [49,127] and four assessed the possibility of transmission via blood transfusion [137–140]. Lastly a total of 74 studies described clusters and outbreaks [6,7,9,16,23,27,28,31–34,37,38,41,43,47,48,57,60,61,63,65,70,74,76–78,80,83,84,86,98–100,103,107,109,116,118,123,128,162–195]. These studies did not report transmission routes, but the transmission patterns helped to determine the most likely routes via which the virus is likely to spread.

Review of evidence

Droplet transmission

Both, SARS-CoV and MERS-CoV viruses are predominantly transmitted via the droplet route [196,197]. The droplet route was recognized as a primary route of transmission of SARS-CoV by the scientific community, based on epidemiological evidence and the reproductive number (R_0) of approximately 3, which is consistent with close contact and therefore transmission through respiratory droplets [148]. Direct and indirect contact between respiratory droplets and the mucous membranes has been implicated as the route of transmission in some healthcare and community SARS outbreaks in Hong Kong [196,197]. Human-to-human transmission of MERS-CoV typically occurred in HCWs and family members who cared for infected persons and were therefore directly exposed to the virus by close contact with respiratory secretions [199]. The R_0 of MERS-CoV is generally considered to be <1, however for nosocomial outbreaks in Saudi Arabia and South Korea it was estimated as 2–5 [200]. One study, which assessed the reproductive number for SARS-CoV-2 early in the epidemic in China, estimated that R_0 could be as high as 5.7 [CI95% 3.8–8.9] and could have been a result of travel and gatherings associated with Lunar New Year celebrations during which time a lack of awareness of the new pathogen could have facilitated its spread [201]. The authors also recognised that compared to SARS-CoV, SARS-CoV-2 has a much higher affinity to the ACE-2 receptor that both viruses use to enter the cell. Therefore SARS-CoV-2 virus is likely to be more infectious, which explains the higher reproductive number.

Epidemiological evidence for SARS-CoV-2

There was inconsistent evidence from four studies [30,51,59,82], which investigated the possibility of droplet transmission for SARS-CoV-2 virus. Two of these studies concluded that droplet transmission was at least partially responsible for SARS-CoV-2 outbreaks. One study which described an outbreak that occurred after the church choir practice [30], reported that a total of 52 of 60 individuals attending the practice were affected, resulting in an attack rate of 86.7%. Authors concluded that there were many opportunities for the droplet and fomite transmission as the individuals moved freely and interacted with each other, and that the act of singing could also have contributed to the aerosol transmission. Another outbreak which was described by two different articles [51,59] involved restaurant patrons in Guangzhou, China. The outbreak involved 10 people across three different families, with each family sat at an adjacent table to the index case. These two articles reached different conclusions about the likely mechanism and route of transmission [51,59]. The authors of one article [56] concluded that droplet transmission was most likely given the close proximity of the affected contacts to the index case. They argued that alternative transmission routes e.g. airborne were less likely given that only 10/91 people eating at the restaurant tested positive for SARS-CoV-2. Furthermore, smear samples from the air conditioner (3 from the air outlet and 3 from the air inlet) were negative for SARS-CoV-2 by reverse transcription PCR. In contrast another group of investigators [51] concluded that as the ventilation rate was low (0.75–1.04 L/s per person) and no close contact or fomite contact was observed, the infection distribution was consistent with a spread pattern representative of exhaled virus-laden aerosols due to poor ventilation. The last study [82] described the circumstances on a long-distance (15hr) flight from China to Canada where one couple (one symptomatic and one pre-symptomatic during the flight) were later diagnosed with COVID-19. There were approximately 350 passengers and flight crew on board and besides the index couple, no secondary cases were identified despite extensive contact tracing and monitoring. Based on these data, the authors concluded that droplet transmission was most likely.

Upon the review of the above evidence, the COVID-19 Rapid Guidance Working Party considers the droplet transmission route to be ***probable****.*

Airborne transmission

There is a current debate within the scientific community about the extent to which SARS-CoV-2 is able to be transmitted via the airborne route. Some confusion also exists because the term 'aerosol' is frequently used as a synonym of 'airborne'. Aerosols refer to respiratory particles, which are found in the air, and their size is the predominant reason for their ability to remain suspended (airborne) [198]. The generally accepted threshold for these particles to be considered airborne is $<5\mu m$ [198]. Thus, the term 'respiratory aerosol' encompasses both the airborne particles and the larger particles which are known as droplets. It is widely accepted that humans may produce both sizes of respiratory aerosols during normal breathing, coughing, or sneezing and that larger droplets may desiccate and form smaller 'airborne' particles [198]. However, it is not known whether infectious SARS-CoV-2 virus is present in these small particles, and if so, how long it can stay viable in the air. As a result, it is currently not known whether this virus can be transmitted via airborne route as a result of normal breathing or coughing. One SARS outbreak in Hong Kong was suspected to be a result of airborne aerosols arising from infected faecal matter, which was distributed via the building's drainage system [199]. The dynamics of nosocomial outbreaks in Hong Kong and Toronto suggested an airborne route was possible in some circumstances [200]. As a result, SARS-CoV virus was coined to be an 'opportunistic' airborne microorganism, meaning that while the droplets may be the main route of transmission, there may be some circumstances when airborne transmission occurs, e.g. during AGPs [200,201] or in rare circumstances when viable virus in excrement became aerosolised after flushing the toilet as reported in one outbreak [198,202]. Despite recognising SARS-CoV virus to be spread primarily via the droplet route, WHO [198] also acknowledged that airborne transmission in some circumstances was likely, mainly occurring when aerosolisation of respiratory droplets occurred, although transmission of aerosolisation of other infectious materials (e.g. faeces or urine through flushing) was also possible. Similarly, MERS-CoV is thought to have an ability to spread via airborne particles as reported during a hospital outbreak among haemodialysis and intensive care unit (ICU) patients [203]. Additionally, evidence from one study, which collected air samples from areas occupied by MERS patients, found culturable virus in rooms, toilets and the neighbouring corridor, suggesting that airborne transmission was possible [204].

Epidemiological evidence for SARS-CoV-2

There was inconsistent evidence from four studies [30,51,59,82], which considered the possibility of airborne transmission. Two of these studies [30,51] reported that airborne transmission was plausible, with one [30] reporting an outbreak which affected 52/60 (86.7%) of choir practice attendees and another [51] reporting 10/90 (11%) of restaurant patrons being infected from an asymptomatic restaurant patron, some of whom had no direct contact or fomite exposure. However, another study which reported the investigation of the same restaurant outbreak concluded that there was no evidence of airborne transmission [59], and one study [82] found no transmission on a long-distance flight, with the authors concluding that droplet transmission was more likely.

Presence of SARS-CoV-2 RNA in air

There was inconsistent evidence from seven environmental surveys [17,18,26,29,66,81,134], which investigated the presence of viral RNA in rooms housing COVID-19 patients. Two of these studies [17,26] found no SARS-CoV-2 RNA in the collected air samples placed in the rooms of COVID-19 patients who were talking, breathing and coughing [17,26], some of whom were also intubated [26]. One of these studies placed air samplers (n=4) in distance less than 1m from the patients [17] while the other set up four impingers (n=4) at a distance of 2–5m away from the patients [26]. In contrast, three studies [29,81,134] reported presence of SARS-CoV-2 RNA in the air surrounding COVID-19 patients. One study [29], which distributed air samplers around the rooms and areas near COVID-19 patients found that 14/40 of air samples from ICUs and 2/16 from general wards contained SARS-CoV-2 RNA and that the virus might have travelled as far as 4m away from the patients. Another study [81] placed a total of twelve air samplers at various distances in and outside of rooms of COVID-19 patients with mild or asymptomatic infection. Seven personal air samplers were used for sampling HCWs entering the rooms wearing appropriate PPE, and who were advised to maintain at least 6ft (1.8m) distance away from the patients. The study reported that five of the twelve samples in rooms and hallways were contaminated with SARS-CoV-2 RNA, two of which were placed at distances further than 1.8m. All seven personal air samplers were also found to contain SARS-CoV-2. Another study collected $1m^3$ air samples (distance from patients not reported) and found that 14/31 of them contained SARS-CoV-2 RNA. Further, two small studies [18,66] assessing presence of SARS-CoV-2 RNA in the air in rooms of COVID-19 patients found four of six rooms which were investigated were contaminated. One of these studies placed NIOSH air samplers in three rooms [15] (n=2 per room) with 12 air changes an hour at a distance of less than 1m to 2.1m away from the patients. The authors reported that particles were of sizes >4μm as well as smaller particles of 1–4μm which can remain in the air for longer. The second study placed air samplers in the rooms and obtained swabs from air outlet fans (n=3 each), and reported that while air samples were negative, two of three air outlets were contaminated. Two of these studies [81,134] assessed the viability of the SARS-CoV-2 virus in culture (Vero E6 [81,134], Caco2 [134]) and neither of them found any evidence of viable virus.

Duration of viable virus in the air

There was weak evidence from one laboratory study [92] assessing the duration that SARS-CoV-2 virus stayed viable in the air. This study used a $10^{5.25}TCID_{50}$ SARS-CoV-2 dose generated by three-jet nebuliser fed into a Collison drum to create an aerosolised environment, with resulting inoculum representative of upper and lower respiratory tract with 20–22 cycle threshold values. The authors reported that SARS-CoV-2 remained culturable in Vero E6 cells after 3hrs of remaining in the air with a reduction of infectious titre from $10^{3.5}$ to $10^{2.7}$ $TCID_{50}/L$.

Viral load

There was inconsistent evidence from four environmental surveys [17,18,64,134] which reported the SARS-CoV-2 viral load assessed as number of viral RNA particles per m^3 or the number of viral RNA particles/m^3/hr. One study [17] reported that no viral copies were found in the four samples collected in the rooms of COVID-19 patients who were breathing talking and coughing, while another [18], which collected samples of less than 1m to 2.1m away from patients reported $1.84x10^3$ to $3.38x10^3$ copies of viral RNA present in the three samples they collected. The authors reported that these were contained in larger droplets of >4μm in size as well as droplet nuclei of 1–4μm. An additional study [64], which investigated viral load as the number of viral particles/m^3/hr collected from a total of 35 samples from air samplers distributed through different locations within the hospital, reported that viral load was up to 113 in ICU, up to 42 in general wards and up to 11 in public areas. The authors reported that not only rooms and toilets were contaminated but also areas such as offices, workstations and changing rooms. The last study [134], which collected air samples from areas housing COVID-19 patients reported that the viral load ranged from 10 to 1000 RNA copies/m^3. This was the only study that assessed the viability of the SARS-CoV-2 virus in Vero E6 and Caco2 cell cultures and it did not find any evidence of the virus being viable.

*Upon the review of the above evidence, the COVID-19 Rapid Guidance Working Party considers the airborne transmission route to be **possible**, although the group acknowledged that this may be circumstance-specific, predominantly during AGPs.*

Transmission via fomites

Fomites are inanimate objects which, when contaminated, can transfer pathogenic microorganisms from one person to another. These objects can become contaminated from person's hands, body fluids and secretions or respiratory droplets settling on their surfaces. Fomites in hospital environment are usually mentioned in the context of different objects surrounding the patient, such as toilet seats, door handles and shared equipment; other, less commonly mentioned objects include hair, clothing, bedding, and eating and drinking utensils. This route of transmission depends on the ability of the microorganism to survive outside the human body. Outbreaks of SARS in healthcare and community settings in Hong Kong [196,197] implicated fomites as the route of transmission and one MERS outbreak occurring in a hospital in South Korea was thought to involve fomites [205].

Epidemiological evidence for SARS-CoV-2

There was weak evidence from two studies, which considered the possibility of indirect human-to-human transmission via fomites in the outbreak involving 35 cases in a shopping centre [8] and in a choir practice outbreak affecting 52 individuals [30]. Both studies concluded that fomites could have contributed to transmission of SARS-CoV-2.

The outbreak in the restaurant described in the droplet and airborne section [51,59] could also be explained by fomite spread on cutlery and crockery following contamination of the hands of the waiter serving these tables with little opportunity for hand hygiene (please see Appendix 9).

Presence of SARS-CoV-2 on surfaces

There was moderate evidence from seven environmental surveys, which assessed the presence of SARS-CoV-2 viral RNA in hospital rooms housing COVID-19 patients, with outcome measures reported either as the number of contaminated surfaces [29,66,81,93,134], the number of contaminated rooms [15,16] or the number of contaminated PPE items [66,67,93]. One study [29], which investigated presence of viral RNA on floors and high touch surfaces found that these were contaminated in ICUs caring for more severe cases (54/124, 44%) as well as in general wards where milder cases were present (9/114, 8%). Another study [66], which investigated toilets, floors and high touch surfaces, reported that 15/25 were contaminated and that the highest contamination was found on toilets (12/14). They found viral RNA on surfaces in three out of five patient rooms, while no contamination was found on floors. Similar findings were obtained in another study [81] which sampled common room surfaces, toilets, and personal items. Of the total of 134 samples tested, 114 (85%) were found to be contaminated with SARS-CoV-2 RNA. These included floors under beds (5/5 sampled), bedside tables or bed rails (18/24), toilets (17/21), personal phones (15/18) and remote controls (12/18). In one study [134], where samples were collected from high touch surfaces including bed rails, sinks, computer keyboards, clinical equipment, ward telephones and other surfaces, a total of 114/218 (52.3%) surfaces were found to be contaminated with SARS-CoV-2 RNA. In contrast, one small study [93] reported no contamination of hospital surfaces including door handles, bedside tables, monitors, sinks and bedrails, although the authors reported that these results might have been confounded by frequent cleaning with 1000mg/L of chlorine (every 4hrs in ICU and 8hrs in general wards). One study [18] which reported the number of rooms contaminated with SARS-CoV-2 RNA, found that 17/30 (57%) of rooms housing COVID-19 patients were contaminated. Another study [17] sampling one room found contamination during the first but not the second episode of sampling. Studies evaluating contamination of PPE where AGPs were not undertaken [63,64,90], found no contamination on gowns, respirators, masks, visors or goggles, while shoes were found to be contaminated only once (1/109 samples). One study attempted to assess viability of the virus obtained from the surfaces [134] in Vero E6 and Caco2 cells and reported that none of the 114 samples contaminated with SARS-CoV-2 RNA yielded culturable virus.

Survival of viable virus on different types of surfaces

There was weak evidence from two laboratory studies [19,92], which assessed the ability of viable virus to survive on different types of surfaces (number of surfaces not provided). One study [19] used 5μl droplet of $10^{7.8}$TCID$_{50}$/ml SARS-CoV-2 viral culture inoculated onto different types of surfaces including printing and tissue paper, wood, cloth, glass, banknote, stainless steel and plastic and maintained at room temperature (22°C) and 65% humidity. The authors reported that virus tends to survive better on smooth surfaces (glass and banknote 4 days, stainless steel and plastic 7 days), than on porous surfaces (paper less than 3hrs, wood and cloth 2 days). Another study [92] used a 10^5 TCID$_{50}$ SARS-CoV-2 virus inoculated onto plastic, stainless steel, copper and cardboard. The authors reported that SARS-CoV-2 remained viable for up to 4 hours on copper surfaces and 24 hours on cardboard. The virus was able to survive up to 48hrs and 72hrs on stainless steel and plastic surfaces respectively, although its infectious titre reduced to $10^{0.6}$TICD$_{50}$ on both surfaces.

*Upon the review of the above evidence, the COVID-19 Rapid Guidance Working Party considers the transmission via fomites to be **possible**.*

Vertical transmission

One meta-analysis, which evaluated the pregnancy outcomes of women infected by beta-coronaviruses [206] found that no cases of vertical transmission occurred in pregnant women affected by SARS (n=14) or MERS (n=4). Thus, vertical transmission was considered unlikely, although poor maternal, foetal, and neonatal outcomes were frequently observed [206].

Epidemiological evidence for SARS-CoV-2

There was moderate evidence from 31 case series/study articles, which investigated the possibility of vertical transmission for SARS-CoV-2 virus [5,10,12,14,17,22,24,31,35,39,42,46,52,54–56,58,71,73,75,94,97,113–115,117,119–121,124,133,136]. The results showed that from the total of 368 babies reported by these studies, twelve (3%) were reported [5,22,39,94,117,120,121,136] to be possibly infected *in utero*. Of these babies, only one was tested (and was found positive) for the presence of SARS-CoV-2 RNA at birth, which suggests that vertical transmission is plausible [136]. The remaining eleven babies were not tested for the presence of SARS-CoV-2 RNA at birth, which raises a possibility that these babies could have been infected intrapartum or postpartum. Additionally, for three of these babies, conclusions were based on the presence of IgM antibodies at birth with no evidence of SARS-CoV-2 presence [22,120].

Evidence for presence of SARS-CoV-2 RNA in maternal/ neonatal tissues and products of conception

There was a moderate evidence from 14 case series/study articles [10,25,31,35,42,54,71,73,94,97,113,115,117,136], which investigated the presence of SARS-CoV-2 viral RNA in different types of maternal and neonatal tissues and products of conception. The analysis of pooled results showed absence of viral RNA in samples obtained from cord blood (n=46), breast milk (n=10), vaginal secretions (n=8) and serum (n=1). Sampling of placenta revealed 4/20 (20%) positive samples, three of which were reported in one study [71] in women with severe COVID-19 disease with authors indicating that contamination from maternal tissues and fluids was likely. The remaining positive sample was reported in the study which found the neonate testing positive for SARS-CoV-2 RNA presence at birth [136]. The same study also found that amniotic fluid was contaminated with SARS-CoV-2 RNA before the rupture of the membranes whilst other studies reporting a total of 44 samples reported no presence of the viral RNA.

*Upon the review of the above evidence, the COVID-19 Rapid Guidance Working Party considers the vertical transmission route to be **unlikely**.*

Transmission of SARS-CoV-2 from different body fluids

Previous studies reported presence of SARS-CoV and MERS-CoV viral RNA in different body fluids and waste products including faeces [207–211], urine [207,209–212] and ocular secretions [213,214], with two further studies reporting infectious virus isolated in culture from urine and stool specimens [215,216]. Viral RNA was also found in gastrointestinal and urinary tracts of individuals affected by SARS or MERS [217,218]. This suggests that infection from exposure to body fluids is, at least theoretically, possible. Furthermore, one study describing an outbreak of SARS in residential complex in Hong Kong demonstrated a link between faeces from a symptomatic patient with diarrhoea and widespread transmission to others via the drainage system [203]. Additionally, unpublished data (being unpublished, these did not meet our criteria for inclusion in this guidance) from Chinese Center for Disease Control and Prevention suggested the possibility of SARS-CoV-2 virus in faeces becoming aerosolised after being flushed in the toilet [219]. The authors reported that the virus was deposited on surfaces (taps, showers, and sinks) of bathrooms in other apartments sharing the same sewage pipe. The data also identified individuals who later became ill with COVID-19, and who were linked to the same sewage pipe, although it is not clear whether these cases became ill as a result of exposure from infectious aerosols arising from the sewage. So far, it is unclear whether body fluids can be potential sources of SARS-CoV-2 infection, concerns also exist for blood and transplant donation recipients since it has been estimated that approximately 40% COVID-19 patients have evidence of viral RNA presence in their blood [220]. Saliva and respiratory fluids were not included in this evidence review as the working party considered them infectious.

Faecal matter

Epidemiological evidence

No evidence was found in studies published so far, that faecal matter was responsible for transmission of SARS-CoV-2 virus to other persons.

Evidence of presence of SARS-CoV-2 RNA in faecal matter

There was moderate evidence from 33 case series, case studies and environmental surveys, which assessed the presence of viral RNA in anal swabs [21,25,36,45,72,88,101,112,126], or stools [15,31,38,50,53,68,69,89–91,95,96,101,104,108,111,122,125,129–131] of COVID-19 patients or in sewage taken during the pandemic in community settings [4,62,105] or in a hospital caring for COVID-19 patients [93]. These studies found consistent evidence for the presence of SARS-CoV-2 RNA in such specimens. Overall, SARS-CoV-2 RNA was found in anal swabs of 25/72 (35%) COVID-19 patients, in stool specimens of 215/439 (49%) patients and in 50/65 (77%) of sewage samples.

Evidence of presence of viable SARS-CoV-2 virus in faecal matter

There was weak evidence from one case series, one case study and two environmental surveys, which assessed the presence of culturable SARS-CoV-2 virus in stools [96,129]or sewage [4,93]. One case series study [96], which assessed virus viability in four stool samples with high SARS-CoV-2 viral load, reported that two of these samples yielded culturable virus and that the patients from whom the samples came, did not have diarrhoea. A case study [129] of one patient with severe pneumonia reported that the SARS-CoV-2 virus isolated from a faecal sample obtained 15 days after the onset of the disease was cultured in Vero E6 cells and observed under scanning electron microscope. The environmental surveys found no viable virus in six sewage samples that they tested. The first of these studies [4] collected the samples from untreated sewage from the municipal pumping station and wastewater treatment plant in the middle of the pandemic, approximately five to seven weeks after the first cases appeared in the area. Of two samples found to be positive for SARS-CoV-2 virus by PCR, neither was viable in culture. Another study [93] collected samples from hospital sewage disinfection pools with the wastewater coming from isolation rooms of COVID-19 patients. Four samples, which were previously found to contain SARS-CoV-2 RNA, yielded no viable virus cultured in Vero E6 cells.

Upon the review of the above evidence, the COVID-19 Rapid Guidance Working Party considers SARS-CoV-2 transmission from infected faecal matter to be ***unlikely****.*

Urine

Epidemiological evidence

No evidence was found in studies published so far, that urine was responsible for transmission of SARS-CoV-2 virus to other persons.

Evidence of presence of SARS-CoV-2 RNA in urine

There was moderate evidence from eleven case series and case studies, which assessed the presence of SARS-CoV-2 RNA in urine, with outcome measure defined as number of patients with positive sample [31,38,53,68,72,91,130,131,135] or number of positive urine samples [15,96]. These studies demonstrated that urine is rarely contaminated with SARS-CoV-2 viral RNA. Studies which assessed the number of patients with any positive urine sample found that in 8/150 (5.3%) urine was contaminated with SARS-CoV-2 RNA. Studies which assessed the outcome as the number of positive urine samples, found no evidence of this occurring (0/82, 0%).

Evidence of presence of viable SARS-CoV-2 virus in urine

There was weak evidence from one case study [135], which attempted to isolate infectious virus from urine sample obtained 12 days post-infection from one COVID-19 patient. This study found evidence that the virus was culturable in Vero E6 cells, with cytopathic effects observed in cells after three days.

Upon the review of the above evidence, the COVID-19 Rapid Guidance Working Party considers SARS-CoV-2 transmission from infected urine to be ***unlikely****.*

Ocular secretions and transmission via ocular surface

Epidemiological evidence

No evidence was found in studies published so far, that ocular secretions we responsible for transmission of SARS-CoV-2 virus to other persons.

There was weak evidence from two case series and case studies [49,127], which reported occurrence of SARS-CoV-2 transmission via ocular surface in three HCWs. These studies reported that all three cases occurred when the HCWs did not wear equipment to protect their eyes, wore it inconsistently, or touched their eyes when working with infected patients.

Evidence of presence of SARS-CoV-2 RNA in ocular secretions

There was moderate evidence from nine case series and case studies, which assessed the presence of SARS-CoV-2 RNA in ocular secretions [11,20,85,87,102,106,110,127,132]. These studies consistently demonstrated a rare presence of SARS-CoV-2 RNA in ocular secretions, with 8/194 (4%) of samples yielding positive results.

Evidence of presence of viable SARS-CoV-2 virus in ocular secretions

No evidence was found in studies published so far, that viable SARS-CoV-2 was found in ocular secretion specimens.

Upon the review of the above evidence, the COVID-19 Rapid Guidance Working Party considers SARS-CoV-2 transmission from infected ocular secretions to be ***unlikely****.*

Upon the review of the above evidence, the COVID-19 Rapid Guidance Working Party considers transmission via ocular surface to be ***possible****.*

Sexual body fluids

Epidemiological evidence

No evidence was found in studies published so far, that sexual body fluids were responsible for transmission of SARS-CoV-2 virus to other persons.

Evidence of presence of SARS-CoV-2 RNA in sexual body fluids

There was weak evidence from three case series studies, which assessed the presence of SARS-CoV-2 viral RNA in sexual body fluids [21,44,79]. One study evaluating the presence of the virus in semen [44] found 6/38 (16%) of specimens being infected while the remaining two studies [21,79] found no SARS-CoV-2 RNA in a total of 45 vaginal secretion samples.

Evidence of presence of viable SARS-CoV-2 virus in sexual body fluids

No evidence was found in studies published so far, which reported that viable SARS-CoV-2 was found in sexual body fluid samples.

Upon the review of the above evidence, the COVID-19 Rapid Guidance Working Party considers SARS-CoV-2 transmission from infected sexual body fluids to be ***unlikely****.*

Blood transfusion and organ transplantation

Epidemiological evidence

There was a weak evidence from four case studies which assessed the possibility of SARS-CoV-2 transmission via blood donation [137–140]. In these studies, a total of five recipients received blood products obtained from four donors, who at the time of donation, were not aware of their infection. None of the five recipients acquired the virus as a result of blood transfusion.

No evidence was found in studies published so far, that organ transplantation resulted in transmission of SARS-CoV-2 virus to organ recipients.

Upon the review of the above evidence, the COVID-19 Rapid Guidance Working Party considers SARS-CoV-2 transmission from blood transfusion and organ transplantation to be ***unlikely****.*

Transmission dynamics of SARS-CoV-2

The transmission dynamics for SARS-CoV and MERS-CoV were different, which may reflect their infectivity via different transmission routes. The SARS outbreak originated in southern China and it is thought that many cases were due to super-spreader index patients who infected many individuals [221]. Examples of individuals who caused such events are a fish-monger from southern China who infected 30 HCWs and eventually was implicated as the index patient in an outbreak in surrounding hospitals; a doctor from a Chinese hospital who infected 23 hotel guests and who subsequently carried the virus to other countries including Vietnam, Canada and Singapore; and a Hong Kong housing estate where one index patient with diarrhoea was responsible for transmitting the virus to over 200 estate residents [203,221–224]. Other outbreaks occurred mostly in hospitals [221] and isolated cases later occurred when researchers working with SARS-CoV in laboratory settings were infected following exposure [225]. Transmission of MERS-CoV occurs mostly from infected camels via direct contact or from consuming camel meat and milk [199]. Human-to-human transmission occurs but is thought to be relatively rare and is limited to a close contact with severely ill people [199]. The majority of secondary cases are known to be either HCWs or close family members sharing the same household. Secondary cases also tend to develop milder symptoms and be less infectious to others [199].

Epidemiological evidence of SARS-CoV-2 transmission occurring within households

There was moderate evidence from 17 outbreak studies [7,16,27,28,31,34,37,41,47,48,54,78,84,86,98,99,128], which investigated the possibility of SARS-CoV-2 transmission occurring between household members. The majority of the studies reported transmission which occurred at the start of the epidemic in their local areas with no restrictions put in place by local government [7,28,31,34,37,41,48,54,82,85,128]. Two studies reported that national surveillance and contact tracing were in place but that no restrictions were implemented at this point [16,99], and further three Chinese studies reported that Wuhan was under lockdown at the time of data collection [27,78,95]. None of the studies reported the use of any mitigation measures to control transmission within the household, e.g., wearing face coverings, staying in separate rooms, or avoiding any close contact. One of the studies reported that the lockdown in Wuhan prompted many residents to return to their provinces, which resulted in the spread the disease across the country [27]. The studies collectively reported a total of 1119 cases with an overall attack rate of 25%. The attack rate varied widely from none, to all members of the household being infected.

Epidemiological evidence of SARS-CoV-2 transmission occurring between family and friends

There was moderate evidence from 14 outbreak studies, which reported a total of 179 cases of SARS-CoV-2 transmission occurring among family members [6,16,23,27,33,34,40,43,74,77,78,107,116,118] and a further five outbreak studies describing 11 cases occurring between friends [33,40,99,107,109]. These persons did not share a household with infected index cases but were reported to have close contact exposure while eating meals, visiting each other or travelling together. The overall attack rate for family contacts was 24.6%, although as with household transmission, this varied widely from 14% to all family members being infected. The overall attack rate for exposure between friends was 8%.

Epidemiological evidence of SARS-CoV-2 transmission occurring in workplaces

There was moderate evidence from six outbreak studies [23,27,70,76,78,80], which investigated SARS-CoV-2 transmission in work environment where there was no exposure to the customers. The studies reported that a total of 122 individuals were affected with an overall 10% attack rate. One study [70] also reported that 94/97 (97%) COVID-19 individuals were working on the same floor, with many also situated on the same side of the building. Another study [76] reported that 7/94 (7%) were most likely infected because of breakout sessions and team building activities which allowed a close and sometimes physical contact between the individuals.

Epidemiological evidence of SARS-CoV-2 transmission occurring in supermarkets and shopping centres

There was weak evidence from three outbreak studies [76,103,123], which investigated SARS-CoV-2 transmission in supermarkets and shopping centres. Two of these studies reported that national surveillance and contact tracing were in place during data collection [76,123], but none reported specific measures for controlling transmission such as the use of face coverings or social distancing. The studies reported a total of 22 employees and 21 customers being infected, with attack rates of 12% and 0.02% respectively. However, in one study [73] where employees had close contact with infected customers, the attack rate was higher (29%).

Epidemiological evidence for SARS-CoV-2 transmission occurring during church service

There was weak evidence from three studies [76,99,116] reporting five outbreaks, where exposure during the church service affected a total of 20 cases with an attack rate of 2%. All studies reported that national surveillance and contact tracing were in place during data collection, but none reported specific measures for controlling transmission such as the use of face coverings or social distancing. Of the 20 cases, four were described as sitting very close to the index patients [76,99] and one was found to occupy the same space during a different service later that day [99].

Epidemiological evidence for SARS-CoV-2 transmission occurring in acute healthcare settings

There was moderate evidence from eight outbreak studies [7,16,28,32,43,83,84,100], which investigated the occurrence of SARS-CoV-2 transmission occurring in acute healthcare settings. The outbreaks showed that transmission in these settings is relatively low and affected 37 HCWs, 13 patients and seven visitors caring for their sick relatives. The attack rate for HCWs was 0.9% and mostly occurred in HCWs who reported prolonged contact with the index patients and being present during AGPs without the use of PPE (31/37, 84%) [32,83,84]; in the remaining six cases the staff were reported to have worn PPE [16]. The overall attack rate for patients and visitors was not established.

Epidemiological evidence for SARS-CoV-2 transmission occurring in care homes

There was weak evidence from one outbreak study [61] describing transmission in a nursing home. This study described an outbreak which involved a total of 101 residents, 50 staff and 16 visitors. The authors did not provide a denominator, but based on the reported bed capacity of 130, the attack rate among residents was 78%.

Epidemiological evidence for SARS-CoV-2 transmission occurring in other settings

There was weak evidence from a total of 11 outbreak studies, [8,23,27,60,63,65,70,74,78,82,128] which investigated transmission occurring in other settings. They reported that the risk of acquiring the virus from these settings was low. One study [27] estimated that 6/1052 (0.6%) of infected cases acquired the virus during public gatherings and a further 5/1052 (0.5%) acquired the virus from no apparent close contact with known COVID-19 cases. Isolated incidents occurred in a public bath (n=8 cases) [57], public transport (n=14), [27,78] tour groups travelling together (n=8) [65,128] and during a flight in which a passenger sat next to an individual later diagnosed with COVID-19 (n=1) [128].

*Upon the review of the above evidence, the COVID-19 Rapid Guidance Working Party conclude that it is **probable that transmission occurs with close contact**, although at the moment it is not possible to determine the distance or the duration for transmission to occur. Transmission from COVID-19 patients to HCWs in hospitals is low, except in small number of cases where HCWs cared for undiagnosed COVID-19 patients and did not use appropriate PPE. Even in these cases, transmission usually occurred during AGPs. Transmission in care homes appears to be very high and needs particular consideration.*

Additional literature published after the initial search

The Working Party considered updating the review in the light of new rapidly emerging evidence. However, the number of articles related to SARS-CoV-2, published since the original search was conducted in May 2020, has increased dramatically. A search conduced between 12 May 2020 to 05 April 2021 in Embase and Medline resulted in an additional 10,931 and 9132 records respectively, thus making timely revisions unfeasible. The Working Party is aware of a number of publications which have not been included in the above evidence review, particularly those in relation to the current debate about aerosol transmission. The evidence cited has not been systematically searched but was obtained from several sources, e.g., expert recommendations and the additional concomitant searches for other COVID-19 related questions. All other methodological aspects of quality assessment and data extraction remained the same in gathering this evidence.

Droplet vs airborne route

Epidemiological evidence for SARS-CoV-2 transmission via droplet vs airborne route

There was inconsistent evidence from seven studies, [142,143,147,149,155,157,158] which considered the possibility of airborne vs droplet transmission. Four of these studies [143,147,155,158] concluded that airborne transmission was likely after observing the transmission patterns in outbreaks affecting 34/55 (62%) of nursing home residents and staff in the Netherlands, [143] 20/79 (25%) of early-shift employees at a meat processing plant in Germany, [147] 52/60 (86.7%) of attendees at a choir practice in the USA [155] and 23/67 (34%) of a group of lay Buddhists travelling on the bus to and from a worshipping event in China. [158] However, one study [157] concluded that transmission patterns were consistent with the droplet route in relation to a small cluster where 2/132 (0.02%) of high and low-risk contacts were infected after one mildly symptomatic index case working as a doctor in a hospital in Germany was diagnosed early at the start of pandemic after acquiring the virus in Italy. [157] One further study [149] reported that it was not possible to confirm or exclude either droplet or airborne transmission. This study described an outbreak on a long-distance flight following which 15/183 (8.2%) of passengers and crew became infected, with the majority of the passengers being within a two-metre range of the index case. Furthermore, one study describing a choir practice in France that affected 19/27 (70%) of attendees concluded that transmission was likely due to both, droplet and aerosol spread.

Presence of SARS-CoV-2 RNA in air

There was inconsistent evidence from nine environmental surveys, [141,144,145,150,152–154,159–161] which investigated the presence of SARS-CoV-2 RNA in hospital rooms, hotels and flats housing known COVID-19 patients. Two of these studies [141,145] found no viral RNA in collected air samples from the rooms of COVID-19 patients who were breathing normally, [141,145] talking or reading a book aloud [141,145] or singing [141] One of these studies placed air samplers at a distance less than 1m from the patients [141] while the second study [145] set them up at a distance of 2–5m away from the patients. In contrast, seven studies [144,150,152–154, 159–161] reported the presence of SARS-CoV-2 RNA in the air surrounding COVID-19 patients. One study found evidence of SARS-CoV-2 viral RNA in the air in all four samples taken from the room of two COVID-19 patients. [150] This study used a water vapour condensation system designed for collecting airborne particles without damage, with samples taken 2m or 4.8m away from the patients. The remaining studies reported relatively low prevalence of SARS-CoV-2-positive air samples. One study [144] reported a single 1/46 (2.2%) weakly positive sample (defined by authors as a sample with cycle threshold between 37 and 38) that was found in a corridor of the COVID-19 ward but not in samples taken in the rooms (at 0.5m distance from the patients) or at the nursing station. A different study [152] reported two positive samples (total number of samples not reported) taken at the distance of 1m away from the patient, one study [153,154] reporting one (1/26, 3.8%) positive sample collected from the toilet in COVID-19 ward and one study [161] reporting 3/44 (6.8%) of samples collected from high and low risk areas in hospital housing COVID-19 patients. One of these studies [150] assessed the viability of the SARS-CoV-2 virus in Vero E6 culture cells and found all four samples to contain infectious virus with 6 and 27 viral genomes/L for samples collected at 4.8m distance and 18 and 74 genomes/L for samples collected at 2m.

Duration of viable virus in the air

There was weak evidence from one laboratory study [146] assessing the duration that SARS-CoV-2 virus stayed viable in the air. The study used a custom-made drum to aerosolise and maintain suspension of the SARS-CoV-2 virus particles in the room. Authors reported that 16 hours after remaining suspended, the reproductive ability of the virus did not reach its half-life and only a minimal decrease in virus concentration was observed. They also reported that scanning electron microscope examination showed that the virus maintained its characteristics (size, shape, morphology) 16 hours after aerosolisation.

Contaminated air vents, ducts and filters

There was weak evidence from three environmental surveys [143,156,159] which reported the presence of SARS-CoV-2 RNA in swabs taken from different parts of ventilation system. Positive samples included 7/19 (37%) of vent openings and 4/19 (21%) of vents ducts taken from rooms housing COVID-19 patients [143] and from an outpatient clinic, [156] and 3/6 (50%) air exhaust outlets in negative pressure rooms with COVID-19 patients. [159] One study reported that two (1/2) filters from air conditioning units and 4/16 (25%) filters from ventilation cabinets, taken from the nursing home unit involved in the outbreak affecting 62% residents and staff, also contained SARS-CoV-2 RNA. [143] One of these studies attempted to determine the virus viability in Vero E6 cells but they reported that their results were inconclusive. [156].

Contaminated exhaled breath

There was inconsistent evidence from three environmental surveys [144,153,154,161] which investigated the presence of SARS-CoV-2 RNA in the exhaled breath of COVID-19 patients. Two of these studies, [153,154,161] both using exhaled breath collection devices (BioScreen, version I and II) to collect their samples, reported the presence of viral RNA in 14/52 (27%) [153,154] and 2/9 (22%) [161] of the collected exhaled breath condensates. Conversely, one study [161] which collected two exhaled breath samples and two expired air samples found no evidence of the SARS-CoV-2 presence. Neither of these studies attempted to determine the viability of the virus.

As mentioned above in the airborne section, aerosols refer to respiratory particles, which are found in the air, and their size is the predominant, although not the only reason, [226] for their ability to remain suspended in the air. [198] The generally accepted threshold for these particles to be considered airborne is $<5\mu m$ [143] and they are assumed to have an ability to travel further than two-metre distance within which the larger droplets are thought to fall to the ground. However, there is evidence that suggests that these larger particles can travel further than two metres. [226] Research suggests that humans may produce both sizes of respiratory aerosols during normal breathing, coughing, or sneezing and that larger droplets may desiccate and form smaller 'airborne' particles, [198] thus the distinction between the droplet and airborne route is not always clear. Both, SARS-CoV and MERS-CoV, among other respiratory viruses, were considered to be predominantly transmitted via the droplet route. [196,197] However, scientists studying the behaviour of expired aerosols argue that, in the distance up to two metres, short-range airborne particles are still the main route of transmission with larger droplet route dominating only up to 0.2 metre distance or 0.5 metre during coughing. [227].

Upon the review of the above evidence, the COVID-19 Rapid Guidance Working Party conclude that the ***above conclusions to the likely routes of transmission remain the same****. Furthermore, in relation specifically to airborne/aerosol/droplet debate, the Working Party consider that this is an academic argument which is unlikely to reach a consensus. The questions that are important to the potential guideline users are whether two-metre distance is sufficient and whether respiratory masks designed for filtering airborne particles are necessary to prevent SARS-CoV-2 transmission.*

Faecal matter

Epidemiological evidence

There was weak evidence from one study [148] which investigated the possibility of faecal matter being responsible for transmission of SARS-CoV-2 virus to other persons. The study described an outbreak of 9 cases occurring in three vertically aligned flats with bathrooms connected via drainage system. Secondary cases occurred in families with no recent travel history and no contact with confirmed or suspected COVID-19 cases. Authors reported that no other cases occurred within the other households, some of which were in close contact with index cases in the elevator. Outbreak investigations showed the presence of SARS-CoV-2 RNA in samples taken from vertically aligned flats, one of which was unoccupied while all samples taken from communal areas were negative. To further strengthen their evidence, authors released tracer gas into the toilet of the index household. Substantial tracer gas concentration was found in the flats of the two affected households and along with two other vertically connected flats. Authors concluded that drainage pipes of vertically aligned toilets probably served as transport routes of faecal aerosols between the flats and that, similarly to the SARS outbreak in Amoy Gardens in 2004, the dry drains allowed the aerosol dispersal into some but not all flats.

Upon the review of the above evidence, the COVID-19 Rapid Guidance Working Party considers SARS-CoV-2 transmission from infected faecal matter to be ***unlikely***.

Transmission dynamics of SARS-CoV-2

Epidemiological evidence for SARS-CoV-2 transmission occurring in acute healthcare settings

There was moderate evidence from 23 studies [165–183,187–189,193,195] which investigated the occurrence of SARS-CoV-2 transmission affecting HCWs in acute healthcare settings. The total number of infected HCWs reported in these studies combined with the studies reported previously [7,16,28,32,83,84,100] was 2170. Seven studies [168,172–174,182,187,189] reported unprotected exposure of HCWs to undiagnosed (and not suspected) COVID-19 patients. Unprotected exposure differed between the studies but all described contact (close or casual) with an infected patient without PPE or with PPE which was not considered sufficient. Combining the results obtained from twelve studies, which reported a total number of exposed and total number of infected HCWs, [7,16,28,32,84,168,172–174,182,187,189] the overall attack rate was 1.6% (84/5298). This included a total of 18/1138 (1.6%) HCWs who were reported to have a high-risk contact (defined in studies as prolonged, at least 10min direct contact <2m with the infected patient or being present during AGPs performed on infected patient). [84,168,173,182,187,189].

Studies which investigated the prevalence of SARS-CoV-2 infection in HCWs reported that unprotected patient-HCW contact was only one of the vectors for SARS-CoV-2 transmission. One UK study [166] reported that after the first wave of pandemic, a total of 1,128 of HCWs in one hospital (11.2% of total 10,034 staff population) tested positive either for SARS-CoV-2 RNA presence through PCR screening or for SARS-CoV-2 antibodies through serological screening test, which suggests they must have acquired an infection at some point from the start of the pandemic. The analysis of the pre-test questionnaires demonstrated that working on COVID-19 wards was one of the risk factors for SARS-CoV-2 acquisition (2.47 [CI 95% 1.99–3.08] $p<0.001$), although transmission still occurred in low-risk areas, which authors suggested, was due to HCW-HCW transmission. After adjusting for COVID-19 areas, exposure to a confirmed household contact was the most important risk factor with 38.5% of staff who tested positive reporting this exposure and (AOR 4.82 [CI 95% 3.45–6.73] $p<0.001$), and further 16.1% reporting exposure to suspected (not confirmed) household contact (AOR 1.75 [1.372.24] $p<0.001$). Contact with COVID-19 confirmed patients without PPE was reported by 17.0% of staff who tested positive (AOR 1.44 [1.24–1.67] $p<0.001$).

Another UK study, [167] used PCR testing to screen symptomatic HCWs both, those who worked in hospitals or general practitioners, at the start of the first wave of the pandemic in the UK between 10th-31st March 2020 (national social distancing measures introduced 20th March followed by 23rd March national lockdown), reported that 240/1654 (14.5% of symptomatic staff, total number of staff not reported) tested positive during this time. Authors reported no difference in the positivity rates between three types of HCWs, i.e., those in patient-facing roles (e.g., nurses, doctors, allied professionals, porters, 128/834, 15%), those in non-patient but high-risk roles (e.g., laboratory and domestic staff, 14/86, 16%) and those in low-risk roles (e.g., administrative, secretariat, IT, 20/109, 18%). Authors suggested that nosocomial transmission from patients to staff was not an important factor. They also observed that the weekly rates of positivity in the HCWs reflected the pattern of transmission in the community rather than nosocomial spread, thus they reported that the isolation protocols and PPE provided to staff were sufficient to protect them from potentially infectious patients.

Similar conclusions were reached by another study [179] which offered asymptomatic weekly screening for staff working in one of London's NHS healthcare networks. Data were reported for five weeks starting the week of the national lockdown on 23rd March 2020. Authors reported that the rate of positivity of the asymptomatic staff who volunteered to participate in this screening programme mirrored the curve of positive cases in London area and the number of COVID-19 inpatients in the trust around this time, and that the trend represented community rather than hospital transmission to HCWs.

These findings are in line with the results of two studies which reported transmission patterns at the start of pandemic in the Netherlands. [169,178] The positivity rate in symptomatic HCWs was reported as 6% (86/1353, or 0.9% of the entire staff in two hospitals participating in the study) [169] and 6% (96/1796 or 0.8% of the entire staff in three hospitals participating in the study). [178] Only three HCWs in each study (representing 3.5%169 and 3%178) reported contact with COVID-19 positive patient before they tested positive, with a total of 21/86 positive HCWs (24%) [169] and 20/96 (21%) [178] also reporting that their roles did not involve patient contact. Other known COVID-19 exposures included fellow HCWs (18/96, 19%), [178] a household member (1/96, 1%) [178] and other contacts outside the hospital (9/96, 9%). [178] Furthermore, one of these studies [178] reported that 10 of the infected 96 HCWs (10%) declared recent foreign travel, 60 (63%) declared carnival attendance with more than 50 people present, and 31 (32%) declared attendance at other event which involved more than 50 people. Both studies concluded that the community rather than hospital transmission most likely contributed to a high prevalence of SARS-CoV-2 infection in these HCWs. Additionally, one of these studies [169] reported that 54/86 (63%) of these HCWs were working while symptomatic, which possibly contributed towards the community and nosocomial spread. Authors reported that this was due to a very narrow case definition of COVID-19 at this time with only 3/86 (3.5%) of positive staff meeting the case definition criteria.

Another study from the Netherlands [175] which described transmission dynamics in one hospital early in the pandemic (3rd April-11th May) reported a higher positivity in symptomatic HCWs (88/362, 13.9). During this time, besides the implemented PPE, staff were not allowed to work in more than one location, social distancing was implemented in break rooms and staff were asked to isolate for at least until 24hrs after symptom resolution. All infected HCWs were questioned about possible infection source and were divided into risk categories: direct patient contact, indirect patient contact, no patient contact. Whole Genome Sequencing, which analysed isolates from 30 HCWs and 20 patients, identified four clusters suggesting multiple introductions to the hospital. Authors reported that the epidemiological and WGS analysis strongly suggested transmission occurring between the healthcare workers as well as from HCWs to patients.

Another study of HCWs in a hospital, which was reported to be a hub of COVID-19 cases in Italy, [170] screened all their staff during the first wave of pandemic and also offered antibody testing to any HCW willing to participate. They identified a total of 58 of 2057 (2.7%) staff who acquired the SARS-CoV-2 infection. They reported that working on COVID-19 wards was a risk factor for acquiring an infection, although only 29/58 (50%) of positive staff had an exposure to COVID-19 +ve patient, while for 26/58 (44.8%) no exposure was traced and for 3/58 (5.2%) exposure was out of hospital. Similarly, another study from Singapore, [181] which undertook a 16-week staff symptom surveillance reported that, over the study period, 2250/9322 (24%) of staff presented to the staff clinic with symptoms and 14/2250 (0.6% of symptomatic or 0.2% of total staff) were found positive. Ten of these 14 workers did not have patient contact and were exposed in the community (71.4%) and the remaining four were infected from another HCW (three of these HCW contacts were outside the hospital).

An additional study from Philippines [180] reported the results of reactive screening (close contact or high exposure to the virus) of HCWs. A total 324 tests were performed, 97 (30%) of which were due to moderate or high-risk exposure. All infections (n=8) occurred in the group screened following the moderate/high exposure (8.2%) and most of the cases were a part of two clusters. The first cluster involved one doctor and two nurses who worked together as a TB team. It is not possible to determine how the doctor became infected, but he subsequently infected two nurses on his team either at work or in the apartment which they shared during the community quarantine; 17 days later another nurse of his team tested positive, but it was not possible to determine whether this HCW was a part of a cluster or an isolated case. Another cluster involved three laboratory technicians who were working together in HIV clinic and were exposed to an infected housemate. Authors reported that transmission may have been low due to appropriate PPE used and other measures implemented but highlighted that HCW exposure is not necessarily due to patients.

Another study from the UK, [176] reported the results of symptomatic screening of all staff combined with asymptomatic screening of staff working in areas with high-risk of exposure or working in areas for clinically vulnerable patients. Staff working in high and moderate risk areas were more likely to test positive than those working in low-risk areas (relative risk not reported). However, authors described one cluster of cases in a low-risk area on a ward with vulnerable population and suggested a potential HCW-HCW or HCW-patient transmission. In high-risk wards, where transmission was high, authors suggested patient-HCW, HCW-HCW or community transmission. Lack of behavioural data prevented the authors to form more firm conclusions.

Finally, in one study from USA [174] all HCWs, who came in close contact with patients in the emergency department, were offered a serology screening approximately a month after the peak of the first wave of pandemic. Of about 200 staff, 138 volunteered to participate in testing of whom seven (5.1%) were reported to have SARS-CoV-2 antibodies suggesting a prior infection. History of risk factors taken from all HCWs showed no significant exposure risks between staff who tested positive and negative, including number of contacts with cases in or outside work, wearing PPE, or number of hours worked. Authors acknowledged that incidence of infection in HCWs was higher than in general population and that the occupational exposure is a risk but were not able to determine whether exposure was from patients or other staff.

The remaining studies attempted to identify the source of infection for the HCWs. One study which investigated exposure to SARS-CoV-2 virus in 110 infected HCWs in Wuhan [171] reported that 17 (15.5%) worked in fever clinics/wards, 73 (66.4%) worked in other departments and 20 (18.2%) did not interact with patients. The relatively low proportion of staff from fever clinics may have been due to PPE worn in these areas, including the respirator masks. A total of 65 (59.1%) infected HCWs attributed their infection to contact with patients who were later diagnosed with COVID-19, 12 (10.9%) to contact with colleagues, 14 (12.7%) to contact with family or friends and 19 (17.3%) could not recall their exposure history. Another similar study [195] reviewed contact history of 32 nurses infected with SARS-CoV-2 in Wuhan. Authors reported that 21 of 32 (65.6%) nurses were infected in hospital (either from patient or another HCW), 5 (15.6%) were infected in community and 6 (18.8%) were unknown. Of the six nurses with no known exposure, four reported that they had no direct contact with COVID-19 patients.

Another study, which described an outbreak in Wuhan hospital at the start of the pandemic when COVID-19 pneumonia was not yet discovered, [183] identified two undiagnosed index patients who were nursed without PPE. A total of twelve confirmed and two suspected HCWs (denominator not provided) developed COVID-19, and further 13 cases were identified in other departments, although these were possibly linked to other unknown index patients. Authors reported that exposure history was available for 17 HCWs who were confirmed positive by PCR test, of whom seven (28%) were likely infected from patients, three (12%) from suspected patients, three (12%) from other HCWs, four (16%) at events and meetings, whilst for eight (32%) infected HCWs exposure was not known.

Another study, [173] which investigated the occupational exposure to SARS-CoV-2 virus in HCWs in Greece, reported that during the first wave of pandemic there were a total of 3398 HCWs were occupationally exposed, 1725 (50.8%) of which were exposures to patients and 1660 (48.9%) to another HCW, and ten (0.3%) to a visitor. In a high-risk exposure group (n=1031) patient was a risk source in 331 (32.1%) of all exposures while remaining 700 were due to another staff (67.9%). A total of 13 staff in high-risk group were subsequently found infected but the authors did not report how many of these were from exposure to patients and how many from other HCWs.

One investigation of a large hospital outbreak involving 39 patients and 80 HCWs in hospital in South Africa, [188] included a review medical records, ward visits, interviews and whole genome sequencing analysis. Phylogenetic analysis strongly suggested that the outbreak was a result from a single introduction from an index patient attending the A&E department who infected another patient. This other patient was subsequently admitted to ICU. Infection spread quickly across five wards, facilitated by frequent patient transfers. Authors suspected that this outbreak also involved a neighbouring nursing home and an outpatient dialysis unit (further 16 cases if including these two facilities). Of 1711 staff tested (approx. 86% of the total) and 80 were positive (4.7%), authors mentioned multiple exposures to patients and other HCWs as possible vectors of transmission, some cases could also have been infected in the community, although whole genome sequencing suggested one cluster. Authors also reported that a rushed intubation of one undiagnosed case involving several HCWs did not result in infection and concluded that not PPE, but hand and environmental hygiene may have been more important in mediating the transmission between staff and patients.

In one outbreak on haematology/oncology unit, where 8/106 (7.5%) HCWs and one patient were infected, [165] index case was not found. Authors identified the first case to be a nursing assistant, but it is possible that this case was infected from another case on a ward. For a total of six of the eight infected HCW (75%) and one patient (denominator not reported), it was not possible to determine how they were infected, while two HCWs (25%) acquired the virus from their colleagues.

Another nosocomial outbreak [193] in the hospital in the UK identified an index patient discharged from ICU to a medical ward. It was not possible to determine how this patient was infected, but it was likely from symptomatic or asymptomatic HCW in ICU although authors said patient-to-patient transmission from unknown case was also possible. The possibility of community transmission was excluded because the patient was in hospital for 41 days before developing symptoms and the hospital visitations stopped due to the national lockdown. Follow up identified 23 symptomatic staff (either confirmed or suspected) and 5 patients infected on a medical ward, as well as 17 ICU staff who were self-isolating around this time. It was reported that seven of the 23 HCWs (30%) were in direct contact with an index patient while others were in contact with symptomatic and pre-symptomatic staff and patients. Authors concluded that transmission was propagated by staff because close contact between staff was common.

Nosocomial transmission to patients was not well described but patients infected from other patients were described in three studies, [172,188,193] from HCWs in four studies [175,176,188,193] and in one study it was not possible to determine whether transmission occurred from HCW or another patient. [165].

Epidemiological evidence for SARS-CoV-2 transmission occurring in care homes

There was weak evidence from six outbreaks reported by eight studies [177,192,184,186,185,190,191,194] describing transmission in a nursing home. Combining the results obtained from six outbreaks, where both number of total number of residents and total number of infected residents were reported, [177,192,184,186,185,190,191,194] the overall attack rate for the residents of these facilities was 410/967 (42.4%). Only one outbreak [177,192] reported a low attack rate 3/80 (3.8%), most likely because the residents lived in the assistive care facility, which involved a minimal contact with staff and other residents. The other five outbreaks were reported to affect between 19% [190] and 64% [184,186,194] of their residents. Combining the results obtained from five outbreaks, where both number of total number of residents and total number of infected residents were reported, [177,192,184,186,190,191,194] the overall attack rate for the staff working in these facilities was 169/719 (23.5%). As with the residents, one study reported low attack rates 2/62 (3.2%) in healthcare workers due to the residents [177,192] requiring minimum staff contact. The remaining four outbreaks involved between 6% [190] and 45% [191] of staff. Of the six reported outbreaks, two implicated a resident as an index case [190,191] although it was not possible to determine how this case was infected, one suspected a transmission from the staff member [184,186] and for the remaining four the index case was not identified. [177,192,185,194] One study [191] concluded that staff in these facilities are likely vectors for SARS-CoV-2 transmission between the patients and that the part-time workers employed across multiple institutions may be responsible for cross-facility spread. The HCW-to-HCW transmission was considered likely in two outbreaks [184,186,191] and one also reported likely multiple introductions from the community via HCW route. [184,186].

Recommendations

Summary of findings

The evidence presented above helps to understand the transmission dynamics and therefore allows the Working Party to make the following conclusions:

- In the community, SARS-CoV-2 transmission most commonly occurs in socially connected cases (household, relatives, friends, co-workers), which suggests close contact between the index and secondary case is required for infection to occur. Thus, the two-metre rule is usually sufficient to prevent transmission. The exceptions may be the activities with large volumes of air expired e.g., during exercise or singing (index case likely to exhale many viral particles); in crowded spaces (where more than one index case is likely or when virus is transmitted transiently between the individuals) or when virus is carried over a long distance (e.g., due to air conditioning carrying respiratory secretions further than two metres).
- Transmission mostly occurs indoors.

- Where transmission occurred, the index and secondary cases were usually present in the same space at the same time which suggests that, despite laboratory studies showing persistence of SARS-CoV-2 virus in air and on surfaces, this is not a likely route of transmission.
- In acute and nursing home care settings, patients/residents, HCWs and visitors are potential vectors for SARS-CoV-2 transmission. This may help explain the often-reported high attack rates in these facilities. This is likely due to complex dynamics involved in interaction between these individuals, where close contact is common, social distancing is difficult to maintain, many index cases may be pre-symptomatic or apparently asymptomatic and where multiple introductions may occur.

The overarching conclusion, which was reached by the members of this Working Party was that SARS-CoV-2 virus does not appear to be transmitted via the routes different to those observed in other respiratory viruses. Thus, same infection prevention mechanisms (mainly the traditional droplet and contact precautions commonly implemented in hospital settings) are considered sufficient by this Working Party to prevent SARS-CoV-2 transmission.

Rationale for recommending preventative measures

Social distancing: since data suggest that close contact is implicated in most transmissions, social distancing remains the most important approach to prevent transmission of SARS-CoV-2 virus. This needs to include social distancing between staff in health and care settings, so that they are protected not only from patients but also from fellow HCWs. It should be the employer's responsibility to introduce appropriate social distancing policies including in social/domestic areas (e.g., number of staff allowed in a staff room or changing room, seating arrangements in the office etc.) and employees' responsibility to adhere to them.

Facial and respiratory protection: data suggest that wearing fluid resistant surgical mask is sufficient to prevent SARS-CoV-2 transmission in health and care settings. This is consistent with studies which investigated the benefit of wearing respirators vs surgical masks to prevent influenza transmission. [227] However, the Working Party members understand that respirators may provide reassurance to HCWs who are in close contact with patients and therefore conclude that the individual institutions may decide to provide them to their front-line staff. Respirators are not only more expensive but are also reported to be uncomfortable and irritating to the skin [228], thus not likely to be worn for extended period. These will also not protect HCWs from each other in staff rooms or offices. The decision to provide respirator masks needs to be carefully balanced and consider factors such as prevalence of SARS-CoV-2 infected individuals, ventilation in the setting and the availability of the respirator masks. The studies which evaluated the risk of SARS-CoV-2 transmission specifically from AGPs found little evidence for this occurring, [229] thus fluid-resistant surgical masks are likely sufficient in preventing the infection. However, since these are considered high-risk procedures, and intubation was previously shown to increase the risk of infection from other respiratory viruses, respirator masks should be recommended for AGPs. Furthermore, since the data suggest that when patient-to-HCW transmission occurs, it is usually when patient is not suspected to be infected with SARS-CoV-2 virus. Therefore, the use of respirator masks should be extended to any AGP, regardless of patient status. In community setting, if individuals adhere to social distancing, close contact is usually brief and cloth-based face covering should be sufficient to prevent transmission.

Gloves and handwashing: Data suggest that fomite transmission is possible, but probably is not the major route of transmission unless combined with close contact (e.g., touching objects in the immediate surrounding of an infectious person). Appropriate hand washing is sufficient in removing respiratory pathogens, including coronaviruses, from contaminated hands. [228] According to the same review, gloves may not offer additional protection, which is in line with French Society for Hospital Hygiene who currently recommend wearing gloves for only some activities involving COVID-19 patients (contact with blood, body fluids or mucous membranes, contact with damaged skin or damaged skin on HCW). However, current protocols recommend the use of gloves for any activity involving a patient placed on contact precautions and therefore gloves should be recommended. As with other pathogens, gloves must be changed, and hands must be decontaminated between the patients. For contact with blood or body fluids (excluding saliva and respiratory secretions), gloves are a part of standard precautions and should be worn regardless of patient COVID-19 status.

Other PPE: Aprons are currently recommended for all activities with patients placed on contact precautions and for activities involving the risk of contact with blood and body fluids, thus these should be recommended for any contact with COVID-19 patient. Face shields should be recommended due to a risk of SARS-CoV-2 virus entering via ocular route. Face shield is currently recommended for patients on contact precautions where there is a risk of splashes thus same should be applied to activities involving COVID-19 patients. During AGPs, where there is a risk of respiratory secretions being sprayed, long sleeved gowns should be recommended.

Recommendations

GR1: Adhere to regulations currently imposed by your government. Specific guidance may be available from your government.

GR2: Maintain the recommended minimum distance, as advised by your government, at all times.

GR3: Use a face covering in enclosed spaces to protect yourself and others.

GR4: Reduce the time of contact with anyone outside your household to a minimum.

GR5: To avoid transmission from fomites, decontaminate your hands frequently using soap and water, and when this is not possible, use alcohol-based hand rub.

Good practice point: Follow World Health Organization advice on how to handwash (https://www.who.int/gpsc/5may/How_To_HandWash_Poster.pdf) and how to handrub (https://www.who.int/gpsc/5may/How_To_HandRub_Poster.pdf)

GR6: Avoid touching your face and eyes with your hands as transmission via ocular surface is possible.

GR7: Evidence suggests that a high proportion of transmissions occur as a result of close contact between family members, friends, and co-workers. Adhere to the above recommendations when in contact with anyone outside your household or support network.

GR8: Available evidence suggests that transmission without close contact or outside is unlikely. Continue maintaining your locally determined distance (which is 2m within the UK) and using face covering in indoor settings. There is no evidence which suggests that respirator masks (e.g. N95, FFP2/3) offer additional protection outside the healthcare settings.

Good practice point: To protect yourself and others, follow WHO advice and avoid 3Cs: **C**losed spaces, **C**rowds, **C**lose contact.

Specific recommendations for persons working in health and care settings:

HR1: You must adhere to regulations imposed by your trust/employer.

HR2: Where there is ongoing transmission, for contact with patients and other healthcare staff, use a fluid-resistant face mask, and adhere to general recommendations listed above.

HR3: For care of patients suspected or confirmed to have COVID-19, in addition to the above, use fluid resistant surgical face mask and adhere to contact and droplet precautions. No other precautions are necessary.

HR4: Risk of SARS-CoV-2 transmission from body fluids (faeces, urine, ocular excretions, and sexual body fluids) is unlikely, use contact precautions and appropriate PPE (including fluid resistant surgical face mask type IIR) and do not use additional precautions (e.g., filtering respiration mask) unless carrying out AGPs. Your employer may make a decision to provide respirator masks for procedures other than AGPs, based on local circumstances.

HR5: Whilst blood and body fluids are not a likely source of SARS-CoV-2 infection, there remains a risk of infection with other pathogens to HCWs and via them to other patients. Use PPE (gloves, plastic aprons, eye protection) as appropriate when there is a risk of exposure to blood, body fluids or any items contaminated with these products and clean your hands immediately after glove removal.

HR6: Literature suggests that most SARS-CoV-2 transmissions from patients to HCWs occurred when HCW did not use protection during AGPs on patients not suspected of having COVID-19. Consider using filtering respiration mask (FFP3) designed for filtering fine airborne particles for any AGPs regardless of a patient's COVID-19 status when local assessment suggests risk of SARS-CoV-2 circulating in the community or local setting.

HR7: Vertical transmission is unlikely. Studies have reported avoiding caesarean delivery where possible and mothers being advised to use a surgical mask.

Summary of recommendations is provided in Table I.

Recommendations for managers in health and care settings:

MR1: Adhere to current national guidelines for IPC, including those specific to COVID-19 as well as general ones for preventing infectious diseases.

MR2: Consider exploring potential factors for SARS-CoV-2 transmission specific to your setting, e.g., inability to maintain social distancing and managing apparently asymptomatic cases.

Conclusions

Determining routes of infection is important because it helps to define the precautions required to stop an infection chain without using excessive PPE and other resources. SARS-CoV-2 appears to spread via the routes commonly implicated in transmission of other respiratory viruses. SARS-CoV-2 virus does not appear to have an increased ability to spread more efficiently via the traditionally defined airborne route. Other reasons, which determined its successful spread around the world and affecting so many individuals, are not related to its transmission routes but other factors such as a higher affinity for ACE2 receptors (especially observed in the new variants), a larger number of apparently asymptomatic/pauci-symptomatic individuals, pre-symptomatic transmission and the possibility of reinfection from different clades of the virus.

Mass vaccination, which already commenced in many countries, may be important in tackling the pandemic, although the impact of vaccination on transmission of the virus is yet to be determined. Emerging new strains of SARS-CoV-2 raise concerns that current vaccines may become less effective when new mutations occur. Interrupting routes of transmission by applying strict IPC measures, including social distancing, remain the most effective means of controlling the spread. [230] In this document, we summarised the evidence of the routes of SARS-CoV-2 transmission, demonstrated that it spreads via the routes commonly used by other respiratory pathogens, and we concluded that the existing recommendations for droplet and contact precautions are sufficient in preventing the transmission.

Further research

Research recommendations

RR1: Outbreak studies, which thoroughly investigate the transmission dynamics of affected cases, for example, in relation to separation distances needed to sufficiently reduce the risk of human-to-human transmission.

RR2: Air sampling studies which use appropriate techniques for obtaining and culturing the SARS-CoV-2 virus.

RR3: Studies on preventing COVID-19 in care home settings.

RR4: Studies of environmental, organisational and workforce related interventions to minimise the transmission of SARS-CoV-2.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhin.2021.04.027.

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