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Usher Network for COVID-19 Evidence Reviews

Summary: What is the evidence for indoor transmission of SARS-CoV-2?

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THE UNIVERSITY of EDINBURGH | usher institute

Title: What is the evidence for indoor transmission of SARS-CoV-2?

We set out to answer ten specific questions, drawing on evidence from epidemiological, microbiological and fluid mechanics studies:

1. What evidence is there for aerosolised transmission?
2. What evidence is there for faecal-oral transmission?
3. What evidence is there regarding the role of ventilation systems in indoor transmission?
4. What evidence is there regarding the role of plumbing systems in indoor transmission?
5. What evidence is there regarding transmission via different indoor surfaces (materials and specific objects)?
6. What evidence is there for the transmission in indoor residential settings?
7. What evidence is there for transmission in indoor workplace settings?
8. What evidence is there for transmission in other indoor settings (social, community, leisure, religious, public transport)?
9. Do particular activities convey greater risk (e.g. shouting, singing, eating together, sharing bedrooms)?
10. What evidence is there for the appropriate length of distancing between people?

Summary answer:

Transmission mechanisms (questions 1 and 2)

Based on the evidence available to date, the most common transmission route for SARS-CoV-2 is person-to-person, short-range spread via mostly respiratory droplets that directly reach recipients either through the air or through touching contaminated surfaces and then transferring the virus on the hands to mucosal membranes. Evidence from numerical simulation and fluid mechanics studies, microbiological laboratory studies and environmental sampling studies suggest that aerosol transmission is theoretically possible and is another potential source of transmission. Evidence from an outbreak linked to a choir practice is also consistent with this. There is no direct evidence of SARS-CoV-2 transmission via the faecal-oral route but this possibility cannot be definitively ruled out.

Role of ventilation and plumbing systems in transmission (questions 3 and 4)

Air currents are responsible for the dispersal of both aerosols and large droplets within buildings, between different rooms and even between different floors. This dispersal can be amplified by a variety of factors, including ventilation and air conditioning systems, differences of temperature between rooms and air currents entering through open windows.

However, ventilation systems are also likely to dilute the concentration of viral particles in the air and thereby to play a potential role in decreasing transmission. Ventilation systems are likely to decrease virus transmission risk near the source but to increase virus transmission risk further away from the source.

There is no direct evidence that SARS-CoV-2 is transmissible via infected faeces; however until this route of transmission is definitively ruled out, it is important to note that aerosolised particles can be generated in vertical soil stack pipes when toilets are flushed. These particles can then enter a room via ventilation systems and defective plumbing systems – specifically U-trap failure/depletion. This is of particular relevance in high occupancy and high-rise buildings.

Transmission via different surfaces and objects (question 5)

Laboratory-based experiments demonstrate that the length of time SARS-CoV-2 remains viable on surfaces depends on the type of surface and the environmental conditions. Evidence suggests that the virus prefers smooth, non-fabric surfaces, low temperatures and damp conditions. It survives for longer on plastic (detectable for up to 72 hours, with a half-life of approximately 7 hours) and stainless steel (detectable for up to 48 hours, with a half-life of approximately 6 hours) than on cardboard (detectable for up to 24 hours, with a half-life of approximately 3.5 hours). Copper has strong anti-viral properties, with no viable virus detectable after 4 hours and a half-life of less than an hour. Experiments investigating the impact of temperature on the virus show that it is highly stable at 4°C (still detectable at 14 days). At 22°C it is detectable at 7 but not at 14 days. At 70°C it is undetectable after 5 minutes. Although the virus persists in both the wet and dry environments, experiments have shown that the dry environment is less favourable for survival. It can also survive under acidic conditions, such as the stomach.

Studies analysing swabs taken from various surfaces and high-touch objects in clinical and non-clinical settings occupied by infected cases detected viral RNA on telephones, keyboards, doorknobs, elevator buttons, TV controls, water dispenser buttons, chairs, toilet floors, bedding and hand sanitiser dispensers. However all three studies which quantified the amount of virus present found minimal amounts of viral material. We found only one epidemiological study which reported explicitly on fomite transmission: a case of secondary transmission through occupying the same seat in a church as the index case, without the infected person coming into direct contact with the index case.

Transmission in different indoor settings (questions 6, 7 and 8)

We found evidence of transmission in domestic, workplace and community/leisure settings. Most of the studies we found were conducted early in the pandemic, when effective and accurate contact tracing was possible. We found higher secondary attack rates (defined as the probability that an infection occurs among susceptible people within a specific group, such as a household or close contacts) in communal residential contexts (range, 18 % to 62 % amongst residents of care homes, shelters for homeless people, cruise ship) than in households (pooled SAR 11 %, 95 % CI 9, 13).

We found evidence of workplace outbreaks in a care home, an assisted and independent living community, shelters for homeless people, shops, meat and poultry processing factories, a cruise ship, a business conference, a customer call centre and a government ministry; however few of the studies provided enough detail to allow meaningful comparison of the risks in different settings. Nevertheless, many of the workplace settings where outbreaks have occurred are characterised by close physical contact and prolonged time spent in crowded indoor spaces. Health inequalities and inadequate social protection are strong drivers of workplace transmission – for example people continuing to work whilst ill, overcrowded housing and transportation to and from work and inadequate health and safety communication and training.

Transmission risk associated with different activities (question 9)

Our study found evidence that within households, the risk of transmission was higher between spouses than between other types of relative. We found evidence that effective social distancing to prevent transmission within households is possible, particularly if the isolated person is able to use a separate bathroom, a separate bedroom, minimise time in the same room as other family members and wear a mask where this is unavoidable. However, such measures are challenging in overcrowded housing and do not take into account that many cases are asymptomatic so individuals will be unaware that they are sick and potentially transmitting the virus to others.

We found evidence that activities associated with a higher risk of transmission are those where people gather in close proximity indoors for prolonged periods. Churches and religious gatherings, sharing meals and bathing facilities, close physical contact and activities such as singing together have all been reported in conjunction with outbreaks. In contrast, there have been fewer reports of transmission in relation to more casual, short term social contact, although this may be because such contacts are subject to recall bias and harder to track and trace. Risks associated with travelling with an affected case are difficult to evaluate – the evidence from these studies was limited and non-specific.

Evidence on the appropriate length of distancing between people (question 10)

Large respiratory droplets, which are believed to be the main route to transmission, are ejected while speaking, coughing and sneezing. These droplets land within less than 1 metre, 2 metres and 8 metres from the source, respectively.

There is clear evidence that aerosolised transmission played a role in the 2003 SARS-CoV outbreak. The evidence is less clear for SARS-CoV-2; however viral RNA has been detected in aerosols and laboratory studies suggest live virus can survive in this form for up to 3 hours. Numerical studies have demonstrated that aerosol can travel significant distances, including across different rooms, floors, and also from one building to another. Epidemiological evidence from a large outbreak linked to a choir practice is also compatible with aerosolised transmission across longer distances indoors. However, the longer the travelled distance, the lower the likelihood that the concentration of virus is above the threshold needed to transmit the disease.

Summary of methods:

Our methods are described in detail in the full version of this review (see link below). We searched PubMed, medRxiv, arXiv, Scopus, WHO COVID-19 database, Compendex & Inspec between 20-05-2020 and 21-05-2020. We also identified articles from other sources (previous reviews, experts, hand searching). We included epidemiological, microbiological and fluid mechanics articles reporting data on any indoor setting; any indoor activities; any potential means of transmission and mechanisms which may influence transmission in indoor environments. We excluded studies investigating transmission in healthcare settings; studies focusing purely on the clinical characteristics of cases; studies focusing on covid-19 prevention interventions and studies set in schools (transmission in schools and among children is the focus of a separate ongoing review which can be found on the UNCOVER website). Screening criteria for mechanistic studies were adapted to include articles reporting data on any respiratory virus and numerical simulation studies focusing on the mechanisms of transmission. Title and abstract and full text screening was conducted by one reviewer, with rejections reviewed by a second reviewer. Data extraction and quality assessment for each article was conducted by a single reviewer. Data extraction was limited to a minimal set of required data items. Where available, we used validated risk of bias tools. We developed our own tool for assessing the quality of experimental studies. Numerical simulation studies were appraised by an expert in the field using a quality appraisal tool which we developed ourselves. Data were synthesised narratively, and meta-analysis was conducted where indicated. Data on secondary attack rates in households were meta-analysed using a fixed effects model. I^2 and Cochrane's Q were calculated to assess heterogeneity. For consistency, the same function was used to estimate confidence intervals for SAR in individual studies that were not included in pooled estimates. Because most of the microbiological evidence on this topic was generated from hospital-based studies, we included microbiological studies which collected samples from both clinical and non-clinical settings. To maximise the transferability and generalisability of these findings to non-clinical indoor settings, we excluded results of samples collected in areas of the hospital such as operating theatres and ICU where aerosol-generating procedures are routinely carried out.
This is an update of two previous rapid reviews (UNCOVER 002-01 – focusing on indoor vs. outdoor transmission, full description of methods available here, literature search conducted 31 March 2020;

and UNCOVER 002-02 – focusing on outdoor transmission, full description of methods available here, literature search conducted 30 April 2020).

Our literature searches identified 1573 unique articles, of which 1447 were rejected through title and abstract screening and a further 60 were rejected at the full-text screening and quality assessment stages. 33 did not provide data relevant to study questions, 26 were poor quality and 1 article could not be retrieved. Our review is based on 66 articles retained for analysis.

Conclusions:

There is a general consensus that the main route of CoV-2 transmission is through person-to-person short-range transmission, which occurs through large respiratory droplets ejected while speaking, coughing and sneezing. There is also potential for aerosolised transmission: viral RNA has been detected in aerosols and laboratory studies suggest live virus can survive in this form for up to 3 hours and there is some epidemiological evidence consistent with aerosolised transmission across longer distances indoors. Ventilation systems can play both positive and negative roles in aerosol transmission, dispersing aerosolised particles widely within buildings but also diluting them. There is no direct evidence of transmission via the faecal-oral route but until this route of transmission is definitively ruled out, it is important to note that defective plumbing systems have the potential to amplify transmission within buildings.

The length of time SARS-CoV-2 remains viable on surfaces depends on the type of surface and the environmental conditions. Evidence suggests that the virus prefers smooth, non-fabric surfaces, low temperatures and damp conditions, detectable for longer on plastic (up to 72 hours) and stainless steel (up to 48 hours) than on cardboard (up to 24 hours).

We found evidence of transmission in domestic, workplace and community/leisure settings. We found higher secondary attack rates in communal residential contexts (care homes, shelters for homeless people, cruise ship) than in households. Many of the workplace settings where outbreaks have occurred are characterised by close physical contact and prolonged time spent in crowded indoor spaces. Health inequalities and inadequate social protection are strong drivers of workplace transmission.

Our review confirms that activities associated with a higher risk of transmission are those where people gather in close proximity indoors for prolonged periods. We found little evidence of transmission in relation to more casual, short term social contact, although this may be because such contacts are more difficult to trace. The overall quality of the evidence is graded as low.

Link to full review:

https://www.learn.ed.ac.uk/webapps/blackboard/content/listContentEditable.jsp?content_id=_4649570_1&course_id=_77596_1&content_id=_4649570_1

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