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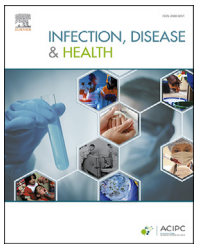

Research paper

Maintaining safe office spaces to minimise risks of SARS-CoV-2 transmission

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KEYWORDS
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Abstract *Background:* SARS-CoV-2 can be transmitted within offices. Traditional respiratory transmission modes have undergone reassessment and a new paradigm has emerged. This paradigm needs examining prior to identifying control measures to prevent office acquired infections (OAI).
Methods: An ongoing assessment of the SARS-CoV-2 transmission literature, including international public health guidance, began 30/1/2020 and continued to submission 7/2/2022. The evidence for the established respiratory transmission paradigm (either droplet or aerosols) and that of a newly emerging paradigm (aerosol and/or droplets) were explored. Based on the new paradigm control measures needed to minimise OAI were produced.
Results: The old paradigm of respiratory transmission of being either droplet ***or*** airborne cannot be evidenced. SARS-CoV-2 is emitted in virus laden particles that can be inhaled ***and/or*** sprayed on facial mucous membranes (Airborne being the dominant route).

Office hygiene measures include: minimising the opportunities for the virus to enter the building. Reducing the susceptibility of people to the virus. Minimising exposure risks within offices, and optimising success in deployment.
Conclusion: Standard office hygiene precautions are needed to reduce OAI risks from SARS-CoV-2. Efforts should focus on enabling the smooth functioning of the office whilst minimising risks that the virus will transmit therein. This includes: local risk assessments as transmission risks vary based on building design, ventilation, capacity, and ways of working. Additionally, using experts to optimise ventilation systems.

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Highlights

- Offices are indoor places where SARS-CoV-2 can transmit. They contain the 3 'Cs' where the highest transmission risks occur: closed spaces, crowded spaces, and where people are close to each other.
- Respiratory transmission for SARS-CoV-2 is undergoing a paradigm shift. From one of transmission by droplets or aerosols, to one of droplets and or aerosols. The inhalation of aerosols (airborne) being the dominant route.
- To minimise the risks of SARS-CoV-2 transmission in offices there needs to be an understanding of the implications of the new paradigm prior to adopting standard control measures.
- As SARS-CoV-2 is now classified as an airborne disease, understanding, and improving ventilation in offices has become a critical control measure.
- All offices are different in form and function and thus in risks to the office workers therein vary also. Therefore, all buildings will need to be risk assessed individually.

Introduction

The SARS-CoV-2 pandemic has highlighted the potential for infections to be acquired in workplaces. At the peaks of pandemic waves, one frequently applied control measure was to reduce the risk of office acquired infections (OAI) by the deployment of working-from-home mandates for non-essential office workers [1]. This paper aims to provide guidance on assessing and reducing the risks of OAI as the pandemic's end remains out of sight. Debate on the transmission routes of SARS-CoV-2 has been ongoing since it was declared. Transmission is now accepted to include short- and long-range aerosols which enter via being sprayed on or inhaled [2—4]. The indirect contact route is still considered plausible. The situation now is that whilst debate is settling around the routes of transmission, the part played by any specific route is still questioned [2—4]. However, the accepted SARS-CoV-2 routes of transmission from international public health authorities, along with the implications for preventing OAI, needs further assessment and clarification.

Although there is no systematic reporting of SARS-CoV-2 from office settings, extrapolation from studies confirms their impact. A European study of the occupation locations of COVID-19 outbreaks were collected over a 4-month period in 2020 [5]. The report detailed 1376 outbreaks from 16 countries and included 65 office outbreaks, involving 410 people and 4 deaths. During the same period, only 22 were reported from educational facilities [5]. As SARS-CoV-2 is transmitted by both respiratory and contact routes, any standard office control measures effective against SARS-CoV-2 transmission have the potential to prevent OAI caused by other pathogens (e.g. influenza or norovirus). Of note however, the heterogeneity of office design, office occupancy and work patterns therein, means that any advocated guidance must be adapted based on local risk assessments.

Aim

To consider the current modes of transmission for SARS-CoV-2 and produce standard office control measures to prevent OAI.

Methods

An ongoing assessment of the SARS-CoV-2 transmission literature began with the declaration on 30/1/2020 by the World Health Organization (WHO) that the novel coronavirus was a public health emergency of international concern [6] International guidance on the prevention of transmission from the WHO [7], the Centres for Disease Control and Prevention (CDC) [8] and the United Kingdom's Health Security Agency [9] was continuously scrutinised alongside scientific publications as they became available until submission in 7/2/2022. The established paradigm of respiratory transmission had been based on the CDC's 2007 guidance; this was of either droplet *or* inhalation transmission [10]. Early in 2021, a new paradigm emerged which suggested transmission was mainly by inhalation [11]. Both paradigms were explored. Control measures for offices based on the new paradigm were identified and advocated.

Findings

How SARS-CoV-2 is transmitted

From the start of the SARS-CoV-2 pandemic there was ongoing debate around the routes of transmission and the relative importance of any specific route [12,13]. Pre-pandemic infection control guidance utilised the old paradigm of respiratory pathogens being transmitted as either droplets ***or*** aerosols based on the dichotomous aerosol size of $\leq$5 μm and $>$5 μm [10]. Droplets it was considered were sprayed on the mucous membranes of the face, and aerosols inhaled to cause airborne infection. What has been notable through this pandemic is that whilst the old paradigm of aerosol ***or*** droplet continued to be used, previous attempts to define a category cut-off point were abandoned in national guidelines for unspecific and untestable 'small' or 'large' [9]. Others escaped the dilemma of a micro size cut off point in guidance by omitting definitions altogether [14].

The WHO in July 2020 issued a position paper, also devoid of definitions, that stated SARS-CoV-2 was mainly transmitted via droplets [7]. However, of their 16 supporting citations only 5 specified a mode of transmission, the rest referred to a space, e.g., 'close contact',

'household transmission' [7]. There was a clear assumption by the WHO that transmission which arose close to infected cases confirmed droplet transmission, whilst that which happened distant from the case was considered airborne [7]. This is evidenced by WHO's summarising where they exclude airborne for the lack of evidence and assuming closeness to cases is equivalent to droplet transmission. However, closeness to a case can neither confirm droplet nor exclude airborne transmission. The WHO's evidence for droplets was equal to their evidence for airborne. The critical evidence was that transmission was happening close to the source [7]. Of note, short-range aerosol transmission (airborne) is more likely to occur where the highest concentrations of virus-laden aerosols are most dense which is again, close to the source [11]. Criticism of the old paradigm included it 'defies physics' [11]. This and many other old paradigm transmission fallacies were exposed [15] and scientific arguments for mainly airborne transmission put forward [16]. There is no evidence to support the old paradigm view that most respiratory infections are spread via droplets [17]. A new paradigm, largely based on the work of aerobiologists, emerged [11].

Respiratory activity emits gas clouds with a ballistic trajectory containing droplets with a continuum of sizes [18]. In the new paradigm, the larger droplets are now delineated at the size of >100 μm [11], This is the threshold of particle size that can remain suspended in the air to be inhaled [11]. Eventually, the large droplets lose momentum and fall to surfaces from where indirect contact transmission can subsequently arise [11]. Whereas aerosols <5 μm can remain suspended indefinitely [17], larger particles 5- <100 μm) can rapidly evaporate to form droplet nuclei which behave like aerosols. Both large droplets and small aerosols are virus laden, but most pathogens are to be found in the smaller sized aerosols (<5 μm) [11,17]. Thus, the old paradigm of airborne ***or*** droplet transmission is now (using old paradigm terms) changed to airborne **and/or** droplet through being either inhaled (airborne) or sprayed on facial mucous membranes (large droplets) [11]. As most particles in exhaled breath are <4 μm and most pathogens are in the <5 μm aerosols, it is argued that most respiratory infections are transmitted via the airborne route [17].

Again, using old paradigm terms, people need protection against both sprays and inhalation at close distance and inhalation when distant from cases [11,17]. The key difference in the new paradigm is that for viruses it can never just be 'droplets (sprayed on)' as a mode of transmission. The aerosols with their virus laden payload can remain airborne for considerable periods of time, float on air currents under doors and down corridors, thus people can be infected who aren't exposed close to the case [11,13,15–17]. Thus, this virus is transmitted via the airborne through the inhalation of both short- and long-range aerosols [11,13,15–17]. One review of respiratory transmission concluded there is unequivocal evidence indicating that for SARS-CoV-2 airborne transmission is the dominant pathway [19].

Apart from the respiratory routes, the contact routes can transmit virus should a case touch another person direct whereby they move virus contamination to their mucous membranes, or via the indirect route being contaminated from touching surfaces. The role of contact routes in the pandemic once considered most important has now declined in importance, but it has not been eliminated [20].

There is evidence that some notable bodies (WHO, CDC, European Centre for Disease Prevention and Control) are transitioning their definitions of SARS-CoV-2 to align with the new paradigm [2–4]. However, although they now admit short- and long-range aerosol transmission exists, there is still a reluctance to recommend outright airborne precautions for the care of all people with SARS-CoV-2 [2].

In summary, the current understanding of SARS-CoV-2 transmission is that it mainly an airborne infection [19]. Virus-laden aerosols and droplets are emitted during respiratory activity [11,18]. They can be sprayed on to mucous membranes from the force of the exhalation, or aerosols inhaled at both short and long range [11,15]. Droplets will fall to contaminate surfaces whereby SARS-CoV-2 can also be transmitted via indirect contact. Direct contact from a case to a susceptible person may also arise. The indirect contact route is now thought to present much less of a transmission risk [20]. The role of ingestion and faecal contamination remains theoretical and not thought to be a major transmission route [21,22].

Identifying standard office control precautions

The hierarchy of controls was devised to manage exposures to occupational hazards, protect workers and determine how to implement feasible and effective control solutions [23]. There are 5 elements in the hierarchy of controls: elimination, substitution, engineering controls, administrative controls, (i.e., changing the way people work and use the office), and the least effective is personal protective equipment (PPE) [23]. However, this hierarchy omits personal behaviours. Therefore, still mindful of the hierarchy of controls, and aware the highest transmission risks have been summarised as the 3 C's: being 'Close' to infected people, being in 'Crowded' spaces and being in 'Closed' spaces [24], the goals for standard office control precautions was based on the following:

- Minimising the opportunities for the virus to enter the building
- Reducing the susceptibility of people to the effects of the virus
- Minimising virus exposure risks within the building
- Optimising success in reducing acquisition risks and by monitoring compliance with new ways of working and ventilation systems.

The need for any of the measures listed below will be based on a local risk assessment [25] of the building, its ventilation, the spaces, and facilities available, and the vulnerability of the staff who work therein.

Minimising the opportunities for the virus to enter the building

SARS-CoV-2 is transmitted from symptomatic and asymptomatic people thus standard office precautions to minimise the risk of the virus entering the building are to:

- Enable and encourage symptomatic and potentially infectious people to stay at home. The list of symptoms that should stop people coming to the office must be wide and include respiratory and gastrointestinal symptoms. Just being a '*bit off*' should also be sufficient to allow working from home.
- A daily health check on arrival at work will ensure only those without infectious disease symptoms are in the office. This shows caring for both individuals who may be sick and those who do not want to become sick.
- Test for SARS-CoV-2 pre-attendance should be done in line with current local and national guidance. This is most important when they are unavoidable larger meetings to be attended.
- Encourage and enable the use of respiratory protection when staff are travelling on public transport and in parts of the building that might not be under your control.

Reducing the susceptibility of people to the effects of the virus

- Advocate vaccination for all vaccine preventable OAI is essential. Not only do they reduce transmission risks they also reduce morbidity and business disruption. Adoption of a 'condition of employment' vaccination policy rather than 'making it mandatory' has been shown to increase compliance without significant loss of employees [26].
- Identify and support any workers who may be immunosuppressed and at special risk to feel and be safe.

Minimising virus exposure risks within the building

This is an airborne disease and most transmission occurs indoors — offices are indoor spaces. The paradigm shift in respiratory transmission has been mirrored by another paradigm shift in recognising the need for safe indoor air and for updated standards for indoor air quality (IAQ) that reflect the activities within buildings (e.g. higher IAQ for gyms) and the mandating monitors displaying the state of IAQ [27].

- Risk assess the existing ventilation system prior to planning any ventilation improvements. The ventilation risk assessment should be undertaken by an expert and the results compared against the national building regulations specifications (which should include the fresh air required per size of floor space) [28] [Of note new design methods to reduce the risk of infection within buildings are already proposed] [29].
- Avoid air recirculation as this can transport viruses from one part of the building to another [30]. The position and direction of air coming from an air-conditioning system was considered responsible for some cases in one SARS-CoV-2 outbreak [31].
- Maximise fresh air by opening windows (if possible). [30].
- Consider providing air-filters and disinfecting the air using UV-C light.
  - High-Efficacy Particulate Air (HEPA) filters can be used to supplement ventilation [30,32]. These filters can remove $\geq$99.97% of particles from the air. HEPA air cleaners in classrooms are reported to reduce overall aerosol particle concentrations by $\geq$ 80% within 30 min [32]. They have also reduced airborne risks in clinical settings [33]. The placement of these within rooms will affect filtration — again expert help will be needed for this.
  - Disinfecting the air using UV-C lights is possible, however, selection and application must be done in consultation with a review of product evidence, engineers, and taking cognisance of any national guidance [30,34].
- Reduce occupancy where air quality is poor and cannot be improved [35]. Other simple measures include, specifying the maximum occupancy for all rooms, increasing spacing by employing any underutilised spaces, using signage to indicate required separation spaces, and creating one-way routes around the office. Staggering arrival and departure times could prevent choke points.
- Continue to use online meetings to prevent any room becoming crowded.
- Personal Protective Equipment (respiratory protection equipment) can significantly reduce transmission risk particularly when people are within 2 m where exhaled aerosols are at their most dense [11]. When office workers are in close contact with visitors, mask policies (for both the visitor and the worker can further reduce risk. The efficacy of masks is well demonstrated [36,37]. The better the mask the greater the protection [37].
- Identify frequently touched sites (FTS), which will enable the identification of the times and places where hand and surface decontamination needs doing FTS may include the door entry system where passes are presented, door plates, kettle switch, common surface use in canteens and various surfaces in the toilet areas.
- Negate the need for touching surfaces could, for example, involve introducing non-touch entry points and keeping open non-fire doors.
- Place surface and hand decontamination stations where FTS have been identified. For example, the first-hand decontamination station should be after the pass-entry system and door plates have been negotiated. A hand decontamination station positioned before a door entry system, and not after, could result in people immediately contaminating hands after cleaning them prior to entering. Other critical points where hand hygiene stations should be present include the kitchen and toilets. Surface decontamination stations are needed when the people using spaces change during working hours, e.g., hot-desks, quiet rooms, meeting rooms.
- Decontamination of surfaces, e.g., after room occupancy or equipment user change, is useful to prevent indirect transmission. Products should be accessible, and the methods should be swift and non-damaging to either the equipment or the environment.
- Deploying a non-touch greeting, e.g., *hello* and *goodbye* signs as used by people with hearing loss, may prevent offence for or by people who are no longer comfortable with a handshake.
- Adopting safe personal habits, e.g., cough hygiene and etiquette should be practiced by all to reduce transmission risks [38].

How to promote success in reducing acquisition risks and compliance with new ways of working

- For these procedures to be effective there must be both compliance with the new procedures and efficacious products. For hand hygiene alcohol-based hand rubs, the concentration of alcohol should be a minimum of 60% and comply with the EN 1500:2013 [39]. Decontamination of surfaces should involve disinfection as well as cleaning [40]. Combined disinfectants and detergents will reduce a two-step process (clean then disinfect) to one (clean whilst disinfecting). The selected disinfectant must be easy to use and reliably achieve decontamination with minimal effort and present no residual harm to people or the environment. If wipes are selected, they should have passed the EN14476:2013 test against viruses as well as the EN 16615:2015 for product delivery [41].
- Carbon dioxide (CO_2) monitoring as a canary measure to assess the ventilation is becoming a norm. CO_2 monitors can determine the degree to which people are inhaling other peoples' air. Their use is being advocated to quantify the risk of indoor air transmission [20,42]. Models have been developed to assess the relative risk of airborne transmission by monitoring CO_2 and occupancy levels [43]. Guidance for the identification of poorly ventilated offices using CO_2 monitors has been produced [44]. Acceptable levels and indicators of poor ventilation have been produced [45]. The Health and Safety Executive recommends starting improvements in areas with the poorest ventilation [44].
- To enable compliance the staff must be competent, they must have the opportunity to comply, and they must have the motivation to comply [46].

Discussion

This assessment of SARS-CoV-2 transmission routes and advocated control measures to prevent OAI is based largely on the emergent literature (not randomised control trials), and the logic of how to avoid exposures which present most commonly as the 3 C's (closeness to cases, crowds and enclosed spaces) [24].

Since the SARS-CoV-2 pandemic was declared, questions related to how it is transmitted were raised [12,13]. The old paradigm illogically presented the scenario where virus laden particles could either be sprayed on ***or*** inhaled based on a dichotomous cut off point of $\leq$5 μm [10]. The new paradigm states that multi-sized and virus-laden particles are emitted from the respiratory tract in the form of gas clouds. The virus enters by being either sprayed on ***and/or*** inhaled [11]. The dichotomous cut off point is now considered to be $>$ 100 μm. Particles of $>$100 μm are considered 'droplets' that mainly drop to surfaces and present an indirect contact transmission risk [11]. The remainder are aerosols which can be inhaled at short or long range or sprayed on [11]. It is now also clear that the second previous delineation of closeness at time of transmission can neither exclude airborne nor confirm droplet transmission. Over time notable bodies including the WHO, ECDC and CDC [2—4] have acknowledged that short- and long-range aerosols are part of the transmission of SARS-CoV-2. Thus, the new paradigm, which follows the laws of physics, has emerged and is being accepted.

Although the airborne route is considered dominant [11,20] other routes of transmission cannot be eliminated. Therefore, precautions are needed against all routes. As each office, its capacity, facilities, occupancy and work practices are different, the need for any and all prevention measures offered for offices need to be considered after undertaking a local risk assessment of both the office and its ventilation system [21]. Of note, no single measure will be sufficient, and a multi-layered approach is needed which addresses all possible SARS-CoV-2 transmission routes [2—4].

The office control measures listed offer options for addressing the goals of minimising the opportunity for virus entry, reducing susceptibility, minimising exposure, and optimising success by addressing behaviours with the new ways of working. Offices are indoor places and indoor places are where most transmission occurs. As stated, key to reducing risks is avoiding crowds, closeness and enclosed spaces [24]. The more people (crowds) the less the quality of air and the greater the risk that someone will be infectious. Enclosed spaces also reduce the likelihood of good ventilation. Finally, the closer one is to people the greater the risk of transmission should someone be infectious.

Many of the control measures require changes to the ways of working and habits that have been established over many years. Thus, the successful deployment of the above control measures is dependent on successful changes of people's behaviour in their work environment. Behaviour is determined by the competency, opportunity, and motivation of people towards a task [45]. The 'Behaviour Change Wheel' can be used to identify what is needed to modify behaviour and thereby optimise safety [45]. Prior to the adoption of new practices an assessment of workforce in terms of what new knowledge is needed, whether staff have all the resource needed to comply and whether they are motivated to follow the required instructions. Everyone who works in the office, including the visitors, must know what the accepted procedures are, and why they are being introduced and how efficacious they are at negating risk. They must also know what to do if they find the procedures are not being adhered to. There should be reminders of what is required throughout the office. It is suggested that placing scores on doors to rate room ventilation will have traction if people are taught how to read the rated ventilation in rooms [46].

As SARS-CoV-2 is expected to present an ongoing risk for some time, assessing and adopting standard control measures to prevent OAI against SARS-CoV-2 presents opportunities to maintain the health of employees and offices are needed. These control measures may also prevent other infections which are spread by the same transmission routes. Finally, new knowledge will continue to emerge, and office managers need to be mindful to reassess risks and adapt precautions when needed.

Conclusions

Critical to the success in minimising OAI (from SARS-CoV-2 and other pathogens) managers must:

- Comply with national mandates and recommendations to maintain safe offices [37, 54-56]
- Undertake a local risk assessment as transmission risks vary based on the buildings design, ventilation, capacity, and ways of working.
- Use experts to identify and improve ventilation systems.

Based on the risk assessment, standard office control measures should focus on enabling the smooth functioning of the office whilst minimising the risks:

- That the virus will enter the building,
- That the virus will transmit to people therein,
- Improving the vulnerability of staff to the virus
- Optimising success by monitoring compliance with new ways of working and ventilation systems.

Ethics

No ethical permission was required for this publication.

Limitations

This paper does not include risks associated with travel to and from the workplace. The advocation of some of these measures are at times precautionary principles being applied to recognizable hazards.

Conflict of interest

None.

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