Coronavirus pandemic: How is it possible to prevent infection through aerosols?

An academic position paper

As the development of the COVID-19 pandemic to date has shown: aerosols contribute significantly to the occurrence of infection – and combating them can significantly reduce a resurgence of infection levels [1– 5]. This is what will matter most next autumn and winter in particular. At the present time, however, only about 70 percent of the population are sufficiently well-informed about infectious aerosols, and those who are less aware do less to protect themselves [6]. This academic position paper therefore sets out to provide information and help prevent further waves of infection that may occur due to seasonal factors, dangerous new viral variants, declining immunity after vaccination or people's lack of willingness to get vaccinated. By summarising the evidence regarding the spread of SARS-CoV-2 viruses through aerosols, this paper aims to help better assess the individual hazards caused by infectious aerosols, thereby enabling effective protective measures to be taken.

The prevention of infection will remain important in the long term: after all, the pandemic cannot be overcome quickly or easily, and more infectious virus variants are circulating. Current modelling predicts that lasting pandemic control cannot be achieved solely based on realistic vaccination rates, so there will be a long-term need for measures aimed at sustainable infection control [7]. Measures to hinder the spread of aerosols not only reduce the risk of infection with SARS-CoV-2 via exhaled aerosol particles*, they also help reduce infection with other airborne pathogens (e.g. influenza viruses).

> *** On the definition of aerosol particles:**
> In this text, the standard VDI definition of "aerosol particles". According to this, all airborne particles with a diameter of between 1 nm and several 100 µm are referred to as aerosol particles. In other disciplines, liquid suspended particles with a diameter larger than 5 µm are often referred to as "droplets". According to the definition used here, therefore, liquid suspended particles with a diameter larger than 5 µm are also aerosol particles.

The measures recommended here are based on the current state of research in various disciplines, taking into account the recommendations of the Robert Koch Institute (RKI) [8], the Center for Disease Control and Prevention (CDC) [9] and the World Health Organisation (WHO) [10].

From the point of view of aerosol research, it makes sense to distinguish between **direct** and **indirect** infection [11], because otherwise the non-uniform use of the terms aerosol particles* and droplets repeatedly gives rise to misunderstandings.

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Direct infection refers to transmission through aerosol particles that are produced when breathing, speaking, coughing, sneezing, for example, and transmitted directly from person to person in large numbers over short distances (less than 1.5 m). Due to the high viral load, **direct** infection is possible even when people interact with each other for a few minutes over small distances (conversation) or are situated physically close to each other (neighbouring workplaces in offices or schools and in public transport, etc.).

Indirect infection refers to transmission through infectious aerosol particles that have accumulated indoors over a period of several hours. If the virus load is sufficient and there are people in the room for long enough (more than 15 minutes), infection can occur even if the distance rules are observed. Since aerosol particles travel long distances with the air and infectious particles can be detected in the air for several hours, other people can become infected even if the “infectious” person is no longer in the room.

These two distinct transmission routes significantly influence the resulting risk of infection.

Both **direct** and **indirect** infection can occur **inside closed rooms**. This is why comprehensive precautions are required to guard against infection indoors.

Outside closed rooms – i.e. in the open air – virtually the only possibility of becoming infected is by **direct** means: **indirect** infection is highly unlikely due to the extensive dilution of the viral load and its rapid removal by air currents. For this reason, fewer protective measures are usually required outdoors than indoors.

This fundamental distinction gives rise to the following recommendations:

<u>Indoors</u>: Prevention of direct and indirect infection via aerosols

According to the current state of research, transmission of SARS-CoV-2 takes place almost exclusively indoors [1-5, 12, 13]. The great risk of infection indoors derives from the fact that both **direct** and **indirect** infection occurs here. **Direct infection** is favoured when people talk to each other over a short distance for an extended period of time without moving (e.g. at a cash register or hotel reception, at the hairdresser’s, conversing with people sitting next to you in an office or at school, contact with a waiter in a restaurant). **Indirect infection** occurs when people remain in a room for an extended period of time (e.g. at a school or children’s daycare centre, in a restaurant, office or shop or on public transport) and there is a high viral load in the room air due to the lack of air exchange. In addition, it must be taken into account that in poorly ventilated indoor spaces, infection can occur even without a direct encounter if an infectious person has previously been there for an extended period of time. For this reason, “cluster infections” or “superspreader events” may occur indoors during the COVID-19 pandemic, such as in old people’s homes, residential homes, care facilities, collective accommodation, schools and even in lifts [14]. The risk of **indirect** infection is also increased during activities that involve more energetic breathing (e.g. choir and orchestra rehearsals, heavy physical work, sports in the gym) [15].

<u>Guidance on reducing the risk of infection from aerosols indoors:</u>

The risk of **indirect** infection can be minimised indoors by people only staying in a room for a short time, by keeping the concentration of infectious aerosols as low as possible by means of intense air exchange or by wearing particle-filtering masks**.

Intense air renewal can be achieved by means of window ventilation, permanently installed ventilation and air conditioning systems or mobile room air purifiers***. Rapid air exchange through window ventilation requires regular cross-ventilation (six times per hour, causing a draught to pass through by opening windows on opposite sides of the room, if necessary also in neighbouring rooms) or equally frequent full ventilation (i.e. fully opening all existing windows in the room being used). A ventilator in the window can further reduce the risk of **indirect** infection. Permanently installed ventilation and air conditioning systems should be operated with 100 percent fresh air (no recirculation) at maximum volume flow. If these measures are not technically possible (no ventilation systems available, too few windows that can be opened), physically ineffective (no temperature difference between indoors and outdoors, insufficient wind at the windows), impractical (interruption of work processes) or unreasonable (too cold, draughts, noise outside too loud), it is possible to reduce the virus load by means of powerful mobile room air purifiers***. Unlike permanently installed ventilation and air conditioning units, high-quality, high-performance mobile air purifiers can be installed at short notice [16-20]. Since ventilation by opening windows, installed ventilation or air conditioning systems and mobile room air purifiers only provide protection from **indirect** infection but do not provide protection from **direct** infection, they are not a substitute for masks, no matter what type. However, when ventilation is combined with measures that provide protection from **direct** infection – such as spacing, surgical masks, good mouth-nose coverings [11] or transparent protective walls [21-23] – they do allow comprehensive infection control indoors.

Alternatively or in addition to the above measures, good and tight-fitting particle-filtering masks** can be used indoors that provide very good protection from both **direct** and **indirect** infection while also preventing the release of large quantities of aerosol particles into the room [11]. However, such particle-filtering masks often cannot be worn for long periods of time and are therefore not usually suitable for protection for the duration of a full

**** On the wearing of masks:**
Correctly worn and tightly fitting certified masks (tested according to DIN standard EN149:2001 and approved as personal protective equipment according to Regulation (EU) 2016/425, such as FFP2, KN95, N95) are best suited to preventing direct and indirect infection. The seal fit of the mask is at least as important for its effectiveness as the separation efficiency of the material, since viruses primarily follow the path of least resistance when breathed in (in this case the gap at the edge of the mask). Certified masks offer very good protection from infection indoors, both for the wearer and for other persons. Medical face masks (surgical masks) and mouth-nose coverings, on the other hand, do not protect the wearer from indirect infection according to the Medical Devices Directive 93/42/EEC because the aerosol particles flow in and out at the edge of the mask unhindered. These masks only offer a certain degree of external protection from direct infection because rapid aerosol spread to the front of the wearer is hindered. Avoid touching the mask while wearing it.

***** On the capacity of mobile room air purifiers:**
Mobile room air purifiers should be able to filter at least six times the room volume per hour in the case of medium room size (approx. 60-100 m²) and maximum occupancy, as in the case of a classroom, for example. In smaller rooms, higher air exchange rates must be ensured due to the smaller room volume. In the case of large indoor spaces (churches, large shops, reception halls), lower air exchange rates are sufficient. Mobile room air purifiers should have filters of class H13 or H14 and be quieter than the natural noise level in the room (if possible quieter than 50 dB(A) at the required volume flow according to the room size) so that they provide sufficient protection and are not switched off. It often makes sense to operate a unit with a higher capacity at a lower level than a small unit at maximum level, as the larger unit will be significantly quieter than a smaller one at the same volume flow.

working day or for attendance at school. Nonetheless, these masks should be worn consistently in indoor areas that cannot be protected in any other way (e.g. in lifts, corridors, public transport, taxis) and by employees who come into close contact with other people (e.g. medical area, nursing staff, waiters). As such, particle-filtering masks are a good option for the individual, short-term protection of the wearer and for others, even where masks are not mandatory and the immunisation of the population is advanced.

Outdoors: Prevention of direct infection via aerosols

Outdoor transmission through aerosols is extremely rare, so "cluster infections" as observed indoors tend to be unlikely.

There are three main reasons for this:

1) there is no enclosed volume of space outdoors in which a virus concentration can accumulate over time. For this reason, there is no significant risk of **indirect** infection outdoors.
2) The virus-carrying aerosol particles released are very quickly diluted and transported away by air currents or due to people moving.
3) People usually engage in different activities outdoors as compared to indoors and do not usually stay physically close together for long periods of time, such as at school, for example. Contact times also tend to be short outdoors (encounters in pedestrian zones when passing by or while walking, jogging or cycling).

The latter point is the reason why there is not just a very low risk of **indirect** infection outdoors but also a low risk of **direct** infection. **Direct** infection can only occur when people talk to each other face to face over short distances or sit close together for a lengthy period of time (e.g. in a beer garden, in a public transport waiting area) or stand close together (e.g. at a bus stop, in a queue, at open-air events or demonstrations), allowing the released viruses to pass **directly** from person to person via aerosol particles [11, 24].

Guidance on reducing the risk of infection from aerosols outdoors:

Since virtually no **indirect** infection can occur outdoors, the risk of infection is generally much lower than indoors. Nevertheless, **direct** infection should be avoided by maintaining a sufficient distance of 1.5 m [11], for example. If this distance cannot be maintained (e.g. at bus stops, in queues, at open-air events, at demonstrations), masks should be worn outdoors as well, although here even simple medical masks or good mouth-nose coverings offer protection from **direct** infection [11].

As a general rule it should be communicated as clearly as possible that COVID-19 is essentially transmitted by aerosols. In order to plausibly justify protective measures, it is possible to use graphic illustrations to show how such measures such as the correct use of masks, ventilation and mobile air purifiers can prevent infection. In addition, regulations and rules of conduct that are as consistent and uniform as possible help ensure compliance with the protective measures.

Conclusion:

1) In order to avoid contact with infectious aerosols in general, the time spent in indoor spaces should be kept as short as possible, and the risk classification issued by the Robert Koch Institute should be followed whenever several people gather together [8].
2) If possible, conditions should be created that are comparable to those outdoors by ensuring frequent full ventilation or cross-ventilation.
3) Operate ventilation and air conditioning systems at maximum volume flow with 100 percent fresh air as far as possible.
4) Where frequent full ventilation or cross-ventilation is not possible or not physically efficient, where it is not implemented or is unreasonable and where no permanently installed ventilation or air conditioning systems are available, use powerful mobile room air purifiers*** with suitable filters.

5) To avoid **direct** infection, in **addition** to points 1) to 4), maintain a safe distance, wear effective masks** or use transparent protective barriers if keeping a distance or wearing a mask is impossible or unreasonable.
6) If none of the above measures are feasible, and in particularly hazardous unventilated indoor spaces, tight-fitting certified masks** should be worn.
7) Larger-scale events such as theatrical performances, concerts and church services should be held outdoors if possible or else large, well-ventilated halls should be used wherever possible. Certified masks** should be worn in confined indoor spaces where there is a high crowd density such as entrances, exits and bathrooms, and reliable ventilation or air purification concepts should be implemented.

As a general rule, a combination of measures to prevent direct infection (contact avoidance, distance rules, masks, protective wall panels) and indirect infection (window ventilation, installed ventilation and air conditioning systems, efficient mobile room air purifiers, suitable masks) should always be applied in order to achieve a high level of safety with as few restrictions on comfort as possible.

Disclaimer:
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