ISAM webinar – July 20, 2020

Breathing is enough – Spread of SARS-CoV-2 via Aerosols and the Consequences for Infection Control

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Overview

- Aerosol
- A Small History of Exhaled Aerosols
- SARS-COV-2 as an Aerosol?
- Consequences?
Aerosol ?
Aerosol

An Aerosol is a **Suspension** (a mixture) of fine solid particles or liquid droplets in air or another gas.

Aerosol particles are the fine solid particles or liquid droplets.

The aerosol particles must stay in the gas for more than a few seconds. Otherwise we are not talking about aerosol (Example: Fog = Aerosol; Rain ≠ Aerosol). There is no upper size limit.

A particle (water droplet) of 10 µm need 6 min to fall to the ground from 1 m high.

There is no 5 µm limit! And a droplet nuclei is not an Aerosol! It might be an aerosol particle!
Deposition in the Respiratory Tract

- Aerosol related
  - Particle size
  - Shape
  - Electrical charge
  - Hygroscopicity

Deposition

- Deposited
- Exhaled
- Intrathoracic Deposition

Particle Diameter, µm

Deposition
History

1986

In an experimental setup with a strong and very sensitive laser photometer we found that during quiet normal breathing of healthy volunteers the lung generated aerosol particles:

1.) The origin of these particles was in the deep lung.

2.) On average they were about 0,4 μm median diameter.

3.) A breathhold could reduce the number of exhaled particles, flow rate did not change concentration significantly.

4.) With an RV (residual volume) breathing manouevre the concentration increased significantly.

5.) We found hugh differences between subjects, concentration between one and several thousand particles per litre of exhaled air.

6.) One day before one of our subjects got sick (airway infection) the concentration went up by several orders of magnitude.
History

Our Conclusions:

1.) The particles were not generated by shear forces. These particles are generated during inhalation and it might be that reopening of collapsed small airways was responsible for this findings.
Droplet formation

Droplet particles (an aerosol) are formed through rupture of RLF film during airway re-opening.
Our Conclusions:

1.) The particles were not generated by sheer forces. These particles are generated during inhalation and it might be that reopening of collapsed small airways was responsible for this findings.

2.) An increased production of surfactant or mucus could increase the exhaled respiratory droplets.

Other research groups have now confirmed our findings. Katharina Schwarz and Jens Hohlfeld from Hannover, Johnson and Morawska as well as the group around Anna-Carin Olin from Gothenburg, Sweden.
Intrasubject variability

Inhalation of isotonic saline reduced significantly the generation of the exhaled particles.

Inhalation of surfactant increased the production.

Do these exhaled particles contain viruses?

Patricia Fabian first showed that in a limited number of patients.

Do these exhaled particles contain viruses?

Donald Milton and colleagues measured the virus RNA in 37 influenza patients.

In the larger size fraction, generated by cough and speaking they found in 16 of 37 Patients Virus RNA. In the fraction < 5µm they found in 34 of 37 Patients Virus RNA.

They also measured the 'Culturability' of the viruses in these droplets:

Viruse in Exhaled Breaths

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Median number for particles > 5 µm = 0 Copies, for particles < 5 µm = 110 copies. 'Fine particles contained 8.8 (95% CI 4.1 to 19) fold more viral copies than did coarse particles'.
Do these exhaled particles contain viruses?

David Lindsley published data in 2016 that he found viable Influenza A viruses in air samples. He investigated 53 subjects with influenza A. In 53% he found virus in particles generated by cough and in 43% in particles generated by breathing only.

His conclusion:

‘Viable influenza A virus was detected more often in cough aerosol particles than in exhalation aerosol particles, but the difference was not large. Because individuals breathe much more often than they cough, these results suggest that breathing may generate more airborne infectious material than coughing over time. ..... Our results are also consistent with the theory that much of the aerosol containing viable influenza originates deep in the lungs.’

What do we know about SARS CoV 2 viruses?

SARS-CoV-2 virus use ACE2 receptors


Reproduced with minor modifications from Anna Bredberg Sahlgrenska Academy, University of Gothenburg, Sweden.
SARS-CoV-2 and Aerosol?

Bae and coworkers found in 4 patients with COVID 19 that virus particles could be detected in petri dishes in front of patients despite the fact that they were wearing facemasks. And they published that no viruses could be detected on the inner surface but at the outside of the masks.

Meanwhile the publication was restricted because some of the measurements were below the official detection limit of the measuring device.

Transmission of SARS-COV 2 as aerosol?

April 2: COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China

Transmission of SARS-COV 2 as aerosol?

March 19: Van Doremalen und coworkers showed that SARS COV 2 Viruses survived over several hours in an aerosol when sprayed into a closed non ventilated room.

April 7: Quian and coworkers found in more than 7,000 infections just one single transmission outside a room: ‘....the corona COVID-19 infection is an indoor phenomenon’ and almost no infections occur outside....

April 10: Lidia Morawska and Junji Cao wrote: Airborne transmission of SARS-CoV-2: The world should face the reality!


Transmission of SARS-COV 2 as aerosol?

April 27: Liu and colleague took aerosol samples in a Wuhan hospital. They found in several of these samples SARS-COV-2 Viruses. In a protective apparel removing room they found most of the viruses in the particle fraction between 0.25-0.5µm.
Transmission of SARS-COV 2 as aerosol?

May 15: Attack Rate Following Exposure at a Choir Practice Skagit County, Washington
Confirmed and probable cases of COVID-19 associated with two choir practices, by date of symptom onset (N = 53) — Skagit County, Washington, March 2020

June 3: Santarpia and colleagues from the University of Nebraska took air samples in a hospital and found SARS-CoV-2 viruses even in samples in a hallway outside of the patients room.

And they found positive air samples even in the absence of cough of the patients.

https://doi.org/10.1101/2020.03.23.20039446
Transmission of SARS-COV 2 as aerosol?

July 8: SARS-CoV-2 is transmitted via contact and via the air between ferrets.

SARS-CoV-2 was transmitted via the air to three out of four indirect recipient ferrets. This study provides experimental evidence of robust transmission of SARS-CoV-2 via the air!

Transmission of SARS-COV 2 as aerosol?

- Yes, there is sufficient evidence to believe that the aerosol route is an important transmission factor in the recent COVID19 pandemic.

- My feeling is: There are two ports of entry for SARS-CoV-2:
  - Nose
    - If this is the main infection site, the disease will be mild.
  - Alveolar Region
    - If infected via tiny aerosol particles in this region, disease can be severe

- Aerosol particles can be generated by breathing, speaking, singing, coughing, sneezing. A distinction between droplets and aerosol is not needed. If particles in the air are inhaled: it is an aerosol infection.
Protection against exhaled virus aerosols

Limit Number of Contacts in a Room (no Parties, no choir practice, closed restaurants, closed schools, …..)

Face Masks

Airfiltration

Reduce concentration of exhaled particles

Other measures
Meta-analysis of randomized controlled trials (RCTs) indicated a protective effect of masks and respirators against clinical respiratory illness (CRI) (risk ratio \( RR = 0.59; 95\% \) confidence interval \([CI]:0.46–0.77\)) and influenza-like illness (ILI) (\( RR = 0.34; 95\% \) CI\( :0.14–0.82\)).

‘Our analysis confirms the effectiveness of medical masks and respirators against SARS. Disposable, cotton, or paper masks are not recommended.’

Renyi Zhang and colleagues found that wearing face masks had an effect on the distribution of SARS-CoV-2 pandemic. "We conclude that wearing of face masks in public corresponds to the most effective means to prevent interhuman transmission, ...in conjunction with simultaneous social distancing, quarantine, and contact tracing, represents the most likely fighting opportunity to stop the COVID-1."
Face Mask?  CON

MacIntyre, 2009 tested wearing of surgical masks, P2 (FFP2) mask and no mask in a controlled study.

Outcome:

ILI (Influenza like illness) was reported in 21/94 (22.3%) in the surgical group, 14/92 (15.2%) in the P2 group, and 16/100 (16.0%) in the control group.

We concluded that household use of face masks is associated with low adherence and is ineffective for controlling seasonal respiratory disease.

1607 healthcare workers were randomized in 3 groups: 1.) wearing no masks; 2.) wear a cloth mask 3.) wear a surgical mask.

Figure 2 Outcomes in trial arms (CRI, clinical respiratory illness; ILI, influenza-like illness; Virus, laboratory-confirmed viruses).

Face Mask: Conclusion

- The use of **Surgical Face Masks** can be strongly recommended.

- The use of **Cloth Face Masks** is questionable:
  ‘....The filtration effectiveness of cloth masks is generally lower than that of medical masks and respirators; however, cloth masks may provide some protection if well designed and used correctly. ...... Until a cloth mask design is proven to be equally effective as a medical or N95 mask, wearing cloth masks should not be mandated for healthcare workers. In community settings, however, cloth masks may be used to prevent community spread of infections by sick or asymptotically infected persons, and the public should be educated about their correct use.'

Chughtai AA, Seale H, Macintyre CR. Effectiveness of Cloth Masks for Protection Against Severe Acute Respiratory Syndrome Coronavirus 2 [published online ahead of print, 2020 Jul 8]. Emerg Infect Dis. 2020;26(10):10.3201/eid2610.200948. doi:10.3201/eid2610.200948
Air Filtration

- One infected person
- Exhalation of 100 virus copies/Liter exhaled air
- 15 breaths/min a 1 Liter
- Room volume: 40 m³
- Time 2 hrs
- Halftime of virus in air: 125 min

Result: 132,000 virus copies after 2 hrs → 3.3 virus copies/Liter

In 10 min another person in this room will inhale 500 virus copies.
Air Filtration

Exhaled Viruses in a Room with an Infected Person

NEP (with 12/5) = number of particles in the room with air-filter that removes 50% of particles in 12/5 min.
Air Filtration

- One infected person
- Exhalation of 100 virus copies/Liter exhaled air
- 15 breaths/min a 1 Liter
- Room volume: 40 m³
- Time 2 hrs
- Halftime of virus in air: 125 min

Result with Filtration: 20.000 virus copies after 2 hrs $\rightarrow$ 0.5 virus copies/Liter

In 10 min another person in this room will inhale only 75 virus copies.
Air Filtration

- The most efficient filtration is: opening the windows!

- If this is not feasible, airfiltration can be an alternative. With existing HEPA filters it is possible to reduce the virus burden by a factor of 5-20.
Virus inactivation by UV Light

Buonanno and colleagues showed that UV Light 222 nm, which is not harmful for human skin can inactivate Corona virus: 1.7 and 1.2 mJ/cm² inactivated 99.9% of aerosolized coronavirus 229E in 25 min.

Michael Schuit and coworkers found that simulated sunlight rapidly inactivates SARS-CoV-2 in aerosols.

Hiroko Inagaki et al. just recently published data that DUV (deep UV) light with 280 nm and 37.5 mJ/cm² resulted in 99.9% inactivation of SARS-CoV-2.


Conclusion

It is plausible that SARS-CoV-2 will be transmitted via aerosols.

Is this the most important transmission? I don’t know.

Wearing of face masks seems a possible measure to reduce transmission.

HEPA filters are able to reduce the risk of infection in closed indoor rooms.

UV-Light might be an alternative to reduce the SARS-CoV-2 viral burden.
Thank You for your attention. DANKE.