UNIVERSITY OF AMSTERDAM

Small Droplet Aerosols from Coughing and Speaking and SARS-CoV-2 Transmission

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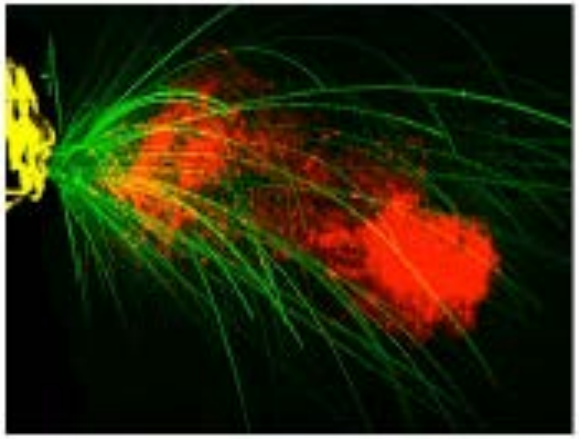
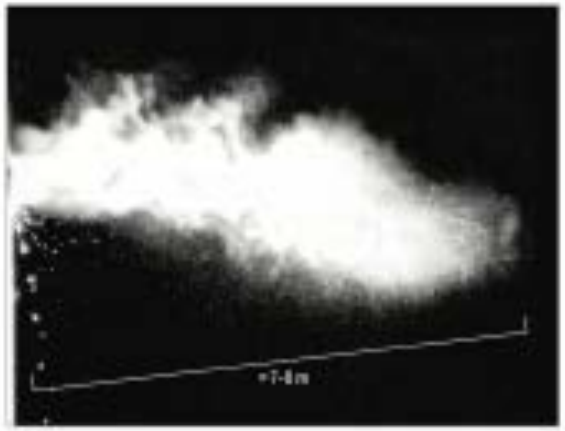
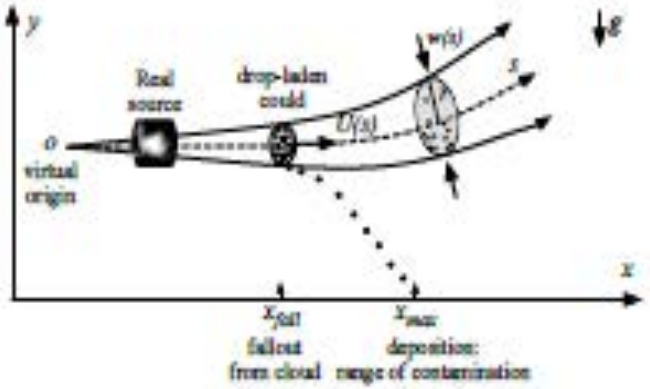
Evidence is piling up that the very efficient spreading of the coronavirus happens by aerosols:
Nature 2020, NEJM 2020, Lancet 2020, PNAS 2020, WHO Scientific brief 9/7/2020

virus transmission is physics!

Aerosols defy the 1.5 m (6 ft) rule





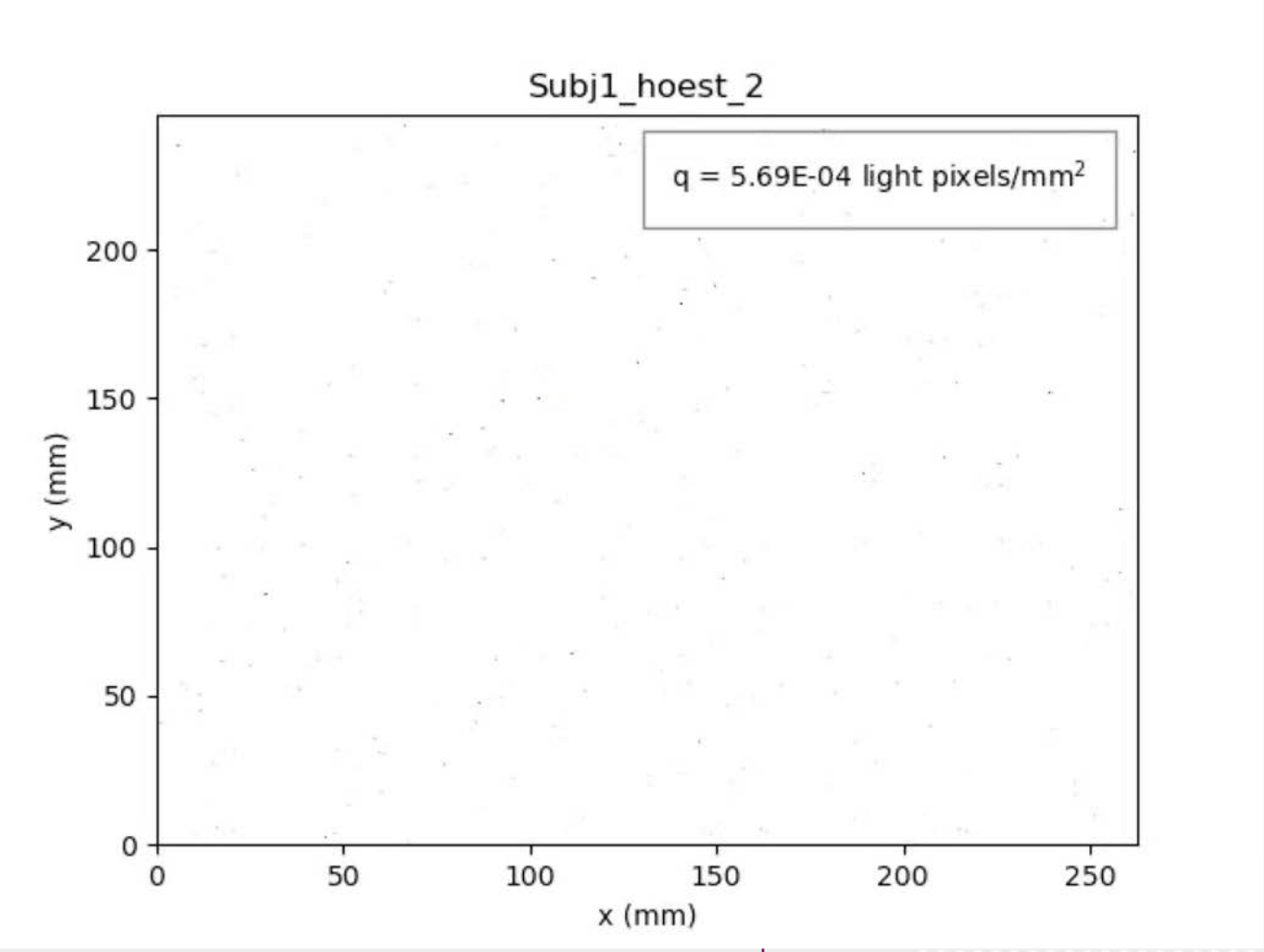


L. Bourouiba et al.J. Fluid Mech. 745, 537 (2014).

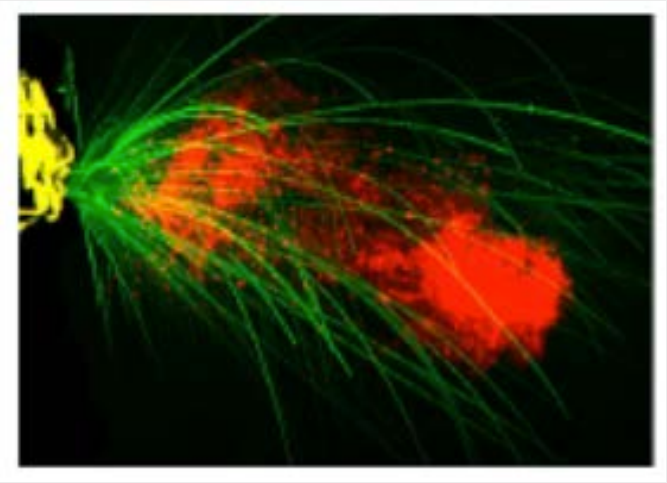
Respiratory masks from the ICU at our academic hospital (Amsterdam UMC)

Can high-flow nasal cannula (HFNC) oxygen therapy be used on Covid-19 patients without risk for the hospital staff?

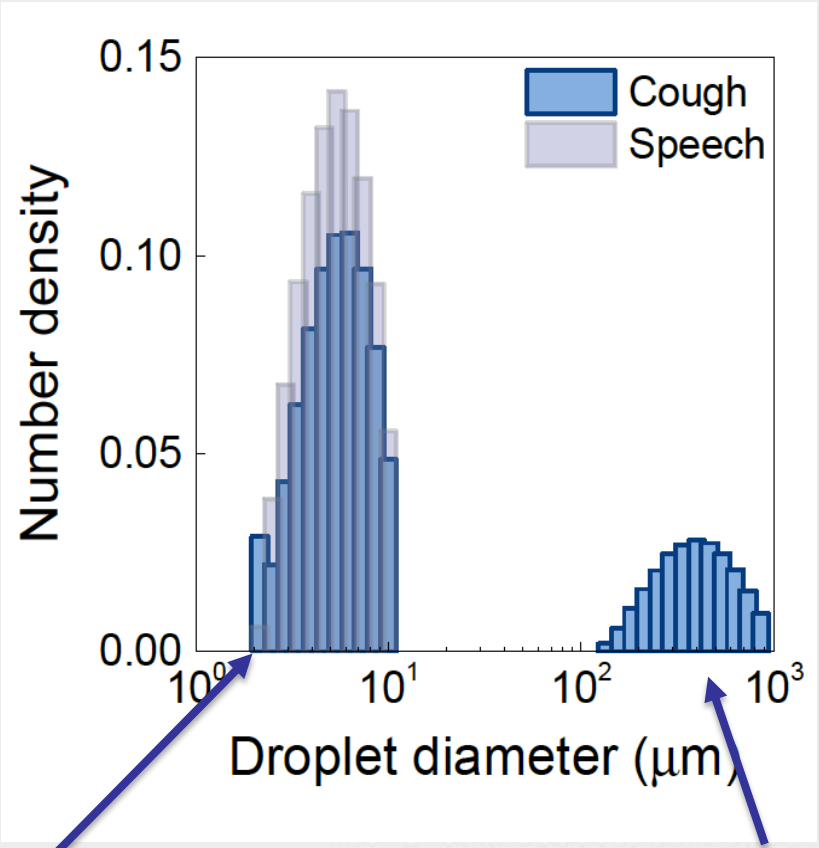
Aerosols: Laser sheet imaging of a cough



Aerosols: Drop sizing (laser diffraction)



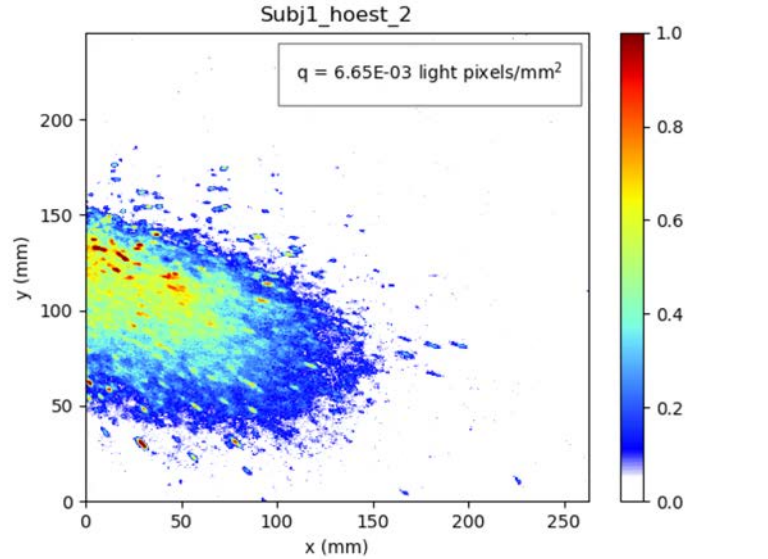
- Small (2-10 μm) drops from both speaking and coughing
- In addition when coughing large (100mm-1μm) drops



Aerosols (usual definition <5μm)

Large drops (‘1.5m rule’)

How many small drops?

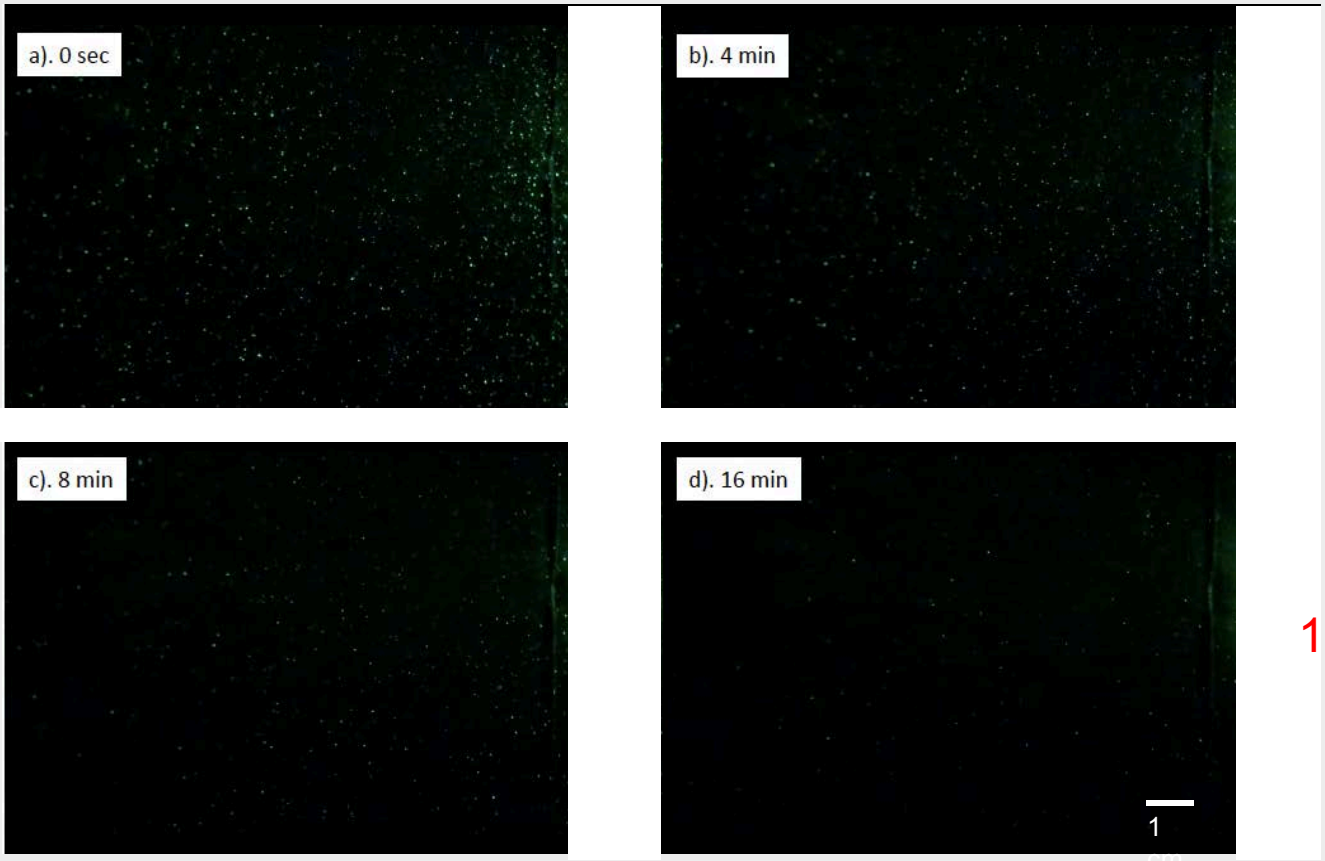


- a single cough: liquid weight of 0.07 $\pm$ 0.05 gram,
- speaking ten times: weight of 0.003 $\pm$ 0.001 gram.

For coughing: volumetric distribution shows 98 $\pm$ 1% of the volume contained in the large drops (100-1000 µm).

Small aerosol droplets, ~20 million microdroplets produced in a single cough and ~7 million for speech

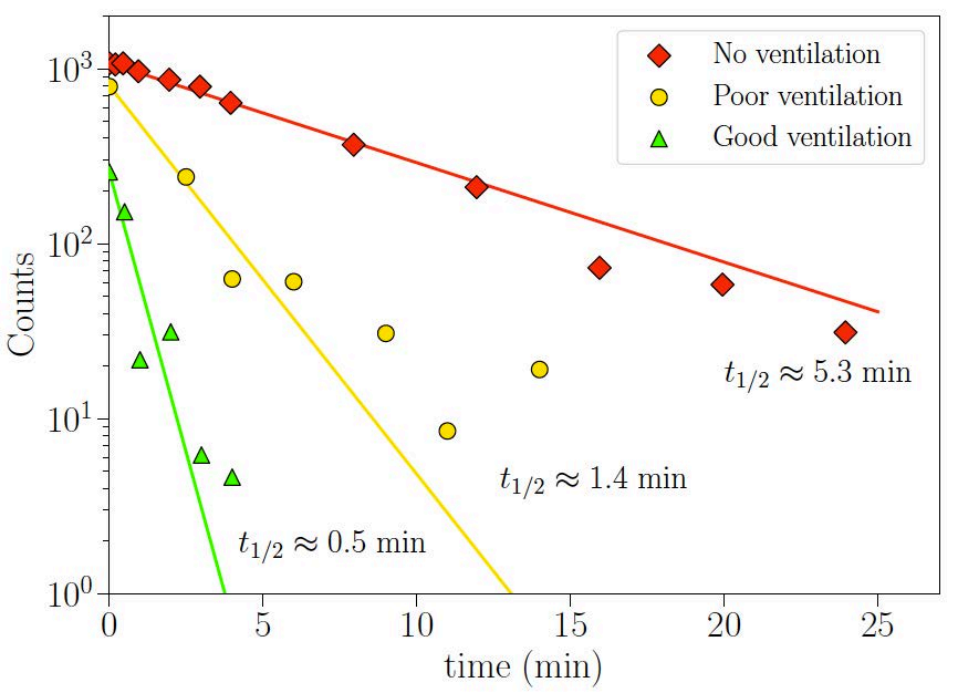
Persistence of aerosols (ill ventilated room)



16 minutes!

Small drops take minutes to sediment

Aerosols: Persistence of small drops in small confined spaces



Small droplet aerosols in poorly ventilated spaces; the need for specific measures to prevent SARS-CoV-2 transmission, A. Somsen et al. Lancet Resp.Med.2020

World Health Organization

Transmission of SARS-CoV-2: implications for infection prevention precautions

Scientific Brief

9 July 2020

….Another recent experimental model found that healthy individuals can produce aerosols through coughing and talking *(19). To date, transmission of SARS-CoV-2 by this type of aerosol route has not been demonstrated; much more research is needed given the possible implications of such route of transmission.

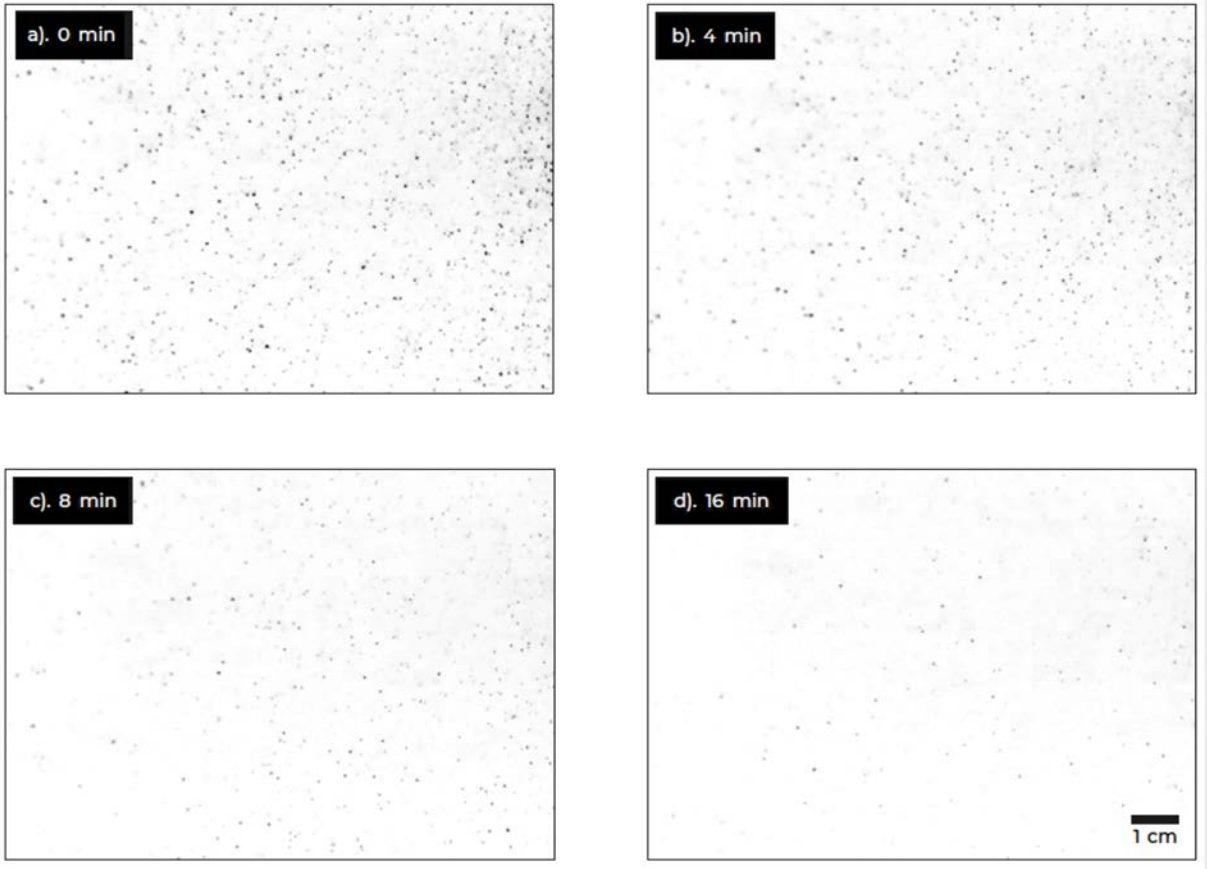
Scientific Brief: SARS-CoV-2 and Potential Airborne Transmissi...

CDC Centers for Disease Control and Prevention

Airborne transmission of SARS-CoV-2 can occur under special circumstances

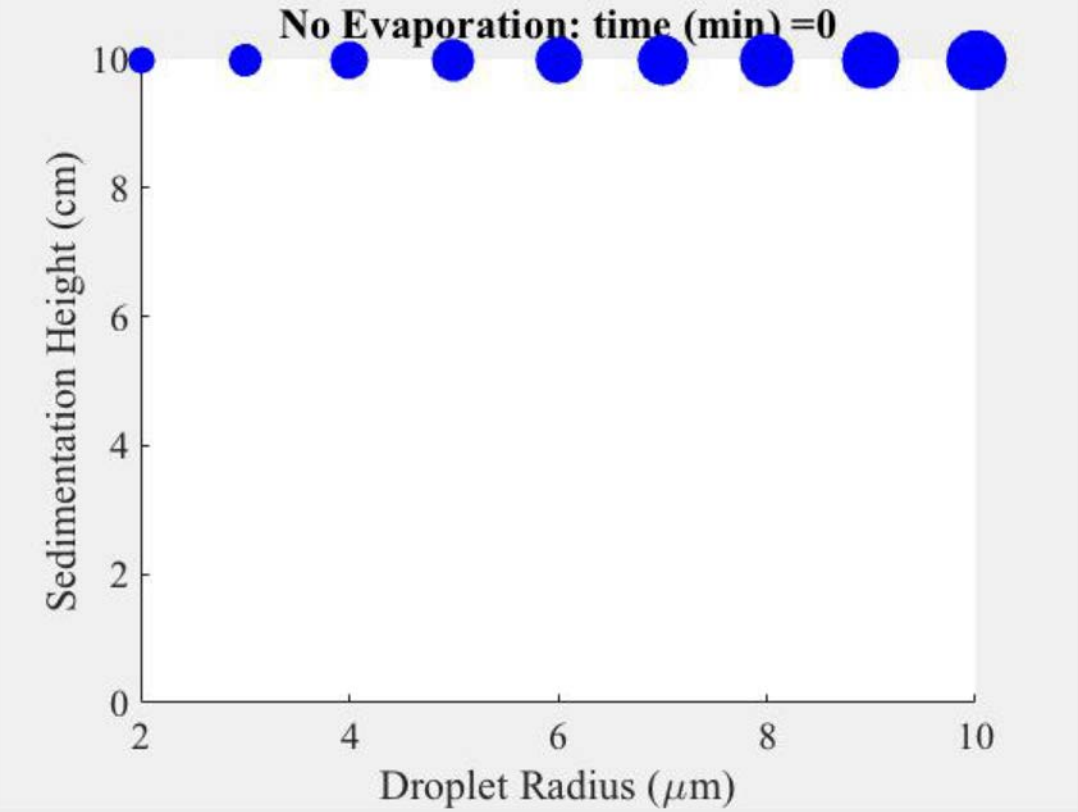
Pathogens that are mainly transmitted through close contact (i.e., contact transmission and droplet transmission) can sometimes also be spread via airborne transmission under special circumstances. There are several well-documented examples in which SARS-CoV-2 appears to have been transmitted over long distances or times.

Can we use this knowledge to do a risk assessment?

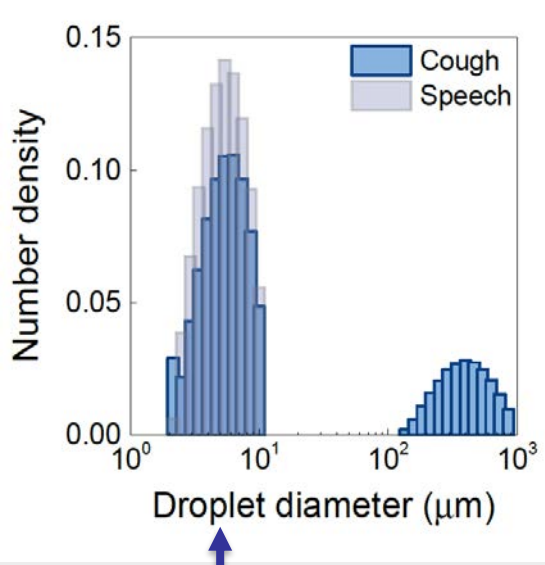


How to model the aerosol persistence?

Aerosols: Persistence of small drops in small confined spaces



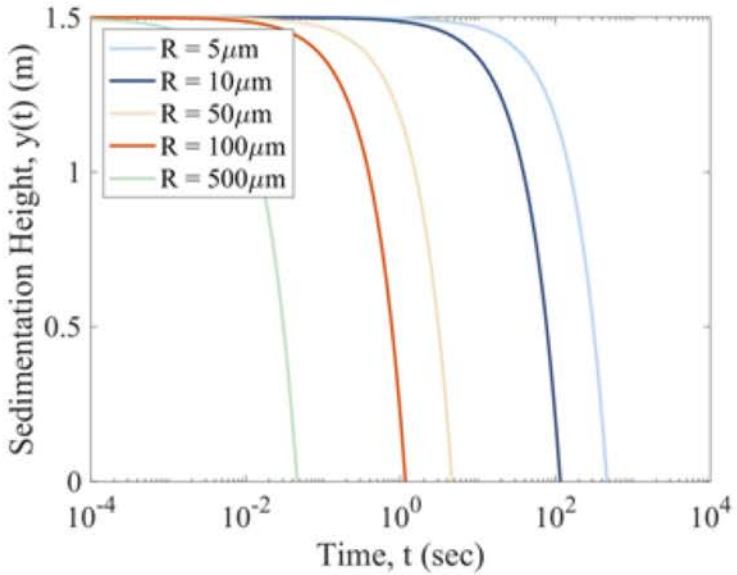
5 μm drop from 1.5m -> 9 minutes

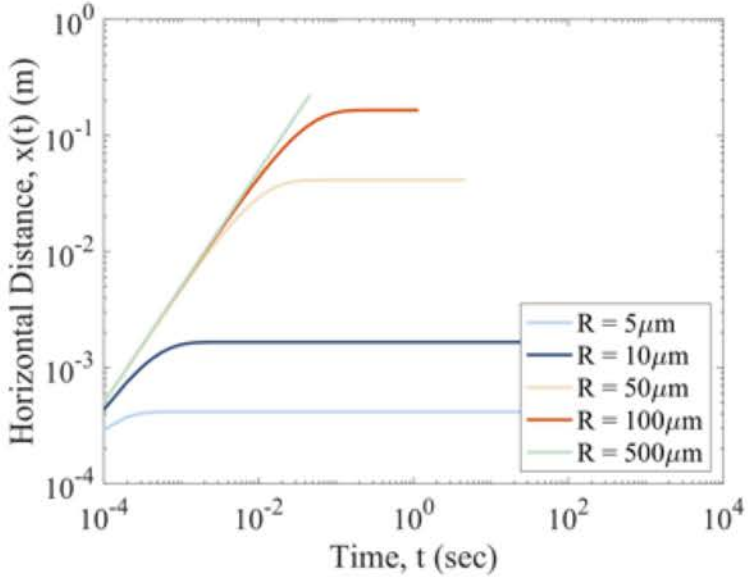


aerosols

Complete model including gravity, evaporation, initial velocity…

Shows that the stopping distance is small, ~1m

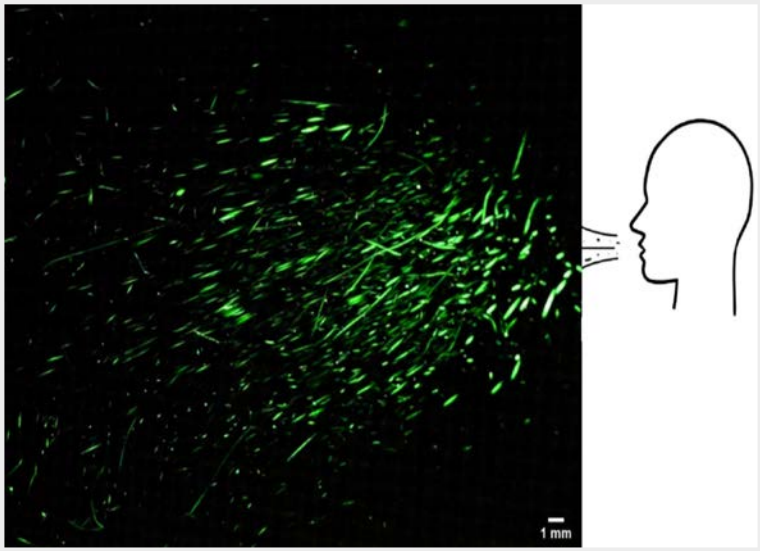


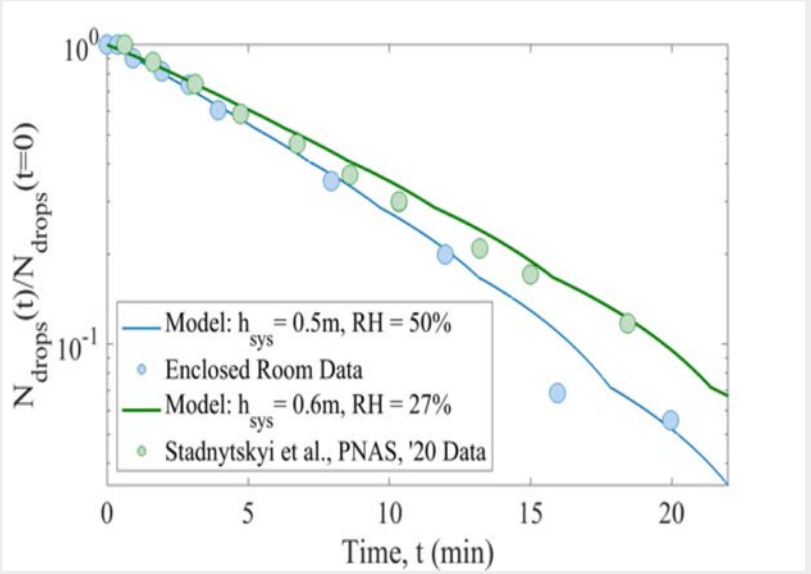


Aerosol persistence in relation to possible transmission of SARS-CoV-2
S. Smith et al., Phys.Fluids (2020) (Today!)

Complete model including gravity, evaporation, initial velocity…

- Quantitatively predicts our and PNAS (Bax and coll.) persistence data





Aerosol persistence in relation to possible transmission of SARS-CoV-2
S. Smith et al., Phys.Fluids. (2020)

Viral load

~7×10^6 virus particles/milliliter

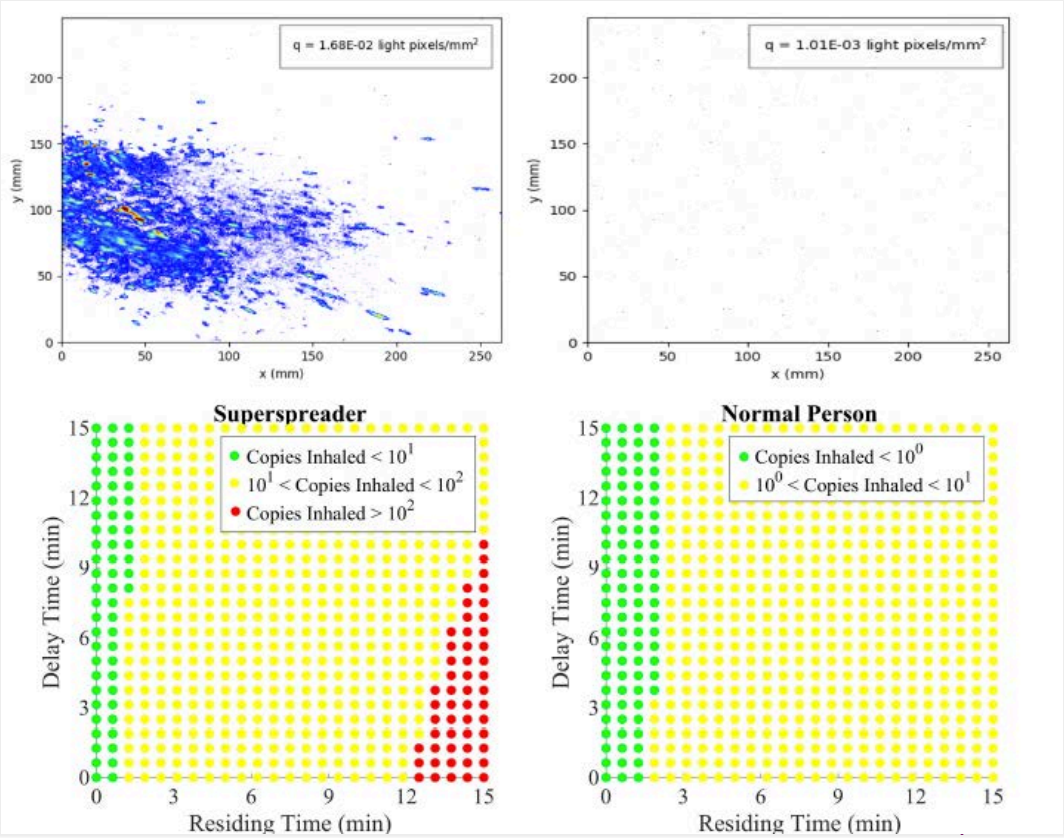
Wölfel et al. *Nature* 2020: **581**: 465-469.

~10^4, in the aerosols after 1 cough

We (Smith et al.)

~infection after inhaling 100-1000 particles

From SARS-CoV-1



Superspreader produces 17 times more volume!

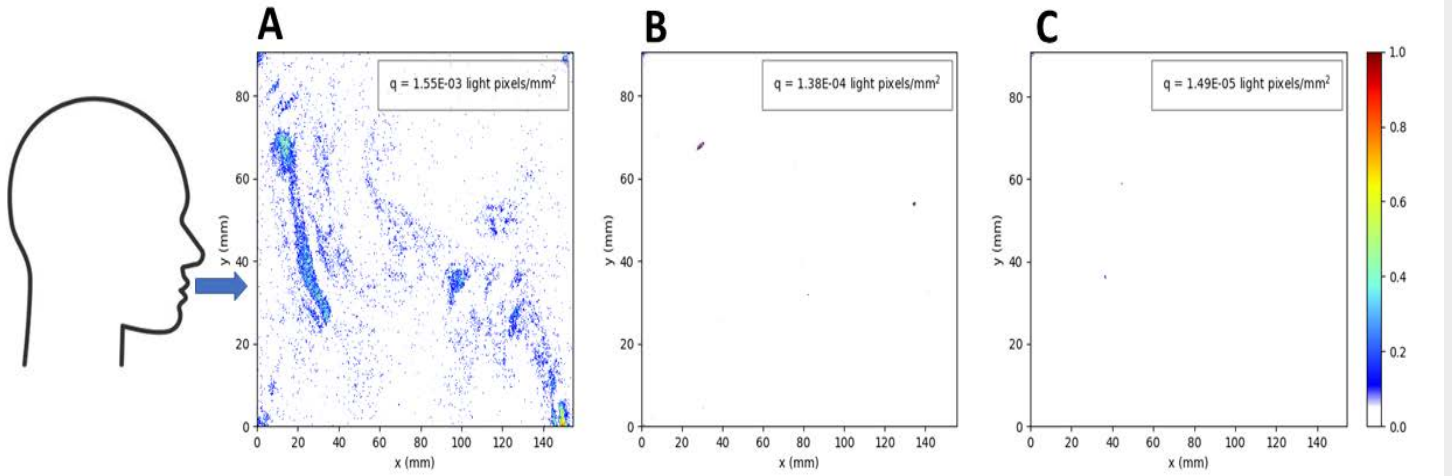
S. Smith et al., Phys.Fluids (2020)

SPACE	SIZE (M^3)	AIR CHANGE PER HOUR (H^{-1})	AEROSOL ORIGIN	50% DECREASE (MIN)	AEROSOL PART/L	RNA COPIES/L	COVID-19 INFECTION RISK
GYM	2000	5-15	25 visitors	1	<10	<1	Low
TRAIN	150	0-5	20 visitors	2	210	<21	Low
MEETING ROOM	30	10	4 visitors	1	45	<5	Low
NIGHT CLUB	2000	5-15	Artificial	1	<10	<1	Low
CAR	3	5-20	2 visitors	0.5	20	<2	Low
AIRPORT	12000	5-10	~120 visitors	1	<10	<1	Low
RESTAURANT	120	8	25 visitors	1	248	<25	Low
RESTROOM	8	1-4	1 visitor	4	7716	<772	Intermediate
OFFICE SPACE	50	10	5 visitors	1	35	<4	Low
UNVENTILATED LIVING ROOM	80	1-4	4 visitors	5	5214	<520	Intermediate
ELEVATOR	8	1-5	2 visitors	5	4350	<435	Intermediate

Respiratory masks from the ICU at our academic hospital (Amsterdam UMC)

Can high-flow nasal cannula (HFNC) oxygen therapy be used on Covid-19 patients without risk for the hospital staff?

Respiratory masks from ICU (laser sheet)



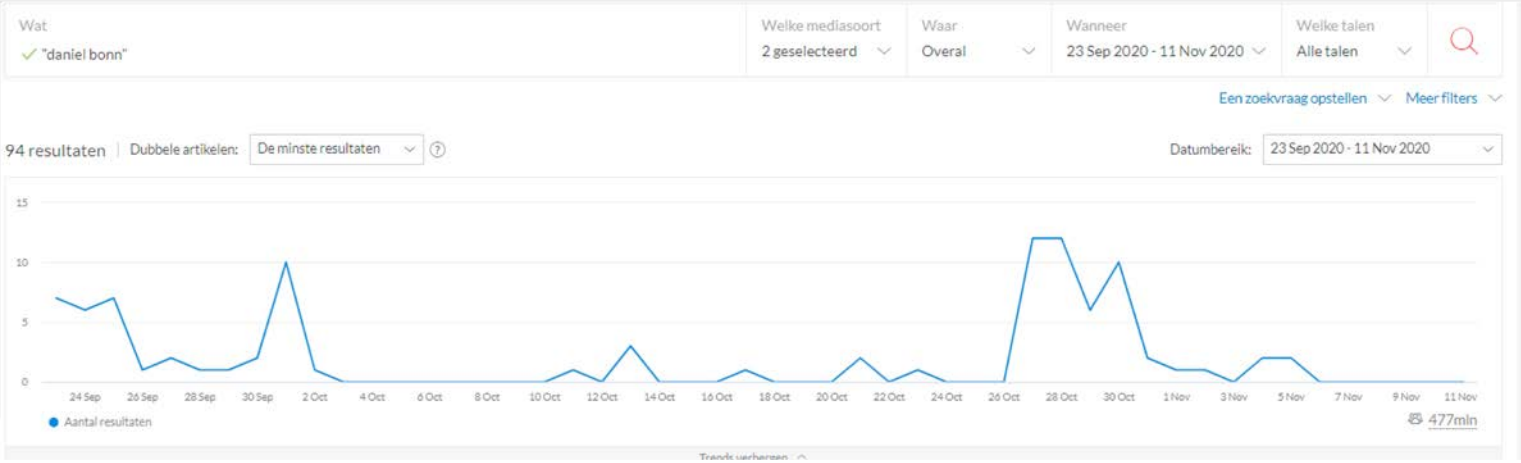
HFNC with nebulization **HFNC alone** **NRM therapy**

R. Bem et al., Aerosol formation during HFNC – risk assessment for SARS-CoV-2 transmission to health care workers, submittted

Risk: LOW

Conclusions

- Aerosol transmission of SARS-CoV-2 is likely to be a risk, but not a very large one
- The solution is: Ventilation, ventilation, ventilation…..
- This is a truly interdisciplinary problem where physics and engineering should be combined with biology and virology



The team

IoP: S. Kooij,   S. Smith

Medspray/ IoP: C. van Rijn 

AMC: R. Bem, MD, Intensive Care Medicine 

Cardiologie Centra Nederland: A. Somsen, MD, Cardiologist 

VUMC: L. Hofstra, MD, Cardiologist 

TC: Alix Wattjes, Daan Giessen, Tijs van Roon, Clint Ederveen Janssen, Johan Mozes

Papers

1. Somsen GA, van Rijn CJM, Kooij S, Bem RA, Bonn D. *Measurement of small droplet aerosol concentrations in public spaces using handheld particle counters.* Phys Fluids (1994) 2020 Dec 1; 32(12): 121707
2. Somsen GA, van Rijn CJM, Kooij S, Bem RA, Bonn D. *Small droplet aerosols in poorly ventilated spaces and SARS-CoV-2 transmission.* G Lancet Respir Med. 2020 Jul; 8(7): 658–659;
3. C van Rijn, GA Somsen, L Hofstra, G Dahhan, RA Bem, S Kooij, D Bonn, *Reducing aerosol transmission of SARS-CoV-2 in hospital elevators.* Indoor air 30 (6), 1065-1066 (2020)
4. Smith SH, Somsen GA, van Rijn C, Kooij S, van der Hoek L, Bem RA, Bonn D. *Aerosol persistence in relation to possible transmission of SARS-CoV-2.* Phys Fluids. 2020 Oct 1; 32(10): 107108