Von der Dichotomie zum Kontinuum: **Tröpfchen, Aerosole, respiratorische Partikel**

Philipp Jent, Leiter Spitalhygiene, Inselspital Universitätsspital Bern

21.03.2023 Zürcher Hygienesymposium

Überblick

- Historische Übertragungsmodelle: **Woher kommen wir?**
- **Was atmen wir aus?**
- **Aerosol-generierende Prozeduren**
- Moderneres **Übertragungsmodell**
- **Inhalierte Virusdosis in Patienteninteraktionen**
- Ist **Lüften** die Lösung?
- **Andere respiratorische Viren**?
- Wenn die Zeit reicht: **Masken** nutzlos? Oder FFP2 für alle?
- **Fazit**

Luft als „Träger“ von Infektionen?

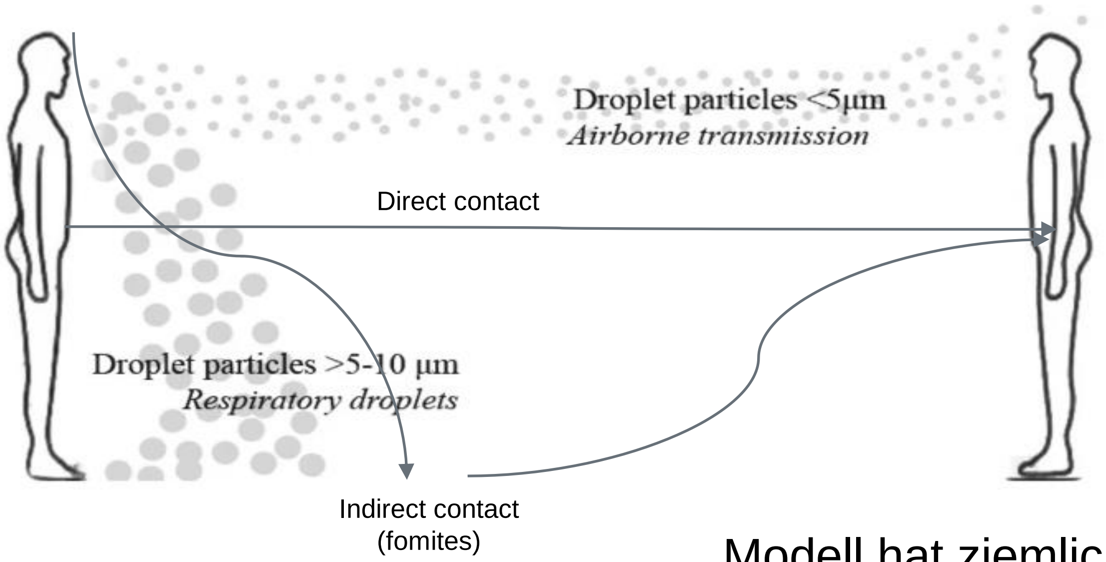
«Miasma»
Schlechte Luft als Mechanismus von Krankheitsausbreitung

Ausbreitung Cholera «über Luft», Bild 1831, wikipedia.org

Chapin, «The sources and modes of infection», 1910:

“There is **no evidence that [air infection] is is an appreciable factor in the maintenance of most of our common contagious diseases**. We are warranted, then, in discarding it as a working hypothesis, and devoting our chief attention to the prevention of contact infection.”

Übertragungsmodi respiratorischer Viren: „Historisches“ dichotomes Modell



Modell hat ziemlich gut funktioniert in der Praxis!

Keine gemeinsame Nomenklatur – keine sinnvolle Kommunikation

Medizin bezeichnet Partikel vor Mund mit 2-10 µm (Sedimentation im Bereich von Minuten) als ***Tröpfchen***

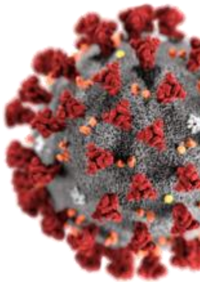
Aerosolphysiker unterscheiden**:**

- **Ballistische Partikel = Tröpfchen**
  Werden geschleudert auf Schleimhaut, nicht inhaliert
- **Schwebepartikel (auch für Sekunden)=** ***Aerosole***
  Werden inhaliert

Korrekt!

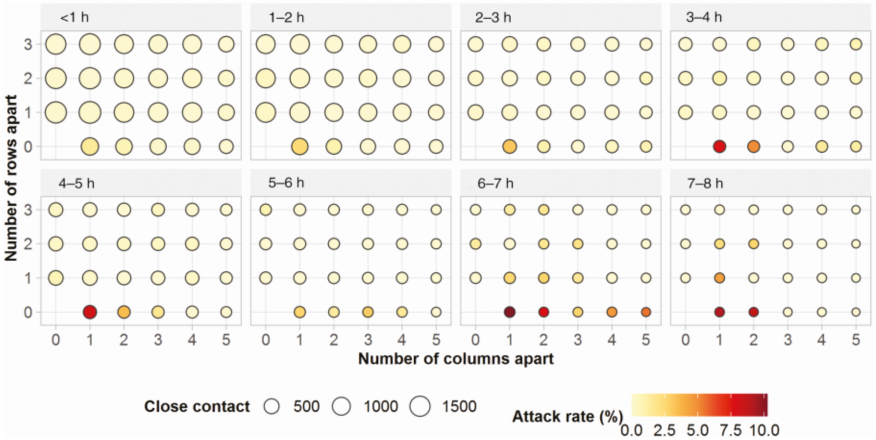
INSELGRUPPE

Übertragung von *SARS-CoV-2*

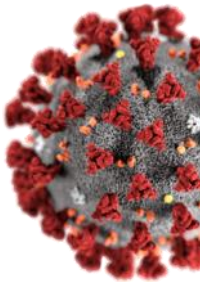


Distanz und Expositionszeit sind die zentralen Determinanten der sekundären «attack rate»

z.B. Analyse bei Zugpassagieren (G train, China, 2568 Fälle)



Hu M, et al. Clin Infect Dis. 2020. doi:10.1093/cid/ciaa1057

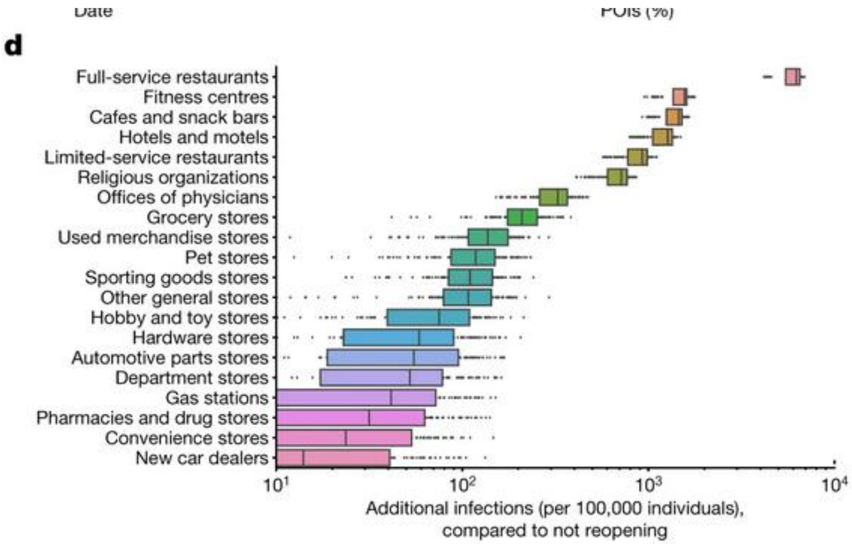


Übertragung von *SARS-CoV-2*

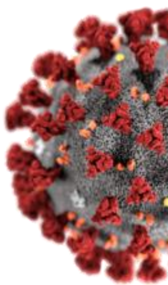
«Seasonality»: Präferenz für Innenraumübertragung

OR für Innenraumübertragung vs Aussenübertragung = 18.7

10.1093/infdis/jiaa742



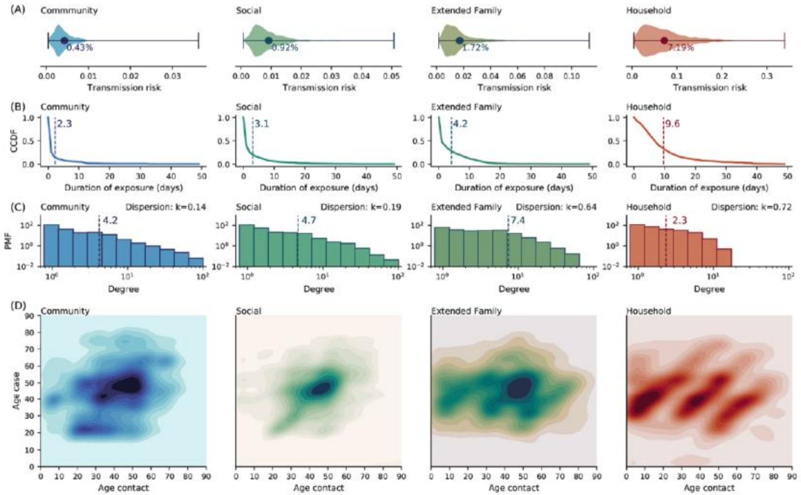
Nature volume 589, pages 82–87 (2021)



Übertragung von *SARS-CoV-2*

Heterogene Transmission

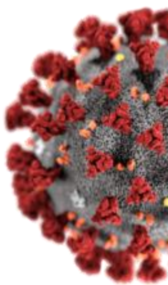
15% der Infizierten sind für 80% der sekundären Infektionen verantwortlich

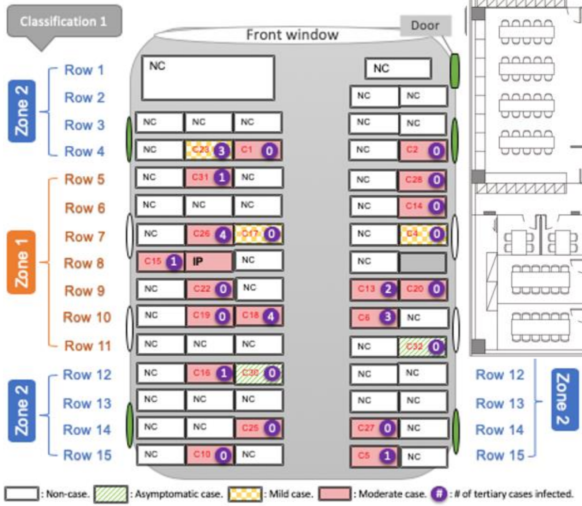


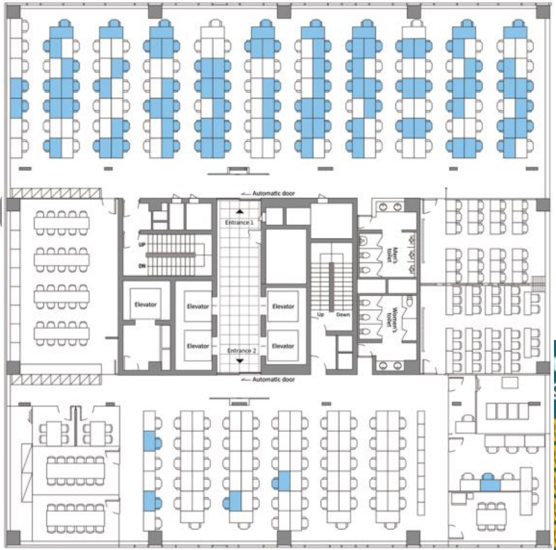
Sun, K. et al., Science. 2020. doi: 10.1126/science.abe2424 (2020).
Nguyen, et al. Lancet Public Health 2020. doi: 10.1016/S2468-2667(20)30164-X

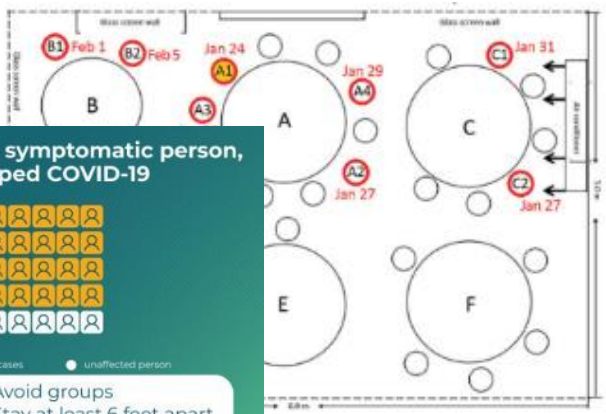
Übertragung von *SARS-CoV-2*

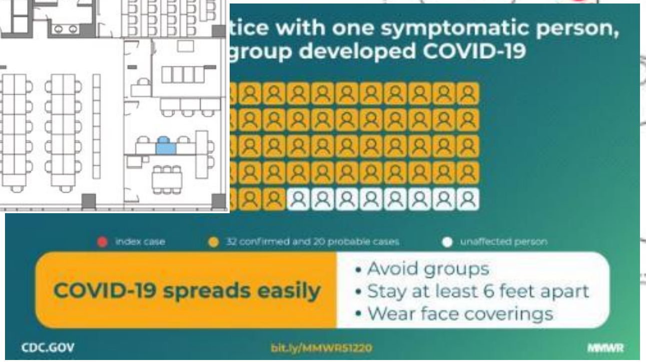
«Superspreading events»







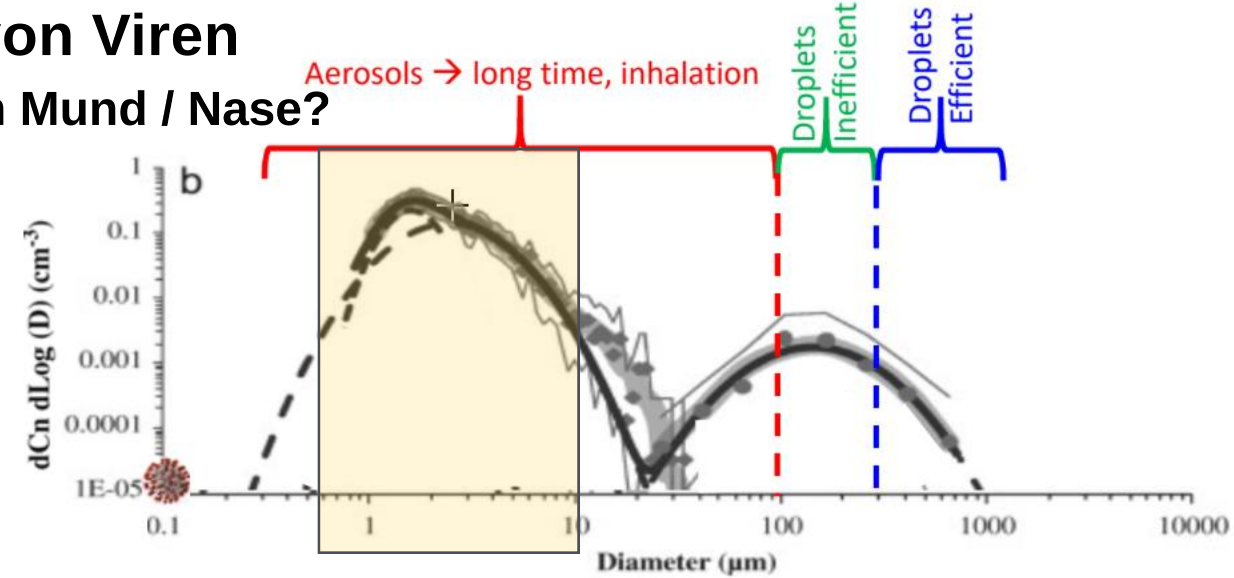




Übertragungsmodi von Viren

Was kommt aus unserem Mund / Nase?

1200x mehr Aerosole als Tröpfchen, grösster Teil zwischen 0.5-10 µm (beim Husten kleinere Partikel als beim Atmen)



Je lauter desto mehr…

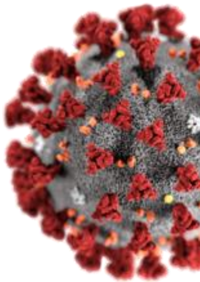
https://doi.org/10.1016/j.jaerosci.2011.07.009

Übertragungsmodi von Viren

Was kommt aus unserem Mund / Nase?

- Nach Mund direkt ca. 50% Volumenverlust durch Verdunstung
- Konkurrenzierend **Sedimentation und Verdunstung**
- **Partikelgrösse** ist die Hauptdeterminante der Suspensionszeit (neben Luftfeuchtigkeit, ….)
  Grösser = kürzere Suspension

INSELGRUPPE



Ausgeatmete Viren: In welchen Partikeln?

Partikel ≠ virushaltige Partikel!

ACCEPTED MANUSCRIPT

Viral Load of SARS-CoV-2 in Respiratory Aerosols Emitted by COVID-19 Patients while Breathing, Talking, and Singing FREE

Kristen K Coleman, Douglas Jie Wen Tay, Kai Sen Tan, Sean Wei Xiang Ong, Than The Son, Ming Hui Koh, Yi Qing Chin, Haziq Nasir, Tze Minn Mak, Justin Jang Hann Chu, Donald K Milton, Vincent T K Chow, Paul Anantharajah Tambyah, Mark Chen, Tham Kwok Wai ✉
Author Notes

Clinical Infectious Diseases, ciab691, https://doi.org/10.1093/cid/ciab691
Published: 06 August 2021 **Article history** ▾

Table 3. Sum Total of Viral RNA Loads Emitted in Coarse and Fine Respiratory Aerosols, for a Subgroup of Patients With COVID-19 With Detectable SARS-CoV-2 in Respiratory Aerosols

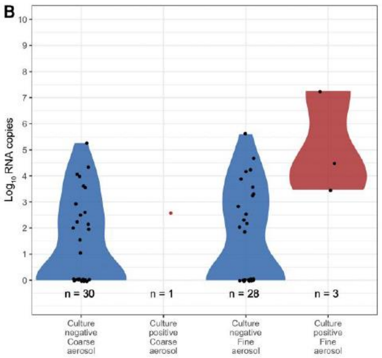
	Coarse Fraction	Fine Fraction	Total (% of column)
Three expiratory activities	4527.3 (14.6)	26 503 (85.4)	31 030.3*
Breathing[a]	897 (45.8; 2.9)	1062.3 (54.2; 3.4)	1959.3 (6.3)
Talking[b]	868.4 (6.9; 2.7)	11 787.5 (93.1; 38)	12 655.9 (40.8)
Singing[c]	2762 (16.8; 9)	13 653.2 (83.2; 44)	16 415.5 (52.9)

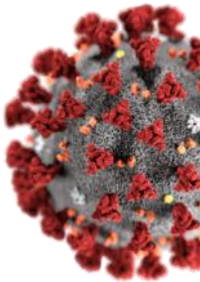
All values are expressed as viral N gene copies (percentage of row) unless otherwise noted. n = 13.
Abbreviations: COVID-19, coronavirus disease 2019; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.
[a]Thirty minutes of tidal breathing.
[b]Fifteen minutes of talking with brief pauses.
[c]Fifteen minutes of continuous singing.
*Overall total.

Clinical Infectious Diseases
MAJOR ARTICLE
IDSA Infectious Diseases Society of America hivma hiv medicine association OXFORD

Exhaled Breath Aerosol Shedding of Highly Transmissible Versus Prior Severe Acute Respiratory Syndrome Coronavirus 2 Variants

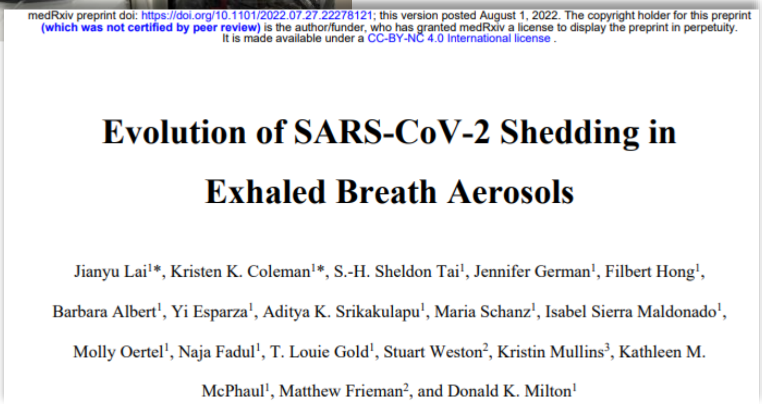
Jianyu Lai,[1,a] Kristen K. Coleman,[1,a] S.-H. Sheldon Tai,[1] Jennifer German,[1] Filbert Hong,[1] Barbara Albert,[1] Yi Esparza,[1] Aditya K. Srikakulapu,[1] Maria Schanz,[1] Isabel Sierra Maldonado,[1] Molly Oertel,[1] Naja Fadul,[1] T. Louie Gold,[1] Stuart Weston,[2] Kristin Mullins,[3] Kathleen M. McPhaul,[1] Matthew Frieman,[2] and Donald K. Milton[1]
[1]Institute for Applied Environmental Health, University of Maryland School of Public Health, College Park, Maryland, USA; [2]Department of Microbiology and Immunology, University of Maryland School of Medicine, Baltimore, Maryland, USA; and [3]Department of Pathology, University of Maryland School of Medicine, Baltimore, Maryland, USA





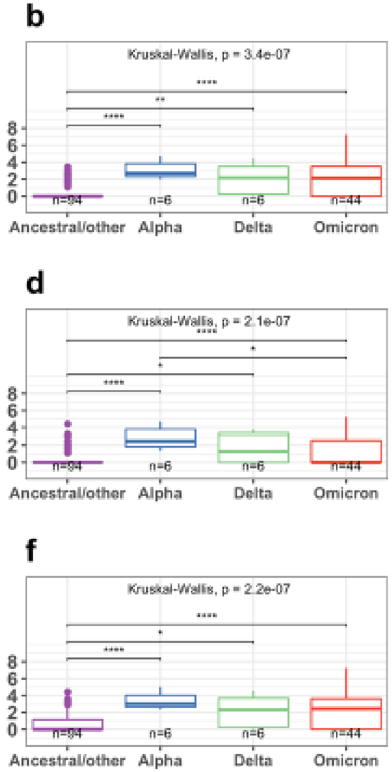
Ausgeatmete Viren: In welchen Partikeln?

- Alpha war etwas mehr «fine aerosol»-lastig
- Klarer Impfeffekt in diesen Daten nicht erkennbar



Evolution of SARS-CoV-2 Shedding in Exhaled Breath Aerosols

Jianyu Lai[1]*, Kristen K. Coleman[1]*, S.-H. Sheldon Tai[1], Jennifer German[1], Filbert Hong[1], Barbara Albert[1], Yi Esparza[1], Aditya K. Srikakulapu[1], Maria Schanz[1], Isabel Sierra Maldonado[1], Molly Oertel[1], Naja Fadul[1], T. Louie Gold[1], Stuart Weston[2], Kristin Mullins[3], Kathleen M. McPhaul[1], Matthew Frieman[2], and Donald K. Milton[1]



Fine aerosol

Coarse aerosol

Combined

„Aerosolgenerierende Prozeduren“: Relevanz?

Tracheal intubation (4 case-control studies)	0.7 (0.1, 3.9) [23]	6.6 (4.1, 10.6); 61.4%
	9.2 (4.2, 20.2) [21]	
	8.0 (3.9, 16.6) [20]	
	9.3 (2.9, 30.2) [24]	

Table 2. Risk of SARS T
Procedures as Risk Fac

Aerosol Generating Proce	Point estimate	Pooled estimate; I^2
Tracheal intubation (4 cohort studies)	3.0 (1.4, 6.7) [25]	6.6 (2.3, 18.9); 39.6%
	22.8 (3.9, 131.1) [26]	
	13.8 (1.2, 161.7) [27]	
	5.5 (0.6, 49.5) [29]	
Tracheal intubation (4 case-control studies)	0.7 (0.1, 3.9) [23]	6.6 (4.1, 10.6); 61.4%
	9.2 (4.2, 20.2) [21]	
	8.0 (3.9, 16.6) [20]	
	9.3 (2.9, 30.2) [24]	
Suction before intubation (2 cohort studies)	13.8 (1.2, 161.7) [27]	3.5 (0.5, 24.6); 59.2%
	1.7 (0.7, 4.2) [25]	
Suction after intubation (2 cohort studies)	0.6 (0.1, 3.0) [27]	1.3 (0.5, 3.4); 28.8%
	1.8 (0.8, 4.0) [25]	
Nebulizer treatment (3 cohort studies)	6.6 (0.9, 50.5) [27]	0.9 (0.1, 13.6); 73.1%
	0.1 (0.0*, 1.0) [28]	
	1.2 (0.1, 20.7) [25]	
Manipulation of oxygen mask (2 cohort studies)	17.0 (1.8, 165.0) [27]	4.6 (0.6, 32.5); 64.8%

Tran et al. PLoS One. 2012;7(4):e35797. doi: 10.1371/journal.pone.0035797.

Woher kommt das?

- **Fallkontrollstudien** v.a. von *SARS-CoV-1*
- Kleine Zahlen, grosse Konfidenzintervalle, *unkorrigiertes «Confunding» wahrscheinlich!*

„Aerosolgenerierende Prozeduren“: Relevanz?

During respiratory activities compared with quiet breathing

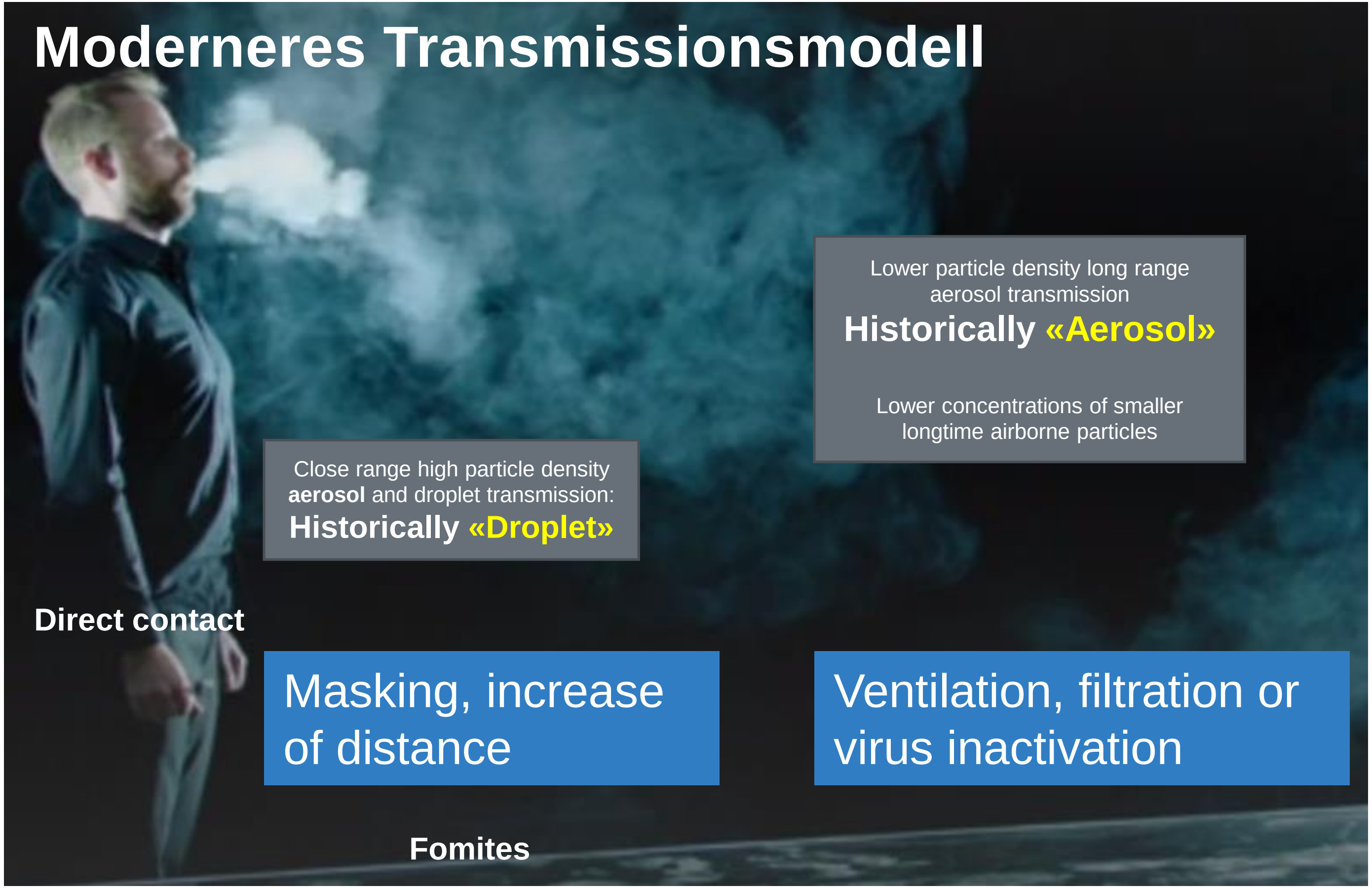
Respiratory activity	Fold change	95%CI	p value
Talking	34.6	15.2–79.1	< 0.001
Exercise	58.0	25.4–132.5	< 0.001
Shouting	163.6	71.6–373.9	<0.001
Forced expirations	227.6	99.6–520.0	<0.001
Coughing	370.8	162.3–847.1	<0.001

During quiet breathing with respiratory therapy compared with quiet breathing alone

Therapy	Flow; $l.min^{-1}$	Fold change	95%CI	p value
HFNO	20	1.3	0.6–2.4	0.472
	40	1.7	0.9–3.3	0.101
	60	2.3	1.2–4.4	0.031
Therapy	**Airway pressure; $cm.H_2O$**			
NIPPV-S	5/5	1.5	0.9–2.3	0.079
	10/10	1.3	0.9–2.1	0.185
	15/10	2.1	1.4–3.3	< 0.001
	20/10	2.4	1.5–3.8	< 0.001
	25/10	2.6	1.7–4.1	< 0.001
NIPPV-D	5/5	1.9	1.1–3.3	0.031
	10/10	2.9	1.6–5.0	< 0.001
	15/10	3.1	1.7–5.4	< 0.001
	20/10	4.6	2.6–8.0	< 0.001
	25/10	7.8	4.4–13.6	< 0.001

Wilson NM, et al. *Anaesthesia*. 2021;76(11):1465-1474. doi:10.1111/anae.15475

Moderneres Transmissionsmodell



Lower particle density long range aerosol transmission

Historically «Aerosol»

Lower concentrations of smaller longtime airborne particles

Close range high particle density **aerosol** and droplet transmission:

Historically «Droplet»

Direct contact

Masking, increase of distance

Ventilation, filtration or virus inactivation

Fomites

Methods

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HOPITAL UNIVERSITAIRE DE BERNE
BERN UNIVERSITY HOSPITAL

UNIVERSITÄT BERN

We used a **sampling dummy emulating a susceptible HCW** to evaluate the inhaled virus dose per particle size fraction in standardized interactions

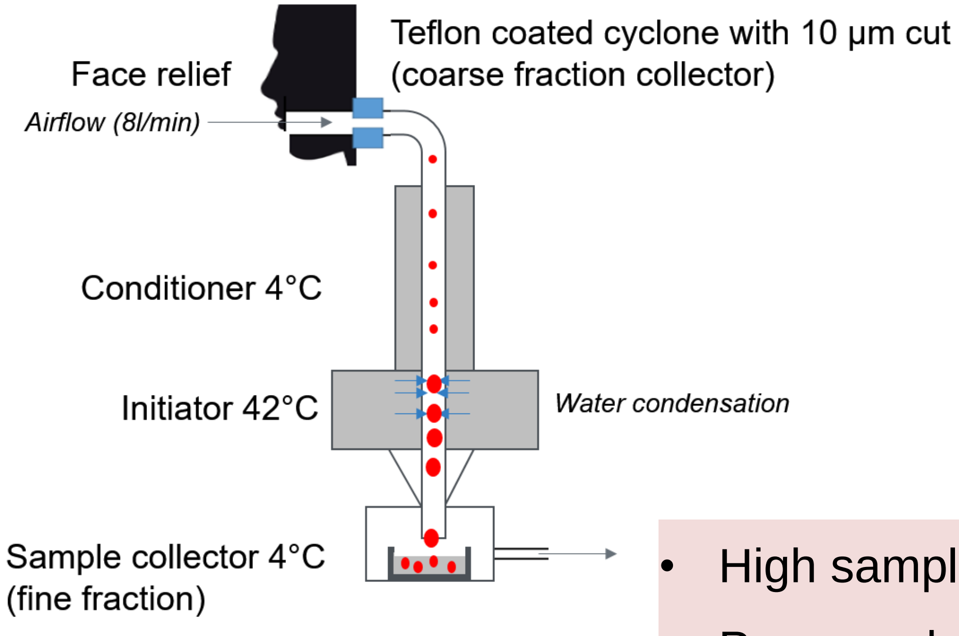
Recruitment
- COVID-19 isolation ward in a tertiary care hospital
- February to October 2021

Inclusion criteria
- Hospitalized patients >18 years
- Positive *SARS-CoV-2* PCR or antigen test
- Ability to consent and follow instructions

Exclusion criteria
- Symptom onset >10 days prior to inclusion
- Pregnancy

Sample processing
- qRT-PCR
- Virus culture using confluent Calu-3 cells

Methods: Sampling dummy



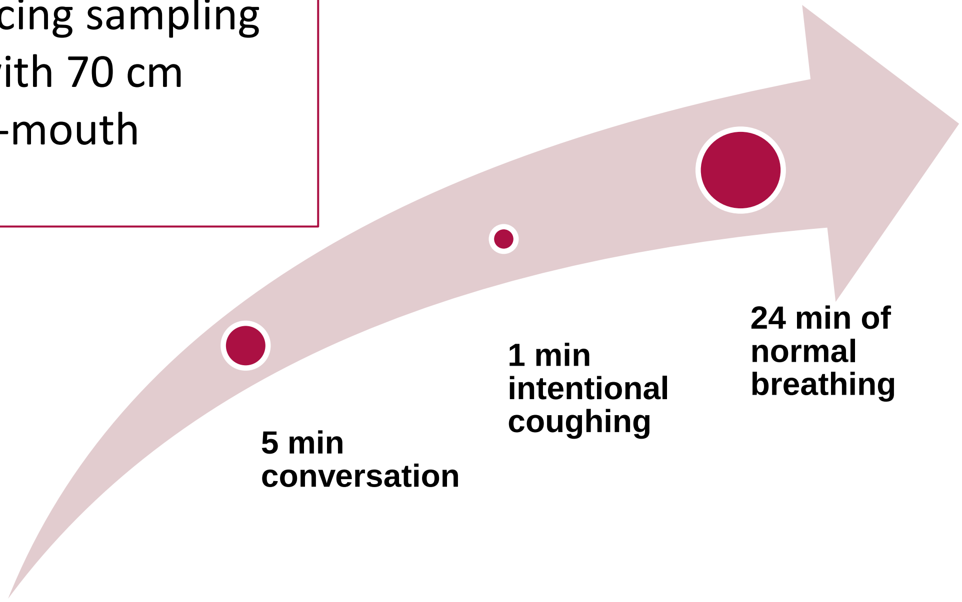
URG™ cyclone for collection of particles ≥10 µm

Biospot-VIVAS™ laminar flow condensation bioaerosol collector for particles <10 µm

- High sampling efficiency: >90% down to 5 nm
- Preserved culturability
- Physiological airflow (8 l/min)

Methods: Standardized HCW interaction

Patient facing sampling dummy with 70 cm mouth-to-mouth distance



Results

Population characteristics (n=23)		
Age (median [IQR]) *years*		63.00 [49.50, 70.50]
Sex (%)	Male	20 (87.0)
	Female	3 (13.0)
SARS-CoV-2 vaccine (%)	No vaccine	18 (78.3)
	1 dose	1 (4.3)
	2 doses	4 (17.4)
Immunocompromised (%)		5 (21.7)
	Solid organ transplant	2 (8.6)
	Chemotherapy for cancer treatment	3 (13.0)
Symptomatic COVID infection (%)		21 (91.3)
Days from sympton onset/test if asymptomatic (mean (SD))		6.09 (2.31)
Pneumonic infiltrate in Rx/CT scan (%)		16 (69.6)
Nasal cannula O2 delivery (mean (SD)) *l/min*		0.48 (0.95)
C-reactive protein (median [IQR]) *mg/l*		38.00 [17.00, 71.50]
Antiviral therapy (%)		0 (0.0)
Corticosteroid therapy (%)		8 (34.8)
Nasopharyngeal swab: PCR CT value (mean (SD))		24.95 (5.76)
Nasopharyngeal swab: Virus culture positive (%)		8 (34.8)

Unpublished data – please do not replicate

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Results

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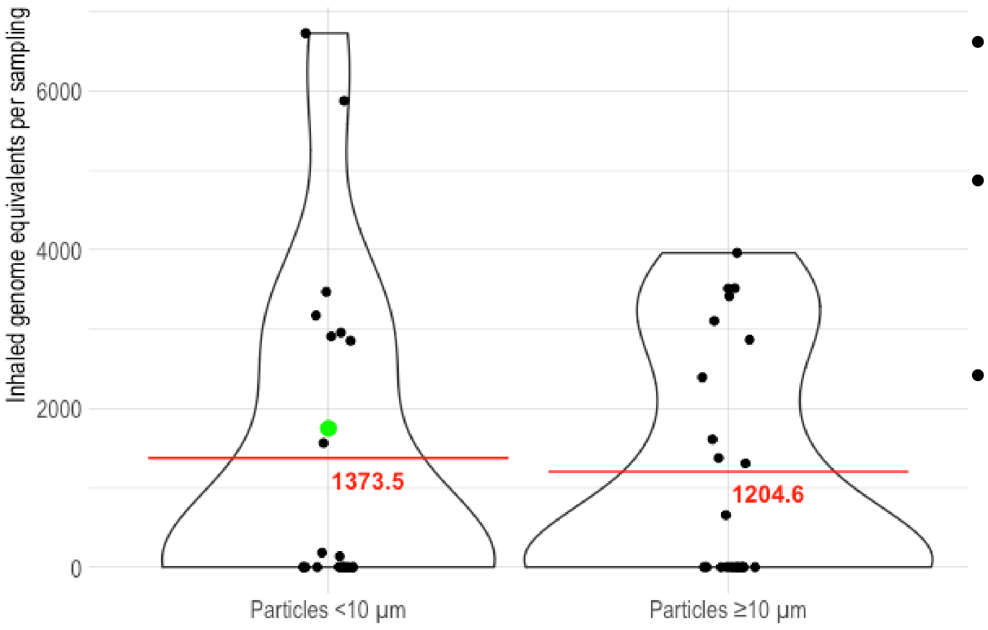
Sampling conditions (n=23)		
Room air changes /hour (mean (SD))		0.35 (0.25)
CO_2 (median [IQR]) *ppm*		1045.00 [984.38, 1656.88]
Humidity (mean (SD)) *%*		33.60 (6.70)
Temperature (mean (SD)) *°C*		25.29 (1.10)
Door position	Closed	23 (100.0)
Window position	Closed	11 (47.8)
	Tilted	9 (39.1)
	Open	3 (13.0)
Light conditions	Daylight sunshine	14 (60.9)
	Daylight overcast	9 (39.1)
Patient position	Sitting	20 (87.0)
	Halflying	1 (4.3)
	Lying	2 (8.7)
Number of persons in room (including patient)		3.04 (1.26)

Unpublished data – please do not replicate

Results:
Inhaled virus dose per interaction



Green: positive virus culture. Red bar: Mean.

Unpublished data – please do not replicate

- Inhaled *SARS-CoV-2* RNA in **18/23** patient interactions
- **53 % of inhaled dose in the fine aerosol range**, 47% in the coarse aerosol or droplet range
- Subgroup with detectable RNA: 1755 (fine fraction) and 1539 (coarse fraction) mean inhaled genome equivalents per 30 min interaction

INSELGRUPPE

Wenn es Aerosole sind, können wir das Transmissionsrisiko einfach weglüften oder filtrieren, oder? (Fazit Aerosolmodelle / Lüftungingenieure)

1. **Verlust der Infektiösität in respiratorischen Partikeln ignoriert**
   - Da nicht / nur schwer messbar, in Modellen nicht/willkürlich abgebildet
   - Meist fehlende Kultivierbarkeit in Luftsamples entspricht nicht fehlender Infektiösität, sondern höherer Nachweisgrenze Viruskultur vs. PCR

Table 4
Estimate of viable virus counts based on $TCID_{50}$ tests.

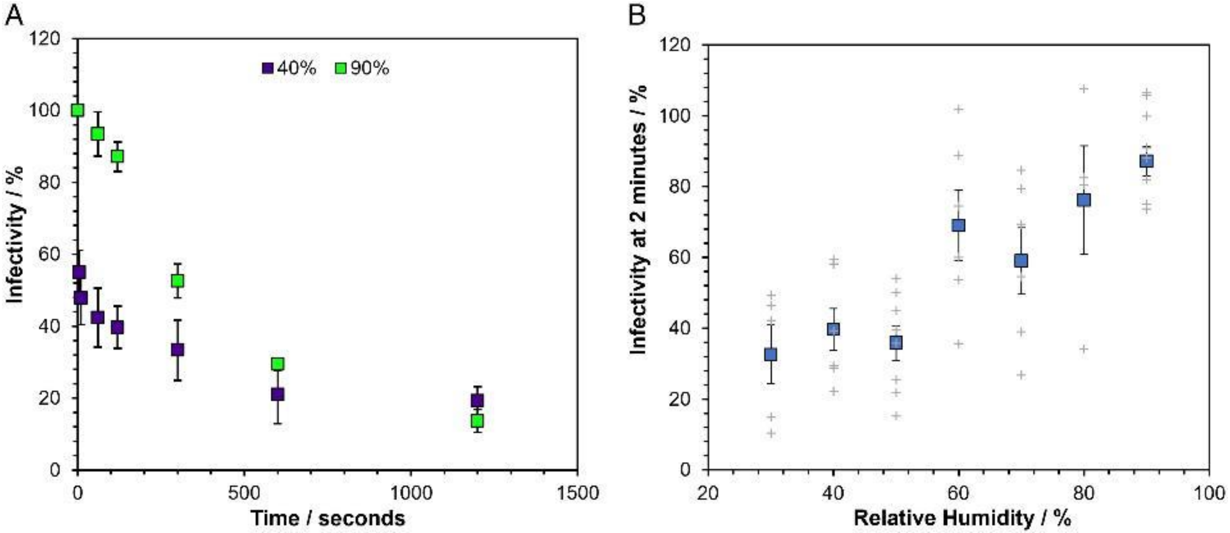
Sample ID	Virus genome equivalents/L of air[a]	$TCID_{50}$/100 µl	Viable virus count/L air
1-1 BioSpot	94	2.68E+04	74
1-2 BioSpot + HEPA	-	0	0
1-3 BioSpot	30	6.31E+03	18
2-1 VIVAS	44	1.00E+04	27
2-2 VIVA S+ HEPA	-	0	0
2-3 VIVAS	16	2.15E+03	6

[a] From Table 2.

Lednicky et al. International Journal of Infectious Diseases 100 (2020) 476–482.

Verlust der Infektiösität

Endlich erste Daten!



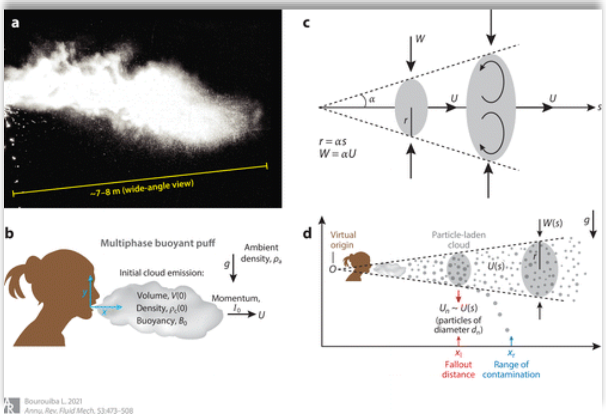
Oswin et al. PNAS. 2022. 119 (27) e2200109119. DOI: 10.1073/pnas.2200109119

5-10 µm Aerosole in elektrischem Feld

Wenn es Aerosole sind, können wir das Transmissionsrisiko einfach weglüften oder filtrieren, oder?
(Fazit Aerosolmodelle / Lüftungingenieure)

2. Partikelverteilung im Raum ist nicht homogen

- **«Turbulent multiphase clouds» - genügender Effekt in «Jet» unwahrscheinlich**
- Dieser Aspekt ist besser mit Fluid dynamics Modellen erfasst – in der Regel lebt der Modellierer aber entweder in einer oder der anderen Welt



Bourouiba L.
Annual Review of Fluid Mechanics. 2021.53:1, 473-508

INSELGRUPPE

Können wir das Transmissionsrisiko einfach weglüften oder filtrieren? (Aerosolmodelle / Lüftungingenieure)

Persönliches Fazit:

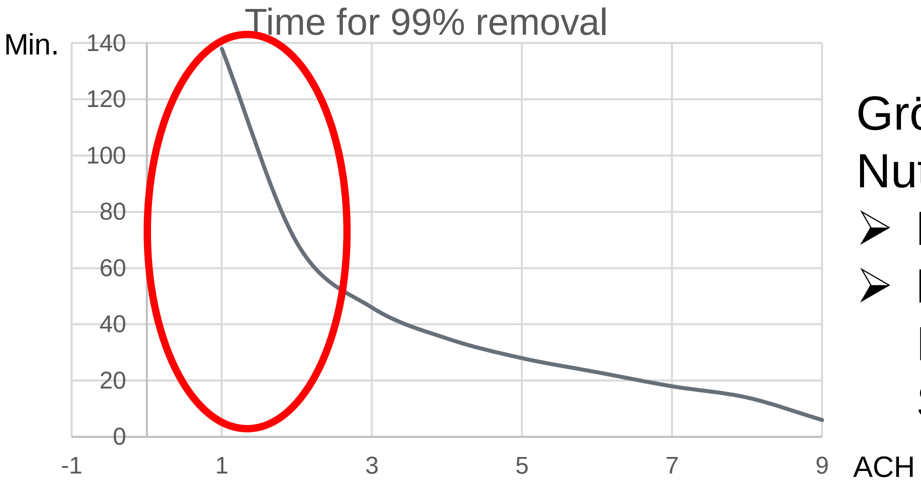
- Ja, Wahrscheinlichkeit einer infektiösen Dosis im Bereich ausserhalb des dynamischen Bereichs von «Turbulent multiphase clouds» wird erwiesenermassen reduziert
- Aber, Effekt geringer als Aerosolmodellierstudien suggerieren

INSELGRUPPE

Weglüften oder filtrieren?

Nochmals aber: Nutzen-Preis-Verhältnis!

- Leider führt 2x Ventilations- / Filtrationsleistung zu 4x Lärm, 4x Energieverbrauch, **….keine lineare Beziehung**



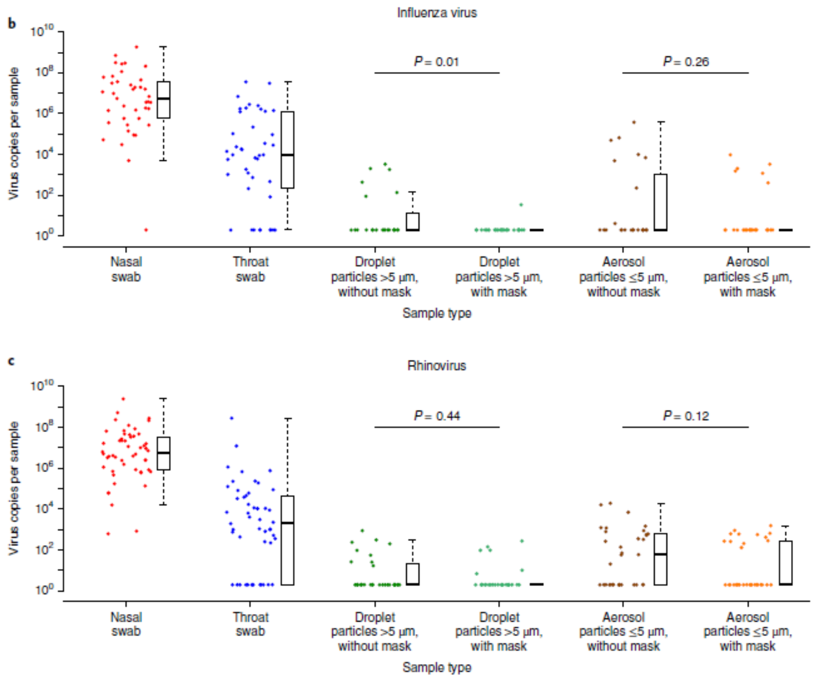
Grösste Chance von positivem Nutzen-Preis-Verhältnis:

- **Bereiche mit desolater Lüftung**
- **Hotspots ohne Maske** (im Spital Pausenräume, ausserhalb Schulzimmer, Discos, etc.)

Aerosole: Was ist mit anderen respiratorischen Viren?

Physikalische Gesetze bleiben, aber jedes Virus hat unterschiedliche Partikelgrössenverteilung und unterschiedliche Empfindlichkeit verschiedener Zielgewebe.

Daten bereits von vor Pandemie zu Influenza, Erkältungs-Coronaviren, RSV, Rhino, Adeno, Masern, MERS, SARS



Leung et al. Nature Med 2020.

INSELGRUPPE

Aerosole: Was ist mit anderen respiratorischen Viren?

Virus name	Scope of studies and/or approaches						
	Air sampling and PCR	Air sampling and cell culture	Animal models	Laboratory or clinical studies	Epidemiological analysis	Simulation and modeling	Size-resolved information
SARS-CoV	(31)	(31)	–	(30)	(30)	(30)	–
MERS-CoV	(32)	(32, 103)	(103, 198)	(32)	–	–	–
SARS-CoV-2	(41–44)	(34, 35, 40)	(33, 37, 199)	(34, 45, 107)	(36, 64, 71, 72, 186)	(36, 50)	(34, 41, 43)
Influenza virus	(22, 23, 98, 102, 106)	(23, 98, 101)	(24, 137, 200, 201)	(24, 138, 202, 203)	(20)	(20, 114, 204)	(23, 105, 106)
Rhinovirus	(9, 27)	(26, 28)	–	(26–28)	–	(27)	(9)
Measles virus	(16)	(16)	–	–	(17)	(17)	(16)
Respiratory syncytial virus (RSV)	(102)	(25)	–	(25)	–	–	(25)

Wang et al. Science. 2021 Aug 27;373(6558):eabd9149.
Doi: 10.1126/science.abd9149.

Brauchen jetzt alle respiratorischen Viren Aerosolisolation?

The Risk of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Transmission from Patients With Undiagnosed Coronavirus Disease 2019 (COVID-19) to Roommates in a Large Academic Medical Center

Abraar Karan,[1] Michael Klompas,[1,2,3] Robert Tucker,[3] Meghan Baker,[1,2,3] Vineeta Vaidya,[3] and Chanu Rhee[1,2,3]; for the CDC Prevention Epicenters Program

[1]Department of Medicine, Brigham and Women's Hospital, Boston, Massachusettts, USA; [2]Department of Population Medicine, Harvard Medical School/ Harvard Pilgrim Health Care Institute, Boston, Massachusetts, USA; and [3]Infection Control Department, Brigham and Women's Hospital, Boston, Massachusetts, USA

We assessed severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission between patients in shared rooms in an academic hospital between September 2020 and April 2021. In total, 11 290 patients were admitted to shared rooms, of whom 25 tested positive. Among 31 exposed roommates, 12 (39%) tested positive within 14 days. Transmission was associated with polymerase chain reaction (PCR) cycle thresholds ≤21.

Birrer *et al.*
Antimicrobial Resistance & Infection Control (2022) 11:2
https://doi.org/10.1186/s13756-021-01038-y
Antimicrobial Resistance and Infection Control

RESEARCH — Open Access

Droplet precautions on-site (DroPS) during the influenza season 2018/2019: a possible alternative to single room isolation for respiratory viral infections

Michèle Birrer[1*], Martin Perrig[2], Fabienne Hobi[1], Christina Gfeller[1], Andrew Atkinson[1], Martin Egger[3], Corinne Bartholdi[2], Drahomir Aujesky[2], Jonas Marschall[1,4] and Rami Sommerstein[1,5*]

Platzisolation funktioniert

Platzisolation funktioniert nicht (gut)

(gleicher Transmissionsmodus)

Brauchen jetzt alle respiratorischen Viren Aerosolisolation?

Sinnvolle Isolationsmassnahmen **nicht alleine vom dominanten physikalischen Transmissionsmodus** abhängig, sondern zusätzlich von:

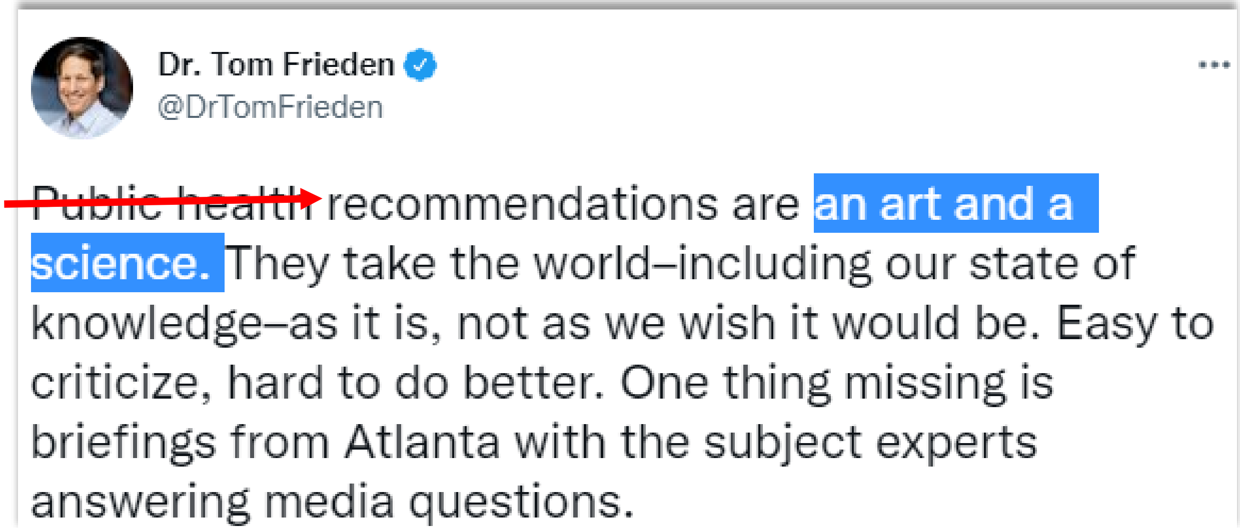
- Kontagiösität
- Virulenz
- «Idealer» Ressourcenallokation

Siehe z.B. **Vogelgrippe:**
Tieferes Risiko von humaner Transmission + physikalisch identisch zu humanen Influenzastämmen – aber gefährlicher + Psychologie «neuer Erreger»

Brauchen jetzt alle respiratorischen Viren Aerosolisolation?

No one true solution!

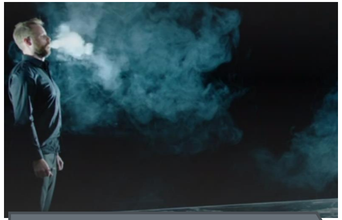
IPC


Dr. Tom Frieden
@DrTomFrieden

~~Public health~~ recommendations are an art and a science. They take the world–including our state of knowledge–as it is, not as we wish it would be. Easy to criticize, hard to do better. One thing missing is briefings from Atlanta with the subject experts answering media questions.

Brauchen jetzt alle respiratorischen Viren Aerosolisolation?

Inselspital: Intermediäre Kategorie zwischen Tröpfen & Aerosol



- Chirurgische Maske bei Patientenkontakt näher als 1½ Meter
- Händedesinfektion
- Auf gute Raumlüftung achten

- Chirurgische Maske bei Patientenkontakt näher als 1½ Meter
- Platzisolation mit Abstand
- Händedesinfektion
- Auf gute Raumlüftung achten

- Chirurgische Maske als Basisschutz
- Wechsel auf FFP2-Maske bei nahem (< 1½ Meter) oder langem Patientenkontakt
- Händedesinfektion
- Auf gute Raumlüftung achten

- FFP2-Maske vor Eintritt ins Zimmer anziehen
- Türe muss geschlossen sein
- Händedesinfektion

Wenn die Zeit reicht: Masken nutzlos? Nur noch FFP2 ?

RESEARCH ARTICLE | APPLIED PHYSICAL SCIENCES

An upper bound on one-to-one exposure to infectious human respiratory particles

Gholamhossein Bagheri, Birte Thiede, Bardia Hejazi, +1, and Eberhard Bodenschatz Authors Info & Affiliations

Edited by Howard Stone, Princeton University, Princeton, NJ (received June 1, 2021; accepted November 1, 2021)

December 2, 2021 | 118 (49) e2110117118 | https://doi.org/10.1073/pnas.2110117118

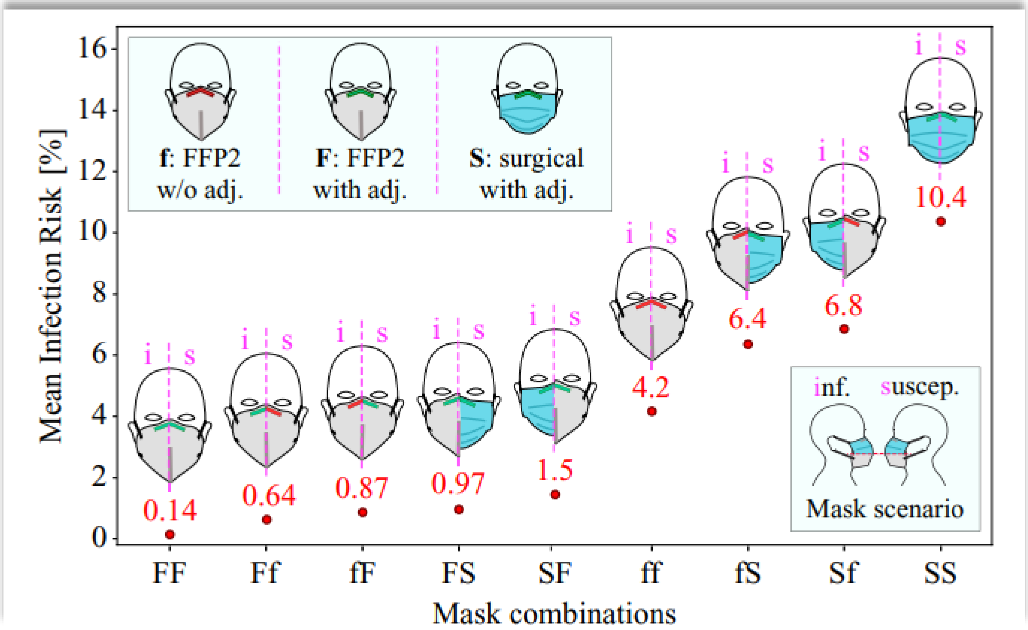


Fig. 6. Mean risk of infection in mask scenarios with different mask combinations for a duration of 20 min. The horizontal axis shows the combination of masks used by the infectious and susceptible with two characters; the first character corresponds to the type of mask worn by the infectious, and the second character corresponds to that of susceptible. Mask types and fittings are abbreviated as follows: f, FFP2 mask without adjustment (Fig. 2, case *i*); F, FFP2 mask with adjustment (Fig. 2, case *ii*); S, surgical mask with adjustment (Fig. 2, case *v*). Other parameters used for generating results shown in this plot are $f_d = 1.0$, $d_{0,max} = 50$ µm, $w = 4$, viral load $\rho_p = 10^{8.5}$ virus copies per mL, and $ID_{63.21} = 200$.

Wenn die Zeit reicht: Masken nutzlos?

Cochrane Library
Trusted evidence. Informed decisions. Better health.
Cochrane Database of Systematic Reviews

[Intervention Review]

Physical interventions to interrupt or reduce the spread of respiratory viruses

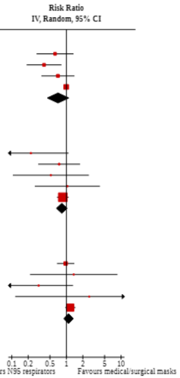
Tom Jefferson[1a], Liz Dooley[2], Eliana Ferroni[3], Lubna A Al-Ansary[4], Mieke L van Driel[5,6], Ghada A Bawazeer[7], Mark A Jones[2], Tammy C Hoffmann[2], Justin Clark[2], Elaine M Beller[2], Paul P Glasziou[2], John M Conly[8,9,10]

There is uncertainty about the effects of face masks. The low to moderate certainty of evidence means our confidence in the effect estimate is limited, and that the true effect may be different from the observed estimate of the effect. The pooled results of RCTs did not show a clear reduction in respiratory viral infection with the use of medical/surgical masks. There were no clear differences between the use of medical/surgical masks compared with N95/P2 respirators in healthcare workers when used in routine care to reduce respiratory viral infection. Hand hygiene is likely to modestly reduce the burden of respiratory illness, and

Intention to mask…

Analysis 2.1. Comparison 2: Randomised trials: N95 respirators compared to medical/surgical masks, Outcome 1: Viral illness

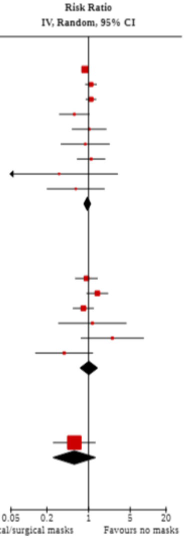
Study or Subgroup	log[RR]	SE	N95 respirators Total	Medical/surgical masks Total	Weight	Risk Ratio IV, Random, 95% CI
2.1.1 Clinical respiratory illness						
MacIntyre 2011	-0.478	0.397	949	492	18.5%	0.62 [0.28 , 1.35]
MacIntyre 2013	-0.942	0.374	581	286	19.7%	0.39 [0.19 , 0.81]
MacIntyre 2013 (1)	-0.357	0.355	516	286	20.8%	0.70 [0.35 , 1.40]
Radonovich 2019	-0.01	0.035	2243	2446	41.0%	0.99 [0.92 , 1.06]
Subtotal (95% CI)			**4289**	**3510**	**100.0%**	**0.70 [0.45 , 1.10]**
Heterogeneity: Tau² = 0.13; Chi² = 8.37, df = 3 (P = 0.04); I² = 64%						
Test for overall effect: Z = 1.54 (P = 0.12)						
2.1.2 Influenza-like illness						
Loeb 2009	-1.496	0.81	210	212	2.0%	0.22 [0.05 , 1.10]
MacIntyre 2009	-0.306	0.45	92	94	6.6%	0.74 [0.30 , 1.78]
MacIntyre 2011	-0.654	0.817	949	492	2.0%	0.52 [0.10 , 2.58]
MacIntyre 2013	0.04	0.7	1097	572	2.7%	1.04 [0.26 , 4.10]
Radonovich 2019	-0.151	0.124	2243	2446	86.7%	0.86 [0.67 , 1.10]
Subtotal (95% CI)			**4591**	**3816**	**100.0%**	**0.82 [0.66 , 1.03]**
Heterogeneity: Tau² = 0.00; Chi² = 3.19, df = 4 (P = 0.53); I² = 0%						
Test for overall effect: Z = 1.68 (P = 0.09)						
2.1.3 Laboratory-confirmed influenza						
Loeb 2009	-0.031	0.186	210	212	27.7%	0.97 [0.67 , 1.40]
MacIntyre 2009 (2)	0.31	0.94	92	94	1.2%	1.36 [0.22 , 8.61]
MacIntyre 2011	-1.171	0.74	949	492	1.9%	0.31 [0.07 , 1.32]
MacIntyre 2013	0.96	1.59	1097	572	0.4%	2.61 [0.12 , 58.93]
Radonovich 2019	0.166	0.11	2243	2446	68.8%	1.18 [0.95 , 1.46]
Subtotal (95% CI)			**4591**	**3816**	**100.0%**	**1.10 [0.90 , 1.34]**
Heterogeneity: Tau² = 0.00; Chi² = 4.15, df = 4 (P = 0.39); I² = 4%						
Test for overall effect: Z = 0.89 (P = 0.37)						



Footnotes
(1) MacIntyre 2013 includes 2 comparisons: N95 vs surgical masks and targeted N95 vs surgical masks
(2) MacIntyre 2009 reported on outcome laboratory confirmed infections

Analysis 1.1. Comparison 1: Randomised trials: medical/surgical masks versus no masks, Outcome 1: Viral illness

Study or Subgroup	log[RR]	SE	Medical/surgical masks Total	No masks Total	Weight	Risk Ratio IV, Random, 95% CI
1.1.1 Influenza/COVID-like illness						
Abaluck 2022 (1)	-0.135	0.036	111525	155268	41.4%	0.87 [0.81 , 0.94]
Aiello 2012	0.095	0.115	392	370	19.8%	1.10 [0.88 , 1.38]
Alfelali 2020	0.095	0.105	3864	3823	21.9%	1.10 [0.90 , 1.35]
Barasheed 2014	-0.55	0.3	75	89	4.6%	0.58 [0.32 , 1.04]
Canini 2010	0.025	0.342	148	158	3.6%	1.03 [0.52 , 2.00]
Cowling 2008	-0.128	0.483	61	205	1.9%	0.88 [0.34 , 2.27]
MacIntyre 2009	0.1	0.28	186	100	5.2%	1.11 [0.64 , 1.91]
MacIntyre 2016	-1.139	1.16	302	295	0.3%	0.32 [0.03 , 3.11]
Suess 2012	-0.494	0.571	26	30	1.4%	0.61 [0.20 , 1.87]
Subtotal (95% CI)			**116579**	**160338**	**100.0%**	**0.95 [0.84 , 1.09]**
Heterogeneity: Tau² = 0.01; Chi² = 11.44, df = 8 (P = 0.18); I² = 30%						
Test for overall effect: Z = 0.71 (P = 0.48)						
1.1.2 Laboratory-confirmed influenza or SARS-cov-2						
Aiello 2012	-0.083	0.223	392	370	25.9%	0.92 [0.59 , 1.42]
Alfelali 2020	0.34	0.215	3864	3823	26.7%	1.40 [0.92 , 2.14]
Bundgaard 2021 (2)	-0.2	0.208	2392	2470	27.4%	0.82 [0.54 , 1.23]
Cowling 2008	0.148	0.674	61	205	5.8%	1.16 [0.31 , 4.34]
MacIntyre 2009	0.92	0.6225	186	100	6.6%	2.51 [0.74 , 8.50]
Suess 2012	-0.942	0.57	26	30	7.7%	0.39 [0.13 , 1.19]
Subtotal (95% CI)			**6921**	**6998**	**100.0%**	**1.01 [0.72 , 1.42]**
Heterogeneity: Tau² = 0.07; Chi² = 8.52, df = 5 (P = 0.13); I² = 41%						
Test for overall effect: Z = 0.07 (P = 0.95)						
1.1.3 Laboratory-confirmed other respiratory viruses						
Bundgaard 2021	-0.55	0.42	2392	2470	100.0%	0.58 [0.25 , 1.31]
Subtotal (95% CI)			**2392**	**2470**	**100.0%**	**0.58 [0.25 , 1.31]**
Heterogeneity: Not applicable						
Test for overall effect: Z = 1.31 (P = 0.19)						



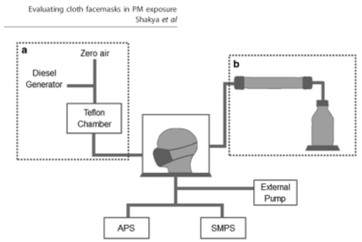
Footnotes
(1) Covid-like-illness
(2) SARS-cov-2

https://doi.org/10.1002/14651858.CD006207.pub6

Wenn die Zeit reicht: Masken nutzlos?

Empfänger trägt Maske: Bis etwa 1 µm chirurgische Maske äquivalent N95 (FFP2), <1 µm unterlegen

Problem = Leckage an Seite, nicht Filtermaterial



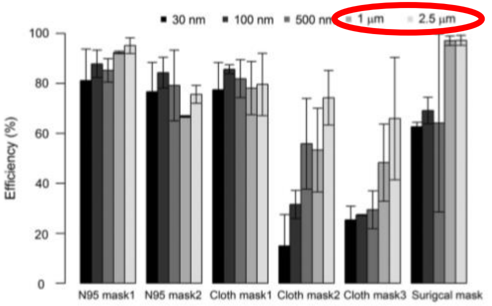


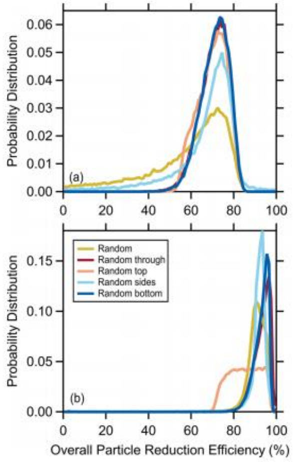
Figure 2. Efficiency of masks in removal of five polystyrene latex (PSL) particle sizes at a flow rate of 19 L/min. Error bars are the standard deviation from three experiments.

Quelle trägt chirurgische Maske

Husten: >90% Effizienz trotz Leckage

Reden: >70% trotz Leckage

➢ In **jedem Fall starke Reduktion** ausgeschiedene Virusmenge!



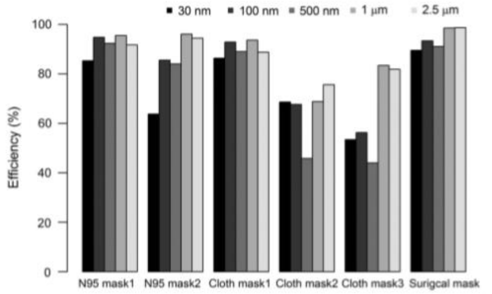


Figure 3. Efficiency of masks in removal of five polystyrene latex (PSL) particle sizes at a flow rate of 8 L/min.

Shakya. Journal of Exposure Science and Environmental Epidemiology (2016) 00, 1–6.
Cappa. Scientific Reports (2021) 11, 12110.

Fazit

- **Dichotomes Tröpfchentransmissionsmodell** physikalisch falsch, hat aber wegen Fokus auf Transmission in Nähe bei respiratorischen Viren mit «mässiger» Kontagiösität erstaunlich gut funktioniert
- *SARS-CoV-2*: **Mitigation gegen Aerosolübertragung** sinnvoll bei hohem Übertragungs- oder Komplikationsrisiko
- **Ventilation / Filtration** ist sinnvoll, aber Nutzen in Aerosolmodellen überschätzt; muss mit <u>Massnahmen an Infektionsquelle</u> ergänzt werden
- FFP2 Masken besser als chirurgische, aber Unterschied nicht riesig

INSELGRUPPE

Herzlichen Dank!