62. Hygienekreis “Lernen aus COVID-19”

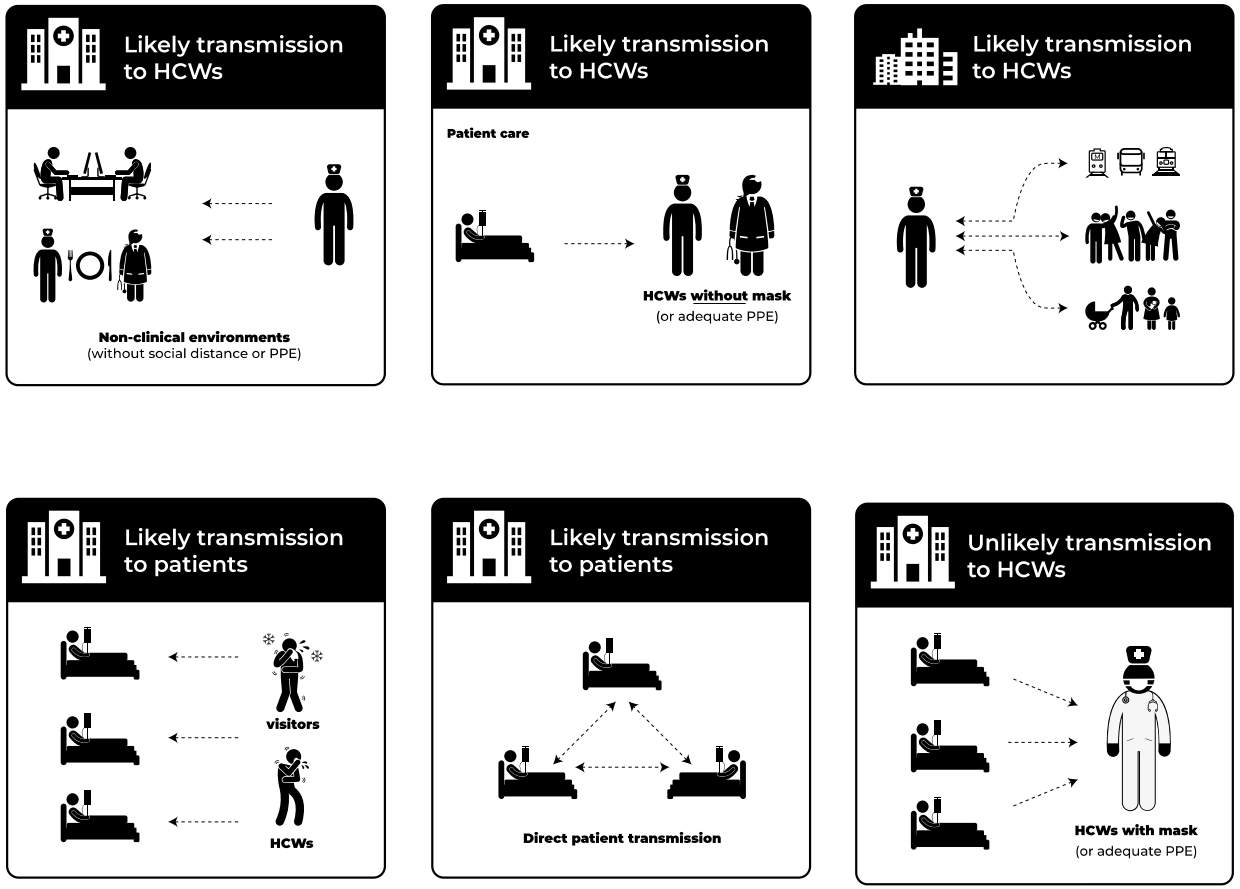
Tröpfchen, Aerosol oder beides?

PD Dr. med. Walter Zingg
Leiter Spitalhygiene USZ

02 November 2021

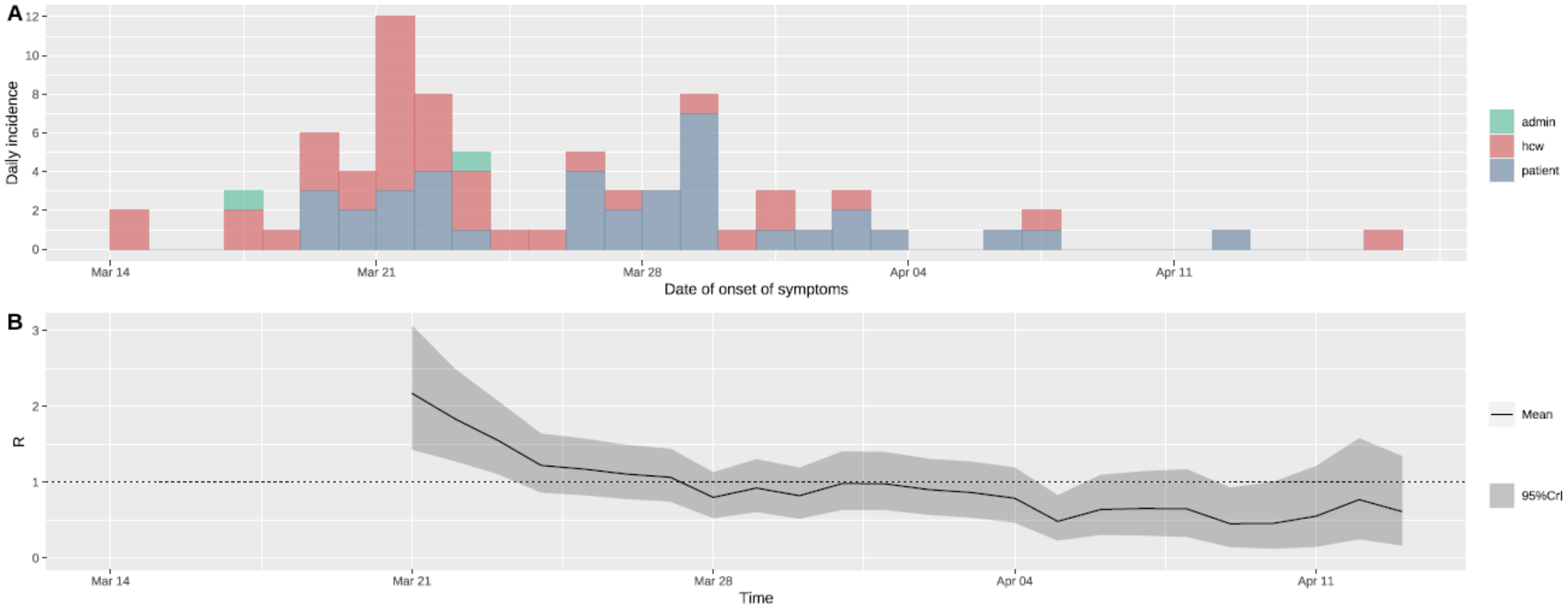
Healthcare-associated COVID-19

Nosocomial transmission and outbreaks of coronavirus disease 2019: the need to protect both patients and healthcare workers

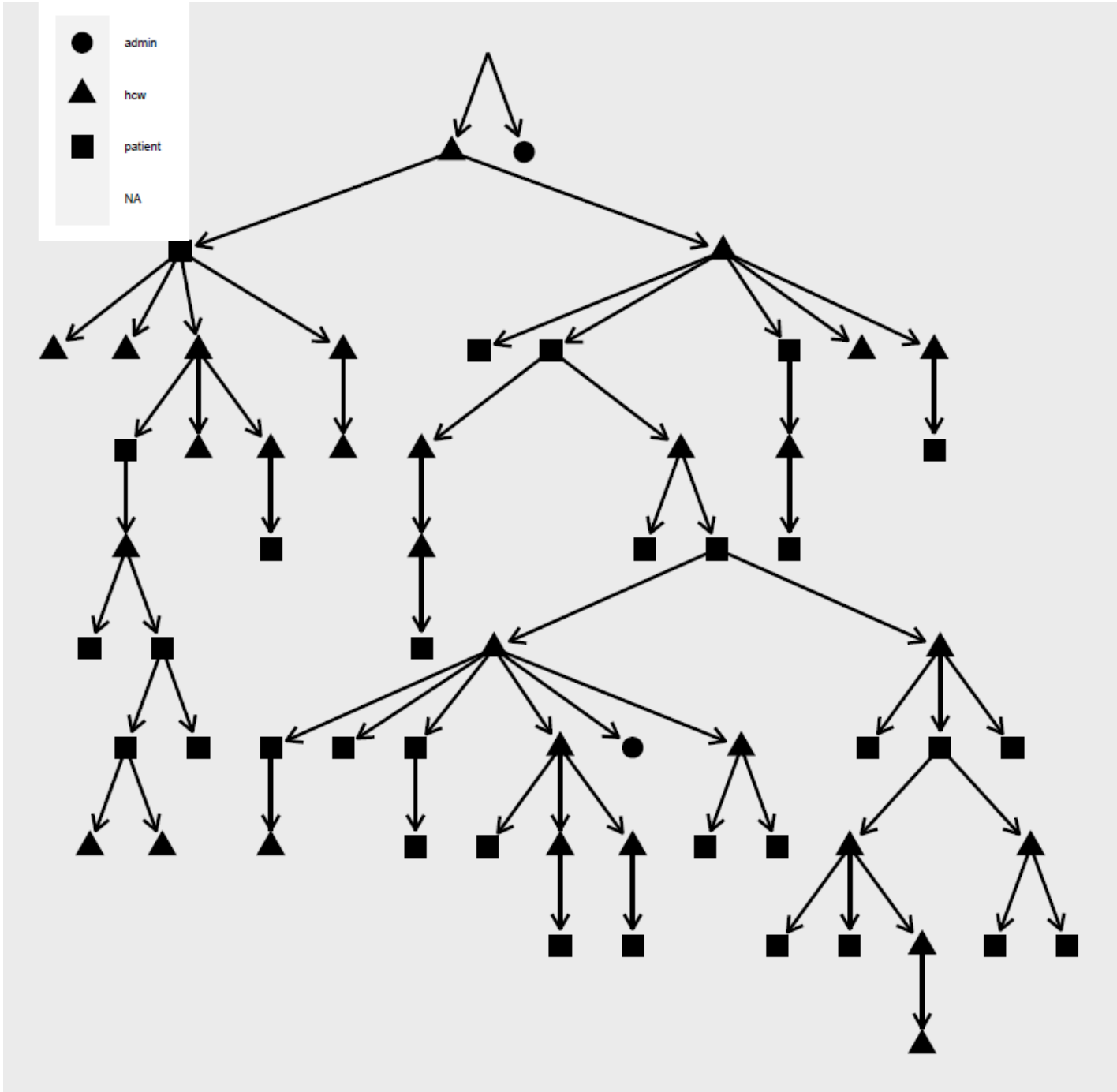


Abbas M, *Antimicrob Resist InfectControl* 2021;10:7

Outbreak Clinique «Jolimont»



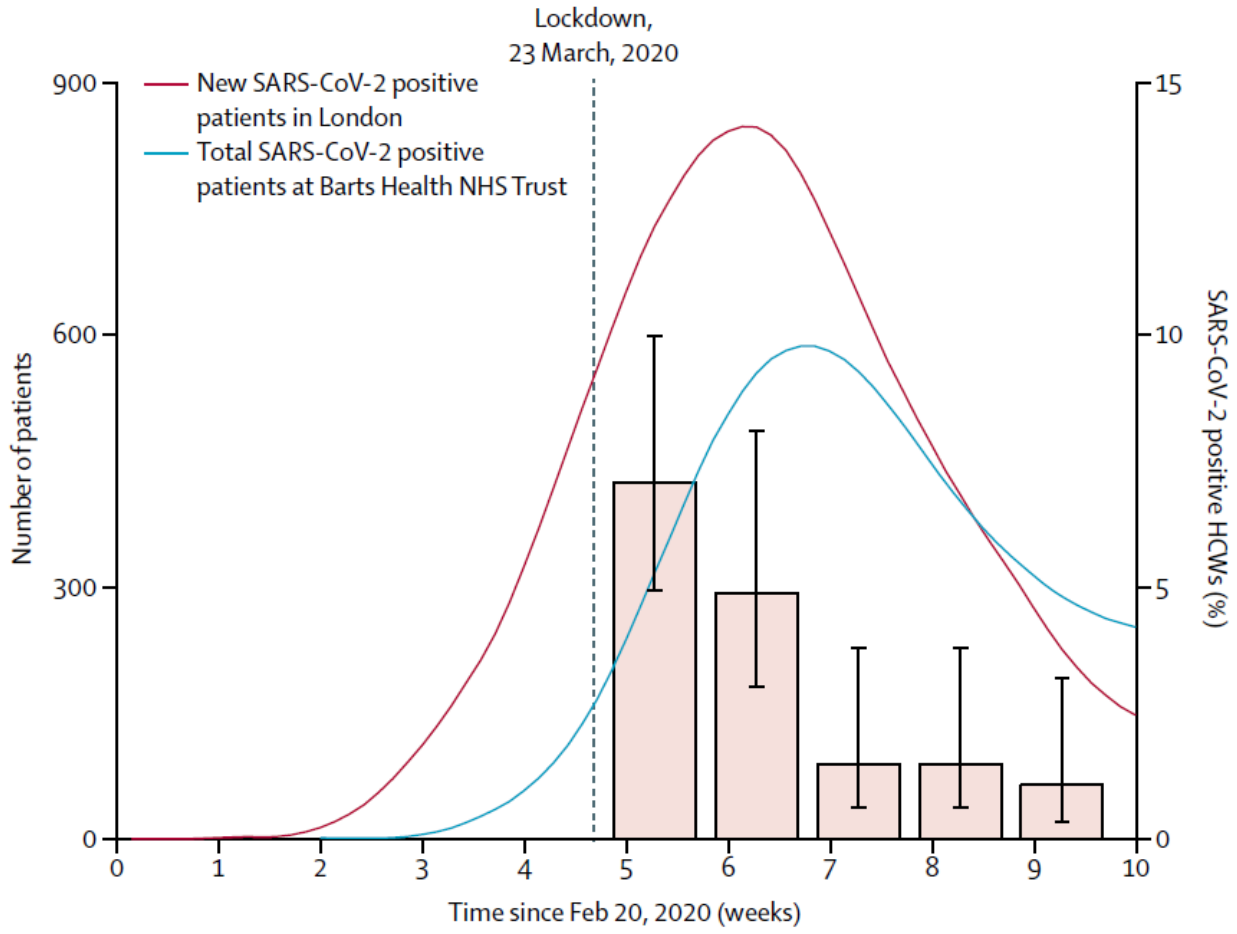
Abbas M, *J Hosp Infect* 2021;117:124



Abbas M, *J Hosp Infect* 2021;117:124

Healthcare workers – England

Acute care hospitals, repeated prevalence



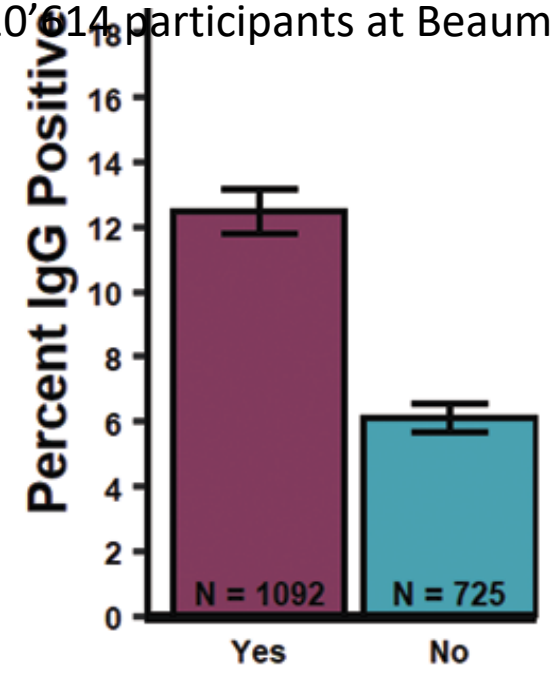
400 asymptomatic healthcare workers in a London NHS trust

→ Infections among HCWs particularly in the **early stage**!

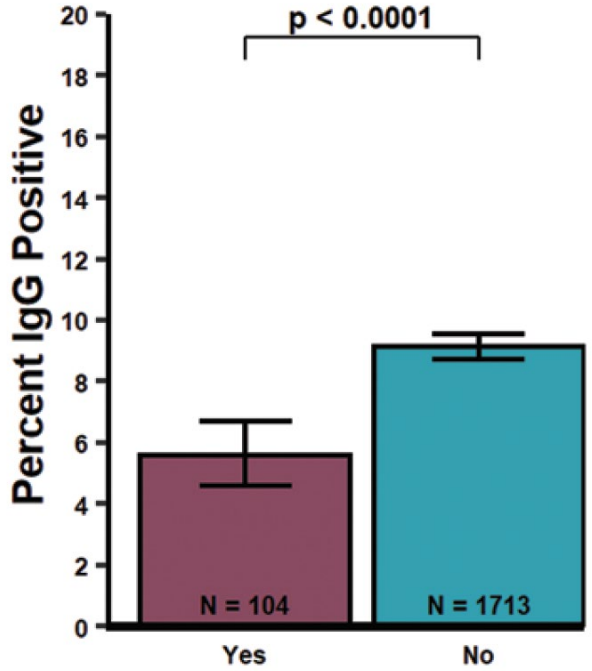
Treibel TA, *Lancet* 2020;395:1608

COVID-19 in healthcare workers

20’614 participants at Beaumont Health (8 hospitals across the Detroit metropolitan area)



Contact with
COVID patients

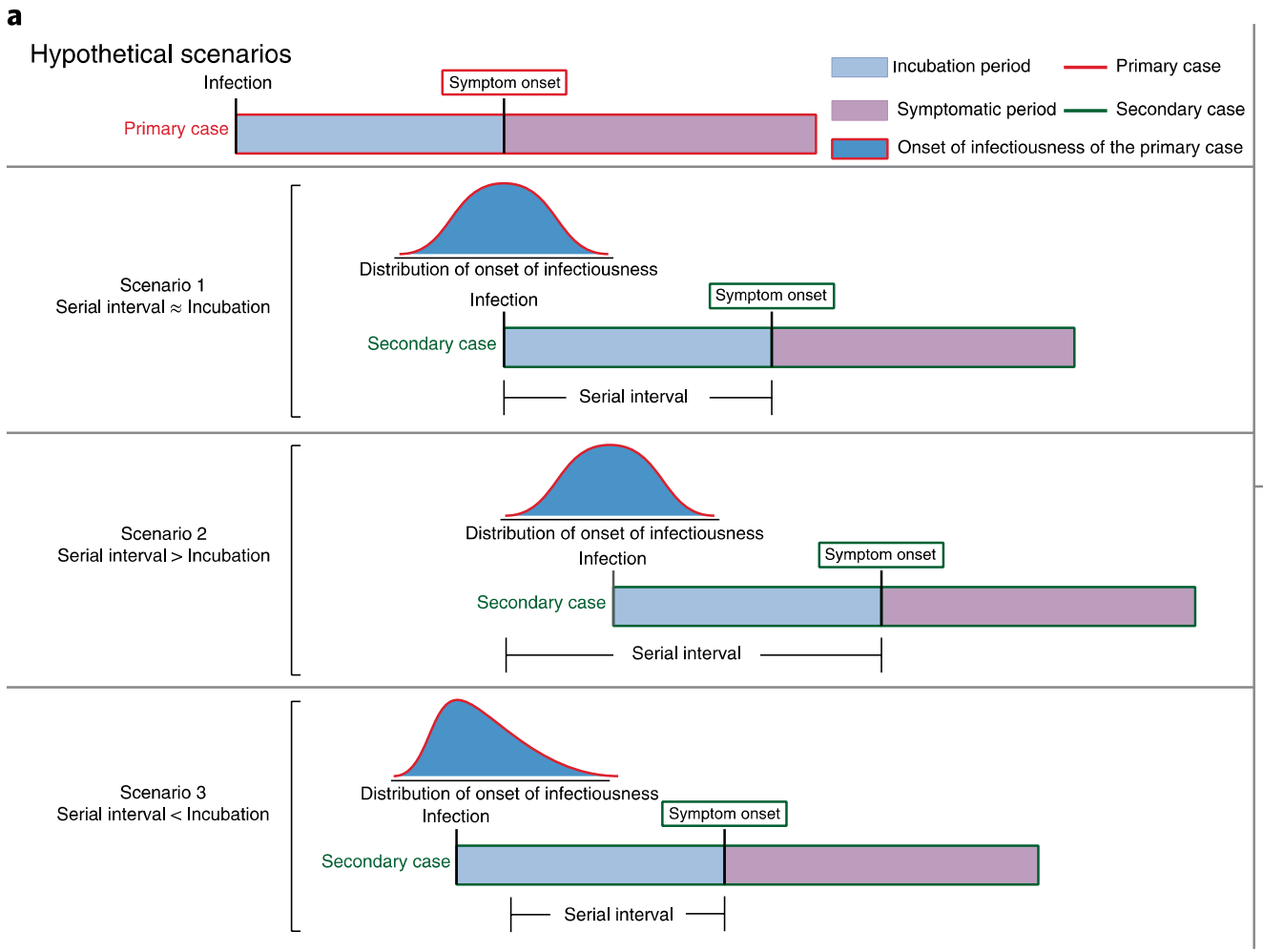


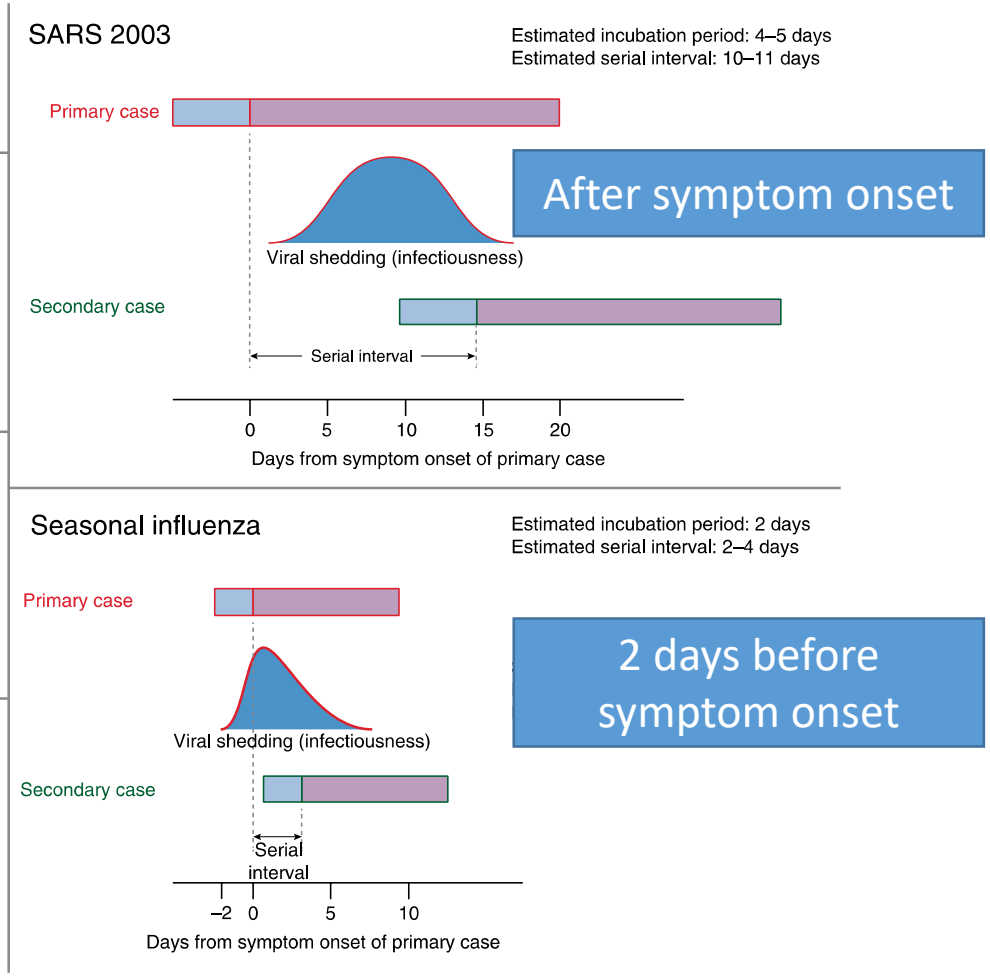
Working from home

Sims MD, *Clin infect Dis* 2020; doi: 10.1093/cid/ciaa1684

Infectiousness

Infectiousness of SARS-CoV-2 ≠ SARS-CoV-1 ≠ Influenza





He X, *Nat Med* 2020;26:672

Airborne or droplet?

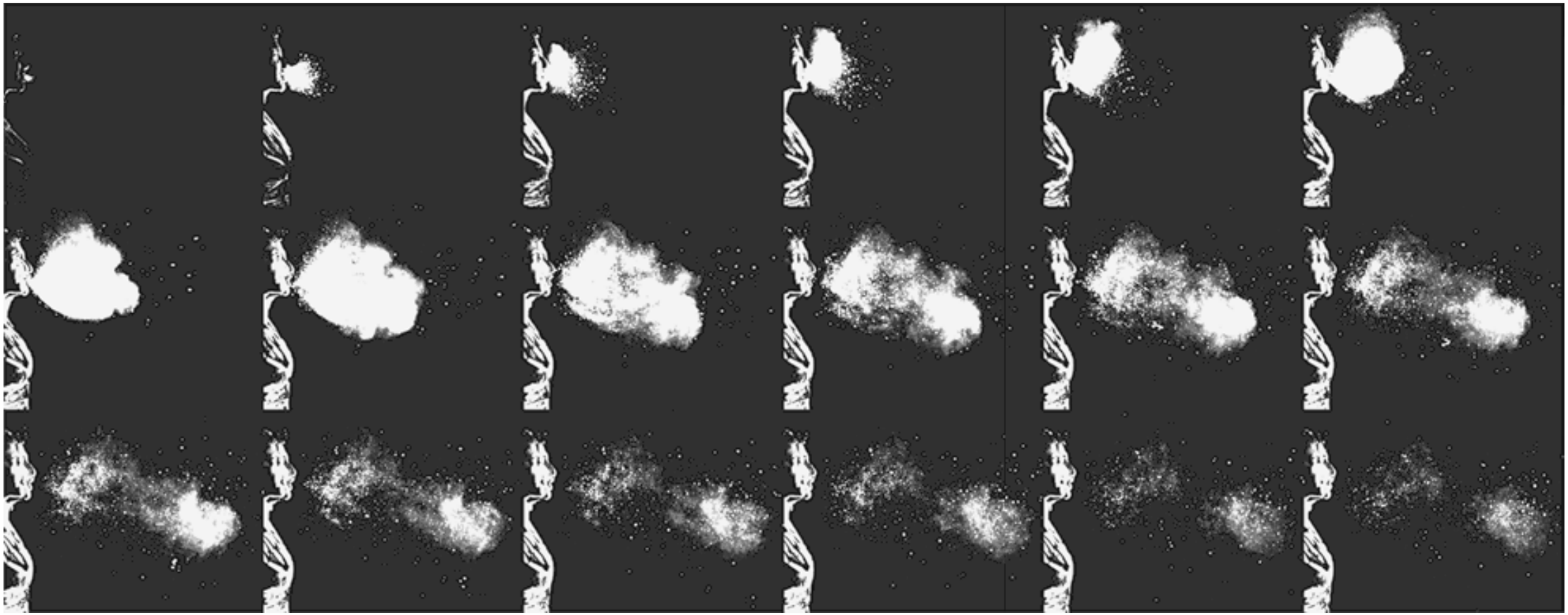
Transmission des germes (5)

par contact direct et indirect

par gouttelette

par l'air

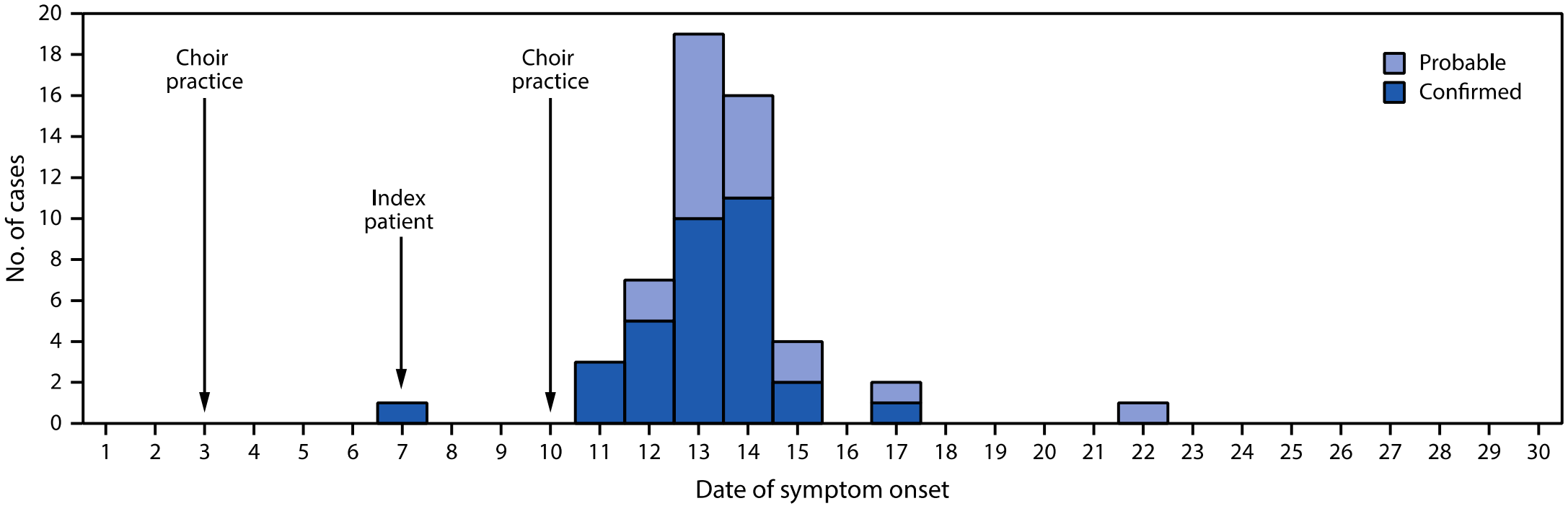
A sneeze…



Bourouiba L, *New Engl J Med* 2020;25;375:e15

Singing

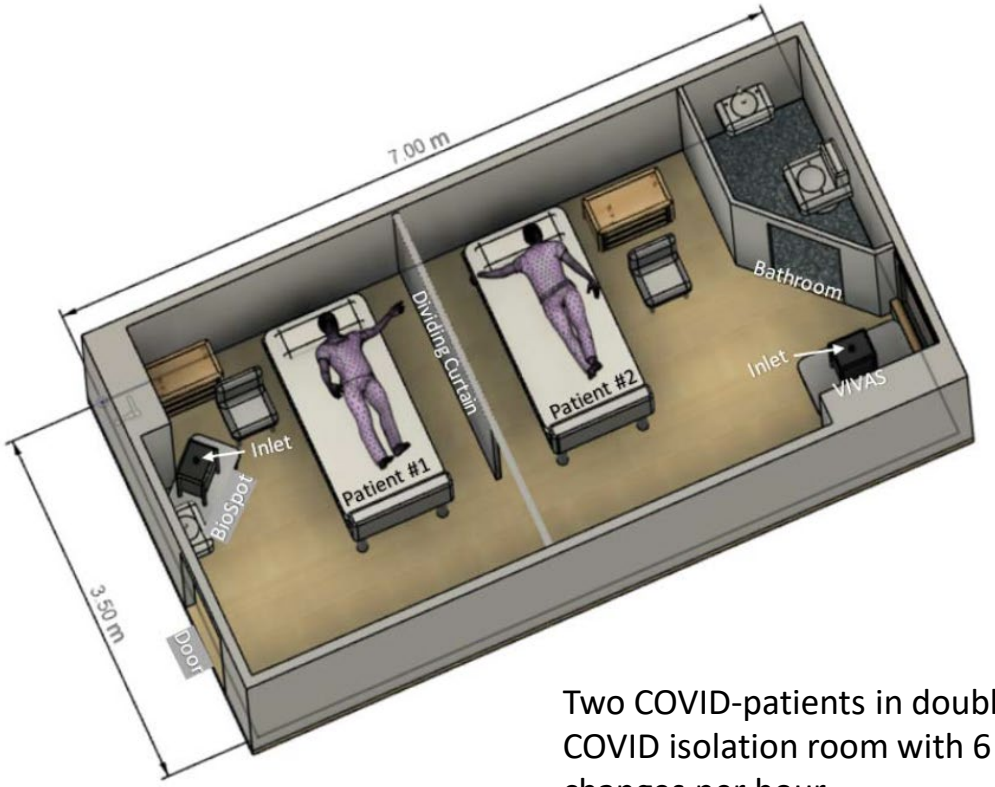
High SARS-CoV-2 attack rate following exposure at a choir pPractice - Skagit County, Washington, March 2020



Hamner L, *MMWR Morb Mort Wkly Rep* 2020;69:606

Viable SARS-CoV-2 in the air of a hospital room

Sophisticated air sampler (water-condensation principle), cell cultures, sequencing



Two COVID-patients in double COVID isolation room with 6 air changes per hour

- Viable virus 2-4.8 metres away from COVID-19 patient
- Identical genomes of virus collected by air sampler and patient
- Estimated viable virus concentration: 16-44/L air

Lednicky JA *In J Infect Dis* 2020;100:476

Airborne vs. droplet transmission – infection?

“Experimental data support the possibility that SARS-CoV-2 may be transmitted by aerosols … many of these same characteristics have previously been demonstrated for influenza and other common respiratory viruses.”

“Demonstrating that speaking and coughing can generate aerosols or that it is possible to recover viral RNA from air does not prove aerosol-based transmission; **infection depends as well on the route of exposure, the size of inoculum, the duration of exposure, and host defences**.“

- Reproduction number of 2.5 similar to influenza – small given a contagious time of about 7 days
- Attack rate among HCWs with surgical masks or not wearing PPE is about 3% (and mostly due to aerosol-generating procedures)
- An **exception** may be prolonged exposure to an infected person in a poorly ventilated space

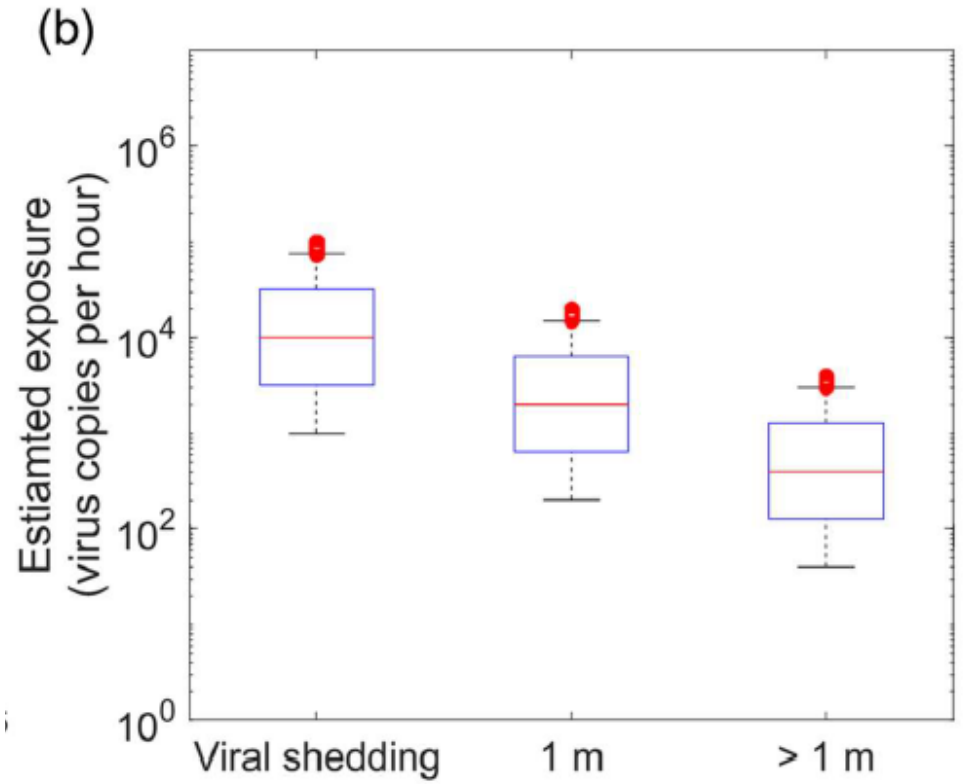
“Keeping 6-feet apart from other people and wearing medical masks, high-quality cloth masks, or face shields when it is not possible to be 6-feet apart (for both source control and respiratory protection) should be adequate to minimize the spread of SARS-CoV-2 (in addition to frequent hand hygiene, environmental cleaning, and optimizing in- door ventilation).”

Klompas M *JAMA* 2020;324:441

Dose-response relation for coronaviruses

Model based on the results of a systematic review (Chu, *Lancet* 2020;395:1973); respiratory shedding (Leung, *Nat Med* 2020 May;26:676); size distribution of particles (Morawska, *J Aerosol Sci* 2020;40:256); lung deposition model for pathogenic bioaerosols (Guha, *Aerosol Sci Technol* 2020;48:1226)

"The developed dose-response relation is an exponential function with a constant *k* in the range of 6.19×10^{4} to 7.28×10^{5} virus copies. The result means that the **infection risk caused by one virus copy in viral shedding is about 1.5×10^{-6} to 1.6×10^{-5}**."



Contrib: Contribution (0.1, 0.25, 0.5, 0.75, 1) of the airborne virus-laden particles to the total dose from both exposure to airborne viruses and contact transmission

Zhang, Wang *Clin Infect Dis* 2020 doi:10.1093

SARS-CoV-2 around COVID-19 patients

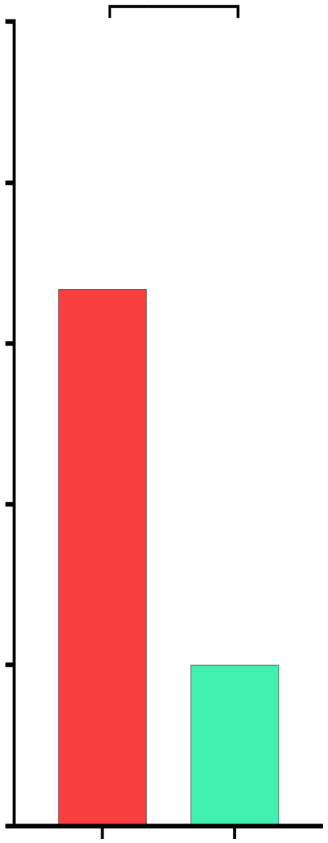
Table 1 Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) detections in the air of hospital rooms of infected patient.

Patient	Day of illness	Symptoms reported on day of air sampling	Clinical Ct value[a]	Airborne SARS-CoV-2 concentrations (RNA copies m^{-3} air)	Aerosol particle size	Samplers used
1	9	Cough, nausea, dyspnea	33.22	ND	>4 μm	NIOSH
				ND	1–4 μm	
				ND	<1 μm	
				ND	-	SKC filters
2	5	Cough, dyspnea	18.45	2,000	>4 μm	NIOSH
				1,384	1–4 μm	
				ND	<1 μm	
3	5	Asymptomatic[b]	20.11	927	>4 μm	NIOSH
				916	1–4 μm	
				ND	<1 μm	

ND none detected.
[a]PCR cycle threshold value from patient's clinical sample.
[b]Patient reported fever, cough, and sore throat until the day before the sampling. Patient reported no symptoms on the day of sampling, however was observed to be coughing during sampling.

Ying Chia, *Nat Comm;* doi: 10.1038/s41467-020-16670-2

SARS-CoV-2 around COVID-19 patients



All surfaces

High-touch surfaces

Patients with contaminated surfaces

Contaminated surfaces

Ying Chia, *Nat Comm;* doi: 10.1038/s41467-020-16670-2

Myth 1: ‘aerosols are droplets with a diameter of 5 µm or less’

Exhaled particles cover a continuum from <1 µm to >100 µm; the smaller **droplets desiccate rapidly to 20-40% of their original diameter, leaving residues called ‘droplet nuclei’**. Respiratory droplets with a wide range of diameters can remain suspended in the air and be considered airborne.

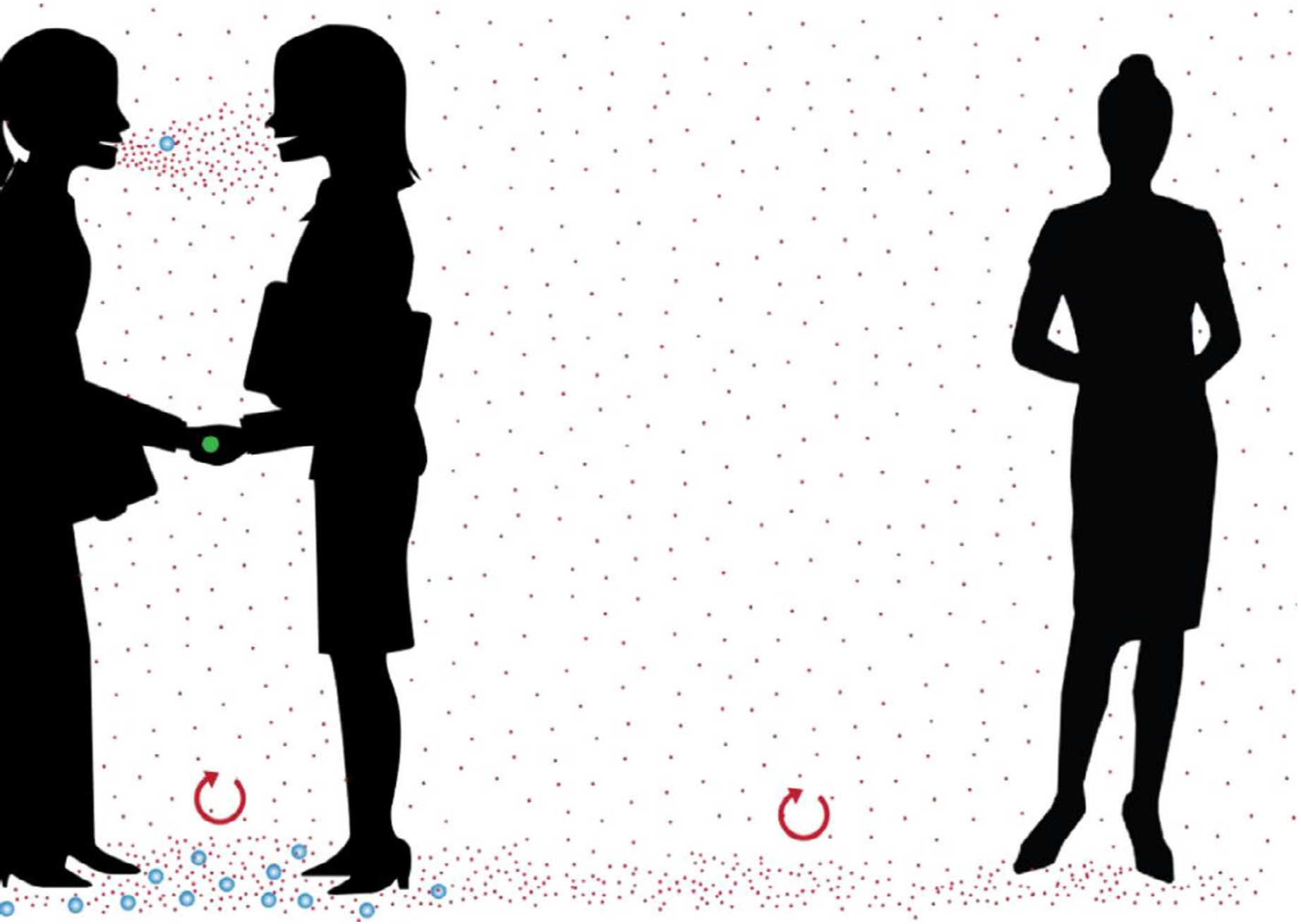
Myth 2: ‘all particles larger than 5 µm fall within 1-2 m of the source’

Exhaled particles of 5-10 µm fall slowly to the ground. **A droplet must be larger than 50-100 µm to have a high probability of landing within 1-2 m** of the emitting indoor source.

Myth 3: ‘if the basic reproductive number, R0, is not as large as for measles, then it cannot be airborne’

R_0 signifies how many people become infected after contact with one infected person, but the **mechanism of transmission is irrelevant**.

Tang JW, *J Hosp Infect* 2021;110: 89



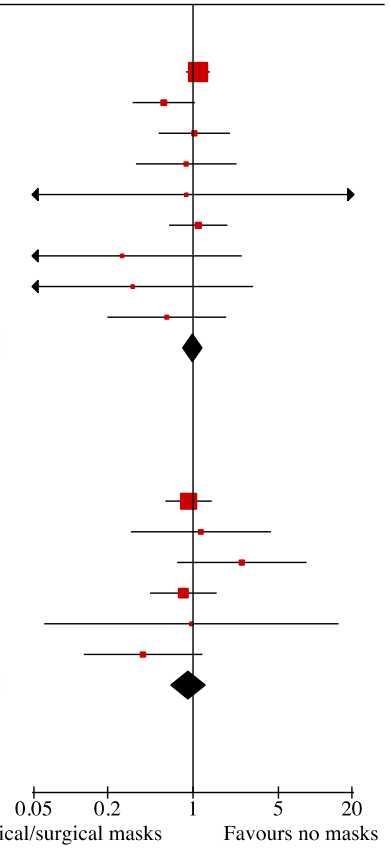
Tang JW, *J Hosp Infect* 2021;110: 89

Efficacy of face masks on respiratory viruses

Systematic review – masks/no masks, various populations

RCTs, up to 1 April 2020, no COVID-19

Study or Subgroup	log[RR]	SE	Medical/surgical masks Total	No masks Total	Weight	Risk Ratio IV, Random, 95% CI
1.1.1 Influenza-like illness						
Aiello 2012	0.095	0.115	392	370	64.5%	1.10 [0.88 , 1.38]
Barasheed 2014	-0.55	0.3	75	89	9.5%	0.58 [0.32 , 1.04]
Canini 2010	0.025	0.342	148	158	7.3%	1.03 [0.52 , 2.00]
Cowling 2008	-0.128	0.483	61	205	3.7%	0.88 [0.34 , 2.27]
Jacobs 2009	-0.126	1.83	17	15	0.3%	0.88 [0.02 , 31.84]
MacIntyre 2009	0.1	0.28	186	100	10.9%	1.11 [0.64 , 1.91]
MacIntyre 2015	-1.335	1.15	580	458	0.6%	0.26 [0.03 , 2.51]
MacIntyre 2016	-1.139	1.16	302	295	0.6%	0.32 [0.03 , 3.11]
Suess 2012	-0.494	0.571	26	30	2.6%	0.61 [0.20 , 1.87]
Subtotal (95% CI)			**1787**	**1720**	**100.0%**	**0.99 [0.82 , 1.18]**
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 7.29$, df = 8 (P = 0.51); $I^2 = 0\%$						
Test for overall effect: Z = 0.13 (P = 0.90)						
1.1.2 Laboratory-confirmed influenza						
Aiello 2012	-0.083	0.223	392	370	51.6%	0.92 [0.59 , 1.42]
Cowling 2008	0.148	0.674	61	205	6.0%	1.16 [0.31 , 4.34]
MacIntyre 2009	0.92	0.6225	186	100	7.0%	2.51 [0.74 , 8.50]
MacIntyre 2015	-0.182	0.32	580	458	25.8%	0.83 [0.45 , 1.56]
MacIntyre 2016 (1)	-0.03	1.414	302	295	1.4%	0.97 [0.06 , 15.51]
Suess 2012	-0.942	0.57	26	30	8.3%	0.39 [0.13 , 1.19]
Subtotal (95% CI)			**1547**	**1458**	**100.0%**	**0.91 [0.66 , 1.26]**
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 5.08$, df = 5 (P = 0.41); $I^2 = 1\%$						
Test for overall effect: Z = 0.58 (P = 0.56)						



Footnotes

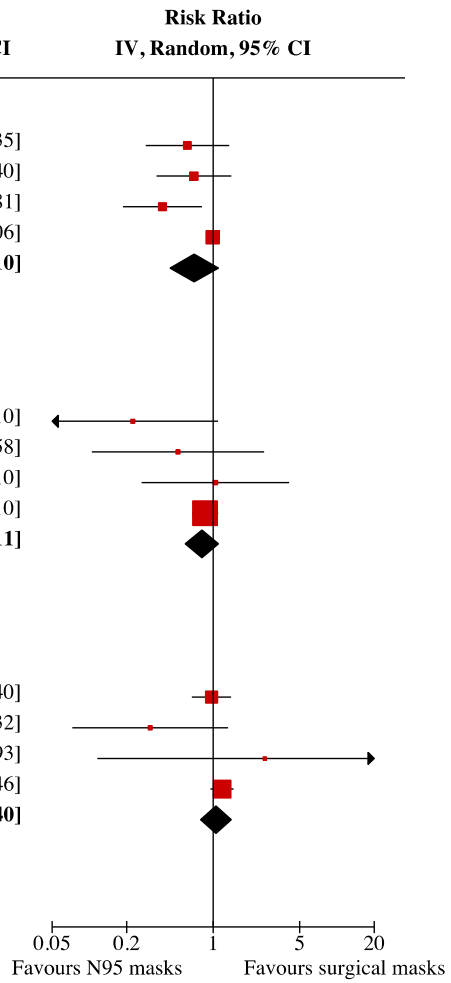
(1) Both MacIntyre studies reported on laboratory confirmed respiratory virus infection

Jefferson T *Cochrane Database Syst Rev* 2020;*CD006207*

Systematic review – N95/surgical masks, healthcare workers

RCTs, up to 1 April 2020, no COVID-19

Study or Subgroup	log[RR]	SE	N95 masks Total	Surgical maks Total	Weight	Risk Ratio IV, Random, 95% CI
2.2.1 Clinical respiratory illness						
MacIntyre 2011	-0.478	0.397	949	492	18.5%	0.62 [0.28 , 1.35]
MacIntyre 2013 (1)	-0.357	0.355	516	286	20.8%	0.70 [0.35 , 1.40]
MacIntyre 2013	-0.942	0.374	581	286	19.7%	0.39 [0.19 , 0.81]
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)						
2.2.2 Influenza-like illness						
Loeb 2009	-1.496	0.81	210	212	3.7%	0.22 [0.05 , 1.10]
MacIntyre 2011	-0.654	0.817	949	492	3.7%	0.52 [0.10 , 2.58]
MacIntyre 2013	0.04	0.7	1097	572	5.0%	1.04 [0.26 , 4.10]
Radonovich 2019	-0.151	0.124	2243	2446	87.6%	0.86 [0.67 , 1.10]
Subtotal (95% CI)			**4499**	**3722**	**100.0%**	**0.81 [0.59 , 1.11]**
Heterogeneity: Tau² = 0.01; Chi² = 3.13, df = 3 (P = 0.37); I² = 4%						
Test for overall effect: Z = 1.33 (P = 0.18)						
2.2.3 Laboratory-confirmed influenza						
Loeb 2009	-0.031	0.186	210	212	36.3%	0.97 [0.67 , 1.40]
MacIntyre 2011	-1.171	0.74	949	492	3.7%	0.31 [0.07 , 1.32]
MacIntyre 2013	0.96	1.59	1097	572	0.8%	2.61 [0.12 , 58.93]
Radonovich 2019	0.166	0.11	2243	2446	59.2%	1.18 [0.95 , 1.46]
Subtotal (95% CI)			**4499**	**3722**	**100.0%**	**1.05 [0.79 , 1.40]**
Heterogeneity: Tau² = 0.02; Chi² = 4.10, df = 3 (P = 0.25); I² = 27%						
Test for overall effect: Z = 0.35 (P = 0.72)						



Footnotes

(1) MacIntyre 2013 includes 2 comparisons: N95 vs surgical masks and targeted N95 vs surgical masks

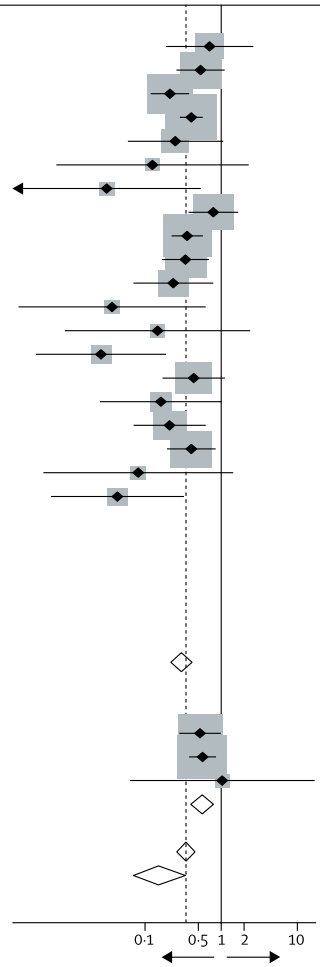
Jefferson T, *Cochrane Database Syst Rev* 2020;*CD006207*

Systematic review – masks/no masks, various populations

Observational studies only up to 3 May 2020

	Country	Respirator (0=no)	Infection	Events, face mask (n/N)	Events, no face mask (n/N)
Health-care setting					
Scales et al (2003)[66]	Canada	0	SARS	3/16	4/15
Liu et al (2009)[51]	China	0	SARS	8/123	43/354
Pei et al (2006)[61]	China	0	SARS	11/98	61/115
Yin et al (2004)[75]	China	0	SARS	46/202	31/55
Park et al (2016)[59]	South Korea	0	MERS	3/24	2/4
Kim et al (2016)[48]	South Korea	0	MERS	0/7	1/2
Heinzerling et al (2020)[44]	USA	0	COVID-19	0/31	3/6
Nishiura et al (2005)[55]	Vietnam	0	SARS	8/43	17/72
Nishiyama et al (2008)[56]	Vietnam	0	SARS	17/61	14/18
Reynolds et al (2006)[64]	Vietnam	0	SARS	8/42	14/25
Loeb et al (2004)[53]	Canada	1	SARS	3/23	5/9
Wang et al (2020)[41]	China	1	COVID-19	0/278	10/215
Seto et al (2003)[67]	China	1	SARS	0/51	13/203
Wang et al (2020)[70]	China	1	COVID-19	1/1286	119/4036
Alraddadi et al (2016)[24]	Saudi Arabia	1	MERS	6/116	12/101
Ho et al (2004)[45]	Singapore	1	SARS	2/62	2/10
Teleman et al (2004)[68]	Singapore	1	SARS	3/26	33/60
Wilder-Smith et al (2005)[72]	Singapore	1	SARS	6/27	39/71
Ki et al (2019)[47]	South Korea	1	MERS	0/218	6/230
Kim et al (2016)[49]	South Korea	1	MERS	1/444	16/308
Hall et al (2014)[43]	Saudi Arabia	1	MERS	0/42	0/6
Ryu et al (2019)[65]	South Korea	1	MERS	0/24	0/10
Park et al (2004)[58]	USA	1	SARS	0/60	0/45
Peck et al (2004)[60]	USA	1	SARS	0/13	0/19
Burke et al (2020)[37]	USA	1	COVID-19	0/64	0/13
Ha et al (2004)[42]	Vietnam	1	SARS	0/61	0/1
Random subtotal (I^2=50%)				**126/3442**	**445/6003**
Non-health-care setting					
Lau et al (2004)[50]	China	0	SARS	12/89	25/98
Wu et al (2004)[74]	China	0	SARS	25/146	69/229
Tuan et al (2007)[69]	Vietnam	0	SARS	0/9	7/154
Random subtotal (I^2=0%)				**37/244**	**101/481**
Unadjusted estimates, overall (I^2=48%)				**163/3686**	**546/6484**
Adjusted estimates, overall (1 COVID-19, 1 MERS, 8 SARS)					

Interaction by setting, p=0·049; adjusted for N95 and distance, p=0·11



The included studies all occurred during recurrent or novel outbreaks of COVID-19, SARS, or MERS; interventions were bundled.

Across 29 studies, **the use of both N95 or similar respirators or face masks** (disposable surgical masks or similar) by those exposed to infected individuals **was associated with a large reduction in risk of infection** with stronger associations in healthcare settings compared with non-healthcare settings.

Chu DK, *Lancet* 2020*;* 395: 1973

Living systematic review on face masks

RCTs and observational studies, 2003 – 2 June 2020

Comparison (Intervention A vs. Intervention B)	SARS-CoV-2 Infection*	SARS-CoV-1 or MERS-CoV Infection*	Influenza, ILI, and Other VRI (Excluding Pandemic Coronaviruses)†
Any mask vs. no mask (*k* = 12 observational studies) (33, 35, 36, 42–45, 47, 50, 53, 55, 57)	–	●	–
N95 vs. no mask (k = 5 observational studies) (33, 45, 47, 50, 52)	■	◆	–
Surgical mask vs. no mask (*k* = 6 observational studies) (33, 35, 42, 45, 47, 55)	–	■	–
N95 or surgical mask vs. no mask (*k* = 1 observational study)	–	■	–
Mask (type not specified) vs. no mask (*k* = 5 observational studies) (36, 43, 47, 53, 55)	–	◆	–
Cloth mask vs. no mask (*k* = 3 observational studies) (33, 44, 55)	–	■	–
Consistent/always mask use vs. inconsistent mask use (*k* = 5 observational studies) (22, 32, 35, 43, 56)	■	◆	–
N95 vs. surgical mask (*k* = 3 RCTs and 5 observational studies) (25, 33–35, 39, 40, 45, 57)	–	◆	●
N95 or surgical mask vs. cloth mask (k = 3 observational studies) (33, 36, 55)	–	■	–
Surgical mask vs. cloth mask (*k* = 1 RCT) (38)	–	–	◆

Strength of Evidence
- ● Moderate
- ◆ Low
- ■ Insufficient
- – No evidence

Direction of Effect
- Favors intervention A
- Effects similar or no difference
- No evidence or unable to determine

Chou R, *Ann Intern Med* 2020;doi:10.7326/M20-3213

Living systematic review on face masks, community

RCTs and observational studies, 2003 – 2 February 2021

Comparison (intervention A vs. intervention B)	SARS-CoV-2 infection	SARS-CoV-1 or MERS-CoV infection †	Influenza, influenzalike illness, and other viral respiratory illness (excluding pandemic coronaviruses) ‡
Mask (type not specified) vs. no mask in households with an index case and other community settings • SARS-CoV-2*: 1 RCT (4) and 3 observational studies (2, 5, 6) • SARS-CoV-1/MERS-CoV: 3 observational studies (14-16)	◆	◆	-
N95§ vs. surgical mask in household contacts • SARS-CoV-2: no studies • SARS-CoV-1/MERS-CoV: no studies • Influenza, influenzalike illness or other viral respiratory illness: 1 RCT (17)	-	-	◆
N95§ vs. no mask in household contacts • SARS-CoV-2: no studies • SARS-CoV-1/MERS-CoV: no studies • Influenza, influenzalike illness or other viral respiratory illness: 1 RCT (17)	-	-	◆
Surgical mask vs. no mask in households with an index case and other community settings • SARS-CoV-2: 1 RCT (4) and 1 observational study (5) • SARS-CoV-1/MERS-CoV: no studies • Influenza, influenzalike illness or other viral respiratory illness: 12 RCTs (17-27)	◆	-	●
Cloth mask vs. no mask in community contacts • SARS-CoV-2: 1 observational study (5) • SARS-CoV-1/MERS-CoV: no studies • Influenza, influenzalike illness or other viral respiratory illness: no studies	■	-	-

Chou R *Ann Intern Med* 2021;doi: 10.7326/L21-0116

Living systematic review on face masks, healthcare

Comparison (intervention A vs. intervention B)	SARS-CoV-2 infection	SARS-CoV-1 or MERS-CoV infection †	Influenza, influenzalike illness, and other viral respiratory illness (excluding pandemic coronaviruses) ‡
Any mask vs. no mask • SARS-CoV-2: 2 observational studies (8, 12) • SARS-CoV-1/MERS-CoV: 12 observational studies (28-39) • Influenza, influenzalike illness or other viral respiratory illness: no studies	■	●	-
N95 vs. no mask • SARS-CoV-2*: 3 observational studies (3, 12, 13) • SARS-CoV-1/MERS-CoV: 4 observational studies (28, 34-36) • Influenza, influenzalike illness or other viral respiratory illness: no studies	■	◆	-
Surgical mask vs. no mask • SARS-CoV-2*: k=3 observational studies (3, 10, 12) • SARS-CoV-1/MERS-CoV: k=6 observational studies (28, 29, 31, 34, 35, 38) • Influenza, influenzalike illness or other viral respiratory illness: no studies	■	■	-
N95 or surgical mask vs. no mask • SARS-CoV-2* k=1 observational study (12) • SARS-CoV-1/MERS/CoV: k=1 observational study (39) • Influenza, influenzalike illness or other viral respiratory illness: no studies	■	■	-
N95 and surgical mask vs. no mask • SARS-CoV-2*: k=1 observational study (3) • SARS-CoV-1/MERS/CoV: no studies • Influenza, influenzalike illness or other viral respiratory illness: no studies	■	-	-
Mask (type not specified) vs. no mask • SARS-CoV-2: no studies • SARS-CoV-1/MERS-CoV: k=5 observational studies (30, 32, 35, 37, 38) • Influenza, influenzalike illness or other viral respiratory illness: no studies	-	◆	-

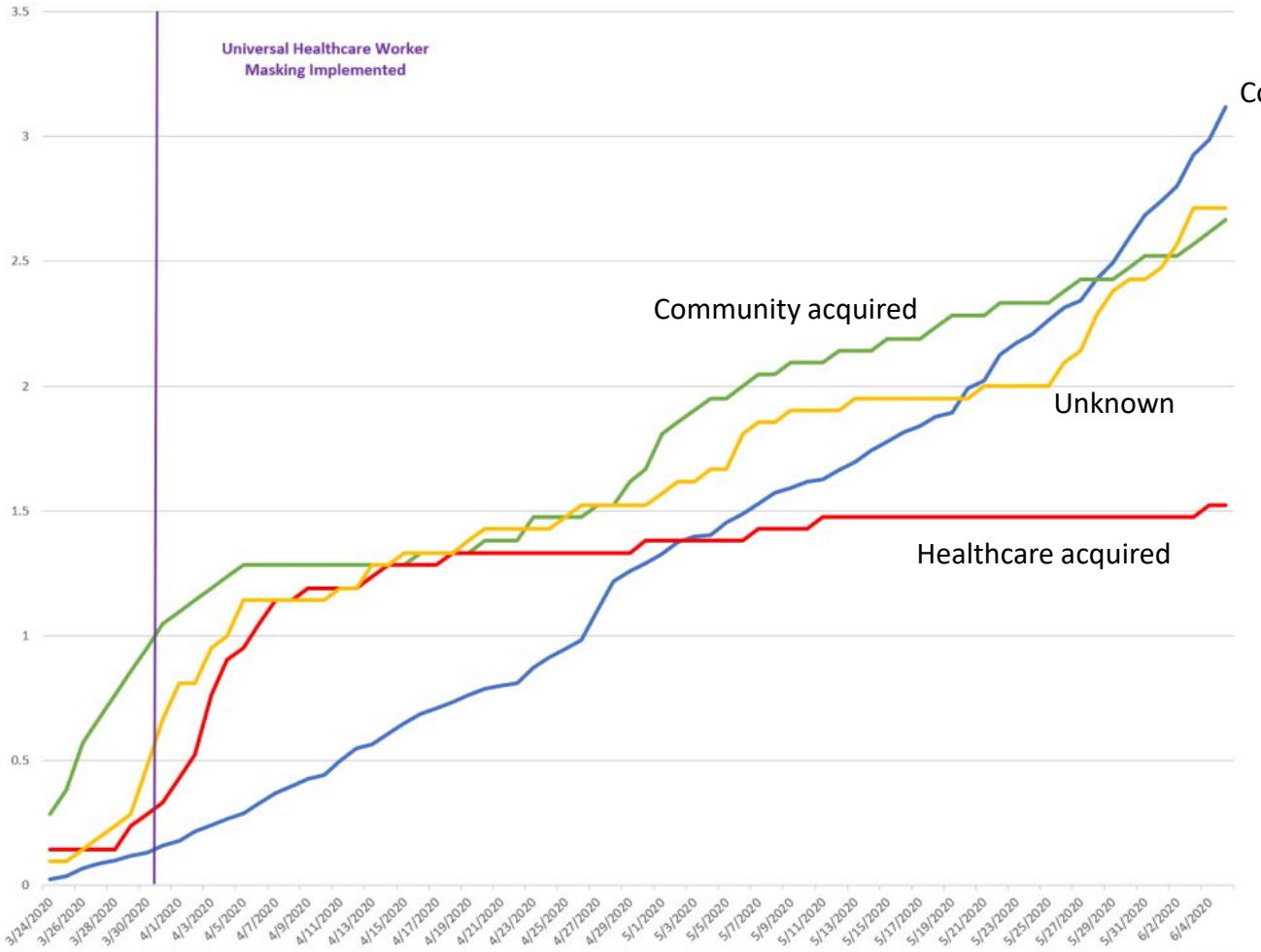
Living systematic review on face masks, healthcare

Comparison (intervention A vs. intervention B)	SARS-CoV-2 infection	SARS-CoV-1 or MERS-CoV infection †	Influenza, influenzalike illness, and other viral respiratory illness (excluding pandemic coronaviruses) ‡
N95 vs. surgical mask • SARS-CoV-2*: k=3 observational studies (3, 11, 12) • SARS-CoV-1/MERS-CoV: k=5 observational studies (28, 29, 34, 39, 42) • Influenza, influenzalike illness or other viral respiratory illness: k=3 RCTs (43-45)	■	◆	●
Consistent/always mask use vs. inconsistent mask use • SARS-CoV-2: k=1 observational study (7) • SARS-CoV-1/MERS-CoV: k=4 observational studies (29, 32, 40, 41) • Influenza, influenzalike illness or other viral respiratory illness: no studies	■	◆	-

Chou R *Ann Intern Med* 2021;doi: 10.7326/L21-0116

Universal masking in healthcare settings

Duke Health: 1 tertiary care hospital, 2 community hospitals, 180 primary care and specialty clinics
21,014 HCWs - 24.3-4.6.2020



→ Many “unknown” aetiologies; compliance issues with masks?

Seidelman J *Infect Control Hosp Epidemiol* 2020; 1:1466

Medical face masks vs. N95 respirators

Review article

41 HCWs were exposed for over **10 min and within 2m of a patient** with confirmed COVID-19 during a difficult intubation and non-invasive ventilation scenario. The **majority** (85%) of the HCWs were wearing a **medical mask** and other appropriate PPE while the remainder a N95 respirator – **no transmission**.

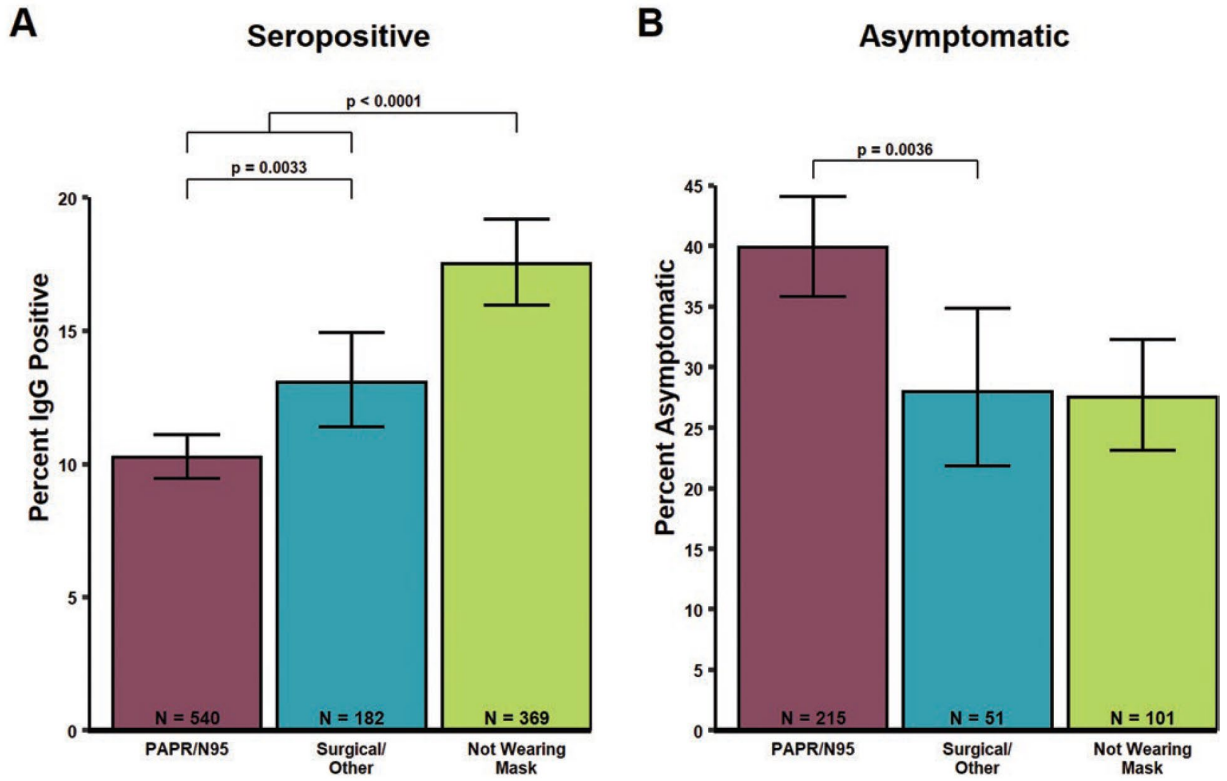
71 staff and 49 patients were exposed to an initially undiagnosed COVID-19 patient with coughing and oxygen therapy at 8 L/min. Staff used **either medical masks or N95 respirators** – no transmission to patients, 6/7 HCW with close contact negative.

48 persons involved in a nosocomial outbreak of SARS-CoV-2 in a paediatric dialysis unit – 7 HCWs, 3 patients and one accompanying person became infected**: all had either cumulative 15 min of face-to-face contact or exposure within a distance of ≤ 2m without use of any PPE**. No transmission of the remaining contacts who had shared the same indoor environment who had contact at a distance of > 2m without any use of PPE.

Conly J *Antimicrob Resist Infect Control* 2020;9:126

COVID-19 in healthcare workers

20’614 participants at Beaumont Health (8 hospitals across the Detroit metropolitan area)

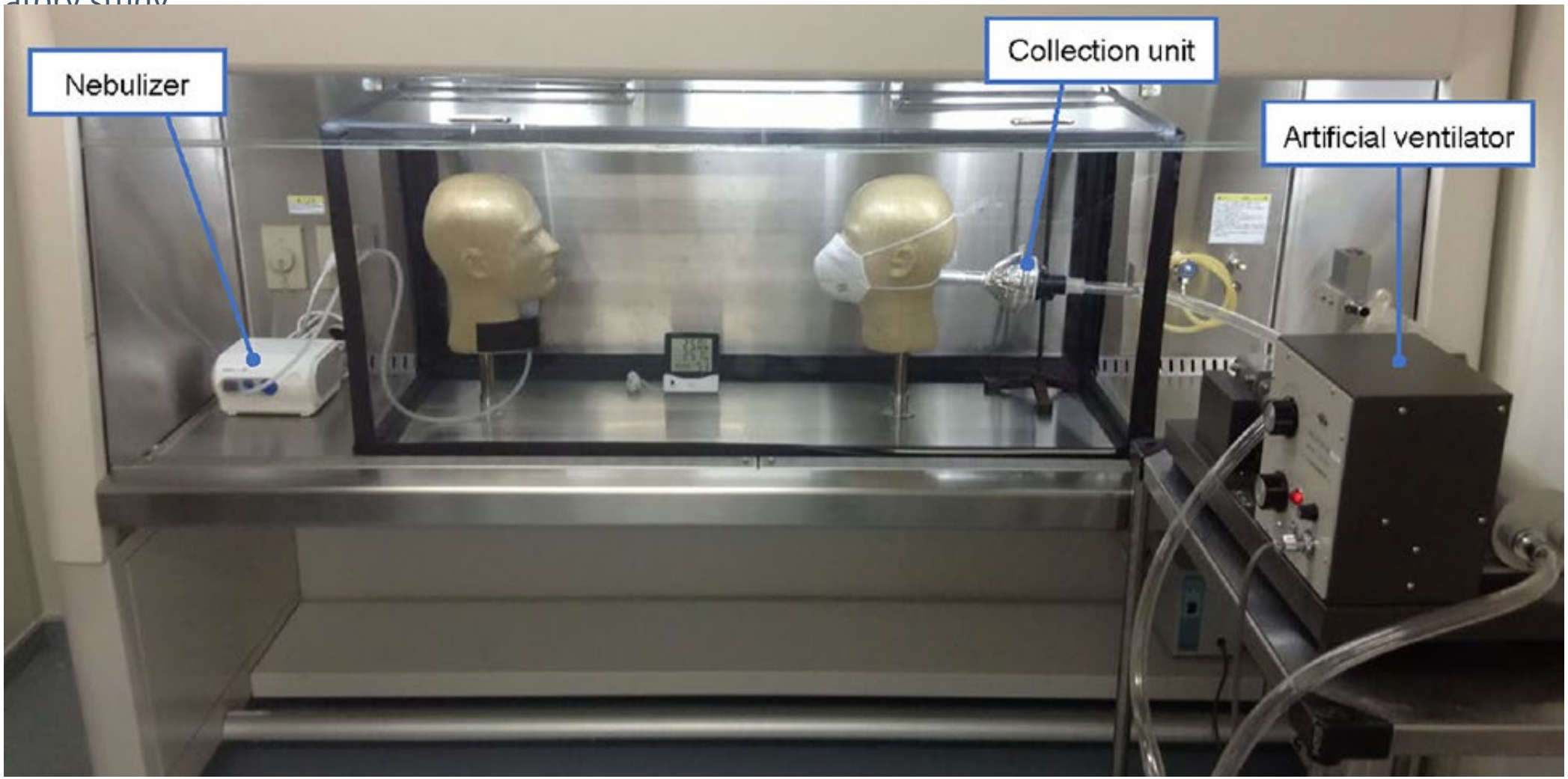


Among the seropositive individuals, 44% reported that they were asymptomatic during the month prior to blood collection

Sims MD, *Clin infect Dis* 2020; doi: 10.1093/cid/ciaa1684

Effectiveness of face masks in preventing SARS-CoV2 transmission

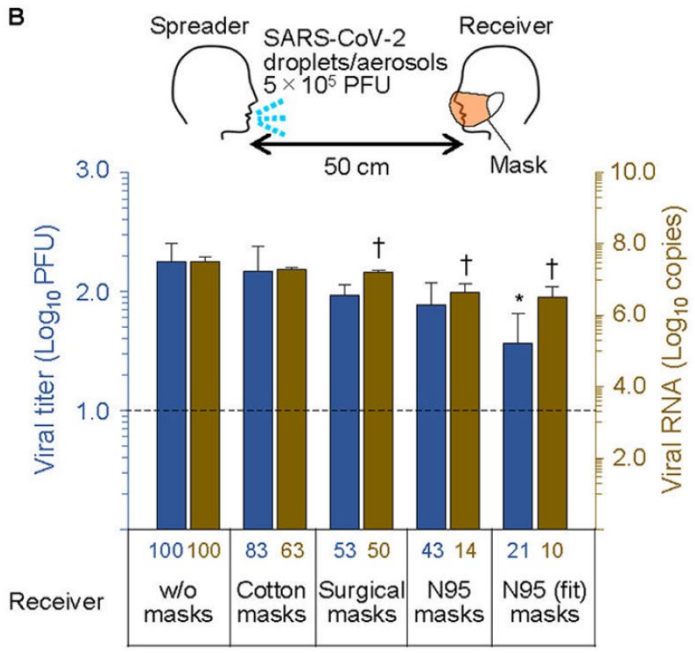
Laboratory study



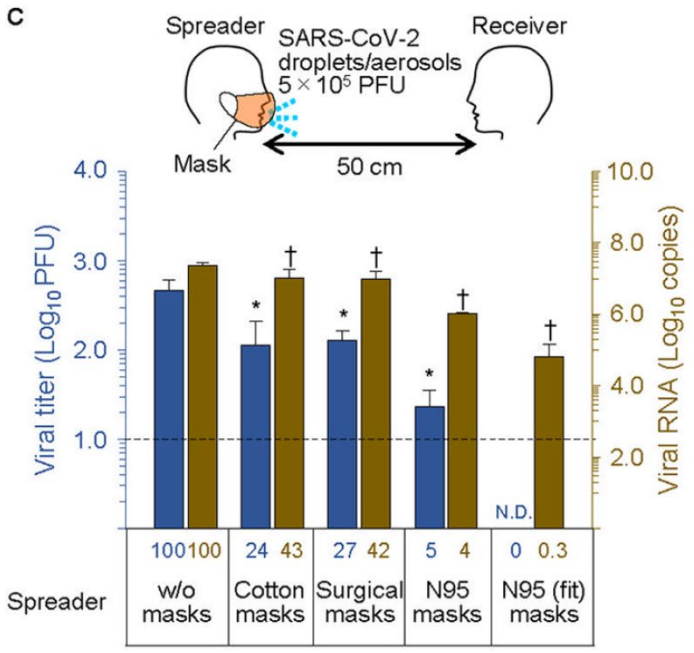
Ueki H, *mSphere* 2020;5:e00637

Effectiveness of face masks in preventing SARS-CoV2 transmission

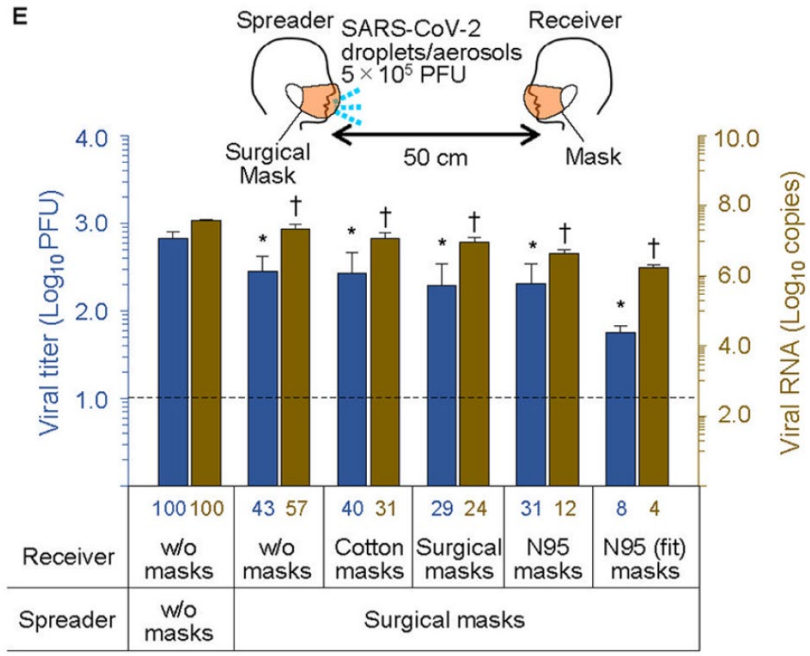
Laboratory study



Protection



Source control



Source control and protection combined

Ueki H, *mSphere* 2020;5:e00637

In summary

Droplet and aerosol transmission is **not a dichotomous concept**

Most transmissions occur during **“at risk” situations** where healthcare workers are exposed without respecting PPE-recommendations or **in the community**.

Still **limited formal evidence-base** for effectiveness of masks in preventing transmission but trends towards risk reduction overall and in favour of FFP2 masks

Best protection by **source control** and **barrier** combined

Virus is not only in droplets or the air but also on **surfaces**

62. Hygienekreis “Lernen aus COVID-19”

Tröpfchen, Aerosol oder beides?

PD Dr. med. Walter Zingg
Leiter Spitalhygiene USZ

02 November 2021