

TRAVEL ASSOCIATED COVID-19

David Jay Weber, M.D., M.P.H., FSHEA, FIDSA, FRSM
Distinguished Professor of Medicine, Pediatrics & Epidemiology
Associate Chief Medical Officer, UNC Hospitals
Medical Director, Hospital Epidemiology
University of North Carolina at Chapel Hill

Picture suggested by Dr. Erica Shenoy, Massachusetts General Hospital
Disclosures: Consultant-PDI, Gernitec, Pfizer; Merck, UV Innovators



Cumulative Reported Clusters, Cases, and Deaths by Type of Cluster

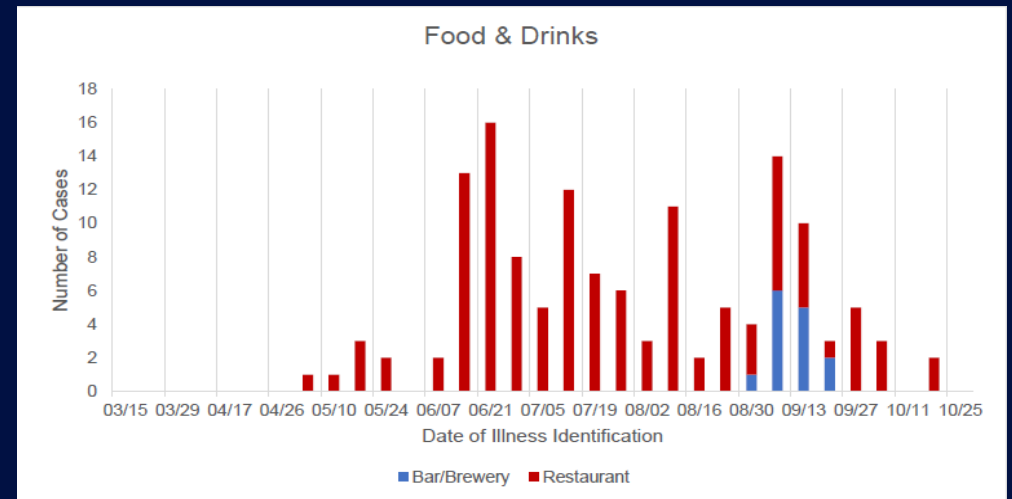
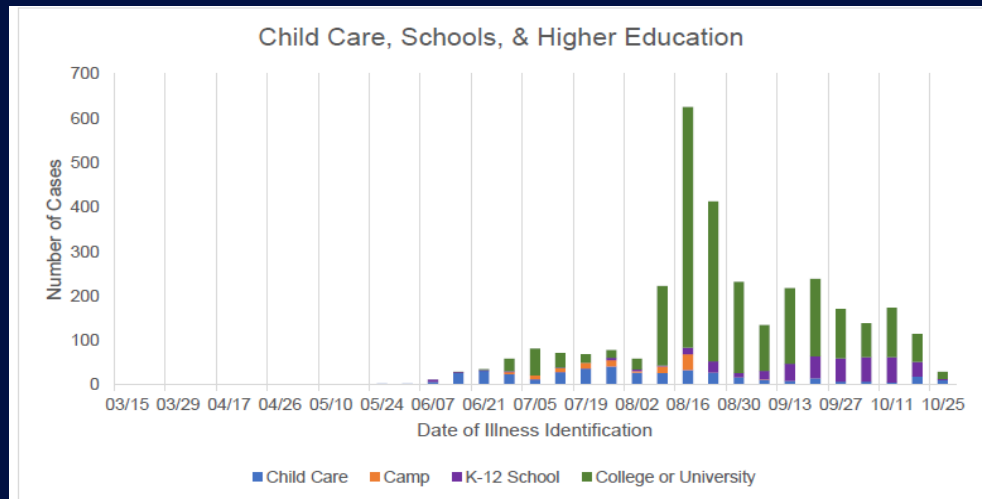
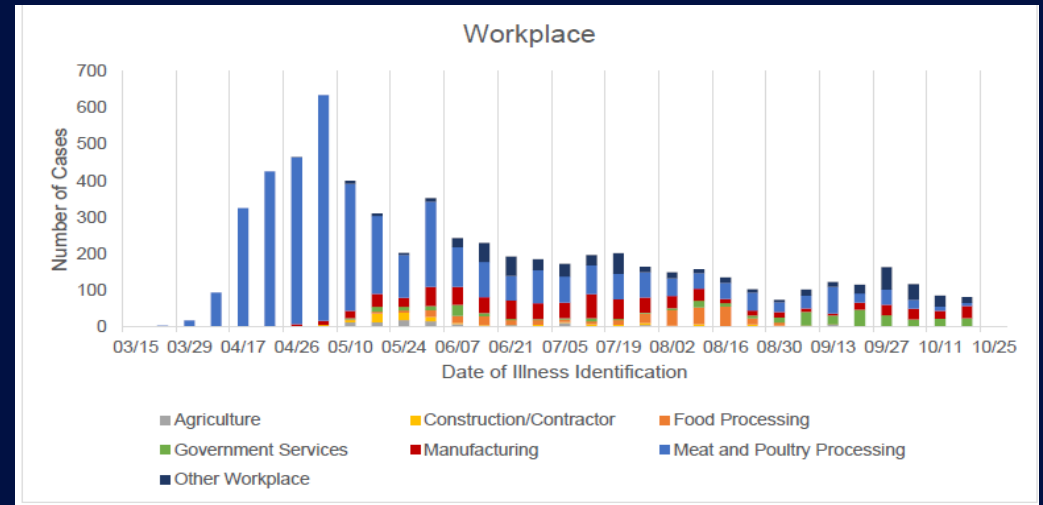
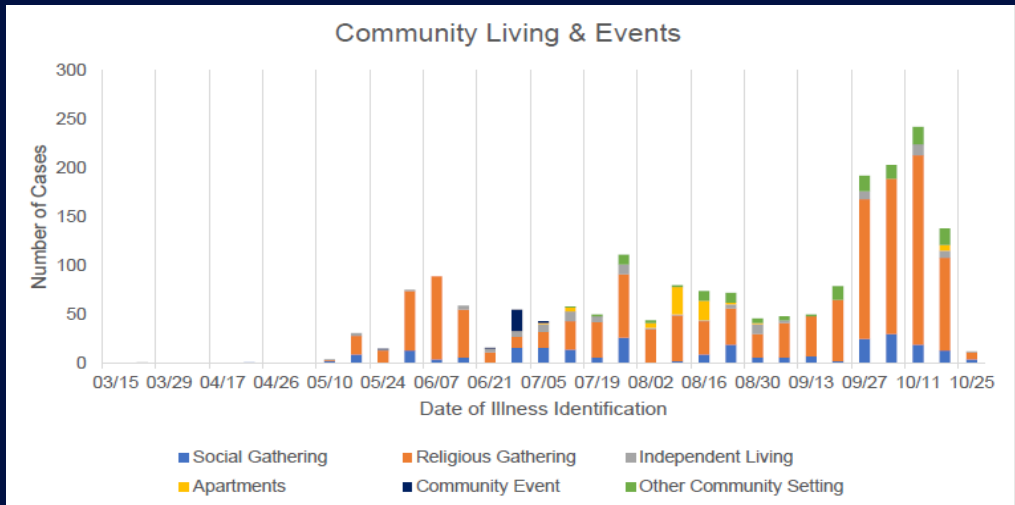
Cluster Category	Setting Type	Number of Total Reported Clusters	Total Cluster-associated Cases	Total Cluster-associated Deaths
Workplace	Agriculture*	9	110	0
	Construction/Contractor	16	121	0
	Food Processing	7	321	1
	Government Services ¹	48	364	2
	Manufacturing	65	813	3
	Meat and Poultry Processing	40	3,859	19
	Other Workplace	59	597	4
Shopping and Services	Retail	9	75	0
	Personal Care Services ²	4	36	5
Food and Drinks	Bar/Brewery	2	14	0
	Restaurant	20	124	2
Child Care, Schools, and Higher Education	Child Care	55	442	3
	Camp	7	104	0
	K-12 School	49	384	0
	College or University	181	2,297	0
Health Care ³	Health Care Setting	26	194	3
Community Living and Events	Religious Gathering	95	1,310	19
	Social Gathering ⁴	27	256	2
	Independent Living Facility	10	102	11
	Apartments**	3	67	0
	Community Event ⁵	1	26	0
	Other Community Setting	18	128	1
Total		751	11,744	75

**Largest risk for travelers =
Social gatherings after travel**

NC Health Dept., updated 2 Nov.

COVID-19 CLUSTERS, NC, UPDATED 2 NOV.

(<https://covid19.ncdhhs.gov/dashboard/outbreaks-and-clusters>)



COVID-19 TRANSMISSION ON SHIPS, BUSES, TRAINS & PLANES

- Ships:
 - Cruise: Multiple outbreaks reported on cruise ships (Moriarty LF, et al. MMWR 2020;69:347-352; Mallapaty. Nature 2020;26 March; Kak V. Microbiol; Spectrum 7 Sept.; Plucinski MM, et al. CID 2020;12 August; Yamagishi T, et al. CID 2020;14 August)
- Buses: 1 report (Shen Y, et al. JAMA 2020)
- Trains: Evaluation of high-speed trains in China revealed that among >2,300 known contacts there was an overall rate of transmission of ~0.3% (Hu M, et al. Clin Infect Dis 2020;29 July)
- Multiple outbreaks related to plane travel
- CDC travel recommendations (updated 21 October)*: www.cdc.gov/coronavirus/2019-ncov/travelers/travel-during-covid19.html

* CDC recommendations may have been reviewed/revised for political reasons

COVID-19 TRANSMISSION ON AIRPLANES

- CDC has investigated 1,600 people who flew while at risk of spreading COVID-19, identifying nearly 11,000 cases of people who were potentially exposed to COVID-19 while flying; some became ill but impossible to determine if illness linked to flying since people did not quarantine after the flight – 6 health departments reported identifying >500 flight-related cases (Washington Post, 19 Sept 2020)
- Investigations of international flights arriving or departing from Greece, 26 Feb through 9 March, 2020
 - Methods: Contact tracing extended up to 4 days before the onset of symptoms and focused on close contacts. Close contacts were defined as persons sitting within a distance of <2 m for >15 min, including passengers seated two seats around the index case and all crew members and persons who had close contact with the index case.
 - Investigation of 18 international flights with 2224 passengers and 110 crew members. Main countries of departure included Northern Italy, Israel and the United Kingdom. In accordance with the national surveillance investigation, in these flights there were 21 index cases and 891 contact traced cases. Six index cases were symptomatic during the flight. Of the 891 contact traced cases, 4 passengers and 1 crew member developed laboratory-confirmed infection (3 with symptomatic COVID-19 and 2 with asymptomatic infection); they travelled on the same flight with two COVID-19 cases).
 - Conclusion: Inflight transmission occurs but uncommon (Pavli A, et al. Travel Med Infect Dis 2020;38:101082, Nov-Dec)

INFECTIONS TRANSMITTED ON COMMERCIAL AIRCRAFT AND CRUISE SHIPS

	Number of reports	Comments
Airborne/fomites		
TB ^{29,30,39-41}	2	Positive TB skin test only. No active TB.
SARS ^{31,46-49}	4	No cases since WHO guidelines.
Common cold ³⁶	0	Difficult to investigate.
Influenza ^{33,37,55}	2	None since ventilation regulations.
Meningococcal disease ³⁴	0	21 reports of ill passengers, no secondary cases
Measles ⁵⁸⁻⁶²	3	Imported cases and international adoptions
Food-borne		
Salmonellosis ^{63,64}	15	No recent outbreaks
Staphylococcus food poisoning ^{63,65}	8	No recent outbreaks
Shigellosis ⁶³	3	No recent outbreaks
Cholera ^{63,67,68}	3	During cholera epidemic
Viral enteritis ⁶⁶	1	Common on other types of transport
Vector-borne		
Malaria ^{69,70}	7	Probably underestimated
Dengue ⁷¹	1	Likely to be airport, not aircraft, transmission
Yellow fever	0	No outbreaks since disinsection of aircraft
Bioterrorism agents		
Smallpox ^{52,627}	1	Before eradication

Table: Reported infections transmitted on commercial airlines

TABLE 1 Infectious pathogens and diseases of potential risk on cruise ships

Gastrointestinal infections	
Noroviral infections	
Enterotoxigenic <i>Escherichia coli</i>	
<i>Salmonella</i> gastroenteritis	
<i>Shigella</i> species	
<i>Vibrio</i> species	
<i>Clostridium perfringens</i>	
<i>Campylobacter jejuni</i>	
<i>Staphylococcus aureus</i> enteritis	
<i>Cyclospora</i> species	
<i>Cryptosporidium</i> species	
<i>Trichinella spiralis</i>	
Hepatitis E	
Hepatitis A	
<hr/>	
Respiratory infections	
Influenza (A and B)	
Rubella	
Measles	
<i>Legionella</i> species	
Diphtheria	
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Skin infections	
Varicella	
Hot tub folliculitis	
Community-acquired methicillin-resistant <i>S. aureus</i> folliculitis	
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Infections that may be acquired at ports of call	
Malaria	
Meningitis	
Yellow fever	
Typhoid	

Mangili A,
Gendreau MA.
Lancet 2005;
365:989-96
Mangili A, et al.
Microbiol Spectrum
2015;Oct

Kak V.
Microbiol;
Spectrum 7 Sept
2020

OUTBREAKS ON CRUISE SHIPS, WORLDWIDE, FEBRUARY TO MARCH 2020, CDC

- During Feb. 7-23, 2020, largest cluster of COVID-19 cases outside of mainland China occurred on Diamond Princess cruise ship, quarantined in port of Yokohama
- AR (Americans, Diamond Princess)=26%: single-person cabin or no infected cabinmates, 18% (58/329); shared cabin with asymptomatic person, 63% (27/43), shared cabin with symptomatic person, 81% (25/31) (Moriarty LF, et al)
- SARS-CoV-2 RNA detected in 10% cabins with cases but not non-case cabins, common areas, or air samples (Yamagishi T, et al.)
- By March 17, confirmed cases of COVID-19 had been associated with at least 25 additional cruise ship voyages
- On March 13, the Cruise Lines International Association announced a 30-day voluntary suspension of cruise operations in the US
- CDC issued a Level 3 travel warning on March 17, recommending that all cruise travel be deferred worldwide

Moriarty LF, et al. MMWR 2020;69:347-352; Plucinski MM, et al. CID 2020;12 August; Yamagishi T, et al. JID 2020

FIGURE 1. Cumulative number of confirmed coronavirus disease 2019 (COVID-19) cases* by date of detection — Diamond Princess cruise ship, Yokohama, Japan, February 3–March 16, 2020

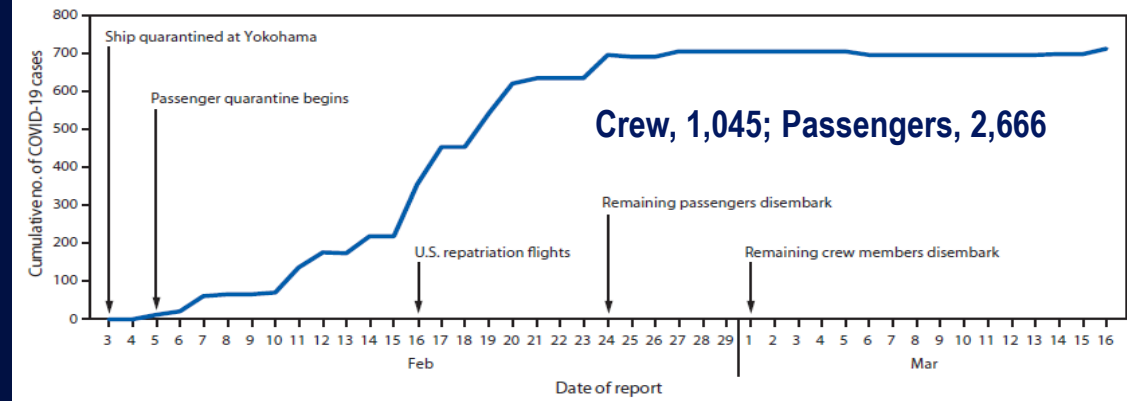
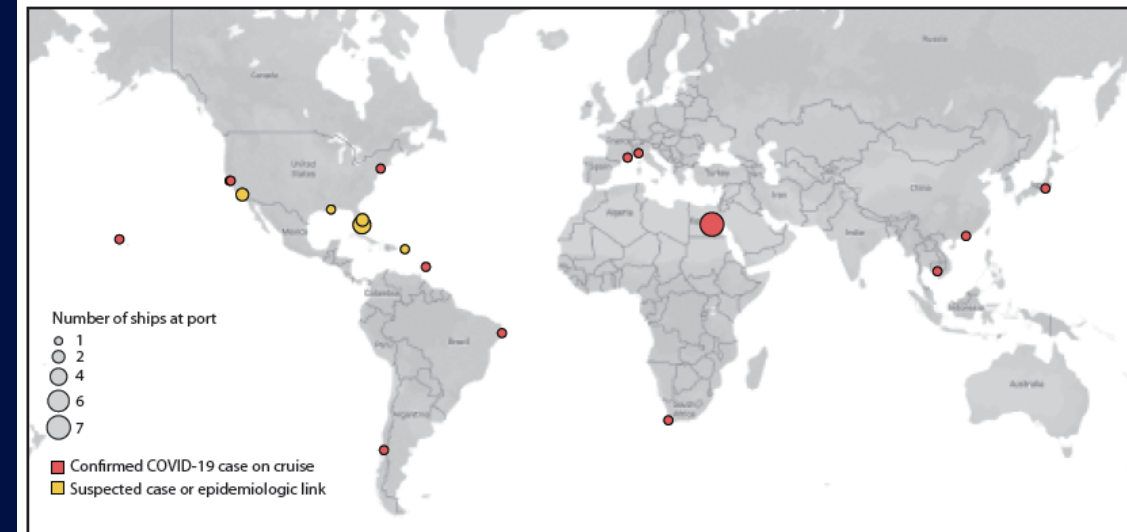
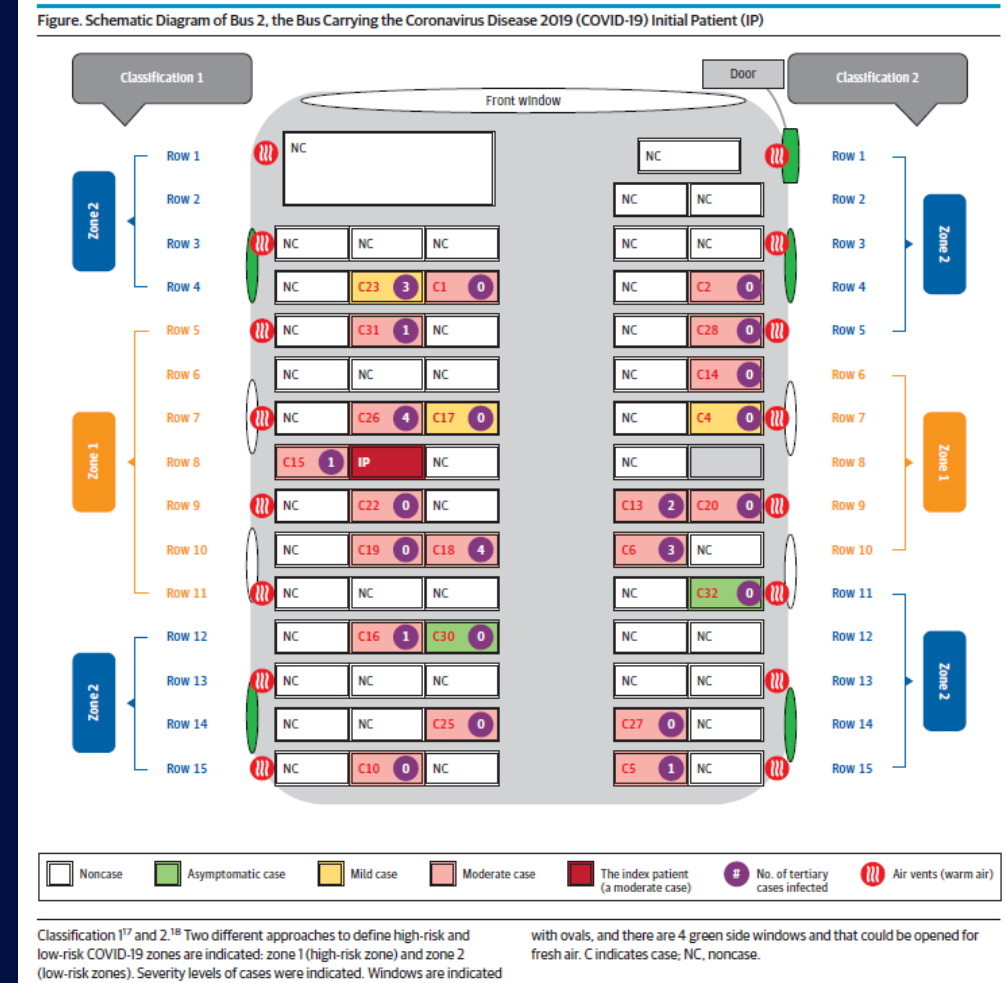


FIGURE 2. Cruise ships with coronavirus disease 2019 (COVID-19) cases requiring public health responses — worldwide, January–March 2020



SARS-CoV-2 TRANSMISSION ON A BUS

- Goal: To investigate potential transmission routes of SARS-CoV-2 during bus travel
- Methods: Cohort study that evaluated 60 persons on bus 1 and 68 persons on bus 2; 100min trip to attend 150min worship event (source patient on bus 2). Seats divided into high and low risk based on distance from source patient. Central air used in buses, recirculation mode.
- Results:
 - On bus 2, 24/68 persons (35.3%) were infected; none on bus 1
 - Among 172 others at worship event, 7 (4.1%) infected
 - Risk of being in bus 2, 34.3% compared to bus 1 and 11.4 (95% CI 5.1-25.4) compared to others at worship event
 - Persons in high risk zone had moderately but non-significant, higher risk
 - On 3 seat side, no persons sitting by window developed infection; only 1 person sitting by an openable window developed infection



RISK OF COVID-19 TRANSMISSION IN TRAIN PASSENGERS

- Goal/Methods: Assess transmission risk on high-speed trains in China using data from 2,334 index patients and 72,093 close contacts with co-travel times of 0-8 hours, 19 Dec. 2019-6 March 2020
- Results: The AR in passengers within a distance of 3 rows and 5 columns of the index patient varied from 0-10.3% (95% CI, 5.3-19.0%), with a mean of 0.32% (0.29-0.37%). AR, adjacent was 3.5% (2.9-4.3%) ; AR, same row was 1.5% (1.3-1.8%); AR, other rows was 0.14% (0.11-0.17%). RR, adjacent seat vs all seats was 18.0 (13.9-23.4). AR increased by average of 0.15% per hour of co-travel (for passengers in adjacent seat, this increase was 1.3%).
- COVID-19 has high transmission rate on trains; risk related to co-travel time and seat location

Table 1. Comparison of Attack Rate Between Location of Seats

Rows Apart	Columns Apart						Average
	Same Column	1	2	3	4	5	
Same row	...	3.53 (2.89–4.31)	1.65 (1.18–2.31)	0.38 (.18–.78)	0.38 (.19–.79)	0.29 (.10–.85)	1.53 (1.30–1.80)
1	0.21 (.11–.38)	0.24 (.14–.41)	0.14 (.06–.32)	0.09 (.03–.25)	0.03 (.00–.16)	0.05 (.00–.30)	0.14 (.10–.20)
2	0.25 (.14–.45)	0.17 (.09–.33)	0.23 (.12–.46)	0.16 (.07–.36)	0.09 (.03–.27)	0.17 (.06–.50)	0.18 (.13–.25)
3	0.05 (.01–.18)	0.05 (.01–.17)	0.13 (.05–.33)	0.10 (.03–.30)	0.10 (.03–.30)	0.06 (.00–.36)	0.08 (.05–.13)
Average	0.17 (.12–.26)	0.68 (.56–.81)	0.41 (.31–.54)	0.16 (.1–.25)	0.12 (.07–.20)	0.13 (.06–.25)	0.32 (.28–.36)

The attack rate is defined as the percentage of coronavirus disease 2019 cases in close contacts of index patients on the train. The numbers in parentheses are the 95% confidence interval of the attack rate.

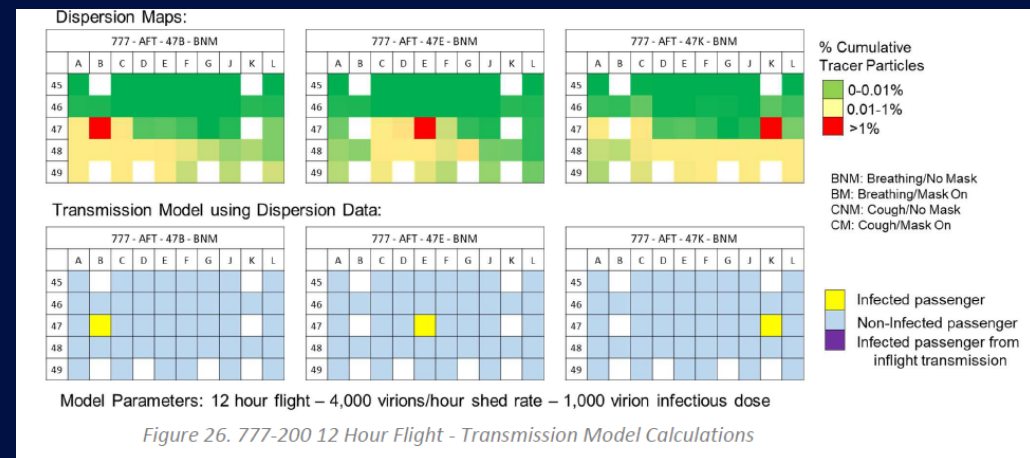
Hu M, et al.
Clin Infect Dis 2020;29 July

COMMERCIAL AIRCRAFT CABIN AEROSOL DISPERSION TESTS

- Goal: Assess risks of aerosol transmission on Boeing 777 and 767 using tracers
- Methods: Tracer aerosols released by a simulated infected passenger, in multiple rows and seats, to determine risk to nearby persons. 300 releases studied
- Results: Minimum reduction of 99.7% at 1um simulated virus aerosol from index source to passengers seated directly next to the source
 - An average of 99.99% reduction was measured for the 40+ breathing zones tested in each section of both aircraft
 - Transmission model calculations using the measured breathing zone penetration data indicated an extremely unlikely aerosol exposure risk for a 12 hour flight when using a 4,000 virion/hr shedding rate and 1,000 virion infectious dose

Air Exchanges & Time to Remove Airborne-Contaminant*		
Building Type	Air Changes per Hour (ACH)*	Time (mins.) Required for Removal 99.9% efficiency
Typical Single Family Home (Low Estimate)	2	207
Typical Single Family Home	4	104
Typical Single Family Home (High Estimate)	6	69
Standard for Hospital Operating Rooms and Isolation Units [†]	12	35
Boeing 767-200 As Tested [§]	32	6 [§]
Boeing 777-300 As Tested [§]	35	6 [§]

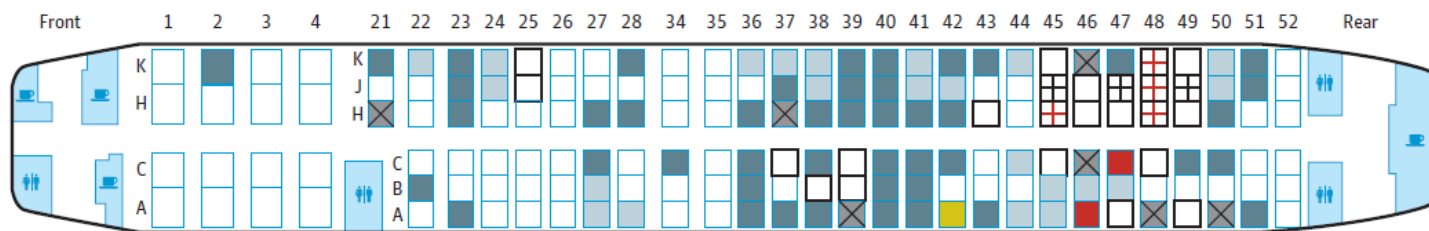
* Adapted from CDC: <https://www.cdc.gov/infectioncontrol/guidelines/environmental/appendix/air.html#table1>
[†] Recommended in ASHRAE / ASHE STANDARD Ventilation of Health Care Facilities (Vol. 4723)
[§] Experimentally determined during this report



COVID-19 TRANSMISSION ON A PLANE I

- Goal: Assess COVID-19 transmission on flight from Tel Aviv to Frankfurt (4hr,10min) – no measures taken to prevent spread
- Results:
 - 102 passengers that included 24 members of a tourist group that had contact with a hotel managed later diagnosed with COVID (7/24 tested positive on arrival; 4 symptomatic during flight)
 - Post-flight testing discovered 2 likely COVID-19 acquisitions
 - Airflow, ceiling to floor and front to rear (may have limited transmission)

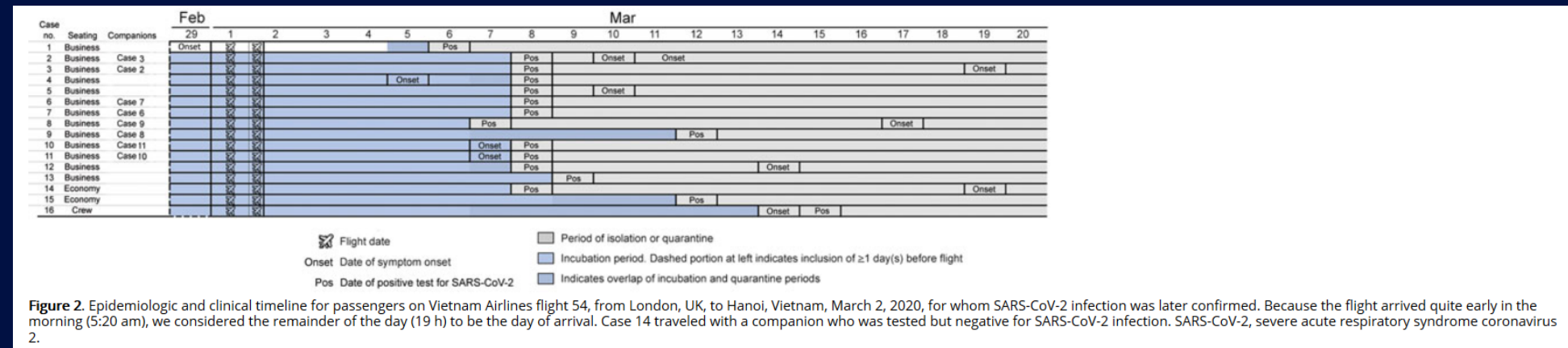
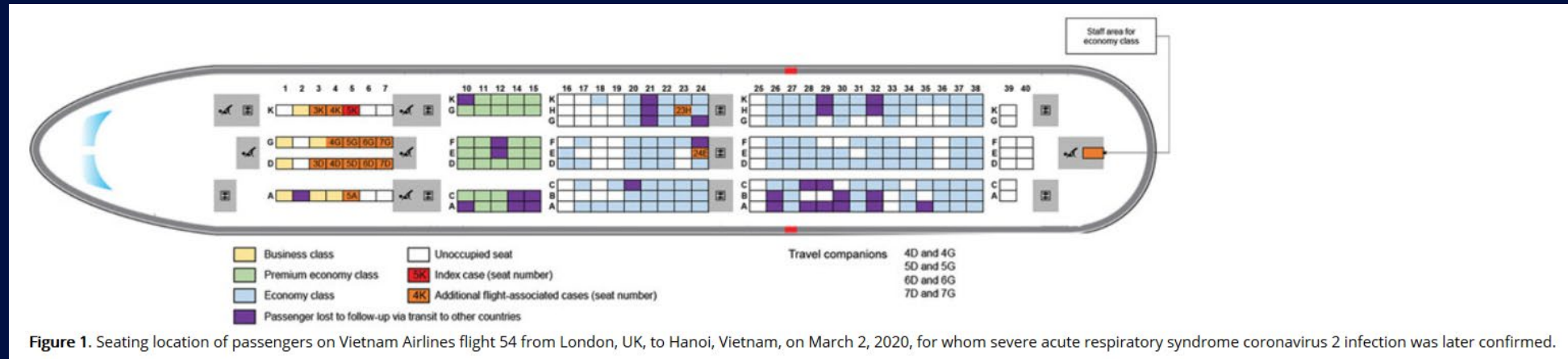
Figure 1. Seating of the Index Cases and Other Passengers on the Aircraft (Boeing 737-900)



Hoehl S et al., JAMA Open

COVID-19 TRANSMISSION ON A PLANE I

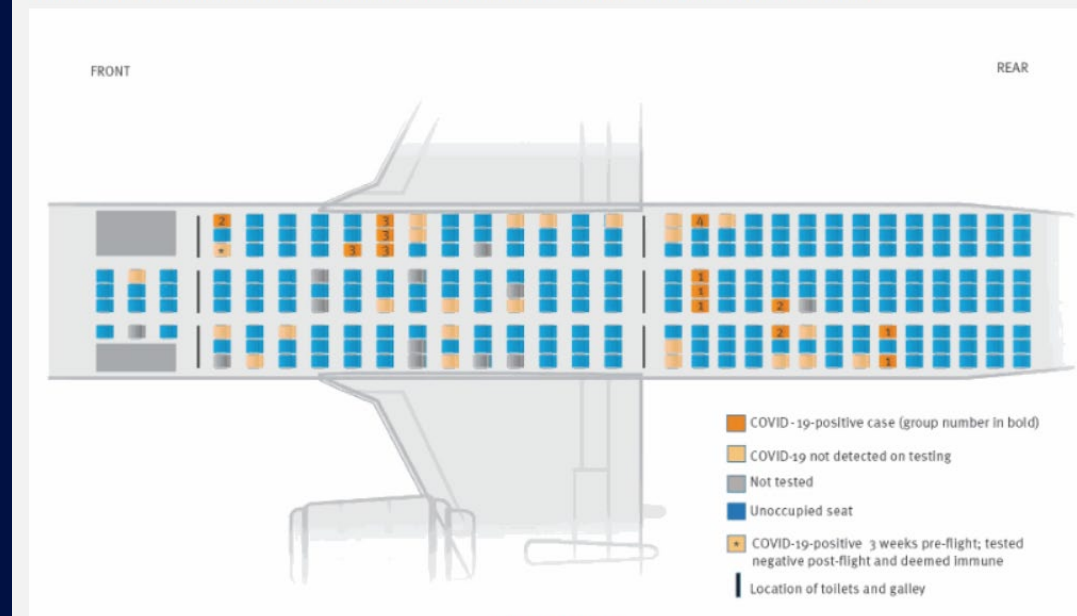
- London to Hanoi, 3/1/20
- 201 passengers, 21 in business class, 25 premium economy, 145 economy
- Probable index case sat in business (AR, 63%)
- Confirmed cases: 14 passengers, 1 crew; 12 in business, 2 passengers plus 1 crew in economy
- RR for being seated within 2m of index = 7.3 (CI, 1.2-46.3) {#=11/12}



COVID-19 TRANSMISSION ON A PLANE IV WITH SECONDARY COMMUNITY TRANSMISSION

Fifty-nine laboratory-confirmed cases of COVID-19 from six of the eight different health regions (Regions A-H) throughout the Republic of Ireland were linked to an international flight into Ireland in summer 2020 (Figure 1). An outbreak case was defined as positive PCR for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (nasopharyngeal swab) in either a passenger or a contact of a passenger. Thirteen cases were passengers on the same flight to Ireland, each having transferred via a large international airport, flying into Europe from three different continents (Groups 1 and 2; Group 3 and Group 4).

Figure 2. Passenger seating diagram on flight, Ireland, summer 2020 (n = 49 passengers)

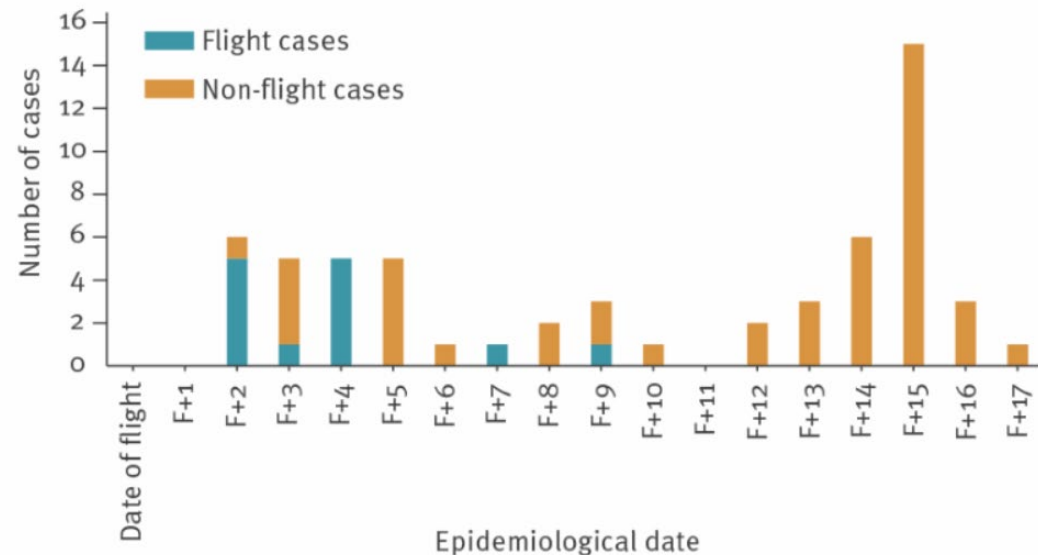


[Click to view](#)

COVID-19: coronavirus disease.

Numbers on the seats indicate the Flight Groups 1-4.

Figure 1. Epicurve of confirmed COVID-19 cases associated with a flight, Ireland, summer 2020 (n = 59)



COVID-19 TRANSMISSION ON A PLANE IV WITH SECONDARY COMMUNITY TRANSMISSION

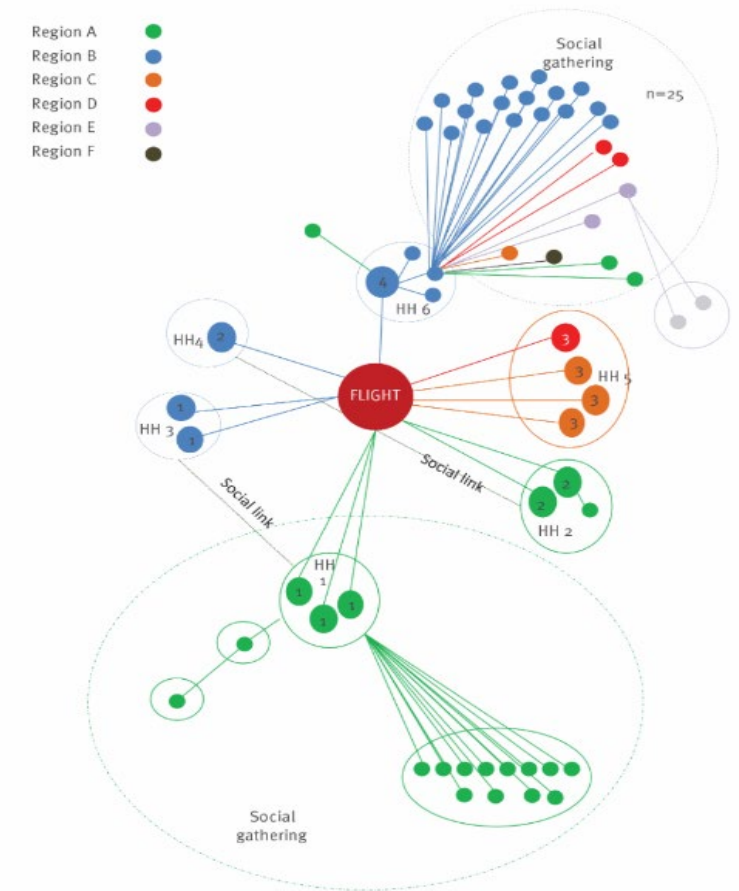
Of the flight groups, Group 1 reported spending up to 12 h overnight in the transit lounge during stopover; Group 2 shared a separate transit lounge; Group 3 and Group 4 had separate short waits of under 2 h in the general airport departure area.

The source case is not known. The first two cases in Group 1 became symptomatic within 48 h of the flight, and COVID-19 was confirmed in three, including an asymptomatic case from this Group in Region A within 5 days of the flight. Thirteen secondary cases and one tertiary case were later linked to these cases. Two cases from Flight Group 2 were notified separately in Region A with one subsequent secondary family case, followed by three further flight cases notified from Region B in two separate family units (Flight Groups 1 and 2). These eight cases had commenced their journey from the same continent and had some social contact before the flight. The close family member of a Group 2 case seated next to the case had tested positive abroad 3 weeks before, and negative after the flight. Flight Group 3 was a household group of which three cases were notified in Region C and one case in Region D. These cases had no social or airport lounge link with Groups 1 or 2 pre-flight and were not seated within two rows of them. Their journey origin was from a different continent. A further case (Flight Group 4) had started the journey from a third continent, had no social or lounge association with other cases and was seated in the same row as passengers from Group 1. Three household contacts and a visitor of Flight Group 4 became confirmed cases. One affected contact travelled to Region E, staying in shared accommodation with 34 others; 25 of these 34 became cases (attack rate 73%) notified in regions A, B, C, D, E and F, with two cases of quaternary spread.

Genome analysis on a subset of COVID-19 demonstrated linkage
AR = 9.8% to 17.8%

Murphy N, et al. Eurosurveillance 2020 25;22 Oct

Figure 3. Diagram of chains of transmission, flight-related COVID-19 cases, Ireland, summer 2020 (n = 59)



[Click to view](#)

COVID-19: coronavirus disease; HH: household.

Numbers indicate the Flight Groups 1–4.

RISK OF COVID-19 DURING AIR TRAVEL, JAMA PATIENT PAGE, 1 OCTOBER 2020

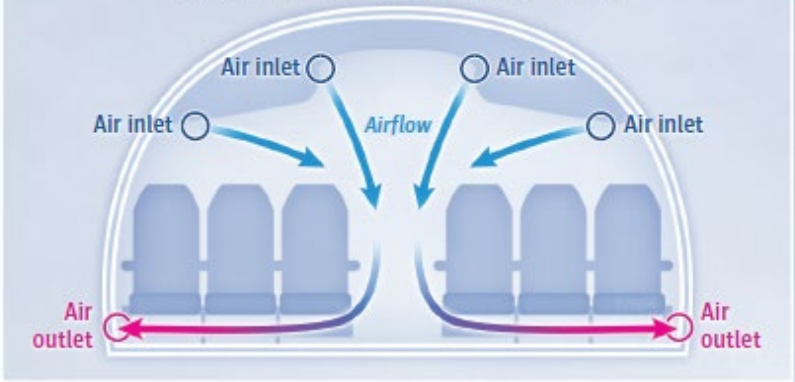
- “The risk of contracting COVID-19 during air travel is lower than from an office building, classroom, supermarket, or commuter train”
- Rationale: Airflow in current jets is much faster than normal indoor buildings. Half of it is fresh from outside, remainder is recycled through HEPA filters.
- Transmission risk “appears small (~42 in total cases reported)”
- Risk reduction: 1) stay home if sick; 2) wear a mask; 3) limit carry on bags; 4) report unwell persons; 5) point overhead air nozzle directly at your head and keep it on full; 6) stay seated, if possible; 7) perform hand hygiene; 8) avoid touching face

Air travel and COVID-19

The risk of contracting COVID-19 during air travel is low. Modern airplanes maintain clean air by circulating a mix of fresh air and air recycled through HEPA filters, the same type of air filters used in hospital operating rooms.

Air enters the cabin from overhead air inlets and flows downward toward floor level outlets at the same seat row or nearby rows. There is little airflow forward and backward between rows.

CROSS SECTION OF AIRPLANE CABIN



✓ Stay seated whenever possible, and follow crew instructions

CONCLUSIONS

- Outbreaks on ships, planes and buses well described
- Multiple outbreaks on cruise ships with very high attack rates reported
- Multiple outbreaks on airplanes but relatively low attack rates; risk related to short distance from infected persons, lack of wearing masks, and possible in direct exposure in bathrooms
- Prevention
 - If sick, don't travel; if possible avoid travel; largest risk is post-travel congregate settings
 - Drive rather than use public transportation. However, no risk analysis available that assesses risk of driving (MVA) versus flying (COVID)
 - If flying: Ideally wear a mask at all times (plus eye protection), practice hand hygiene frequently, disinfect local area (especially tray table), fully open vent, airstream on face; maintain physical distancing while in airport (if possible),
 - If using a bus, same as airplane (except open window, if possible)
 - Cruise ships: No data yet available on success of steps recommended take to reduce infection. Cruise lines have introduced screening COVID-19 tests prior to boarding and other measures to reduce risk – no published reports on current risk