# COVID-19
# Evidence Update

COVID-19 Update from SAHMRI, Health Translation SA
and the Commission on Excellence and Innovation in Health

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## *Risks of transmission of COVID-19 on plane flights*

### Executive Summary


Overview:

While probable, there is very limited evidence of transmission of SARS-Cov-2 during plane flights to date. A properly working ventilation system appears to reduce the risk of transmission while on board [1], relative to other confined spaces.

Usual physical distancing of 1.5m may not be practicable on planes. However, other risk mitigation strategies can be employed, including: discouraging unwell travelers from flying (by removing financial barriers to flight changes and symptoms screening prior to boarding); physical distancing in airports and during boarding; hand sanitation stations; regular cleaning of trays and other surfaces; and universal mask wearing.

Further, the prevalence of SARS-COV-2 in Australia is likely to be very low (at the time of writing), further reducing the risk of transmission on domestic flights.

Scientific literature - COVID-19: There are very few empirical studies that have directly evaluated inflight transmission of COVID-19. One case study that followed up close contacts of a symptomatic case found no evidence of transmission [2]. Three case studies used a process of elimination to conclude that in-flight exposure was the source of transmission [3-5]. These three studies had significant weaknesses and/or did not convincingly exclude other sources of transmission. Quantifying risk is difficult due to insufficient publications, non-comprehensive contact tracing, long incubation periods and disentangling whether exposure occurred prior to boarding and after disembarking from a flight.

Scientific literature - pre COVID-19: A stronger body of evidence exists for other diseases, notably influenza but also SARS and TB. Multiple factors increase the risk of in-flight transmission of acute respiratory diseases: high crowd densities and enclosed spaces, high passenger throughput providing greater chance of fomite spread, the infectivity of the source, the ventilation rate, humidity and temperature, and immunity of the susceptible host [6-8]. Many studies and several reviews have documented and quantified the risks of in-flight transmission from symptomatic influenza cases. There is a large variation in attack rates across studies and the quality of evidence is moderate [9]. Close proximity (within 2 rows of index case) increases the risk but there were cases where transmission has occurred beyond the 2-row risk zone [10]. Studies have documented both cases and absence of cases of inflight transmission of SARS.



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Industry and media reports: Peak airline industry bodies and Qantas assert that there have been no cases of transmission of SARS-COV-2 on planes, citing multiple physical reasons, including ventilation. Furthermore, there appears to be little anecdotal reporting of transmission on planes in traditional and social media.

Other relevant evidence about COVID-19: Increasingly, evidence indicates that SARS-COV-2 is spread via droplet transmission, making physical distancing, cleaning of surfaces and personal sanitation highly effective forms of control. Additionally, while pre-symptomatic transmission can occur, symptomatic transmission is more likely. Self-isolation while symptomatic, however mild, is another critical form of communicable disease control for COVID-19. Mask wearing has been shown to have efficacy in reducing droplet spread from a source.

## Context (including industry reporting)

- Air transportation is implicated in the spread of epidemics through the displacement of an infectious person from one area to another [not the focus of this briefing] and through secondary transmission that occurs when flying with a person infected with a disease [11].
- Public health agencies including the World Health Organization (WHO) and the US Centres or Disease and Control and Prevention (US CDC) define contact with an infectious person during air travel as sitting within two rows (in front or behind) symptomatic cases [12, 13]. Note that this assumes that cabin airflow and passenger and crew movements play negligible roles in disease transmission [10].
- A 2008 report produced by the Australian Transport Safety Bureau [14] made the following points:
    - There are perceptions that cabin air quality is poor.
    - Cabin conditions of confined space, limited ventilation, prolonged exposure times and recirculating air are risk factors for transmission of upper respiratory tract infections in other settings.
    - In modern aircraft, the airflow is from the top of the cabin downwards to the floor, where it is vented and either exhausted or re-circulated. It is usually designed so that air entering the cabin at a given seat row is exhausted at the same seat row, limiting the front and back movement of air. Most aircraft also use high efficiency particulate air (HEPA) filters, reducing the chance that recirculated air will contain infectious agents.
    - The data indicate that the risk of transmission of infectious diseases within an aircraft cabin is low but the only way of eliminating all risk would be to prevent potentially infective passengers from flying.
    - Transmission is likely to occur due to proximity with an infectious person rather than through the ventilation system, which makes the risk similar to other environments were crowds of people congregate (e.g. airport terminals, restaurants, other forms of mass transport).
- A press release by Qantas (19th May 2020), in preparation for increased domestic travel, revealed their 'Fly Well' program which comprises of a range of temporary measures designed to ensure safe air travel. The press release included a statement from Qantas Group medical director Ian Hosegood: "*The data shows that actual risk of catching Coronavirus on an aircraft is already extremely low. That's due to a combination of factors, including the cabin air filtration system, the fact people don't sit face-to-face and the high backs of aircraft seats acting as a physical barrier. As far as the virus goes, an aircraft cabin is a very different environment to other forms of public transport."*
- A statement from the Qantas news room states: *"There's been no confirmed cases of transmission of the Coronavirus to employees or customers on board our aircraft, or any aircraft globally for that matter. That*

*includes instances where someone unwittingly travelled on one of our flights while infected with Coronavirus, based on our discussions with health authorities."*

- It has been reported that 59 Qantas staff, including 37 cabin crew, have tested positive for COVID-19. Qantas indicates that the cases was almost all from community transmission overseas.

- International news articles have reported stories from flight attendants believing that they caught COVID-19 from passengers or other crew members (LA Times; The Guardian).
- News articles have quotes from airline representatives stating that in-flight transmission is unlikely (Malaysian airline experts; Southwest CEO) or non-existent (IndiGO CEO)
- The basis for these statements appears to be a report/presentation (5 May 2020) from the International Air Transport Association (IATA), which represents 290 airlines from 120 countries. The report was produced by a medical advisor and referenced four COVID-19 case reports and included results from their own internal analysis (Note: no methodological details were provided).
    - Slides showed the following:
        - **Published studies:**
            - Contact tracing for a flight China-Canada revealed no transmission
            - Contact tracing for a flight New York –Taipei no transmission (all tested)
            - One pre-publication suggested transmission, but no information provided
            - One pre-publication suggested transmission but looks very unlikely
                - Refs: https://www.cmaj.ca/content/cmaj/192/15/E410.full.pdf, https://www.nownews.com/news/20200422/4046494/, https://www.sciencedirect.com/science/article/pii/S1477893920301125?via%3Dihub
        - **IATA analysis:**
            - Reportedly asked medical contacts of 18 airlines (14% global traffic) about any cases of suspected in-fight transmission:
                - 3 instances suspected passenger to crew
                - 4 instances pilot to pilot (but timing unknown)
                - None of passenger to passenger
            - More detailed examination – 4 airlines with public health follow up of 1100 confirmed cases post-flight (total pax>>100K).
                - No known secondary cases amongst other passengers and 2 of possible crew cases.
- The list of flights carrying passengers with confirmed COVID-19 is lengthy (e.g. NSW) but the publicly available data on source of transmission does not indicate whether it was related to air travel. It would be difficult to ascertain whether in-flight transmission occurred due to confounding factors (e.g. transmitted prior to boarding).

## Key summary from the evidence

### 1. Published evidence

### COVID-19 – case studies

- Qian 2020 [3], case series (QJM):
  - Of 91 patients with COVID-19**, 11 (12%) flew together on the same flight and were believed to be infected during the flight**; no person could be singled out as the index patient within this group.
  - The remaining patients had either been in contact with a local case or had been in Wuhan/Hubei in the previous 2 weeks.
  - Note: very little other details are provided e.g. seating plan or whether cases were known to each other.

- Yang 2020 [4], case series (medRxiv pre-print, not peer-reviewed, 30 March 2020):
  - 325 passengers and crew members flying from Singapore to China (5-hours) were screened for fever or respiratory symptoms prior to boarding and on arrival; none were symptomatic prior to boarding. Flight crew wore masks but most passengers did not.
  - **1 passenger became symptomatic (fever) during the flight** and everyone was then quarantined for 14 days. Passenger 1 did not wear a mask.
  - **A further 11 passengers subsequently tested positive for SARS-CoV-2** (2 were not investigated further). Of the 10 passengers with COVID-19 who were followed up, no previous exposure could be identified. (Note: No previous exposure could be found for patient 1 either, but he was from Wuhan).
  - The authors calculated the risk of transmission as 3.69% (12/325), Median incubation period was 3 days (IQR2-7).
  - The authors conclude: *we believe that the most plausible index case resulting transmission of SARS-CoV-2 in the other nine passengers was patient 1, the 45-year-old man from Wuhan, who had onset of fever during this flight*.
  - Notes: The authors did not have access to data on seating plans and could not determine whether transmission occurred during or immediately before the flight. There was no reporting of how many of the cases (other than the index case) were from Wuhan. Or whether cases were known to each other.

- Schwartz 2020 [2], letter (CMAJ):
  - **Index patient was symptomatic**, with a dry cough during a **15-hour flight** into Canada from Wuhan.
  - There were approximately 350 passengers on board. Close contacts were identified as those sitting within 2m of the index case during the flight, flight crew members and 1 close contact on arrival. Close contacts to actively monitored for 14 days.
  - **No secondary transmission of COVID 19 was detected**: 1 close contact developed a cough but tested negative for COVID-19; 5 non-close contact passengers who contacted public health officials became symptomatic but also tested negative for COVID-19.
  - Authors noted that **mild symptoms and masking during the flight** may have mitigated transmission.

- Eldin 2020 [5], letter (Trav Med Infect Dis):
    - Investigation of source of transmission for 1 person with COVID-19 concluded that it was most likely acquired during a flight from Bangui, Central African Republic to Paris, France.
    - Note: The strength of evidence included in this study is very low. The authors concluded that transmission occurred during flight because, through their process of elimination, they determined it was unlikely to have occurred elsewhere.
- Lytras 2020 [15], brief report (J Trav Med):
    - Repatriated passengers from flights arriving in Greece from the UK, Spain and Turkey (all countries with presumed widespread SARS-CoV-2 infection) were tested on arrival.
    - Only **1 person was symptomatic during the flight** and subsequently tested positive for SARS-CoV-2.
    - More positive cases emerged from in the days following arrival, but **whether transmission occurred prior to flying or during the flight was not investigated.**

## Evidence of in-flight transmission of other respiratory viruses

- Mangili 2005 [7], review (Lancet): Risk of disease transmission can be difficult to assess accurately due to incubation periods lasting longer than air travel and infrequent reporting.
    - Aircraft cabin environment: during a flight, the aircraft cabin is a ventilated enclosed environment that exposes passengers to hypobaric hypoxia, dry humidity and close proximity to fellow passengers. An environmental system controls pressurisation, temperature, ventilation and air filtration. Air circulation patterns are side-to-side with little front-to-back airflow, thereby limiting the spread of airborne particles throughout the passenger cabin. Most commercial aircraft recirculate 50% of the air, which usually passes through high efficiency particulate air filters (HEPA) before delivery into the cabin. Air exchange rates are typically 15-20 changes per hour.
    - Disease spread in a cabin may be influenced by proximity, infectiousness of the source, duration of exposure, environmental conditions (ventilation, humidity, temperature) and immune status of the host. Recirculation of air was not identified as a risk factor in multiple studies.
    - **Tuberculosis**: 2 of 7 investigations revealed a probable link of onboard transmission. The authors reported a 1 in 1000 probability of infection, which is no higher than the risk in other confined spaces.
    - **SARS**: 5 of 40 flights have indicated probable on-board transmission.
    - **Influenza**: Only 3 investigations reported but results indicate probable onboard transmission.
- Leder 2005 [16], review, (Intern Med J): similar to Mangili 2005 [7] conducted around the same time.
- Leitmeyer 2016 [9], review, (Epidemiology): critically appraised the evidence for **influenza transmission** aboard aircraft.
    - The review included 14 articles and covered 23 flights of varying flight duration.
    - All investigations described retrospective follow-up of passengers after identifying one or more index cases with influenza or symptoms of influenza-like illness (ILI). The proportion of contacts

identified and traced ranged from 4% to 100% of all flight passengers; in total 51% of all passengers were followed up.

- As shown in the table below, the attack rate varied across studies. Based on these figures, an overall attack rate of 8% was reported for all successfully traced passengers, although this dropped to 2% when restricted to laboratory-confirmed secondary cases.
- There was evidence of secondary cases occurring more than two rows away from an index case. Overall, the average quality of evidence was moderate.
- There is evidence that transmission occurs aboard aircraft but the published data are inconclusive on the risk and extent of transmission.
- Limitations include the completeness of contact tracing, potential bias from a possible common exposure before (e.g. waiting hall, boarding), within (e.g. toilets), and after (e.g. exiting the aircraft, border security) the flight, and extent of circulating disease in the country of origin.

**TABLE 2.** Number and Percentage of Successfully Traced Passengers After In-flight Exposure to Influenza, Number of Index, and Secondary Cases, and Percentage of Secondary Cases Seated Within Two Rows of an Index Case, With and Without Restriction to Laboratory-confirmed Secondary Cases Infected with influenza A(H1N1)pdm09, by Study/Flight

| Data from All Studies | | | | | | | | | Restriction to Laboratory-confirmed Secondary Influenza A(H1N1)pdm09 Cases | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| First Author, Flight | Passengers Aboard | Passengers Traced | % | Index Cases | Secondary Cases Identified | Attack Rate % | Secondary Cases Within 2 Rows | % Sec. Cases in 2 Rows | Index Cases | Secondary Cases Identified | Secondary Cases Within 2 Rows | % Sec. Cases in 2 Rows |
| Shankar[23a] | 277 | 43 | 16 | 1 | 5 | 12 | 1 | 20 | 1 | 5 | 1 | 20 |
| Young[24a] | 278 | 239 | 86 | 6 | 10 | 4 | 5 | 50 | | | | |
| Zhang[26], flight 1 | 274 | 82 | 30 | 1 | 9 | 11 | 8 | 89 | 1 | 9 | 8 | 89 |
| Zhang[26], flight 2 | 144 | 140 | 97 | 1 | 0 | 0 | 0 | na | 1 | 0 | 0 | na |
| Neatherlin[27] | 265 | 159 | 60 | 1 | 8 | 5 | | | | | | |
| Neatherlin[27] | 167 | 133 | 80 | 1 | 7 | 5 | 3 | 43 | | | | |
| Catala[28] | 165 | 74 | 45 | 6 | 4 | 5 | 4 | 100 | 6 | 4 | 4 | 100 |
| Foxwell[29], flight 1 | 445 | 188 | 42 | 10 | 24 | 13 | 9 | 38 | 4 | 2 | 2 | 100 |
| Foxwell[29], flight 2 | 293 | 131 | 45 | 3 | 6 | 5 | 4 | 67 | 0 | 1 | 1 | 100 |
| Ooi[30] | 596 | 26 | 4 | 1 | 5 | 19 | 2 | 40 | 1 | 5 | 2 | 40 |
| Kim[31] | 338 | 199 | 59 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| Baker[32] | 379 | 121 | 32 | 11 | 2 | 2 | 2 | 100 | 9 | 2 | 2 | 100 |
| Han[33], flight 1 | 91 | 91 | 100 | 1 | 0 | 0 | 0 | na | 1 | 0 | 0 | na |
| Han[33], flight 2 | 87 | 87 | 100 | 1 | 0 | 0 | 0 | na | 1 | 0 | 0 | na |
| Han[33], flight 3 | 87 | 87 | 100 | 2 | 1 | 1 | 1 | 100 | 2 | 1 | 1 | 100 |
| Bin[35] | 141 | 141 | 100 | 1 | 0 | 0 | 0 | na | 1 | 0 | 0 | na |
| Marsden[10] | 75 | 75 | 100 | 1 | 20 | 27 | 9 | 45 | | | | |
| Klontz[11], flight 1 | 44 | 44 | 100 | 8 | 18 | 41 | 18 | 100 | | | | |
| Klontz[11], flight 2 | 46 | 46 | 100 | 3 | 5 | 11 | 2 | 40 | | | | |
| Moser[9] | 60 | 59 | 98 | 1 | 38 | 64 | | | | | | |
| Total | 4,252 | 2,165 | 51 | 61 | 163 | 8 | 68 | 42 | 27 | 30 | 21 | 70 |

For details, see eAppendix 2 (http://links.lww.com/EDE/B6).
[a]Appears to be the same flight but slightly different numbers/denominator.
na indicates not applicable.

- Browne 2016 [8], review (J Travel Med): Assessed whether air, sea and ground mass transport systems or hubs are associated with transmission of influenza, SARS or MERS based on 41 studies that met the inclusion criteria.
    - 30 studies on air transport, mostly related to influenza and used a range of methods including observational and modelling studies.
    - The results for influenza showed that in-flight transmission has occurred on multiple occasions and that symptomatic passengers aboard were essential for in-flight transmission to occur. The authors reported that the rate of infection ranged substantially across studies; up to 4 confirmed secondary cases per affected flight have been reported, and attack rates of up to 20% have been suspected, although other sources of exposure could not be ruled out. Noteworthy studies within this review (*Note: the observational studies were also reviewed in Leitmeyer 2016 [9], summarised above)*:
        - Moser 1979 [17] (**seminal paper**): A jet airline was grounded for three hours after an engine failure during a take-off attempt. Most passengers stayed on board; within 72 hours, 72% of passengers had developed flu-like symptoms. The airplane ventilation system was inoperative during the delay, which may explain the high attack rate.
        - Gupta 2012 [6] (modelling, Influenza): A case of influenza spread was studied using deterministic and probabilistic approaches in a fully occupied twin-aisle cabin with the index case seated in the centre of the cabin. The risk of infection was calculated for the passengers seated near the index case for 4-hours (total ventilation rate of 33.7 air change per hour). The probabilistic approach indicated that the number of secondary infection cases can be reduced from 3 to 0 and 20 to 11, for influenza cases if N95 respirator masks are used by the passengers.
        - Wagner 2009 [18] (modelling, Influenza): The risk of catching influenza is confined to the same cabin as the index case and the risk increases with length of flight. Generally, first class (1st) travel has a lower risk of in-flight transmission than economy class (2nd) travel, but this depends on occupancy. Likely number of infections: 5-hour flight is 0-1 (1st) and 2-5 (2nd); 11-hour flight is 1-3 (1st) and 5-10 (2nd); 17-hour flight is 2-5 (1st) and 7-17 (2nd). Results also indicate that the greater the infectivity of the index case, the greater the effect of flight duration on increasing the number of infections.

- In-flight transmission has also been reported for **symptomatic passengers with SARS** [19, 20] [see also [21]], but there have also been flights where there has been **no secondary transmission of SARS** [22] [see also [23]]. Secondary MERS transmission was modelled to be possible [24] (see below), but no studies had observed this in real life.
    - Olsen 2003 [20] (**observational**, **SARS**): 1 index case infected 18 passengers and 2 flight attendants on a 3-hour flight from Hong Kong to Beijing. Only 9 (50%) of the infected passengers were seated within 2 rows of the index case.
    - Coburn 2014 [24] (**modelling, MERS**): Using a mathematical model to predict the potential for within-flight transmission of MERS, the results showed that transmission would be confined to the cabin where the index case was located, and that on a 5h flight, 1 infection could occur if the index case was located in first class and 3 infections could occur if the index case was in economy. Infections could double on a 13-hour flight, and could quadruple if the index case was a super spreader (releasing about 140 quanta per hour).

- The risk of transmission is theoretically highest when seated close to an index case and increases with flight duration, but it should be noted that movement within a cabin is generally not accounted for in risk models. The possibility that contagious airport workers can be a source of transmission has also been identified.

## Risk potential due to in-flight dynamics

- Hertzberg 2018 [11], observational, modelling (PNAS): Prior to this study, numerous cases of inflight transmission of serious infections (e.g. SARS, influenza) had been documented but the **risk of transmission of respiratory viruses in an airplane cabin was unknown**. It was noted that the main route of transmission of influenza and SARS is likely to be respiratory droplets, requiring close contact or touching a contaminated surface. Close contact in airplane cabins can arise from being seated in a nearby seat, or when individuals move around the cabin.
  - Observation of passenger movements on 10 transcontinental flights of single-aisle aircraft in the US revealed that one 1 out of 1540 passengers was coughing moderately, and none coughed severely. During the flight, 38% never left their seat, 38% left once, 13% left twice and 11% left 2 or more times. Those seated in aisle seats were more likely to move than those in window seats. The most common behaviours were checking the overhead bin or lavatory-related. Of those who moved, the median number of contacts was 44. Crew members were in contact with passengers for approximately 67 mins and spent 155 mins in the gallery (average flight length of 238 mins).
  - **Modelling** a scenario with an **index patient seated mid-cabin** ($14^{th}$ row, aisle seat) and a conservatively high transmission rate of 0.018 per minute of contact, the results indicate that the 11 nearest neighbours have a high probability of becoming infected but the probability for the remaining passengers is low. **On average, this translated into 0.7 additional infected passengers per flight (ICR: 0.4-1.5).**
  - **Modelling** a scenario with an **infectious crew member** based on a low transmission rate (0.0045) shows that, **on average, 4.6 (IQR: 3.2-5.7) passengers will become infected**.
  - Air and surface samples (n=229) collected during the flights were all negative for 18 common respiratory viruses.
  - Important to note that transmission may occur while waiting in the airport, while boarding, or while deplaning. The length of the flight, and the size of the plane and cabin-disinfection protocols may also influence the risk of transmission.

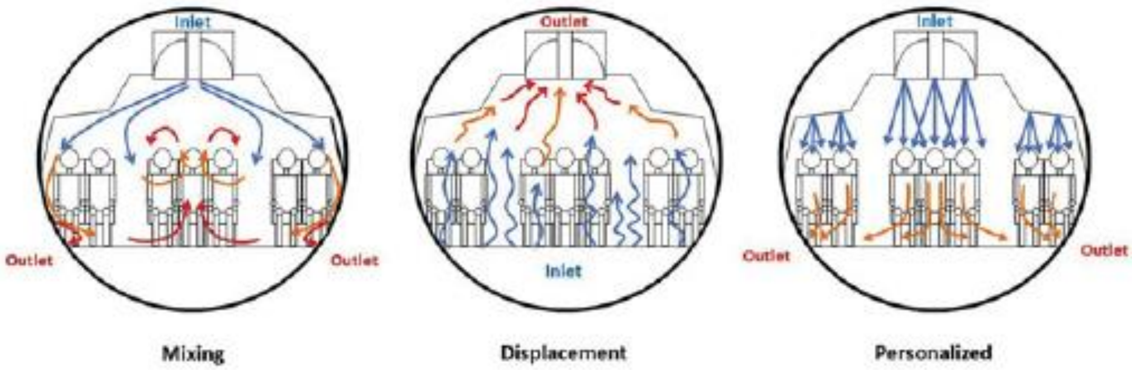
- Hertzberg 2016, review (Annals of Global Health): Examination of seat plans where in-flight transmission of respiratory infections occurred (5 reports available) showed that there were 30 cases within and 26 cases outside the 2-row risk zone, equivalent to 10% and 5% of those at risk, respectively. The authors speculated that cabin airflow and movements of passengers and flight attendants increased the risk of infection for those outside the 2-row risk zone.

- Multiple models of passenger movement dynamics have been developed to simulate how infection may spread in airplanes [25, 26]. These models can be used to develop policies that reduce contacts and curb infection spread, but mostly apply to boarding and deplaning.

**Outside of scope of search (examples provided; more evidence may be available).**

**Cabin air quality**

- Elmaghraby 2018 [27], review (Sci Technol Built Environ): Different ventilation systems can influence air quality and disease spread. The 3 main types are mixing, displacement and personalised (see figure below), with mixing ventilation the most common. Personalised ventilation is a newer system but provide the most promising results for air quality enhancement and reduction in cross-contamination in aircraft cabins.




**Modelling (transmission via air travel in general, not risk of transmission during flight)**

- Daon 2020 [28] (pre-print medRxiv): The risk posed by 1364 airports to initiate a COVID-19 outbreak (second wave) was modelled. The risk varied according to flight volumes, connections and population density. The airports with the highest risk were: Beijing Capital International Airport (0.74), Hong Kong International Airport Kai Tak (0.63) and Singapore Changi Airport (0.53). Dubai International Airport was 5th (0.49) and London Heathrow Airport was 7th (0.46). The risk at Australia's highest-ranking airport, Sydney Kingsford Smith International Airport, was 0.14.
- See also Colizza 2006 [29]

**Development of symptoms during a flight**

- Pitman 2005 [30] (BMJ): Assuming that symptomatic cases were screened and prevented from flying prior to boarding, for SARS, an infected passenger would have a 0-11% chance of progression during a 6-hour flight. For influenza, which has a much shorter incubation period than SARS, a passenger infected 2 days before departure would have a 50% chance of progression during a 10-hour flight.

**Other mass transport**

- Zhen 2020 [31] (South African Med J): a rapid review identified 4 in-scope studies; results indicated that there was an increased risk of viral transmission with public transportation use that may be reduced with improved ventilation.

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**Expert input:** Prof Steve Wesselingh

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