

the cruise phase, where it converged to approximately 10%. In all aircraft, a rearward flow was observed. Literature notes cabin air exchange rates between 10 and 30 times per hour.

Source

Literature was used to characterise two types of virus sources. For a normal index passenger, the viral concentration in the mucus of the index was assumed to follow a lognormal distribution with a mean of 7.53 and standard deviation of 1.28 RNA copies / mL (i.e. an average shedding level of 107.5 RNA copies / mL). For a passenger who sheds an extraordinary amount of infectious aerosol particles (a so-called super shedder), emission with a concentrations of 1010 RNA copies / mL was assumed (i.e. a super shedders emits on average 316 times as much RNA copies/mL as the average normal shedder). Total aerosol emission volumes for breathing (assumed to occur 80% of the time) and speaking (20% of the time) were taken from literature .

In the in-cabin particle dispersion measurements, the source was represented by a manikin-mounted nozzle, connected to an aerosol pump. Artificial saliva was injected into the cabin from this nozzle. For the particle dispersion simulations, the aerosols emitted by an index passenger were modelled to start from a 10 centimetre diameter sphere, located 10 centimetres in front of the index passenger.

Particle dispersion

In addition to the measurements investigating cabin environmental conditions, simultaneous measurements on particle dispersion were conducted. To this effect, manikins (optionally heated, to represent normal passenger heat emission) were placed in the seats in the 7-row cabin section under investigation. Following emission of artificial saliva by the source, particle sensing equipment was used to detect aerosol particle numbers and size throughout the cabin section investigated. Particulate matter sensors were placed on all manikins and two aerodynamic particle sizers were positioned in two strategic locations. Measurements were conducted under a variety of conditions, in order to cover the impact of a large number of variables: cruise and taxi condition, use of gaspers (passenger-controlled air inlets), index passenger mask usage, manikin heating (only in taxi condition), pack setting and index location (only in Boeing 787-8). Additional manikins and particulate matter sensors, placed further away from the index passenger, were furthermore used in the single-aisle aircraft measurements to assess the effectiveness of HEPA-filters.

Dispersion of aerosols was simulated across seven rows of passengers in a ventilated aircraft cabin. A Reynolds-averaged Navier-Stokes (RANS) method was used to model the air flow and the dispersion of particles, taking into account the cabin configuration of the aircraft types studied, cabin environmental conditions, ventilation system properties and buoyancy effects due to heat sources inside the cabin. Cabin environmental conditions, air inflow, heat source and thermal conditions were modelled using a combination of measurement results, aircraft specifications and academic literature. Following the introduction of particles into the simulation, their trajectories were modelled, influenced by the air flow and gravity. In turn, the airflow is for example modelled to be influenced by air flowing into and out of the aircraft cabin and buoyancy effects due to cabin occupants emitting heat (potentially yielding a slight upward flow just in front of the occupants). (in turn, influenced by e.g. inflow and outflow and buoyancy effects due to cabin occupants emitting heat) and gravity on droplet trajectories is modelled. The number, volume and residence time of particles entering a 30 × 30 × 30 centimetre 'inhalation box' was logged and subsequently used as input for the risk assessment.

Cross-checks between measurement data and simulation output of the Airbus A320 and Boeing 787-8 yielded similar aerosol dispersion per row. Both measurement and simulation data showed a predominantly rearward dispersion of aerosols, especially for the single aisle aircraft, consistent with the earlier observation of a rearward flow.

<summary of impact of selected variables will be added> Studying the influence of selected parameters, mask usage by the index passenger was shown to clearly reduce the number and volume of aerosols detected after emission by the index. Gasper settings and index location were also found to affect particle dispersion, but to a varying or limited extent. Very low particle volumes detected further away from the index passenger suggest that, at least at the measurement location, re-emergence of aerosols from recirculated air has a low contribution to the spread of the used aerosols. Very low particle volumes detected further away from the index passenger suggest HEPA-filters are effective in removing aerosols from recirculated air. It is however uncertain what exact share of air volume is recirculated or discharged by the ventilation system at the specific location in the aircraft cabin.

Risk assessment

Using the experimental and simulated particle dispersion results and literature on virus shedding, dose-response and face mask effectiveness, a QMRA was conducted in order to estimate risk of illness. For that purpose, aerosol concentrations were converted to transfer fractions: the fraction of the emitted source that would be inhaled by a passenger located at a particular seat. Variability in exposure conditions was taken into account by considering distributions of exposure factors, such as inhalation rate, aerosol volume emitted by the index and virus concentration in sputum. A Monte Carlo simulation was conducted based on these distributions, yielding a dose and risk of illness.

Conclusions

For a typical cruise flight (ranging between 0.9 hour for the Airbus A320 and 8.7 hours for the Boeing 787-8), mean illness risks were estimated to be in the range of 1/2000 to 1/200 amongst the passengers seated in the seven rows around the index passenger. In the case of a super shedder, risks increased up to 1/31. These findings were found to be in line with other model and measurement studies on in-flight illness risk. Due to the shorter typical flight durations, a flight on board a single-aisle aircraft was found to result in lower risks than a flight on a twin-aisle

aircraft.

The expected number of flights to result in at least 1 case of COVID-19 due to transmission of aerosolised SARS-CoV-2 particles aerosol transmission from a 'regular' index passenger was estimated to range from 4 to 50 cruise flights of durations typical for the aircraft types in the study. In case of longer durations cruise flights, the expected number of flights ranged from 4 to 20. The expected number of flights to result in at least 1 case of aerosol transmission from a 'super shedder' index passenger was estimated to range from 1 to 9 flights (typical duration cruise) and 1 to 4 flights (longer duration cruise).

<summary of personal risk will be added>

Although difficult to validate, estimates on the likelihood of one infectious passenger boarding an aircraft based on an upper limit of 5% of the current prevalence in the Netherlands would indicate a likelihood of approximately 42 per 100.000 passengers. Depending on the number of passengers per aircraft (100 - 300), every 12th flight would carry an infectious passenger and about 3% of these would be a super shedder.

Statistical analysis of the measurement data revealed that distance and angle relative to the virus shedding passenger was highly significant in all cases, which is consistent with simulation results. The risk assessment included the literature data on the effect of wearing a mask by all passengers. The experimental data suggested that a face mask was particularly effective in prevention emission of the larger aerosols and altered the speed and direction of the emitted aerosols. More data is required to validate these findings.

Major sources of high variability of the risk estimates based on measurement and simulation data were the viral concentration in the aerosols and the volume of aerosol emitted by the virus shedding passenger. These varied Their variation has an impact of over an order of magnitude ($\times 10$ or more) on the risk. The flight duration, and the efficiency of masks to limit aerosol emission and inhalation had a direct proportional effect on the risks, but not over an order of magnitude (i.e., less than $\times 10$).

Applicability

The study assumed compliance with EASA and ICAO-recommended best practices, such as wearing non-medical face masks, except when drinking or eating (assumed to occur 10% of the time). The study addressed the risk of transmission on board of an aircraft via inhalation of virus bearing aerosols if one infectious passenger (index) was present in the cabin, based on the study of three common aircraft types used for commercial passenger transport. As the transmission risk is highly dependent on the (unknown) location of a possible index passenger, Tthe study results cannot be used to in general classify particular seat positions according to higher or lower levels of risk, since the index passenger can be located at any seat.

From: 5.1.2e <5.1.2e@rivm.nl>

Sent: dinsdag 1 juni 2021 16:03

To: 5.1.2e <5.1.2e@rivm.nl>; 5.1.2e <5.1.2e@rivm.nl>; 5.1.2e
<5.1.2e@rivm.nl>; 5.1.2e <5.1.2e@rivm.nl>

Cc: 5.1.2e <5.1.2e@rivm.nl>; 5.1.2e <5.1.2e@rivm.nl>

Subject: RE: Kamerbrief NLR/RIVM

Hoi,

Ik ben geen communicatie expert, maar op twee plaatsen zou ik overwegen de randvoorwaarden van de risico-analyse (wellicht ten overvloede) te benadrukken. De uitspraak dat wij zeggen 'risico op besmetting aan boord van vliegtuigen klein is', kan gemakkelijk uit zijn verband gelezen worden, bv. Tenminste, dat lijkt mij.

Groeten,

5.1.2e

From: 5.1.2e <5.1.2e@rivm.nl>

Sent: Tuesday, 1 June 2021 15:32

To: 5.1.2e <5.1.2e@rivm.nl>; 5.1.2e <5.1.2e@rivm.nl>; 5.1.2e <5.1.2e@rivm.nl>

Cc: 5.1.2e <5.1.2e@rivm.nl>; 5.1.2e <5.1.2e@rivm.nl>

Subject: RE: Kamerbrief NLR/RIVM

Dank 5.1.2e

Best okay, paar kleine dingetjes aangegeven

Mij ook niet duidelijk waarom het alleen naar jou gaat: wsch ben je gewoon de meest communicatieve *

5.1.2e is de routing voor jullie duidelijk?

Vr gr

5.1.2e

From: 5.1.2e <5.1.2e@rivm.nl>
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Subject: FW: Kamerbrief NLR/RIVM

Fyi, mocht iemand hier nog input op willen leveren. Ik weet niet zo goed waarom ik wel in deze loop zit en jullie niet.

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Cc: 5.1.2e) - DCO <5.1.2e@minienw.nl>; 5.1.2e) - DGLM <5.1.2e@minienw.nl>; 5.1.2e (5.1.2e) - BSK <5.1.2e@minienw.nl>; 5.1.2e) - DGMo <5.1.2e@minienw.nl>; 5.1.2e) - 5.1.2e <5.1.2e@minienw.nl>; 5.1.2e 5.1.2e - DGLM <5.1.2e@minienw.nl>; 5.1.2e) - DGLM <5.1.2e@minienw.nl>; 5.1.2e) - DGLM <5.1.2e@minienw.nl>
Subject: Kamerbrief NLR/RIVM

Beste allen,

Op verzoek van 5.1.2e hierbij de opzet voor de Kamerbrief project CORSICA. Zien jullie kans voor aanstaande donderdag 12 uur te reageren met eventuele aan- of opmerkingen, of vragen?

Heel hartelijk dank vast.

Groeten,

5.1.2e

Met vriendelijke groet,

5.1.2e

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