Restoring Aviation During COVID-19

Medical evidence for possible strategies as at 6 August 2020 IATA Medical Advisory Group

Introduction

Many international groups are exploring possible pathways to facilitate a “restoration” of airline aviation, which for international operations is at 2-4% of normal capacity, and the lifting of mandatory quarantine requirements which have depressed demand. The large-scale resumption of international flights will require a number of hurdles to be crossed in order for Governments to allow travel, and further hurdles in terms of the passenger journey, which includes the airports of departure and arrival, the flights themselves, and other elements. Domestic flights are also severely affected in most markets, but this is generally due to reduction in demand more than state-imposed restrictions. Strategies being explored by the many groups involved depend on sound medical evidence. The aim of this paper is to review the current state of medical evidence regarding those elements with a view to possible pathways to scaling up aviation.

The state of knowledge is changing rapidly; thousands of research articles have been published since the start of the outbreak, and an enormous amount of work is in progress with both researchers and industry. Therefore, this document which has undergone several iterations, must be read with its latest review date in mind.

There are many logistical, financial, and political aspects to scaling up aviation, and most of these are well beyond the scope of this discussion, which will be confined to the medical aspects. There are also reports specific to airports and immigration processes which are also out of scope here. The report has been prepared by IATA’s Medical Advisor along with the Medical Advisory Group of ten airline medical directors, on the basis of extensive review of available literature, advice and expertise during the pandemic thus far. Several revisions have been completed.

Restoring normal aviation requires two key components: first, governments must be prepared to allow passengers to travel, between countries and regions. Secondly, passengers must have sufficient confidence that they can travel safely, and achieve what they wish to do on their journey. For the passenger journey, an acceptable risk of in-flight transmission is a key factor, but this is along with other considerations such as risk of illness while away, risk of being quarantined, availability of safe and suitable accommodation, availability of travel insurance, etc. For governments, in-flight transmission is secondary to the greater risk of importation of people who are incubating the illness and can become sources of infection. This is a more challenging problem to solve, but will employ many of the same layers of protection which are discussed here.

In-flight Transmission

Relatively little research has been published on in-flight transmission of COVID-19. One paper from Canada reports careful follow up of a long-haul flight on which Canada's first COVID case was later confirmed, and was unwell at the time of flight, but no secondary cases resulted. A recent public report shows that a flight on 31 March from USA to China Taipei with 12 people subsequently confirmed to be symptomatic at the time of flight, generated no secondary confirmed cases from the 328 other passengers and crew members, who all tested negative.

There was also a pre-print (Yang et al) suggesting that on a Singapore-Hangzhou flight on 23 January with 325 on board had an appreciable rate of in-flight transmission, but the analysis did not exclude pre-flight infection, and had not evaluated seating location of the cases. A more recently published peer-reviewed paper (Chen et al) analysed a flight from Singapore to Hangzhou just the following day, on 24 January 2020, and all 335 passengers were isolated and monitored for two weeks. In this study the travel histories and seating locations were carefully analysed; many of the passengers had originated their travel in Wuhan, and many had been on tour together. Of the 16 who tested positive, the authors identified only one who may have been infected during the journey, according to the authors.

A flight from Dubai to Hong Kong from which 26 passengers tested positive on arrival, resulted in no further cases amongst the remaining passengers and crew, all of whom were quarantined and tested (unpublished data).

A public health investigation into a flight from UK to Vietnam on 2 March 2020 suggests transmission by one passenger to up to fourteen other passengers (twelve of whom were seated nearby the presumed index case) and a cabin crew member. Initial information has been obtained from this investigation, but publication of a scientific journal article is awaited. This is the only event known to IATA of likely on-board transmission to a number of people. We are aware of a second investigation from elsewhere, also expected to be published soon, in which the public health analysis (including gene sequencing) points to in-flight spread with 3 presumed primary cases and up to 11 secondary cases.

By contrast, an informal survey of 18 major airlines in correspondence with IATA identified, during Jan-Mar 2020, just four episodes of suspected in-flight transmission, all from passenger to crew, and a further four episodes of apparent transmission from pilot to pilot, which could have been in-flight or before/after (including layover); there were no instances of suspected passenger-to-passenger transmission reported by the group of airlines. The group of airlines represents 14% of global traffic for that period. A request to a much larger group of 70 airlines (representing half of global passenger traffic) also failed to identify any cases of suspected passenger-to-passenger transmission. And finally, closer analysis with IATA was able to be carried out by four airlines which had close contact with local public health authorities during the outbreak. The four airlines (with a combined annual traffic of 329 billion RPK) together followed up around 1100 passengers who were identified as confirmed cases having recently flown. The flights in question represent about 125000 passengers. There was just one possible secondary passenger cases identified in the total, along with just two crew cases, thought to be the result of possible in-flight transmission – although further analysis is under way. By comparison, a recent article from Shenzhen China on transmission quotes an overall transmission rate of 6.6% across modes of contacts (household, travel, or meals), which would equate to a predicted 72 cases from those 1100 passengers, compared with the very small number that we have observed.

By comparison a recent detailed analysis of transmission on high speed trains in China, looking at over 2300 index cases, indicates an average attack rate of 0.32% for close contacts (within 3 rows), with greater risk from closer proximity.

The reasons for the apparently low rate of in-flight transmission are not known precisely but are expected to encompass a combination of the lack of face-to-face contact, and the physical barriers provided by seat backs, along with the characteristics of cabin air flow. Further study is under way to determine the contribution of these factors.

Vaccination

Over 150 vaccine candidates are being evaluated, with several of them in phase 3 large human clinical efficacy trials. The eventual arrival of a reliable vaccine, with production scaled up to allow widespread availability, would be expected achieve immunity for those vaccinated. However, it is not a certainty that a safe and successful vaccine will be produced, with this being the world's first attempt at a vaccine against a coronavirus, and the duration of immunity is yet to be determined. Best-case estimates of the time course for release of a viable vaccine are mostly not before the 2021 calendar year, and then there are challenges of scaling up production, and achieving adequate uptake by the population, to be met. If a vaccine was successfully produced and widely distributed, a certificate of immunity such as mentioned above would become a viable tool to facilitate travel.

Summary: A highly desirable solution, being vigorously pursued, but there are many hurdles to be cleared before this is available.

Multi-layered approach:

The current aviation system was designed to incorporate multiple protective layers including cleaning/disinfection, airflow and filtration, to reduce disease transmission on aircraft and in airports. In response to the pandemic, airlines and airports have been reinforcing these protective layers and supplementing extra measures such as distancing in the airport, touchless check-in and other processes, and mandatory face mask use. Some protective layers are more effective than others. Measures involving testing and screening of passengers for COVID-19, if successful can have the dual benefit of reducing both disease transmission during travel and also the importation of infected individuals across borders. However, many of the measures come at the cost of increased inconvenience or expense, which may be borne variously by passengers, airlines, airports, and governments.

Of course, no single measure can eliminate the risks entirely. The combination of intrusive and burdensome measures creates a travel experience far removed from 'normal' operations and one which is unlikely to be commercially sustainable for any significant period. However most are likely to be preferable to 14-day quarantine periods. These new protective layers do provide a potential pathway towards recovery and reconnection. It is likely that as the pandemic evolves, there will be a stratified approach which employs more measures to routes, or passenger groups, which entail higher risk at the time.

Summary: A multi-layered approach will almost certainly be required to allow scaling up of aviation.

Temperature screening

Fever (elevated core body temperature) is a sign of COVID-19 in many people who develop symptoms, but by no means all the infectious population, and temperature fluctuates even in those who experience fever. Surface skin temperature measurement is less reliable than core temperature, but is much faster and more affordable to implement, which is why it has been used at many airports. The various methods of measuring passenger temperature include handheld measuring devices which may be contact (eg aural) or contactless, remote thermal scanning, and newly developed devices with cameras which are apparently able to measure temperate, pulse and respiration rate from a distance.

Temperature screening has been employed at both departure and arrival. It will miss many of those with early illness, asymptomatic illness, those whose symptoms do not include fever, and in some cases, those who have taken antipyretic medication (such as acetaminophen/paracetamol) to lower their temperature. It has been documented however, that in the early stages of the COVID-19 pandemic, several new cases were detected in passengers who underwent routine temperature checks after arriving at their destination.

Survey research during the COVID-19 outbreak has indicated that airline passengers are reassured by temperature screening undertaken in airports. It may also have an effect of deterring passengers who might otherwise travel when feeling unwell.

Temperature screening needs to be done with validated equipment, and if done manually, by staff who have appropriate training and personal protective equipment (PPE). Safe systems need to be in place to manage those who are test positive on the screening. IATA maintains that it should not be the role of airline staff to carry out such screening.

Even under these conditions there will be false positive and false negative results. Temperature (and other) screening is more likely to be useful in populations where COVID-19 prevalence is higher (such as returned travelers) than in low-prevalence groups such as the general travel population. To this end, it is usually combined with a symptom questionnaire (see below).

Thermal imaging of the tear duct has been shown to provide a reliable estimate of core temperature, and has been automated using artificial intelligence applications. False positives due to exertion (or exposure to hot outside conditions) can be reduced by re-measuring those who test positive on an initial screen.

Summary: Temperature screening has deficiencies and should be undertaken with appropriate precautions and using the most up to date methods. It is expected to be of benefit, applied selectively along with other measures such as symptom screening.

Symptom screening

Many countries have been using a questionnaire to ask travelers about symptoms (usually fever, cough, breathing difficulties) as an added screen to detect people possibly currently suffering from COVID-19, usually upon arrival; a declaration of symptoms could also be added to a nation's electronic visa process as another layer of protection prior to travel. Some questionnaires include questions about symptoms such as loss of taste or smell which are very specific to COVID-19 compared with other conditions. Effectiveness obviously depends on the honesty of the answers but it is likely that travelling while symptomatic is less likely to occur now than it was early in the pandemic when public knowledge of the risks was more limited. Furthermore, being required to make a declaration of being symptom-free could provide a deterrent to travelling while unwell. Various groups are developing electronic applications which can assist with screening for symptoms, often in conjunction with applications to facilitate contact tracing. It is noted that many countries already had symptom screening in place when the virus was imported; many studies have now documented the level of asymptomatic spread, which contributes to transmission and limits the usefulness of symptom screening.

Summary: Symptom screening is a necessary measure but has limitations; it may be an effective adjunct to other measures such as temperature screening.

Use of masks and PPE

The primary method of spread of COVID-19 is exhaled droplets, with a secondary method of spread from those droplets via surfaces and hands. There is ongoing research into the level to which smaller aerosol particles, which can remain suspended for longer times or distances, contribute to spread. Early in the pandemic, WHO advice was to prioritise mask use for those unwell or those who are caring for those who are unwell. Increasingly, authorities have been promoting or requiring the use of non-medical face coverings for those who are in public, especially in situations where physical distancing is not possible. This "source control" strategy is intended to protect the public from the wearer, by creating a physical barrier to the exhalation of droplets and/or aerosols. Studies increasingly suggest that such use of face coverings is effective at reducing spread, and more recently there is evidence that they may be effective not only as source control, but also at protecting the wearer. Advice is publicly available on how to create suitable masks from cloth, in situations where disposable surgical masks are in short supply.

As the pandemic has progressed, more aviation authorities have encouraged or required passengers to wear face coverings and required crew members to use surgical masks, with appropriate instruction and training, and disposal methods, and associated with meticulous hand hygiene. It is reasonable to require mask use for those airline workers in situations where physical distancing cannot be ensured (not just crew but also gate staff, ground staff who board the aircraft, etc) until, according to official public health advice, risk is judged to be sufficiently reduced. Many countries have gone further and required more extensive PPE for cabin crew. Passengers, and in most situations crew, do not require N95 (P2) or N99 masks which are designed for use in a contaminated environment such as in healthcare settings, and are very uncomfortable with prolonged wear. In fact, N95 "respirator" masks with an expiratory valve should not be worn on board as they allow a jet of droplets to be ejected.

Masks are not an infallible protection but form one crucial element of an overall set of measures. They are expected to significantly reduce the chance of on-board transmission. The types of masks required for passengers needs to be specified, and clear guidance provided on the limited circumstances in which an exemption might be allowed.

Summary: Face coverings for passengers along with suitable PPE (at least, surgical masks) for crew and other airline staff are a useful element of a multi-layered protection strategy.

Physical distancing

Beyond isolating those who are unwell, the mainstay of interrupting the spread of COVID-19 in the community is preventing people from having close contact with each other, since the most efficient method of spread is by inhalation of exhaled droplets from an infected person.

This is believed to be most likely when coughing, sneezing or talking loudly, face to face. All of the measures employed currently around the world to slow the spread make use of maintaining distance between individuals as much as possible, and guidance around the ideal distance ranges from 1-2 metres (3-6 feet). It is possible to modify airport check-in, immigration, security, departure lounge, and boarding processes in such a way as to ensure such physical distancing, and both ICAO and the Airports Council International (ACI) has published guidance on this.

On board the aircraft, it is difficult to achieve such a high degree of distancing, unless the aircraft loadings are so light as to be uneconomical. However, other protections are in place including the fact that people all face the same direction rather than face-to-face, they generally remain in their seat after boarding, except to visit bathrooms. Additional engineered protection is derived from the physical barrier of the seat backs, and the direction of cabin air flow which is generally from ceiling to floor, at a much higher rate than in public buildings, with little fore-aft flow. Contamination of the supplied air is reliably avoided by the presence of HEPA filters, which are installed in those modern jet airliners which use recirculation. The greatest challenges for distancing may relate to when passengers are moving, particularly boarding, disembarking, and using bathrooms. During boarding, in many cases, neither the APU or ground power supply is operating, and therefore the air supply is provided from the ground rather than the aircraft's own environmental control system, which may mean reduced air flow and purity during that phase.

Physical distancing measures currently in use by airlines include: management of the boarding process to minimize passengers passing each other; limiting carry-on baggage; sequenced boarding (rear first, window first); allocation of bathrooms for each area; co-ordination of bathroom visits (allowing only one passenger at a time to go to each bathroom). Interactions of crew and passengers face-to-face are avoided by pre-placing service items (food, water, and trash containers) on seats before boarding. Finally, as is recommended by WHO in situations where physical distancing cannot be maintained, these measures are supplemented by the wearing of face coverings or masks by passengers and crew alike.

That leaving empty seats could further reduce risk is expected, since it would limit the total number of passengers on board to around 62% (depending on aircraft configuration) of the normal maximum. However, alternate seat blocking does not achieve the required physical distancing employed in other settings and participants would still be in the breathing zone of others. If the risk of this phase of the journey (seated on board) is lower that other phases (airport, boarding, arrival, etc) then this measure will not contribute significantly to overall risk management. There is a reasonable body of published literature on the nature and risk of droplet spread in the cabin air environment, but this is a complex area to study given the many factors including passenger movement, individual differences in droplet exhalation (taking into account factors such as speech, coughing, and movement on board as well as use of different types of face coverings). Intense study is currently under way employing review of previous research, new computational modelling, and planning for simulation studies.

Some airlines are currently, while load factors are low, also achieving a degree of distancing by leaving every second seat empty, or similar; however on a sustained basis, this scenario this would be economically unviable. Given the data presented above regarding in-flight transmission from passenger to passenger, its justification is questionable. There may however be benefit in leaving empty seats in the region where crew are seated (in their jump seats) face to face with passengers, or in situations where passenger seating is face to face within the breathing zone.

Summary: Physical distancing on board can be achieved to a large degree especially during the airport processes and boarding, but leaving large numbers of empty seats on a routine basis is probably unsustainable, and looks likely to be unjustified given the low rate of transmission on board and to the protections which were designed into the cabin environment. Further protection is derived from universal mask use as outlined above.

Cleaning and Disinfection

While the primary route of transmission is direct respiratory droplet spread (exhaled and then inhaled), fomite transfer via surfaces and hands is also considered to be important, and in addition to the primary preventive tool of hand hygiene, cleaning and disinfection of frequently/recently touched surfaces is advised by WHO and other health agencies. Concern has been heightened by research indicating potential virus survival on a range of surfaces for up to a few days. However, the presence of virus does not necessarily equate to a biologically important dose, and how quickly the risk of fomite transfer declines over time is still to be determined. Cleaning with normal agents such as alcohol 60% is very effective at destroying the virus on such surfaces, and other agents such as quaternary ammonium compounds, commonly used in aviation, are also effective; manufacturers have updated advice on compounds to be used.

On the aircraft, there is potential for transmission in this manner particularly on short-haul flying where rapid turnarounds have previously prevented extensive cleaning between sectors. Many airlines have increased the frequency and extent of their routine cleaning. Some regulators (including China CAAC and EASA) have recommended particular cleaning procedures as a routine. It is likely that improved routine cleaning provides reassurance to passengers, whether or not it reduces risk of transmission. Another possibility which has been adopted for rapid turnaround flights is for passengers to be given material (alcohol wipes etc) to use on the surfaces in their seat area, so that they know it is freshly disinfected and have some agency in the process; this has been shown to be reassuring for passengers. Some airlines are applying disinfectant through electrostatic "fogging" devices. Surfaces should be cleaned prior to disinfectant application, and given sufficient "dwell" time. There are other potentially promising methods of disinfection such as UV light and gaseous ozone, which are beginning to be evaluated or adopted in the airline setting.

Summary: Cleaning and disinfection procedures, in excess of the previous norms, form an important part of the range of measures required in scaling up aviation operations and improving passenger confidence.

COVID-19 Testing

Background: An increasing number of regions/countries have introduced testing into the requirements for travelers, either before departure (perhaps incorporated into an electronic visa process), or after arrival. In discussing testing, it is important to identify two related but different objectives: the first is preventing passengers travelling while potentially infectious. The second and more challenging one is preventing travelers from entering the destination while incubating, and then becoming infectious after arrival.

The viability of testing as part of normal passenger processes needs to consider four main factors: reliability, speed (at scale), timing, and acceptability to passengers. All medical testing has limitations. The mainstay of testing for current infection (presence of virus) in the general community is a reverse-transcriptase polymerase chain reaction (RT-PCR) test which involves taking a swab of the upper throat and amplifying the genetic material in a laboratory until it can be detected and confirmed. This method achieves high reliability but not speed (requiring at least some hours and sometimes days) because of the time required to extract and amplify the genetic material. Most RT-PCR testing has been done on the basis of swabs of the throat through either the nose or mouth.

When considering testing technologies as part of the travel process, the first consideration is reliability: whether the tests would have demonstrated adequate reliability when compared with standard PCR technology. In order to act as a screen acceptable to the relevant public health authorities, it is likely that firstly, they would require a very low false negative rate (ideally less than 1%); however, for the aviation setting it is also very important that there is a very low false positive rate, because any significant percentage of false positives will result in large numbers of passengers having to cancel their travel when the result is received. This reliability performance needs to be certified by reputable national or international agencies, whether scientific, therapeutic, or public health.

An important consideration is the timing of testing: even PCR can miss some people with the infection, particularly early in the illness, if the person has recently been infected and is still incubating; there will be a window during which the person may become infectious (and turn positive), AFTER testing. Pre-departure testing means that more of this window occurs in the departure location, and it also opens an opportunity for becoming infected after testing, and prior to departure. Post-arrival testing means that more of the delay occurs in the arrival country and the person could infect others while the result is awaited, unless isolated.

Another limitation, even of PCR, is the converse problem: late in the illness, or when recovered, it appears that a small percentage of people continue to test positive (due to viral remnants) without actually being infectious, so this represents a false positive which is problematic for non-infectious travelers, whether it occurs in their own country or a foreign country for them.

Some States or pairs of States have approved travel processes incorporating two tests, one before departure and another after arrival, to close these windows.

For the specific purposes of ensuring safe travel, the ideal time to test is as close as possible prior to travel. It might appear that for convenience and simplicity, this would be best done at the airport of departure. However, this depends on the next factor which is speed. With all PCR tests there is a delay waiting for the result – which is at best around two hours with laboratory batch tests, and possibly as little as 45 minutes for the latest RT-PCR point-of-care tests. In an airport setting this speed would need to be achieved at large scale, many hundreds of tests per hour. Even in the best case, this is likely to make testing at the departure airport unviable because of backlogs and delays at the airport. It also introduces the risk of people introducing infection to the airport, it requires special facilities at the airport, and it allows for the possibility of highly disruptive last minute cancellations in the event of a positive test. For these reasons IATA has advocated testing before departure (in the last 48 hours before departure, to keep the window of uncertainty smaller). This leads to a need to have reliable, fraud-proof documentation of the test result in place.

Turning to acceptability: testing with throat swabs is somewhat invasive and uncomfortable, and requires the sample to be taken by a trained person (usually a health care worker such as a nurse) who is also equipped and competent with PPE. Saliva sampling has recently become available and approved for diagnostic use with PCR tests. It is minimally invasive, and potentially self-sampled (as it is with at-home tests), presenting an attractive option for passenger screening, either at the airport, or outside the airport before departure. Saliva-based PCR testing is starting to be adopted in community settings, most notably at London Heathrow.

Many alternative technologies are now either in development or available, which can either rapidly amplify the genetic material, or can use other components of the virus (antigens) such as surface proteins. In order to be able to be used as part of the airport process (either departure or arrival) they would need to be able to perform at speed (results within minutes) but also at sufficient scale (hundreds of tests per hour) for this to be practical. Existing tests would achieve this only at the cost of some reliability. However, there is scope for using <u>two</u> tests to compensate for this loss of reliability. This is also closely related to the discussion on quarantine below.

Summary: Rapid point-of-care testing is an important potential extra layer of protection. Technology for rapid on-site PCR tests, molecular tests and alternative antigen tests, is advancing rapidly, and if validated by a reputable scientific organization could be an additional layer of protection. Existing PCR tests would probably need to be conducted prior to the airport; if testing in an airport setting was considered, it would need to be
- validated by a reputable National scientific, therapeutic, or public health agency, to achieve

less than 1% false negatives and the lowest possible false positive rate compared with PCR;
- deployable in an airport setting, preferably using saliva and able to be sampled without use of PPE;
- capable of scaling to achieve hundreds of tests per hour, with results well inside one hour.

Antibody Testing

Many serological (antibody) tests for COVID-19 have been developed. These typically use a blood sample which can be obtained from a finger-prick. Detection of antibodies early on can confirm current or recent infection and later on, can confirm immunity. The detection of antibodies could, once validated, be used to indicate that someone is able to travel without risk of either contracting or transmitting infection (see below). Antibodies are not detected early in the infection and are therefore not useful for diagnosis, except in some specific cases in conjunction with PCR tests. Some countries have not licensed antibody tests for clinical use.

There are many epidemiological estimates that the number of mild recovered cases could greatly exceed the number of confirmed cases, and with suitable widespread serology (antibody) testing, there may be a large enough population of recovered and immune individuals. Indeed, many serology studies of closed communities (small towns, ships, etc) have shown a high proportion of individuals to have been infected – however, in larger population studies the highest proportions have been around 20% which is insufficient to provide a significant population of immune individuals.

It also remains unclear for how long immunity is maintained or its extent; some coronaviruses generate relatively short-lived immunity and therefore this is not yet a reliable protection. If antibody testing were adopted for use in connection with an "immunity passport" (below), the testing would initially need to have a short "validity" since the duration of immunity would not be known. Furthermore, WHO advice has consistently been that there are no validated and reliable antibody tests available for use on an individual level, and that such tests should be used only for studying populations to understand the nature of the pandemic and its transmission.

Summary: This is not yet a reliable tool other than for epidemiological study. It has potential in the aviation setting only when validated and supported by major health bodies such as WHO, and with further experience.

Immunity Passports

This concept arises from the fact that once someone has recovered from a viral infection (or in future, having been vaccinated), they normally retain immunity; there is evidence from animal and human studies to suggest that immunity to COVID-19 will be retained at least for some months. The concept of immunity passports is that if someone can be documented as having recovered from COVID-19 (or in future, having been vaccinated) they are presumed to be immune, therefore many of the normal protections would not be required; this would mean that by showing their documentation (or incorporating it into a prior electronic visa process), they could achieve the airport, boarding and on-board processes bypassing many of the protective steps such as face cover, temperature checks etc. Those airport staff and aircrew who were immune could similarly omit many of the requirements, including for PPE and physical distancing.

The main difficulty is that even now, the proportion of the population who are recovered cases is very small – serological surveys have typically shown less than 10% of the population with evidence of immunity, although more recently some locations have shown around 20%. Furthermore, a proportion of those cases have been diagnosed clinically rather than with laboratory confirmation, and Governments would be unlikely to require laboratory documentation before granting such a passport, which would make the population even smaller. Although these levels would not be enough to allow a significant scale-up of aviation, they are likely to increase as the pandemic progresses, and it is possible that the population of immune people may eventually become big enough to make this a more viable proposition.

There are also important potential unintended consequences of such a measure. For example, granting of privileges to those who have recovered could incentivize people to contract the disease. This "perverse incentive" could tempt people to deliberately expose themselves, and thereby undermine public health measures and propagate the pandemic.

Summary: Limited potential unless global spread continues to a large proportion of the population. Some risks as ongoing immunity is not assured; unwise at the current time.

Quarantine

One of the key measures which is being imposed by governments is a period of quarantine for incoming travelers – almost universally 14 days, to exceed the 12 days which is considered the maximum incubation period. There are considerable logistical difficulties and cost in implementing quarantine, to ensure all needs of transport, accommodation, food, exercise, and communication are met, and there is no cross-contamination between those in quarantine including the staff. In most cases, the quarantine is accompanied by COVID-19 testing so that the measure is not solely dependent on people recognizing and reporting symptoms.

While this can be an effective means of ensuring any imported cases do not spread, it is known to be a major disincentive to travel, particularly if required after both (outbound and return) legs of an international journey. In some countries, the availability of quarantine facilities is a limitation on even the numbers of nationals who are able to return home, and it is therefore a major obstacle to travel.

If traveling from an area of low risk to one of high risk, then it is difficult to support an argument for quarantine on arrival.

In situations where travel is between two countries with similar levels of community transmission in the community, any travelers who had been COVID-19 tested negative (with PCR or equivalent testing) upon departure, would be of lower statistical risk than the non-tested members of the surrounding community, so the argument could be advanced that they should be subject to no more restrictions than the others in the community.

Even when travel is from a community with higher transmission risk than the destination, negative testing on one or more occasion could in many cases reduce the risk to a lower level than the community in the arrival destination, and therefore testing procedures could be one of the considerations against which to balance a decision about quarantine. There is evidence to show that one negative PCR test reduces the risk of an undetected positive case by 10%, and that a second test (a few days apart) further reduces it to 1% of the original risk. This goes alongside the measures adopted during travel as outlined in the ICAO "Take-off" recommendations, including discouraging symptomatic passengers from travelling; health declarations including symptom screening and temperature screening; on-board hygiene and disinfection; airport distancing procedures; mask use on board; and contact tracing measures after arrival.

These are all questions for the government of the destination country to resolve. IATA advocates for application of a risk-based analysis to both the epidemiological situation and also the mitigation measures. In many cases quarantine could be avoided.

Summary: Quarantine is a major inhibitor of travel and on a careful analysis of the risks, governments may determine that it can safely be avoided in many scenarios. If prevalence of infection of arriving passengers is less than or equal to the local prevalence, quarantine could be eliminated. Even if it is greater, the use of testing can lower the risk to a level which permits quarantine to be shortened or avoided.

Measures to assist contact tracing

Although the prime objective will be to prevent anyone travelling while infected, an important back-up to this is the ability to rapidly identify and trace the contacts of anyone who, after travelling, is discovered to have been infected during travel. Measures to assist and facilitate such tracing have been employed as part of arrival procedures in a number of countries. They could be as simple as providing contact details for follow-up if required. In many cases these have made use of technology such as phone applications which, with the user's consent, allow their movements and even their close contacts to be traced and tracked. The use of such technologies could be a condition applied by governments to allowing international (or indeed domestic) travel in a scale-up of aviation. A further element to this would be ensuring early reporting of any instances where passengers are unwell in flight, with symptoms consistent with COVID-19. Ground-based medical services could have a role here in ensuring public health processes are triggered.

Summary: Procedures, and technologies, for contact tracing are likely to be part of the suite of measures introduced.

Measures related to crew members

In the current operations, aircrew (pilots and flight attendants) are almost the only people travelling regularly between countries. On long-haul sectors, it is necessary for them to layover at destination. Governments and health authorities allow this to occur contingent on strict procedures to prevent them becoming infected while on layover, and increased passenger traffic will also depend on them being maintained. These measures include social distancing (e.g. being confined to a layover hotel, having meals delivered), use of masks, special arrangements for transport, and temperature/symptom checks; they are encapsulated in the ICAO CART "Take-off" guidance. Increasingly, COVID-19 testing is also part of the picture; the risk assessment for crew is different from that for passengers, and the testing approach may also be different. For example, there is scope for use of lower efficacy, non-invasive, point-of-care tests which are inexpensive enough that they could be repeated daily, during and following a tour of duty for each crew members. In some countries, the approach of daily testing has been adopted in other occupational groups such as factories and mine sites.

There are also a range of in-flight procedures related specifically to crew aimed at preventing transmission between passengers, or between crew and passengers; both the "Take-off" guidance and separate IATA documents detail these. With the use of these measures, which include testing, countries could avoid the need to apply the same quarantine requirements as are imposed on passengers.

Summary: Procedures for crew in flight and during layover form a significant part of the required measures to allow aviation to be scaled up.

Treatment

If a medical treatment became available which drastically and reliably reduced the mortality and severity of disease (or even better, to act as an effective prophylaxis against infection) then the concerns of both Governments and travelers would be massively reduced, potentially leading the way a resumption of travel. No such measures are currently available but there are some treatments which have been shown in research trials to be moderately effective, and more are being researched.

Summary: Potentially a major help but not yet a solution to the threat.

This multi-layered approach, incorporating most of the above possible protective measures, is proposed as a pathway for aviation recovery.

Reference Links

Testing and Immunity

https://www.who.int/news-room/commentaries/detail/advice-on-the-use-of-point-of-care-immunodiagnostic-tests-for-covid-19
https://www.cebm.net/covid-19/comparative-accuracy-of-oropharyngeal-and-nasopharyngeal-swabs-for-diagnosis-of-covid-19/
http://publichealth.lacounty.gov/eprp/lahan/alerts/LAHANCOVID041620.pdf
https://www.tga.gov.au/covid-19-point-care-tests
https://www.rcpa.edu.au/getattachment/6a74686a-e558-4efa-bc6c-a9921b7837df/RCPA-advises-against-COVID-19-IgGIgM-rapid-tests-f.aspx
https://jamanetwork.com/journals/jama/fullarticle/2764954
https://science.sciencemag.org/content/early/2020/04/14/science.abb5793.full
https://www.fda.gov/news-events/press-announcements/coronavirus-covid-19-update-serological-test-validation-and-education-efforts
https://www.gov.uk/government/publications/national-covid-19-surveillance-reports/sero-surveillance-of-covid-19
https://science.sciencemag.org/content/early/2020/05/19/science.abc4776.full
https://www.ams.edu.sg/view-pdf.aspx?file=media%5c5558_fi_168.pdf&ofile=Period+of+Infectivity+Position+Statement+(final)+23-5-20.pdf
https://www.nejm.org/doi/full/10.1056/NEJMp2015897?query=TOC
https://www.medrxiv.org/content/10.1101/2020.05.30.20117291v1.full.pdf
https://www.medrxiv.org/content/10.1101/2020.06.13.20130252v1.full.pdf
https://www.nature.com/articles/s41591-020-0965-6 Immunity short duration possibly
https://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736(20)31357-X.pdf Herd immunity vs controls
https://www.medrxiv.org/content/10.1101/2020.06.22.20136309v2.full.pdf Daily testing
https://www.medrxiv.org/content/10.1101/2020.07.24.20161281v2 Shorter quarantine

Temperature screening

https://link.springer.com/article/10.1186/1471-2334-11-111
https://www.sciencedirect.com/science/article/pii/S0026286204000548?casa_token=STBdLK8i4OYAAAAA:O_liww5MDjh8yJ1v6GhyyxnoZ5Yz_9fplQsalRyDHigaGp8HJSBq0VNqoBxQ8s1MVNbUvNJ3fWA
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3294528/?tool=pmcentrez&report=abstract
https://science.sciencemag.org/content/367/6483/1177.full
https://www.researchgate.net/profile/James_Mercer3/publication/259066625_Fever_screening_and_infrared_thermal_imaging_Concerns_and_guidelines/links/5587f06208ae71f6ba918d0b/Fever-screening-and-infrared-thermal-imaging-Concerns-and-guidelines.pdf
https://www.eurosurveillance.org/content/10.2807/ese.14.06.19115-en
https://onlinelibrary.wiley.com/doi/epdf/10.1111/1742-6723.13578 Case Control

Masks/PPE

https://www.preprints.org/manuscript/202004.0203/v2
https://academic.oup.com/jtm/article/27/3/taaa056/5822103

https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/diy-cloth-face-coverings.html
https://www.canada.ca/en/transport-canada/news/2020/04/new-measures-introduced-for-non-medical-masks-or-face-coverings-in-the-canadian-transportation-system.html
https://smartairfilters.com/en/blog/comparison-mask-standards-rating-effectiveness/
https://cen.acs.org/biological-chemistry/infectious-disease/best-material-homemade-coronavirus-face/98/web/2020/04
https://academic.oup.com/jtm/article-abstract/doi/10.1093/jtm/taaa054/5820895
https://jamanetwork.com/journals/jama/fullarticle/2765525 Face shields
https://www.cdc.gov/mmwr/volumes/69/wr/mm6919e6.htm
https://www.thelancet.com/journals/lanres/article/PIIS2213-2600(20)30134-X/fulltext Masks
https://arxiv.org/abs/2005.03444
https://www.nejm.org/doi/10.1056/NEJMc2007800
https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)31142-9/fulltext
https://arxiv.org/abs/2005.10720 Masks
https://www.nejm.org/doi/full/10.1056/NEJMc2020836?query=TOC
https://ucsf.app.box.com/s/blvolkp5z0mydzd82rjks4wyleagt036 Masks bidirectional protection UCSF
http://dx.doi.org/10.1016/j.jhin.2013.02.007 Surgical masks and influenza

Spread

https://jamanetwork.com/journals/jama/fullarticle/2763852 https://reader.elsevier.com/reader/sd/pii/S016041202031254X?token=79F9307F93BA32E2DC7C8DF22DBD7129982E2358B43CBDBC86CCEE3102F8756A648F063656814DBD3A7F81D499B68169 Distance
https://academic.oup.com/jid/advance-article/doi/10.1093/infdis/jiaa189/5820886
https://www.biorxiv.org/content/10.1101/2020.03.08.982637v1.full Aerosol
https://jamanetwork.com/journals/jama/fullarticle/2766821 Aerosol
https://www.nejm.org/doi/full/10.1056/NEJMc2007942
https://www.nejm.org/doi/full/10.1056/NEJMc2007800 Droplets
https://www.nejm.org/doi/full/10.1056/NEJMc2004973 Surfaces
https://www.nature.com/articles/d41586-020-00974-w Airborne
https://www.mdpi.com/1660-4601/17/8/2932/htm
https://wwwnc.cdc.gov/eid/article/26/7/20-0282_article?deliveryName=USCDC_333-DM25287 R0
https://www.medrxiv.org/content/10.1101/2020.04.04.20053058v1.full.pdf Indoor Spread
https://wwwnc.cdc.gov/eid/article/26/7/20-0764_article Spread in a restaurant
https://wwwnc.cdc.gov/eid/article/26/8/20-1274_article Spread in a call centre
https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-College-COVID19-NPI-modelling-16-03-2020.pdf Modelling
https://www.thelancet.com/journals/lanres/article/PIIS2213-2600(20)30193-4/fulltext Eyes as a route
https://www.smh.com.au/national/it-was-very-joyous-to-get-out-first-quarantined-australians-head-home-as-36-others-test-positive-20200408-p54i9g.html
https://www.sciencedirect.com/science/article/pii/S016041202031254X
https://science.sciencemag.org/content/early/2020/04/24/science.abb5793.full Transmission dynamics
https://www.nejm.org/doi/full/10.1056/NEJMc2009316?query=featured_home Asymptomatic spread
https://www.nejm.org/doi/full/10.1056/NEJMoa2006100 Asymptomatic spread
https://www.bmj.com/content/368/bmj.m1165 Asymptomatic spread
https://www.medrxiv.org/content/10.1101/2020.03.05.20031815v1 Generation interval
https://www.medrxiv.org/content/10.1101/2020.04.17.20053157v1 Asymptomatic in small town
https://cmmid.github.io/topics/covid19/control-measures/pre-symptomatic-transmission.html
https://www.nature.com/articles/s41591-020-0869-5 Pre-symptomatic spread
https://www.acpjournals.org/doi/10.7326/M20-3012 Asymptomatic spread
https://www.nap.edu/read/25769/chapter/1#3
https://www.nejm.org/doi/full/10.1056/NEJMe2009758?query=RP
https://www.medrxiv.org/content/10.1101/2020.03.09.20033217v1.full.pdf Surfaces
https://www.thelancet.com/action/showPdf?pii=S1473-3099%2820%2930561-2 Surface spread low

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3551767 temperature and humidity
https://www.ashrae.org/file%20library/about/position%20documents/pd_infectiousaerosols_2020.pdf
https://wellcomeopenresearch.org/articles/5-67 Superspreading:
https://www.researchsquare.com/article/rs-29548/v1 Superspreading
https://covid.idmod.org/data/Stochasticity_heterogeneity_transmission_dynamics_SARS-CoV-2.pdf
https://arxiv.org/pdf/2006.08471.pdf Asymptomatic cases
https://academic.oup.com/occmed/article/doi/10.1093/occmed/kqaa080/5849370 Airborne spread
https://www.bmj.com/content/370/bmj.m2720?=&utm_source=adestra&utm_medium=email&utm_campaign=usage&utm_content=daily&utm_term=picture Airborne spread
https://www.medrxiv.org/content/10.1101/2020.07.13.20153049v1 Aerosol on cruise ships
https://arxiv.org/pdf/2005.10988v1.pdf Aerosols MIT

Transmission in flight

https://www.faa.gov/data_research/research/med_humanfacs/cer/media/InfectiousDiseaseTransmission.pdf
https://academic.oup.com/qjmed/article-abstract/doi/10.1093/qjmed/hcaa089/5809152
https://doi.org/10.1016/j.tmaid.2020.101643
https://www.cmaj.ca/content/cmaj/192/15/E410.full.pdf
https://www.pnas.org/content/115/14/3623.short
https://www.nownews.com/news/20200422/4046494/
https://www.nejm.org/doi/full/10.1056/NEJMoa031349
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7104167/
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3884702/
https://thanhnien.vn/thoi-su/nu-benh-nhan-thu-17-nhiem-covid-19-doi-cho-4-lan-tren-chuyen-bay-vn0054-1193094.html
https://suckhoedoisong.vn/cap-nhat-danh-sach-benh-nhan-covid-19-n171531.html?fbclid=IwAR2vMJxtjvrROWucek_hNK19l_Fniguinzhl986zKauNVNDz0rAatveGPgU
https://www.sciencedirect.com/science/article/abs/pii/S1477893920303124 Singapore China Chen
https://www.medrxiv.org/content/10.1101/2020.07.02.20143826v2.full.pdf Middle seat
https://www.medrxiv.org/content/10.1101/2020.03.28.20040097v1.full.pdf In-flight China Yang
https://healthtranslationsa.org.au/wp-content/uploads/2020/06/covid-19-evidence-update-how-safe-is-domestic-air-travel.pdf Review
https://academic.oup.com/cid/article/doi/10.1093/cid/ciaa1057/5877944 Spread on Trains

Management and Clinical

https://academic.oup.com/cid/article/doi/10.1093/cid/ciaa410/5818134
https://watermark.silverchair.com/ciaa354.pdf?token=AQECAHi208BE49Ooan9kkhW_Ercy7Dm3ZL_9Cf3qfKAc485ysgAAAmswggJnBgkqhkiG9w0BBwagggJYMIICVAIBADCCAk0GCSqGSIb3DQEHATAeBglghkgBZQMEAS4wEQQMWFDK...
https://www.cdc.gov/quarantine/air/managing-sick-travelers/ncov-airlines.html
https://www.cdc.gov/quarantine/air/managing-sick-travelers/index.html
https://www.cdc.gov/quarantine/air/managing-sick-travelers/commercial-aircraft/infection-control-cabin-crew.html
https://www.who.int/docs/default-source/coronaviruse/getting-workplace-ready-for-covid-19.pdf
https://www.cambridge.org/core/journals/journal-of-clinical-and-translational-science/article/clinical-characteristics-associated-with-covid19-severity-in-california/B58EB9C431C6404D867BF70DBCAEBA19 Features predicting severity
https://www.thelancet.com/action/showPdf?pii=S0140-6736%2820%2931096-5 Immunity Certificates
https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-covid-19-final-report.pdf

Mortality

https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(20)30195-X/fulltext#back-bib4
https://www.medrxiv.org/content/10.1101/2020.05.06.20092999v1.full.pdf+html
https://www.medrxiv.org/content/10.1101/2020.03.04.20031104v1
https://www.who.int/publications/i/item/WHO-2019-nCoV-Sci-Brief-Mortality-2020.1

Airline Procedures

https://www.iata.org/contentassets/094560b4bd9844fda520e9058a0fbe2e/quick-reference-guide-ground-handling-covid.pdf
https://www.iata.org/contentassets/df216feeb8bb4d52a3e16befe9671033/iata-guidance-cabin-operations-during-post-pandemic.pdf
https://www.iata.org/en/programs/safety/health/diseases/
https://apps.who.int/iris/bitstream/handle/10665/331488/WHO-2019-nCoV-Aviation-2020.1-eng.pdf
http://www.icscc.org.cn/content/details_49_3342.html
https://www.easa.europa.eu/covid-19-references
https://www.icao.int/Security/COVID-19/Pages/default.aspx
https://www.ncbi.nlm.nih.gov/books/NBK207485/