

# Screening for Infectious Diseases at International Airports: The Frankfurt Model

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Historically, ships brought infectious diseases to the continents of the world, but in this modern era, infectious diseases and pandemics are primarily spread through aviation as a mode of travel. This is a significant issue in the realm of infection control because of the increased potential for the rapid worldwide transmission and spread of disease. Although the transmission of infectious diseases to airline passengers inside an aircraft is a rare occurrence, it is essential to implement entry and exit screening procedures at airports within the context of the International Health Regulations (IHR) in order to slow down the spread of infection, especially during the early phases of a pandemic event. Currently, there are no standardized procedures for health screening at airports, thus allowing individual regional authorities to determine what they deem to be appropriate screening measures for implementation. In this paper, we will discuss a new pragmatic approach for entry and exit screening procedures at international airports, propose a new classification system for contacts within the aircraft, and discuss changing the fixed enforcement of standardized community mitigation measures to the implementation of measures that correspond to specific characteristics of individual pathogenic agents. The proposed catalog of screening measures is aimed at attaining the goals of the IHR, which states that the measures should be reasonable while avoiding inconvenience or harm to passengers and should not be any more disruptive to the smooth handling of passenger traffic than is necessary.

**Keywords:** entry screening, exit screening, international health regulations, SARS, WHO, color coding, public health measures.

**P**ANDEMICS WILL MOVE as rapidly as the vectors that transport the pathogen. In the case of human infectious diseases, transmission via ships has been replaced almost completely by air traffic. Today, global reach is readily attainable using nonstop flights and connections through just a few so-called hubs (like Frankfurt Airport) where up to 50% of the passengers are making flight connections that will bring them to their final destination. These hubs thus represent pivotal points in international air travel (10). As ports of entry for infectious diseases, they are of especial interest for public health service providers.

Mathematical models indicate that travel restrictions have a limited effect on the spread of infectious diseases (6,10). In addition, for political and economic reasons, these restrictions will be very difficult to enforce. Therefore, we will focus on appropriate preventative public health measures that could be implemented at international airports.

To develop such measures, it is essential to investigate patterns of infectious disease transmission and assess the effectiveness of past public health responses to the

causative agent. A good example of this can be found in the case of Severe Acute Respiratory Syndrome (SARS) and its ensuing rapid dissemination across four continents within 3 d by means of global air traffic, whereby it reached pandemic proportions. In this paper, we will use the lessons learned from the SARS event to draw conclusions about the modified airport procedures to be used in the event of a future pandemic.

An inoperative air conditioning/ventilation system creates a particular risk for infection transmission within the aircraft (3,13,25). In one such case, an aircraft was delayed on the ground for 3 h. As a result, 72% of all of the travelers on this flight became infected by a single passenger who was suffering from influenza. These co-travelers developed the symptoms of influenza within 3 d of landing (13).

Without an intact air conditioning system to provide ventilation and pressurization, modern aircraft are not serviceable. This may be a reason why, fortunately, the infection of airline passengers as a result of contact with infected co-passengers inside the aircraft seems to be a rare occurrence (1,3,11,12). The risk of infection increases when the aircraft is on the ground, the main engines are off, and the auxiliary power unit is not available for use (1,3,13).

In the case of SARS, there were four flights with documented transmission of infection directly related to the air travel (4,8,14,17,22–24). All of the affected flights originated directly from a so-called “area with recent local transmission” of the infection (20). During the SARS pandemic, at an early stage of the local outbreak, the primary intention was to prevent people who were already ill—and thus contagious—from departing (exit screening). To achieve such a goal, it is necessary to implement an effective health screening procedure for passengers before their departure. On the other hand, passengers

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arriving at their destination airport may need to be screened (entry screening) whenever there is suspicion that the exit screening procedure in the affected departure country has been insufficient. This can be especially important during the early phase of a pandemic, when such measures can be made mandatory within the context of the International Health Regulations (IHR), which became effective on June 15, 2007 (18). In Annex 1 of the IHR, entry and exit controls are required as core capacities for designated airports “for responding to events that may constitute a public health emergency of international concern” (18). In this way, international airports must be prepared to manage pandemics and other infectious disease emergencies.

The Frankfurt Airport in Germany, as a major airport traffic hub, has the potential to facilitate the worldwide dissemination of infectious diseases (10). Taking into account our experience in pandemic management in Frankfurt, this paper describes the World Health Organization (WHO) recommendations and the present situation regarding pandemic management at all major airports. Based on discussions involving practical experiences with SARS and other highly infectious diseases, as well as problems associated with traveler contact tracing, proposals concerning the optimization of infection control procedures at international airports will be made.

#### *Historical Lessons: SARS*

The WHO made recommendations for the identification of contacts aboard aircraft during the SARS pandemic in 2003 which were applied worldwide (16,21). In these recommendations, only two groups of contacts and other passengers are distinguished. The relevant WHO wording for SARS cases reads (21):

##### *“Contacts*

1. All contacts of the ill passenger should have already been identified during the flight. For the purposes of air travel a contact is defined as:
  - passengers sitting in the same seat row or within at least 2 rows in front of or behind the ill passenger;
  - all flight attendants on board;
  - anyone having intimate contact, providing care or otherwise having contact with respiratory secretions of the ill passenger;
  - anyone on the flight living in the same household as the ill passenger;
  - if it is a flight attendant who is considered to be a suspect or probable SARS case, all the passengers are considered to be contacts.”

*Other passengers:* “As a precautionary measure, passengers and cockpit crew not defined as contacts should also provide to the health authorities identification and address/contact details valid for 14 days after the flight...” “...These passengers should be free to travel unless they develop any symptoms compatible with SARS.” (21).

#### *SARS Cases in Germany Due to Infections Aboard Aircraft*

Of the nine SARS patients in Germany reported to the WHO, three patients met all of the WHO ‘diagnostic’ criteria, including evidence of the virus, and were thus

confirmed cases. The first two SARS cases in Europe, a nosocomially infected physician from Singapore (the index case) and his wife, were successfully treated in Frankfurt (15). The third case was a German patient who, on his flight from Singapore to Frankfurt, sat one row in front of the Frankfurt index patient while the latter was flying from Singapore via Frankfurt to New York to attend a congress. On this flight, the index patient was already symptomatic, but without a cough. Genome analysis confirmed that the strains of the German patient and the index patient from Singapore were identical (personal note: this is unpublished information by Lawrence Stanton, SARS Congress, Lübeck, 2004). On the index patient’s return flight from New York to Frankfurt 2 d later, a flight attendant became infected, although “the contact of the stewardess with him was brief and only involved serving and picking up the food tray.” (23). Interesting in this respect is a study regarding the transmission of SARS on a scheduled flight from Hong Kong to Beijing (14). In this case, the number of infection transmissions that occurred across the entire aircraft cabin was strikingly large. Furthermore, a member of the cabin crew who had worked the first class section without any known contact to the index case also became infected.

#### *General Problems with Identification of Contacts Aboard the Aircraft*

*Seat rows:* The circulating air-conditioning system of an aircraft could be a relevant factor in averting the longitudinal dissemination of an infectious agent (3,25). However, in the horizontal direction, the distance between the index case and the contacts seems to be a key point in the transmissibility of infectious agents (3,11,17). We believe the current definition, which singles out as contacts in an aircraft all passengers sitting in the same row and two rows ahead and behind the index patient, is too general (4,21). Depending on the aircraft type, there can be various patterns and numbers of contacts: e.g., with a Canadair CRJ 100, a total of 20 patients would be classified as contacts; with an Airbus A319-100 30 or a Boeing B747-400, there would be 50 contacts. With larger aircraft, it is even more questionable whether the passengers at the end of the affected seat row are more likely to be infected than, perhaps, those in the third row in front of or behind an index case. If, for example, the index patient aboard a Boeing B747-400 is sitting on seat 27A, the seat’s distance from seat 27K in the same row is considerably longer than that from seats 24A–30A, which would not be covered. The new wide-body aircraft (e.g., Airbus A 380 X) will have even more seats per row. Overall, the individual risk of acquiring infection is certainly much higher on a small aircraft than on the larger airplanes.

*Aircraft manifests accuracy:* Gaps in the identification of persons who have had contact with an index case occur for several reasons. Often, passenger lists obtained from the airlines are incomplete, which leads to gaps in the identification of persons having had contact with an index case, especially if the latter is detected only after

they leave the aircraft (4). Additionally, passengers frequently do not occupy the seats assigned by ground personnel. Or, as in the case of some “low-cost carrier” airlines, there are no fixed seat assignments. Therefore, the misclassification of contacts according to the definition described is inevitable.

*Epidemiological features of the agents and their impact on community mitigation measurements:* Passengers may be healthy at the time of boarding the aircraft and then develop symptoms of an infectious disease during the flight. The probability of this occurring is greater in the case of diseases with short incubation times (e.g., pulmonary plague, influenza, SARS). This is particularly possible during long-distance flights. When it is necessary to change aircraft, it is possible, for example, that a passenger who contracted pulmonary plague just before he began his trip will develop symptoms within 10 to 12 h after entering the aircraft. With the onset of symptoms, he is contagious and poses a threat of infection to other passengers. Therefore, the decision of whether the contact person may continue on his journey to his destination depends on the length of the flight and on the transmissibility features of the infectious disease, such as the incubation period and contagious period.

With SARS, transmission occurs through close direct contact with droplets from the infected person’s respiratory tract containing the virus. Data show that only symptomatic patients harbor a risk of transmission (4,14). One can thus clearly define when a passenger may have infected his or her fellow travelers.

This is not the case in all human-to-human transmissible diseases. With influenza, for example, patients can be contagious up to 1 d before the onset of symptoms and even earlier in the case of children. This shorter period of time significantly hampers the detection of infectious suspects during entry and exit screening processes. The definition of the contagious period then becomes as arguable as the identification of contacts. As soon as an ill person on board is apparently suffering from a potentially infectious disease, the basic rule should be that all possible measures will be taken during the flight to limit the potential for transmission. This includes the measure of isolating the sick passenger in an empty seat row, giving her/him a facemask, etc. (16,20).

*Color coding for entry screening in Asia:* To simplify the subsequent procedures for contacts, a method described as “color-coding” was developed for the Hong Kong Airport. This method was based on inspecting the passengers while they were still on board the aircraft as soon as it reached the parking position after landing. Depending on the type of aircraft, at least two members of the medical staff (as a rule, a physician and a paramedic or nurse, all with personal protection equipment) board the aircraft, interview the flight attendants, inform the passengers about the disease, and then inspect the passengers while they are still in their seats. If the cabin crew reports a suspicious case or the screening team discovers a passenger with the suspected disease, that passenger is given a facemask and marked using a red sticker. Family members, co-travelers on the same

tour group, and the flight attendants who took care of the patient(s) are marked with an orange sticker. Yellow is reserved for the contacts in the two rows ahead and behind, as well as for those in the same seat row as the patient. All other passengers are given green stickers.

#### *Proposals for Exit and Entry Screening Procedures (Frankfurt Model)*

With the publication of the IHR (2005) by the WHO, capacities for exit and entry screening became mandatory in certain situations for the member states (18). It is up to the regional authorities to determine and implement appropriate screening measures. According to the IHR, these measures should, however, be reasonable, so as to avoid unduly inconveniencing or even harming passengers, and should not disrupt the smooth handling of passenger traffic more than is necessary (16,18). The following catalog of proposed measures developed in Frankfurt is aimed at attaining these IHR objectives. It could also be used as a foundation for standardized procedures at other designated international airports.

*Exit screening:* Exit screening must be performed in a country where an epidemic or pandemic has emerged (18). However, there are currently no recommendations from the WHO, the airport working groups, the airlines, or the authorities on how to manage exit screening. We, therefore, propose the following model: screening measures will be limited to passengers on international flights. “Meeters,” “greeters,” and airport employees are not included in this procedure but will instead be segregated from passengers immediately upon entering the terminal by appropriate routing. A total of four groups are defined as follows:

1. Passengers with paper tickets;
2. Passengers with electronic tickets;
3. “Meeters and greeters”; and
4. Employees.

The paper ticket and ID of the passenger in question will be checked in front of the terminals (prechecking). Passengers with valid tickets will go directly to the medical screening, which is located at designated terminal entrances. If the medical screening clears the passenger for travel, s/he will receive an official stamp that allows him or her to continue to check in for his or her flight.

Passengers with electronic tickets will go to designated check-in counters, initially without medical screening, to pick up their final tickets. They will subsequently be directed to the medical screening location. Once they receive medical clearance, they may proceed and check in for their travel.

The main advantage of this procedure is that passengers will not submit their checked baggage for processing before the medical screening. If medical screening is performed after check-in, rather than before, the checked baggage of any ill person would have to be traced for removal. In a worst-case scenario, the whole baggage compartment of the aircraft might need to be unloaded.

The medical screening is intended to detect ill passengers or suspect passengers. The form and scope of the

examination must, therefore, be adapted to the underlying infectious disease. In principle, the following options can be applied at the medical screening station:

- Health questionnaire.
- Temperature scanning (e.g., non-contact infrared forehead thermal imagers, non-contact infrared thermal imagers or ear temperature measurements). Infrared thermometry had a sensitivity of 0.82 for the detection of fever, which was defined as tympanic temperature of  $> 38^{\circ}\text{C}$  in 2026 patients of an emergency department (9), where the corresponding negative predictive value was 0.99. In a population of travelers with an even lower prevalence of fever, infrared thermometry will satisfy the requirements as a screening method.
- Medical inspection (e.g., skin/eyes/throat/general condition ...).
- Medical examination (specific to the typical symptoms associated with the specific agent).
- A back-up medical system will be installed in the terminal, where "suspect" or other unclear passenger cases can be supported on short notice within the immediate vicinity of the screening stations. The back-up station is staffed by an experienced physician, a medical assistant, a secretary, and at least two persons from the security service for protection. Passengers discovered with symptoms of a relevant disease should be sent to the medical staff at the airport clinic accompanied by security personnel. There they will be subjected to further testing or will be sent to a designated clinic with a department for infectious diseases. The number of "meeters and greeters" should be reduced to the absolute minimum by early-stage information through close cooperation with the media. Airport employees are not subject to the medical screening procedure.

*Entry screening:* While exit screening essentially identifies diseased persons to prevent them from exposing other passengers to infection, entry screening takes place after other travelers have potentially been exposed. Therefore, it may involve contact tracing and, subsequently, measures such as quarantine. Balancing the need for public health measures with the requirement regarding the smooth handling of passenger traffic according to the IHR may become very demanding.

Diseases of close association but with limited infectiousness, like TB or meningococcal meningitis, are rarely transmitted to fellow passengers on long-haul flights. According to WHO recommendations, passengers in the same row as an index case with infectious tuberculosis, and those two rows in front and those two rows behind, are considered to be close contacts if the flight is 8 h or longer (5,19). Those potentially exposed to TB should undergo follow-up testing for tuberculosis infection.

In the case of more infectious diseases such as SARS or influenza, we believe that transmission is more likely to occur at the airport before or after, rather than during, the flight. This would be due to the persons' close proximity to an infectious individual and the reduced level of ventilation compared with on-board ventilation. Possible routes of infection include:

1. Before boarding the aircraft
  - En-route to the airport by public transport
  - In line at the check-in counter
  - Waiting in the gate area
  - Access to the aircraft via "jetways" or transport to the aircraft by bus
  - Other crowded and confined spaces
2. After leaving the aircraft

- Passport control and customs
- Waiting in the baggage claim area
- En-route from the airport by public transport
- Other crowded and confined spaces

In all zones mentioned above, passengers are often forced to stand together in tight spaces where the air ventilation devices do not meet the standards of modern aircraft. Taking these considerations into account, it would seem that the WHO recommendations for the identification of contacts aboard an aircraft do not entirely appreciate all of the possible opportunities for acquiring infection.

We, therefore, propose the following procedure:

1. In the event of an outbreak or an infectious disease emergency of international concern, all travelers must complete mandatory passenger locator cards (PLC) (e.g., the PLC recommended by the WHO/ICAO). Alternatively, the airlines should optimize capturing the data on passengers at the time flights are booked, as this would be the best time to gather data when there are minimal implications for air travel. The relating financial issues are controversial and should be further discussed with all stakeholders. Finally, establishing an online system requiring the passenger to supply data to the local public health authority should be considered. This type of system is currently used by the Australian government's Electronic Travel Authority to issue visas and since January 2009 by the U.S. Department of Homeland Security (Electronic System for Travel Authorization). National privacy rules need to be respected in this context. Entry screening may become mandatory in the event of a disease outbreak. To facilitate the identification of contacts, all screening measures should be performed on board the aircraft. Temperature screenings using non-contact infrared thermometry or ear temperature assessments are options for use in detecting febrile passengers.
2. Modified color coding: To cope with the expected huge number of contacts, the four-color coding system currently used at the Hong Kong Airport is reduced to a three-color system. No orange stickers are used in this model. The colors used are:

Red: Index patient.

Yellow (Category I): close contacts, i.e., family members, co-travelers in the patient's tour group, passengers sitting next to the patient (within a range of 6 ft) and flight attendants taking care of the sick passenger. The contacts will be selected by means of questioning performed by the medical staff at the airport as detailed above.

Green (Category II): passengers and crewmembers without close contact to the index case.

The index patient ("red") is directly transferred by means of a specially equipped ambulance to the isolation ward at the Frankfurt University Hospital for further medical examination. The two passenger groups ("yellow" and "green") are directed to color-coded buses and driven to different locations. Here, apart from a PLC, passengers coded "green" are handed printed information about the suspected condition and instructions on how to act should they develop symptoms of the disease. Once the "green" group receives the information, they may continue on their travels.

Passengers coded "yellow" are immediately taken to designated rooms in the terminal or a separate building where medical staff awaits them. Apart from health information being handed out, PLC are also issued, which the passengers will have to complete. Depending on the nature of the outbreak, the health authority responsible may also call for further pandemic protection measures, such as quarantine, observation, and avoidance of attending the workplace. The medical staff checking the passengers (generally a physician and at least one paramedic, depending on the type of aircraft) are equipped with adequate personal protective equipment and protected by airport security and the state or federal police.

3. The next steps depend directly on the characteristics of the pathogen concerned:
  1. If the incubation period of the specific agent is longer than the estimated flight time needed to reach even long-distance destina-

tions, all contacts may continue traveling to their final destination. The public health services responsible at the final destination should be informed about the entering contacts in advance of their anticipated arrival time by the originating local public health authorities. Upon arrival at their final destination, all passengers should be able to contact their local public health authority to obtain immediate specific information or medical care/treatment.

- II. If the transmission of a highly contagious and life-threatening disease according to the list of European Network of Infectious Diseases (EUNID) (7) is possible within a short incubation period and only after the onset of symptoms, quarantine measures for all contacts [Category I (“yellow”), Category II (“green”)] are indicated. Otherwise, the further spread of the infection could become uncontrollable. Category I contacts (“yellow”) will always be subjected to an extensive medical examination and be quarantined separately from Category II contacts (“green”). Quarantine at home may be considered for persons that are residents of the destination country—but only if the trip can still be completed within the incubation period and the public health authority responsible for the region in question can be informed.
- III. If there is a risk of transmission of the pathogen even before symptoms develop, then classic quarantine should be rejected (2). In this case, the procedure is based on the level of danger represented by the pathogen. With a highly contagious and life-threatening disease, all contacts (Categories I and II) must be accommodated individually wherever possible (e.g., at a hotel) in order not to subject them to the risk of contracting undetected infections from their fellow travelers. Here too, Category I contacts must always first undergo an extensive medical check. This procedure is possible for only a few suspect cases – with increasing numbers of cases, one must proceed pragmatically.
- IV. With infectious diseases whose characteristics are hardly known or even unknown (as with SARS in the early phase of the pandemic), the procedure is based on the current data available. The information needs to be evaluated and assessed by experts. In an extreme case, it may be necessary to impose drastic public health measures and restrictions on passengers.

Procedures proposed for entry screening in this section will be tenable if they are restricted only to aircraft arriving from one country or one region. Further steps will be discussed in the next section.

### Discussion

The management of highly contagious and life-threatening diseases must be flexible in order to account for the characteristics of the particular disease. The procedures we propose for the airport in Frankfurt meet this requirement; they are pragmatic and consistent with the IHR in that inconvenience for passengers and the disruption of international air traffic will be avoided if possible. The procedures were developed after SARS emerged. For historical reasons, they could not be validated within the context of a real-world scenario.

In the face of a developing pandemic, larger clusters of patients are expected to emerge from a geographical area. To contain the further spread of infection, exit screening may become mandatory at the airports of the country where the emerging disease is observed. In addition, the WHO or local government may require that entry screening procedures also be implemented. If such a decision were made for the Frankfurt Airport, all passengers arriving from the region where an outbreak had occurred would have to fill out a PLC. A medical doctor and a paramedic would enter the aircraft to explain the situation and screen the passengers using the methods described above. In the advanced stages of a pandemic,

entry screening will be halted because medical assets will not be sufficient to screen passengers from any region during entry screening; instead, they would be used for treatment and health care provision.

In a setting with a growing number of suspected cases that cannot be resolved, none of the prescribed procedures may be sustained over time (e.g., with pandemic influenza). Adjustments will then occur due to decreasing passenger numbers, which will happen on its own. Apart from the development of procedures, the provision of a sufficient number of quarantine locations (scenario: Airbus A 380 X, > 550 passengers; 1 patient suspected of having a highly infectious life-threatening disease) is a necessity. During the early stages of a new or rare disease, detection might be difficult. Therefore, it is essential, in any event, that sufficient diagnostic and therapeutic expertise (24 h/365 d) be available in close proximity to major airports so that sound decisions can be made as quickly as possible.

The case of a passenger whose infectiousness is detected only after he has left the aircraft is problematic. Passenger manifests provided by the airlines currently do not meet the requirements for adequate contact tracing. This can only be achieved by improving the data acquisition standards of the international aviation authorities based on the IHR. This includes modifying the rules on the minimum data requirements for the passenger lists, the data retention period, and rulings on guaranteed access to those lists by the responsible authorities when needed on short notice. Detailed data acquisition provided by the airlines at the time of booking or mandatory online systems which are actually used, e.g., by the Australian and the U.S. Governments, are presumably possible steps in that direction. Moreover, we suggest discussing the introduction of mandatory landing cards, which is common practice across many countries, apart from the EU. Finally, health authorities are legally obligated to trace contacts to control infectious diseases. Therefore, it is not sufficient to collect contact details on a voluntary electronic system level.

Due to the IHR, community mitigation measurements must be implemented very carefully. The specific microbiological characteristics of the agents are crucial aspects to be considered in the implementation of public health measurements in order to reduce the spread of infectious diseases. In particular, the severity of the disease, the incubation period, and the transmissibility of the agent with or without symptoms, as well as the potential risks to the population, are the main points that must be considered.

As mentioned above, there are also other spatial locations inside and outside of airports where passengers might become infected by other travelers. In order to address that issue, deliberations concerning the planning of subject zones should be made in order to protect passengers in these specific areas. For example, air ventilation systems in waiting areas at the airport gates should be optimized, considering the risk of droplet infections. Another possibility is the implementation of a strict boarding process that calls groups of seat rows in order,

as is currently executed in many airports, in order to avoid queuing at the passenger bridges or in the aisles of airplanes. In addition, the airflow of the ventilation systems in the passenger bridges—if jetways are equipped with this capability—should be flowing toward the outside. In general, aggressive air-sanitation measures (e.g., germicidal ultraviolet irradiation) must be installed, with the regular maintenance legally required. The suggested measures are technically easy to install or implement, but the cost factor must be considered.

In summary, the prevailing WHO recommendations for the contact tracing of air travelers should be modified to include all possible sources of infection. The WHO should intensify its existing successful collaboration with organizations such as ICAO, IATA, and ACI in order to promote procedures for the effective management of highly contagious and life-threatening diseases. The process and procedures would be applicable at all international airports that are considered to be designated points of entry.

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