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Original Research

Transmission of SARS-CoV-2 arising from international flights arriving in Ireland in December 2020: a descriptive analysis using national surveillance data

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ABSTRACT

Objectives: There is limited evidence on the risk of in-flight transmission of SARS-CoV-2. This study estimated the extent of in-flight SARS-CoV-2 transmission on international flights arriving in Ireland during December 2020.
Study design: This was a cross-sectional analysis.
Methods: National surveillance data identified all notified cases of COVID-19 who were infectious while travelling on international flights to Ireland during December 2020. Close contacts of cases were tested for SARS-CoV-2, and the results were collated to estimate the pooled secondary attack rate across all flights. Laboratory and epidemiological data were obtained from the Health Service Executive Covid Care Tracker, a national database of COVID-19 cases in Ireland.
Results: A total of 165 infectious cases of COVID-19 were identified on 134 incoming flights; 40.0% were symptomatic on board. There were 2099 flight close contacts identified, of whom 40.9% had results of a SARS-CoV-2 polymerase chain reaction test within 14 days of arrival. The pooled secondary attack rate for these contacts was 7.0% and was higher among those on flights of ≥5-hour duration ($P = 0.008$). More than half (59.1%) of close contacts had no SARS-CoV-2 test result recorded; the reasons included incorrect or absent contact details (26.5%) and no response when contacted (17.8%).
Conclusions: In this national study investigating transmission of SARS-CoV-2 from international flights arriving into Ireland, the pooled secondary attack rate was 7.0%. International travel is likely to have contributed to the third wave of SARS-CoV-2 infections in Ireland in early 2021. Application of non-pharmaceutical interventions remains central to mitigating the risk of in-flight transmission.
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Introduction

The COVID-19 pandemic has reduced air travel worldwide since 2020 because of governmental policies to limit non-essential travel within and across states.[1]

The role of air travel in the transmission of SARS-CoV-2 has been reviewed.[2] Most published studies have evaluated the extent of transmission on individual flights[3,4] or have reported on isolated outbreaks.[5–9] Large outbreaks on aircraft have been reported,[5,7,8] with secondary attack rates (SARs) varying considerably from 4.8% to 62%.[6,7] Few studies have examined transmission across multiple flights. Those that have have reported lower SARs of 0.2%–3.8%.[10,11]

December 2020 was a phase of rapidly rising COVID-19 case numbers in Ireland, as the country entered its third and largest

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wave. Wild type was the dominant variant at this time; the first alpha variant case was notified in Ireland in week 51 (14 December to 20 December 2020) and the first beta variant case in week 52 (21 December 2020 to 27 December 2020).

In December 2020, predeparture polymerase chain reaction (PCR) testing, postarrival testing and flight contact tracing were standardised. Evidence of a negative predeparture SARS-CoV-2 PCR test taken within the 72 h before arrival in Ireland was required of passengers from 'orange' regions within the European Union (EU), in line with the EU Traffic Light System, which became operational in Ireland on 8 November 2020.[12] SARS-CoV-2 PCR testing was also offered to incoming travellers from 'red' regions and from the United Kingdom on day 5 after arrival.

At the time of the study, close contacts of any infectious case on a flight were identified as per European Centre for Disease Prevention and Control (ECDC) guidance, systematically contacted and referred for a free SARS-CoV-2 PCR test as soon as possible and 10 days after exposure to the infectious case.[13]

The aim of this study was to estimate the rate of SARS-CoV-2 transmission arising from international flights arriving in Ireland in December 2020, where at least one infectious case was on board, by measuring the pooled SAR.

Methods

All notified cases of COVID-19 who flew into Ireland from 30 November 2020 to 31 December 2020 inclusive were identified through the Health Service Executive's Covid Care Tracker, the national COVID-19 surveillance database. Every case with a SARS-CoV-2 PCR positive swab was notified to the Medical Officers of Health (MOHs) and recorded in the Covid Care Tracker, which triggered a systematic process of contact tracing. If a confirmed case flew during his or her infectious period, the passenger manifest for that flight was sought from the airline. The contact details of the passengers were uploaded to the Covid Care Tracker and contact tracing of the relevant passengers commenced. Where contact information for close contacts was missing from passenger manifests, passenger locator forms (PLFs; both electronic and paper), which travellers to Ireland were required to complete since May 2020,[14] were inspected to obtain additional contact information.

Definitions

A *primary case* was defined as a case who was infectious on the flight. This included any case whose COVID-19 illness began up to 10 days before, or up to 48 h after, the flight's arrival in Ireland, and any asymptomatic case who tested positive up to 10 days before, or within 24 h after, the flight's arrival.

A *secondary case* was defined as a close contact of a primary case who had a positive SARS-CoV-2 PCR result between 48 h and 14 days after a flight.

A *close contact* was defined as an individual sitting within a two seat radius of an infectious case, where one infectious case was identified on a flight. If any close contact sitting within a two seat radius of an infectious case tested positive, all passengers on board were then considered close contacts.[13] If there were two or more unrelated infectious cases on board the same flight, all passengers were considered close contacts.

Where a secondary case was identified on a flight, an investigation was conducted to determine whether the primary and secondary cases had epidemiological links outside of the flight (e.g. household links). Where needed, an outbreak control team was convened by the MOH for investigation and control.

The details of the primary cases' flights, including flight origin, destination, dates of departure and arrival, flight duration, as well as the details and test results of all cases and close contacts, were obtained from the Covid Care Tracker. The primary cases' details, including date of symptom onset, or positive PCR test result if asymptomatic, were recorded. The close contacts of the primary cases were identified, and their PCR swab results were obtained to determine the SAR. Where close contacts had no SARS-CoV-2 swab result, the reasons for this were sought from the Covid Care Tracker. The SAR was calculated by dividing the total number of secondary flight cases by the total number of close contacts tested.

The SARS-CoV-2 PCR swabs of all linked primary and secondary cases were sought and, where available, were sent to the National Virus Reference Laboratory (NVRL) for phylogenetic analysis to analyse and compare the pair's SARS-CoV-2 genomes and deduce whether in-flight transmission was likely to have occurred. Where pairs of primary and secondary cases had epidemiological links outside of the flight, phylogenetic analysis was not requested for their pairs of swabs.

All statistical analyses were conducted using Stata version 15 (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC.). Categorical variables were expressed as counts and percentages. Differences between groups for categorical variables were estimated using Chi-squared tests. Statistical significance at the level of $P < 0.05$ was assumed throughout.

Results

One hundred sixty-five passengers on 134 flights were identified as primary cases. A total of 135,900 passengers arrived in Ireland by air in December 2020, and there were an estimated 2098 flights arriving in Ireland in December 2020.[15] Of these flights, 6.4% had a notified case of COVID-19 on board, who was infectious during the flight.

Of 134 flights with primary cases, 60 (45%) originated in Great Britain (GB), 53 (40%) in mainland Europe, 14 (10%) in North America, and 7 (5%) in the Middle East. The highest number of primary cases arrived in Ireland on flights on 19 December 2020 (Fig. 1). Twenty flights (14.9%) had a duration of ≥5 h. Residents of Ireland accounted for 152 primary cases (92.1%), with 2 (1.2%) primary cases residing in Northern Ireland, 2 (1.2%) residing outside the island of Ireland, and 9 (5.5%) with unknown addresses. Of the primary cases resident in Ireland, they resided in 22 of 26 counties across all regions of Ireland.

Sixty-six (40%) primary cases were symptomatic, 60 (36.4%) were presymptomatic, 27 (16.3%) were asymptomatic on the flight, and the symptom status was unknown for 12 (7.3%). In total, the 165 primary cases had 2099 close contacts identified on their respective flights. The median number of close contacts per primary case was 12 (interquartile range: 8–16). A total of 859 (40.9%) close contacts had a recorded SARS-CoV-2 test result within 14 days of exposure to a primary case.

Of the 859 close contacts tested, 60 were identified as secondary cases, indicating an SAR of 7.0% (Table 1). The SAR in flights of ≥5 h duration was significantly higher than shorter flights ($P = 0.008$, Chi-squared = 7.0522). The highest SAR was measured on flights containing presymptomatic primary cases, followed by flights containing already symptomatic and asymptomatic cases, but this finding was non-significant ($P = 0.3$, Chi-squared = 2.4110).

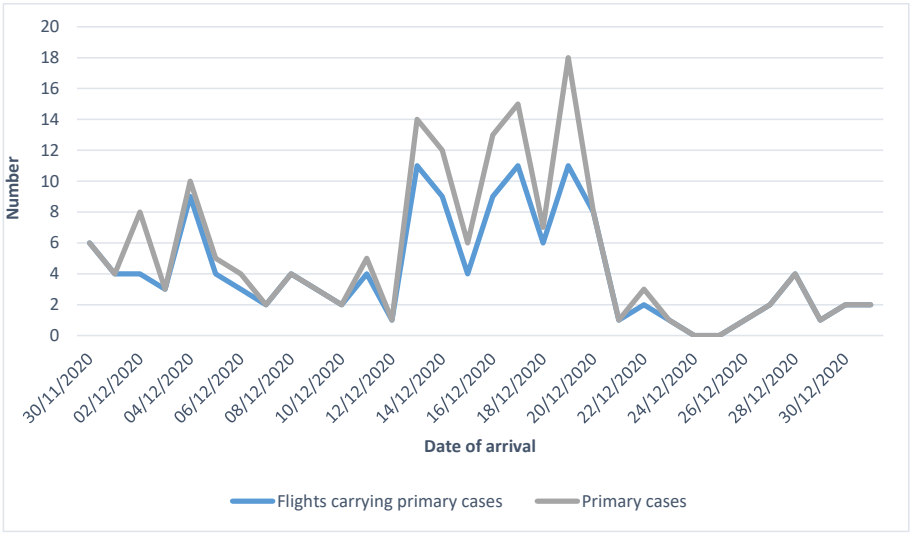

Fig. 1. Arrival of primary cases (n = 165) and their affected flights (n = 134) in Ireland, 30 November to 31 December 2020.

Table 1
SARS-CoV-2 secondary attack rates related to international flights arriving in Ireland, 30 November to 31 December 2020.

Variable	*N*	%	*P* value
SAR (overall)	60/859	7.0%	
SAR (flight-only close contacts)	45/844	5.3%	
SAR (flights ≥5 h)	10/67	14.9%	
SAR (flights <5 h)	50/792	6.3%	0.008
SAR (flights originating in GB)	22/467	4.7%	
SAR (flights originating outside GB)	38/392	9.6%	0.004
SAR (flights with only symptomatic cases)	24/302	7.9%	
SAR (flights with only presymptomatic cases)	20/177	11.3%	
SAR (flights with only asymptomatic cases)	5/82	6.1%	0.3

GB = Great Britain, SAR = secondary attack rate.

Of the 60 secondary cases, 15 had epidemiological links to the primary case outside of the flight. Among flight-only close contacts, 45 secondary cases emerged from 844 close contacts, giving an SAR of 5.3%. It is unknown, however, how many of these 844 close contacts were flight-only close contacts and how many had epidemiological links to the primary cases outside of the flight.

Nine laboratories were contacted to request whole genome sequencing in relation to the primary and secondary cases; 12 swabs were available to be sent to the NVRL, and seven swabs were amenable to sequencing. Of the seven sequenced swabs, four were alpha variants, two were wild-type variants, and one was beta variant. No pairs of swabs for primary and secondary cases, where in-flight transmission was suspected, were available for sequencing. Therefore, phylogenetic analysis of epidemiologically linked swabs could not be performed.

Most close contacts identified (59.1%) had no SARS-CoV-2 test result recorded on the Covid Care Tracker. The principal reasons for this included the following: incorrect or absent close contacts' phone numbers on the contact tracing system (26.5%); close contacts did not answer the phone to be informed of their close contact status (17.8%); and unknown reasons (47.3%; Table 2).

Discussion

In this descriptive analysis, we demonstrated a pooled SARS-CoV-2 SAR of 7.0% on international flights arriving in Ireland in December 2020. This pooled SAR is higher than in earlier studies. In-flight transmission of SARS-CoV-2 on 18 flights to and from Greece over a 13-day period in February to March 2020 yielded a pooled SAR of 0.56%.[10] A study of transmission on 18 international flights to the United Kingdom in January to March 2020 demonstrated a pooled SAR of 3.8% among successfully contact traced close contacts.[11] The findings of earlier studies, which have measured lower SARs, may be explained by limited access to testing or under-recognition of asymptomatic transmission of SARS-CoV-2. Another key difference is that wild-type variants of SARS-CoV-2 were circulating during the study periods of earlier studies, as opposed to the more transmissible alpha variant, which emerged was captured in our study.

We found that 6.4% of flights had an infectious case on board. This tallies with a recent modelling study from the Netherlands,

Table 2
Reasons close contacts were not tested for SARS-CoV-2 on flights to Ireland, 30 November to 31 December 2020 (n = 1240).

Reason for lack of testing	*N*	%
Unknown reason[a]	587	47.3%
Incorrect or absent contact details	329	26.5%
No response when contact made	221	17.8%
Already departed Ireland	50	4.0%
Already tested negative on private testing post-flight	40	3.2%
Refused to be tested	9	0.7%
Previous positive case in prior 3 months[b]	4	0.3%

[a] Routine testing of asymptomatic close contacts in the community, as opposed to close contacts identified on flights, was halted in Ireland in late December 2020 due to the surge in case numbers. This may have led to some flight close contacts not attending for testing.

[b] In Ireland in December 2020, the duration of presumptive immunity after SARS-CoV-2 infection was 3 months, and repeat testing within this period was not required for individuals identified as close contacts.

which estimated that 3–10% of flights would be expected to have an infectious passenger on board.[16] We measured a significantly higher pooled SAR related to flights of ≥5 h duration. This is consistent with other studies, where it has been observed previously that outbreaks with higher SARs have occurred on long-haul flights.[5,7,16] We observed a non-significant trend of a higher pooled SAR where the infectious case was presymptomatic on board, with the lowest SAR measured when asymptomatic cases were on board. A systematic review cited reports of viral load peaks during the prodromal phase of illness or at the time of symptom onset.[17]

The testing of contacts proved challenging. Only two-fifths (40.9%) of close contacts had a SARS-CoV-2 test result recorded postarrival, despite advice to travellers from a large number of countries in December 2020 to get a SARS-CoV-2 PCR test at least 5 days after arrival.[18] Flight close contacts are typically identified by contact tracing later than 5 days after arrival, and many close contacts in our study may have had already undergone private testing by the time they were contacted. Private laboratories are not required to report negative results to the Covid Care Tracker. The COVID-19 case numbers were increasing so rapidly in Ireland by the end of 2020 that public health resources became overstretched, and this hindered the effectiveness and timeliness of contact tracing for flights.

Our analysis found that incorrect or absent contact details for over one-fourth of close contacts (26.5%), alongside unanswered calls (17.8%), played an important role in reducing the offering, and thus the uptake, of testing among close contacts. Passenger manifests may have contained inaccurate contact information, as passengers were not obliged to provide a correct phone number to airlines; close contacts may have ceased using international phones or international subscriber identification module cards on arrival in Ireland; PLFs, which were used to obtain additional contact information, may have contained inaccurate information, and there may have been errors as phone numbers were transcribed from passenger manifests onto the Covid Care Tracker.

It was not possible to conduct phylogenetic analysis on any pair of epidemiologically linked PCR specimens due to a number of factors, including early disposal of specimens due to storage issues and inadequate samples. Of interest, the first known COVID-19 cases in Ireland caused by both alpha and beta variants were found in primary cases on flights and captured in this study, and the increased transmissibility of variants of concern may be reflected in this study's pooled SAR. It is noteworthy that although only a very small proportion of PCR specimens in this study underwent sequencing, COVID-19 cases caused by the alpha and beta variants were detected, giving evidence that these variants of concern were imported into Ireland via air travel and indicating that the importation of variants of concern may have been underestimated, as many specimens could not be sequenced.

The need for ongoing mitigation of in-flight transmission is highlighted by our study. It has been postulated that SARS-CoV-2 transmission can be suppressed on aircraft through the implementation of various infection prevention and control measures, including enhanced cleaning and the use of face masks by passengers and crew.[19] In previous studies, flights where mask-wearing was rare or optional recorded higher SARs.[7,20] The design of aircraft, which limits passenger movement and face-to-face interaction and features an air exchange system that reduces the spread of respiratory particles, may decrease the risk of transmission on board.[19] Air cabins tend to have low levels of relative humidity, however, which may facilitate easier transmission of viral particles.[21]

The strengths of this study include the use of national surveillance data to estimate the extent of SARS-CoV-2 transmission related to international flights arriving in Ireland. This study had a larger number of identified close contacts, as distinct from co-passengers, than previously published studies. We accessed a national database, which maximised the likelihood of identifying true cases of COVID-19.

Although we demonstrated a pooled SARS-CoV-2 SAR of 7.0% in our study, the true pooled SAR is unknown. First, this SAR was estimated by calculating the positivity rate among all flight close contacts, including those who had epidemiological links to primary cases outside of the flight. Although we estimated an SAR of 5.3% when we included only the secondary cases who were flight-only close contacts, it is not known how many flight-only close contacts there were among the total number of close contacts tested. Second, not all infectious cases on flights are likely to have been identified, as testing on arrival in Ireland was advisory only, and we may have underestimated imported infectious cases. We cannot rule out the possibility of selection bias: the close contacts who were not tested for SARS-CoV-2 may have been more likely to be feeling well on arrival in Ireland and perhaps less likely to have COVID-19, leading to potential overestimation of SAR.

This study did not focus on the impact of imported COVID-19 cases on the dynamics of the epidemic in Ireland at the time. It is noteworthy, however, that Ireland had one of the lowest 14-day incidences of COVID-19 in the EU and European Economic Area in early to mid-December 2020[22] but had the highest 14-day incidence 1 month later.[23] The risk associated with the importation of cases of COVID-19 into a country potentially poses a greater risk to the control of the epidemic within a population than the risk posed by SARS-CoV-2 transmission on aircraft itself.[24,25] We found that infectious cases resided in various locations around the country and likely, alongside undetected cases, seeded infection in disparate locations after arrival in Ireland. In addition, 45% of the flights containing infectious cases in our analysis came from GB, where the alpha variant was rapidly becoming the predominant variant at the time. It is plausible, therefore, that international travel played a role in seeding infections caused by the alpha variant in Ireland, which, in turn, contributed to the occurrence of a third wave of infections in the country in early 2021.

National contact tracing systems are being strengthened, including the validation of contact information through Ireland's electronic PLF as a condition of boarding and to supplement airline information where needed. The proposed multicountry digital approach to flight contact tracing should be progressed to increase efficiency and timeliness.[26] Whole genome sequencing capacity is important to facilitate genomic surveillance of all imported cases. All imported COVID-19 cases' swabs continue to be referred for whole genome sequencing, which will facilitate further study on patterns of importation.

The findings from this study lend support to the continued implementation of non-pharmaceutical interventions as well as widespread vaccination to further reduce the risk of transmission of SARS-CoV-2 on flights.

Author statements

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Departments of Public Health of Ireland, the HSE COVID-19 Contact Management Programme (CMP), the Health Protection Surveillance Centre (HPSC) and the UCD National Virus Reference Laboratory (NVRL), as well as the HSE Port Health Network.

Ethical approval

This analysis was undertaken in conjunction with the HSE Port Health Network as part of the public health response to the COVID-19 pandemic. It was undertaken by public health physicians and Medical Officers of Health in line with Infectious Disease Regulations 1981.[27] Therefore, ethical approval was not required.

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Competing interests

None declared.

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