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MAJOR ARTICLE

# Population-Based Assessment of Contact Tracing Operations for Coronavirus Disease 2019 in Pirkanmaa Hospital District, Finland

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***Background.*** The coronavirus disease 2019 (COVID-19) epidemic overwhelmed local contact tracing (CT) efforts in many countries. In Finland, severe acute respiratory syndrome coronavirus 2 incidence and mortality were among the lowest in Europe during 2020–2021. We evaluated CT efficiency, effectiveness, and transmission settings.

***Methods.*** Polymerase chain reaction (PCR) test–positive COVID-19 cases and high-risk contacts in the population-based CT database of Pirkanmaa Hospital District (population 540 000) during June 2020–May 2021 were interviewed.

***Results.*** Altogether 353 926 PCR tests yielded 4739 (1.3%) confirmed cases (average 14-day case notification rate, 34 per 100 000 population); about 99% of confirmed cases and high-risk contacts were reached by a CT team. Of 26 881 high-risk contacts who were placed in quarantine, 2275 subsequently tested positive (48% of new cases), 825 (17%) had been in quarantine ≥48 hours before symptoms, and 3469 (77%) of locally acquired cases were part of transmission chains with an identified setting. The highest secondary attack rates were seen in households (31%), healthcare patients (18%), and private functions (10%). Among the 311 hospitalized patients, COVID-19 diagnosis or exposure was known in 273 (88%) before emergency room admission (identified patients). Healthcare workers had the highest proportion of work-related infections (159 cases [35%]). The source of infection was classifiable in 65% and was most commonly a coworker (64 cases [62%]).

***Conclusions.*** Our data demonstrate the role of effective testing and CT implementation during the cluster phase of COVID-19 spread. Although half of newly diagnosed cases were already in quarantine, targeted public health measures were needed to control transmission. CT effectiveness during widespread community transmission should be assessed.

**Keywords.** COVID-19; contact tracing; effectiveness; indicators.

Finland was one of the least affected European countries during the first 2 years of the coronavirus disease 2019 (COVID-19) pandemic [1] with no overwhelming of hospital capacity and one of the smallest death tolls in Europe, even though governmental restrictions have been less stringent than in many other European countries [2]. This is likely due to several factors. Finland has the advantage of having the lowest population density in the European Union [3], from a European perspective lower-than-average everyday person-to-person contacts [4], and above-average trust between citizens and officials [5, 6]. In addition, public health actions such as testing and contact tracing (CT) were implemented early in the epidemic and coordinated nationally.

In May 2020, the Finnish government adopted "test, trace, isolate, and treat" as the national strategy [7]. However, isolations and quarantines had already been used locally in hospital districts in Finland since the beginning of the pandemic. Core CT operations include effective testing, active case finding, timely isolation of cases, and quarantine of high-risk contacts to interrupt onward transmission. We assessed the efficiency of COVID-19 CT operations and their impact on severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission in Pirkanmaa Hospital District. We also evaluated transmission in workplaces and schools.

## METHODS

### Setting

In Finland (population 5.5 million), the healthcare system is organized in 20 hospital districts (HDs), each having a central hospital. Pirkanmaa HD has a catchment population of 540 000 inhabitants, including the city of Tampere with

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240 000 inhabitants. Pirkanmaa HD is one of the 5 university HDs, with Tampere University Hospital as the central hospital. Public health functions are integrated into primary healthcare, and surveillance, CT, quarantine, and isolation decisions of the Pirkanmaa HD and its 23 municipalities were coordinated by the Infection Control Unit of Tampere University Hospital. This central coordination allowed our unit to maintain real-time analysis of the population-based CT data and ongoing physician-lead development of CT operations for the whole region, such as digitalization and automation, and improvements to data management and analysis. [8]. Our team has infectious disease specialists (during the study period, 2 were working full time in CT and more part time), doctors from other fields specifically recruited for CT (1–2 physicians), a team of nurses trained in CT (8–15 nurses and 1–2 secretaries), and a roster of medical students (2–6 working at a time in the evenings and weekends). Most calls were made by this team. In addition, the municipalities have at least 1 communicable disease control physician and they have recruited CT teams (usually 1–2 nurses) that act as a fallback when there are sudden surges in amounts of high-risk contacts to quarantine. Furthermore, a national COVID-19 digital proximity tracing app (Koronavilkku) was used, but it was shown to have only marginal benefit in our region [9].

According to the Finnish Communicable Disease Act, the HDs are responsible for coordinating the infection control activities in their region, and the municipalities (communicable disease control physicians) are responsible for implementing control measures in their own municipality. Official isolation or quarantine is ordered by the responsible communicable disease physician either in the district (the head of the infection control unit) or in the municipality. Violating isolation or quarantine is an act subjected to sanctions, but very few, if any, sanctions have been given in our region. No specific centers have been used for either of these; they were always carried out in their homes (or hospital if needed due to symptoms).

#### Inclusion Criteria

All SARS-CoV-2 polymerase chain reaction (PCR)–positive cases identified in Pirkanmaa HD between 1 June 2020 and 31 May 2021 were included. Some results are stratified by calendar time as in spring 2021 the variants of concern (VOCs) began to spread, and the results might also reflect the effect of increasing COVID-19 vaccination coverage. Testing was conducted in public and private healthcare in Pirkanmaa or other parts of Finland or on Finnish borders. At the time, SARS-CoV-2 antigen tests were not used in public healthcare (or for self-testing) in our district. During the study period all persons with any symptoms related to COVID-19 were encouraged to get tested for SARS-CoV-2 via nasopharyngeal swab taken by a healthcare professional free of charge. Asymptomatic contacts were generally not tested as part of routine CT, except during healthcare-associated outbreaks when asymptomatic staff or patients were screened on a case-by-case basis. During the study period, the quarantine protocol in our region did not include exit testing of asymptomatic cases.

#### Data Collection

All SARS-CoV-2–positive cases were systematically interviewed during a CT phone call. Details about settings, duration of contact with other people, and activities during the past 2 weeks to assess the probable source of infection were asked and the data were documented in a central database, used both by the infection control unit and the municipalities. The definitions of isolation and quarantine lengths and high-risk exposures requiring quarantine were in accordance with national and European Centre for Disease Prevention and Control (ECDC) guidelines [10, 11]. High-risk (or close) contact was defined as a direct contact with infectious secretions of a COVID-19 case, being in a closed environment or $<2$ meters apart with a COVID-19 case for $>15$ minutes, or being a healthcare worker (HCW) to a COVID-19 case without wearing the recommended personal protective equipment. Mask wearing (the case, the exposed, or both) outside healthcare lifted the threshold for quarantine with a certain time-dependent algorithm. Extended physical contact such as hugging was also deemed high risk independent of the exposure time. The contact with a COVID-19 case had to occur from 2 days before and 10 days after symptom onset in the case. Transmission was defined as school-related when it occurred between a teacher and a pupil or 2 pupils who did not spend significant amounts of time together outside of school, that is, where a classroom or school cafeteria setting was judged to be the setting of the transmission. The setting in infection among children who spent substantial amount of time together outside school was classified as a contact between friends or relatives. Similarly with HCWs; if they did not spend time together outside work, the transmission was judged to be work-related. Events such as birthday parties, weddings, and housewarmings were classified as private parties, whereas shorter, less intensive, and less sustained free-time contacts were classified as meetings between friends and relatives. When the index case and secondary case lived together full time or most of the time, the transmission was classified as a household transmission. Stairwell transmission was defined to occur among residents who shared the same stairwell in an apartment building and had no other known exposure within 10 days of first positive case. Only 1 case per apartment was defined as stairwell transmission, and secondary cases in each household were defined as household transmission.

We defined CT efficiency based on the CT performance indicators developed by the ECDC [11]: for example, the proportion of cases where CT is initiated, proportion of high-risk

contacts reached by phone call, proportion newly diagnosed cases that were part of known transmission chains, proportion of contacts who develop COVID-19 in quarantine (quarantined before positive test result). In addition, the timeliness of initiating investigations and lack of delays in testing and contacting exposed persons are important indicators of CT efficiency. By effectiveness we refer to assessing the CT system's effects on the epidemiological parameters of the epidemic (eg, reductions in proportion of positive tests, secondary attack rates, the 14-day incidence rate) or other health outcomes (eg, transmission chain interruption).

#### Ethical Review and Patient Consent Statement

This is a retrospective analysis of our CT registry data; because of acute public health response, ethical review or informed consent was not required according to the Communicable Disease Act.

#### Variants of Concern and Vaccinations

The sequencing method for VOCs has been described elsewhere [12]. In accordance with national guidelines, the samples for sequencing were chosen randomly from positive PCR tests of clinical laboratories and sent to the Finnish Institute for Health and Welfare for sequencing. COVID-19 vaccinations began on 27 December 2020 in Pirkanmaa HD. Vaccinations began from selected HCWs and long-term care facility residents and then continued to elderly with descending age groups [13]. The majority of vaccinated persons received Pfizer-BioNTech COVID-19 vaccine (Comirnaty) with a 12-week dose interval. AstraZeneca (Vaxzevria, persons >65 years) and Moderna (Spikevax) vaccines were used to a lesser extent, both with a 12-week interval.

#### Statistical Analysis

We used a Finnish computer software (SAI, Neotide Corporation, Vaasa, Finland) to register the cases and their contacts. Microsoft Excel and IBM SPSS version 26.0 software programs were used for the statistical analysis in this article. Fourteen-day case notification rate was calculated by the number of COVID-19 PCR-positive cases per 100 000 residents in Pirkanmaa HD in the preceding 14 days.

## RESULTS

#### General Data

During the study period, 415 730 SARS-CoV-2 PCR tests were done in Pirkanmaa HD. Public healthcare collected 353 926 samples, taken from 198 980 individuals. The remaining 61 804 tests were collected and analyzed in private healthcare. The number of samples obtained from passengers arriving to Finland from abroad who came to Pirkanmaa cannot be counted. There were altogether 4739 PCR-positive cases found in tests. There were few cases during June to August 2020 and the highest peak was in March 2021 (Figure 1). During the 7 months, defined as fall 2020 (1 June–31 December 2020), there were fewer cases (1618) than during the 5 months, defined as spring 2021 (1 January–31 May 2021; 3121 cases) (Table 1). Median age was 33 years (interquartile range [IQR], 21–48 years) with lower median age in spring 2021 than in fall 2020 (31 vs 36 years, respectively). CT was initiated in 100% of the laboratory-confirmed cases, and 99.6% (4719/4739) were interviewed by telephone. The proportion of all high-risk contacts reached is not known, but we estimate it to be >90% among household members, friends, relatives, workplaces, and schools and substantially lower in other places such as bars and nightclubs. There were 248 high-risk contacts who were delegated to other HDs (no information whether they have been reached) and 236 high-risk contacts (<1% of known high-risk contacts) who were not reached (or quarantined).

#### Time Delays

Median time from symptom onset to the laboratory test was 2 days (IQR, 1–3 days). The mean processing time of laboratory test improved from 2.1 days in fall 2020 to 1.3 days in spring 2021 (no change in median times); the overall median processing time was 0 days (IQR, 0–0 days) after the test and 4706 (99.3%) of index cases were contacted within 24 hours of positive laboratory results. Known high-risk contacts of the index cases were also contacted within 24 hours, but occasionally the list of contacts was completed >24 hours after the test result. Altogether, the median time from onset of symptoms in the primary case to the first CT call was 3 days (IQR, 2–4 days).

#### Hospitalizations and Deceased

Table 2 presents hospitalizations and COVID-19–associated deaths in our region. Of 4739 cases, 311 (6.6%) required hospitalization, of which 31 (10.0%) were treated in an intensive care unit (ICU). The case-fatality proportion within 28 days of the positive test result was 0.9% for all cases and 14% for hospitalized patients. A larger proportion of COVID-19–positive cases required hospitalization during fall 2020 than spring 2021 (9.0% vs 5.3%, respectively). Among hospitalized cases, COVID-19 diagnosis was already known in 166 (53%), and an additional 107 (34%) were in quarantine or exposure to COVID-19 was otherwise known before admission (identified patients); 38 (12%) patients were diagnosed with COVID-19 during hospitalization without prior evidence of COVID-19 disease or contact (unidentified patients).

#### Transmission Settings

The setting of transmission was identified for 3469 (73%) newly diagnosed cases and were part of known transmission chains. The setting was unknown for 1042 (22%) cases (Table 3). For 235 cases (5%), the source of infection was abroad. In cases where the setting was known, the index case could be identified

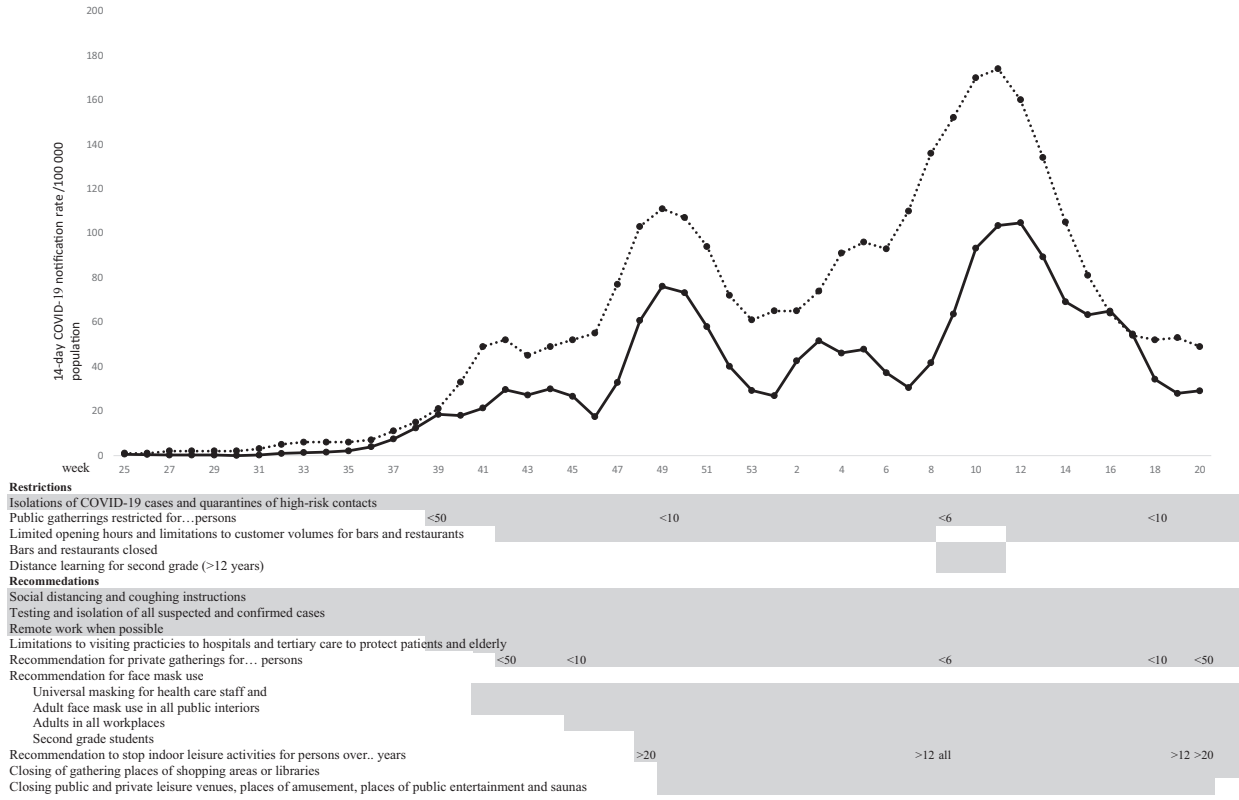


**Figure 1.** 14-day COVID-19 case notification rate per 100 000 population in Pirkanmaa hospital district during 1 June 2020–31 May 2021 (black line), whole Finland (dotted line), and actions taken to control epidemic locally.

in 2057 cases (59%). In the rest, there were either many potential primary cases or the primary case could not be determined. Most of the known transmission events occurred at home (Table 3). Transmission events detected at day care centers or schools accounted for 2.5% of all known infections (Tables 3 and 4). Thirty-four children contracted COVID-19 infection from day care (1.0%). Fifty-one infections of children and teens aged <18 years were traced to school (1.5% of all known sources or 8.4% of known sources in age group of 7–18 years). The source of infection was another pupil in 40 (78%), and the rest were from teachers.

### Workplace Transmission

Workplaces accounted for 13% of all known infections (458 cases) (Tables 3 and 4). Healthcare workers constituted 35% (159 cases) of all work-related infections. In healthcare settings, most classifiable transmissions occurred between coworkers (64 cases [62%]) or from unidentified (undiagnosed or not known to be exposed) COVID-19 patients (34 cases [33%]). Only in 5 cases (5%) transmission occurred from an identified (diagnosed or known exposed) COVID-19 patient. In 56 cases (35%) the source of infection could not be classified. These were cases associated with epidemics in healthcare facilities with many potential indexes (3 different outbreaks with >10 identified cases).

### Proportion of Contacts Who Developed Confirmed COVID-19 in Quarantine and Attack Rates

We ordered 30 425 official quarantines for the known high-risk contacts. The total number includes extensions of quarantine due to new positive household member and new quarantines for the same individual in different setting. Quarantines were ordered to 26 881 individuals (Table 1) with a median of 2 quarantined contacts per case. The proportion of quarantined contacts who developed confirmed COVID-19 was 8.5% (2275/26 881). The attack rate was highest among persons quarantined because of exposure in the household (31.1% [1236/3976]) (Table 3). The attack rate among workplace quarantines was 4.3% (199/4659). The proportion in schools was only 0.6% (38/5959) and in day care, 1.5% (31/1986).

### Vaccinations

By 31 May 2021, 42.8% of Pirkanmaa HD residents had have received at least 1 dose of COVID-19 vaccination and 8.3% received 2 doses. Of those who had received 1 dose, 128 later tested PCR positive in Pirkanmaa HD; the median time from first dose to symptom onset was 25 days. Fourteen cases had

**Table 1. Demographics of the Coronavirus Disease 2019 Epidemic of Pirkanmaa Hospital District, Finland, During 1 June 2020–31 May 2021**

| Demographics | All | Fall 2020 | Spring 2021 |
|---|---|---|---|
| Inhabitants | 540 465 | | |
| COVID-19 PCR tests[a] | 353 926 | 180 028 | 173 898 |
| Different patients[b] | 198 980 | 132 065 | 123 230 |
| COVID-19 PCR-positive (% of all tests) | 4739 (1.3) | 1618 (0.9) | 3121 (1.8) |
| Age, y, median (IQR) | 33 (21–48) | 36 (22–53) | 31 (20–46) |
| Age group, y | | | |
| ≤12 | 514 (10.8) | 105 (6.5) | 409 (13.1) |
| 13–18 | 416 (8.8) | 150 (9.3) | 266 (8.5) |
| 19–30 | 1238 (26.1) | 404 (25.0) | 834 (26.7) |
| 31–65 | 2238 (47.2) | 793 (49.0) | 1445 (46.3) |
| 66–75 | 181 (3.8) | 70 (4.3) | 111 (3.6) |
| >75 y | 152 (3.2) | 96 (5.9) | 56 (1.8) |
| Average 14-d notification rate of COVID-19 cases per 100 000 (range) | 34 (0–105) | | |
| Individuals in quarantine | 26 881 | 10 657 | 16 857 |
| Median No. of quarantines on each positive case (range) | 2 (0–187) | 3 (0–187) | 2 (0–116) |
| PCR-positive cases in quarantine before positive laboratory test | 2275 | 742 | 1530 |
| % of positive cases | 48.0 | 45.9 | 49.0 |
| % of individuals in quarantine | 8.5 | 7.0 | 9.1 |
| Quarantine began before symptoms | 1375 | 418 | 957 |
| % of positive cases | 29.0 | 25.8 | 30.7 |
| % of individuals in quarantine | 5.1 | 3.9 | 5.7 |
| Quarantine began ≥48 h before symptoms | 825 | 228 | 597 |
| % of positive cases | 17.4 | 14.1 | 19.1 |
| % of individuals in quarantine | 3.1 | 2.1 | 3.5 |

Data are presented as No. (%) unless otherwise indicated.

Abbreviations: COVID-19, coronavirus disease; IQR, interquartile range; PCR, polymerase chain reaction.

[a]Data are public only; private sector, 61 804 SARS-CoV-2 PCR tests. No data on number of tests in national borders.

[b]Public only.

received 2 doses before the positive result. Thirty-two of the vaccinated patients needed hospitalizations (median age, 57 years; 2 patients with 2 doses) and 6 died (median age, 86 years; 1 patient with 2 doses).

#### Variants of Concern

The first VOC (501.V2, Beta) was detected in a random sample taken on 4 January 2021. The first B.1.1.7 variant (Alpha) was detected on 10 January 2021. In April 2021 the Beta variant was temporarily detected from nearly half of the random samples sequenced in our region (n = 394) (Supplementary Figure). By the end of May, >80% of all sequenced samples have been the Alpha variant, but with B.1.617.2 (Delta) variant rising in the last weeks of May (first detected from sample taken 7 May 2021).

## DISCUSSION

During the study period, the average 14-day COVID-19 case notification rate (34 per 100 000 population) in our region represented the median in Finland [14] but was substantially lower than in most European countries [1]. Of the laboratory-confirmed cases, almost 100% were reached and contacted within 24 hours after the positive test result. The exact number of all high-risk contacts is unknown, but among household members and other settings with known denominator, high proportion were contacted and provided information. Of the high-risk contacts who developed laboratory-confirmed disease, about half were in quarantine before their positive test result. About four-fifths of all domestically acquired new cases were part of known transmission chains. Importantly, almost 90% of hospitalized cases had been identified (diagnosed or known to be exposed) already before admission to the emergency room, reducing the risk of nosocomial transmission.

Most published reports evaluating the effectiveness and efficiency of COVID-19 CT have been mathematical modeling studies and there are few population-based cohort studies with real-world data [15–18]. Systematically collected data on testing and CT implementation in our region suggested high efficiency and a contribution to reduction in onward transmission based on the CT performance indicators developed by the ECDC [19]. However, no national or international benchmarks or goals are available for direct comparison. The limitations of quarantine in containing COVID-19 have been noted in some reports [16]. Because of its fast spread, SARS-CoV-2 control cannot rely solely on CT and quarantines, even in a country with low incidence. In our region, almost 27 000 individuals were placed in official quarantine as a result of CT.

**Table 2. Hospitalizations and Coronavirus Disease 2019–Associated Deaths in Pirkanmaa Hospital District, Finland, During 1 June–31 December 2020, 1 January–31 May 2021, and Both**

| | All (1 June 2020–31 May 2021) | | | Fall (1 June–31 December 2020) | | | Spring (1 January–31 May 2021) | | |
|---|---|---|---|---|---|---|---|---|---|
| Hospitalizations and Deceased | No. | % of COVID-19 PCR Positive | Median Age, y (IQR) | No. | % of COVID-19 PCR Positive | Median Age, y (IQR) | No. | % of COVID-19 PCR Positive | Median Age, y (IQR) |
| Hospitalized COVID-19 patients | 311 | 6.6 | 65 (50–79) | 145 | 9.0 | 77 (60–87) | 166 | 5.3 | 57 (45–71) |
| Hospital | 217 | 4.6 | 59 (46–73) | 82 | 5.1 | 64 (51–80) | 135 | 4.3 | 55 (42–69) |
| ICU | 31 | 0.7 | 61 (53–74) | 7 | 0.4 | 69 (64–78) | 24 | 0.8 | 60 (52–72) |
| Municipal health facility | 63 | 1.3 | 85 (78–90) | 56 | 3.5 | 86 (78–90) | 7 | 0.2 | 78 (76–88) |
| COVID-19–associated death ≤28 d after diagnosis and treatment | 42 | 0.9 | 81 (75–88) | 26 | 1.6 | 86 (80–91) | 16 | 0.5 | 78 (71–82) |
| In hospital | 19 | 0.4 | 80 (72–86) | 9 | 0.6 | 82 (80–86) | 10 | 0.3 | 78 (71–83) |
| In ICU | 6 | 0.1 | 77 (69–78) | 2 | 0.1 | 73 (70–76) | 4 | 0.1 | 77 (71–80) |
| In municipal health facility | 17 | 0.4 | 88 (81–93) | 15 | 0.9 | 88 (83–94) | 2 | 0.1 | 81 (77–85) |

Abbreviations: COVID-19, coronavirus disease; ICU, intensive care unit; IQR, interquartile range; PCR, polymerase chain reaction.

Some 29% of new COVID-19 cases occurred in persons who were in quarantine before symptom onset and 17% were in quarantine 48 hours before symptom onset (ie, entire infectious period). Various factors influence the success of quarantines. First, the transmission may have occurred abroad or in higher-incidence regions within the country; second, there may have been delays from symptom onset to contact call; third, the compliance with testing recommendations might not have been consistent. Despite these potential limitations, CT has been an effective strategy in controlling the spread of SARS-CoV-2 in our setting, in contrast with some previous reports from other countries [18, 20–22]. However, the overall epidemic control depends on, for example, sufficient vaccination uptake and people's willingness and ability to reduce their exposure by limiting contacts and maintaining physical distance.

Few cases (6.5%) required hospitalization and only 0.7% were admitted to intensive care. The overall case-fatality ratio was also low and affected primarily the elderly as 79% of deaths were in persons >75 years old, similar to reports from other countries [23, 24]. Direct comparisons are difficult, however, as testing thresholds, age distribution of cases, and hospital admission criteria may be different.

Contact tracing provided information on the transmission setting in 77% of confirmed cases in our region, enabling public health officials to target restrictions for minimal harm and maximal effect. Household was the most common setting of transmission, as noted before [25–28]. The index case in the household contracted COVID-19 most commonly from meetings with friends or relatives, workplaces, private parties, or other contacts of known COVID-19 cases. Transmission setting data have uncertainties as it was not possible to identify the index case in some of the places. Nevertheless, in most settings the index was known, and the relatively low incidence in the region helped in identifying the probable place of transmission. We also detected a few sporadic cases where the transmission likely occurred among residents sharing the same stairwell in an apartment building without known contact such as visiting with the index (72 cases, 45 different apartment buildings). In this setting the route of transmission is unclear for us.

Although schools were open almost the entire study period, very few infections were traced to symptomatic children at schools (51 cases [1.5%]) (Figure 1). Transmission in children occurred mostly in households, and school transmission accounted only for 8.4% of known sources in school-aged children. A study from Germany also concluded that school-related origin of infection was unlikely in majority of cases [29]. The proportion of quarantined children who developed confirmed COVID-19 in our schools was only 0.6%, suggesting that the quarantines should be better targeted. However, there might have been untested asymptomatic carriers.

Healthcare workers accounted for 35% of cases defined as work-related although they comprise only 8% of the workforce in Finland. Some of the detected cases may be associated with the more common practice of screening HCWs for asymptomatic virus carriage than in other workplaces, but the proportion is still disproportionately high. The most common source for work-related HCW infection was a coworker. Even though unidentified COVID-19 patients (undiagnosed or not known to be exposed) accounted for only 12% of all hospitalized patients, they were associated with much higher proportion of HCW infections than COVID-19 patients who were already identified before admission to emergency room [30, 31]. A potential reason for this finding could be that the identified cases had been symptomatic for a longer time and were therefore less infectious during hospitalization than the unidentified cases. The different stage of the patient's infectious period is probably also one reason why no transmission to HCWs in the ICU

**Table 3. Transmission Settings for 4739 Polymerase Chain Reaction–Confirmed Coronavirus Disease 2019 Cases and Setting-Specific Attack Rates Among Quarantined High-Risk Contacts in Pirkanmaa Hospital District, Finland, During 1 June–31 May 2021**

| Transmission Setting | No. (%) | Cases in Quarantine Before Positive Laboratory Test Result, No. (Days 0–14) | Individuals Placed in Quarantine by Setting of Transmission, No. | Attack Rate, %[a] |
|---|---|---|---|---|
| All | 4739 (100) | 2275 | 26 881 | NA |
| Abroad[b] | 235 (5.0) | 17 | 18 | NA |
| Domestic, unknown source | 1035 (21.8) | 0 | 0 | NA |
| Domestic, known source | 3469 (73.2) | 2258 | 26 863 | NA |
| Transmission setting in the known domestic sources | | | | |
| Same household | 1452 (41.9) | 1236 | 3976 | 31.1 |
| Friends and relatives | 659 (19.0) | 376 | 4034 | 9.3 |
| Workplace | 458 (13.2) | 199 | 4659 | 4.2 |
| Private party | 184 (5.3) | 123 | 934 | 13.2 |
| Hobby | 146 (4.2) | 81 | 2045 | 4.0 |
| Patient in healthcare | 115 (3.3) | 66 | 365 | 18.1 |
| Customer in a restaurant, bar, or night club with known index | 92 (2.7) | 19 | 263 | NA |
| Dormitory (eg, military, student, reception center) | 92 (2.7) | 55 | 425 | NA |
| Stairwell[c] | 72 (2.1) | 0 | 0 | NA |
| School (students 7–18 y) | 51 (1.5) | 38 | 5959 | 0.6 |
| Day care (children <7 y) | 34 (1.0) | 31 | 1986 | 1.6 |
| Other known contact | 114 (3.3) | 34 | 642[d] | NA |

Abbreviation: NA, not available.

[a]Attack rates among quarantined high-risk contacts by transmission setting are shown only if the number of quarantined contacts was considered an accurate estimate of all high-risk contacts in the setting.

[b]Persons arriving from abroad were recommended to self-quarantine, but they were not ordered in official quarantine because of travel history. Above-mentioned 18 cases were known to be exposed abroad.

[c]Forty-five different apartment buildings (see Methods for definition).

[d]The setting of transmission data missing from 1575 quarantines.

**Table 4. Transmission Setting in Workplaces and Schools in Pirkanmaa Hospital District, Finland, During 1 June 2020–31 May 2021**

| Transmission Setting | No. (%) |
|---|---|
| Work | 458 (100) |
| Healthcare | 159 (34.7) |
| Transmission from coworker (% of healthcare transmission) | 64 (40.3) |
| Transmission from unidentified COVID-19 patient (undiagnosed or not known to be exposed) | 34 (21.4) |
| Transmission from identified COVID-19 patient (diagnosed or known exposed) | 5 (3.1) |
| Transmission unclassifiable[a] | 56 (35.2) |
| Office | 85 (18.6) |
| Construction | 62 (13.5) |
| Industry | 50 (10.9) |
| Service | 47 (10.3) |
| Day care | 35 (7.6) |
| School | 10 (2.2) |
| Transmission from pupil (% of school transmission) | 5 (50.0) |
| Transmission from coworker | 5 (50.0) |
| Other | 10 (2.2) |
| Age and school level | 51 (100) |
| 7–12 y (elementary school) | 21 (41.2) |
| 13–15 y (middle school) | 23 (45.1) |
| 16–18 y (high school or vocational school) | 7 (13.7) |
| Transmission from pupil to pupil | 40 (78.4) |
| Transmission from teacher to pupil | 11 (21.6) |

Abbreviation: COVID-19, coronavirus disease 2019.

[a]Epidemics in facilities with many potential index cases.

was identified in our district; the ICU patients were not as infectious as they had been symptomatic for longer than COVID-19 patients not in ICU. The lower risk among ICU workers has been noted before [32].

Unidentified COVID-19 patients have been noted to be a risk for their roommates in hospitals [33]. Patients who are exposed at the hospital and continued the hospitalization are especially problematic. Some hospital outbreaks have been very difficult to control because the secondary cases had also been hospitalized during their most infectious period.

Some 26 881 individuals were placed in quarantine during the study period and the median number of quarantines per positive case was 2. The majority (92%) of contacts did not develop laboratory-confirmed COVID-19 during quarantine, a percentage similar to some other reports [25, 34]. During fall 2020, however, persons who were exposed to a confirmed COVID-19 case but remained asymptomatic were rarely tested. The large number of quarantine restrictions of high-risk individuals may have helped to avoid need for implementing restrictions impacting the whole population, such as curfew. Furthermore, according to the Finnish Communicable Diseases Act, all persons ordered in quarantine or isolation are eligible to receive an allowance for the duration of quarantine or isolation that is proportional to their regular income. This financial support system is likely an important factor in

the high compliance with quarantine in Finland and containing the spread of the epidemic [35, 36].

In the summer of 2021, the Delta VOC spread throughout the world, including our region. It was estimated to be twice as transmissible as previous variants [37]. Therefore, the secondary attack rates in this study were likely higher in the Delta era. Due to the soaring case numbers, our CT principles changed considerably. Isolations continued mostly through digitalized process (text message with a request to fill an online form) and only unvaccinated household members were placed in quarantine. Outbreaks in healthcare facilities were also a priority area for CT. Guidelines for seeking testing and quarantine protocols changed frequently and database insertions were reduced to a minimum, preventing collection of reliable data. During this community spread phase, the contribution of CT to epidemic control decreased in our region. Soon after the Omicron wave began, it became obvious that the volume of cases and transmission speed exceeded CT capacity and that the rationale of CT operations needed reconsideration. Therefore, CT was limited primarily to healthcare-associated cases, and national recommendations for the general public emphasized the importance of self-isolation for individuals with respiratory symptoms.

In conclusion, our data provide evidence on the role of effectively implemented CT operations in maintaining epidemic control during COVID-19 cluster phase spread in our population. CT provided data on major transmission settings, and the high rate of isolations and quarantines reduced onward transmission. Nevertheless, even during a low-incidence period, effective COVID-19 control required a combination of public health measures, including societal restrictions.

## Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

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