

Infection control behaviours, intra-household transmission and quarantine duration: a retrospective cohort analysis of COVID-19 cases

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The incursion of SARS-CoV-2 into the Australian community from returning travellers and subsequent community transmission has required a significant public health response since the commencement of the pandemic. In the Australian setting COVID-19 cases are presently managed through isolation, with imposed quarantine of identified close contacts according to the Communicable Diseases Network Australia (CDNA) Series of National Guidelines (SoNG) to minimise chances of secondary transmission.¹ The location in which individuals undertake this isolation or quarantine is determined at the direction of each state Chief Health Officer. In the context of large outbreaks and limited hospital resources, telemedicine enables those with COVID-19 infection to be managed in community-based isolation.

The structure and outcomes of implementing the virtual ward, a community telemedicine model of care, have been previously described.² Patients under the original model of care were adults with non-delta SARS-CoV-2 strains who had returned from overseas and isolated at home away from other household members. Recently a SARS-CoV-2 delta-strain outbreak involving predominantly school-aged children as the index case, representing a new demographic of outbreak in our setting, necessitated implementation of a virtual ward. The age

Abstract

Objectives: To study COVID-19 (Delta Variant) cases and close contacts co-located within households. Focusing on epidemiology of transmission of COVID-19, quarantine duration and utilisation of infection control behaviours under a telehealth model of care in an elimination setting.

Methods: A retrospective cohort analysis examined household spread of infection, duration of quarantine and change in PCR CT value during illness. A survey explored infection control behaviours used by household members during isolation and quarantine.

Results: The cohort was 141 individuals in 35 households. Thirty-seven were index cases, and 48 became positive during quarantine, most within 10 days. Whole-household infection occurred in 12 households with multiple members. Behaviours focused on fomite transmission reduction rather than preventing aerosol transmission. The median duration of close contact household quarantine was 25 days. The majority of COVID-19 cases were de-isolated after 14 days with no evidence of further community transmission.

Conclusion: Intrahousehold transmission was not universal and, if it occurred, usually occurred quickly. Behaviours utilised focused on fomites, suggesting a need for improved education regarding the potential utilisation of strategies to prevention the transmission of aerosols. Households experienced long durations of home-based quarantine.

Implications for public health: The impact of long quarantine durations must be considered, particularly where most community benefit from quarantine is achieved within 10 days from exposure in the setting of the Delta Variant. Education of households regarding aerosol risk reduction is a potential strategy in the household setting of individuals at risk of disease progression.

Key words: COVID-19, infection control, quarantine, transmission, household

of index cases posed a unique challenge in isolating cases from household members who did not have diagnosed infection on entry to the virtual ward. The outbreak occurred in the context of an elimination-strategy setting for SARS-CoV-2.

The importance of infection control behaviours in prevention of SARS-CoV-2 transmission is well documented.³ Current research examining behaviours used to prevent transmission within households suggests highly variable implementation.^{4,5}

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This cohort of households with children and parents co-locating for isolation and quarantine provided opportunity for further examination of engagement in and practicability of infection control behaviours.

The psychological impact of isolation and quarantining can be significant.⁶ Reported impacts include depression, post-traumatic stress disorder (PTSD), anxiety, and perceived stigma.^{7,8,9} The incidence and impact of these is thought to be proportional to longer durations of isolation or quarantine.¹⁰ Given this, description of the duration of isolation and quarantine in the Australian context is important.

We aim to report the epidemiology around transmission of infection, infection-control behaviours utilised, and length of quarantine in a cohort of households within which household members were isolating and quarantining together, in an elimination-strategy setting.

Methods

Outbreak description

An outbreak of COVID-19 (Delta variant) began in the last week of July 2021 in Brisbane, Queensland. At this time an elimination strategy was being applied to the management of COVID-19 cases and outbreaks. It was the first outbreak to spread in the school setting in Queensland. The relevant local government areas went into lock down and on-line school learning was stood up. The outbreak lasted approximately four weeks and involved the 141 individuals within the 35 households in this study. Most studied households lived in their own house and had a shared bathroom.

Virtual ward structure and workflow

The workflow and structure of the virtual ward has previously been described.² In brief, a medical and nursing workforce utilise telehealth to communicate and manage COVID-19 positive patients in their home environment. Patients underwent clinical assessment typically twice a day and a symptom scoring system was utilised to escalate patients to the medical team for appropriate management. Patients requiring closer observation, oxygen, or other intravenous therapies were transferred to an in-hospital setting for care. All household members received testing for COVID-19 at the time an index household member

was identified as a positive case, and those household members negative for SARS-CoV-2 were subsequently tested both at regular intervals and if experiencing symptoms to detect the development of COVID-19 infection. De-isolation of positive members of the household was allowed by the Chief Health Officer if an individual met CDNA SoNG criteria for release from isolation.¹ The standard criteria were fourteen days after infection onset provided there was adequate symptom resolution, however provision was made for both early and delayed de-isolation based on symptoms and testing (exit swab). On meeting criteria, de-isolated individuals could re-enter the community after the household received education on household environmental cleaning and hand hygiene by the deisolated individual on leaving their property. Remaining SARS-CoV-2 household members were quarantined at their home for 14 days after the last household member was deisolated as per the SoNG.¹ At the commencement of isolation and quarantine, households received information about strategies they could utilise to prevent the transmission of infection from the Public Health Unit.

Diagnostic testing

Due to reporting of initial polymerase chain reaction (PCR) deep nasal/throat swab testing for SARS-CoV-2 testing from multiple pathology providers in the community, a range of testing platforms were utilised. Subsequent deep nasal/throat swabs and serological testing were performed by a collection service attached to the virtual ward service. All household members underwent PCR deep nasal/throat swab on admission to the virtual ward, and negative household members were subsequently tested at routine intervals. SARS-CoV-2 salivary testing of negative household members at more frequent intervals (3rd daily) was introduced two weeks after implementation of the virtual ward service. All positive salivary samples were confirmed by testing on a deep nasal/throat swab. SARS-CoV-2 household members were also offered additional testing if they developed new symptoms suggestive of infection. SARS-CoV-2 negative household members were required to have a confirmatory negative deep nasal/throat swab at the end of the 14-day quarantine period to meet criteria for release from quarantine.

In real time PCR a positive reaction is detected by accumulation of cumulative fluorescent signal. The CT is defined as the number or target amplification cycles are required for the fluorescent signal to exceed background level. The lower the CT this occurs at the greater the amount of target in the sample. As different platforms and thus PCR targets were utilised, the lowest CT from any target utilised in the testing of the sample is presented in the analysis of results.

All detected virus underwent genotyping at the direction of the Chief Health Officer. Serological testing on blood samples consisted of an in-house total antibody neutralisation assay performed by the local public health reference laboratory.

Data collection

The Virtual Care Stream database was used to collect cohort data retrospectively. Testing results were obtained from the relevant pathology provider database. As different platform and thus PCR targets were utilised the cycle threshold from one target is presented in the analysis of results. A survey on infection control strategies utilised in households during admission was sent to the household groups at the conclusion of their quarantine to assess utilisation of the strategies provided to patients by the Public Health Unit on initial directive to quarantine.

Statistical analysis

Routine statistical analysis was utilised. Descriptive statistics were expressed as number (%) values for categorical data and median or mean (range) values for continuous variables.

Human research and ethics approval to conduct this research was obtained from the Royal Brisbane and Women's Hospital Human Research Ethics Committee (HREC EX/2021/QRBW/79533).

Results

One hundred and forty-one individuals in 35 households were admitted to the virtual ward over the outbreak period: 72 adults and 69 children. Two households consisted of only one individual. A child was defined for clinical management purposes as less than 16 years of age. The median adult age was 45 (range 16–76) years, and the median child age was 11 (range 2–15) years. There were 30 vaccinated adults and 6 partially vaccinated adults in the cohort.

Eighty-five individuals were diagnosed with COVID-19 either at entry onto the virtual ward or during their period of quarantine after exposure to a SARS-CoV-2 positive case. Genotyping revealed the variant of concern Delta (B.1.617.2) in all cases. Most patients met criteria for mild disease.¹¹ Seven patients met criteria for moderate disease.¹¹ Three individuals required hospital review during their illness due to concern regarding severity of symptoms, all of whom were unvaccinated. Following hospital review one patient remained an inpatient in the hospital setting for the rest of their illness, one was discharged after observation for 24 hours and the third was discharged from the emergency medicine department.

With the exception of two single individual households, household size ranged from three to six individuals. The two households made up of only a single individual admitted to the virtual ward will not be mentioned in discussion of transmission. The index cases (37 out of 85 patients) were identified from testing directed by the Public Health Unit from a high-risk exposure setting with a positive case. Most infections within households were identified by day 10 after identification of the index case through a combination of routine and symptom-triggered screening (Figure 1). One household was an outlier in disease identification, and two additional cases were picked up on routine screening at day 14 and then day 21 after the positive notification of the household index case. Both cases were asymptomatic and had negative results on prior third daily oral saliva testing. Each of the individuals had re-exposure within the preceding eight days to a newly identified case within the household.

Infection of all household members occurred in only 12 of the 33 households with more than one member (Figure 2). In seventeen households at least one adult member had received at least one COVID-19 vaccine dose. Infection control strategies utilised within households are presented in Tables 1 and 2. In three of the 33 households that responded to the survey no adults utilised any strategies to prevent disease transmission or acquisition, and in five of the 33 households no children utilised any strategies. Strategies directed at fomite transmission were utilised more commonly by households than strategies directed at minimising aerosol transmission. Generally, strategies to prevent transmission were more commonly utilised by SARS-CoV-2

Figure 1: Day from index case further infections in the household were identified (n=48, 33 households).

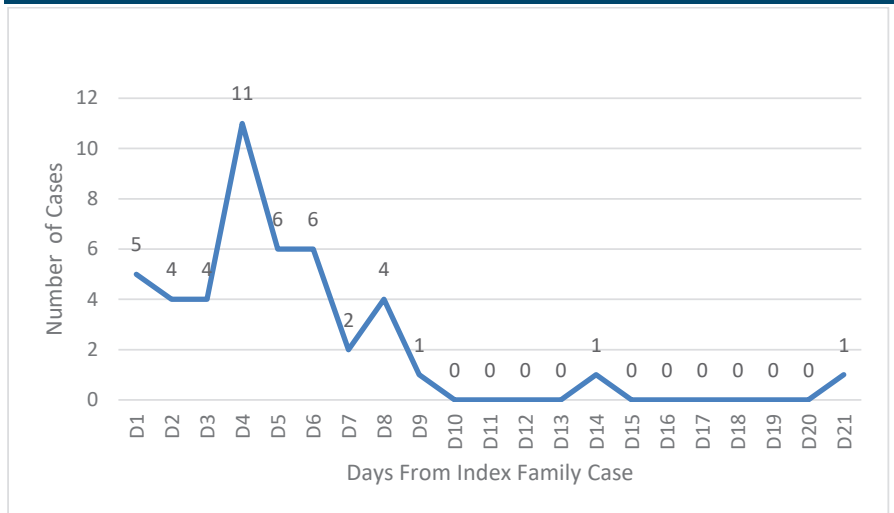


Table 1: Prevention of transmission behaviours utilised by household adults or children with SARS-CoV-2 infection.

Infection control behaviour/strategy utilised	Household behavior of adults with SARS-CoV-2 (n=20)	Household behavior of children with SARS-CoV-2 (n=32)
Isolated in own room	5	10
Used separate bathroom	6	12
Cleaned bathroom each time after use	3	3
Stayed at least 1.5m from others	6	8
Avoided common areas	5	10
Wore a mask when moving through shared spaces in the house	5	7
Wore a mask when in the same room as others	2	7
Avoided preparing food for other people in the household	7	16
Avoided sharing household items	7	13
Regular disinfection of house	7	13
Regular hand hygiene while at home	16	24
Washed shared sheets often	6	9
None of the above strategies utilised	2	5
Median number of strategies used	6	10

Table 2: Infection control prevention of acquisition behaviours utilised by household adults or children without SARS-CoV-2.

Infection control behaviour/strategy utilised	Household behavior of adults without SARS-CoV-2 (n=21)	Household behavior of children without SARS-CoV-2 (n=16)
Isolated in own room	1	2
Used separate bathroom	6	5
Cleaned bathroom each time after use	2	1
Stayed at least 1.5m from others	3	3
Avoided common areas	1	0
Wore a mask when moving through shared spaces in the house	2	2
Wore a mask when in the same room as others	2	1
Avoided preparing food for other people in the household	0	3
Avoided sharing household items	5	5
Regular disinfection of house	7	5
Regular hand hygiene while at home	10	11
Washed shared sheets often	4	2
None of the above strategies utilised	3	5
Median number of strategies used per household	2.5	3

positive household members than by those SARS-CoV-2 negative when there was a positive case within the household.

Testing results as part of this process are presented in Figure 3. Day nine exit nasopharyngeal swabs or serology were not routinely performed in children less than 16 years of age. As per the CDNA SoNG, a fourteen-day period with complete resolution of fever and significant improvement in respiratory symptoms in the prior 72 hours was the predominant criteria used for de-isolation.¹ There was provision in the CDNA SoNG for early release after day 10 depending on symptoms and testing results. Some adults who may have been suitable for consideration of early discharge elected not to be tested at day nine of isolation and await meeting the clinical criteria at 14 days. Only two patients with COVID-19 met the CDNA SoNG criteria for early de-isolation at day 10 with negative PCR tests. Two vaccinated individuals were discharged after 10 days of illness after discussion and agreement of an Expert Advisory Group (EAG). They met

Figure 2: Household infection rate after end of the final quarantine period of last family member (including the index case).

	Partial Infection of Household	Complete Infection of Household
Number of families (%)	21/33 (64)	12/33 (36)

clinical criteria for discharge at day 10 with significant reduction in respiratory symptoms and had evidence of a total neutralising antibody response and a PCR cycle threshold (CT) at day nine of ≥ 30 from deep nasal/throat swab. The CT values for individual adults from whom entry and exit deep nasal and throat swabs were obtained are presented in Figure 3. Seven individuals had a CT value of less than 25 on the exit swab taken and 13 had CT values of less than 30. The last positive patient was discharged from the ward on 9 September 2021. There has been no identification of any linked community transmission following discharge of the cases based on community screening.

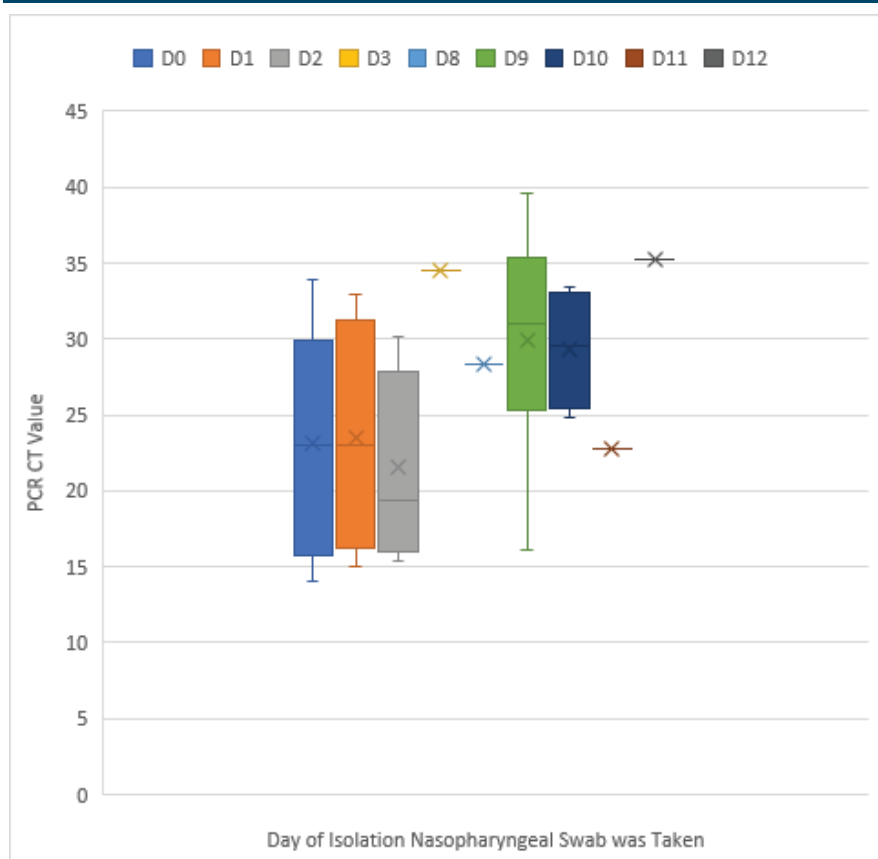
Excluding four individuals who quarantined in a separate dwelling from the index case, fifty-four close contacts in 22 households remained in quarantine in their own home after the last positive household member had been deisolated and discharged from the virtual ward. The 54 individuals consisted of 33 adults and 21 children. They continued with 3rd daily oral saliva testing and a deep nasal/throat swab 2 days prior to the expected end of their quarantine period. Of these, only two individuals became positive for COVID-19. The total length of quarantine for the other 52 close contacts was a median of 25 days (range 21–29) days.

Discussion

We describe the experience of households with members undertaking isolation and quarantine for COVID-19 together. This cohort provides information to help inform decision making around management of households exposed to COVID-19. This outbreak was unique in that children were the main index cases and the ward catered for households composed of both SARS-CoV-2 positive individuals and negative close contacts, isolating and quarantining together. None of the cohort were immunosuppressed and only mild or moderate COVID-19 disease was represented. Twenty-six per cent of the cohort were vaccinated.

Of the cohort described just under half of the household members who tested negative on initial screening developed infection during quarantine. Fifty-two of the 54 individuals in quarantine were identified as positive within 10 days post household index infection. The remaining two positive cases were identified after this 10-day period. No new infection developed after 10 days from exposure to the most recently positive case in the household. This was in the setting of a regular screening strategy for high-risk contacts. Long periods of quarantine for non-converting household members were experienced with only two additional cases being detected after day 10 from the index case in a household. The mental health strain imposed on all household members due to isolation and quarantine needs to be considered in balance with community risk. Implications for public health are shorter quarantine periods could be considered for the infected households with the delta COVID-19 strain. In the setting of no tolerance of transmission perhaps supplementary testing and masking

Figure 3: Boxplot (mean and quartile) of the cycle threshold value of COVID 19 PCR nasopharyngeal swabs results entry (D0-3) and exit swabs (D9-12) for Adults^a (n=25).



Note:
 a: Two or more targets on differing platforms are utilised in the testing algorithm. For purposes of their graph the lowest cycle threshold from any target from each test was utilised.

strategies could be utilised to reduce the risk of development of infection outside this 10-day period.

Eighty-seven per cent of the households utilised some strategy to prevent disease transmission. The strategies mainly focused on hand hygiene and home disinfection. Strategies were more likely to be used to prevent disease transmission from a case than acquisition by a close contact. Strategies focused at reducing fomite transmission were more commonly used than those aimed at reducing aerosol transmission. Five households elected not to utilise any infection control strategies. This survey did not explore the rationale of households behind choice of strategies employed, however households were predominantly composed of families with young children, so practicability of some strategies may have been a consideration. The cohort was generally considered low risk for severe infection. In the setting of future household education strategies by public health, particularly where there is potentially high consequence infection, further information could be provided on the utilisation of masking strategies in the home.

CT values across the course of different severities of illness in both unvaccinated and vaccinated individuals have been previously published.^{12,13} Thus representing differing levels of viral control relating to severity of illness and existing individual immunity to infection. The median lowest CT values from testing of the 19 samples that were taken on day nine of isolation in this study was 30.98 (range 16.14–37.94). It should be remembered when considering these results that the testing was done on several platforms. With that in mind individuals with mild or moderate infection and the lowest target CT values from sample testing of less than 25 at day nine of isolation were able to be safely discharged back into the community based on clinical criteria at day 14. The study setting applied a track and trace approach to any individual cases of COVID-19 for months after the release of the last person in this cohort with the goal of maintaining elimination. It is unlikely that onward community spread of COVID-19 would have been missed in this setting due to high community testing rates, public awareness of SARS-CoV-2, and the follow-up of all cases of COVID-19 by public health. This supports the view that clearance specimens are not indicated for release from isolation in

our non-immunosuppressed cohort.

The limitations of this study are that it represents a small retrospective cohort in a single setting. In addition, the management of cases of COVID-19 has many nuances in each geographical setting. Testing platforms for PCR were also not uniform and CT values on the day of patient discharge from self-isolation were not obtained. Finally, as families were under isolation and quarantine directions, there may be a bias towards favourable reporting of infection control behaviours.

In summary the study describes the experience of households in quarantine during the Delta wave of COVID-19 infection in Australia. The cohort was younger, with limited comorbidities and experienced mainly mild disease. Not all close contacts in a household with an index case developed infection. Most infections developed by ten days after the index case was identified in the household. The cohort experienced long periods of quarantine. Household infection control strategies, if utilised, focused on fomite rather than aerosol reduction of transmission. Households with members at risk of potentially high consequence infection could be educated in future on the utilisation of masking strategies in the home.

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