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### Permalink

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### Journal

Infection, Disease and Health, 27(1)

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### Publication Date

2022-02-01

### DOI

10.1016/j.idh.2021.09.001

Peer reviewed

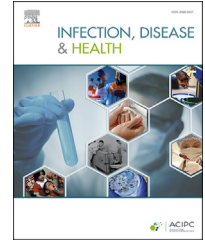


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Research paper

# Performance of hospital-based contact tracing for COVID-19 during Australia's second wave

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Received 3 July 2021; received in revised form 26 August 2021; accepted 4 September 2021

Available online 22 September 2021

## KEYWORDS

COVID-19;  
SARS-CoV-2;  
Contact tracing;  
Healthcare;  
Hospital

**Abstract** *Background:* Hospital-based contact tracing aims to limit spread of COVID-19 within healthcare facilities. In large outbreaks, this can stretch resources and workforce due to quarantine of uninfected staff. We analysed the performance of a manual contact tracing system for healthcare workers (HCW) at a multi-site healthcare facility in Melbourne, Australia, from June–September 2020, during an epidemic of COVID-19.

*Methods:* All HCW close contacts were quarantined for 14 days, and tested around day 11, if not already diagnosed with COVID-19. We examined the prevalence and timing of symptoms in cases detected during quarantine, described this group as proportions of all close contacts and of all cases, and used logistic regression to assess factors associated with infection.

*Results:* COVID-19 was diagnosed during quarantine in 52 furloughed HCWs, from 483 quarantine episodes (11%), accounting for 19% (52/270) of total HCW cases. In 361 exposures to a clear index case, odds of infection were higher after contact with an infectious patient compared to an infectious HCW (aOR: 4.69, 95% CI: 1.98–12.14). Contact with cases outside the workplace increased odds of infection compared to workplace contact only (aOR: 7.70,

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95% CI: 2.63–23.05). We estimated 30%, 78% and 95% of symptomatic cases would develop symptoms by days 3, 7, and 11 of quarantine, respectively.

**Conclusion:** In our setting, hospital-based contact tracing detected and contained a significant proportion of HCW cases, without excessive quarantine of uninfected staff. Effectiveness of contact tracing is determined by a range of dynamic factors, so system performance should be monitored in real-time.

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### Highlights

- Health care workers were identified as close contacts by hospital-based contact tracing on 483 occasions.
  - 11% developed COVID-19 in quarantine, accounting for 19% of all healthcare worker cases.
  - Odds of COVID-19 were higher after contact with infectious patients compared to infectious healthcare workers.
  - Odds of COVID-19 were higher if close contact occurred outside of work.
- 

## Introduction

Contact tracing is a key part of the public health response to novel coronavirus disease 2019 (COVID-19) [1]. Modelling suggests that effective case isolation, contact tracing and quarantine can effectively control outbreaks, and that these strategies provide additional benefit when combined with population wide non-pharmaceutical interventions (NPIs) to limit physical contact [2]. In Australia, implementation of coordinated contact tracing, together with strict border measures, has allowed easing of NPIs without sustained community transmission [3].

Health care workers (HCWs) are at significantly elevated risk of COVID-19 [4, 5], so implementation of effective contact tracing in health care settings should be prioritised. However contact tracing is resource intensive [6], and in the context of large outbreaks quarantining large numbers of HCW can heavily impact health systems [7].

Various frameworks have been suggested to guide contact tracing in health care settings [6, 8]. However, there is a need to determine the most effective, and least restrictive, strategies for isolation, testing, and return to work [9]. We conducted a retrospective analysis of contact tracing data during an outbreak to examine the rate and timing of COVID-19 onset among HCW close contacts identified through hospital-based contact tracing, and to identify factors associated with increased risk of infection in this group.

## Methods

### Setting

We sourced data from a large public tertiary hospital in Melbourne, Victoria. The facility includes a 550 bed tertiary campus, a 150 bed aged care and sub-acute campus, a large mental health service and four residential aged care facilities. Around 10,000 staff were employed across 32 sites, although about 70% worked at the two main metropolitan campuses.

Victoria experienced a second epidemic of COVID-19 between June and October 2020, driven largely by local transmission within Melbourne. Stage 3 restrictions (including the closure of bars, entertainment venues, and places of worship, limiting restaurants to take-away only, and prohibiting public gatherings of more than two people) were implemented in 10 postcodes from 2 July, and expanded to all of metropolitan Melbourne from 8 July. From 2 August, Stage 4 restrictions were introduced (including an overnight curfew, limits on movement to within a 5 km radius of one's residence except for essential activities, and a 1 h limit on outdoor exercise). The epidemic included around 18,650 cases and peaked on 4 August with 687 new diagnoses [10]. The temporal distribution of new diagnoses of COVID-19 in HCWs across the facility over this period resembled the shape of the epidemic curve for Victoria as a whole [10, 11].

Use of NPIs to reduce transmission risk to HCWs at the facility changed significantly over the same period. In particular, mandatory universal mask wearing, even in non-clinical settings, was introduced and expanded from early July (Supplementary table 1). From mid-July, staff were required to wear N95 masks at all times in high-risk areas such as wards dedicated to the care of COVID-19 patients.

### Contact tracing

For the purposes of this report, we define isolation as separation of suspected or confirmed cases from the general population, and quarantine as separation of non-cases deemed to be at elevated risk of infection based on exposure history. Furlough refers to the temporary removal of HCW from the workforce, while in isolation or quarantine.

Hospital-based contact tracing was undertaken by the Infection Prevention and Surveillance Service (IPSS) in accordance with guidelines provided by the Victorian Department of Health and Human Services (DHHS) [12]. Cases were notified to IPSS by the hospital laboratory, if tested at the facility. If tested elsewhere, cases were

notified by DHHS, the positive staff member themselves, or their manager.

An IPSS staff member interviewed each HCW case via phone as soon as practical after they were notified. Contact tracing was performed for the infectious period from 48 h prior to symptom onset, or first positive test if asymptomatic at notification, until the case was isolated. Close contacts were defined by DHHS as people who had either:

- a)  $\geq 15$  min cumulative face-to-face contact during the prior week,
- b)  $\geq 2$  h in a confined space shared with a confirmed or probable case during the prior week, or
- c) been exposed to a particular setting judged by IPSS to be associated with a high risk of infection (such as a ward experiencing a widespread outbreak) [12].

HCWs wearing appropriate personal protective equipment (PPE) during care of suspected, probable or confirmed patient cases were not considered close contacts unless a breach in PPE was identified [12]. From 11 July, following advice from DHHS, mask use was considered when risk assessing contact between HCWs. In instances where both case and contact were HCWs, and both were masked, the above close contact definition was no longer applied. Instead, designation as a close contact was subject to individual risk assessment by IPSS, considering nature and duration of contact, as well as whether the case was symptomatic. Data were collected on all close contacts within the facility, and any close contact with other staff that occurred external to the facility. Data were entered into a REDCap database at the time of contact tracing.

HCW close contacts were contacted via phone and furloughed for 14 days from the last date of close contact. IPSS staff or a wellbeing team staff member provided regular follow up over the quarantine period and assisted contacts to seek testing if they developed symptoms. Return to work was contingent on a negative test result on or after day 11 and completion of quarantine, regardless of test results, although some staff also underwent asymptomatic testing earlier in the quarantine period. Testing was performed using polymerase chain reaction (PCR) on upper respiratory tract samples (nose and throat swab). Testing for respiratory viruses other than severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was not routinely performed.

### Data source and study population

We extracted data from the REDCap database used by IPSS for case and contact management. We defined HCWs as anyone working or undertaking study in the facility and who could be exposed either directly or indirectly to SARS-CoV-2 in that setting. We included data from June–September 2020 for all cases of COVID-19 diagnosed in HCWs who attended the facility, and all HCW close contacts of another HCW, patient, or visitor case. We excluded records for HCW close contacts of a case in the community who was not also a HCW, because these contacts were not identified through hospital-based contact tracing. We also excluded records where there were insufficient data to determine why the

HCW had been designated a close contact. Individual HCWs could have multiple instances in the database if they were furloughed on multiple occasions.

### Data analysis

Data analysis was performed in R version 6.3.1 [13]. We calculated the overall proportion of HCW close contact instances resulting in diagnosis of COVID-19 during quarantine. We excluded from further analysis instances where HCW were furloughed without a clear index case, i.e. they were defined as a close contact according to definition c) above, but there were insufficient data to identify details and timing of specific cases they were exposed to.

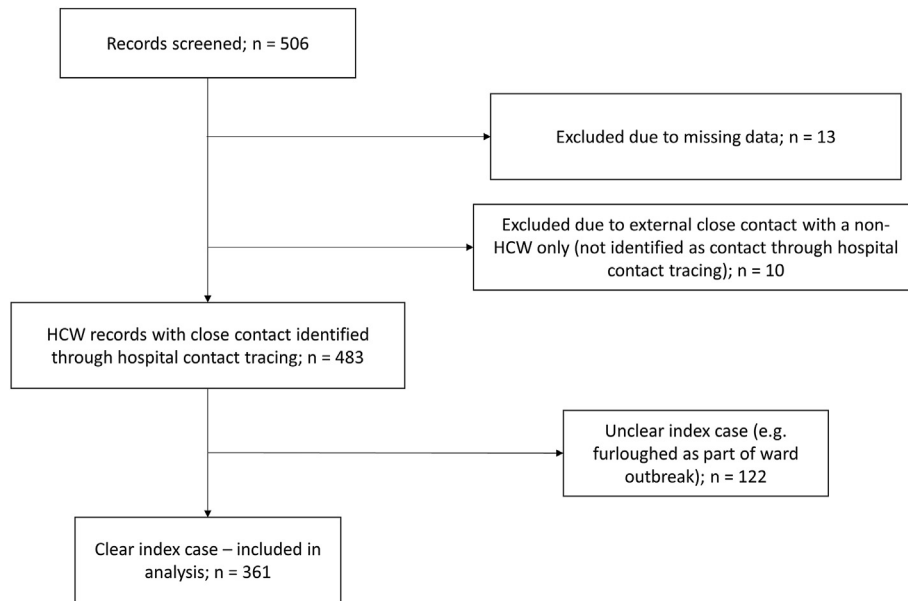
For each HCW close contact instance, we extracted data on age, sex, role, symptom onset, test dates and results, number of linked potential source cases, whether the linked case first resulting in the HCW being quarantined (index case) was another HCW, a patient, or a visitor, place of contact with the index case, and date of last close contact. We classified role as “clinical” for HCWs involved directly with patient care, for example nurses, doctors, and allied health staff. Other staff, for example cleaning, administrative, security, or food handling staff we classified as “non-clinical”. We classified place of close contact into either “workplace only”, or “external  $\pm$  workplace” where there had been close contact external to the facility, for example in a household or social setting, regardless of whether there was also contact within the facility.

We used univariate and multivariate logistic regression models to assess potential factors associated with increased odds of testing positive during quarantine, based on data available from the contact tracing database. We included HCW role, number of linked cases, place of contact with the index case, and type of index case as categorical predictors in both univariate and multivariate models, based on a priori assumptions of possible independent causal effects. We tested interactions between these variables, but none were statistically significant, and we did not include them in the multivariate model (data not shown). We included sex and age group in the multivariate model in an attempt to reduce confounding due to unmeasured behavioural factors.

For HCW close contacts who tested positive during quarantine and developed symptoms, we plotted a histogram of symptom onset by days since last close contact. We fitted gamma, Weibull and lognormal distributions using the R package “fitdistrplus” [14]. We chose the best fitting model based on the Akaike information criterion (AIC), calculated 95% confidence intervals by bootstrapping with 1000 iterations, and calculated 95% prediction intervals for developing symptoms by days 3, 7, and 11 post last close contact.

### Results

We screened 506 HCW close contact records, excluded 13 due to missing data, and a further 10 identified through community rather than hospital-based contact tracing (Fig. 1). In the remaining 483 instances, HCWs were designated as close contacts and furloughed through hospital-



**Figure 1** Selection of health care worker (HCW) database records for inclusion.

based contact tracing. Of these, 11% (52/483) resulted in diagnosis of COVID-19 during quarantine, which represented 19% (52/270) of HCW cases identified in the facility. In 25% (122/483) of instances, HCWs were furloughed without recorded contact with an index case, while in 75% (361/483) of instances, HCWs were furloughed following close contact with an index case. Twelve of 122 instances (10%) where there was no known contact with an index case resulted in a diagnosis of COVID-19. These instances were not analysed as specific index case data were not available. Forty of the remaining 361 instances (11%) where there was known contact with an index case resulted in a diagnosis of COVID-19. These 361 instances represent data from 357 unique HCWs, as 4 were quarantined more than once.

The median age of these 357 furloughed HCWs was 32 years (range 21–70), 283 (79%) were female, and 314 (88%) worked in clinical roles (218 nurses, 58 doctors, 26 allied health staff, and 12 students). These HCWs were furloughed due to close contact with at least one of 97 source cases, including 71 HCW cases, 24 patient cases where contact occurred without appropriate PPE, and two visitor cases. In 28 instances HCWs were identified as close contacts of more than one case and in 333 as close contacts of one case only (Table 1). In the multivariate model, odds of infection were higher for close contact with a patient versus a HCW index case (aOR: 4.69, 95% CI: 1.98–12.14), and for close contacts with any close contact occurring external to the workplace (aOR: 7.70, 95% CI: 2.63–23.05, Table 1). For sex, age group, role of the HCW contact, and the number of linked cases, estimated effect sizes were small, and confidence intervals included an odds ratio of 1.

The timing of testing and symptom onset was analysed in 39 of 40 HCW cases diagnosed in quarantine (Fig. 2, test dates were missing for one HCW). Seventeen cases were initially tested within 3 days of furlough either because of symptoms (8/17) or as part of asymptomatic screening (9/17), among whom 65% (11/17) were positive (Fig. 2).

Symptoms developed in 63% (25/40) of cases during the quarantine period. For these cases, the distribution of days from last contact to symptom onset was best approximated by a gamma distribution, with marginally lower AIC than the lognormal distribution (Supplementary figure 1). Based on the fitted model parameters we estimated 30% (95% CI: 16–46%) of symptomatic infected HCWs would develop symptoms by 3 days since last close contact, 78% (95% CI: 65–92%) by 7 days and 95% (95% CI: 88–100%) by 11 days (Supplementary table 2).

In 9% (31/361) of instances, HCWs reported COVID-19 compatible symptoms in quarantine but were not identified as cases. However, all reported onset prior to 11 days since last close contact and tested negative around day 11. Of these 31 HCWs, 27 had also earlier tested negative at onset of symptoms.

## Discussion

In our study, approximately one in ten close contact HCWs tested positive for SARS-CoV-2 during quarantine, representing 19% of all HCW infections. We identified close contact with infected patients compared with infected HCWs, or close contact outside the health-care facility as possible risk factors for infection in quarantined HCWs. More than a third of cases diagnosed in quarantine did not develop symptoms. We estimated that almost all symptomatic infected HCWs developed symptoms by 11 days after their most recent close contact with an infectious case.

Strategies for contact tracing and quarantine should consider both individual and workforce impacts of furloughing staff, as well as the benefits associated with preventing transmission. In our setting, approximately 9 non-infected close contacts were furloughed for every case contained in quarantine. Given the substantial proportion

**Table 1** Characteristics of health care workers (HCWs) furloughed due to close contact on 361 occasions, results of univariate and multivariate logistic regression predicting diagnosis of COVID-19 by polymerase chain reaction (PCR) during 14 day quarantine.

	HCW characteristics		Univariate models	Multivariate model
	Total number of close contacts	Number PCR positive (% of total)	Odds ratio (95% confidence interval)	
<b>Sex</b>				
Female	287	30 (10%)	Reference	Reference
Male	74	10 (14%)	1.34 (0.60–2.8)	1.35 (0.57–2.99)
<b>Age group</b>				
<30	142	17 (12%)	Reference	Reference
30–39	110	8 (7%)	0.58 (0.23–1.35)	0.63 (0.24–1.55)
≥ 40	109	15 (14%)	1.17 (0.55–2.47)	1.29 (0.58–2.88)
<b>HCW role</b>				
Non-clinical	43	4 (9%)	Reference	Reference
Clinical	318	36 (11%)	1.24 (0.47–4.32)	1.12 (0.37–4.3)
<b>Number of linked cases</b>				
1	333	35 (11%)	Reference	Reference
≥2	28	5 (18%)	1.85 (0.59–4.83)	1.03 (0.31–2.93)
<b>Place of contact with index case</b>				
Workplace only	327	31 (9%)	Reference	Reference
External ± workplace	34	9 (26%)	3.44 (1.41–7.82)*	7.70 (2.63–23.05)**
<b>Type of index case</b>				
Staff	218	17 (8%)	Reference	Reference
Patient	133	23 (17%)	2.47 (1.27–4.89)*	4.69 (1.98–12.14)**
Visitor	10	0 (0%)	–	–

\*p &lt; 0.01, \*\*p &lt; 0.001.

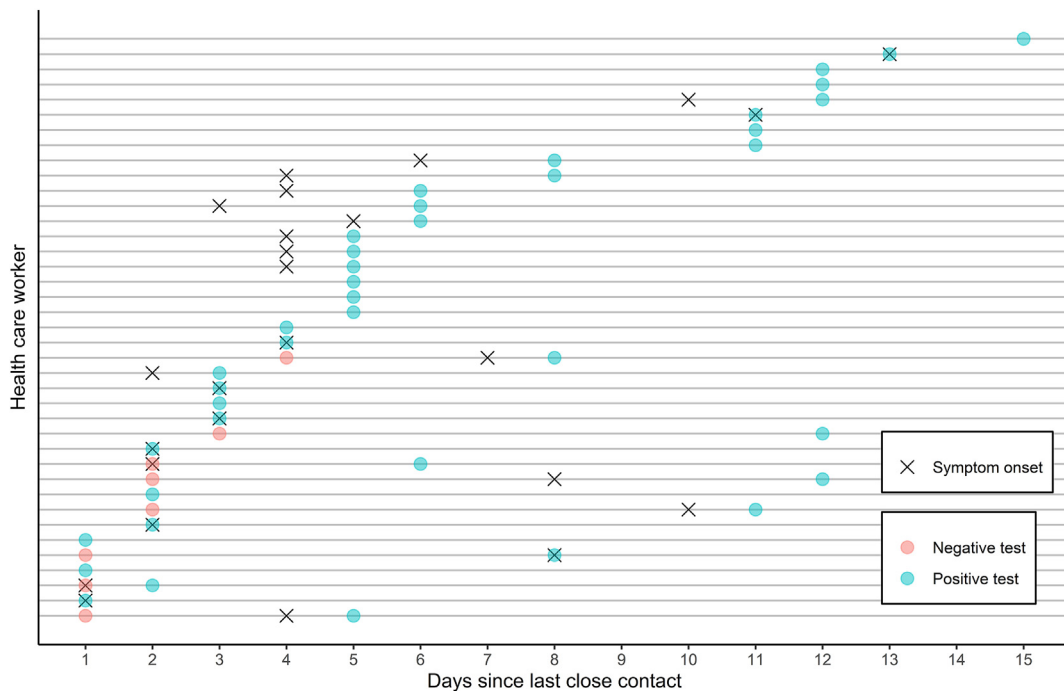
of overall SARS-CoV-2 transmission from asymptomatic and presymptomatic cases to (estimated to be between 20% and 70%) [15], we believe this represents a favourable trade-off. The consequences of transmission in a high-risk setting are serious, although these have to be balanced with the risks of furloughing a significant proportion of a critical workforce.

This study was conducted in the setting of widespread community transmission, with increasing HCW infections mirroring an increase in cases in the community. Our finding that risk of infection was increased with contact outside the healthcare setting is in keeping with previous investigations of infected HCWs [16], and the known propensity of SARS-CoV-2 to spread within households [17]. Our investigation highlights that hospital infection control and prevention teams need to effectively cooperate with and conduct joint risk assessments with public health authorities conducting community contact tracing.

During the COVID-19 epidemic in Victoria, about 70% of HCW or aged-care worker infections were thought to be acquired at work [18]. However, the minority of cases in our facility were detected through workplace contact tracing, with the majority detected either through symptomatic testing or wider asymptomatic screening [11]. Clearly, effective contact tracing should be accompanied by other strategies to reduce workplace transmission. Such strategies include targeted asymptomatic testing, screening everyone entering the workplace for symptoms of COVID-19, as well as optimising air flow and use of PPE [19].

Our findings suggest that among those quarantined, contact with known infected patients presented higher risk of infection than contact with known infected HCWs. This might reflect generally higher viral loads among admitted patients, associated with more severe disease [20], and differences in nature and extent of HCW-HCW and HCW-patient close contact. Several studies have attempted to follow-up HCWs exposed to COVID-19 patients, and have generally found low rates of infection [21–24]. However these typically involve a small number of selected patients [21–24], and hospital seroprevalence studies suggest many HCW cases go undiagnosed [25, 26]. Thus, there is a need for systematic prospective research involving follow-up and testing of casual contacts of hospitalised COVID-19 patients to better define risk of infection and to refine quarantine requirements.

We estimated that 88–100% of HCWs who develop symptoms after being quarantined will do so within 11 days of last close contact. This is consistent with data on the incubation period of SARS-CoV-2 [27], accounting for some HCWs being infected prior to the most recent exposure. Given SARS-CoV-2 viral load in upper respiratory tract samples peaks around symptom onset [20, 28], and that viral load appears to be similar in asymptomatic and mildly symptomatic cases [29–31], testing on day 11 could be expected to detect the vast majority of HCW cases who would otherwise pose a risk of onwards transmission. Our findings suggest that a strategy involving testing on days 3 or 7 might fail to detect a substantial proportion of



**Figure 2** Timing of symptom onset and testing in 39 health care workers diagnosed with COVID-19 during quarantine.

asymptomatic or pre-symptomatic cases. Indeed, a number of HCW cases in our study were PCR-negative when tested early in the quarantine period. However, earlier identification of infected HCWs in quarantine would have facilitated earlier identification of their contacts, providing opportunities to prevent further transmission.

Our study has several limitations. First, due to the substantial workload on contact tracing staff, data sometimes contained limited information on nature of contact or possible exposures outside of the workplace, preventing more detailed analysis. Further, during the peak of the second epidemic, delays of up to several days in both turnaround time of results from some external pathology services, and in case follow-up and reporting by the DHHS, in turn led to unavoidable delays in initiating contact tracing, which may have affected the ability of cases to provide an accurate history of contact at the time of interview.

Second, when investigating factors associated with risk of infection in close contacts, we considered information about the index case, but not other cases the HCW was subsequently identified as having been exposed to. While this approach may be helpful in informing risk assessment in real-time, it does not account for possible sources of infection other than the index case. While exposure misclassification due to undocumented contact is likely to have occurred, we did not set out to make inferences based on a complete picture of each individual's exposures, but to determine how contact tracing data could be used to better define risk.

Third, it is possible some asymptomatic cases with long incubation periods may have gone undetected on day 11 testing, biasing estimates around symptom onset towards earlier in the quarantine period. However, this seems unlikely based on current incubation period data [27], and we are not aware of any study HCWs being diagnosed in the immediate period following quarantine.

Fourth, caution should be used in attempting to apply our findings to other settings, as a range of dynamic and difficult to measure factors affect generalisability. These include HCW factors, such as the proportion of staff vaccinated or previously infected, facility factors including close contact definitions and workplace practices, and pathogen factors including the presence of more infectious variants.

The COVID-19 pandemic has demonstrated the critical importance of systems for hospital contact tracing, but has also put them under unprecedented strain. In our setting, contact tracing detected and contained a substantial proportion of HCW cases, without requiring furlough of an excessive number of non-infected staff. These data demonstrate that our contact tracing and furlough procedures likely prevented many more cases in HCWs, although there were significant impacts on the workforce. Collection of large amounts of data for contact tracing purposes poses logistical challenges, but it also provides opportunities to gain insight into how systems are performing and may be improved. This requires hospitals to implement robust processes for data collection and storage, facilitating near to real-time analysis. This may be aided by better integrating systems for contact tracing run by hospitals and other public health agencies, and by exploring novel methods for automated contact tracing [32]. Planning for hospital-based contact tracing should be accompanied by workforce planning that can accommodate furlough of large numbers of staff.

## Ethics

This study was assessed by the Melbourne Health Human Research Ethics Committee (HREC) as an evaluation activity not requiring HREC review (QA2020192).



## Authorship statement

CB: formal analysis, investigation, methodology, visualisation, writing – original draft. VL: data curation, investigations, writing – review & editing. EO: investigation, writing – review & editing. ES: data curation, software. CK: writing – review & editing. KLB: writing – review & editing. BCC: writing – review & editing. MDK: supervision, writing – review & editing. SGS: supervision, writing – review & editing. CM: conceptualisation, investigation, methodology, writing – review & editing.

## Conflict of interest

The authors have no conflicts of interest to report.

## Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Provenance and peer review

Not commissioned; externally peer reviewed.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.idh.2021.09.001>.

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