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Number Needed to Quarantine and Proportion of Prevented Infectious Days by Quarantine: Evaluating the Effectiveness of COVID-19 Contact Tracing

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Abstract

Objectives: Information on the effectiveness of COVID-19 contact tracing is lacking. We proposed 2 measures for evaluating the effectiveness of contact tracing and applied them in a public health unit in northern Portugal.

Methods: This retrospective cohort study included the contacts of people with COVID-19 diagnosed July 1–September 15, 2020. We examined 2 measures: (1) number needed to quarantine (NNQ), as the number of quarantine person-days needed to prevent 1 potential infectious person-day; and (2) proportion of prevented infectious days by quarantine (PPID), as the number of potential infectious days prevented by quarantine divided by all infectious days. We assessed these measures by sociodemographic characteristics, types of contacts, and intervention timings (ie, time between diagnosis or symptom onset and intervention). We considered 3 scenarios for infectiousness periods: 10 days before to 10 days after symptom onset, 3 days before to 3 days after symptom onset, and 2 days before to 10 days after symptom onset.

Results: We found an NNQ of 19.8-41.8 person-days and a PPID of 19.7%-38.2%, depending on the infectiousness period scenario. Effectiveness was higher among cohabitants and symptomatic contacts than among social or asymptomatic contacts. NNQ and PPID changed by intervention timings: the effectiveness of contact tracing decreased with time from diagnosis to quarantine of contacts and with time from symptom onset of the index case to contacts' quarantine.

Conclusions: These proposed measures of contact tracing effectiveness of communicable diseases can be important for decision making and prioritizing contact tracing when resources are scarce. They are also useful measures for communication with the general population, policy makers, and clinicians because they are easy to understand and use to assess the impact of health interventions.

Keywords

COVID-19, contact tracing, effectiveness, number needed to quarantine, public health, Portugal

The COVID-19 pandemic has provided a unique challenge for societies and health systems. Traditional public health measures to control the transmission of infectious diseases still remain essential, with the transmission of SARS-CoV-2 occurring primarily through contact with a person who has COVID-19.[1] Quarantine, social restriction (ie, avoiding unnecessary contacts), and isolation are 3 nonpharmacological interventions used to control outbreaks. Quarantine, which has been used since the 14th century to break transmission pathways, is probably the best example.[2-4] Although historically the definition of quarantine corresponds to the separation of people, animals, and goods suspected of carrying an infectious agent,[2] it is currently defined as a compulsory physical separation of healthy individuals who were potentially exposed to a contagious disease.[4] The main objective of

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quarantine adoption during the COVID-19 pandemic has been to delay the epidemic peak or even delay the entry of the disease in a certain geographic area. It is therefore complementary to isolation, which corresponds to the separation of individuals who are already known to be infected with a contagious disease. Contact tracing is paramount to identify individuals who must be quarantined. The purpose of contact tracing is to block further transmission through rapid identification and management of possible secondary cases. The effectiveness of contact tracing depends on identification of all cases and contacts.[5] Contact tracing is widely recognized as an effective approach to limit the spread of outbreaks, including the COVID-19 pandemic.[6-12] However, information is lacking on its effectiveness (ie, how many cases can be prevented through contact tracing).

To measure and compare interventions, health professionals and policy makers rely on effectiveness measures that are easy to understand and explain. One of the most intuitive measures is number needed to treat, which is the number of individuals needed to be treated to prevent 1 undesirable outcome.[13-16] This concept has been adapted to evaluate the effectiveness of other interventions, such as vaccination, by using the number needed to vaccinate.[17-21] The concepts of number needed to treat and number needed to vaccinate can also be adapted to assess the effectiveness of quarantine.

Our study aimed to evaluate the effectiveness of contact tracing during the COVID-19 pandemic in the Espinho/Gaia (E/G) Public Health Unit (PHU) area in Portugal through 2 new measures: (1) number needed to quarantine (NNQ), which is conceptually similar to number needed to treat and number needed to vaccinate; and (2) proportion of prevented infectious days by quarantine (PPID), the number of potential infectious days prevented by quarantine divided by all infectious days. We also assessed various timings of public health interventions—namely, time from diagnosis to quarantine of contacts and time from onset of index case symptoms to contacts' quarantine—and we examined the sociodemographic characteristics of contacts for comparability with future studies.

Methods

Study Design and Population

The sample of our retrospective cohort study included the contacts of all people with confirmed COVID-19 residing in the E/G PHU area who were diagnosed July 1–September 15, 2020. We excluded from analysis contacts residing in a different area (ie, not the E/G PHU area) from confirmed (index) cases.

Contact Tracing Details and Public Health Intervention

Portugal has followed the European Centre for Disease Prevention and Control's recommendations for COVID-19 prevention and control—namely, case definition, quarantine, risk criteria, and contact tracing.[22,23] All positive cases and laboratory results of mandatory notifiable diseases, including COVID-19, need to be immediately reported through the national epidemiologic surveillance system (online platform) and become immediately available to public health authorities. In Portugal, local public health authorities were responsible for contacting all people with confirmed COVID-19 residing in that geographic area and asking them to list all individuals with whom they came into contact from 2 days before symptom onset until the day they were contacted.

As part of the pandemic response, the E/G PHU staff collected data during COVID-19 contact tracing and follow-up. PHU staff interviewed each person with confirmed COVID-19 (ie, confirmed case), generally within 24 hours after receiving a positive test result, to identify the transmission pathway and the people with whom the confirmed case was in contact (ie, at risk of developing COVID-19). PHU staff also monitored contacts for 14 days after their last contact with the confirmed case. All contacts were classified according to their level of risk (high or low).[11,24] High-risk contacts were those who had physical contact with a person with confirmed COVID-19 within 2 m for >15 minutes during a 24-hour period. High-risk contacts were quarantined and contacted daily for symptomatic evaluation for not longer than 14 days since their last exposure to a person with confirmed COVID-19. Low-risk contacts were those who had contact with a person with confirmed COVID-19 for <15 minutes, >2 m apart, in an outdoor or ventilated environment. Low-risk contacts were advised to monitor their symptoms and practice social restriction. PHU staff classified all contacts by exposure context as cohabitants, social, work related, school related, travel related, and health professionals. Social contacts include those who do not belong to any other category, such as family members who are not cohabitants.

Testing Policy

According to national guidelines, all people, regardless of their risk, were tested if they developed symptoms during quarantine that were compatible with clinical manifestations of COVID-19, such as signs or symptoms of respiratory infection (fever, new-onset or worsening dyspnea, shortness of breath or cough patterns, myalgia, headache), anosmia, dysgeusia, or ageusia.[6-9,23,25] During the study period, the E/G PHU tested all cohabitants as soon as a case was confirmed, as well as on the 8th through 12th days after their last contact. The remaining high-risk contacts were also tested on the 8th through 12th days after their last exposure.

Infectiousness Period

To measure the effectiveness of contact tracing, we first calculated the number of potential infectious days, defined as the period between the start of the infectiousness period and the diagnosis date (ie, positive reverse transcription polymerase chain reaction test). Given the uncertainty about the infectiousness period, we adopted 3 scenarios and compared the effectiveness of contact tracing for each:

Scenario A: This scenario included the entire possible infectiousness period as previously described (ie, from 10 days before symptom onset to 10 days after symptom onset).[26-30]

Scenario B: In this scenario, the infectiousness period spanned 3 days before symptom onset to 3 days after symptom onset. This scenario focused on highly infectious days because only a small proportion of transmission occurs at the end of the transmission window.[28]

Scenario C: In this scenario, the infectiousness period spanned 2 days before symptom onset to 10 days after symptom onset, following the European Centre for Disease Prevention and Control's recommendations for contact tracing.[11]

For asymptomatic cases (ie, confirmed cases without symptoms), we calculated a potential date of symptom onset: for cohabitants, we added the median serial interval (ie, the time between illness onset of 2 consecutive cases [5 days]) to the index case symptom onset date[31,32]; for the remaining contacts, we added the median time from infection to onset of symptoms, or incubation time (6 days), to the last high-risk contact date.[33-38] We also calculated the generation time for the study sample, which corresponded to the median time between the date when COVID-19 was confirmed in the index case and the date when COVID-19 was confirmed in secondary cases (contacts with a positive test result).

Effectiveness Measures

We used the number of potential infectious days to calculate the NNQ and the PPID but with different formulas and goals.

NNQ: measures the "cost" of quarantine—specifically, the number of person-days from all contacts who needed to be quarantined to prevent 1 potential infectious day:

$$NNQ = \frac{\text{Total number of person-days of quarantine}}{\text{Total number of infectious person-days prevented by quarantine}}$$

PPID: measures the proportion of prevented infectious days through quarantine by all infectious days, regardless of the "cost" (ie, number of people in quarantine):

$$PPID = \frac{\text{Total number of infectious person-days prevented by quarantine}}{\text{Total number of infectious person-days of all contacts who turned positive}}$$

Together, both measures provide a clear picture of contact tracing effectiveness by comparing the desired outcome (number of potential infectious days prevented) with its "cost" (ie, comparing PPID and NNQ, respectively).

Statistical Analysis

We calculated NNQ and PPID using the 3 infectiousness period scenarios. We assessed these measures by sociodemographic characteristics and types of contacts (ie, cohabitants, social contacts), as well as by various intervention timings—namely, time from diagnosis to quarantine of contacts and time from onset of symptoms in the index case to contacts' quarantine. We did not evaluate other types of contacts, such as school related, work related, health professionals, and travel contacts, because they represented only 5% of contacts with a positive test result. We performed all statistical analyses using R version 4.0.3 (R Foundation). The study was approved by the Northern Region Health Administration Ethics Committee and abided to the Declaration of Helsinki. The Northern Region Health Administration Ethics Committee authorized the use of patients' data without written consent, because all data were previously collected for contact tracing and reused.

Results

From July 1 through September 15, 2020, a total of 152 people with confirmed COVID-19 were residing in the E/G PHU area. A total of 1582 contacts were identified; 849 (53.7%) were in the E/G PHU area and were included in the study (Table 1). Of the 849 contacts, 725 (85.4%) were considered high-risk contacts and quarantined. Nearly half of quarantined contacts were social contacts (48.1%, n = 349), followed by cohabitants (26.9%, n = 195), work-related contacts (14.5%, n = 105), and school-related contacts (9.9%, n = 72). However, in terms of quarantined contacts from the E/G PHU area who later received a positive test result for COVID-19 (n = 117), social contacts (50.4%, n = 59) and cohabitants (45.3%, n = 53) made up nearly the whole group. The median (interquartile range [IQR]) time from receiving a validated positive test result from the laboratory to the contacts' quarantine was 1.0 (1.0-2.0) day. The median (IQR) time from symptom onset in a confirmed case to contacts' quarantine was 5.0 (4.0-8.0) days. The median (IQR) time from last contact with a confirmed case to contacts' quarantine was 4.0 (2.0-6.0) days, ranging from a median of 1 day for cohabitants to 5 days for school-related contacts. The median time from diagnosis of a confirmed case to contact tracing was 1 day. We found a median (IQR) of 6.0 (3.0-10.5) high-risk contacts per confirmed COVID-19 case.

The E/G PHU determined quarantine for 6525 person-days of quarantine, with a median (IQR) of 9.0 (7.0-12.0) days. From the screened quarantined contacts living in the

Table 1. Characteristics of contacts (N = 849) of people with confirmed COVID-19 (n = 152), by type of contact, in a study of 2 measures used to assess the effectiveness of contact tracing, E/G PHU area, Portugal, July 1–September 15, 2020[a]

		Quarantined contacts	
Characteristic	**All contacts (N = 849)**	**Overall (n = 725)**	**Received a positive COVID-19 test result (n = 117)**
Male, no. (%)	388 (45.7)	338 (46.6)	47 (40.2)
Age, y, no. (%)			
0-17	181 (21.3)	168 (23.2)	25 (21.4)
18-29	128 (15.1)	115 (15.9)	9 (7.7)
30-49	220 (25.9)	181 (25.0)	23 (19.7)
50-69	252 (29.7)	199 (27.4)	36 (30.8)
≥70	68 (8.0)	62 (8.6)	24 (20.5)
Type of contact, no. (%)			
Social (family or friends, not cohabitant)	416 (49.0)	349 (48.1)	59 (50.4)
School	76 (9.0)	72 (9.9)	0
Work	151 (17.8)	105 (14.5)	3 (2.6)
Cohabitant	201 (23.7)	195 (26.9)	53 (45.3)
Health professional	2 (0.2)	1 (0.1)	0
Travel	3 (0.4)	3 (0.4)	2 (1.7)
Had symptoms at start of quarantine, no. (%)	92 (10.9)[b]	91 (12.6)[c]	36 (30.8)
Measures of time, median (IQR), d[b]			
Time from last contact with index case to contacts' quarantine	4.0 (2.0-6.0)	4.0 (1.0-6.0)	2.0 (1.0-7.0)
Time from index case diagnosis to contacts' quarantine	1.0 (1.0-2.0)	1.0 (1.0-2.0)	1.0 (1.0-1.0)
Time from index case symptom onset to contacts' quarantine	5.0 (4.0-8.0)	6.0 (4.0-8.0)	6.5 (4.0-8.0)
Serial interval	NA	NA	4.0 (1.0-6.0)[d]
Generation time	NA	NA	3.0 (2.0-5.0)

Abbreviations: E/G PHU, Espinho/Gaia Public Health Unit; IQR, interquartile range; NA, not applicable.
[a]A total of 152 people with confirmed COVID-19 were identified during the study period in the E/G PHU area, and 849 contacts lived in the area and were included in this study.
[b]Data missing on 6 contacts.
[c]Data missing on 5 contacts.
[d]Data missing on 48 contacts.

E/G PHU area, 117 of 725 (16.1%) received a positive test result (ie, newly confirmed cases), 36 (30.8%) of whom had symptoms at the start of quarantine (Table 1).

The NNQ was 19.8 in scenario A, 41.8 in scenario B, and 23.0 in scenario C (Table 2). By sex, the NNQ was 20.1 in scenario A, 42.8 in scenario B, and 22.3 in scenario C among females and 19.4, 40.8, and 23.8 among males. Contacts aged ≥70 years and 0-17 years had the lowest NNQ estimates of all age groups, and among contact types, cohabitants had lower estimates than social contacts. Additionally, the presence of symptoms at the start of quarantine decreased the NNQ overall.

We found 1677, 609, and 743 potential infectious days in scenarios A, B, and C, respectively, of which 330 (19.7%), 156 (25.6%), and 284 (38.2%) were spent in quarantine (ie, PPID) (Table 3). By sex, the PPID was 16.8% in scenario A, 21.7% in scenario B, and 34.7% in scenario C among females and 23.9%, 31.2%, and 43.1% among males. Contacts who were aged 18-29 years had the highest PPID estimates across all age groups. Contacts without symptoms at the start of quarantine had a higher PPID estimate than contacts with symptoms. Additionally, cohabitants had higher PPID estimates than social contacts overall (ie, contacts with or without symptoms), although the opposite was true among contacts with symptoms.

The evolution of NNQ and PPID according to the number of days since diagnosis (Figure A and C) and symptom onset of the index case (Figure B and D) showed an increasing NNQ and a decreasing PPID. NNQ estimates increased with the delay from diagnosis of a confirmed case to quarantine of contacts, while PPID decreased with the increase of this interval. NNQ estimates increased with time from symptom onset of the confirmed case to quarantine of contacts, with a steep increase after day 4. PPID estimates decreased with the increase of this interval, presenting a sharp drop on day 5, after which they were stable.

Discussion

This study provides information to reinforce and improve contact tracing by gathering a sample of contacts who received follow-up from quarantine until discharge,

Table 2. Number needed to quarantine, by age group, presence of symptoms at start of quarantine, and type of contact, in 3 scenarios of COVID-19 exposure in a study of 2 measures used to assess the effectiveness of contact tracing, Portugal, July 1–September 15, 2020[a]

				Cohabitant contact			Social contact		
		Symptoms at start of quarantine		Symptoms			Symptoms		
Scenario: age, y	**Total**	**Yes**	**No**	**Yes**	**No**	**Total**	**Yes**	**No**	**Total**
A									
0-17	25.1	18.1	26.0	5.6	8.8	8.7	NA	47.8	57.5
18-29	34.2	28.5	34.5	NA	18.4	20.3	17.3	60.4	44.7
30-49	27.4	21.8	27.7	8.3	15.0	14.8	18.6	35.6	32.4
50-69	16.1	4.8	19.5	5.3	11.2	10.4	3.7	17.3	13.5
≥70	6.4	1.8	7.8	1.0	8.8	8.3	1.9	7.5	5.9
Overall	19.8	9.7	21.8	7.3	12.3	12.0	8.6	22.4	18.9
B									
0-17	43.4	145.0	39.8	39.0	13.2	14.8	NA	79.7	95.8
18-29	43.3	114.0	40.0	NA	22.9	25.4	69.0	60.4	61.5
30-49	58.3	58.0	57.5	8.3	31.7	28.9	NA	64.0	74.5
50-69	44.3	13.2	53.2	32.0	27.3	27.6	8.3	53.0	37.3
≥70	15.9	6.8	17.5	1.0	12.0	11.1	8.7	22.5	19.7
Overall	41.8	32.2	42.6	20.7	21.3	21.7	29.3	52.1	48.0
C									
0-17	28.7	18.1	30.3	5.6	9.3	9.1	NA	95.6	115.0
18-29	36.4	28.5	37.1	NA	19.3	21.4	17.3	70.5	49.2
30-49	32.9	21.8	34.2	8.3	21.1	20.2	18.6	35.6	32.4
50-69	19.2	5.0	24.2	5.3	17.5	15.1	3.9	18.1	14.2
≥70	7.4	2.5	8.6	1.0	9.4	8.9	2.6	8.4	7.0
Overall	23.0	10.5	25.7	7.3	15.2	14.5	9.8	25.0	21.2

Abbreviations: E/G PHU, Espinho/Gaia Public Health Unit; NA, not applicable.

[a]A total of 152 people with confirmed COVID-19 were identified during the study period in the E/G PHU area, and 849 contacts lived in the E/G PHU area and were included in this study. Number needed to quarantine is the number of quarantine person-days needed to prevent 1 potential infectious person-day. We considered 3 infectiousness periods: 10 days before to 10 days after symptom onset (scenario A), 3 days before to 3 days after symptom onset (scenario B), and 2 days before to 10 days after symptom onset (scenario C).

during a period of 2.5 months. In our sample, we found a median of 6 quarantined contacts per case, with a median of 9 days of quarantine. We calculated our own transmission-dynamic periods for contacts who received a positive test result: a generation time value of 3 days (ie, the time between an individual's infection and the moment that the person infects another) and a serial interval value of 4 days. The generation time is 2 days fewer than what is described in the literature,[28] which can represent the impact of contact tracing by anticipating diagnosis in 2 days, as contacts were tested not only if symptomatic but also when public health staff established quarantine for cohabitants and for all high-risk contacts on the 8th through 12th days. These measures allow calculation of the infectiousness period in asymptomatic cases and for comparison with future studies.

This study proposed 2 measures for assessing the effectiveness of contact tracing that can be continuously monitored. By considering all contacts, NNQ provides information on the effectiveness and efficiency of contact tracing (ie, estimating the number of person-days of all contacts needed to be quarantined to prevent 1 infectious day), meaning that a lower value is desirable. PPID complements NNQ by focusing on evaluating the proportion of infectious days that were prevented by quarantine from the total number of infectious days, meaning that a more effective intervention will have a higher PPID. The ideal combination should be a low NNQ and a high PPID so that the intervention is effective and "cost" effective.

Given the uncertainty in the infectiousness period, we considered 3 scenarios. Scenario A includes the longest infectiousness period but may overestimate the effect of quarantine because of the residual transmission that occurs at both ends of the infectiousness period. Scenario B includes the most likely infectiousness period because it is stricter. As recommended by the European Centre for Disease Prevention and Control, scenario C evaluates the basis for the contact tracing process used in Portugal but may underestimate the presymptomatic infectiousness period. Although we obtained different magnitudes by scenario, we found similar patterns when comparing the groups by demographic characteristics (eg, age, type of contact).

Table 3. Proportion of prevented infectious days, by age group, presence of symptoms at start of quarantine, and type of contact, in 3 scenarios of COVID-19 exposure in a study of 2 measures used to assess the effectiveness of contact tracing, Portugal, July 1–September 15, 2020[a]

		Symptoms at start of quarantine		Cohabitant contact			Social contact		
				Symptoms			Symptoms		
Scenario: age, y	Total	Yes	No	Yes	No	Total	Yes	No	Total
A									
0-17	17.4	6.8	23.4	7.8	23.9	18.2	0	21.7	16.7
18-29	28.4	13.3	33.7	NA	37.8	37.8	13.3	31.8	21.1
30-49	20.3	9.5	24.1	5.9	27.5	21.7	15.2	21.4	19.7
50-69	19.6	15.5	21.3	20.0	35.1	31.9	15.4	15.7	15.6
≥70	18.5	10.8	23.2	4.3	23.1	18.2	12.1	24.8	19.2
Overall	19.7	11.3	23.6	8.8	28.5	23.2	13.2	20.0	17.6
B									
0-17	27.0	2.1	43.2	2.8	41.9	27.6	0	50.0	33.3
18-29	57.8	8.3	75.6	NA	76.2	76.2	8.3	87.5	40.0
30-49	25.4	9.4	31.1	15.0	36.0	30.0	0.0	29.4	21.7
50-69	20.2	15.5	22.2	9.1	43.2	35.4	19.5	14.3	15.8
≥70	21.3	8.5	28.8	11.1	44.0	35.3	7.9	24.5	17.2
Overall	25.6	9.1	33.5	7.9	44.6	34.3	11.0	24.4	19.7
C									
0-17	38.6	14.8	56.0	16.7	55.2	40.4	0	62.5	35.7
18-29	70.5	28.6	90.0	NA	90.5	90.5	28.6	100.0	50.0
30-49	39.0	22.2	44.8	15.8	46.6	39.0	29.4	50.0	43.4
50-69	34.9	32.9	35.7	42.9	53.2	50.8	32.1	29.7	30.4
≥70	33.9	16.4	45.2	14.3	56.0	46.9	16.7	43.8	31.6
Overall	38.2	22.5	45.9	20.7	56.0	46.3	24.0	39.1	33.6

Abbreviations: E/G PHU, Espinho/Gaia Public Health Unit; NA, not applicable.
[a]A total of 152 people with confirmed COVID-19 were identified during the study period in the EG/PHU area, and 849 contacts lived in the E/G PHU area and were included in this study. The proportion of prevented infectious days by quarantine is the number of potential infectious days prevented by quarantine divided by all infectious days. We considered 3 infectiousness periods: 10 days before to 10 days after symptom onset (scenario A), 3 days before to 3 days after symptom onset (scenario B), and 2 days before to 10 days after symptom onset (scenario C).

In this study, we determined that to prevent 1 potential infectious person-day, 19.8-41.8 person-days of quarantine (NNQ) are needed, depending on the scenario. Contact tracing prevented 19.7%-38.2% of all preventable infectious person-days (PPID), thus limiting disease spread. We identified subgroups in which contact tracing effectiveness was higher, and these subgroups may be considered a priority for contact tracing. Contacts aged ≥70 years had the lowest NNQ estimates, with contact tracing and subsequent quarantine being more efficient than for other age groups; yet, PPID estimates in this age group were not higher than the overall PPID estimates for each scenario. This apparent contradiction may be the result of the low number of contacts in this age group. For contacts aged 18-29 years, we found the highest estimates of the PPID and NNQ. While NNQ estimates may depend on the large number of contacts in this age group, quarantine helped to prevent a large number of infectious days, as shown by the high PPID estimates. The presence of symptoms at the start of quarantine implied a reduction of about half of the NNQ. However, PPID was lower for already symptomatic contacts, which was expected given that the infectiousness period varies according to the date of symptom onset. Cohabitants had lower NNQ but higher PPID as compared with social contacts, highlighting another priority group.

This study evaluated the effectiveness of contact tracing according to public health intervention timings. NNQ and PPID estimates varied with the time from diagnosis of a confirmed case to quarantine of contacts (ie, NNQ increased with time from diagnosis of a confirmed case to quarantine of contacts and PPID decreased). Moreover, both measures showed that postponing quarantine by 1 day had a marked impact on contact tracing effectiveness, by tripling the NNQ estimate and halving the PPID estimate, thereby reinforcing the importance of timely intervention. In addition, it showed a decrease in contact tracing effectiveness with

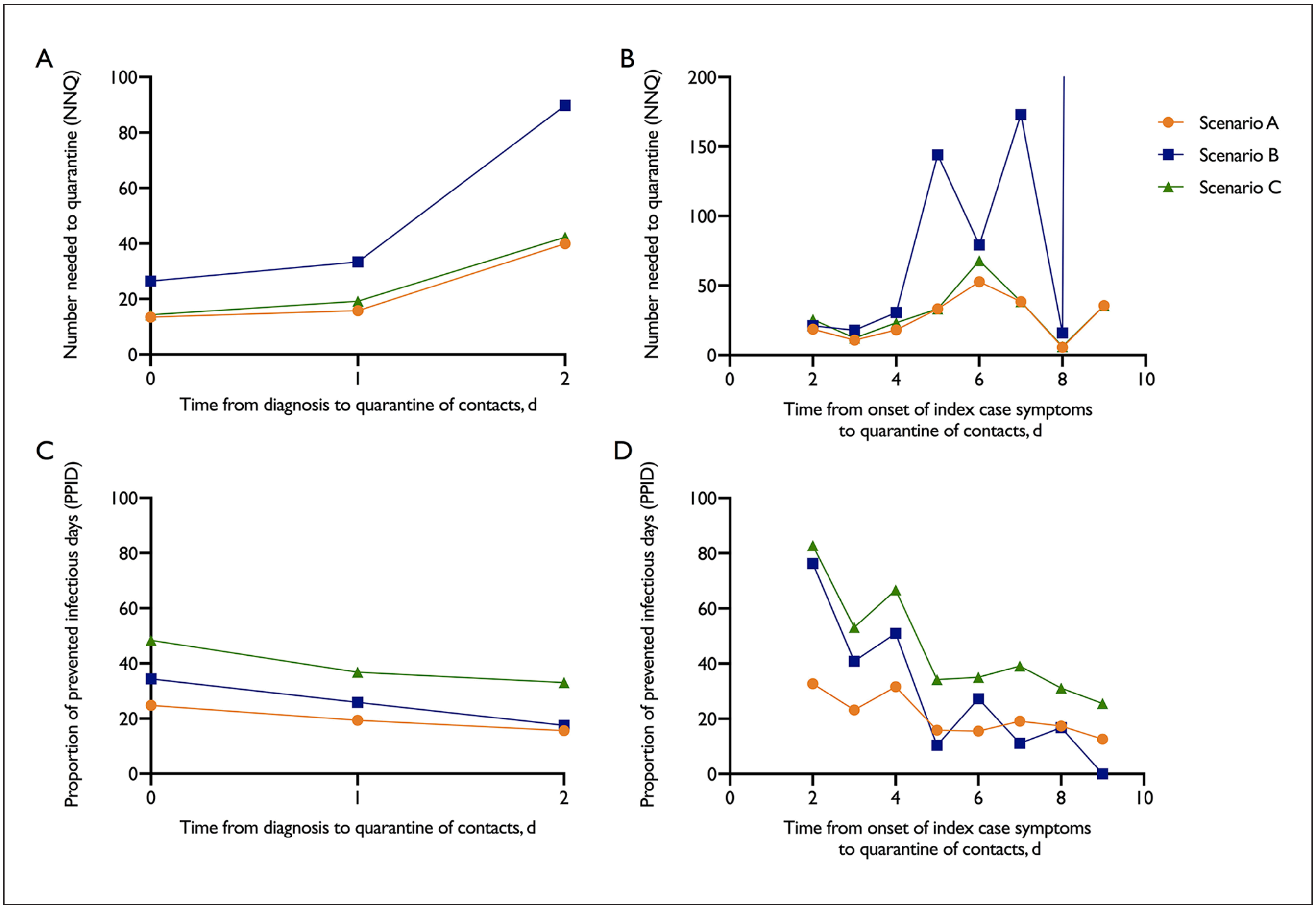

Figure. Estimates of number needed to quarantine (NNQ) (A and B) and proportion of prevented infectious days by quarantine (PPID) (C and D), according to time from index case diagnosis to contacts' quarantine (A and C) and time from index case symptom onset to contacts' quarantine (B and D), in 3 scenarios of COVID-19 exposure in a study of 2 measures used to assess the effectiveness of contact tracing, Portugal, July 1–September 15, 2020. NNQ is the number of quarantine person-days needed to prevent 1 potential infectious person-day. PPID is the number of potential infectious days prevented by quarantine divided by all infectious days. We considered 3 infectiousness periods: 10 days before to 10 days after symptom onset (scenario A), 3 days before to 3 days after symptom onset (scenario B), and 2 days before to 10 days after symptom onset (scenario C).

time from symptom onset of the index case to quarantine of contacts. The minimum NNQ estimate was on the eighth day, explained by an outbreak in a long-course bus trip (n = 24 positive contacts). On another note, contact tracing effectiveness decreased on day 4 or 5 after the onset of index case symptoms, which is compatible with our estimated serial interval, providing a possible opportunity for forward tracing (ie, screening contacts of high-risk contacts). Thus, future studies should assess whether immediate testing and forward tracing of secondary contacts should be considered, if resources are available, to quickly deter disease spread. Also, given the various pandemic phases that each country or region goes through during a pandemic, these measures may be useful to inform and guide prioritization for various stages and groups for thorough contact tracing.

Limitations

This study had several limitations. First, our results might be underestimated because our local contact tracing seemed to anticipate diagnosis by 2 days, with a generation time that was 2 days lower than the median generation time found in other studies (ie, 5 days) in which surveillance was not implemented.[28] In fact, because the diagnosis date was the endpoint to calculate the number of potential infectious days, the early diagnosis provided by timely contact tracing reduced the number of potential infectious days prevented. Second, these data refer to a period in which public health measures (eg, lockdowns) were not as strict as during other periods of the pandemic. However, contact tracing has limitations: some contacts might not have been reached (eg, information errors and/or memory bias); there was information bias related to reporting symptom onset date, despite our extensive symptoms questionnaire; and some contacts were already self-isolated (considered quarantined), while others might not have adhered to quarantine measures. Finally, NNQ may vary because of small numbers or larger outbreaks, which highlights the need to consider this value alongside PPID and the need for additional and larger studies.

Conclusions

Our study showed that contact tracing effectiveness (and "cost" effectiveness) is higher until 24 hours after a COVID-19 diagnosis or until 4 or 5 days of symptom onset in a person with confirmed COVID-19. Furthermore, our proposed measures can be important tools for decision making and prioritizing contact tracing. Because contact tracing effectiveness was high among cohabitants and symptomatic contacts, public health agencies should prioritize these groups when resources are scarce. Additionally, NNQ and PPID can be useful measures for communication with the general population, policy makers, and clinicians because they are easy to understand and use to assess the impact of health interventions.

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