



## Research Letter | Infectious Diseases

## Household Transmission of SARS-CoV-2

Joshua P. Metlay, MD, PhD; Jennifer S. Haas, MD, MSc; Alexander E. Soltsoff, BS; Katrina A. Armstrong, MD, MSCE

## Introduction

The primary mode of spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)—the virus that causes coronavirus disease 2019 (COVID-19)—is by person-to-person contact via respiratory droplets.<sup>1</sup> Given that most virus transmission has occurred in homes,<sup>2</sup> we investigated whether home addresses recorded in the electronic medical record could be used to accurately estimate transmission risk and identify risk factors for transmission.

Author affiliations and article information are listed at the end of this article.

## Methods

We conducted a retrospective cohort study of COVID-19 risk among exposed children and adults in households where an index case of COVID-19 was diagnosed between March 4 and May 17, 2020. The study was conducted within the Mass General Brigham system, a large integrated hospital and ambulatory care network based in Boston, Massachusetts. No participant contact was required for

Table 1. Coronavirus Disease 2019 Infection Risk Among 17 917 Exposed Household Members

| Characteristic                        | Individuals exposed, No. | Individuals with infection, No. (%) <sup>a</sup> | P value <sup>b</sup> |
|---------------------------------------|--------------------------|--------------------------------------------------|----------------------|
| Age group, y                          |                          |                                                  |                      |
| ≤18                                   | 4672                     | 210 (4.5)                                        | <.001                |
| 19-29                                 | 3471                     | 302 (8.7)                                        |                      |
| 30-49                                 | 4322                     | 547 (12.7)                                       |                      |
| 50-64                                 | 3160                     | 464 (14.7)                                       |                      |
| 65-74                                 | 1134                     | 154 (13.6)                                       |                      |
| ≥75                                   | 1158                     | 132 (11.4)                                       |                      |
| Sex                                   |                          |                                                  |                      |
| Female                                | 9341                     | 986 (10.6)                                       | .03                  |
| Male                                  | 8576                     | 823 (9.6)                                        |                      |
| Household size, No. of members        |                          |                                                  |                      |
| 2                                     | 1339                     | 185 (13.8)                                       | <.001                |
| 3-5                                   | 7061                     | 763 (10.8)                                       |                      |
| 6-10                                  | 6888                     | 662 (9.6)                                        |                      |
| 11-19                                 | 2358                     | 184 (7.8)                                        |                      |
| 20-25                                 | 271                      | 15 (5.5)                                         |                      |
| Comorbid conditions                   |                          |                                                  |                      |
| Asthma                                | 2280                     | 323 (14.2)                                       | <.001                |
| Cancer                                | 348                      | 73 (21.0)                                        | <.001                |
| Cardiovascular disease                | 437                      | 91 (20.8)                                        | <.001                |
| Chronic obstructive pulmonary disease | 798                      | 116 (14.5)                                       | <.001                |
| Dementia                              | 85                       | 15 (17.7)                                        | .02                  |
| Diabetes                              | 1440                     | 288 (20.0)                                       | <.001                |
| HIV                                   | 71                       | 9 (12.7)                                         | .90                  |
| Hypertension                          | 1271                     | 274 (21.6)                                       | <.001                |
| Liver disease                         | 235                      | 60 (25.5)                                        | <.001                |
| Obesity                               | 3727                     | 543 (14.6)                                       | <.001                |
| Kidney disease                        | 225                      | 54 (24.0)                                        | <.001                |

<sup>a</sup> Percentages indicates the row percentage. A total of 1809 exposed individuals were infected.

<sup>b</sup> P values were calculated with either the  $\chi^2$  or Mantel-Haenszel  $\chi^2$  test for trend.

**Open Access.** This is an open access article distributed under the terms of the CC-BY License.

this study, which was determined to be exempt and for which patient informed consent was waived by the Mass General Brigham institutional review board. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.

Index cases were identified on the basis of a positive reverse transcriptase-polymerase chain reaction test result for SARS-CoV-2. Patients whose home addresses could not be geocoded were excluded. The at-risk cohort was compiled on the basis of identifying all patients registered at the addresses of index cases (including unit numbers) and excluded all patients who did not have at least 1 visit to the health system within the preceding 60 months. Addresses with more than 25 identified residents were excluded, although we included sensitivity analyses with smaller household sizes to test the validity of the home address field. Follow-up for all eligible patients continued until the end of the study period or until they had a positive SARS-CoV-2 test result documented in the system.

Characteristics of household contacts were extracted from the electronic medical record. The comparison of risk between groups was conducted with either the  $\chi^2$  or Mantel-Haenszel  $\chi^2$  test for trend as appropriate. Mixed-effects logistic regression models were used to calculate the adjusted infection risk, accounting for clustering of exposed subjects within households. Two-sided  $P < .05$  was considered to be statistically significant. Analyses were performed using Stata SE version 16.1 (StataCorp LLC).

## Results

The 7262 index cases were linked to 17 917 additional at-risk individuals assigned to the same addresses. These at-risk individuals consisted of 9341 (52.1%) females and 8576 (47.9%) males; 6888 (38.4%) resided in households of 6 to 10 people. Their mean (SD) age was 36.1 (23.3) years, and 4672 (26.1%) were 18 years or younger (**Table 1**). Within this exposed cohort, 1809 cases of COVID-19 were subsequently diagnosed, resulting in an overall incidence of COVID-19 of 10.1%

Table 2. Independent Risk Factors for COVID-19 Among Exposed Household Members

| Characteristic          | Adjusted OR (95% CI) <sup>a</sup> | P value |
|-------------------------|-----------------------------------|---------|
| Age group, y            |                                   |         |
| ≤18                     | 1 [Reference]                     |         |
| 19-29                   | 2.13 (1.70-2.66)                  | <.001   |
| 30-49                   | 3.48 (2.83-4.26)                  | <.001   |
| 50-64                   | 3.66 (2.92-4.59)                  | <.001   |
| 65-74                   | 2.73 (2.03-3.66)                  | <.001   |
| ≥75                     | 1.85 (1.34-2.55)                  | <.001   |
| Sex                     |                                   |         |
| Female                  | 1 [Reference]                     |         |
| Male                    | 0.89 (0.79-1.01)                  | .08     |
| Household size, members |                                   |         |
| 2                       | 1 [Reference]                     |         |
| 3-5                     | 0.80 (0.63-1.02)                  | .07     |
| 6-10                    | 0.76 (0.59-0.97)                  | .03     |
| 11-19                   | 0.59 (0.42-0.82)                  | .002    |
| 20-25                   | 0.32 (0.12-0.81)                  | .02     |
| Comorbid conditions     |                                   |         |
| Asthma                  | 1.31 (1.07-1.59)                  | .008    |
| Cancer                  | 1.61 (1.12-2.33)                  | .01     |
| Cardiovascular disease  | 1.45 (1.02-2.06)                  | .04     |
| Diabetes                | 1.67 (1.36-2.06)                  | <.001   |
| Hypertension            | 1.93 (1.58-2.44)                  | <.001   |
| Liver disease           | 2.01 (1.32-3.07)                  | .001    |
| Obesity                 | 1.35 (1.15-1.57)                  | <.001   |

Abbreviation: OR, odds ratio.

<sup>a</sup> Adjusted for other comorbid conditions, including chronic obstructive pulmonary disease, HIV, kidney disease, and dementia.

(Table 1). The median time to diagnosis from the date of the index case was 3 days (interquartile range, 1-9 days).

Independent factors significantly associated with higher transmission risk included age greater than 18 years (eg, adjusted odds ratio [OR] for those aged 50-64 years, 3.66; 95% CI, 2.92-3.66;  $P < .001$ ) and multiple comorbid conditions (eg, adjusted OR for individuals with hypertension, 1.93; 95% CI, 1.58-2.44;  $P < .001$ ) (Table 2). In sensitivity analyses limiting the maximum size of the household to as small as 2 persons, the calculated transmission risk increased to only 13.8%.

## Discussion

Our study showed an overall household infection risk of 10.1%, consistent with reported transmission risk based on more traditional contact tracing, including a recent meta-analysis that reported an overall transmission risk of 17.1%, although there was wide variation across studies.<sup>3,4</sup>

The major limitation of our study is that we relied on home addresses within our electronic medical records, which likely led to both undercounting and overcounting of household members. Although we acknowledge that contact investigations are the standard approach for estimating household transmission risk, we believe that the consistency of our results with these approaches suggests that our approach may provide a more efficient method for risk estimation and household contact identification. Moreover, our sensitivity analysis indicated that the results were qualitatively similar when restricted to smaller households. In addition, because testing of household members was driven by care-seeking behavior, it is likely that we did not observe all infections that occurred in the households. In addition, the relatively short median interval between the index case and infected household members suggests that some household infections were due to common exposures rather than transmission from one household member to another.

SARS-CoV-2 transmission in US households is a major source of new infections. Electronic medical record data may support intensive infection control efforts.

## ARTICLE INFORMATION

**Accepted for Publication:** January 7, 2021.

**Published:** February 26, 2021. doi:10.1001/jamanetworkopen.2021.0304

**Open Access:** This is an open access article distributed under the terms of the [CC-BY License](#). © 2021 Metlay JP et al. JAMA Network Open.

**Corresponding Author:** Joshua P. Metlay, MD, PhD, Division of General Internal Medicine, Department of Medicine, Massachusetts General Hospital, 100 Cambridge St, 16th Floor, Boston, MA 02114 ([jmetlay@mg.harvard.edu](mailto:jmetlay@mg.harvard.edu)).

**Author Affiliations:** Division of General Internal Medicine, Department of Medicine, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts.

**Author Contributions:** Dr Metlay had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

*Concept and design:* Metlay, Haas, Armstrong.

*Acquisition, analysis, or interpretation of data:* All authors.

*Drafting of the manuscript:* Metlay.

*Critical revision of the manuscript for important intellectual content:* All authors.

*Statistical analysis:* Metlay, Armstrong.

*Administrative, technical, or material support:* Metlay, Soltoff.

*Supervision:* Haas.

**Conflict of Interest Disclosures:** None reported.

## REFERENCES

1. Meyerowitz EA, Richterman A, Gandhi RT, Sax PE. Transmission of SARS-CoV-2: a review of viral, host, and environmental factors. *Ann Intern Med*. 2021;174(1):69-79. doi:10.7326/M20-5008
2. Massachusetts Department of Public Health COVID-19 Dashboard. Weekly COVID-19 public health report. Published October 29, 2020. Accessed November 1, 2020. <https://www.mass.gov/doc/weekly-covid-19-public-health-report-october-29-2020/download>
3. Luo L, Liu D, Liao X, et al. Contact settings and risk for transmission in 3410 close contacts of patients with COVID-19 in Guangzhou, China: a prospective cohort study. *Ann Intern Med*. 2020;173(11):879-887. doi:10.7326/M20-2671
4. Madewell ZJ, Yang Y, Longini IM Jr, Halloran ME, Dean NE. Household transmission of SARS-CoV-2: a systematic review and meta-analysis. *JAMA Netw Open*. 2020;3(12):e2031756. doi:10.1001/jamanetworkopen.2020.31756