SARS CoV-2 Serial Interval Variation, Montana, USA, March 1–July 31, 2020

Isaiah G. Reed, Ethan S. Walker, Erin L. Landguth

We report mean severe acute respiratory syndrome coronavirus 2 serial intervals for Montana, USA, from 583 transmission pairs; infectors' symptom onset dates occurred during March 1–July 31, 2020. Our estimate was 5.68 (95% CI 5.27–6.08) days, SD 4.77 (95% CI 4.33–5.19) days. Subperiod estimates varied temporally by nonpharmaceutical intervention type and fluctuating incidence.

In support of efforts in response to the emergence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the pathogen causing novel coronavirus disease (COVID-19), the scientific community has attempted to predict its transmission trends, often through disease modeling. However, disease-specific parameter estimates for SARS-CoV-2 vary greatly. These parameters include the serial interval (SI), or the duration between onset of symptoms in connected primary and secondary cases, which is crucial in estimating epidemic reproduction numbers (R_0) and assessing the effects of nonpharmaceutical interventions (NPIs) on transmission (*1*). Recent studies report SARS-CoV-2 SIs ranging from 2.97 to 7.5 days, with estimates representing primarily densely populated and urban settings (Table 1; Figure 1). The rural United States was relatively untouched in early epidemic waves, but major outbreaks followed in subsequent waves, so it is unknown whether rural- and urban-based transmission differ. Our objective was to report and compare SARS-CoV-2 SI values for Montana, USA, a primarily rural population, with other global and urban estimates. The study was defined as a public health surveillance activity by the University of Montana Institutional Review Board.

Author affiliations: Montana Department of Public Health and Human Services, Helena, Montana, USA (I.G. Reed); University of Montana, Missoula, Montana, USA (E.S. Walker, E.L. Landguth)

DOI: https://doi.org/10.3201/eid2705.204663

The Study

We acquired COVID-19 data, reported by local health jurisdictions, from the Montana Department of Public Health and Human Services; we obtained 45,102 case records as of November 15, 2020. We examined a subset of cases with symptom onset dates during March 1–July 31, 2020 (n = 4,793), as well as secondary cases resulting from primary infections during that period, regardless of onset date. We selected this period because all reported cases were PCR positive, all NPI stages were represented (pre–shelter-in-place [pre-SIP], shelter-in-place [SIP], and reopening phase 1 and phase 2), and the proportion of identifiable transmission chains among cases was relatively high (March–June 39%–44%; July 11%) compared with later periods (August–November 0%–2%).

We assessed the records to identify all epidemiologic links. We defined links as cases having contact with another reported case, when viral infection through accepted modes of transmission was plausible. Linked records (n = 1,005) were organized into pairs and designated as primary or secondary cases. When appropriate, cases were listed as primaries for multiple secondary cases; however, cases were limited to 1 secondary designation. For some secondary cases, 1 specific primary was not clearly defined. To estimate a serial range in these situations, we assigned upper and lower bounds using the shortest and longest SIs from all possible primaries. We excluded records when we could not determine an epidemiologic link or transmission direction. We identified 583 pairs, with 466 primary and 583 secondary cases.

We gave temporal markers to pairs on the basis of the primary case's symptom onset date, consistent with forward-looking SIs (*2*), and grouped them by the corresponding statewide NPI: pre-SIP, March 1–27; SIP, March 28–April 25; phase 1, April 26–May 31; phase 2 (June), June 1–30; and phase 2 (July), July 1–31. We divided phase 2 into 2 subperiods to account for changing incidence trends.

Table 1. Published mean serial interval estimates for severe acute respiratory syndrome coronavirus 2, 2020*

Publication†	Study location, dates (all in 2020 except as indicated)	No. cases (pairs)	SI mean (95% CI)	SI SD (95% CI)	SI estimate method
This study	Montana, USA, Mar 1–Jul 31	4,793 (583)	5.68 (5.27–6.08)	4.77 (4.33–5.19)	Forward
Prete et al. (*13*)‡	Brazil, Feb 25–Mar 19	NA (65)	2.97	3.29	Other
Talmoudi et al. (*14*)‡	Tunisia, Feb 29–May 5	NA (491)	5.30 (4.66–5.95)	0.26 (0.23–0.30)	Other
Lavezzo et al. (*15*)	Vo', Italy, Feb 21–Mar 7	81 (41)	7.2 (5.9–9.6)	NA	Other
Aghaali et al. (*16*)	Qom, Iran, Feb 20–Mar 8	88 (37)	4.55	3.30	Forward
You et al. (*17*)‡	China (OHP), as of Mar 31	14,828 (198)	4.60	5.55	Intrinsic
Ali et al. (*1*)‡	China (OHP), Jan 9–Feb 13	9,120 (677)	5.1 (4.7–5.5)	5.3 (5.0–5.6)	Forward
Zhang et al. (*18*)	China (OHP), Jan 19–Feb 17	8,579 (35)	5.1 (1.3–11.6)	NA	Forward
Du et al. (*10*)‡	China (OHP), Jan 21–Feb 8	752 (468)	3.96 (3.53–4.39)	4.75 (4.46–5.07)	Backward
Liao et al. (*19*)	China (CTGCH), Jan 7–Mar 20	46 (12)	6.50 (2.45–17.38)	NA	Forward
Zhao et al. (*20*)	Hong Kong, Jan 16–Feb 15	56 (21)	4.9 (3.6–6.2)	4.4 (2.9–8.3)	Other
Chan et al. (*21*)	Hong Kong, Jan 23–Apr 6	915 (47)	6.5 (0–18)	4.7	Unknown
Bi et al. (*22*)	Shenzhen, China, Jan 14–Feb 9	391 (48)	6.3 (5.2–7.6)	4.2 (3.1–5.3)	Other
Wang et al. (*23*)	Shenzhen, China, Jan 19–Feb 22	417 (27)	5.9 (3.9–9.6)	4.8 (3.1–10.1)	Other
Ganyani et al. (*24*)‡	Tianjin, China, Jan 14–Feb 27	135 (NA)	3.95 (–4.47 to 12.51)	4.24 (4.03–4.95)	Other
Tindale et al. (*25*)	Tianjin, China, Jan 21–Feb 22	135 (72)	4.31 (2.91–5.72)	0.716	Forward
Li et al. (*26*)	Wuhan, China, as of Jan 22	425 (6)	7.5 (5.3–19.0)	3.4	Other
Ganyani et al. (*24*)‡	Singapore, Jan 21–Feb 26	91 (NA)	5.21 (–3.35 to 13.94)	4.32 (4.06–5.58)	Other
Tindale et al. (*25*)	Singapore, Jan 23–Feb 26	93 (56)	4.17 (2.44–5.89)	0.882	Forward
Ki et al. (*27*)	South Korea, Jan 10–Feb 10	28 (12)	6.6 (3–15)	NA	Unknown
Mettler et al. (*12*)‡	South Korea, Jan 20–Jun 30	5,201 (102)	3.43 (2.62–4.24)	NA	Forward
Chun et al. (*28*)‡	South Korea, Jan 23–Mar 31	9,887 (69)	3.18 (2.22–4.24)	0.75 (0.47–1.03)	Forward
Son et al. (*29*)	Busan, South Korea, Feb 21–Mar 24	108 (28)	5.54 (4.08–7.01)	3.90 (2.47–5.32)	Other
Nishiura et al. (*30*)	Meta-analysis, 2019 Dec 21–2020 Feb 12	NA (28)	4.7 (3.7–6.0)	2.9 (1.9–4.9)	Other
He et al. (*11*)‡	Meta-analysis, Jan 21–Feb 12	NA (77)	5.8 (4.8–6.8)	NA	Other

*All articles published during 2020 except this study. CTGCH, Chongqing Three Gorges Central Hospital; NA, not available; OHP, outside Hubei Province; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; SI, serial interval.
†See References and Appendix (https://wwwnc.cdc.gov/EID/article/27/5/20-4663-App1.pdf) for full publication information.
‡Study included negative-valued serial interval pairs in the estimate.

We analyzed data using R version 3.6.2 and the EpiEstim package (*3*,*4*). Complying with EpiEstim functional requirements, we assigned pairs with a zero-valued SI an upper bound of 1 day, with lower bounds unchanged (n = 52 pairs). No negative-valued SIs were identified. We excluded pairs with a SI >2 incubation periods (>28 days). We determined that a gamma distribution was most appropriate using the R0 package *est.GT* function (*5*). Next, we used EpiEstim *estimate_R*, with case-pair and daily incidence data, to perform a Bayesian estimation of the SI gamma distribution using Markov chain Monte Carlo specified for the joint posterior sample of possible SI values (*6*,*7*).

Montana's overall mean SI estimate was 5.68 (95% CI 5.27–6.08) days (SD 4.77 [95% CI 4.33–5.19] days) (Figure 2). Pre-SIP provided the longest subperiod estimate, 6.84 (95% CI 5.84–7.87) days. The SI shortened during SIP, to 5.54 (95% CI 3.34–8.26) days, and again during phase 1, to 5.26 (95% CI 3.64–7.21) days. However, the SI lengthened during phase 2 (June) to 6.23 (95% CI 5.59–6.85) days, almost reaching pre-SIP levels. Phase 2 (July) demonstrated a sharp reduction to the shortest SI observed, 4.42 (95% CI 3.92–4.93) days. Sensitivity analyses of NPI impact delays resulted in altered subperiod estimates, especially for phase 1 relative to other subperiods (Table 2). Additional sensitivity analyses, comparing forward- and backward-looking SIs, produced vastly dissimilar point estimates and trends.

Conclusions

Analysis of SARS-CoV-2 transmission in Montana during March 1–July 31, 2020, identified a mean SI of 5.68 (95% CI 5.27–6.08) days, falling within the bounds of 16 of 24 published estimates from more urbanized settings across the globe (Table 1; Figure 1). However, an aggregate estimate derived from data spanning multiple outbreak stages may not accurately describe Montana-based transmission because changing contact patterns and environmental influences may cause variation (*1*,*2*). Temporal analyses suggest that NPIs influenced transmission patterns, as demonstrated by Montana's epidemic curve and fluctuating SI values (Figure 2). Ali found that SIs shorten as stricter NPIs are applied (*1*,*8*), which our subperiod estimates mostly support. However, phase 2 (July) contradicts the premise, with the shortest subperiod SI and a less restrictive NPI (Table 2). Furthermore, when accounting for NPI impact delays, the alignment falters during phase 2. This difference may occur because Ali did not assess additional epidemic

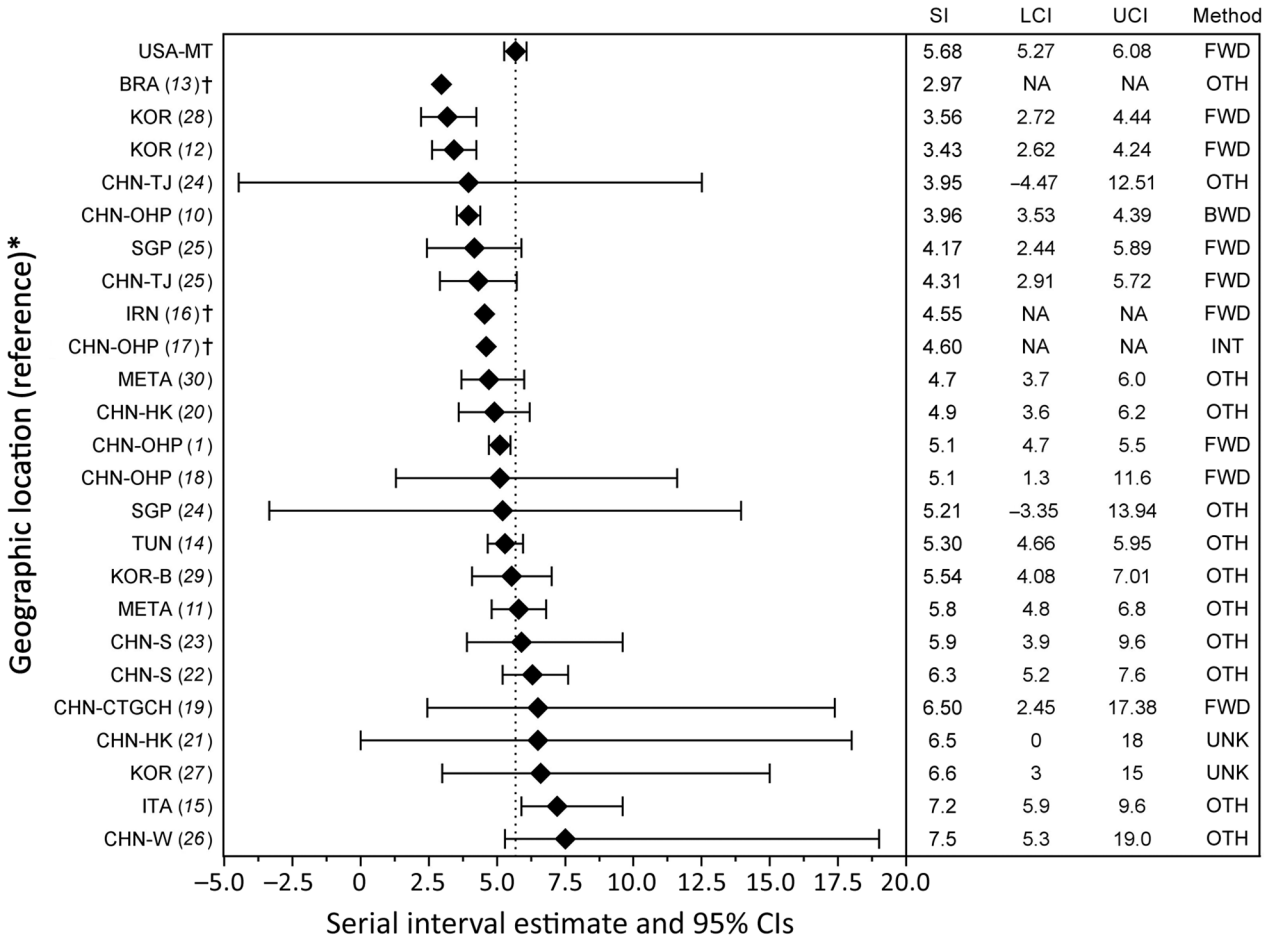


Figure 1. Published mean serial interval estimates for severe acute respiratory syndrome coronavirus 2. *See References and Appendix (https://wwwnc.cdc.gov/EID/article/27/5/20-4663-App1.pdf) for full study information. †These studies did not report CIs. Only point estimates are given. BRA, Brazil; BWD, backward; CHN-CTGCH, China–Chongqing Three Gorges Central Hospital; CHN-HK, China–Hong Kong; CHN-OHP, China–outside Hubei Province; CHN-S, China–Shenzhen; CHN-TJ, China–Tianjin; CHN-W, China–Wuhan; FWD, forward; INT, intrinsic; IRN, Iran; ITA, Italy; KOR, South Korea; KOR-B, South Korea–Busan; LCI, lower confidence interval; META, meta-analysis; NA, data not available; OTH, other; SGP, Singapore; TUN, Tunisia; UCI, upper confidence interval; UNK, unknown; USA-MT, United States–Montana.

waves, which complicates direct NPI comparisons (*1*). Park agreed with Ali, while also offering a mathematical proof for the relationship between epidemic growth rates, calculated from incidence data, and forward-looking SIs (*2*,*9*). Park showed that as growth rates increase, forward SIs lengthen, and that when incidence decreases (either over time or because of external factors) forward SIs shorten (*2*). This better describes Montana's incidence and our subperiod estimates, with NPIs providing context (Figure 2). Increased incidence and longer SIs during pre-SIP and phase 2 (June) stem from nonexistent and relaxed NPIs, whereas decreased incidence and shorter SIs during SIP and phase 2 (July) likely result from stricter NPIs and increased compliance with public health recommendations (e.g., mask wearing and social distancing). Additional data describing social compliance would benefit this interpretation.

The first limitation of this study is that the proportion of cases with identifiable transmission chains was lower during July than in previous periods. Despite this limitation, we felt it was necessary to report an SI for a period experiencing sizable incidence fluctuations. In addition, whereas others have reported negative-valued SIs among 1.2%–14.46% of infector–infectee pairs (*10*–*14*), we failed to identify any within our data. This difference could be caused by multiple factors, including incorrectly reported symptom onset dates,

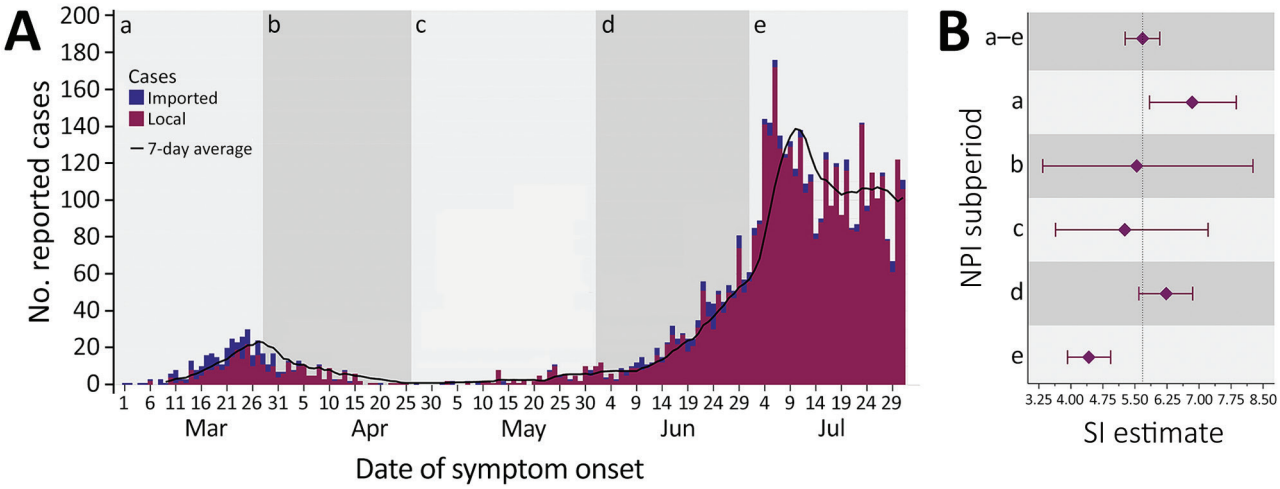


Figure 2. Reported COVID-19 cases and SARS-CoV-2 SI estimates by NPI subperiod, Montana, USA, March 1–July 31, 2020. A) COVID-19 cases, by date of symptom onset. Total cases, 4,793; total pairs, 583. For subperiod pair totals, see the Forward section of Table 2. B) SI estimates and 95% CIs (error bars). Overall mean SI was 5.68 (95% CI 5.27–6.08) days, overall SD 4.77 (95% CI 4.33–5.19) days. For subperiod SI and SD estimates, see the Forward section of Table 2. SI estimates are forward-looking and are based on the symptom onset date of the primary case in the infector–infectee pair. NPI subperiods: a) Pre-SIP, March 1–27, no NPIs in place; no. cases, 285. b) SIP, March 28–April 25, statewide stay-at-home order instituted and all nonessential businesses closed; no. cases, 168. c) Phase 1, April 26–May 31, statewide stay-at-home order lifted and limited business types allowed to open with reduced capacity; no. cases, 99. d) Phase 2 (June), June 1–30, all business types allowed to open under less restrictive capacity regulations; no. cases, 824. e) Phase 2 (July), July 1–31, all business types allowed to open under less restrictive capacity regulations; no. cases 3,417. Black line is the average number of cases for the preceding 7 days. Imported case: COVID-19 case linked to out-of-state OR out-of-county transmission; local case: nonimported COVID-19 case linked to in-state AND in-county transmission. COVID-19, coronavirus disease 2019; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; SI, serial interval; SIP, shelter-in-place.

misidentified transmission direction between pairs, or both. However, the absence of negative SIs was not unique to our study; 14 of 24 published SI estimates did not include negative-valued pairs (Table 1).

Furthermore, to include pairs with a zero-valued SI, our study required changing their upper range. A sensitivity analysis of the adjustment showed minimal impact to the resulting estimate, whereas another sensitivity analysis, examining zero-valued pairs' exclusion, returned a substantially elevated estimate. These analyses indicate that nontraditional SIs play key roles in generation time, SI, and R_0 studies, especially for SARS-CoV-2, and that inclusive methods should be used when possible.

Our study offers evidence that rural-based SARS-CoV-2 SI estimates are consistent with those describing transmission occurring in urban settings. Furthermore, temporal variations in incidence, which can be caused by NPIs, must be considered when assessing SI distributions and other transmission measures. More period-based analyses of varying NPIs and their effects on transmission dynamics would help corroborate these findings.

Acknowledgments

We thank Montana's local county and tribal health jurisdictions for their dedication and commitment in responding to the COVID-19 pandemic and for collecting the data used in this study. We also thank the Montana Department of Public Health and Human Services, Communicable Disease Epidemiology Section, for allowing us access to the state's COVID-19 case investigation data; the authors of the serial interval publications referenced in this paper who kindly responded to our inquiries concerning their studies; as well as Todd Harwell, Curtis Noonan, Erin Semmens, Jeffrey Shaman, Scott Whittenburg, Laura Williamson, and the anonymous reviewers for offering feedback on the manuscript.

This research was supported by the National Institute of General Medical Sciences of the National Institutes of Health (NIH), United States (award no. P20GM130418) and Montana state special revenue funds.

About the Author

Mr. Reed is an epidemiologist with the Office of Epidemiology and Scientific Support at the Montana Department of Public Health and Human Services, where

Table 2. Sensitivity analyses: forward and backward severe acute respiratory syndrome coronavirus 2 serial interval estimates by nonpharmaceutical intervention subperiod and length of intervention effects delay*

SI estimate method	NPI subperiod	Measure	Sensitivity analysis scenarios†		
			No delay	1-week delay	2-week delay
Forward: onset of primary case	Pre–shelter-in-place, Mar 1–27	No. pairs	95	105	113
		Mean SI (95%CI)	6.84 (5.84–7.87)	6.83 (5.67–8.07)	6.66 (5.61–7.80)
		SD (95% CI)	5.56 (4.45–6.80)	5.78 (4.48–7.24)	5.61 (4.50–6.84)
	Shelter-in-place, Mar 28–Apr 25	No. pairs	20	10	3
		Mean SI (95% CI)	5.54 (3.34–8.26)	4.08 (2.61–5.85)	2.46 (1.24–4.10)
		SD (95% CI)	5.30 (2.69–8.76)	2.83 (1.47–4.66)	1.52 (0.38–3.38)
	Reopening, phase 1, Apr 26–May 31	No. pairs	25	64	114
		Mean SI (95% CI)	5.26 (3.64–7.21)	7.45 (6.02–9.02)	7.10 (6.08–8.16)
		SD (95% CI)	4.74 (2.86–7.09)	6.24 (4.70–8.03)	5.82 (4.77–6.99)
	Reopening, phase 2, Jun 1–30	No. pairs	248	296	289
		Mean SI (95% CI)	6.23 (5.59–6.85)	5.39 (4.88–5.94)	5.08 (4.56–5.59)
		SD (95% CI)	5.32 (4.61–6.05)	4.59 (4.01–5.21)	4.32 (3.75–4.94)
	Reopening, phase 2, Jul 1–31	No. pairs	195	117	76
		Mean SI (95% CI)	4.42 (3.92–4.93)	4.20 (3.65–4.78)	3.98 (3.36–4.67)
		SD (95% CI)	3.51 (2.97–4.06)	3.20 (2.65–3.80)	2.90 (2.29–3.60)
Backward: onset of secondary case	Pre–shelter-in-place, Mar 1–27	No. pairs	61	89	105
		Mean SI (95% CI)	4.82 (3.88–5.84)	5.83 (4.86–6.82)	6.48 (5.55–7.51)
		SD (95% CI)	3.84 (2.88–4.93)	4.91 (3.86–6.08)	5.50 (4.44–6.63)
	Shelter-in-place, Mar 28–Apr 25	No. pairs	54	26	11
		Mean SI (95% CI)	8.57 (6.77–10.58)	9.03 (6.73–11.66)	7.58 (4.29–11.83)
		SD (95% CI)	6.95 (5.10–8.99)	6.52 (4.28–9.22)	6.21 (2.91–10.73)
	Reopening, phase 1, Apr 26–May 31	No. pairs	19	30	62
		Mean SI (95% CI)	3.79 (2.46–5.37)	4.95 (3.53–6.60)	4.57 (3.64–5.60)
		SD (95% CI)	3.10 (1.70–4.90)	4.41 (2.78–6.43)	3.73 (2.72–4.90)
	Reopening, phase 2, Jun 1–30	No. pairs	202	280	310
		Mean SI (95% CI)	5.38 (4.72–6.08)	5.14 (4.64–5.67)	5.22 (4.73–5.77)
		SD (95% CI)	4.59 (3.86–5.41)	4.31 (3.77–4.90)	4.38 (3.85–4.97)
	Reopening, phase 2, Jul 1–31	No. pairs	233	161	106
		Mean SI (95% CI)	5.43 (4.85–6.05)	5.82 (5.12–6.56)	6.45 (5.37–7.57)
		SD (95% CI)	4.52 (3.90–5.17)	4.88 (4.14–5.70)	5.41 (4.35–6.64)

*NPI, nonpharmaceutical intervention; SI, serial interval.
†Serial interval estimation methods and delay scenarios contain dissimilar pair totals because of their temporal differences (forward pairs, n) no delay: 583; 1-week delay: 592; 2-week delay: 595; (backward pairs, n) no delay: 569; 1-week delay: 586; 2-week delay: 594.

he manages the state's hospital discharge data and public health data visualization systems. His primary research interests include infectious disease modeling, vectorborne disease, and global health.

References

1. Ali ST, Wang L, Lau EHY, Xu XK, Du Z, Wu Y, et al. Serial interval of SARS-CoV-2 was shortened over time by nonpharmaceutical interventions. Science. 2020;369:1106–9. https://doi.org/10.1126/science.abc9004
2. Park SW, Sun K, Champredon D, Li M, Bolker BM, Earn DJD, et al. Forward-looking serial intervals correctly link epidemic growth to reproduction numbers. Proc Natl Acad Sci U S A. 2021;118:e2011548118. https://doi.org/10.1073/pnas.2011548118
3. R Core Team. R: A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing; 2019 [cited 2021 Feb 11]. https://www.R-project.org
4. Cori A. EpiEstim: estimate time varying reproduction numbers from epidemic curves. R package version 2.2–1; 2019 [cited 2021 Feb 11]. https://CRAN.R-project.org/package=EpiEstim.
5. Boelle P, Obadia T. R_0: estimation of R^0 and real-time reproduction number from epidemics. R package version 1.2–6; 2015 [cited 2021 Feb 11]. https://CRAN.R-project.org/package=R0.
6. Reich NG, Lessler J, Cummings DAT, Brookmeyer R. Estimating incubation period distributions with coarse data. Stat Med. 2009;28:2769–84. https://doi.org/10.1002/sim.3659
7. Thompson RN, Stockwin JE, van Gaalen RD, Polonsky JA, Kamvar ZN, Demarsh PA, et al. Improved inference of time-varying reproduction numbers during infectious disease outbreaks. Epidemics. 2019;29:100356. https://doi.org/10.1016/j.epidem.2019.100356
8. Griffin J, Casey M, Collins Á, Hunt K, McEvoy D, Byrne A, et al. Rapid review of available evidence on the serial interval and generation time of COVID-19. BMJ Open. 2020;10:e040263. https://doi.org/10.1136/bmjopen-2020-040263
9. Ma J, Dushoff J, Bolker BM, Earn DJD. Estimating initial epidemic growth rates. Bull Math Biol. 2014;76:245–60. https://doi.org/10.1007/s11538-013-9918-2
10. Du Z, Xu X, Wu Y, Wang L, Cowling BJ, Meyers LA. Serial interval of COVID-19 among publicly reported confirmed cases. Emerg Infect Dis. 2020;26:1341–3. https://doi.org/10.3201/eid2606.200357
11. He X, Lau EHY, Wu P, Deng X, Wang J, Hao X, et al. Temporal dynamics in viral shedding and transmissibility of COVID-19. Nat Med. 2020;26:672–5. https://doi.org/10.1038/s41591-020-0869-5
12. Mettler SK, Kim J, Maathuis MH. Diagnostic serial interval as a novel indicator for contact tracing effectiveness exemplified with the SARS-CoV-2/COVID-19 outbreak in South Korea.

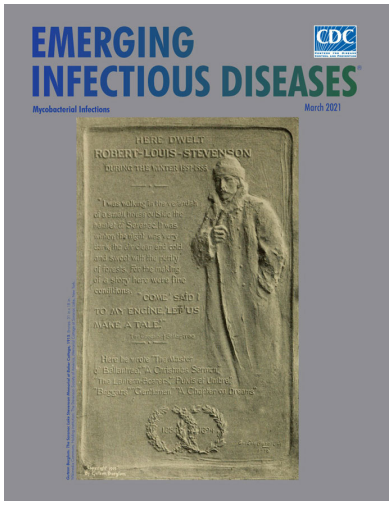
Int J Infect Dis. 2020;99:346–51. https://doi.org/10.1016/j.ijid.2020.07.068

13. Prete CA, Buss L, Dighe A, Porto VB, da Silva Candido D, Ghilardi F, et al. Serial interval distribution of SARS-CoV-2 infection in Brazil. J Travel Med. 2021;28:taaa115. https://doi.org/10.1093/jtm/taaa115
14. Talmoudi K, Safer M, Letaief H, Hchaichi A, Harizi C, Dhaouadi S, et al. Estimating transmission dynamics and serial interval of the first wave of COVID-19 infections under different control measures: a statistical analysis in Tunisia from February 29 to May 5, 2020. BMC Infect Dis. 2020;20:914. https://doi.org/10.1186/s12879-020-05577-4

Address for correspondence: Isaiah G. Reed, Montana Department of Public Health and Human Services, 1400 Broadway, Rm A113, PO Box 202951, Helena, MT 59620-2951, USA; email: isaiah.reed@mt.gov

March 2021
Mycobacterial Infections

- Parallels and Mutual Lessons in Tuberculosis and COVID-19 Transmission, Prevention, and Control
- Genomic Evidence of In-Flight Transmission of SARS-CoV-2 Despite Predeparture Testing
- Evaluation of National Event-Based Surveillance, Nigeria, 2016–2018
- Clinical Features and Comparison of Kingella and Non-*Kingella* Endocarditis in Children, Israel
- Use of US Public Health Travel Restrictions during COVID-19 Outbreak on Diamond Princess Ship, Japan, February–April 2020
- Systematic Review of Pooling Sputum as an Efficient Method for Xpert MTB/RIF Tuberculosis
- Testing during COVID-19 Pandemic Decentralized Care for Rifampicin-Resistant Tuberculosis, Western Cape, South Africa
- Transmission of Antimicrobial-Resistant *Staphylococcus aureus* Clonal Complex 9 between Pigs and Humans, United States
- Epidemiology and Clinical Course of First Wave Coronavirus Disease Cases, Faroe Islands Oral Human Papillomavirus Infection in Children during the First 6 Years of Life, Finland
- Clusters of Drug-Resistant Mycobacterium tuberculosis Detected by Whole-Genome Sequence Analysis of Nationwide Sample, Thailand, 2014–2017



- Daily Forecasting of Regional Epidemics of Coronavirus Disease with Bayesian Uncertainty
- Quantification, United States Fluconazole-Resistant *Candida glabrata* Bloodstream Isolates, South Korea, 2008–2018
- Excess All-Cause Deaths during Coronavirus Disease Pandemic, Japan, January–May 2020
- Mycoplasma genitalium and Other Reproductive Tract Infections in Pregnant Women, Papua New Guinea, 2015–2017
- Effectiveness of Preventive Therapy for Persons Exposed at Home to Drug-Resistant Tuberculosis, Karachi, Pakistan
- Familial Clusters of Coronavirus Disease in 10 Prefectures, Japan, February−May 2020
- Population-Based Geospatial and Molecular Epidemiologic Study of Tuberculosis Transmission Dynamics, Botswana, 2012–2016
- Extrapulmonary Nontuberculous *Mycobacteria* Infections in Hospitalized Patients, United States, 2010–2014
- Genomic Characterization of hlyF-positive Shiga Toxin–Producing *Escherichia coli*, Italy and the Netherlands, 2000–2019
- Isolate-Based Surveillance of *Bordetella pertussis*, Austria, 2018–2020
- Decline of Tuberculosis Burden in Vietnam Measured by Consecutive National Surveys, 2007–2017
- Foodborne Origin and Local and Global Spread of *Staphylococcus saprophyticus* Causing Human Urinary Tract Infections
- Prevalence of SARS-CoV-2 Antibodies in First Responders and Public Safety Personnel, New York City, New York, USA, May–July 2020
- Local and Travel-Associated Transmission of Tuberculosis at Central Western Border of Brazil, 2014–2017
- Antibody Responses 8 Months after Asymptomatic or Mild SARS-CoV-2 Infection
- Lung Pathology of Mutually Exclusive Co-infection with SARS-CoV-2 and *Streptococcus pneumoniae*

EMERGING INFECTIOUS DISEASES

To revisit the March 2021 issue, go to:
https://wwwnc.cdc.gov/eid/articles/issue/27/3/table-of-contents

Article DOI: https://doi.org/10.3201/eid2705.204663

Severe Acute Respiratory Syndrome Coronavirus 2 Serial Interval Variation, Montana, USA, March 1–July 31, 2020

Appendix

Additional References, Table 1 and Figure 1

15. Lavezzo E, Franchin E, Ciavarella C, Cuomo-Dannenburg G, Barzon L, Del Vecchio C, et al.; Imperial College COVID-19 Response Team; Imperial College COVID-19 Response Team. Suppression of a SARS-CoV-2 outbreak in the Italian municipality of Vo'. Nature. 2020;584:425–9. PubMed https://doi.org/10.1038/s41586-020-2488-1

16. Aghaali M, Kolifarhood G, Nikbakht R, Saadati HM, Hashemi Nazari SS. Estimation of the serial interval and basic reproduction number of COVID-19 in Qom, Iran, and three other countries: A data-driven analysis in the early phase of the outbreak. Transbound Emerg Dis. 2020;67:2860–8. PubMed https://doi.org/10.1111/tbed.13656

17. You C, Deng Y, Hu W, Sun J, Lin Q, Zhou F, et al. Estimation of the time-varying reproduction number of COVID-19 outbreak in China. Int J Hyg Environ Health. 2020;228:113555. PubMed https://doi.org/10.1016/j.ijheh.2020.113555

18. Zhang J, Litvinova M, Wang W, Wang Y, Deng X, Chen X, et al. Evolving epidemiology and transmission dynamics of coronavirus disease 2019 outside Hubei province, China: a descriptive and modelling study. Lancet Infect Dis. 2020;20:793–802. PubMed https://doi.org/10.1016/S1473-3099(20)30230-9

19. Liao J, Fan S, Chen J, Wu J, Xu S, Guo Y, et al. Epidemiological and clinical characteristics of COVID-19 in adolescents and young adults. Innovation (N Y). 2020;1:100001. PubMed https://doi.org/10.1016/j.xinn.2020.04.001

20. Zhao S, Gao D, Zhuang Z, Chong MKC, Cai Y, Ran J, et al. Estimating the serial interval of the novel coronavirus disease (COVID-19): a statistical analysis using the public data in Hong Kong from January 16 to February 15, 2020. Front Phys. 2020;8:347. https://doi.org/10.3389/fphy.2020.00347

21. Chan YWD, Flasche S, Lam TLT, Leung MHJ, Wong ML, Lam HY, et al. Transmission dynamics, serial interval and epidemiology of COVID-19 diseases in Hong Kong under different control measures [version 2; peer review: 2 approved with reservations]. Wellcome Open Res. 2020;5:91. https://doi.org/10.12688/wellcomeopenres.15896.1

22. Bi Q, Wu Y, Mei S, Ye C, Zou X, Zhang Z, et al. Epidemiology and transmission of COVID-19 in 391 cases and 1286 of their close contacts in Shenzhen, China: a retrospective cohort study. Lancet Infect Dis. 2020;20:911–9. PubMed https://doi.org/10.1016/S1473-3099(20)30287-5

23. Wang K, Zhao S, Liao Y, Zhao T, Wang X, Zhang X, et al. Estimating the serial interval of the novel coronavirus disease (COVID-19) based on the public surveillance data in Shenzhen, China, from 19 January to 22 February 2020. Transbound Emerg Dis. 2020;67:2818–22. PubMed https://doi.org/10.1111/tbed.13647

24. Ganyani T, Kremer C, Chen D, Torneri A, Faes C, Wallinga J, et al. Estimating the generation interval for coronavirus disease (COVID-19) based on symptom onset data, March 2020. Euro Surveill. 2020;25:2000257. PubMed https://doi.org/10.2807/1560-7917.ES.2020.25.17.2000257

25. Tindale LC, Stockdale JE, Coombe M, Garlock ES, Lau WYV, Saraswat M, et al. Evidence for transmission of COVID-19 prior to symptom onset. eLife. 2020;9:e57149. PubMed https://doi.org/10.7554/eLife.57149

26. Li Q, Guan X, Wu P, Wang X, Zhou L, Tong Y, et al. Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus-Infected Pneumonia. N Engl J Med. 2020;382:1199–207. PubMed https://doi.org/10.1056/NEJMoa2001316

27. Ki M; Task Force for 2019-nCoV. Epidemiologic characteristics of early cases with 2019 novel coronavirus (2019-nCoV) disease in Korea. Epidemiol Health. 2020;42:e2020007. PubMed https://doi.org/10.4178/epih.e2020007

28. Chun JY, Baek G, Kim Y. Transmission onset distribution of COVID-19. Int J Infect Dis. 2020;99:403–7. PubMed https://doi.org/10.1016/j.ijid.2020.07.075

29. Son H, Lee H, Lee M, Eun Y, Park K, Kim S, et al. Epidemiological characteristics of and containment measures for COVID-19 in Busan, Korea. Epidemiol Health. 2020;42:e2020035. PubMed https://doi.org/10.4178/epih.e2020035

30. Nishiura H, Linton NM, Akhmetzhanov AR. Serial interval of novel coronavirus (COVID-19) infections. Int J Infect Dis. 2020;93:284–6. PubMed https://doi.org/10.1016/j.ijid.2020.02.060