



Emerging Evidence on COVID-19

Evidence Brief of Maximum Incubation Period

Introduction

What evidence exists that the incubation period of SARS-CoV-2 is greater than two weeks?

What policies are currently used for quarantine durations to account for longer incubation periods?

The incubation period determined by the [World Health Organization \(WHO\)](#), the [European Centers for Disease Control \(ECDC\)](#), [US Centers for Disease Control and Prevention \(CDC\)](#) and [Public Health Agency of Canada](#) ranges from 0-14.0 days, 0-14.0 days, 2.0-14.0 days, and 1.0-14.0 days, respectively. A comparison across coronaviruses in one review reported average incubation periods of SARS 4.6 days (95% CI: 3.8-5.8 d) and MERS 5.2 days (95% CI: 1.9-14.7 d) (1). This evidence brief focuses on the evidence up to January 25, 2020, on prolonged incubation periods beyond a 14-day quarantine period, and regions that have recently extended the quarantine period for some or all travellers.

Key Points

- The incubation period across all meta-analyses was an average or median of 5-7 days with the longest incubation period reported to be 32 days. There was some evidence the average incubation period may be longer for children and older adults compared to adults (Table 1). Over dispersion in the tail of incubation periods was noted, which may result in the mean and confidence intervals being skewed towards higher values due to a few very long incubation periods in the dataset. The reported range in upper percentiles across meta-analyses were:
 - 90th percentile: 9.7 days (95% CI: 8.1–11.6)
 - 95th percentile: 11.2 days (95% CI: 10.7–11.8) to 11.7 days (95% CI: 9.7–14.2)
 - 97.5th percentile: 11.5 days (95% CI: 8.2–15.6) to 19.2 days (95% CI: 17.4-21.4)
- Study point estimates ranged from 1%-6.7% and 0-1.4% of infected individuals would still be in their incubation periods at 14 days and 21 days, respectively.
- The Canadian model estimating incubation period over the pandemic up to November 2020 reported a mean of 6.89 days, a median of 6 days and 90th, 95th, 99th percentiles of 11, 12, 13.5 days. They also indicated results suggested a slight increase in the incubation period over time.
- As of January 25, 2021, four regions have increased the quarantine duration for travellers entering their borders (Table 2). No evidence was found for longer incubation periods of COVID-19 or a larger proportion of cases falling beyond the commonly accepted 14-day threshold (including the variants of concern) within the literature.

Overview of the Evidence

Eleven reviews were included, mainly systematic reviews and meta-analysis, which summarized studies that measured incubation periods. In addition, eleven primary research studies presented evidence of incubation periods beyond 14 days. The final paper is a quantitative model on incubation period developed using Canadian data (Table 1).

Most incubation period data comes from public health contact tracing investigations mainly from studies done in Asia. Contact tracing investigations were at high risk of bias due to their retrospective nature. The data may also be affected by the fact that people do not know with certainty that they were exposed at a certain time or place. The systematic reviews were not evaluated by AMSTAR-2 due to the speed that this brief was developed, however the quality of individual reviews is highly variable ranging from few systematic review attributes to well conducted systematic reviews. The systematic reviews and meta-analyses overlap in the studies included. The quantitative model uses Canadian data to estimate the incubation period in the Canadian context. This model would be sensitive to the quality of the data used to develop the model.

As noted above, most of the data used to estimate incubation period were from studies conducted in Asia and are largely from early in the pandemic. Knowledge gaps include few recent studies and limited global representation of data on incubation period.

Other related evidence reviews are available on SARS-CoV-2 [infectious period](#) (2) and the [efficacy of various quarantine strategies](#) (3) by request.

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INCUBATION PERIODS

Table 1: Evidence of Incubation Period Beyond 14 Days (n=23)

STUDY	METHODS	KEY OUTCOMES
Reviews (n=11)		
Public Health Ontario (2020) (4) Rapid review NA	Search included references found in Nov 2020; and 16 meta-analyses were included. PHO compiled 4 systematic reviews and meta-analysis studies	Range of median incubation periods (tail-end analysis) reported across included meta-analyses: <ul style="list-style-type: none"> • 50th percentile: 5.1 days (95% CI: 4.5–5.8) to 5.4 days (95% CI: 5.0–5.7)

<p>Nov 2020</p>	<p>(Quesada, 2020; McAloon, 2020; Li, 2020; Lauer, 2020) for tail-end analysis of the pooled estimates of the median incubation period.</p>	<ul style="list-style-type: none"> • 75th percentile: 6.7 days (95% CI: 5.7–7.9) to 8.5 days (95% CI: 7.9–9.1) • 90th percentile: 9.7 days (95% CI: 8.1–11.6) • 95th percentile: 11.2 days (95% CI: 10.7–11.8) to 11.7 days (95% CI: 9.7–14.2) • 97.5th percentile: 11.5 days (95% CI: 8.2–15.6) to 16.5 days (95% CI: 14.8–18.3) <p>Mean incubation period ranged from 4.2 to 6.7 days across all studies.</p>
<p>Quesada (2021) (5) Systematic review and meta-analysis NA Mar 2020</p>	<p>Systematic review was conducted with a search up to March 21, 2020. The meta-analysis included 7 studies.</p>	<p>The mean incubation period ranged from 5.6 (95% CI: 5.2 to 6.0) to 6.7 days (95% CI: 6.0 to 7.4), high heterogeneity (I^2 83.0%, $p < 0.001$), depending on the statistical model used.</p> <p>A meta-regression of the 95th percentile data including mean age explained observed heterogeneity. Where for each 10 year increase in age, there was a 1 day increase in incubation period. Where the 95th percentile by mean age was 10.5, 11.5 and 12.5 days for 40, 50 and 60 year old, respectively.</p>
<p>McAloon (2020) (6) Rapid review and meta-analysis NA Apr 2020</p>	<p>Rapid review and meta-analysis with search conducted April 8, 2020. 24 studies were included for review, 9 of them were analysed.</p>	<p>Mean incubation period was 5.8 days (95% CI: 5.0 to 6.7) days with uncertainty in tail of the distribution.</p> <p>Median incubation period of 5.1 (95% CI: 4.5 to 5.8) days.</p> <p>The 95th percentile was 11.7 (95% CI: 9.7 to 14.2) days.</p>
<p>Li (2020) (7) Preprint Systematic review NA May 2020</p>	<p>Systematic review search conducted May 30, 2020, 64 studies were included, 30 studies were analysed, 12 of which included incubations greater than 14 days.</p>	<p>Incubation period 4.9 days (95% CI: 4.6–5.2) and a 97.5th percentile of 19.2 days (95% CI: 17.4–21.4).</p>
<p>Lauer (2020) (8) Meta-analysis</p>	<p>Pooled analysis of 181 cases reported Jan 4 – Feb 24, 2020 outside of Hubei province.</p>	<p>Median incubation period 5.1 days (95% CI: 4.5 to 5.8 days).</p>

<p>NA Jan – Feb 2020</p>		<p>97.5% of symptomatic cases developed symptoms within 11.5 days (CI: 8.2 to 15.6 days). Authors report that these estimates indicate that from 10,000 cases, 101 would develop symptoms after 14 days.</p>
<p>Daley (2020) (9) Preprint Systematic Review NA Jul 2020</p>	<p>Systematic review, search conducted July 18, 2020 and included 21 studies reporting incubation period.</p>	<p>Across studies the mean 5.9 days and median 5.6 days were in agreement.</p>
<p>Khalili (2020) (10) Systematic review and meta-analysis NA Mar 2020</p>	<p>A systematic review was conducted up to March 11, 2020, 18 studies were included in the meta-analysis of incubation period, only 2 were from outside China.</p>	<p>The pooled mean incubation period was 5.68 (99% CI: 4.78- 6.59) days, I²= 98.4%.</p>
<p>Wang (2020) (1) Review NA Mar 2020</p>	<p>Narrative review of SARS, MERS, and SARS-CoV-2.</p>	<p>Average incubation period: <ul style="list-style-type: none"> • SARS : 4.6 d (95% CI: 3.8-5.8 d), • MERS : 5.2 d (95% CI: 1.9-14.7 d), • SARS-CoV-2: 6.4 d (range, 0-24.0 d)/ median 4 days (IQR 2-7) (Guan 2020) </p>
<p>Lin (2020) (11) Systematic Review NA Jun 2020</p>	<p>Search date was Feb 21, 2020. 8 studies were included in the meta-analysis of incubation period.</p>	<p>The median incubation 5.90 days (IQR 4.78–6.25) across 9 studies.</p>
<p>Wei (2020) (12) Preprint Systematic review NA Apr 2020</p>	<p>56 studies in the meta-analysis (4095 observations).</p>	<p>Median incubation period of 5.8 days (95% CI: 5.3 - 6.2, I² = 96.1%, P < 0.0001) and mean 6.9 days. Incubation period was longer for asymptomatic cases (median, 7.7; 95% CI: 6.3–9.4, P = 0.0408) and children (median, 7.3 d; 95% CI: 6.2–8.6, P = 0.0219). An estimated 6.7% (95% CI: 2.4–11.2%) and 1.4% (95% CI: 0.1–3.6%) of infected</p>

		<p>people had incubation periods over 14 d and 21 d respectively.</p> <p>The 97.5th percentile was 18 days incubation period for symptomatic cases, 14 days for asymptomatic and 25 days for children.</p>
<p>Bikbov (2021) (13)</p> <p>Letter to the Editor</p> <p>NA</p> <p>Jul 2020</p>	<p>Letter to the Editor, the authors summarize as a narrative synthesis the evidence of COVID-19 incubation period beyond 14-days (Koff, 2020; Guan, 2020; Tan, 2020; Jiang, 2020; Bai, 2020; Qiu, 2020; Bi, 2020).</p>	<p>The author's strongly advocate the need for open access data, specifically concerning incubation period of COVID-19 infection.</p>
<p>Primary Literature (n=11)</p>		
<p>Koff (2020) (14)</p> <p>Case Report</p> <p>USA</p> <p>Oct 2020</p>	<p>A case report of a patient who developed COVID-19 in California.</p>	<p>Patient with a confirmed incubation period of at least 21 days.</p>
<p>Guan (2020) (15)</p> <p>Case Series</p> <p>China</p> <p>Feb 2020</p>	<p>The study reported clinical data for 1099 patients.</p>	<p>The preprint mentioned 1 individual with an incubation period of 24 days, but this was labelled as a double exposure when WHO objected the data. The accepted article does not use this 24 day length in quantifying the incubation period and does not provide an upper limit.</p>
<p>Tan (2020) (16)</p> <p>Preprint</p> <p>Case Series</p> <p>China</p> <p>Jan-Feb 2020</p>	<p>A cohort of 67 patients admitted to hospital in China from Jan 26 – Feb 5, 2020.</p> <p>Cases confirmed by observation of corona viral particles by transmission electron microscopy.</p>	<p>Median incubation period of 6.0 days (range 1-15 days). The study notes a longer incubation period is observed in children.</p> <p>1/67 (1.5%) were observed to have an incubation period greater than 14 days (15 days reported).</p>
<p>Jiang (2020) (17)</p> <p>Preprint</p> <p>Case Series</p> <p>China</p> <p>Jan 2020</p>	<p>Data from 136 patients who travelled to Hubei from Jan 5 - 31, 2020 and returned to their respective 21 cities after 48 hours or less in Hubei.</p>	<p>Cases 15-64 years old had a median incubation period of 7.0 days (95% CI, 6.1-8.1 days).</p> <p>Cases in the 65-86 year old range had a median incubation period of 10.9 days (95% CI, 8.9-13.6 days).</p> <p>A maximum of 17 days was observed (within the 65-86 year cohort).</p>

<p>Bai (2020) (18)</p> <p>Case Series</p> <p>China</p> <p>Jan-Feb 2020</p>	<p>This case series follows a familial cluster of 5 symptomatic patients and 1 asymptomatic family member.</p>	<p>The asymptomatic case had a reported incubation period of 19 days from initial contact with family members on January 10, 2020 to a positive RT-PCR test on Jan 28 (negative tests reported Jan 26, Feb 5, and Feb 8).</p> <p>It should be noted that this period is from first potential exposure, and may reflect a longer period than clinically experienced.</p>
<p>Qiu (2020) (19)</p> <p>Contact tracing investigations</p> <p>China</p> <p>Jan-Feb 2020</p>	<p>Results of contact investigations of 104 cases of COVID-19 in Hunan province, all were confirmed by RT-PCR.</p>	<p>The median incubation period was 6 (range, 1-32) days, which of 8/104 patients had incubation periods longer than 14 days: 18-32 days.</p>
<p>Bi (2020) (20)</p> <p>Contact tracing investigations</p> <p>China</p> <p>Jan-Feb 2020</p>	<p>Results of contact investigations of 391 cases of COVID-19 in Shenzhen province, all were confirmed by RT-PCR. 183 cases were considered to have well defined timelines for exposure and symptom onset.</p>	<p>Median incubation period reported as 4.8 days (95% CI: 4.2-5.4 days). 95% of symptomatic cases developed symptoms within 14 days (95% CI: 12.2-15.9 days)</p>
<p>Li (2021) (21)</p> <p>Preprint</p> <p>Case series</p> <p>China</p> <p>NR</p>	<p>787 cases from outside Wuhan were identified from a database in China. Gamma distribution best fit the data, thus a long tail.</p>	<p>The mean incubation period is 7.8 (7.4-8.5) days.</p> <p>Percentiles:</p> <p>50th, 7.0 (6.7~7.3) days</p> <p>75th 10.0 (9.7~10.4) days</p> <p>97.5th 17.9 (17.1~18.7) days</p>
<p>Liu (2020) (22)</p> <p>Retrospective Cohort</p> <p>China</p> <p>Jan-Mar 2020</p>	<p>Until the end of March 2020, 93 patients were identified in Jilin province China. This study details the epidemiology and clinical results of the 93 RT-PCR confirmed COVID-19 cases.</p>	<p>The mean period of incubation for 87 patients was 10.4 days (range 2-25 days). The authors acknowledge this is longer than many other reports.</p>
<p>Leung (2020) (23)</p> <p>Case series</p> <p>China</p>	<p>A Google search for cases in China was conducted up to Feb 12, 2020. 175 cases with exposure data that included travel to Wuhan or known contact with</p>	<p>The Weibull distribution provided the best fit of the incubation period data and there was a dichotomy by whether the person had travelled to Hubei (mean 1.8 days, variance 0.7) or was not a traveller,</p>

Jan-Feb 2020	infected person/place were included.	meaning local exposure, (mean 7.2 days, variance 16.2). This study found incubation period length at the 95% confidence interval was between 14.6-17.1 days, which is longer than current quarantine interventions.
Zhu (2020) (24) Preprint Contact tracing investigations China Feb-Apr 2020	Analysis of 670 COVID-19 cases imported into China that underwent quarantine and RT-PCR testing.	Median incubation period was 3 days (IQR 1-6 days.) The 95 th percentile 11.6 days. (Table 3 lists incubation periods of 19 studies and the 95 th percentile crosses 14 days in most estimates).
Model (n=1)		
Paul (2020) (25) Preprint Model Canada Nov 2020	SEIR model of the Canadian epidemic was developed to estimate the incubation period up to Nov 2020.	Estimates include a mean incubation period of 6.89 days, a median of 6 days and 90 th percentile of 11 days, 95 th percentile of 12 days and 99 th percentile of 13.5 days. The model predicts a peak incubation period at 6 days with a second smaller peak at 10 days. This model also detected a slight increase over time in incubation period.

NR = not reported, NA = Not applicable

QUARANTINE POLICIES BEYOND 14 DAYS

Early in the COVID-19 pandemic, a maximum incubation period of 14 days was established by WHO and accepted as a standard quarantine or isolation period for travelers, cases and contacts by many countries and regions. At this point in the pandemic a few countries have eliminated or have very little local transmission of SARS-CoV-2, while other countries are reporting their highest case counts. There are also new variants of concern that have been identified and may be more transmissible than the original SARS-CoV-2. As such, countries with well controlled SARS-CoV-2 situations have amended their policies on quarantine duration as a precaution (Table 2). The table below describes the current quarantine requirements from countries with extended quarantine as of January 25, 2021.

Table 2: Government Quarantine Policies (n=4)

POLICY	KEY OUTCOMES
Australia	Hotel quarantine is required for those entering Australia, minimum 14 days, to a maximum of 24 days.

<p>National Policy, Hotel Quarantine FAQ</p> <p>Posted Jan 22, 2021 (Accessed Jan 25, 2021)</p>	<p>Testing is conducted on days 2 and 12. Quarantine ends after 14 days for those with negative test results and no symptoms.</p> <p>A positive test, symptoms or close contact with a case restarts the 14 day count.</p> <p>Those refusing testing are quarantined the full 24 days.</p>
<p><u>Beijing, China</u></p> <p>Entry/exit requirements, listed by Government of Canada</p> <p>Posted Jan 21, 2021 (Accessed Jan 25, 2021)</p>	<p>Nationally, China requires a 14 day quarantine in a government designated facility. This procedure may vary by port of entry or final destination.</p> <p>International travellers entering Beijing will be subject to:</p> <ul style="list-style-type: none"> • 21 days of quarantine in a local government designated facility; you may be allowed to self-isolate at home for the last 7 days. • An additional 7 days of health monitoring. <p>International travellers entering Beijing via any other Chinese city will be subject to:</p> <ul style="list-style-type: none"> • 21 days of self-isolation at the international point-of-entry, before they can continue to Beijing. • An additional 7 days of health monitoring upon arrival to Beijing.
<p><u>Hong Kong</u></p> <p>Quarantine Extension, Press Release</p> <p>Posted Dec 25, 2020 (Accessed Jan 25, 2021)</p>	<p>Those arriving in Hong Kong who have been anywhere other than China in the past 21 days are subject to a 21 day quarantine in a designated hotel.</p> <p>Further, anyone who has spent more than 2 hours in the United Kingdom or South Africa in the past 21 days are not allowed entry to Hong Kong.</p>
<p><u>Singapore</u></p> <p>Quarantine Requirements</p> <p>Posted Jan 25, 2021 (Accessed Jan 26, 2021)</p>	<p>Singapore requires a 14 days quarantine for all travelers entering the country. Quarantine is spent at a designated facility.</p> <p>Recently, the quarantine for travellers from the United Kingdom and South Africa has been increased to a mandatory 21 days. The first 14 days are spent at a designated facility, with an addition 7 days at their place of residence.</p>

Methods:

A daily scan of the literature (published and pre-published) is conducted by the Emerging Science Group, PHAC. The scan has compiled COVID-19 literature since the beginning of the outbreak and is updated daily. Searches to retrieve relevant COVID-19 literature are conducted in Pubmed, Scopus, BioRxiv, MedRxiv, ArXiv, SSRN, Research Square and cross-referenced with the COVID-19 information centers run by Lancet, BMJ,

Elsevier, Nature and Wiley. The daily summary and full scan results are maintained in a reworks database and an excel list that can be searched. Targeted keyword searching was conducted within these repositories to identify relevant citations on COVID-19 and SARS-CoV-2. Search terms used included: (incubation period AND (prolonged OR review)). This review contains research published up to January 25, 2021.

A Google search and search of targeted government websites was conducted to find publicly available reports, protocols and clinical data pertinent to the evidence questions. Search terms used included: COVID-19 AND incubation period; quarantine AND increase; quarantine AND length; variant AND quarantine. Searches were conducted and websites accessed on January 25, 2021.

Each potentially relevant reference was examined to confirm it had relevant data, and relevant citations were explored for further detail; relevant data was extracted into the review.

Prepared by: Ainsley Otten and Lisa Waddell. Emerging Science Group, PHAC. phac.evidence-donnees.probanes.aspc@canada.ca

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