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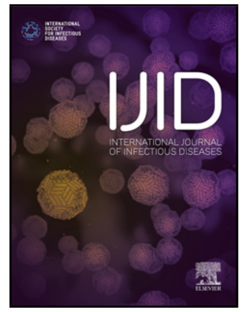

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Potential Fecal Transmission of SARS-CoV-2: Current Evidence and Implications for Public Health

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Abstract

Coronavirus disease 2019 (COVID-19) emerged in Hubei Province, China in December 2019 and has since become a global pandemic, with hundreds of thousands of cases and over 165 affected countries. Primary routes of transmission of the causative virus, severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), are through respiratory droplets and close person-to-person contact. While information about other potential modes of transmission are relatively sparse, evidence supporting the possibility of a fecally-mediated mode of transmission has been accumulating. Here, current knowledge on the potential for fecal transmission is briefly reviewed and the possible implications are discussed from a public health perspective.

Introduction

The current pandemic of coronavirus disease 2019 (COVID-19) emerged in Hubei Province, China in December 2019 and has spread rapidly to over 165 countries in approximately 3 months (Johns Hopkins University Center for Systems Science and Engineering, 2020, Shanmugaraj et al., 2020). The primary routes of transmission of the virus, SARS-CoV-2 (severe acute respiratory syndrome coronavirus-2), are through respiratory droplets and close person-to-person contact, but knowledge about other potential modes of transmission (e.g., fomite-based, vertical, and fecal-oral transmission) remains relatively sparse (Cai et al., 2020a, Chen H. et al., 2020, Ghinai et al., 2020, Gu et al., 2020, Li et al., 2020, van Doremalen et al., 2020, Wang W. et al., 2020, Xiao et al., 2020, Yeo et al., 2020). However, recently, evidence supporting the possibility of a fecally-mediated route of transmission has been accumulating (Chen Y. et al., 2020, Gu et al., 2020, He et al., 2020, Wang W. et al., 2020, Xiao et al., 2020, Zhang H. et al., 2020). Specifically, an increasing number of studies have detected the presence of viral RNA in stool from COVID-19 patients, and to date, there are at least three reports of viable virus having been identified in patient stool samples (Wang W. et al., 2020, Xiao et al., 2020, Zhang Yong et al., 2020). Given the quickly evolving situation, it is imperative that the most current information be considered in the ongoing public health response to COVID-19. In this article, recent evidence about the potential for fecal transmission of SARS-CoV-2 is briefly summarized, and the possible implications for transmission mitigation and disease control are discussed from a public health perspective.

Prior Knowledge on Related Viruses

Coronaviruses are comprised of a family of >30 viruses that exhibit a substantial amount of genetic diversity and have the largest known genomes out of all RNA viruses. Studies conducted prior to the emergence of SARS-CoV-2 have demonstrated that other coronaviruses can be shed in feces (Corman et al., 2014, Dominguez et al., 2007, Drosten et al., 2013, Kim et al., 2016, Xu et al., 2005). For example, the Middle East respiratory syndrome coronavirus (MERS-CoV) has been detected in fecal samples from some infected individuals at low viral loads (Centers for Disease Control & Prevention, Corman et al., 2016, Drosten et al., 2013, Wu et al., 2015), though there have been no confirmed cases of fecal transmission, to our knowledge (Bak et al., 2018). Similarly, after the 2002 SARS epidemic, which was caused by a virus (SARS-CoV) that shares ~80% genetic homology with SARS-CoV-2, fecal shedding was noted in a subset of patients (Cheng et al., 2004, Xu et al., 2005), and SARS-CoV RNA was detected in sewage water from Beijing hospitals that were treating SARS patients, though infectious virions were not identified (Lee, 2003, Wang et al., 2005a, Wang et al., 2005b, Yeo et al., 2020).

Current Knowledge on SARS-CoV-2

To date, a number of studies have utilized reverse-transcriptase polymerase chain reaction (RT-PCR) for the detection of viral RNA in stool samples and anal swabs from patients with COVID-19 (see references in Table 1). With the exception of a report on a familial COVID-19 cluster (Chan et al., 2020), all of these studies have identified RNA from the novel coronavirus, SARS-CoV-2, in stool or anal swabs from at least some infected patients (Table 1). Prevalence of positivity from stool specimens has varied widely across studies, but most reports have been based on a small number of patients and the timing of specimen collection has been largely inconsistent and unstandardized. This is unsurprising, as most reports are from case reports or case series of patients treated on the frontlines during the pandemic (as opposed to formally structured research studies). While some of these case series have described the collection of multiple specimens over the course of illness or hospitalization (Chen W. et al., 2020, Ling et al., 2020, The COVID-19 Investigation Team, 2020, Wu et al., 2020, Xiao et al., 2020), it remains challenging to assess exactly when the virus may have started shedding in the stool initially (e.g., during the incubation period, upon onset of illness, and/or during convalescence). Further, it is unclear how long the shedding tends to continue, though a few studies that collected samples serially have observed durations of positivity between 1 to >30 days post onset of illness (Ling et al., 2020, The COVID-19 Investigation Team, 2020, Wu et al., 2020, Xiao et al., 2020, Zhang Yong et al., 2020). However, more consistent serial specimen monitoring on a larger number of patients is warranted before clear conclusions about duration of shedding can be drawn.

Currently, it remains unclear whether there may be associations between detection in stool and severity of disease or patterns of symptomatology. Observations to date indicate that a subset of COVID-19 patients (2-35%) have experienced some gastrointestinal (GI) symptoms, such as abdominal discomfort, diarrhea, GI bleeding, nausea, and vomiting, though these symptoms are much less prevalent than respiratory involvement (Wang D. et al., 2020, Yeo et al., 2020). Some early reports indicated that mild GI symptoms sometimes precede respiratory signs and fever in about 10% of patients (Gu et al., 2020, Holshue et al., 2020, Wang D. et al., 2020); however, some patients who had later onsets of GI symptoms, did not experience GI symptoms during the course of illness, or had recovered from illness still tested positive for viral RNA in stool (Cai et al., 2020b, Kam et al., 2020, Ling et al., 2020, Wang W. et al., 2020). For example, Ling et al. reported the presence of viral RNA in the stool of 11 convalescing adult patients who were no longer febrile or experiencing respiratory symptoms (Ling et al., 2020).

Interestingly, Tang et al. found viral RNA in stool samples of an asymptomatic child, whose parents tested negative for the virus on two separate occasions that were two weeks apart, using sputum, nasopharyngeal, and stool specimens (Tang et al., 2020). In another recent case report, a 6-month old asymptomatic infant who had close contact with his infected parents tested negative for viral RNA in stool samples on the second day of hospitalization, while he was both viremic and positive on nasopharyngeal swabs (Kam et al., 2020). However, on the ninth day, a stool specimen tested positive, though the infant was still not experiencing gastrointestinal symptoms. On the seventeenth day, nasopharyngeal swabs became negative, but another stool specimen was not collected.

Potential for Fecal Transmissibility

While current studies imply that SARS-CoV-2 may be shedding through stool in at least a subset of patients, the detection of viral genetic material in stool does not necessarily indicate that viable infectious virions are present in fecal material or that the virus can or has spread through fecal transmission (e.g., fecal-oral, -fomite, or -aerosol/droplet) (de Graaf et al., 2017). A small number of studies have addressed the former directly (Wang W. et al., 2020, Xiao et al., 2020, Zhang Yong et al., 2020). The Chinese Center for Disease Control and Prevention (CCDC) isolated viable SARS-CoV-2 from a stool sample of a laboratory-confirmed patient from Heilongjiang Province, China about 15 days after onset of disease (Zhang Yong et al., 2020). In a recent study, Wang et al. cultured 4 patient stool specimens that had high viral RNA copy numbers and was able to use electron microscopy to observe live virus in two of them (Wang W. et al., 2020). Additionally, Xiao et al. briefly mentioned having identified live virions from stool, but details are unavailable, as the data are yet unpublished (Xiao et al., 2020). Because these findings are based on a very small number of patients, additional studies are strongly warranted on how frequently viable virus is present in patient stool, and when present, what the range of viral loads may be, particularly because the ability of the virus to be spread through fecal transmission is largely contingent on these factors. It is presently believed that SARS-CoV-2 may have a low infective dose (Lee and Hsueh, 2020), implying that low viral loads in stool could still be a concern for transmissibility.

With regard to possible fecal-oral transmission specifically, it is relevant that cells in the oral cavity, esophagus, and other parts of the gastrointestinal tract express angiotensin converting enzyme 2 (ACE2) receptors. ACE2 has been identified as the host receptor that interacts with the viral spike protein to facilitate entry of SARS-CoV-2 into the host cell (Gu et al., 2020, Xu et al., 2020). Xiao et al. reported positive staining for SARS-CoV-2 in GI tissue samples from one patient who underwent endoscopic biopsy on the tenth day of illness (Xiao et al., 2020). The authors also discussed that positive staining was detected in other patients' tissue specimens, though these data were not presented. These findings highlight the urgent need for further research on potential fecal-oral transmission and the possible significance and/or sequelae of viral presence in the GI tract.

Implications for Public Health

Based on current knowledge, additional precautions for preventing potential fecal transmission should be strongly considered until future studies can establish whether this is a plausible (and if so, frequent) mode of transmission for SARS-CoV-2 (He et al., 2020). Considerations regarding sewage exposure, nosocomial infections, residential care facilities, and food preparation are briefly discussed below. If it is confirmed that the virus can be transmitted through fecal contamination, more extensive measures, including a public education campaign, may be necessary to help mitigate the spread of COVID-19.

Fecal-oral and waterborne transmission routes could be particularly problematic in areas with inadequate sanitation and limited access to uncontaminated drinking water (de Graaf et al., 2017, World Health Organization, 2019, Yeo et al., 2020). There are presently no relevant data on the load of viable virus that would be necessary for infection through drinking water. Adequate chlorination of water is currently believed to be sufficient treatment for inactivation of the virus (Centers for Disease Control & Prevention, 2020f). During processing of wastewater, the U.S. Centers for Disease Control and Prevention (CDC) recommends that workers at wastewater treatment plants take standard precautions (i.e., wearing personal protective equipment) to prevent exposure to aerosolized sewage. Although there is no evidence of any SARS-CoV-2 transmission through this mechanism to date, in 2003, SARS transmission in the Amoy Gardens housing complex in Hong Kong was thought to be accelerated through sewage aerosol (Hung, 2003). Exposure to aerosolized sewage was perpetuated by an inadequate bathroom floor drainage system that allowed for the formation of virus-containing droplets, which were likely circulated further by the ventilation system in the room (Bell et al., 2004, Hung, 2003). Incidentally, the Amoy Gardens cluster was impacted disproportionately by gastrointestinal symptoms, compared to other SARS clusters (Lee, 2003, World Health Organization, 2003).

If fecal transmissibility of SARS-CoV-2 is confirmed, healthcare and laboratory settings present another possible target for preempting further disease spread. According to Yeo et al., strict preventive measures should be taken when handling stool or fecal samples from SARS-CoV-2 infected patients (Yeo et al., 2020). Standard precautions are already adopted by laboratory personnel who handle fecal specimens (Centers for Disease Control & Prevention, 2016, The American Society for Microbiology, 2019, World Health Organization, 2020).

Currently, the CDC recommends that virus isolation and cultures be handled in Biosafety Level 3 (BSL-3) settings, whereas routine diagnostic testing be conducted in a BSL-2 lab (Centers for Disease Control & Prevention, 2020d). Interim recommendations are also available for preventing nosocomial infection in healthcare settings treating COVID-19 patients, but are largely based on prevention of respiratory droplet and contact transmission, and will likely need to be updated as information evolves on how prevalent fecally-mediated modes of transmission may be for SARS-CoV-2 (Centers for Disease Control & Prevention, 2020c).

Peng et al. have recently described specific recommendations for prevention of COVID-19 spread in dental practices (Peng et al., 2020). They suggest a gamut of preventive strategies in the dental clinic setting, such as patient evaluation (e.g., checking body temperature), utilization of rubber dam isolation to prevent aerosol, and the use of personal protective equipment [PPE] (including masks, goggles, gloves, caps, face shields, etc.) for all healthcare providers (not just dental professionals). Specifically with regard to fecal-oral transmission potential, they emphasize the importance of hand hygiene. Hand-to-mouth contact is common in dental practices, and while gloves can help mitigate risk, PPE can become contaminated if best practices are not followed (for example, when putting on, removing, or changing gloves) (World Health Organization, 2009). Although official guidelines on COVID-19 specific to dental practices are not yet available, the CDC states that recommendations for practitioners are under development (Centers for Disease Control & Prevention, 2020a). As of 20 March 2020, they are advising the postponement of elective or non-urgent dental procedures to conserve PPE for hospitals.

Based on prior literature, possible fecal transmission can also have implications for residential care facilities, such as nursing homes or other institutions in which residents may not be able to maintain meticulous personal hygiene (e.g., due to disability, illness, or cognitive impairment) (Cohen et al., 2017, Montoya and Mody, 2011). Such facilities have already been associated with COVID-19 outbreaks (Fabbre and Mccoppin, 2020, Hendrix, 2020). Besides following the most up-to-date recommendations from relevant public health entities (Centers for Disease Control & Prevention, 2020e), more stringent tactics may be warranted to avoid fecal transmission. For example, restrooms should be sanitized several times throughout the day with disinfectants that are appropriate for use against SARS-CoV-2 (e.g., List N from the U.S. Environmental Protection Agency) (United States Environmental Protection Agency, 2020). Personal-sized hand sanitizer can be provided to residents, and they can be instructed on frequent use. Janitorial staff should be made aware of the potential routes of transmission and be trained on best practices for sanitization and personal prevention.

In facilities with incontinent residents, such as nursing homes, hospitals, and home healthcare settings, some individuals may require assistance with changing and disposal of absorbent pads, disposable underwear, or diapers. In fact, by some estimates, approximately half of all nursing home residents are affected by some level of urinary or fecal incontinence (Al-Samarrai et al., 2007, Ouslander and Schnelle, 1995). Caring for these patients or residents may pose an additional risk for transmission, and nursing staff responsible for incontinence care should be aware that immediate and appropriate disposal of contaminated materials, proper PPE use, and hand hygiene are of heightened importance. If not already, these processes should be standardized, and ample hand sanitizing stations with automatic dispensers, as well as signage to remind staff to wash their hands, should be installed, if not already in place (Arbogast et al., 2016, Doronina et al., 2017, Kampf et al., 2009). Preventive strategies in such environments should be a high public health priority, given the increased COVID-19 mortality risk among geriatric populations and individuals with existing health conditions (Weiss and Murdoch, 2020).

If fecal transmissibility of SARS-CoV-2 is shown to be plausible, hygienic food preparation will be another key consideration. Due to other fecally transmissible illnesses (e.g., salmonellosis, Hepatitis A, etc.), frequent washing of hands, utensils, and materials used in cooking is already strongly advisable and is a standard component of food handler safety training/certification curricula (Cohen et al., 2017). Many places that have enacted social distancing or shelter in place orders to reduce COVID-19 incidence classify restaurants as an essential service and permit them to serve take-out food (U.S. Department of Homeland Security, 2020). Thus, public health agencies should engage in educational tactics to inform staff who handle food that fecal-oral transmission of COVID-19 may be possible. Screening food handlers for fever or obvious symptoms each day is a proactive step that restaurants and grocery stores can also consider.

Clearly, sufficient hand hygiene is a mainstay of prevention against droplet, fomite-based, and fecal-oral spread of disease (Lei et al., 2020). The recent public health messaging and media campaigns about the importance of hand-hygiene related to the pandemic should help reduce transmission regardless of whether or not fecal transmission is possible. However, understanding all key mechanisms of spread can assist public health officials with targeting messaging more effectively or adapting recommendations, as appropriate. For example, recommendations on how long individuals should stay isolated after recovery can be expanded, if future research finds that SARS-CoV-2 tends to persists at infectious doses longer than expected in the stool of cases who are convalescing or have achieved clinical recovery.

In addition to appropriate hand hygiene practices, the role of environmental disinfection is crucial for preventing fomite-based transmission. In general, fomites are already a known reservoir for many fecal pathogens (Boone and Gerba, 2007, Julian et al., 2013). The potential for fomites to act as a SARS-CoV-2 reservoir is already of significant concern given that virus-harboring droplets or aerosol can contaminate surfaces (or hands then surfaces through touch) and that the virus can remain viable for several hours on certain types of surfaces (Ong et al., 2020, van Doremalen et al., 2020). If future research establishes that viable virus can be found in stool at potentially relevant doses, this would support the need for further precautions in residences, public restrooms, and numerous other facilities. Use of an effective disinfectant to frequently and thoroughly sanitize surfaces and objects is a mainstay of prevention of fomite-based transmission.

Finally, it should be noted that as hospitals reach capacity and extend patient care to overflow facilities, appropriate engineering controls need to be in place, especially in case of a shortage of PPE (Centers for Disease Control & Prevention, 2020b), and the specific environmental control strategies could vary depending on whether transmission is commonly occurring through multiple routes. For instance, indoor restroom facilities may need to be carefully inspected in any high-capacity facility, such as a dormitory or hotel, to avoid a situation like the Amory Gardens SARS outbreak.

Out of an abundance of caution, the public health community should continue to contemplate what additional preventive measures or recommendations, with regard to hygiene, environmental disinfection, engineering controls, and other avenues, may be warranted based on the currently available evidence about potential fecal transmissibility of SARS-CoV-2. While existing measures (e.g., social distancing measures, stay at home orders, hand hygiene education campaigns, etc.) may be helpful in the context of our present understanding of how COVID-19 is transmitted, there are many other public health strategies that can be considered if new evidence consistently supports possible fecal transmissibility.

Conclusions

Our understanding of COVID-19 is advancing rapidly, and future research on all possible modes of transmission are strongly justified given the scale of this pandemic. Current knowledge on whether fecal transmissibility (either orally, through fomites, or by aspiration of fecally-contaminated droplets) is likely to be an important mode of COVID-19 spread is still limited. In particular, evidence about whether infectious virions can be found in stool is based on a small number of patients whose specimens were collected at different times over the course of illness or convalescence. Further research is warranted to elucidate whether SARS-CoV-2 is present in stool at potentially infectious doses, and if so, to assess the duration of viral persistence in fecal matter. These questions are of public health significance and should be examined in larger studies to help inform future disease mitigation guidelines. Efforts to test for the presence of SARS-CoV-2 in sewage are already underway in some cities, and very preliminary evidence suggests that viral RNA may be detectable in sewage samples in certain circumstances (BioBot.io, Medema et al., 2020). Additional research on whether the virus is consistently detectable in other bodily fluids, such as breast milk, sweat, or semen, would also help fill some important gaps in the current literature.

Study*	Date Range of Specimen Collection*	Geographic Location	Definition of Positive Result**	Relevant Specimen Type	Number of Positive Patients† $N_{positive}/N_{Total\ Tested}$ (%)	Availability of Test Results on Consecutive Specimens	Gastrointestinal Symptoms°	Notes
Wang et al. (Wang W. et al., 2020)	1 January – 17 February	Hubei, Shandong, and Bejing, China	Detection of viral RNA: open reading frame lab (ORF1ab); Ct-value <40 ---------- Fecal culture conducted on 4 samples with high copy numbers	Fecal samples	44/153 (*29*)	Not presented	Culture found viable virions in stool from 2 patients *without* diarrhea.	It is unclear whether these 4 cultured samples were from unique patients. Viable virions were detected in 2/4 (50%) of samples.
J. Zhang et al. (Zhang J. et al., 2020)	27 January – 9 February	Jinhua, China	Detection of viral RNA; details not specified	Fecal samples	5/14 (*36*)	Yes, some serial test results on fecal samples were available for 6 patients.	No patients with diarrhea or vomiting noted.	Small number of patients in combination with inconsistency in days of testing precludes formal conclusions.
W. Zhang et al. (Zhang W. et al., 2020)	-	Wuhan, China	Detection of viral RNA: spike gene; Ct-value <40	Anal swabs¥	First day of sampling: 4/16 (*25*); Fifth day of sampling: 6/16 (*38*)	Yes, 4 patients initially negative for virus from anal swabs (and from oral swabs) on the first day of sampling became positive from anal swabs on the fifth day. The other two patients were positive on the first day on oral swabs, but negative on anal swabs.	-	The report indicates that a larger number of suspected patients were tested but not included in the detailed results because they were negative for viral RNA from all specimens collected (oral/anal swabs, blood, and serum)- thus implying that they were not confirmed COVID-19 patients.
Cai et al. (Cai et al., 2020b)	19 January – 3 February	Shanghai and Qingdao, China	Detection of viral RNA: ORF1ab and	Fecal samples	Day 3-13 after onset of illness: 5/6	Yes, 5 patients whose samples initially tested	No diarrhea noted.	Pediatric patients

			nucleoprotein gene; Ct-value <35		(*83*); Day 18-30 after onset of illness: 5/5 (*100*)	positive were retested and remained positive on follow-up test (Day 18-30).		
Xiao et al. (Xiao et al., 2020)	1 February-14 February	Zhuhai, China	Detection of viral RNA: ORF1ab and nucleoprotein gene; Ct-value <37 ---------- Viral nucleocapsid straining in biosy tissue collected through endoscopy	Fecal samples ------- Biopsy tissue from esophagus, stomach, duodenum, and rectum available on one patient	39/73 (*53*)	Yes, 17 (23%) remained positive on fecal samples after becoming respiratory-sample negative. Duration of positivity in fecal samples reported as 1-12 days, with 17 patients still positive when manuscript was written.	A subset of patients (approx. 40%) who tested positive for viral RNA in fecal samples had diarrhea. A very small number also exhibited GI bleeding.	Tissue samples from the esophagus, stomach, duodenum, and rectum were collected on Day 10 of illness from one patient. All stained positive for viral nucleocapsid. Data on this patient also indicated that 3 fecal samples collected between Day 3-7 were negative; 11 samples taken between Day 9-26 were positive.
Tang et al. (Tang et al., 2020)	1 February-14 February	Zhoushan, China	Detection of viral RNA: ORF1ab and nucleoprotein gene; reported Ct-values for results considered positive are all <40, but threshold is not directly specified	Fecal samples	1/3 (*33*)	Yes, 8 samples were obtained from the positive case in 2 weeks. The last two samples (from 13th and 14th of February) were negative. All prior samples were positive.	Case was asymptomatic.	This study was a case report of one family (parents and 10-year old male child) who were exposed to COVID-19 cases, but were asymptomatic. The parents tested negative on multiple specimen types and cannot be considered cases. The positive fecal sample was from the asymptomatic child.
Young et al. (Young et al., 2020)	23 January-25 February	Singapore	Detection of viral RNA: ORF1ab, spike,	Fecal samples	4/8 (*50*)	Yes, on 6 total patients (3 were negative on all	Authors reported that a subset (n=5) of patients were	

			and nucleoprotein gene; Ct-value <40			collected samples).	treated with antivirals, and of those, 4 developed GI symptoms. (Treatment is likely a confounding factor.)	
COVID-19 Investigation Team[‡] (The COVID-19 Investigation Team, 2020)	20 January – 5 February	AZ, CA, IL, MA, WA, and WI, United States	Detection of viral RNA; details not specified (appendix of laboratory methods is currently unavailable)	Fecal samples	7/10 (*70*)	Yes, collected every 2-3 days, when possible, for first 17 days of illness. 3 samples remained positive after patients' symptoms were resolved. Duration of positivity reported to be ~2-3 weeks (max: 25 days) post onset of illness.	All 3 patients with diarrhea were positive for viral RNA in stool. Transient GI symptoms were also noted in patients treated with antiviral.	Describes the first 12 cases in the U.S. Some correlation between stool and respiratory positivity reported. *Report has not been peer-reviewed (preprint only).*
Ling et al. (Ling et al., 2020)	20 January-10 February	Shanghai, China	Lab test data was abstracted from medical records to determine whether samples were positive for viral RNA through RT-PCR	Fecal samples	54/66 (*82*)	Yes, 11 (17%) still positive upon last observation. Median duration of positivity was 11 days (range: 9-16) post admission for 55 patients who cleared the virus. 43 of 55 patients (78%) had viral presence in stool longer than in throat swabs (about 2-day lag with range of 1-4 days).	-	CD4 + T cell counts were correlated with duration of positivity in stool.
Chen et al. (Chen W. et al., 2020)	January-February	Guangzhou, China	Detection of viral RNA: ORF1ab and	Anal swabs[¥]	11/28 (*39*)	Data from 1 patient with a repeat swab is	-	Higher proportion of patients with positive anal swabs

			nucleoprotein gene; Ct-value not specified. (Authors state that positives were defined as one or both primer/probe sets providing a “reliable signal.”)			presented.		had severe disease, but this was based on small numbers.
Chan et al. (Chan et al., 2020)	January	Guangdong, China	Detection of viral RNA: RdRp (RNA-dependent RNA polymerase) and spike genes; Ct-value not directly specified	Fecal samples	0/7 (*0*)	No	Two patients with diarrhea were negative for viral RNA in stool, but authors point out that timing of fecal specimen collection was after diarrhea had subsided.	Family cluster
Kam et al. (Kam et al., 2020)	4 February-20 February	Kallang, Singapore	Detection of viral RNA: ORF1ab and nucleoprotein gene; all Ct-values reported as positive <40, but threshold is not directly specified	Fecal samples	1/1	Yes, negative on Day 2 of hospitalization, positive on Day 9.	No GI symptoms. Patient was virtually asymptomatic.	6 month old infant was asymptomatic, with the exception of being febrile for ~1 hour on Day 2 while viremic. On Day 17, nasopharyngeal swabs became negative, but another stool specimen was not collected.
Y. Zhang et al. (Zhang Yong et al., 2020)	1 February	Heilongjiang, China	Culture through inoculation of stool suspension into cells, followed by	Fecal sample	1/1 (The report implies that specimens from other confirmed	No	-	Duration between onset of illness and collection of the sample from which the virus was

			virus detection through electron microscopy		patients were processed, but virus was not detected from those specimens. However, the total number of specimens is not provided.)			isolated was 15 days. Virus was also sequenced and found to have high genetic identity with the first isolated virus from Wuhan.
Wu et al. (Wu et al., 2020)	16 January-15 March	Zhuhai, China	Detection of viral RNA: RdRP, nucleoprotein, and membrane genes; Ct-value not directly specified	Fecal samples	41/74 (*55*)	Yes, samples were collected every 1-2 days (as available) until 2 sequential negative results were observed. Among the 41 initially positive patients, fecal samples remained positive for an average of 27.9 days (standard deviation: 10.7) after onset of first symptom. One patient tested positive 47 days after onset.	Authors stated that the presence of GI symptoms was not associated with viral RNA presence in fecal samples.	It is notable that first symptom onset dates were used to calculate duration (rather than date of hospitalization, for example). Duration of positivity did not differ significantly by disease severity. On average, fecal samples remained positive for approximately 11 days longer than respiratory samples.

Note. It is possible that some patients may be overlapping between studies. This cannot always be clarified based on publically available data.

* Year is 2020 for study publication and specimen collection dates.

** Ct=Cycle threshold for reverse-transcriptase polymerase chain reaction (RT-PCR). RT-PCR is the standard method used to detect viral RNA. Lower values correlate with higher viral copy numbers.

† Unit of observation is the patient (not stool samples) in prevalence of positive results.

‡ Includes one case that is also reported on by Holshue et al., which has, therefore, been excluded from the table (Holshue et al., 2020).

¥ Anal swabs may not be as directly relevant to the topic under review as stool specimens for several reasons (e.g., differences in cell content), but are presented to provide a more comprehensive perspective.

º Pertinent information provided as reported, *if* any were specifically noted to be among patients tested for viral markers using relevant specimens (e.g., stool or anal swabs). Note that not all studies provide enough details to definitively assess whether patients with GI symptoms were the same as those who tested positive/negative for viral markers in relevant specimens. Symptoms considered gastrointestinal (GI) include diarrhea, nausea, vomiting, GI discomfort, or GI bleeding.

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Highlights

- Evidence supporting the possibility of a fecally-mediated route of transmission of SARS-CoV-2 has been accumulating.
- Several descriptive case series have reported the presence of viral genetic material in the stool of some COVID-19 patients.
- If the possibility of fecal transmission (e.g., fecal-oral, -fomite, or -aerosol/droplet) is established, it will impact public health messaging and recommendations, including guidelines on sewage exposure, nosocomial infections, residential care facilities, and food preparation.