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**The Presence of COVID-19 in Urine: A Systematic Review and Meta-analysis of the Literature**

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**Abstract:**

**Purpose:** To investigate the literature on the presence of COVID-19 virus in urine of infected patients and evaluate the attributes and clinical significance of COVID-19 in urine including probability of infection transmission through urine.

**Data sources:** A systematic review of literature from December 2019 to 6th May 2020 was conducted on PubMed, google scholar, ovid, scopus and ISI web of science.

**Study eligibility criteria:** Studies which investigated urinary viral shedding of COVID-19 in infected patients were included.

**Study appraisal and synthesis methods:** Two reviewers selected relative studies and performed quality assessment of individual studies. Meta-analysis was performed the pooled case reports and case series. Fixed-effects model was used for analysis as no significant heterogeneity was observed between studies.

**Results:** Thirty three studies were finally included in the systematic review including 12 case reports, 20 case series, and one cohort. Urinary samples from 430 patients were investigated. Ten studies reported the presence of COVID-19 in urinary samples from 16 patients. The rate of COVID-19 presence in urinary samples was 3.7%. Urinary viral load was low in most reports. The presence of virus in urine was not related to the disease course of the illness. Urinary COVID-19 was mostly detected from patients with moderate to severe disease (13 pts) but was also isolated from two children (one neonate and one 7 year-old girl) and one adult with mild disease. The pathogenicity of virus isolated from urine has been demonstrated in cell culture media in one study.

**Conclusions:** This review highlights the low frequency of COVID-19 presence in urine of infected individuals and the potential of isolated virus for cytopathic effects. Therefore the probability of infection transmission through urine can be suggested. Caution must be exerted when dealing with urine of patients infected with COVID-19 including medical interventions like endoscopy and urethral catheterization.
The Presence of COVID-19 in Urine: A Systematic Review and Meta-analysis of the Literature

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INTRODUCTION

Novel coronavirus disease (COVID-19) first reported form Wuhan is a new disease caused by severe acute respiratory syndrome- coronavirus-2 (SARS-CoV-2), manifesting as an acute respiratory illness, however the involvement of multiple organs including kidney has been reported\textsuperscript{1}. The pathophysiological mechanisms for SARS-CoV-2 infection and organ invasion are not yet fully discovered, which leads to difficulties in understanding routes of transmission, clinical diagnosis and treatment\textsuperscript{2}.

Genomic sequence analysis indicated that SARS-CoV-2 has 75%-80% genomic similarity to coronavirus causative agent for severe acute respiratory syndrome (SARS) namely SARS-CoV\textsuperscript{3}. In previous reports of SARS and the Middle East respiratory syndrome coronavirus (MERS-CoV) infections, acute kidney injury was observed in 5% to 15% cases and was associated with a high (60%–90%) mortality rate\textsuperscript{4}.

The angiotensin-converting enzyme 2 (ACE2), known to be a cell receptor for human SARS-CoV, is also reported to play the same role for cellular entry of SARS-CoV-2 \textsuperscript{5}. In addition to respiratory organs, upregulation of ACE2 expression was also identified in urogenital system including kidney proximal tubule cells, bladder urothelial cells \textsuperscript{6} and genital organs including testis\textsuperscript{7,8}.

The widely accepted routes of human to human transmission for COVID-19 are through respiratory droplets and direct contact, however viral shedding in urine has been reported and infection transmission through infected urine remains a possibility. The idea of virus transmission thorough urine originated from the homogeneity of viral SARS-CoV-2 genome with SARS virus and the abundant previous evidence on the presence of SARS virus in urine\textsuperscript{9,10}. Original protocols for sample collections from COVID-19 patients included urine sample collection\textsuperscript{11}. Nevertheless,
the mechanism of virus shedding urine is unclear. Two suggested mechanisms for SARS-CoV-2 shedding in urine have been proposed: Firstly, Sepsis and cytokine storm results in renal dysfunction and subsequent leakage of SARS-CoV-2 from circulation into urine; Secondly, virus may directly invade the urinary system via binding to ACE2 receptors and shed into the urine. Although the virus shedding into the urine is hypothetically probable, most studies showed that virus is absent in the urine of infected patients. However, contradicting results exist in the literature as virus shedding was found in some studies.

Therefore, we performed a systematic review on the published literature to provide a summary of evidence on detection of SARS-CoV-2 in urinary samples.

**METHODS**

*Search strategy and data sources*

We conducted a comprehensive systematic literature review of online databases, including Web of Science, PubMed, Scopus, Ovid, and google scholar from 1st December 2019 till 6th May 2020. The search was performed by two independent investigators. The search terms used was: “(covid-19 OR ncovid-19 OR sars-cov-2 OR covid OR ncovid) AND urine”.

Database searching was started on March 29th 2020 and was regularly updated during extraction and analysis of retrieved studies to find newly published articles. The latest electronic search on cited databases was performed on May 6th, 2020.

References of retrieved articles were manually searched to find eligible studies. The search and selection criteria were restricted to English language.
Study selection

The title and abstract of retrieved studies were screened through two different researchers independently. After removing duplicates and irrelevant studies, the full texts of articles were examined for presence of original data on the presence of COVID-19 in urine (Figure 1). Any disagreement was resolved by a third person. Personal viewpoints, opinion articles, correspondence, and letters not presenting original data were excluded as well as studies which did not report their result of urinary testing for COVID-19. Locations of studies was noted to identify duplicate case reports/series from the same area. When there was reports from the same area or suspicion of reports from same population of patients, authors were contacted to confirm independence in population of patients. All the search results were evaluated in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The results of the search revealed 33 studies suitable for meta-analysis.

Data Extraction

The main outcome in this study is the evaluation of virus shedding into the urine of patients infected with COVID-19. Data were extracted from the eligible manuscripts into pre-defined data-fields including study location, sample size, mean or median age, gender of patients, illness category, total number of patients and/or urine samples tested, urine assessment technique, total number of positive urine samples, and sampling time.

Quality assessment of included studies

The included studies were evaluated in terms of quality according to the quality assessment tool for case series reported by the National Heart, Lung, and Blood Institute form the National...
Institutes of Health\textsuperscript{18}. This tool evaluates the quality based on a 9 item questionnaire. The questions focus on study population description, case definition, methods of including cases, comparability of included cases, description of interventions or assessments, follow-up and statistical methods used. The total score ranges from 0-9. Scores ≤ 3 were considered poor. Score of 4-6 was considered fair and score of 7-9 was considered good in terms of quality (Table 1).

**Statistical methods**

Extracted data from 33 studies were used for statistical analysis. Case reports and case series with a sample size of 6 or less were cumulated into one case series with sample size of 37 including 12 case reports and 7 case series. Thirteen case series and one cohort study with sample size of 9 or higher were also included in meta-analysis.

The effect size of individual studies was calculated by weighting each one of them by its inverse variance, and a confidence interval (CI) was thus obtained\textsuperscript{19}. Each study was weighted inversely proportional to its variance. To calculate the variance of each study, a binomial distribution was used. To investigate heterogeneity, the Q statistics and I\textsuperscript{2} index with \(\alpha\) significance level of less than 10\% were used. In this study, the random-effects model was considered, when there is heterogeneity among the studies (I\textsuperscript{2} > 50\%). The authors used the Egger's test to check publication bias. In this study, Metaprop command in STATA used to stabilize the variances\textsuperscript{20}. STATA software (version 16) was used to analyze the data.
The relationship between disease severity in each study and frequency of viral shedding in urine was investigated by weighting each study according to its sample size and performing spearman correlation.

**RESULTS**

A total of 1112 articles were retrieved using the search strategy mainly through google scholar search engine. After studying the title and abstract of studies, and removing duplicate studies, the number was reduced to 146 studies. Full text of these 146 studies were studied and non-original studies including communications without original data, personal reviews and letters were excluded resulting in 33 articles. (Figure 1) These 33 articles include one formally unpublished article retrieved by google scholar search engine from a database of unpublished studies (medRxiv).

There were 12 case reports, 20 case series, and one cohort study from 12 different countries. The characteristics of the included studies are shown in Table 1. Out of the total reported population of 1870 patients in these 33 studies, urinary testing has been performed on 430 patients during admission and up to day 52 after illness onset. Positivity of urinary specimens were reported in 10 studies ranging from 1 to 4 positive urinary samples in each study summing to a total of 16 patients (3.7% frequency of viral shedding in patients’ urine). Positive urinary samples were reported form China (8 studies, 14 patients) and Korea (2 studies, 2 patients). The time of urine sampling in positive patients were reported as admission day+day 10, day 7, day 9, days 6 through 17, days 9 through 12, day 30, and day 52 after illness onset. The patient urine sample that was considered
positive in day 52 in this review was not positive on urine but was positive on urinary sediment. Excluding studies with a sample size of 1-2 patients, the percent positivity of COVID-19 in urine samples of different included studies varies from zero in most reports to as high as 11 percent in a 2 reports of 9 patients from Guangdong, and Guangzhou\(^2\) on adults and children.

The meta-analysis forest plot which takes into account the weight of each study according to the inverse of its variance revealed a pooled estimate of 1.23% (CI 95%: 0.12 – 3.06%) for viral shedding in urine of patients (Figure 2). Meta-regression analysis revealed that the positivity rate of urinary viral shedding was not related to sample size of studies (graph not shown). The Begg’s funnel plot failed to reveal publication bias (Figure 3).

One of the studies which confirmed the presence of viral RNA of the COVID-19 in urine of a patient stated that the positivity of the urine did not meet the reference for positivity in rRT-PCR (real time reverse transcriptase PCR), however in the diagram of patient diagnostic tests the level of detected E and RdRp genes at days 9 and 12 of illness were higher than cut off value in rRT-PCR. This patient urine sample was considered positive in the current review. The detection of COVID-19 RNA was observed from the end of the first week after illness till patient improvement\(^2\).

Peng et al. reported the presence of COVID-19 in urine of one of the 9 studied patients on day 7 after symptom onset. The patient urine sample turned negative on day 10 after symptom onset. In this study, virus quantity in urine sample was lower than rectal and oropharyngeal samples. The patient with positive urinary PCR for COVID-19 did not complain of any urinary symptoms\(^2\).
Wang et al. investigated urinary samples of patients with chronic kidney disease (CKD) versus patients with normal renal function. Urinary PCR was positive in one of 5 patients with CKD versus 3 out of 48 patients with normal renal function. In this study, the clinical course of COVID-19 disease and characteristics of patients with COVID-19 in urine were not different compared with patients without COVID-19 in their urine\textsuperscript{16}.

Ling and colleagues reported 66 patients with COVID-19 from Shanghai, China. Urine samples of 4 patients (6.9\%) was positive for COVID-19. In 3 patients, urinary samples were positive even after clearance of virus in oropharyngeal samples\textsuperscript{17}.

Han et al. reported the presence of COVID-19 virus in urine of a neonate born from an infected mother. The virus was discovered in samples form oropharynx, saliva, urine and feces. However, the urine viral load was relatively low. Nevertheless, urine viral load was above the diagnostic cut off for days 6 through 17 after illness onset (11 days). The urine viral load was still positive after clearance of virus from nasopharyngeal and plasma samples\textsuperscript{23}.

In another study on children, the urine sample of 1 out of nine infected children was positive for COVID-19 by real time RT-PCR. All children in this study suffered from asymptomatic or mild disease. The urine was positive in a 7 year-old girl who presented only with fever (38.7 °C) without cough or respiratory symptoms\textsuperscript{21}.

In a landmark study, Sun and colleagues investigated the urine samples of a 72 year-old male with severe COVID-19 infection. Urinary sampling was performed on days 12, 30 and 42 after symptom onset. The viral load was above diagnostic threshold \textbf{only} on day 30. The authors inoculated Vero E6 cells with urine of patient on day 12 (with viral load \textbf{below} diagnostic
threshold). Interestingly cytopathic effects were observed after 3 days. Electron microscopy revealed the presence of virus in inoculated cells by demonstration of spherical-shaped particles with distinct surface projections, resembling spikes. The authors furthermore used serum sample from this patient (who had high IgM and IgG against SARS-CoV-2) and a healthy candidate and demonstrated staining of inoculated cells in immunofluorescent assay only with patient serum and not with control serum\textsuperscript{24}.

Yang et al. reported \textit{urine sediment} positivity in a 44 year-old man who had initially recovered with negative throat swab test but then revealed throat, and salivary positive COVID-19 rRT-PCR results. The urine was negative for COVID-19 RT-PCR on day 52 after illness onset however, urinary sediment was positive for COVID-19 RT\_PCR in the same day\textsuperscript{25}.

The severity of disease has been reported in some case reports and case series. The severity of disease was correlated with urine positivity (spearman correlation coefficient: 0.26, P<0.001). In most reports (7 reports including 13 patients) the presence of COVID-19 in urine was detected in patients with moderate to severe disease. However, in three reports the virus has been isolated from urine of patients with mild disease (one neonate, one 7 year-old girl and a 44 year-old man)\textsuperscript{21,23,25}.

\textbf{DISCUSSION}

This is the first report to provide a comprehensive overview of the available evidence from December 2019 to 30\textsuperscript{th} April 2020 for detection of SARS-CoV-2 in urine samples. Thirty three studies are included with a total of 430 patients in whom results of urinary testing for COVID-19 is reported across 12 countries. Initially during the COVID-19 outbreak, evaluation and investigation of urinary samples were considered part of routine sampling as stated by the World
Health Organization interim guideline for laboratory testing in COVID-19\textsuperscript{11}. Later publications pointed to the rarity of viral presence in urine or totally rejected the presence of COVID-19 in urine\textsuperscript{26}. Then, quite recently several publications revealed the presence of COVID-19 in urine. Herein, we reported the detection of COVID-19 in urinary samples in 8 studies.

COVID-19 is a rapidly emerging pandemic which threatens the security and biosafety at the world level. According to the latest World Health Organization situation report number 107 released on 6\textsuperscript{th} May, more than 3.5 million people have been infected worldwide leaving more than 240000 deaths \textsuperscript{27}.

Preparedness against such a vast pandemic requires efforts in diagnosis, epidemiology, prevention and treatment. Clinical, laboratory, imaging, and prognostic studies as well as disease outcome analysis builds up the core knowledge necessary for any new disease. Several questions in the context of COVID-19 have been addressed including spectrum of disease severity (asymptomatic to fatal)\textsuperscript{28} and the bodily organs or secretions in which the virus in present.

ACE2 is the cellular receptor for SARS-CoV, and high structural similarity has been demonstrated between cellular binding sites for SARS-CoV and 2019-nCoV\textsuperscript{29}. Virus usual initial binding site is through ACE2 receptor at ciliated bronchial epithelial cells, and then spread of infection happened to other organs. COVID-19 infection induces a cytokine storm in the body incorporating a cascade of immune responses. ACE2 expression is tissue-specific, and is mainly expressed in the cardiovascular, respiratory, renal and gastrointestinal systems. A 1% positivity of ACE2 receptor in cells has been suggested for organ involvement in COVID-19 by Zhou et al. Based on this assumption, heart, lung, esophagus, ileum, bladder, and kidneys has been suggested as potential...
organs for COVID-19 invasion\textsuperscript{26}. Also in another study, the expression of ACE2 in testis has been demonstrated\textsuperscript{7}. Therefore, the possibility of viral shedding in urine and semen can be postulated\textsuperscript{7}.

Urinary samples were not routinely collected in earliest infected patients in the initial outbreak of COVID-19 in many countries due to delay in proper diagnosis of COVID-19 in patients referring with respiratory symptoms\textsuperscript{30}.

The presence of COVID-19 in urine samples was not related to clinical course of disease in 53 patients reported from Wuhan\textsuperscript{16}. Nevertheless, in most studies patients with positive urine for COVID-19 were in severe clinical disease or needed oxygen supplement. On the other hand, no association has been reported between urinary symptoms and presence of virus in urine\textsuperscript{2} while some investigators have reported a positive association between urine analysis and clinical severity of illness\textsuperscript{28}. The presence of proteinuria and microscopic hematuria has been associated with greater clinical severity of COVID-19 disease\textsuperscript{31}. Combination of previous findings can point toward kidney involvement and urinary alteration in COVID-19 as a result of cytokine storm\textsuperscript{12} in comparison with direct invasion of kidney parenchyma by the virus.

Han et al. reported a relatively long duration of urinary viral shedding in a neonate. Interestingly, the virus was also detected in saliva from this patient and urinary shedding was observed for 11 days during infection in comparison with 1-2 days of viral shedding in adult patients suggesting a higher potential for infection transmission in case of neonatal infection. Also, Lu et al.\textsuperscript{21} reported one infected urine sample in 9 children with asymptomatic to mild COVID-19 raising further concerns over infection transmission through urine of asymptomatic children.
In most reports that have reported the presence of virus in urinary samples, the quantity of virus in urinary samples have been low in comparison with rectal or pharyngeal specimens\(^2\) or has been marginally above the diagnostic threshold of the PCR assay\(^{22}\). However, Sun et al. isolated COVID-19 from urine of a patient with viral load below the diagnostic threshold of rRT-PCR and showed cytopathic effect of isolated virus in cell culture. This observation challenges the results of several studies that have reported negative urinary rRT-PCR based on readings below or marginally above test cut off\(^{22}\) and suggests the possibility that the real frequency of COVID-19 in urine could be higher than reports based on diagnostic cut off of conventional real time RT-PCR assays.

The timeline for positivity of urinary samples in not consistent between reports. While Xu and colleagues reported urine positivity on day 7 after onset of symptoms and clearance of virus in urinary sample on the 10\(^{th}\) day\(^{32}\), Ling et al. reported the persistence of COVID-19 in urinary samples of 3 patients after clearance of virus in their nasopharyngeal samples\(^{17}\).

Collectively, COVID-19 was reported in 3.7 percent of urinary samples from 430 patients. The highest frequency of infected urinary samples (in studies with more than 3 patients) belongs to the report of Peng et al. and Lu et al. from Guangdong, and Guangzhou who reported one infected urinary sample within urinary samples of 9 patients (11%). This rate is greatly lower in comparison with urinary infection rates of up to 42% which were previously reported for SARS-CoV\(^{33}\). One of the possible reasons for the low detection rate of COVID-19 can be short duration of virus presence in urine. Kim et al. investigated urinary samples from two Korean patients. They evaluated urinary samples from day 3 through day 14 of the illness. The PCR for RdRp was marginally positive only on day 12 and for gene E was again marginally positive only on day 9.
Another cause can be low quantity of virus in urinary samples which makes its detection in real time PCR assays difficult. However, as indicated above Sun et al. suggested the pathogenicity of low urinary viral load in cell cultures.

This review investigated the presence of COVID-19 in urine of infected patients or evaluated its pathogenic effects in cell cultures. The clinical significance low urinary viral load of patients and the potential of urine to be a source of infection transmission remains to be further investigated.

The significance of the findings of the current systematic review relies on the reported low overall positive rate of COVID-19 infection in patients’ urinary samples which has been confirmed in several studies. We think that medical intervention like urethral catheter insertion and urinary endoscopic operations should be performed with caution considering the possibility of urine infection and possibility of COVID-19 transmission through this route.

CONCLUSIONS

We performed a systematic review of literature on the presence of COVID-19 in urine of infected patients. The results of this review revealed an average positivity rate of 3.7% for COVID-19 in patients’ urine samples. The quantity of virus in most reports were lower than rectal or oropharyngeal samples. Nevertheless, we emphasize the low rate of urinary infection in COVID-19 and propose regular cautions in dealing with urinary samples in patients with COVID-19 infection and when performing medical interventions including urethral catheter passage and endoscopy in patients with COVID-19.

DECLARATION OF INTERESTS
He authors report on conflict of interest.

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No funding was available for the current meta-analysis.

AUTHORS’ CONTRIBUTIONS

AHK concepted of the study, helped in data gathering, helped in data analysis, and drafted the article.

MF helped in data gathering and in revising the manuscript.

EA helped in data gathering and in manuscript revision.

MV helped in data gathering, drafting the manuscript, and revising manuscript.

All authors approved the final version of the manuscript.

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| No. | Location                           | Journal            | Study type     | Quality Assessment | Technique                        | Total study population | Mean age (range) or [Median, IQR; years] | Sex ratio or M/F | Frequency of severe illness | Total number of urine samples (patients) tested | Age of patient/patients with urine test (year) | Total number of positive urine samples (patients) | Urine Sampling timing* |
|-----|------------------------------------|--------------------|----------------|--------------------|-----------------------------------|------------------------|------------------------------------------|------------------|----------------------------------|-----------------------------------------------|-----------------------------------------------|------------------------------------------------|-------------------------|
| 14  | Hubei and Shandong provinces and Beijing, China | JAMA               | Case series    | Good               | rRT-PCR                           | 205                    | 44 (5-67)                               | 68% male         | 19%                              | 72                                            | NR                                            | 0                                              | NR                      |
| 15  | NR                                 | The Lancet         | Case series    | Good               | N-gene-specific quantitative RT-PCR | 82                     | NR                                       | NR               | NR                               | 2                                             | NR                                            | 0                                              | 3-15 days               |
| 16  | Shenzhen, China                    | The Lancet         | Case series    | Good               | In-house real-time RT-PCR assay    | 6                      | NR (36-66)                               | NR               | NR                               | 6                                             | NR                                            | 0                                              | NR                      |
| 17  | Melbourne, Australia               | Nature Medicine    | Case report    | Good               | real-time RT-PCR                  | 1                      | 47                                       | female           | 0%                               | 1                                             | 47                                            | 0 (0)                                          | NR                      |
| 18  | Seoul, Korea                       | J Kor Med Sci      | Case report    | Good               | Real-time RT-PCR                  | 1                      | 10                                       | female           | 0%                               | 1                                             | 10                                            | 0 (0)                                          | Day 3 and day 8         |
| 19  | Ho Chi Minh City, Vietnam          | The Lancet         | Case report    | Good               | real time RT-PCR                  | 1                      | 73                                       | male             | 0%                               | 1                                             | 73                                            | 0 (0)                                          | Days 4 to 24            |
| 20  | Scotland                           | J Inf              | Case report    | Good               | real time RT-PCR                  | 1                      | 51                                       | male             | 0%                               | 1                                             | 51                                            | 0 (0)                                          | NR                      |
| 21  | 31 provinces in China              | N Eng J Med        | Case series    | Good               | real time RT-PCR                  | 1099                   | [47, NR]                                 | 41.90% female    | 173/1099                          | 4                                             | NR                                            | 1 (1)                                          | Day 9 *                 |
| 22  | Melbourne, Australia               | Med J Aust         | Case report    | Good               | Real time RT-PCR                  | 1                      | 57                                       | Male             | NR                               | 6 (1)                                         | 57                                            | 0 (0)                                          | Days 1-8                |
| 23  | Anhui and Shandong, China          | Clin Inf Dis       | Case series    | Good               | Duplex one step real time RT-PCR  | 10                     | 6 (0-11)                                 | 4/6              | NR                               | (6)                                           | (3-11)                                        | 0                                              | Day 3                  |
| Study / Location                    | Journal / Series        | Quality / Method | qRT-PCR / Real time RT-PCR | Days / Window | Sex / Gender | Days / Window | Days / Window |
|------------------------------------|-------------------------|------------------|-----------------------------|---------------|--------------|---------------|---------------|
| Hangzhou, China                    | BMJ                     | Case series      | Good                         | 96            | 55 [IQR: 44-64] | 58/38         | 74/96         | NR            | 1            | Admission, day 10 * |
| Singapore                          | JAMA                    | Case series      | Good                         | 18            | 47 (31-73)    | 9/9           | 6/18          | 10            | NR           | 0            | 0-14         |
| Wuhan, China                       | Am J Nephrol            | Case series      | Good                         | 53            | 54 (20-95)    | 58% male      | 46/116        | (53)          | NR           | (4)          | NR           |
| Hong Kong                          | Lancet Inf Dis          | Cohort           | Good                         | 23            | 62 (37-75)    | 57% male      | (18)          | NR            | 0            | 0            | NR           |
| US                                 | Arch Path Lab Med       | Case series      | Fair                         | 3             | 34, 34, 30    | Female         | NR            | (2)           | 34, 30       | 0            | 0            | NR           |
| Guangdong, China                   | medRxiv                 | Case series      | Fair                         | 9             | 38.9 (27-62)  | 4/5           | NR            | (9)           | 31           | (1)          | Day 7*        |
| Shanghai, China                    | Chin Med J              | Case series      | Good                         | 66            | 44 [IQR: 34-62] | 38/28       | NR            | (58)          | NR           | (4)          | NR           |
| Korea                              | J Kor Med Sci           | Case series      | Good                         | 2             | 35, 55        | 1/1           | 0%            | (2)           | 35           | (1)          | Day 9-12*     |
| Singapore                          | Clin Inf Dis            | Case report      | Good                         | 1             | 0.5           | Male           | NR            | 2 (1)         | 0.5          | 0            | Day 2, 9      |
| Guizhou, China                     | J Inf Dis               | Case report      | Fair                         | 1             | NR            | Female         | 0%            | (1)           | 0.1          | 0            | NR           |
| Taiwan                             | J Formosonian Med Ass   | Case report      | Good                         | 1             | 55            | Female         | NR            | (1)           | 55           | 0            | Day 25        |
| Hong Kong                          | J Clin Microbiol       | Case series      | Fair                         | 23            | NR            | NR            | NR            | 33 (15)       | NR           | 0            | NR           |
| Zhongnan Hosp., Wuhan, China       | J Med Virol             | Case series      | Fair                         | 42            | 51 (42-62)    | 15/27         | 11/42         | (10)          | NR           | 0            | NR           |
| Munich, Germany                    | Nature                  | Case Series      | Fair                         | 9             | NR            | 0%            | 27 (9)        | NR            | 0            | Days 2-4     |
| Guangzhou, China                   | Emerg Microbes Infec    | Case report      | Good                         | 1             | 72            | Male           | 100%          | 3(1)          | 72           | (1)          | Day 30*       |
| Country     | Journal               | Study Type | Quality | Technique | Duration | Age | Sex | Percentage Positivity | Duration | Days 1-32 |
|-------------|-----------------------|------------|---------|-----------|----------|-----|-----|----------------------|----------|-----------|
| Italy       | J Endocrinol Invest   | Case Report| Good    | rRT-PCR   | 12       | 31  | Male | 0%                   | 1 (1)    | 31        | 0         | Days 4-32 |
| US          | Nat Med               | Case Series| Good    | rRT-PCR   | [53, 21-68] | 8/4 | 1/12 | (10)                 | NR       | 0         | Days 4-32 |
| Seoul, Korea| Clin Infect Dis       | Case Report| Good    | rRT-PCR   | 1         | 0.1 | Female | 0%                   | 7 (1)    | 0.1       | 6 (1)     | Days 6-17 * |
| France      | Lancet Infect Dis     | Case Series| Good    | rRT-PCR   | 5         | [47 (30-80)] | 3/2 | 3/5       | (4)      | 47        | 0         | Days 2-13 |
| Beijing, China| Clin Infect Dis     | Case Series| Fair   | droplet digital PCR and RT-PCR | 76         | [40, 32-63] | 38/38 | 22%      | 14       | NR        | 0         | NR |
| Macau, China| Int J Biol Sci        | Case Series| Good    | qRT-PCR   | 10        | [54, 27-64] | 3/7 | 40%      | 49 (10)  | NR        | 0         | Days 2-18 |
| Wuhan, China| J Med Virol           | Case Report| Fair   | RT-qPCR   | 1         | 44  | Male | 0%                   | (1)      | 44        | (1)       | Day 52‡ |
| Guangzhou, China| Clin Radiol          | Case Series| Fair   | Real time RT-PCR | 9         | 7.8 (0.2-15) | 5/4 | 0%       | (9)      | 7         | (1)       | NR |

NR: not reported; y/o: year old; IQR: interquartile range; rRT-PCR: real time RT-PCR; qRT-PCR: quantitative RT-PCR

*In case urine sample is reported positive for COVID-19, the sampling time of patients with positive samples or the sampling time of positive samples from a patient is reported.

† Number in parenthesis reveals the number of patients with a positive urinary result for SARS-CoV-2, and number outside parenthesis indicates the number of urinary samples positive for SARS-CoV-2.

‡ The virus was positive in urinary sediment on day 52 in a patient who had recovered from COVID-19 in addition to viral positivity in throat and saliva.
FIGURE LEGENDS:

**Figure 1.** Flow diagram of included studies.

**Figure 2.** Forest plot of the frequency of urinary viral shedding in each study and the pooled estimate.

**Figure 3.** Funnel plot for evaluation of publication bias.
Figure 1. Flow diagram of included studies.

Records identified through database searching (n = 1089)

Additional records identified through other sources (n = 23)

Records screened (n = 1112)

Records excluded (n = 938)

174 records, 28 duplicates

Full-text articles assessed for eligibility (n = 146)

Full-text articles excluded, with reasons (n = 113)
Not including original data on urinary shedding of COVID-19 (n = 110)
Duplicate patient source (n = 3)

Studies included in qualitative synthesis (n = 33)

Studies included in quantitative synthesis (meta-analysis) (n = 33)
**Figure 2.** Forest plot of the frequency of urinary viral shedding in each study and the pooled estimate.

| Study                        | ES (95% CI)               |
|------------------------------|---------------------------|
| Case Reports                 |                           |
| Wang et al. (China)          | 0.00 (0.00, 4.99)         |
| Zheng et al. (Hangzhou, China)| 1.04 (0.03, 5.67)        |
| Young et al. (Singapore)     | 0.00 (0.00, 30.85)        |
| Wang et al. (Wuhan, China)   | 7.55 (2.09, 18.21)        |
| To et al. (Hong Kong)        | 0.00 (0.00, 18.53)        |
| Peng et al. (Guangdong, China)| 11.11 (0.28, 48.25)      |
| Ling et al. (Shanghai, China)| 6.90 (1.91, 16.73)       |
| Chan et al. (Hong Kong)      | 0.00 (0.00, 21.80)        |
| Chen et al. (Wuhan, China)   | 0.00 (0.00, 30.85)        |
| Wolfe et al. (Germany)       | 0.00 (0.00, 33.63)        |
| COVID Team (USA)             | 0.00 (0.00, 30.85)        |
| Yu et al. (China)            | 0.00 (0.00, 23.16)        |
| Lo et al. (China)            | 0.00 (0.00, 30.85)        |
| Lu et al. (China)            | 11.11 (0.28, 48.25)       |
| Overall (I² = 0.00%, p = .)  | 1.23 (0.12, 3.06)         |
Figure 3. Funnel plot for evaluation of publication bias.