Rapid systematic review of neonatal COVID-19 including a case of presumed vertical transmission

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ABSTRACT
Objective To carry out a systematic review of the available studies on COVID-19 (coronavirus disease 2019) in neonates seen globally since the onset of the COVID-19 global pandemic in 2020. The paper also describes a premature baby with reverse transcription (RT)-PCR-positive COVID-19 seen at the Blackpool Teaching Hospitals NHS Foundation Trust, UK.

Design We conducted a multifaceted search of the Cumulative Index to Nursing and Allied Health Literature, Embase, Medline and PubMed from 1 December 2019 to 12 May 2020 to harvest articles from medical journals and publications reporting cases of COVID-19 in neonates from anywhere in the world. Additional searches were also done so as not to miss any important publications. Write-up was in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, the protocol for the review was registered with International Prospective Register of Systematic Reviews (PROSPERO), and risk of bias was analysed with the Newcastle-Ottawa tool. Additionally, the preterm neonate with COVID-19 from our hospital is also reported.

Results The systematic review has revealed eight studies where neonates have been described to have confirmed COVID-19, with low risk of bias. Of the 10 reported cases elsewhere, only three are likely to be vertically transmitted, while seven occurred in the postnatal period and are likely to have been postnatally acquired. All neonates had a mild course, recovered fully and were negative on retesting. Our case of COVID-19 in a 32-week premature baby from the UK was delivered by emergency caesarean section, with the mother wearing a face mask and the family having no contact with the neonate, suggesting vertical transmission. On day 33, the neonate was asymptomatic but was still RT-PCR-positive on nasopharyngeal airway swab.

Conclusions Neonatal infection is uncommon, with only two previously reported cases likely to be of vertical transmission. The case we report is still RT-PCR-positive on day 28 and is asymptomatic. Ongoing research is needed to ascertain the epidemiology of COVID-19 in neonates.

INTRODUCTION
The novel coronavirus disease (COVID-19) is a highly contagious disease that was first reported in Wuhan, Hubei Province, China in December 2019. Within weeks of the emergence of the disease, it has spread to several countries, and the WHO declared the outbreak as a public health emergency of international concern in January 2020 and as a pandemic in March 2020. According to the WHO’s Situation Report 113 published on 12 May 2020, coronavirus now affects 210 countries and 2 international conveyances, and has affected more than 410,000 persons, with more than 283,000 individuals dead. COVID-19 is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), previously known as the 2019 novel coronavirus or 2019-nCoV. SARS-CoV-2 is a novel member of coronaviruses, which are a large class of highly diverse, enveloped, positive-sense, single-stranded RNA viruses. Most reported cases of the disease are in adults, but the disease has also been reported in children, including neonates.

While COVID-19 typically presents as acute respiratory disease and pneumonia, it has been reported to also impact other systems including the gastrointestinal tract. The first reported paediatric case of COVID-19 was probably of a 10-year-old boy from Shenzhen, China diagnosed with the condition in...
January 2020. Since then, there have been a few other reports of confirmed COVID-19 in neonates.

We did a rapid systematic review to summarise the published data on neonatal presentations of COVID-19. We also report a case of a 32-week premature baby with COVID-19 born to a COVID-19-affected mother.

**METHODS**

**Search strategy and study selection**

This study is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. The protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO). Considering the date of the earliest confirmed reports of COVID-19, we have searched PubMed, Medline, Embase and Cumulative Index to Nursing and Allied Health Literature for studies published since 1 December 2019. The WHO database of publications on novel coronavirus was additionally searched for potentially relevant publications. We also searched the references listed within the retrieved articles to try and identify additional citations that may have been missed during the electronic search.

Eligible studies (including case reports, case series, cohort studies and retrospective studies) published in English-language peer-reviewed journals that have described original demographic and clinical characteristics of children diagnosed with COVID-19 were included for analysis. Review articles and opinion articles not reporting original data were excluded.

For the purpose of the electronic search, studies were identified with the following search terms: (coronavirus OR covid19 OR COVID-19 OR SARS-CoV2 OR 2019-nCoV) AND (neonatal OR infant OR preterm OR premature OR Prem) AND (case report OR case series OR symptom OR symptoms OR characteristics OR characteristic*). We included both medical subject headings and free-text terms.

Two independent reviewers (MG and TK) evaluated the titles and abstracts of papers to identify relevant studies. Articles identified were then independently assessed by the two reviewers using predefined eligibility criteria. Any disagreements between authors regarding study inclusion were resolved through discussion among the reviewers.

**Risk of bias**

For cohort and case–control studies, we used the Newcastle-Ottawa tool to assess the risk of bias. For case reports and case series, we used the tool suggested by Murad et al. This had previously been used in published systematic reviews, and was adapted from the Newcastle-Ottawa tool by the removal of items that relate to comparability and adjustment (which are not relevant to non-comparative studies) and retained items that focused on selection, representativeness of cases, and ascertainment of outcomes and exposure. This resulted in five criteria in the form of questions with a binary response (yes/no), whether the item was suggestive of bias or not. We considered the quality of the report as good (low risk of bias) when all five criteria were fulfilled, moderate when four were fulfilled, and poor (high risk of bias) when three or fewer were fulfilled. In the end, all the eight selected studies had a low risk of bias and were deemed good (table 1).

**Data extraction**

Data were extracted independently by the two reviewers on to a Microsoft Excel spreadsheet using a predefined checklist. Extracted data included but were not limited to the following: study design, year of publication, country, author name(s), number of patients, patient demographics, gastrointestinal symptoms and/or signs, other clinical symptoms and timing of gastrointestinal symptoms in relation to respiratory symptoms. The extracted data were compared and differences were discussed and resolved by consensus.

**Statistical analysis**

Statistical analyses were mainly descriptive (numerical and graphical). Frequencies and proportions were used to summarise qualitative variables, whereas means, medians, SD and quartiles or ranges were used to summarise quantitative variables. Where possible, meta-analyses

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**Table 1 Risk of bias assessment of the included studies (case reports and case series)**

<table>
<thead>
<tr>
<th>Study</th>
<th>Cases (n)</th>
<th>Question 1</th>
<th>Question 2</th>
<th>Question 3</th>
<th>Question 4</th>
<th>Question 5</th>
<th>Risk of bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alzamora et al</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Low</td>
</tr>
<tr>
<td>Kamali Aghdam et al</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Low</td>
</tr>
<tr>
<td>Chacón-Aguilar et al</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Low</td>
</tr>
<tr>
<td>Piersigilli et al</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Low</td>
</tr>
<tr>
<td>Wang et al</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Low</td>
</tr>
<tr>
<td>Wang et al</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Low</td>
</tr>
<tr>
<td>Yu et al</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Low</td>
</tr>
<tr>
<td>Zeng et al</td>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Low</td>
</tr>
</tbody>
</table>

**Tool details**

Low risk items: Green shading, Unclear risk: Yellow shading, High risk: red shading
using the random-effects model were performed to assess associations between demographic features and gastrointestinal symptoms. All statistical analyses were performed using StatsDirect statistical software.

Case report
The research and development department approved the writing of this paper.

Patient and public involvement
Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

RESULTS
Our search was performed on 12 May 2020, and initial screening yielded 27 publications for full-text searching when screened against the inclusion and exclusion criteria. One of these publications was unrelated to neonates and was excluded. Ten other publications were excluded as the neonate(s) in all these were not confirmed to be infected. It is worth noting that one of the cases reported a COVID-19-positive mother who was very unwell and delivered by caesarean section at the bedside; the 35-week neonate unfortunately died within 2 hours. No further details regarding the neonate are described and confirmation of diagnosis is not reported; hence, this case was excluded.

Four other publications were excluded as these were review articles (figure 1). This left eight articles that described neonates with COVID-19 confirmed on reverse transcription (RT)-PCR swabs. The characteristics of the included studies are shown in table 2. They included descriptions of one neonate each from Peru, Iran, Spain, and Belgium and six from China. The clinical characteristics of the 10 babies described in the eight publications are listed in table 2.

The report from Peru describes the occurrence of COVID-19 in a presumed 34-week baby who tested positive as early as 16 hours of life. The baby was intubated on day 0 and needed respiratory support for 6 days, but made an uneventful recovery thereafter. Imaging was negative. The baby had been separated from the mother at birth and had no postnatal contact with the family or anyone who was coronavirus-positive. This may be a case of vertical transmission.

The Iranian case report describes the occurrence of COVID-19 in a 15-day-old neonate. Details regarding the neonate’s delivery records are sketchy. This is unlikely

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Figure 1 Flow diagram for study selection.
### Table 2: Characteristics of included studies reporting COVID-19 cases in neonates

<table>
<thead>
<tr>
<th>Study, country, setting</th>
<th>Sample size</th>
<th>Age of symptom onset</th>
<th>Symptom onset</th>
<th>Gestations of neonate at delivery</th>
<th>Diagnosis present in the mother and method</th>
<th>Delivery details/method/Apgar/resuscitation</th>
<th>PPE procedures undertaken at delivery</th>
<th>Method of COVID-19 diagnosis and timing</th>
<th>Symptoms and complications</th>
<th>Therapy</th>
<th>Length of follow-up/final outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alzamora et al.29 Peru, secondary hospital</td>
<td>1</td>
<td>Day 0</td>
<td>Unclear, presumed 34 weeks.</td>
<td>Nasopharyngeal swab RT-PCR assay positive.</td>
<td>The neonate weighed 2970 g, with Apgar scores of 6 and 8 at 1 and 5 min, respectively. He was immediately separated from his mother and was not exposed to family members.</td>
<td></td>
<td>Nasopharyngeal swab of neonate for SARS-CoV-2 RT-PCR, obtained 16 hours after delivery.</td>
<td>Neonate was electively intubated at birth.</td>
<td>Baby required 12 hours, then continuous positive airway pressure and was weaned successfully.</td>
<td>On the sixth day of life, the newborn had mild respiratory difficulty and sporadic cough requiring supplemental oxygen with nasal cannula.</td>
<td></td>
</tr>
<tr>
<td>Kamali Aghdam et al.,30 Iran, children’s hospital</td>
<td>1</td>
<td>15 days</td>
<td>Term.</td>
<td>CS, no diagnostic tests in mother.</td>
<td>Not stated in detail.</td>
<td>Not reported.</td>
<td>Pharyngeal swab RT-PCR assay positive.</td>
<td>Fever, no cough, mild subcostal recession.</td>
<td>Oxygen and fluids, vancomycin and amikacin given.</td>
<td>Discharged well on day 6 after admission.</td>
<td></td>
</tr>
<tr>
<td>Chacón-Aguilar et al.,31 Spain, secondary hospital</td>
<td>1</td>
<td>26 days</td>
<td>Not reported.</td>
<td>Symptomatic family members, no further details.</td>
<td>Unremarkable history, nil else noted.</td>
<td>Not reported.</td>
<td>A nasopharyngeal swab sample was tested for SARS-CoV-2 on admission.</td>
<td>Swinging fever, cranial ultrasound and EEG were normal.</td>
<td>Empirical antibiotics.</td>
<td>Day 6 discharge, neurologically normal and follow-up appointment booked.</td>
<td></td>
</tr>
<tr>
<td>Piersigilli et al.,32 Belgium</td>
<td>1</td>
<td>From birth</td>
<td>26 weeks+4 days’ gestation.</td>
<td>Diagnosed on day 6 with chest symptoms and by RT-PCR from nasopharyngeal swab.</td>
<td>CS section due to maternal HELLP syndrome, Apgar’s 5/8/8 at 1 min/5 min/10 min.</td>
<td>None reported.</td>
<td>Day 7 when mother’s results returned by RT-PCR.</td>
<td>Normal preterm course, chest radiograph showed no parenchymal infiltrates.</td>
<td>Initial non-invasive positive pressure ventilation and surfactant, pneumothorax at 12 hours.</td>
<td>Swab negative at 14 days, still in neonatal unit receiving care.</td>
<td></td>
</tr>
<tr>
<td>Wang et al.,33 China, secondary hospital</td>
<td>1</td>
<td>17 days</td>
<td>38 weeks 6 days.</td>
<td>Mother and father positive for nucleic acid testing.</td>
<td>Normal delivery, no resuscitation.</td>
<td>Not reported.</td>
<td>Day 20 negative nasopharyngeal swab for RT-PCR, positive on day 23.</td>
<td>Day 17 vomiting and loose stools, day 18 fever, day 20 cough.</td>
<td>No active management described.</td>
<td>Day 29 RT-PCR swabs negative and child discharged on day, discharged 14 days after admission, well.</td>
<td></td>
</tr>
<tr>
<td>Wang et al.,34 Wuhan, China, secondary hospital</td>
<td>1</td>
<td>N/A as asymptomatic</td>
<td>Term.</td>
<td>Pharyngeal swab positive.</td>
<td>Emergency CS, Apgar 8 at 1 min, 9 at 5 minute.</td>
<td></td>
<td>The mother had been wearing an N95 mask throughout the operation, and the baby had no contact with the mother after birth.</td>
<td>The result of pharyngeal swab for SARS-CoV-2 was positive at 36 hours after birth. All products of delivery negative.</td>
<td>Asymptomatic.</td>
<td>No treatment needed.</td>
<td>Day 17 swabs negative, discharged on day 18.</td>
</tr>
</tbody>
</table>

Continued
Table 2 Continued

<table>
<thead>
<tr>
<th>Study, country, setting</th>
<th>Sample size</th>
<th>Age of symptom onset</th>
<th>Gestations of neonate at delivery</th>
<th>Diagnosis present in the mother and method/ Apgar/ resuscitation</th>
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<th>Symptoms and complications</th>
<th>Therapy</th>
<th>Length of follow-up/final outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zeng et al, China, tertiary hospital</td>
<td>33 babies</td>
<td>1. Day 2</td>
<td>1. 40 weeks.</td>
<td>All mothers had confirmed COVID-19 pneumonia by nasopharyngeal swabs (RT-PCR).</td>
<td>All three were elective CS due to maternal COVID-19 pneumonia.</td>
<td>Not described in the communication.</td>
<td>Nasopharyngeal and anal swabs sent for SARS-CoV-2 RT-PCR in all three babies; all were positive on day 2 and day 4, and negative by days 6–7.</td>
<td>Lethargy + fever with pneumonia on X-ray; resolved by 6 days.</td>
<td>Same as one above.</td>
<td>Final devolution not described in the article, but stated as favourable outcomes in all three babies.</td>
</tr>
<tr>
<td>China, tertiary hospital</td>
<td>33 babies</td>
<td>2. Day 1</td>
<td>2. 40+4 weeks.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>3. Day 1</td>
<td>3. 31+2 weeks.</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

CS, caesarean section; EEG, electroencephalogram; HELLP, hemolysis, elevated liver enzymes, and a low platelet count syndrome; N/A, not applicable; PPE, personal protective equipment; RDS, respiratory distress syndrome; RT-PCR, reverse transcription PCR; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

Case report

A 36-year-old, gravida 3, mother presented at 32 weeks of gestational age with cough, high fever, lymphopenia and nasopharyngeal swabs tested positive for SARS-CoV-2. She underwent an emergency caesarean section after being given two doses of antenatal steroids and 12 hours later, the entire operative team wore a fluid-resistant mask and the entire operative team underwent a flu-resistant caesarean section after being given two doses of antenatal steroids and 12 hours later, the entire operative team wore a fluid-resistant mask and the entire operative team underwent a flu-resistant caesarean section. The baby was a live, female newborn weighing 2150 g. She was dressed in full personal protective equipment. The mother was asymptomatic and had normal blood oxygen levels. The baby was discharged after 14 days with no respiratory symptoms and remained healthy on follow-up.

The report by Ma et al. describes the case of a COVID-19-positive mother in a tertiary hospital in China. The baby was delivered by caesarean section and remained well. The report by Wang et al. describes a case of a COVID-19-positive mother in a tertiary hospital in China. The baby was delivered by caesarean section and remained well. The report by Wang et al. describes a case of a COVID-19-positive mother in a tertiary hospital in China. The baby was delivered by caesarean section and remained well. The report by Wang et al. describes a case of a COVID-19-positive mother in a tertiary hospital in China. The baby was delivered by caesarean section and remained well. The report by Wang et al. describes a case of a COVID-19-positive mother in a tertiary hospital in China. The baby was delivered by caesarean section and remained well.
was directly handed over to the neonatal team without any contact with the mother. Postnatally, she has had no contact with the mother or the father or any family member.

She needed respiratory support, increasing from high-flow nasal oxygen and then requiring surfactant via less invasive surfactant administration, progressing to intubation. The baby was extubated the next day and then moved to biphasic positive airway pressure support, weaning over the next few days to air.

The radiograph showed findings consistent with surfactant deficiency lung disease. The initial RT-PCR swab on day 1 of life was negative, but the child had a positive swab on day 4, day 14 and also on day 21, while being asymptomatic.

While the baby gradually recovered and is being isolated in the neonatal unit and being fed and nursed, the mother deteriorated rapidly after the delivery and was kept on a ventilator in the intensive care unit of the hospital for a week. She underwent tracheostomy. Over the past week, she continued to improve, and she has now been moved out of the intensive care unit and the tracheostomy has been closed. She remains on oxygen at the time of writing this paper.

The baby remained RT-PCR-positive on day 28 of life, but was clinically well, and was discharged with the mother on day 33 of life.

**DISCUSSION**

This systematic review of published literature has shown only 10 case reports of neonatal COVID-19 infection. While seven of these ten babies were full-term, three were preterm, the lowest being at 26+4 weeks of gestation. Three are suspected to be vertically transmitted, in addition to our own case, the summary of which has been described. Ours is the first case of a premature baby with COVID-19 in the UK and the fourth preterm baby globally. Also, our baby continued to remain positive at 28 days of life. It remains to be seen when the baby will become RT-PCR-negative, although it is clear that the baby is otherwise asymptomatic from the coronavirus infection.

Global knowledge about this new infectious pandemic is evolving. The current knowledge is that the virus is less virulent in children, although there have been case reports of older children dying as a result of contracting the infection. There is no available proven treatment, although many trials on different known and new drugs are ongoing both in the UK and elsewhere in the world.

Our rapid review concentrates on neonatal COVID-19. The methodology was performed rapidly; however, this did not impact the high-quality systematic approach that such a review requires. We present only 10 positive neonatal cases from the global literature within the last 5 months since the pandemic started to emerge, and only three were potentially of vertical transmission. Within our excluded studies, it is worth noting that a further 65 neonates were reported as born to COVID-19-positive mothers who themselves tested negative on RT-PCR. As the goal of the review was not to report well neonates born to infected mothers, this is likely a small representation of a much larger sample of reported cases of well neonates. Therefore, it does currently seem reasonable to suggest that vertical transmission to neonates and neonatal infection from infected family members are both rare occurrences. Additionally, when they do occur, the course appears mild. A previous review which was performed up to March 2020 considered children and neonates and found a similar mild course within these cohorts.

The main limitation of this review is the relative novelty of COVID-19. It is possible that many more cases are either not reported to scholarly texts or in the process of peer review, and the reader must bear this in mind. Therefore, it is likely this review will be rapidly out of date and a repeat review will be required. Similarly, the scope of the review was very precise, and therefore it is inappropriate to suggest any firm conclusions regarding the incidence of COVID-19-negative neonatal cases born to infected mothers or the details of maternal outcomes, which would both have to be specific outcomes and are better covered in works focused on these issues, some of which were uncovered in this review.

We believe that many other reports of this kind will emerge. It is key that future research considers the possibility of transmission from asymptomatic mothers. This will likely become of greater interest as population testing increases. It is also of particular interest that the case we report has remained RT-PCR-positive on day 28 and on discharge, despite being asymptomatic. Questions as to the time needed for seroconversion in infected children, the ability to spread while being asymptomatic and ongoing immunity after infection all require future investigation.

**CONCLUSIONS**

Neonatal infection has only been reported in 10 cases, with this study adding a case report of an eleventh case. Three occurred in the late neonatal period and three were presumed cases of vertical transmission, with the addition of the case we report likely to be of vertical transmission. All 10 previously reported cases had a mild course, and respiratory symptoms were generally consistent with their gestational age. Ongoing research is needed to ascertain the epidemiology of COVID-19 in neonates.

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**Contributors** MG and TK led the systematic review and manuscript drafting, KR, CR, MIA and AG cared for the neonate reported, contributed to the manuscript and approved the submission.
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Competing interests None declared.

Patient consent for publication Next of kin consent obtained.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information.

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