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ABSTRACT
In December 2019, cases of pneumonia of unknown cause first started to appear in Wuhan in China; subsequently, a new coronavirus was soon identified as the cause of the illness, now known as Coronavirus Disease 2019 (COVID-19). Since then, infections have been confirmed worldwide in numerous countries, with the number of cases steadily rising. The aim of the present review is to provide an overview of the new severe acute respiratory syndrome (SARS) coronavirus 2 (SARS-CoV-2) and, in particular, to deduce from it potential risks and complications for pregnant patients. For this purpose, the available literature on cases of infection in pregnancy during the SARS epidemic of 2002/2003, the MERS (Middle East respiratory syndrome) epidemic ongoing since 2012, as well as recent publications on cases infected with SARS-CoV-2 in pregnancy are reviewed and reported. Based on the literature available at the moment, it can be assumed that the clinical course of COVID-19 disease may be complicated by pregnancy which could be associated with a higher mortality rate. It may also be assumed at the moment that transmission from mother to child in utero is unlikely. Breastfeeding is possible once infection has been excluded or the disease declared cured.

ZUSAMMENFASSUNG
Introduction

The number of cases infected with the new coronavirus (SARS-CoV-2) is currently rising daily. So far, 23 129 cases have been confirmed in Germany (last updated 22.03.2020 12:43 hrs). The number of cases worldwide is over 300 000 – and still rising.

Coronaviruses (CoV) are RNA viruses and belong to the order of nidoviruses. Until December 2019, the family of coronaviruses comprised six human pathogenic species, amongst these the severe acute respiratory syndrome coronavirus (SARS-CoV) and the Middle East respiratory syndrome coronavirus (MERS-CoV). With SARS-CoV-2, a seventh human pathogenic species has been added [1,2]. Four “endemic” species (HKU1, OC43, 229E, NL63) have so far been of clinical significance, often producing rather mild symptoms of a cold, and are responsible for about 10% of seasonal airway diseases not caused by influenza. SARS-CoV and MERS-CoV, which cause very serious airway infections and diseases associated with a high mortality rate (10–30%), have so far been limited to a one-off outbreak in 2002/2003 (SARS-CoV) or 2012/2013 (MERS-CoV), respectively.

Since the occurrence of cases is only recent, there is so far little evidence available on the clinical course of a SARS-CoV-2 infection outside China. In particular, little is known about the clinical course and possible risks and complications for infected pregnant patients and newborn children of infected mothers. The aim of this article, therefore, is to provide an overview of disease courses involving infections with the highly pathogenic coronaviruses SARS-CoV and MERS-CoV and to deduce from this possible risks for pregnant women suffering from a SARS-CoV-2 infection. In addition, the publications to date on infections with SARS-CoV-2 in pregnancy will be presented.

Overview/Review

The first cases of a form of pneumonia of unknown cause were observed at the beginning of December 2019 in Wuhan, the capital of Hubei Province, in Central China [3].

The point of origin is currently assumed to be the Wuhan Huanan Seafood Wholesale Market [4], in the vicinity of which transmission of a zoonotic pathogen to humans occurred.

Between 31st December 2019 and 3rd January 2020, 44 cases were reported to the World Health Organisation (WHO) – since then confirmed cases of a SARS-CoV-2 infection have been steadily rising. By 22.03.2020 (last update 12:43 hrs), 311 988 cases were known to have been confirmed worldwide [5].

At the end of December 2019, sputum samples were taken by bronchoalveolar lavage from three patients suffering from pneumonia of unknown cause, who had been to the market a few days before onset of their symptoms, and from this material the new virus SARS-CoV-2 was identified by high-throughput sequencing (next generation sequencing) and PCR [6] (Fig. 1).

Based on recent studies, men are more often and more severely affected than women; the median age of onset is 47 years [7,8]. The majority of observed deaths involves individuals over 70 years of age and those with severe underlying conditions. The disease is usually only mild in children and adolescents.

According to current knowledge, transmission of SARS-CoV-2 is via droplet infection [4]. Like SARS-CoV, SARS-CoV-2 is also regularly isolated from stool, where it is also infectious, although the epidemiologic relevance of a faecal-oral transmission is as yet unclear [9–11]. The incubation period is approx. 5.2 (95% confidence interval: 4.1–7; 95th percentile: 12.5) days [3]. Current
data published by the WHO, based on 55 924 cases of laboratory-
confirmed SARS-CoV-2 infection, show that approx. 80% of cases 
have a mild to moderate clinical course and heal spontaneously. 
Asymptomatic cases occur at a still unknown rate. ▶ Table 1 
presents the typical symptoms. Not all cases of this group develop 
pneumonia.

In 13.8% of cases, disease progression is severe, associated 
with shortness of breath, a respiratory rate of ≥30 per minute, 
blood oxygen saturation ≤93%, PaO2/FiO2 ratio < 300 and/or ra-
diologically proven pulmonary infiltrates. In 6.1% of SARS-CoV-2 
infections, a critical course is evident, associated with respiratory 
failure, septic shock and/or multiple organ failure [12].

Details about mortality rates are heterogeneous at this point in 
time. The WHO puts them at 3.8% [12]. However, it should be 
noted that the reported mortality rate refers to cases confirmed 
in the laboratory by identification of the pathogen, and non-con-
firmed – e.g. asymptomatic – cases are not taken into account, so 
this data is only provisionally valid. According to the worldwide in-
fected [12].

fection numbers published on a daily basis, the mortality rate is 
3.4% [5]. It is approx. 0.86% in China, outside the Hubei province. 
A recently published study from China, which evaluated 
1099 cases with confirmed SARS-CoV-2 infection up to 29th Janu-
ary 2020, reports a mortality of 1.4% [7]. It is evident in various 
countries involved that these mortality numbers are subject to 
availability and number of tests performed in patient populations 
with mild as well as severe disease forms, to the preferred practice 
of registering only severe cases, and to the ability of a healthcare 
system to take controlled measures. Compare, for example, Iran 
(2.6%), Italy (4.2%) and South Korea (0.6%). These available de-
tails will remain purely speculative in the absence of fundamental 
social epidemiological studies yet to be conducted. They alone will 
record the actual prevalence of infection.

In order to deduce possible risks and complications of an infec-
tion in pregnancy and potential obstetric and neonatal outcome, 
experience from the SARS and MERS epidemics must also be taken 
to account at this point in time. In the following sections, 
therefore, the current state of knowledge regarding pneumonia in 
pregnancy and infections with other coronaviruses in preg-
nancy will be presented.

Pneumonia in pregnancy

Regardless of COVID-19, pneumonia is a known significant cause 
of morbidity and mortality of pregnant patients and represents 
the most important non-obstetric infection during pregnancy. In 
25% of cases, it involves intensive care treatment and is an indica-
tion for mechanical ventilation [13]. Viral pneumonia is associated 
with higher morbidity and mortality in comparison with bacterial 
pneumonia [14]. The most important complications of pneu-
monia in pregnancy are premature rupture of the membranes 
(PROM), preterm labour, intrauterine fetal death (IUD), intra-
terine growth restriction (IUGR) and neonatal death [13, 15, 16].

SARS-CoV and pregnancy

The SARS-CoV epidemic occurred between November 2002 and 
July 2003. During this period, 8422 patients suffered from pneu-
monia caused by the newly identified SARS-CoV. A total of 
916 deaths have been reported in 29 countries [17]. No further 

cases have been observed since 2004. Pneumonia was diagnosed 
in almost all known cases.

Given that pregnancy status was not recorded in the interna-
tional survey of SARS-CoV infections during the epidemic, the ex-
act number of cases of infected pregnant patients is not known, 
rendering impossible any systematic analysis of pregnancy out-
comes. It is estimated that approx. 120 pregnant women were in-
fected [18]. Small case series of pregnancy courses were pub-
lished, and these will be presented as an overview in the following.

The largest published case series comprised 12 pregnant wom-
en from Hong Kong with confirmed SARS-CoV. Clinical and labo-
ratory findings of these cases were identical to those of non-preg-
nant patients; pneumonia was diagnosed in all 12 cases by CT 
scan. Ventilation treatment was indicated in four female patients; 
three of them died over the further clinical course from respirato-
ry failure or sepsis [19].

Seven women became ill during the first trimester. Four wom-
en suffered early abortion, two patients wanted termination of 
pregnancy for social indications, and one child was born at term 
and was healthy. Five patients contracted SARS after the 24th 
week of pregnancy (WOP). In three cases, an emergency C-section 
was performed for reduced general condition of the mother 
secondary to SARS-CoV infection (26th, 28th, 32nd WOP). The 
birth weight of all three children was appropriate for gestational 
age (AGA). On the other hand, those children who were born after 
recovery of the mother in the 33rd week of pregnancy and at 
term, presented IUGR associated with oligohydramnios.

Vertical transmission of SARS-CoV was not detected in any of 
the cases with live-birth children [20].

As regards outcome in the neonatal period, the authors report 
that surfactant administration for acute airways syndrome was in-
dicated for the fetuses born in the 26th and 28th WOP. One child 
went on to develop bronchopulmonary dysplasia. Two children 
suffered gastrointestinal complications – necrotising enterocolitis 
in one case and ileum perforation in the other. Whether these pul-

Table 1

Typical symptoms of a SARS-CoV-2 infection [12].

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever</td>
<td>87.9%</td>
</tr>
<tr>
<td>Dry cough</td>
<td>67.7%</td>
</tr>
<tr>
<td>Fatigue</td>
<td>38.1%</td>
</tr>
<tr>
<td>Sputum production</td>
<td>33.4%</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>18.6%</td>
</tr>
<tr>
<td>Sore throat</td>
<td>13.9%</td>
</tr>
<tr>
<td>Headache</td>
<td>13.6%</td>
</tr>
<tr>
<td>Myalgia/arthritis</td>
<td>14.8%</td>
</tr>
<tr>
<td>Chills</td>
<td>11.4%</td>
</tr>
<tr>
<td>Nausea/vomiting</td>
<td>5.0%</td>
</tr>
<tr>
<td>Nasal congestion</td>
<td>4.8%</td>
</tr>
<tr>
<td>Diarrhoea</td>
<td>3.7%</td>
</tr>
<tr>
<td>Haemoptysis</td>
<td>0.9%</td>
</tr>
<tr>
<td>Conjunctival congestion</td>
<td>0.8%</td>
</tr>
</tbody>
</table>

Table 1 ▶
monary and gastrointestinal complications are to be regarded as being related to maternal SARS infection or as the result of premature birth, remains unclear because of the small amount of data available [21].

Of the 12 cases reported above, ten were compared in a case-control study with 40 non-pregnant, but SARS-CoV-infected women [22]. Cases and controls were matched for age, sex, profession, underlying illness, and risk area comprising a high number of cases of SARS-CoV-infected persons. This study demonstrated that pregnancy has a significant impact on the disease course and outcome of an infected patient: thus, hospital stay of pregnant patients was longer. The development of renal failure, sepsis or disseminated intravascular coagulopathy, as well as the need for intensive-care treatment, was occurred significantly more often in the group of pregnant women. Mortality of pregnant infected patients was also significantly increased [22].

Another publication reports on the outcome of five pregnant patients suffering from a SARS-CoV infection in China [23]. In two cases, infection occurred in the second trimester, while three patients became ill during the last trimester of pregnancy. Whereas all the patients in this population also presented abnormal radiological findings, there was no fatality. In accordance with the above data, no vertical viral transmission onto the child was observed in this patient population either. Nor did the children in the published cases from the USA and Canada present any post-partum signs of infection [24–26].

MERS-CoV and pregnancy

The Middle East Respiratory Syndrome (MERS) is caused by a further, newly reported coronavirus: MERS-CoV. The zoonotic MERS-CoV virus is excreted by infected camels (dromedaries) and transferred to humans in a not yet fully understood way. The first cases of this viral disease were detected in April 2012 in Saudi Arabia, and with time it spread across the Arabian Peninsula, with focal outbreaks as far away as the USA and North Korea. So far, approx. 2500 cases have been confirmed, of which approx. 860 patients died. Human-to-human transmission is usually by droplet infection, with the incubation period being an average of 5.2 days. Similar to SARS, the male sex, advanced age and the presence of underlying conditions as well as the traditional handling of camels have been identified as risk factors [27].

The clinical course of an infection is often asymptomatic in healthy patients or presents mild flu-like symptoms; infections of household contacts develop with moderate frequency [28]. Severe clinical courses may arise in immunocompromised patients and patients with underlying conditions such as chronic lung diseases, diabetes or chronic kidney disease [29] and are associated with the development of pneumonia and transition to acute respiratory distress syndrome. Diarrhoea often occurs as a concomitant symptom [1,30].

So far, there is also only little data available on MERS-CoV infections in pregnancy. Nonetheless, the 11 reported symptomatic cases [31] demonstrated more severe courses than with an infection with SARS-CoV in pregnancy. It must remain uncertain whether this is the expression of the three-fold higher mortality rate of MERS in comparison with SARS or whether there are influencing factors specific to MERS.

Average maternal age was 33.7 years, and the gestational age at onset of infection was 26.3 weeks of pregnancy (WOP). The clinical course was comparable to the disease pattern of non-pregnant patients. Intensive-care treatment became necessary in six patients. Three patients died after delivery. As regards fetal outcome, three fatalities were reported – two fetuses suffered intrauterine death, one child died four hours after birth by C-section in the 25th WOP. Two premature babies and five full-term children had unremarkable outcomes [31].

Placental function and histology secondary to SARS-CoV infection and potential impact on the course of pregnancy

Due to the small number of published case numbers of pregnant patients and their outcomes, the available literature on possible placental changes and the consequences for the course of pregnancy during an infection in graviditate is thin. While in this regard there is no published data on MERS, there is a study available involving seven female patients with SARS-CoV infection and an unremarkable case history [32]. These seven cases were treated in Hong Kong at the Princess Margaret Hospital. During the SARS epidemic, this hospital had the only obstetric department in Hong Kong which was allowed to treat pregnant SARS patients. The reported cases are part of the case series already mentioned above. Given the relevance and subsequent potential repercussions for the clinical management of patients with confirmed COVID-19 disease, the specific circumstances of these cases will once again be dealt with in more detail.

At the time of giving birth, three patients (Cases 1–3) were in the acute disease stage, with respiratory failure and the need for mechanical ventilation. Four patients (Cases 4–7) were considered cured at the time of delivery, with no indication for mechanical ventilation during the acute disease phase. Only the administration of oxygen was necessary in two cases for nine (Case 4) and 21 days (Case 5). Further complications of the individual cases are presented in Table 2.

In the three cases of an acute stage of illness, delivery by C-section was in the 26th, 28th and 32nd WOP. Two patients died over the further clinical course of respiratory failure (Cases 1 and 2).

In three cases (Cases 4, 5, 7), delivery was in patients who had already recovered from their SARS disease. In two cases, delivery was after the 37th WOP (Cases 5, 7). One birth (Case 7) was induced and proceeded uneventfully with unremarkable Apgar scores and normal birth weight. One patient (Case 5) developed spontaneous contractions. Secondary C-section was performed for a pathological CTG with delivery of an SGA fetus with unremarkable Apgar scores.

Another patient (Case 4) went into premature labour with a subsequent uneventful spontaneous delivery in the 33rd WOP. The Apgar scores were also unremarkable.

In the two cases just presented, IUGR developed over the course of pregnancy. This became evident in each case with a decrease in fetal growth, with no Doppler ultrasound abnormalities of the umbilical artery. There was no Doppler ultrasound report of any other relevant vessels which would allow assessment of IUGR (middle cerebral artery, uterine arteries, ductus venosus).
<table>
<thead>
<tr>
<th>SARS disease stage</th>
<th>maternal complication</th>
<th>GA (week)</th>
<th>GA at delivery</th>
<th>delivery mode</th>
<th>CTG</th>
<th>fetal growth</th>
<th>placental weight</th>
<th>amniotic fluid volume</th>
<th>placental histology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1 acute</td>
<td>respiratory failure with indication for mechanical ventilation • hypotension • died</td>
<td>27</td>
<td>28</td>
<td>maternal indication for C-section secondary to respiratory failure</td>
<td>variability ↓</td>
<td>AGA</td>
<td>190</td>
<td>n. s.</td>
<td>increased intervillous fibrin deposition</td>
</tr>
<tr>
<td>Case 2 acute</td>
<td>respiratory failure with indication for mechanical ventilation • died</td>
<td>32</td>
<td>32</td>
<td>maternal indication for C-section secondary to respiratory failure</td>
<td>not stated</td>
<td>AGA</td>
<td>250</td>
<td>n. s.</td>
<td>increased intervillous fibrin deposition calcifications ↑</td>
</tr>
<tr>
<td>Case 3 acute</td>
<td>respiratory failure with indication for mechanical ventilation • acute renal failure</td>
<td>26</td>
<td>26</td>
<td>maternal indication for C-section secondary to respiratory failure</td>
<td>not stated</td>
<td>AGA</td>
<td>190</td>
<td>n. s.</td>
<td>increased intervillous fibrin deposition</td>
</tr>
<tr>
<td>Case 4 cured</td>
<td>oxygen administration for 9 days • elevated aPTT • steroid psychosis</td>
<td>28</td>
<td>33</td>
<td>spontaneous birth in preterm labour</td>
<td>variability ↓</td>
<td>IUGR</td>
<td>170</td>
<td>oligo-hydramnios</td>
<td>accelerated villous maturation avascular villi (19%)</td>
</tr>
<tr>
<td>Case 5 cured</td>
<td>oxygen administration for 21 days • DIC • hepatitis</td>
<td>30</td>
<td>37</td>
<td>C-section due to pathological CTG</td>
<td>variability ↓</td>
<td>IUGR</td>
<td>240</td>
<td>oligo-hydramnios</td>
<td>avascular villi (8%) placental infarctions (9 %) calcifications ↑</td>
</tr>
<tr>
<td>Case 6 cured</td>
<td>no indication for oxygen administration</td>
<td>12</td>
<td>15</td>
<td>maternal wish for termination of pregnancy</td>
<td>no CTG</td>
<td>AGA</td>
<td>75</td>
<td>n. s.</td>
<td>calcifications ↑</td>
</tr>
<tr>
<td>Case 7 cured</td>
<td>no indication for oxygen administration</td>
<td>3</td>
<td>38</td>
<td>spontaneous birth after induction of labour</td>
<td>no abnormalities</td>
<td>AGA</td>
<td>410</td>
<td>n. s.</td>
<td>normal</td>
</tr>
</tbody>
</table>

GA: gestational age; CTG: cardiotocography; AGA: appropriate for gestational age; IUGR: intrauterine growth restriction; n. s.: not specified; aPTT: activated partial thromboplastin time; DIC: disseminated intravascular coagulopathy
Histological examination of both placentas of the IUGR fetuses demonstrated a large number of avascular villi, as well as an accelerated villous maturation (Case 4) or placental infarction and increased calcifications (Case 5).

The authors regard the large number of avascular villi as noteworthy in both cases. While there is no possible explanation in Case 4, a connection with disseminated intravascular coagulopathy is seen in Case 5.

The authors also found no evidence for placental infection, in which manifestations of avascular villi typically develop. Therefore, vertical transmission of the SARS-CoV infection has so far not been histologically confirmed either.

The placentas of Cases 1–3 also showed signs of placental failure, here in the form of increased intervillous fibrin deposition. The authors consider these abnormalities to be the result of reduced placental perfusion secondary to hypoxia or shock [32].

Both patients whose onset of infection was in the first trimester did not present any placental abnormalities. In Case 6, in which termination of pregnancy was undertaken upon the mother’s request due to the SARS infection, the histological examination of the placenta only showed increased calcifications with an otherwise normal placental structure, while a normal placental structure was reported for Case 7 with an infection during early pregnancy and delivery in the 38th WOP.

In summary and in view of the histological examinations, it may be assumed that infection after the first trimester can result in reduced placental function and theses pregnancies require intensive monitoring.

The new SARS-CoV-2 and pregnancy

At this point in time, there are two retrospective studies on pregnancies complicated by COVID-19 disease [33, 34]. Over 19 cases were reported in all.

The first study (“Wuhan patient population”) [34] comprises nine cases which presented between 20th January 2020 and 31st January 2020, inclusively, at the Zhongnan Hospital of Wuhan University. The second study (“Hubei patient population”) [33] reports of nine patients infected with SARS-CoV-2 and ten neonates (eight singleton and one twin pregnancy), who were treated between 20th January 2020 and 5th February 2020 in five hospitals in Hubei.

In both studies, the clinical symptoms of an infection with SARS-CoV-2 were identical to those of cases involving non-pregnant female patients [4]. All cases had a high-risk exposure. Pneumonia developed in each case; typical infiltrates were detected by computed tomography in both study populations. Typical clinical symptoms of the “Wuhan patient population” are presented in Table 3. In this patient population, the laboratory results showed decreased white blood cells and lymphocytes, mild thrombocytopenia and elevated liver function tests.

None of the cases required mechanical ventilation. There were no fatalities either.

Table 4 presents the maternal and obstetric outcome of the “Wuhan patient population”, Table 5 shows the neonatal outcome. For comparison, Table 6 presents the obstetric and neonatal outcome of the “Hubei patient population”. During COVID-19 pneumonia, two cases of premature rupture of the membranes developed in the “Wuhan patient population”, while three premature membrane ruptures were observed in the “Hubei population”. Pathological CTGs were registered in the different patient populations in two and six cases, respectively. Whereas all patients included in the “Wuhan patient population” gave birth by C-section, there were two spontaneous births in the “Hubei patient population” and seven C-section deliveries.

Transmission from mother to child

At the present time, there is only little data available about the risk of vertical transmission from mother to child due to the small number of published cases. No case of such viral transmission was reported to have occurred during the SARS epidemic [20]. The risk of SARS-CoV-2 transmission was examined in the study recently published in the Lancet on the “Wuhan patient population”. For this purpose, samples were taken from amniotic fluid, umbilical cord blood and throat swabs of the newborns immediately after delivery. All specimens were negative. Milk samples taken during this study immediately after the first postpartum breast engorgement were also unremarkable. In the study examining the “Hubei patient population”, on the other hand, only throat swabs taken from the children were tested, not samples from the umbilical cord or amniotic fluid. In this patient population, all postpartum swabs were also negative. In a case study, placentas of three clinically symptomatic pregnant women with
Table 4 Clinical and obstetric characteristics of the known SARS-CoV cases from Wuhan (“Wuhan patient population”) [34].

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
<th>Case 5</th>
<th>Case 6</th>
<th>Case 7</th>
<th>Case 8</th>
<th>Case 9</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td>33</td>
<td>27</td>
<td>40</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>29</td>
<td>28</td>
<td>34</td>
</tr>
<tr>
<td><strong>GA on admission (weeks + days)</strong></td>
<td>37 + 2</td>
<td>38 + 2</td>
<td>36 + 0</td>
<td>36 + 2</td>
<td>38 + 1</td>
<td>36 + 2</td>
<td>36 + 2</td>
<td>38 + 0</td>
<td>39 + 4</td>
</tr>
<tr>
<td><strong>Exposure to a SARS-CoV-2-relevant environment or contact with infected person</strong></td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td><strong>Case of infection in the family</strong></td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td><strong>Onset to delivery (days)</strong></td>
<td>1</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td><strong>Infection-related complications</strong></td>
<td>influenza</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td><strong>Pregnancy-related complications</strong></td>
<td>no</td>
<td>no</td>
<td>gestational hypertension</td>
<td>pre-eclampsia</td>
<td>pathological CTG</td>
<td>no</td>
<td>PROM</td>
<td>pathological CTG</td>
<td>PROM</td>
</tr>
<tr>
<td><strong>Delivery</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Mode of delivery</strong></td>
<td>C-section</td>
<td>C-section</td>
<td>C-section</td>
<td>C-section</td>
<td>C-section</td>
<td>C-section</td>
<td>C-section</td>
<td>C-section</td>
<td>C-section</td>
</tr>
<tr>
<td><strong>Indication for operative delivery</strong></td>
<td>elevated ALT/AST; COVID-19 pneumonia</td>
<td>COVID-19 pneumonia; history of previous C-section</td>
<td>pre-eclampsia; COVID-19 pneumonia</td>
<td>pathological CTG; COVID-19 pneumonia</td>
<td>history of 2 × IUFT; COVID-19 pneumonia</td>
<td>PROM; COVID-19 pneumonia</td>
<td>pathological CTG; COVID-19 pneumonia</td>
<td>PROM; COVID-19 pneumonia</td>
<td></td>
</tr>
<tr>
<td><strong>Postpartum treatment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Oxygen administration</strong></td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td><strong>Antiviral therapy</strong></td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td><strong>Antibiotic treatment</strong></td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td><strong>Corticosteroids</strong></td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

GA: gestational age; ALT: alanine aminotransferase; AST: aspartate aminotransaminase; CTG: cardiotocography; PROM: premature rupture of membranes; IUFT: intrauterine fetal death
confirmed SARS-CoV-2 infection were examined. No infection was diagnosed in any of the newborns. No histopathological correlates for infection were found in the placentas [35].

In summary, at the present time and based on very low case numbers of published pregnancies and their outcomes as well as on experience gained during the SARS epidemic, it does not appear that there is any intrauterine transmission of SARS-CoV-2 onto the fetus. Nevertheless, caution is needed: neonatologists should closely monitor children of infected mothers to be able to detect an infection early. As it is not conclusively clear whether infections can develop in utero or in the peripartum phase, children of infected mothers should be isolated after birth for the protection of other newborns.

Neonatal outcome

The following is known about neonatal outcome from both studies: all the children in both patient populations had unremarkable Apgar scores after one and five minutes. Elevated cardiac enzymes were discovered in one child of the "Hubei patient population" on the first postpartum day, but these were of no clinical relevance. No neonatal fatalities were reported. In contrast, in the "Hubei patient population", one child died after birth in the 34 + 5 WOP of multiple organ failure with disseminated intravascular coagulopathy on its ninth day of life. On the whole, outcome was worse for the "Hubei patient population" than for the "Wuhan patient population". Thus, respiratory distress syndrome developed in six newborns, followed by gastrointestinal symptoms (n = 4), fever (n = 2), tachycardia (n = 1) and vomiting (n = 1). According to the authors, COVID-19 disease was not diagnosed in any of the children. In the "Wuhan patient population", on the other hand, one child tested positive for SARS-CoV-2 36 hours post partum. The assumption at the moment is that the child became infected post partum. All the other reported children had an unremarkable neonatal period (Table 5).

Management of infected pregnant patients

With regard to management of infected pregnant women, the authors of two recently published reviews [36, 37] regard it as appropriate at the moment to observe the following measures:

- Treatment regarded as appropriate for non-pregnant cases of infection should not be withheld from pregnant patients merely because of their state of pregnancy, provided there are no clear contraindications for the available therapy.
- Various therapeutic options are currently under consideration (e.g. remdesivir, hydroxychloroquine). Studies on several treatment options have already been started. Further developments need to be awaited. Ultimately, benefit and potential risks for mother and child should be carefully weighed up, as with any form of treatment in pregnancy.
- With suspected cases, the decision to isolate pregnant women should be made generously and early.
- Tests should be carried out for SARS-CoV-2 and possible (bacterial and viral) co-infections. If necessary, oxygen support should be given, and mechanical ventilation should be commenced early should signs of respiratory failure develop.
- Empiric antibiotic treatment for secondary bacterial infections is indicated. Furthermore, blood cultures are recommended before starting any antibiotic therapy in order to adjust treatment if necessary as the clinical course develops.
- As regards fetal monitoring, regular CTG examinations and regular follow-up checks for growth, as well as Doppler and amniotic fluid examinations should be performed to exclude placental failure with the development of IUGR.
- As regards the mode of delivery for infected pregnant women, no recommendation can be given at the present moment because of the small number of cases. It is currently considered improbable that infection of the child can occur in the birth canal.

Breastfeeding in cases of suspected infection or confirmed SARS-CoV-2 infection

Given that no pathogen has been isolated in maternal milk in the studies carried out to date, transmission via breastfeeding is currently regarded as improbable. In case of suspected infection or after confirmed infection of the mother, the milk should be pumped off and feeding should be provided by a healthy assistant. For this situation, the European Institute for Breastfeeding and Lactation recommends sterilisation of all used vessels and pump sets in addition to adequate hand hygiene [38]. These rec-

| Table 5 Neonatal outcome of the known SARS-CoV cases from Wuhan (“Wuhan patient population”) [34]. |

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
<th>Case 5</th>
<th>Case 6</th>
<th>Case 7</th>
<th>Case 8</th>
<th>Case 9</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA at delivery (weeks + days)</td>
<td>37 + 2</td>
<td>38 + 3</td>
<td>36 + 0</td>
<td>36 + 2</td>
<td>38 + 1</td>
<td>36 + 3</td>
<td>36 + 2</td>
<td>38 + 0</td>
<td>39 + 4</td>
</tr>
<tr>
<td>Birth weight (g)</td>
<td>2870</td>
<td>3730</td>
<td>3820</td>
<td>1880</td>
<td>2970</td>
<td>3040</td>
<td>2460</td>
<td>2800</td>
<td>3530</td>
</tr>
<tr>
<td>Low birth weight (&lt; 2500 g)</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Premature delivery</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Apgar scores after 1/5 min</td>
<td>8/9</td>
<td>9/10</td>
<td>9/10</td>
<td>8/9</td>
<td>9/10</td>
<td>9/10</td>
<td>9/10</td>
<td>8/10</td>
<td>8/10</td>
</tr>
<tr>
<td>Severe neonatal asphyxia</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>0</td>
</tr>
<tr>
<td>Neonatal death</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>0</td>
</tr>
<tr>
<td>IUFT</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>0</td>
</tr>
</tbody>
</table>

GA: gestational age; g: gram; min: minute; IUFT: intrauterine fetal death
### Table 6 Obstetric and neonatal outcome of the “Hubei patient population” [33].

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
<th>Case 5</th>
<th>Case 6</th>
<th>Case 7</th>
<th>Case 8/9</th>
<th>Case 10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline and pregnancy data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td>25</td>
<td>35</td>
<td>35</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>29</td>
<td>34</td>
</tr>
<tr>
<td><strong>Symptom onset</strong></td>
<td>Delivery day</td>
<td>Delivery day</td>
<td>2 days after delivery</td>
<td>3 days after delivery</td>
<td>6 days before delivery</td>
<td>4 days before delivery</td>
<td>1 day before delivery</td>
<td>3 days before delivery</td>
</tr>
<tr>
<td><strong>Initial symptoms</strong></td>
<td>fever</td>
<td>fever</td>
<td>cough</td>
<td>fever</td>
<td>cholecystitis, fever</td>
<td>fever, cough</td>
<td>fever, cough, sore throat, diarrhoea</td>
<td>fever, cough</td>
</tr>
<tr>
<td><strong>Pathological CTG</strong></td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td><strong>PROM</strong></td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td><strong>Amniotic fluid volume</strong></td>
<td>oligohydramnios</td>
<td>normal</td>
<td>normal</td>
<td>normal</td>
<td>normal</td>
<td>polyhydramnios</td>
<td>normal</td>
<td>normal</td>
</tr>
<tr>
<td><strong>Obstetric outcome</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Delivery mode</strong></td>
<td>C-section</td>
<td>C-section</td>
<td>spontaneous birth</td>
<td>C-section</td>
<td>C-section</td>
<td>C-section</td>
<td>C-section</td>
<td>spontaneous birth</td>
</tr>
<tr>
<td><strong>GA at delivery</strong></td>
<td>38 + 4</td>
<td>33 + 6</td>
<td>34 + 2</td>
<td>34 + 5</td>
<td>39</td>
<td>37</td>
<td>34 + 6</td>
<td>31</td>
</tr>
<tr>
<td><strong>Neonatal outcome</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Birth weight</strong></td>
<td>SGA</td>
<td>AGA</td>
<td>AGA</td>
<td>AGA</td>
<td>AGA</td>
<td>LGA</td>
<td>AGA</td>
<td>AGA/AGA</td>
</tr>
<tr>
<td><strong>Apgar score 1 min</strong></td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>9</td>
<td>9/9</td>
</tr>
<tr>
<td><strong>Apgar score 5 min</strong></td>
<td>10</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>10</td>
<td>10/10</td>
</tr>
<tr>
<td><strong>Initial symptom</strong></td>
<td>vomiting</td>
<td>tachypnoea</td>
<td>tachypnoea</td>
<td>tachycardia</td>
<td>diffuse skin rashes</td>
<td>–</td>
<td>tachypnoea, moaning</td>
<td>tachypnoea, cyanosis</td>
</tr>
<tr>
<td><strong>Transfusion of blood product</strong></td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>platelets, red blood cells, plasma</td>
<td>no</td>
<td>no</td>
<td>gamma-globulin, plasma, platelets</td>
<td>no/no</td>
</tr>
<tr>
<td><strong>Complications</strong></td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>multiple organ failure, DIC</td>
<td>no</td>
<td>no</td>
<td>DIC</td>
<td>no/no</td>
</tr>
<tr>
<td><strong>Outcome</strong></td>
<td>cured</td>
<td>cured</td>
<td>cured</td>
<td>died</td>
<td>cured</td>
<td>in hospital</td>
<td>cured</td>
<td>in hospital</td>
</tr>
</tbody>
</table>

AGA: appropriate for gestational age; SGA: small for gestational age; LGA: large for gestational age; PCIS: Paediatric Critical Illness Score; DIC: disseminated intravascular coagulation
ommendations may be subject to change if new findings are published. Furthermore, by March 3rd, 2020, the German Board and College of Obstetrics and Gynecology (GBCOG), in collaboration with Professional Association of Gynecologists (BVG) and German Society for Gynecology and Obstetrics e.V. (DGGG) published a “FAQ for pregnant women and their families” [39].

Conclusion

In summary, it can be confirmed that the literature available on the management of pregnant women infected with SARS-CoV-2 is very limited. Pregnant women with confirmed infection and their fetuses should be closely supervised and monitored to be able to recognise early any clinical deterioration of mother and child. At the moment, it is to be assumed that pregnancy can complicate the clinical course of COVID-19 disease and may be associated with a higher mortality rate, but by far not as bad as with MERS or SARS. Pregnant women are at particular risk of respiratory virus infections, especially influenza. On the other hand, given their age, they usually belong to a patient population with a lower risk of developing severe COVID-19 clinical courses. At the moment there is no indication of intrauterine virus transmission to the fetus, nor for virus transmission via breastfeeding after a cured infection.

Conflict of Interest

The authors declare that they have no conflict of interest.

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