Objective To describe characteristics, risk factors and maternal, obstetric and neonatal outcomes of pregnant women infected with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).

Design Multi-centre prospective population-based cohort study.

Setting Nationwide study in the Netherlands.

Population Pregnant women with confirmed SARS-CoV-2 infection admitted to hospital or in home-isolation: 1 March 2020 to 31 August 2020.

Methods Pregnant women with positive polymerase chain reaction or antibody tests were registered using the Netherlands Obstetrics Surveillance System (NethOSS). (Selective) testing occurred according to national guidelines. Data from the national birth registry (pregnant pre-coronavirus disease 2019 [COVID-19] cohort) and an age-matched cohort of COVID-19-positive women (National Institute for Public Health and the Environment; fertile age COVID-19 cohort) were used as reference.

Main outcome measures Incidence of SARS-CoV-2 infection in pregnant women. Maternal, obstetric and neonatal outcomes including hospital and intensive care admission.

Results Of 376 registered pregnant women with confirmed SARS-CoV-2 infection, 20% (74/376) were admitted to hospital, of whom 84% (62/74) were due to SARS-CoV-2; 10% (6/62) were admitted to intensive care and 15% (9/62) to obstetric high-care units. Risk factors for admission were non-European country of origin (odds ratio [OR] 1.73, 95% CI 1.01–2.96) and being overweight/obese (OR 1.86, 95% CI 1.51–3.20). No maternal or perinatal deaths occurred. Caesarean section after labour-onset was increased (OR 1.58, 95% CI 1.09–2.28). Hospital and intensive care admission were higher compared with the fertile age COVID-19 cohort (OR 6.75, 95% CI 5.18–8.81 and OR 2.52, 95% CI 1.11–5.77, respectively).

Conclusions Non-European country of origin and being overweight/obese are risk factors for severe course of SARS-CoV-2 infection in pregnancy, risk of caesarean section and hospital and intensive care unit admission are increased.

Keywords coronavirus disease 2019, obstetric surveillance system, pregnancy, pregnancy complications, severe acute respiratory syndrome coronavirus 2.

Tweetable abstract Pregnant women with SARS-CoV-2 in the Netherlands show increased hospital/ICU admission and caesarean section.
Introduction

The coronavirus disease 2019 (COVID-19) pandemic, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has had a major impact worldwide. High-risk populations have been identified, including the elderly, obese and ethnic minority groups. Evidence is increasingly showing that pregnant women and their unborn children may also comprise a vulnerable group, with higher rates of intensive care (ICU) admission and mechanical ventilation.2,3

It is known that pregnant women are not only more frequently affected by pneumonia, but their outcomes are often worse compared with non-pregnant women.4,5 Maternal physiological adaptations in pregnancy, and the physiological state of relative immune suppression, place pregnant women at increased risk of poor outcomes. It is likely that these mechanisms will also play a role in COVID-19. During previous coronavirus epidemics with SARS-CoV and Middle East respiratory syndrome coronavirus, risk of maternal mortality and morbidity, as well as miscarriages and preterm labour, were considerable.6,7 A meta-analysis indicated that pregnant women may be at increased risk of ICU admission compared with age-matched non-pregnant women and that rates of vertical transmission appear to be very low.8 A population-based cohort of pregnant women with SARS-CoV-2 admitted to UK hospitals showed an over-representation of women from Black, Asian or other minority ethnic backgrounds and those with obesity or pre-existing medical conditions.9 Most studies have only reported on women admitted to hospital, so it is unclear whether the risk of admission itself is increased among pregnant women, and whether findings in terms of risk groups can be generalised to all pregnant women with SARS-CoV-2.8,10

In the present study, we have collected information on pregnant women with confirmed SARS-CoV-2 infection in the Netherlands, both in home-isolation and admitted to hospital. To provide health professionals with information on SARS-CoV-2 and pregnancy, crude numbers of collected cases were previously published on the website of the Dutch Society of Obstetrics and Gynaecology.11 In-depth analysis or comparisons with reference groups are presented here.

The primary aim of this study was to investigate the incidence and maternal, obstetric and neonatal outcomes including hospital and ICU admission and medication use in pregnant women with SARS-CoV-2 infection. Secondary aims were (1) to assess factors associated with a more severe course of disease and (2) to explore the effect of pregnancy itself in women of fertile age with SARS-CoV-2 infection.

Method

This is a multi-centre prospective nationwide population-based cohort study conducted between 1 March 2020 and 31 August 2020. Cases were ascertained using the Netherlands Obstetric Surveillance System (NethOSS), a nationwide registration system functioning under the umbrella of the Dutch Birth Registry (Perined), in which maternal mortality, severe maternal morbidity and rare diseases in pregnancy are registered.12,13 All hospitals in the Netherlands with an obstetrician-led maternity unit (n = 74) were asked to report pregnant or postpartum women up to 42 days with a confirmed SARS-CoV-2 infection to NethOSS. All midwifery practices (n = 577) were approached through the Society of Midwifery (KNOV), maternity care (BO geboortezorg) and Perined and were also asked to report. From March 2020, the joint national guideline on SARS-CoV-2 infection in pregnancy of the Dutch Society of Obstetrics and Gynaecology (NVOG), the Royal Society of Midwifery (KNOV) and maternity care (BO geboortezorg), the Dutch Society of Paediatricians (NVK) and the Dutch National Institute for Public Health and the Environment (RIVM) indicated that all confirmed cases had to be reported to NethOSS.

In each of the 74 hospitals with an obstetrician-led maternity unit, a NethOSS reporting physician or midwife was nominated to report cases on behalf of the perinatal cooperation group, based on the organisation of Dutch birth care. Weekly requests were sent by email to reporting professionals. This email contained a reporting link specific to each reporter. Clinicians were asked to report any case meeting the inclusion criteria or reply with ‘0’ if they had no cases to report. For every reported case, information with regard to the woman’s birth year, parity, estimated due date, date of positive SARS-CoV-2 test and information on hospital admission, management and birth was provided. Subsequently, a data collection form with additional questions was sent to each reporting physician or midwife. This form was designed by the International Network of Obstetric Survey Systems, based on the UK Obstetric Survey System form with input from the World Health Organization and slightly adapted to the Dutch healthcare system.14

For nationwide comparison, two reference groups were established. One reference group consisted of pregnant women pre-COVID-19 (pregnant pre-COVID-19 cohort) using information from Perined. This registry contains population-based information pertaining to 99% of pregnancies in the Netherlands.15 Specific information of all women in the registry who had given birth between 1 March 2017 and 1 March 2018, the most recent year with complete data, was used. A second reference group
consisted of all women of fertile age (20–50 years) with SARS-CoV-2 (fertile age COVID-19 cohort), regardless of pregnancy status, obtained through RIVM. These women were confirmed SARS-CoV-2-positive by polymerase chain reaction or imaging and registered until 31 August 2020. It was unknown whether women were pregnant or not, so this group might also have included pregnant women. The number of ICU admissions was obtained from the National Intensive Care Evaluation, and the number of hospital admissions from the RIVM.

To study the main objective, that is to study characteristics of pregnant women with SARS-CoV-2 infection, we described the characteristics of the women enrolled in the NethOSS cohort and compared them with the pregnant pre-COVID-19 cohort. To study the secondary aims, which are to assess factors associated with a more severe course of disease, we performed a nested case–control within the NethOSS cohort (in hospital versus in home-isolation group) and comparison of the NethOSS cohort with the pregnant pre-COVID-19 cohort. To explore the effect of pregnancy itself in women of fertile age with SARS-CoV-2 infection, we compared the NethOSS cohort with the fertile age COVID-19 cohort.

As a result of limited testing capacity, the testing policy from 12 March 2020 focused on severely ill people with a suspected SARS-CoV-2 infection, high-risk groups and healthcare staff working during the COVID-19 pandemic. Pregnant women were at that time not considered a high-risk group. Between 12 March 2020 and 30 April 2020, the policy of the RIVM stated that pregnant women required testing only in case of significant symptoms or if hospital admission for SARS-CoV-2-related symptoms was required. Testing capacity was slowly increased and from 30 April 2020 all people were asked to test if they had symptoms related to SARS-CoV-2 infection for longer than 24 hours. Because of this change in testing capacity, a sensitivity analysis was performed on the results before and after 30 April. The two available tests in the Netherlands were a polymerase chain reaction using samples taken from the nose and throat, or a serological test based on the presence of SARS-CoV-2-specific antibodies. Neonates born of SARS-CoV-2-positive mothers were tested for SARS-CoV-2 if signs or symptoms such as fever or increased infectious parameters were found.

Outcomes collected were signs of pneumonia on imaging, hospital admission, ICU, neonatal ICU or obstetric high-care admission and administration of pharmacological therapy. We recorded the characteristics of women including body mass index (BMI), age, country of origin, comorbidities and gestational age at onset of symptoms. For women who had given birth, mode of delivery, labour induction, analgesia, intrapartum or peripartum transmission and breastfeeding were assessed. Admission to hospital was defined by hospital stay for longer than 24 hours, but women admitted for birth only were not included. Women at birth were divided into a symptomatic and an asymptomatic group. Women were considered symptomatic if complaints related to SARS-CoV-2 infection were reported at onset of labour. The incidence of SARS-CoV-2 infection was estimated using the most recently available data from Perined in 2018, which included 79 962 pregnancies reported over a period of 6 months.

Country of origin was based on the definition of Statistics Netherlands. If the woman was born in the Netherlands with at least one of her parents born abroad, she was considered to be from the same origin as her parent(s) from outside the country. Body mass index was defined according to the first recorded weight in pregnancy up to 12 weeks. Overweight pertained to BMI above 25 kg/m² and obesity to a BMI above 30 kg/m². Gestational age was based on the first-trimester dating ultrasound.

No core outcome sets were used in this study and the study did not have active patient involvement. No funding was received.

Statistical analyses were carried out using IBM SPSS 25 (IBM, Armonk, NY, USA). Descriptive analyses were performed. Proportions are presented as percentages, and skewed distributions as medians with ranges. For categorical data, differences are presented as odds ratios (OR) with 95% CI.

Results

Between 1 March 2020 and 31 August 2020, 394 SARS-CoV-2-positive pregnant women were registered. In 18 pregnant women, a positive test result was reported, but additional information could not be retrieved. Additional data were returned for the remaining 376 women (95%). The estimated incidence of SARS-CoV-2 among pregnant women in the Netherlands over these 6 months was 4.70 per 1000 maternities. The number of collected cases was highest during the first 2 months of registration (March and April, n = 216) with an estimated incidence of 8.10 per 1000 maternities. The number of positive cases per week can be seen in Figure S1. Testing capacity increased after 30 April. In March and April 57/216 (26%) women were admitted, May to September 17/160 (11%) women were admitted. Sensitivity analysis between cases before and after 30 April did not affect our general conclusions.

The majority of pregnant women with SARS-CoV-2 were not admitted to hospital (302/376, 80%). Instead, they stayed, as advised by the government, in home-isolation until symptoms had subsided and 2 weeks after disease-onset. Of pregnant women with SARS-CoV-2 admitted to hospital (74/376, 20%), admission was COVID-related in 62/74 (85%). Other reasons for admission were signs of

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imminent premature birth and hypertensive disorders. Six women required ICU treatment, which represents 10% (6/62) of all pregnant women with SARS-CoV-2 who were admitted to hospital and 2% (6/376) of all registered pregnant women with SARS-CoV-2. Another nine (9/62, 15%) were admitted to obstetric high-care units with additional monitoring facilities but did not require mechanical ventilation. No maternal death was reported.

Signs of pneumonia on imaging were found in 35/376 (9%) registered pregnant women. They most frequently complained of cough (180/376, 47%), breathlessness (91/376, 24%), flu-like symptoms (95/376, 25%) and fever (149/376, 39%). Antibiotics were administered in 41/376 (11%) women and antiviral drugs in 5/376 (1%) (oseltamivir, n = 2; remdesivir, n = 3). In 14/376 (4%), corticosteroids were administered to stimulate fetal lung maturation. This was due to signs of threatened preterm labour (7/14, 50%) or high risk of iatrogenic preterm labour because of the severity of the SARS-CoV-2 infection (7/14, 50%). Oxygen supplementation was used in 30/376 women (8%) with signs of breathlessness and low oxygen levels. Four pregnant women (4/376, 1%) needed mechanical ventilation of whom three were ventilated in prone position.

An overview of background characteristics of pregnant women with SARS-CoV-2 and comparison with the pregnant pre-COVID-19 cohort is shown in Table 1. Table 2 compares pregnant women with SARS-CoV-2 requiring hospital admission with pregnant women with SARS-CoV-2 in home-isolation. Among pregnant women testing positive for SARS-CoV-2, non-European women were disproportionately represented in comparison with the pregnant pre-COVID-19 cohort. The risk of hospital admission with pregnant women with SARS-CoV-2 was also compared with the fertile age–110 women testing positive for SARS-CoV-2 669/19 110 (3.5%) were admitted to hospital and 122/19 110 (6%) to ICU. ORs for hospital and ICU admission were considerably increased: OR 6.75, 95% CI 5.18–8.81 and OR 2.52, 95% CI 1.11–5.77, respectively.

Discussion

Main findings

This large nationwide population-based registration study (NethOSS) provides outcomes of pregnant and postpartum women in the Netherlands who had been infected with SARS-CoV-2, during the first wave up to 31 August 2020. No maternal mortality was reported. Among pregnant women with SARS-CoV-2 admitted to hospital compared with home-isolation, those who were overweight and from non-European countries of origin were over-represented. Labour induction was more common among pregnant women with SARS-CoV-2 and pregnant women with SARS-CoV-2 had a higher risk of caesarean section after labour-onset, especially when symptomatic at birth compared with a pregnant pre-COVID-19 cohort. Risk of preterm birth was only elevated for pregnant women who were symptomatic at birth. No vertical transmission was
Table 1. Background characteristics: pregnant women with SARS-CoV-2 versus reference group

| Characteristics                          | Pregnant women with SARS-CoV-2 (N = 376) n (%) | Reference group of pregnant women (pregnant pre-COVID-19 cohort)* (N = 183 413) n (%) | OR (95% CI)** |
|-----------------------------------------|-----------------------------------------------|-------------------------------------------------------------------------------------|----------------|
| **General**                             |                                               |                                                                                     |                |
| Age (years)                             |                                               |                                                                                     |                |
| <25                                     | 26 (7)                                        | 16 662 (9)                                                                           | 0.75 (0.50–1.11) |
| 25–30                                   | 97 (26)                                       | 54 837 (30)                                                                          | 0.82 (0.65–1.03) |
| 30–35                                   | 153 (41)                                      | 70 615 (39)                                                                          | 1.10 (0.90–1.35) |
| 35–40                                   | 71 (19)                                       | 34 290 (19)                                                                          | 1.01 (0.78–1.32) |
| >40                                     | 28 (7)                                        | 6913 (4)                                                                             | 2.06 (1.40–3.03) |
| Missing                                 | 1                                             | 96                                                                                   |                |
| **Country of origin**                   |                                               |                                                                                     |                |
| European                                | 189 (58)                                      | 161 464 (90)                                                                         | 0.16 (0.13–0.20) |
| African                                 | 69 (21)                                       | 5 (0)                                                                                |                |
| Asian                                   | 19 (6)                                        | 7401 (4)                                                                             | 1.44 (0.91–2.29) |
| South American                          | 5 (2)                                         | 4681 (3)                                                                             | 0.58 (0.24–1.41) |
| Other                                   | 45 (14)                                       | 6599 (4)                                                                             | 4.17 (3.05–5.72) |
| Missing                                 | 49                                            | 3263                                                  |                |
| **BMI (kg/m²)**                         |                                               |                                                                                     |                |
| Normal (<25)                            | 161 (49)                                      | na                                                                                    |                |
| Overweight (25–30)                      | 100 (30)                                      | na                                                                                    |                |
| Obese (>30)                             | 67 (20)                                       | na                                                                                    |                |
| Missing                                 | 48                                            | na                                                                                    |                |
| **Smoking**                             |                                               |                                                                                     |                |
| Current                                 | 16 (5)                                        | na                                                                                    |                |
| Missing                                 | 43                                            | na                                                                                    |                |
| **Pre-existing medical problems**       |                                               |                                                                                     |                |
| Pulmonary disease                       | 23 (7)                                        | na                                                                                    |                |
| Cardiac disease                         | 6 (2)                                         | na                                                                                    |                |
| Diabetes                                | 6 (2)                                         | na                                                                                    |                |
| Missing                                 | 34                                            | na                                                                                    |                |
| **Pregnancy**                           |                                               |                                                                                     |                |
| Parity                                  |                                               |                                                                                     |                |
| Nulliparous                             | 159 (42)                                      | 79 518 (43)                                                                          | 0.95 (0.78–1.17) |
| Multiparous                             | 217 (58)                                      | 103 549 (56)                                                                         | 1.05 (0.85–1.29) |
| Missing                                 | 0                                             | 346                                                                                   |                |
| Trimester at positive test              |                                               |                                                                                     |                |
| First trimester                         | 49 (13)                                       | N/A                                                                                  |                |
| Second trimester                        | 101 (27)                                      | N/A                                                                                  |                |
| Third trimester                         | 200 (54)                                      | N/A                                                                                  |                |
| Postpartum                              | 19 (5)                                        | N/A                                                                                  |                |
| Missing                                 | 7                                             |                                                                                     |                |
| Multiple pregnancy                      | 9 (2)                                         | 5 270 (3)                                                                            | 0.91 (0.47–1.77) |
| Missing                                 | 33                                            | 41                                                                                   |                |
| Signs of premature labour               | 18 (5)                                        | 4226 (2)                                                                             | 2.37 (1.47–3.82) |
| Missing                                 | 40                                            | 2197                                                                                  |                |

na, not available.

*Reference group from pregnant women in the Dutch Perinatal Registry (Perined) between 1 March 2017 and 1 March 2018.

**Odds ratio between pregnant women with SARS-CoV-2 who have given birth and reference group from Dutch Perinatal Registry.
Table 2. Background characteristics: pregnant women admitted to hospital compared with pregnant women in home-isolation

| Characteristics                              | Pregnant women admitted to hospital (N = 74) n (%) | Pregnant women in home-isolation (N = 302) n (%) | OR (95% CI)*  |
|----------------------------------------------|--------------------------------------------------|-------------------------------------------------|--------------|
| **General**                                  |                                                  |                                                 |              |
| Age (years)                                  |                                                  |                                                 |              |
| <25                                          | 4 (5)                                            | 22 (7)                                          | 0.73 (0.24-2.17) |
| 25–30                                        | 15 (20)                                          | 82 (27)                                         | 0.68 (0.37–1.26) |
| 30–35                                        | 36 (49)                                          | 117 (39)                                        | 1.49 (0.89–2.49) |
| 35–40                                        | 13 (18)                                          | 58 (19)                                         | 0.89 (0.46–1.73) |
| >40                                          | 6 (8)                                            | 22 (7)                                          | 1.12 (0.44–2.87) |
| Missing                                      | 0                                                | 1                                               |              |
| **Country of origin**                        |                                                  |                                                 |              |
| European                                     | 32 (47)                                          | 157 (61)                                        | 0.58 (0.34–0.99) |
| African                                      | 17 (25)                                          | 52 (20)                                         | 1.33 (0.71–2.49) |
| Asian                                        | 5 (7)                                            | 14 (5)                                          | 1.39 (0.48–4.00) |
| South American                               | 2 (3)                                            | 3 (1)                                           | 2.59 (0.42–15.79) |
| Other                                        | 12 (18)                                          | 33 (13)                                         | 1.47 (0.71–3.02) |
| Missing                                      | 6                                                | 43                                              |              |
| **BMI (kg/m²)**                              |                                                  |                                                 |              |
| Normal (<25)                                 | 26 (37)                                          | 135 (52)                                        | 0.54 (0.31–0.93) |
| Overweight (>25)                             | 25 (36)                                          | 75 (29)                                         | 1.36 (0.78–2.37) |
| Obese (>30)                                  | 19 (27)                                          | 48 (19)                                         | 1.63 (0.88–3.01) |
| Missing                                      | 4                                                | 44                                              |              |
| **Smoking**                                  |                                                  |                                                 |              |
| Current                                      | 8 (11)                                           | 8 (3)                                           | 4.03 (1.46–11.16) |
| Missing                                      | 3                                                | 40                                              |              |
| **Pre-existing medical problems**            |                                                  |                                                 |              |
| Pulmonary disease                            | 6 (8)                                            | 17 (6)                                          | 1.35 (0.51–3.57) |
| Cardiac disease                              | 2 (3)                                            | 4 (1)                                           | 1.90 (0.34–10.59) |
| Diabetes                                     | 1 (1)                                            | 5 (2)                                           | 0.75 (0.09–6.49) |
| Missing                                      | 2                                                | 32                                              |              |
| **Pregnancy**                                |                                                  |                                                 |              |
| Parity                                       |                                                  |                                                 |              |
| Nulliparous                                  | 32 (43)                                          | 127 (42)                                        | 1.05 (0.63–1.76) |
| Multiparous                                  | 42 (57)                                          | 175 (58)                                        | 0.95 (0.57–1.59) |
| Missing                                      | 0                                                | 0                                               |              |
| **Trimester at positive test**               |                                                  |                                                 |              |
| First trimester                              | 4 (5)                                            | 156 (53)                                        | 0.01 (0.00–0.03) |
| Second trimester                             | 14 (19)                                          | 7 (2)                                           | 0.56 (0.30–1.05) |
| Third trimester                              | 44 (60)                                          | 7                                              | 1.31 (0.78–2.19) |
| Postpartum                                   | 12 (16)                                          | 7 (3)                                           | 7.96 (3.01–21.04) |
| Missing                                      | 0                                                | 32                                              |              |
| Multiple pregnancy                           | 2 (3)                                            | 6 (2)                                           | 1.06 (0.22–5.21) |
| Missing                                      | 1                                                | 39                                              |              |
| Signs of premature labour                    | 12 (16)                                          | 8.43 (3.04–23.34)                              |              |
| Missing                                      | 1                                                |                                                 |              |

*Odds ratio between pregnant women with SARS-CoV-2 admitted to hospital and pregnant women with SARS-CoV-2 in home-isolation.
Interpretation

Even though the majority of pregnant women with SARS-CoV-2 infection experienced mild symptoms, a small but significant group developed severe morbidity. This study recognises several risk factors for hospital admission of pregnant women such as increased BMI and non-European background. When comparing the results of pregnant women to those of all fertile women in the same age group, the pregnant women in our study were more often admitted to hospital and ICU. The reference group contained women up to 50 years of age. As risk of hospital admission is reported to increase with age, and pregnant women in our study population above 40 years of age were scarce (8%) and above 45 years were absent, we assume that the risk could be even higher when compared with women up to 40 years of age. This reference group will also have included some pregnant women, because pregnancy was not registered by RIVM or National Intensive Care Evaluation. This may have reduced the OR, as pregnant women with higher risk of admission were also included in the reference group. This is the first study to show increased risk of hospital admission in SARS-CoV-2-infected pregnant women in comparison with age-matched infected non-pregnant women. Increased ICU admission is supported by recent evidence.

The incidence of SARS-CoV-2 infection among pregnant women in the Netherlands was higher than reported for the UK, but the UK sample was limited to women admitted to hospital, rendering comparisons only possible after individual patient data meta-analysis. It is very likely that the incidence of all infections was much higher in the UK, as reflected in the general population.22 Most other

| Table 3. Birth characteristics | Pregnant women with SARS-CoV-2 who have given birth (N = 289) n (%) | Pregnant pre-COVID-19 cohort, pregnant women who have given birth* (N = 183 413) n (%) | OR (95% CI)** Pregnant women with SARS-CoV-2 compared with pregnant pre-COVID-19 cohort | Pregnant women with SARS-CoV-2 who were symptomatic at birth (N = 70) n (%) | OR (95% CI)*** Pregnant women with SARS-CoV-2 who were symptomatic compared with pregnant pre-COVID-19 cohort |
|-----------------------------|---------------------------------------------------------------|-----------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| Mode of birth               |                                                               |                                               |                                                               |                                                               |                                                               |
| Vaginal birth               | 227 (79)                                                      | 123 709 (76)                                  | 1.31 (0.92–1.76)                                              | 43 (61)                                                       | 0.50 (0.31–0.80)                                               |
| Instrumental vaginal birth  | 17 (6)                                                       | 12 802 (8)                                    | 0.75 (0.46–1.22)                                              | 6 (9)                                                        | 1.09 (0.47–2.53)                                               |
| Pre-labour caesarean section| 20 (7)                                                       | 13 477 (8)                                    | 0.85 (0.54–1.33)                                              | 10 (14)                                                      | 1.84 (0.94–3.59)                                               |
| Caesarean section after onset of labour | 32 (11)                                                | 12 203 (8)                                    | 1.58 (1.09–2.28)                                              | 11 (16)                                                      | 2.29 (1.20–4.36)                                               |
| Missing                     | 8                                                            | 21 222                                        |                                                               |                                                               |                                                               |
| Gestational age at birth (weeks) |                                                       |                                               |                                                               |                                                               |                                                               |
| 16<36                        | 28 (10)                                                      | 12 352 (10)                                   | 1.01 (0.68–1.49)                                              | 13 (19)                                                      | 2.02 (1.11–3.69)                                               |
| 37–40                        | 196 (72)                                                     | 80 431 (66)                                   | 1.29 (0.99–1.68)                                              | 47 (67)                                                      | 1.05 (0.64–1.73)                                               |
| ≥41                          | 50 (18)                                                      | 29 009 (24)                                   | 0.71 (0.53–0.97)                                              | 10 (14)                                                      | 0.53 (0.27–1.04)                                               |
| Missing                      | 15                                                           | 61 639                                        |                                                               |                                                               |                                                               |
| Induction                    |                                                               |                                               |                                                               |                                                               |                                                               |
| Total                        | 107 (39)                                                     | 36 885 (22)                                   | 4.05 (3.18–5.17)                                              | 32 (46)                                                      | 5.47 (3.41–8.78)                                               |
| Foley catheter               | 65 (61)                                                      | 14 453 (8)                                    | 3.16 (2.39–4.18)                                              | 18 (58)                                                      | 3.59 (2.10–6.14)                                               |
| Prostaglandin                | 11 (10)                                                      | 5036 (3)                                      | 1.30 (0.71–2.38)                                              | 6 (19)                                                       | 2.96 (1.28–6.84)                                               |
| Oxytocin/amniotomy           | 31 (29)                                                      | 17 396 (11)                                   | 1.07 (0.74–1.56)                                              | 4 (13)                                                       | 0.52 (0.19–1.42)                                               |
| Missing                      | 15                                                           | 22 024                                        |                                                               |                                                               |                                                               |
| Analgesia                    |                                                               |                                               |                                                               |                                                               |                                                               |
| Analgesic – opiates          | 36 (13)                                                      | 17 314 (9)                                    | 0.82 (0.58–1.17)                                              | 15 (22)                                                      | 1.65 (0.93–2.93)                                               |
| Epidural during labour       | 72 (25)                                                      | 32 227 (18)                                   | 0.88 (0.67–1.15)                                              | 17 (25)                                                      | 0.89 (0.51–1.54)                                               |
| Epidural and analgesic – opiates | 11 (4)                                                    | na                                            |                                                               | 2 (3)                                                        |                                                               |
| Missing                      | 3                                                           | 67 115                                        |                                                               |                                                               | 3                                                               |

na, not available.

*Reference group from pregnant women in the Dutch Perinatal Registry (Perined) between 1 March 2017 and 1 March 2018.

**Odds ratio between pregnant women with SARS-CoV-2 who have given birth and reference group from Dutch Perinatal Registry.

***Odds Ratio between pregnant women with SARS-CoV-2 who were symptomatic at birth and reference group from Dutch Perinatal Registry.
reported studies are facility-based.\textsuperscript{9,23} Population-based registration studies into SARS-CoV-2 in pregnancy performed so far all from members of the International Obstetric Survey System Network (INOSS). This highlights the importance of a registration system such as NethOSS, which enables rapid data collection, for instance in the case of a pandemic.

An increased risk of caesarean section after labour-onset was demonstrated in SARS-CoV-2-infected women, especially when they had symptoms at birth. Similar increases have been reported in the UK, Italy and New York City.\textsuperscript{9,23,24} This might be due to increased caution of the attending physician or presence of specific background characteristics such as high BMI and pre-existing disease, which increase the risk of both SARS-CoV-2 infection and caesarean section. Neonatal outcomes in our study were reassuring and similar to results in other studies.\textsuperscript{8}

To guide therapy and vaccination policies in the vulnerable group of pregnant women, especially subgroups at risk of severe disease, international individual patient data meta-analysis based on robust population-based data is warranted within INOSS, where in 17 countries uniform data on hospital-admitted SARS-CoV-2-positive pregnant women were collected. Long-term consequences of SARS-CoV-2 infection for women and their babies remain unknown and information is urgently needed.\textsuperscript{25–29}

### Conclusions

It is increasingly clear that pregnant women may comprise a vulnerable group in the COVID-19 pandemic. In the Netherlands, not being of European country origin and being overweight or obese were risk factors for hospital admission. Infected women had higher odds of being

### Table 4. Neonatal characteristics

| Level of care          | Neonates of women with SARS-CoV-2 (N = 295) n (%) | Pregnant pre-COVID-19 cohort neonates\(^*\) (N = 201 000) n (%) | OR (95% CI)** Pregnant women with SARS-CoV-2 compared with pregnant pre-COVID-19 cohort neonates |
|------------------------|--------------------------------------------------|----------------------------------------------------------|-------------------------------------------------------------------------------------------|
| No hospital admission  | 231 (83)                                          | 108 106 (70)                                             | 2.12 (1.55–2.91)                                                                         |
| Neonatal ward          | 47 (17)                                           | 40 675 (26)                                              | 0.57 (0.42–0.78)                                                                         |
| NICU (total)           | 7 (3)                                             | 6030 (4)                                                 | 0.64 (0.30–1.35)                                                                         |
| Missing                | 17                                                | 46 189                                                   |                                                                                          |
| 5-minute Apgar score   |                                                   |                                                         |                                                                                          |
| ≤4                     | 2 (1)                                             | 2944 (2)                                                 | 0.55 (0.14–2.21)                                                                         |
| 5–7                    | 8 (3)                                             | 4739 (3)                                                 | 1.04 (0.51–2.10)                                                                         |
| ≥8                     | 262 (96)                                          | 159 314 (95)                                             | 1.26 (0.67–2.38)                                                                         |
| Missing                | 23                                                | 34 003                                                   |                                                                                          |
| Perinatal deaths (during labour or postpartum <28 days) | 0                                                | 121 (0.06)                                               |                                                                                          |
| Birthweight (median, IQR)** |                                                 |                                                         |                                                                                          |
| **Median              | 3519                                              | 3440                                                    |                                                                                          |
| **IQR 25               | 3008                                              | 3080                                                    |                                                                                          |
| **IQR 75               | 3762                                              | 3775                                                    |                                                                                          |
| **Missing              | 17                                                | 16 521                                                   |                                                                                          |
| Culture                |                                                   |                                                         |                                                                                          |
| High vaginal tested    | 21 (9)                                            | N/A                                                     |                                                                                          |
| Positive               | 1 (5)                                             | N/A                                                     |                                                                                          |
| Amniotic fluid tested  | 7 (3)                                             | N/A                                                     |                                                                                          |
| Positive               | 1 (14)                                            | N/A                                                     |                                                                                          |
| Neonate tested         | 24 (10)                                           | N/A                                                     |                                                                                          |
| Positive               | 0                                                 | N/A                                                     |                                                                                          |
| Missing                | 50                                                | N/A                                                     |                                                                                          |

IQR, interquartile range; N/A, not applicable.

\(^*\)Reference group of neonates from pregnant women in the Dutch Perinatal Registry (Perined) between 1 March 2017 and 1 March 2018.

\(^**\)Odds ratio between neonates of women with SARS-CoV-2 and reference group from the Dutch Perinatal Registry.

\(^***\)Birthweight in grams.
induced or giving birth by caesarean section. Pregnant and postpartum women infected with SARS-CoV-2 appear to be at higher risk of hospital and ICU admission compared with SARS-CoV-2-negative women in the same age group. Pregnant women should therefore be advised to adhere to social distancing and early testing and registration should be facilitated. Moreover, pregnant women with SARS-CoV-2 infection should be closely monitored, particularly in presence of additional risk factors, and long-term follow-up studies are warranted.

Disclosure of interests
The authors report no conflict of interest.

Contribution to authorship
EO and KB designed the study. EO wrote the first draft of the manuscript. EO and AR carried out the analyses. EO, AR, JZ, TS, TvDA and KB contributed to the development and conduct of the study. EO, AR, JZ, TV, TS, TvDA and KB contributed to interpretation of data, and edited and approved the final version of the article.

Details of ethical approval
All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The NethOSS registration system is part of the National Perinatal Registry foundation in the Netherlands (Perined). This study did not require specific ethical approval and informed consent of participants was not obtained because Perined is allowed administrative permission in the Netherlands to access patient information from patient charts if the information used is not personally identifiable, concerns large numbers of participants and it is not feasible to trace and contact individual participants.

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Supporting Information
Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure S1. Number of SARS-CoV-2-infected pregnant women each week.

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