A review of 92 obstetric patients with COVID-19 in the Bronx, New York and their peripartum anaesthetic management

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Abstract

Background: The Bronx is a borough of New York City that has been profoundly affected by the COVID-19 pandemic. Limited reports exist discussing the anaesthetic management of obstetric patients infected with COVID-19. We review a cohort of obstetric patients in the Bronx with COVID-19 and report their delivery data, anaesthetic management, and maternal-fetal outcomes.

Material and methods: We reviewed 92 pregnant patients with laboratory-confirmed severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) who delivered between 1 February 2020 and 1 May 2020. Medical records were reviewed for patient characteristics, anaesthetic management, and clinical outcomes. Patients were stratified by mode of delivery and COVID-19 disease severity.

Results: Of the 92 deliveries, 49 (53%) were vaginal, 14 (15%) were scheduled caesareans, and 29 (32%) were unscheduled caesareans. 64 patients (70%) were asymptomatic for COVID-19 (mild disease: 18 patients [19%], moderate disease: 7 patients [8%], severe disease: 2 patients [2%], critical disease: 1 patient [1%]). 83 patients (90%) received neuraxial analgesia and/or anaesthesia, with combined spinal-epidural (CSE) and dural puncture epidural (DPE) as the most common techniques. 5 patients (5%) required general anaesthesia (GA) for caesarean delivery, 3 (3%) of whom were intubated for severe or critical COVID-19 disease.

Conclusions: Given the risks associated with SARS-CoV-2 aerosol transmission, GA was avoided in all but the most critically ill patients. CSE and DPE were optimal for minimizing catheter failure rates and risk of conversion to GA. SARS-CoV-2 infection in obstetric patients may be associated with an increased risk for adverse outcomes including pre-eclampsia, preterm delivery, unscheduled caesarean delivery, and mechanical ventilation.

Key words: caesarean section, COVID-19, obstetric anaesthesia.

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Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was first reported in New York City (NYC) on 1 March 2020 [1]. NYC was one of the earliest and most profoundly impacted cities in the United States (US) by the COVID-19 pandemic, which continues to be a global crisis. As of 1 December 2020, NYC has recorded more than 290,000 confirmed cases and 19,000 deaths [2].

The Bronx is a borough of NYC and has been the most devastated by COVID-19, with case rates considerably higher than its sister boroughs of Manhattan, Brooklyn, Queens, and Staten Island [3]. The borough is also home to the poorest congressional district in the US [4], and has a higher proportion of racial and ethnic minorities compared to the other NYC boroughs [3]. Socioeconomic disparities have played a major role in increased COVID-related mortality witnessed in the Bronx [5]. Investigating the outcomes of COVID-19 in this vulnerable population at the "epicentre of the epicentre" of disease in the US is critical for our understanding of the complete impact of the COVID-19 pandemic.

Given the historically adverse outcomes associated with the previous severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus (MERS-CoV) epidemics during pregnancy [6], COVID-19 infection

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in obstetric patients is of particular concern. High rates of complications including preterm delivery, intrauterine growth restriction (IUGR), and maternal death have been reported, as well as an increased case fatality rate compared to non-pregnant patients [6]. Despite increasing literature regarding the epidemiology, presentation, and management of COVID-19 disease across most subspecialties, there are only limited reports discussing the anaesthetic implications and subsequent management of obstetric patients infected with COVID-19 [7–12].

The purpose of this study was to explain the anaesthetic management and maternal-fetal outcomes in a cohort of pregnant patients carrying the diagnosis of SARS-CoV-2 who were admitted during the early months of the COVID-19 pandemic to labour and delivery (L&D) units within one of the busiest hospital systems in NYC.

METHODS

Study design and participants

A historical review of medical records was conducted on pregnant patients with concomitant SARS-CoV-2 infection admitted to the L&D units at Montefiore Medical Center's Jack D. Weiler Hospital and Wakefield Hospital in the Bronx, New York, USA from 1 February 2020 to 1 May 2020. This study was approved by the Albert Einstein College of Medicine Montefiore Medical Center Institutional Review Board (069109). The requirement for written informed consent was waived by the Institutional Review Board. Diagnosis of COVID-19 infection was defined as an on-site laboratory-confirmed positive SARS-CoV-2 result on reverse transcription polymerase chain reaction (RT-PCR) of a nasopharyngeal sample obtained during the hospital stay. All obstetric patients admitted to the L&D unit who tested positive for SARS-CoV-2 were included in this study. Changes to hospital policy were made during the investigation period on 2 April 2020, prompting universal screening of patients admitted for delivery upon entry to the emergency department (ED) or L&D triage. Prior to the implementation of universal screening, patients received an RT-PCR test based on exhibited symptoms and/or risk factors for COVID-19 disease. All newborns received 2 RT-PCR tests for SARS-CoV-2, using nasopharyngeal samples obtained 24 hours and 72 hours after delivery.

Initial guidance regarding the care of obstetric patients testing positive for SARS-CoV-2, including contact precautions, staff training, heightened emphasis of early placement of neuraxial analgesia for labour, and overall considerations for general anaesthesia (GA) were influenced by recommendations set by the Society for Obstetric Anesthesia and Perinatology, first published on 15 March 2020 [13].

Data collection

We conducted a manual review of medical records for all COVID-affected patients ($n = 92$) for information on demographic data, presenting symptoms and vital signs, anaesthetic management, inpatient medications, anticoagulation protocol, clinical outcomes, and imaging studies. Clinical outcomes (e.g. acute kidney injury [AKI], acute respiratory distress syndrome [ARDS]) were reported as defined by the treating physician. We used Clinical Looking Glass proprietary hospital software to collect laboratory data. Patients were stratified into groups based on mode of delivery and COVID-19 disease severity. Modes of delivery included vaginal delivery, scheduled caesarean delivery, and unscheduled caesarean delivery. Disease severity (asymptomatic, mild, moderate, severe, critical) was determined by clinical and laboratory parameters, as defined by criteria set by the World Health Organization (Appendix 1) [14].

Statistical analysis

No sample size was calculated given that all individuals with a diagnosis of COVID-19 during the aforementioned timeframe were included in this study. All patient data were de-identified and compiled in a secured Microsoft Excel spreadsheet. Statistical analysis was performed with Microsoft Excel. Continuous variables were expressed as median (25^{th}–75^{th} percentile; range) and categorical variables were expressed as number/total number (%). ANOVA was used to compare continuous variables and $\chi 2$ tests were used to compare categorical variables. All tests were two-sided and *P*-values < 0.05 were considered to have statistical significance.

RESULTS

Patient characteristics

Between 1 February 2020 and 1 May 2020, 1694 obstetric patients were delivered at Jack D. Weiler Hospital and Wakefield Hospital. Among those, 92 patients (5%) tested positive for SARS-CoV-2 infection. Of the 92 patients, 49 (53%) had vaginal deliveries, 14 (15%) had scheduled caesarean deliveries, and 29 (32%) had unscheduled caesarean deliveries (Table 1). The majority of patients identified as Hispanic or Latino (45 patients [49%]) or Black/non-Hispanic (26 patients [28%]).

The most common comorbidities were hypertension (14 patients [15%]), diabetes (11 patients [12%]), and asthma (10 patients [11%]). Additional comorbidities are shown in Table 1. There was no significant difference in frequency of comorbidities between cohorts stratified by mode of delivery.

Laboratory values were obtained from patients during their hospital stay (Table 2). Median values

TABLE 1. Demographic data on COVID-positive obstetric patients stratified by mode of delivery

Characteristic	Total ($n = 92$)	Vaginal ($n = 49$)	Scheduled Caesarean ($n = 14$)	Unscheduled Caesarean ($n = 29$)	*P*-value
	Median (25th–75th percentile; range)				
Age, years	30 (25–35; 19–42)	28 (24–31; 19–41)	36 (33–37; 27–19)	32 (29–37; 23–42)	< 0.001*
Gestational age at presentation, weeks	38 (36–39; 19–41)	39 (38–39; 19–41)	39 (38–39; 35–39)	36 (33–38; 25–40)	0.027*
BMI, kg m^{-2}	32 (29–37; 21–56)	33 (29–38; 21–47)	30 (28–32; 24–39)	34 (30–35; 21–56)	0.18
	No./total no. (%)				
Race/ethnicity					
Hispanic or Latino	45/92 (49)	23/49 (47)	8/14 (57)	14/29 (48)	0.79
Black/non-Hispanic or Latino	26/92 (28)	15/49 (31)	3/14 (22)	8/29 (28)	0.79
Asian/non-Hispanic or Latino	3/92 (3)	2/49 (4)	1/14 (7)	0/29 (0)	0.26
White/non-Hispanic or Latino	1/92 (1)	0/49 (0)	0/14 (0)	1/29 (3)	0.47
Declined to report	17/92 (19)	9/49 (18)	2/14 (14)	6/29 (21)	0.87
Past medical history					
Asthma	10/92 (11)	5/49 (10)	0/14 (0)	5/29 (17)	0.27
COPD	0/92 (0)	0/49 (0)	0/14 (0)	0/29 (0)	1
Hypertension	14/92 (15)	7/49 (14)	1/14 (7)	6/29 (21)	0.48
Diabetes	11/92 (12)	5/49 (10)	1/14 (7)	5/29 (17)	0.61
Kidney disease	3/92 (3)	1/49 (2)	1/14 (7)	1/29 (3)	0.57
Cancer[a]	1/92 (1)	0/49 (0)	1/14 (7)	0/29 (0)	0.15
Thyroid disease	4/92 (4)	1/49 (2)	2/14 (14)	1/29 (3)	0.14
Autoimmune disease	0/92 (0)	0/49 (0)	0/14 (0)	0/29 (0)	1

[a]Patient had a history of stage II breast cancer, status post neoadjuvant chemotherapy, radiation therapy, and mastectomy.
*$P \leq 0.05$
BMI – body mass index, COPD – chronic obstructive pulmonary disease

TABLE 2. Laboratory values obtained from COVID-positive obstetric patients stratified by COVID-19 disease severity

Laboratory value	Total ($n = 92$)	Asymptomatic ($n = 64$)	Mild ($n = 18$)	Moderate ($n = 7$)	Severe ($n = 2$)	Critical ($n = 1$)	*P*-value
	Median (25th–75th percentile; range)						
Albumin, g dL^{-1}	3.3 (3–3.6; 2.4–4.1)	3.4 (3–3.6; 2.4–4.1)	3.3 (3.1–3.7; 3–4)	3.1 (2.9–3.3; 2.5–3.5)	3.1 (2.8–3.4; 2.4–3.6)	2.2 (2.1-2.4; 2-3.4)	0.082
Creatinine, mg dL^{-1}	0.59 (0.5–0.7; 0.34–1.49)	0.59 (0.5–0.7; 0.4–1.49)	0.6 (0.49–0.66; 0.34–0.81)	0.73 (0.63–0.78; 0.34–0.79)	0.58 (0.48–0.61; 0.41–0.69)	0.63 (0.59-0.69; 0.44-0.95)	0.6
D-dimer, µg mL^{-1}	1.99 (1.54–3.21; 0.43–13.91)	1.99 (1.63–2.86; 0.43–10.55)	3.85 (3.74-4.7; 1.39–13.91)	1.52 (1.42–1.61; 1.32–1.71)	1.49[a]	N/A	0.0019*
Fibrinogen, mg dL^{-1}	510 (458–633; 202–861)	505 (455–638; 202–861)	516 (440–610; 363–678)	594 (555–634; 515–673)	472[b]	469	0.82
Haemoglobin g dL^{-1}	10.7 (9.3–11.5; 7.2–13.5)	10.6 (9.2–11.3; 7.2–13.5)	10.7 (9.7–11.6; 7.8–13.1)	10.8 (10.3–11.3; 9.3–11.8)	10.7 (10.3–11.7; 9.6–13.2)	8.9 (8.3-9.5; 7.6-12.2)	0.84
WBC, G L^{-1}	7.7 (6.7–10.1; 4.3–21.6)	8.1 (6.8–10.7; 4.3–17.5)	7.2 (6.6–9.2; 4.4–12.4)	10 (7.5–13; 6.4-21.6)	7.3 (6.4–10.8; 3.8–16.7)	8.4 (8.25-8.7; 7.4-10.3)	0.1
Platelets G L^{-1}	220 (182–263; 55–473)	223 (188–265; 55–473)	204 (156–237; 103–373)	246 (176–261; 146–398)	168 (138–187; 105–231)	155 (152-183; 141-205)	0.44

[a]D-dimer was obtained for one patient who had severe disease. [b]Fibrinogen was obtained for one patient who had severe disease.
*$P \leq 0.05$
N/A – not applicable, WBC – white blood cells

for albumin, creatinine, fibrinogen, haemoglobin, WBC count, and platelet count were all within normal physiologic limits for pregnant women [15], with no significant variance between groups strati-

fied by disease severity. The highest WBC count (21.6 G L^{-1}) was recorded in a patient with moderate COVID disease and bilateral interstitial pneumonia. The lowest platelet counts were recorded in 1 patient diagnosed with benign gestational thrombocytopenia (platelets: 55 G L^{-1}) and 1 patient diagnosed with HELLP syndrome (platelets: 74 G L^{-1}). Both patients with thrombocytopenia were asymptomatic for COVID-19 disease. Median D-dimer values were elevated across all levels of disease severity, with the highest elevations noted in patients with mild disease.

Presenting symptoms

Upon admission to the L&D unit, the most common symptoms were cough (23 patients [25%]), shortness of breath (11 patients [12%]), and fever (10 patients [11%]) (Table 3). Patients who underwent unscheduled caesarean delivery presented with these symptoms at a greater frequency than those who underwent scheduled caesarean delivery or vaginal delivery. 64 patients (70%) were asymptomatic upon initial presentation, with more asymptomatic patients in the vaginal and scheduled caesarean groups compared to the unscheduled caesarean group.

Anaesthetic management

In our cohort, 83 patients (90%) received neuraxial labour analgesia or surgical anaesthesia prior to delivery. Combined spinal-epidural (CSE) and dural puncture epidural (DPE) were the most common techniques used across all modes of delivery. In the unscheduled caesarean group, 11 patients (38%) received neuraxial labour analgesia for trials of labour prior to caesarean delivery. All epidural catheters placed for neuraxial labour analgesia in this group were successfully converted for surgical anaesthesia without necessitating replacement, and the remainder of patients who did not receive neuraxial labour analgesia had de-novo epidural catheters placed in the operating room (OR) for CSE anaesthesia.

Five patients (5%) ultimately required caesarean delivery under GA, all of whom were in the un-

TABLE 3. Presenting COVID-19 symptoms upon admission and COVID-19 disease severity stratified by mode of delivery

Characteristic	Total ($n = 92$)	Vaginal ($n = 49$)	Scheduled Caesarean ($n = 14$)	Unscheduled Caesarean ($n = 29$)	*P*-value
	No./total no. (%)				
Symptom					
Fever	10/92 (11)	2/49 (4)	1/14 (7)	7/29 (24)	0.017*
Chills	5/92 (5)	2/49 (4)	0/14 (0)	3/29 (10)	0.43
Cough	23/92 (25)	9/49 (18)	2/14 (14)	12/29 (41)	0.046*
Sore throat	4/92 (4)	1/49 (2)	1/14 (7)	2/29 (7)	0.47
Rhinorrhoea	6/92 (7)	2/49 (4)	1/14 (7)	3/29 (10)	0.52
Congestion	9/92 (10)	2/49 (4)	2/14 (14)	5/29 (17)	0.12
Anosmia/ageusia	5/92 (5)	0/49 (0)	0/14 (0)	5/29 (17)	0.004*
Chest pain	2/92 (2)	0/49 (0)	1/14 (7)	1/29 (3)	0.22
Shortness of breath	11/92 (12)	2/49 (4)	1/14 (7)	8/29 (28)	0.0067*
Headache	7/92 (8)	1/49 (2)	0/14 (0)	6/29 (21)	0.011*
Dizziness/light headedness	0/92 (0)	0/49 (0)	0/14 (0)	0/29 (0)	1
Vision changes	0/92 (0)	0/49 (0)	0/14 (0)	0/29 (0)	1
Abdominal pain/cramps	2/92 (2)	1/49 (2)	0/14 (0)	1/29 (3)	0.99
Nausea	3/92 (3)	1/49 (2)	0/14 (0)	2/29 (7)	0.57
Vomiting	3/92 (3)	1/49 (2)	0/14 (0)	2/29 (7)	0.42
Diarrhoea	1/92 (1)	1/49 (2)	0/14 (0)	0/29 (0)	1
Disease severity					
Asymptomatic	64/92 (70)	39/49 (80)	10/14 (71)	15/29 (52)	0.035*
Mild	18/92 (19)	8/49 (16)	4/14 (29)	6/29 (21)	0.59
Moderate	7/92 (8)	2/49 (4)	0/14 (0)	5/29 (17)	0.079
Severe	2/92 (2)	0/49 (0)	0/14 (0)	2/29 (7)	0.12
Critical	1/92 (1)	0/49 (0)	0/14 (0)	1/29 (3)	0.47

*$P \leq 0.05$

TABLE 4. Anaesthetic management of COVID-positive obstetric patients stratified by COVID-19 disease severity

Characteristic	Total ($n = 92$)	Asymptomatic ($n = 64$)	Mild ($n = 18$)	Moderate ($n = 7$)	Severe ($n = 2$)	Critical ($n = 1$)	*P*-value
	No./total no. (%)						
Vaginal	$n = 49$	$n = 39$	$n = 8$	$n = 2$	$n = 0$	$n = 0$	
Spinal[a]	1/49 (2)	1/39 (3)	0/8 (0)	0/2 (0)	0/0 (0)	0/0 (0)	0.35
Epidural (labour analgesia)	4/49 (8)	4/39 (10)	0/8 (0)	0/2 (0)	0/0 (0)	0/0 (0)	0.89
CSE (labour analgesia)	25/49 (51)	19/39 (49)	4/8(50)	2/2 (100)	0/0 (0)	0/0 (0)	0.09
DPE (labour analgesia)	14/49 (29)	10/39 (26)	4/8 (50)	0/2 (0)	0/0 (0)	0/0 (0)	0.6
None (labour analgesia)	5/49 (10)	5/39 (13)	0/8 (0)	0/2 (0)	0/0 (0)	0/0 (0)	0.68
Scheduled Caesarean	$n = 14$	$n = 10$	$n = 4$	$n = 0$	$n = 0$	$n = 0$	
Spinal (surgical anaesthesia)	1/14 (7)	0/10 (0)	1/4 (25)	0/0 (0)	0/0 (0)	0/0 (0)	0.62
Epidural (surgical anaesthesia)	0/14 (0)	0/10 (0)	0/4 (0)	0/0 (0)	0/0 (0)	0/0 (0)	1
CSE (surgical anaesthesia)	13/14 (93)	10/10 (100)	3/4 (75)	0/0 (0)	0/0 (0)	0/0 (0)	0.62
DPE (surgical anaesthesia)	0/14 (0)	0/10 (0)	0/4 (0)	0/0 (0)	0/0 (0)	0/0 (0)	1
GA	0/14 (0)	0/10 (0)	0/4 (0)	0/0 (0)	0/0 (0)	0/0 (0)	1
Unscheduled Caesarean	$n = 29$	$n = 15$	$n = 6$	$n = 5$	$n = 2$	$n = 1$	
Spinal (labour analgesia)	0/29 (0)	0/15 (0)	0/6 (0)	0/5 (0)	0/2 (0)	0/1 (0)	1
Epidural (labour analgesia)	0/29 (0)	0/15 (0)	0/6 (0)	0/5 (0)	0/2 (0)	0/1 (0)	1
CSE (labour analgesia)	6/29 (21)	6/15 (40)	0/6 (0)	0/5 (0)	0/2 (0)	0/1 (0)	0.13
DPE (labour analgesia)	5/29 (17)	3/15 (20)	2/6 (33)	0/5 (0)	0/2 (0)	0/1 (0)	0.58
None (labour analgesia)	18/29 (62)	6/15 (40)	4/6 (67)	5/5 (100)	0/2 (0)	0/1 (0)	0.71
Spinal (surgical anaesthesia)	4/29 (14)	1/15 (7)	1/6 (17)	2/5 (40)	0/2 (0)	0/1 (0)	0.75
Epidural (surgical anaesthesia)	1/29 (3)	1/15 (7)	0/6 (0)	0/5 (0)	0/2 (0)	0/1 (0)	0.36
CSE (surgical anaesthesia)	15/29 (52)	9/15 (60)	3/6 (50)	3/5 (60)	0/2 (0)	0/1 (0)	0.44
DPE (surgical anaesthesia)	5/29 (17)	3/15 (20)	2/6 (33)	0/5 (0)	0/2 (0)	0/1 (0)	0.58
GA	5/29 (17)	2/15 (13)	0/6 (0)	0/5 (0)	2/2 (100)	1/1 (100)	0.89
Medications							
Antepartum corticosteroids	10/92 (11)	6/64 (9)	3/18 (17)	0/7 (0)	1/2 (50)	0/1 (0)	0.71
Intrapartum antibiotics	74/92 (80)	54/64 (84)	11/18 (61)	6/7 (86)	2/2 (100)	1/1 (100)	0.09
Anticoagulation	27/92 (29)	14/64 (22)	5/18 (28)	3/7 (43)	2/2 (100)	0/1 (0)	0.89

[a]Patient experienced precipitous labour and delivered in the hospital lobby without labour analgesia. Spinal anaesthesia was subsequently administered for operative repair of cervical laceration sustained during delivery.
CSE – combined spinal-epidural, DPE – dural puncture epidural, GA – general anaesthesia

scheduled caesarean group (Table 4). Two of those patients were asymptomatic for COVID-19 disease, 2 had severe disease, and 1 had critical disease. Of the 2 asymptomatic patients, 1 patient initially received CSE for surgical anaesthesia and was subsequently converted to GA after needing emergent hysterectomy for placenta percreta in the setting of significant postpartum haemorrhage. The other asymptomatic patient underwent delivery under GA secondary to rapidly falling low platelet count associated with HELLP syndrome, which ultimately contraindicated neuraxial placement.

Of the 2 patients with severe COVID-19 disease, both were admitted to the hospital due to respiratory distress and pre-emptively intubated for caesarean delivery under GA before further respiratory decompensation could occur. The 1 patient with critical COVID-19 disease was initially admitted for expectant management with intravenous insulin for euglycaemic diabetic ketoacidosis (DKA) and observation in the setting of mild COVID-19 symptoms. However, the patient's respiratory status rapidly deteriorated, necessitating emergent intubation and subsequent caesarean delivery under GA. All 3 patients with severe or critical COVID-19 disease were intubated by the anaesthesiology team in the OR and underwent caesarean delivery immediately after induction. Following delivery, all 3 patients were transferred to the intensive care unit (ICU), where they remained on mechanical ventilation. The 2 patients with severe disease were extubated within the same day and the 1 patient with critical disease was extubated 2 days postpartum. All 3 patients were ultimately discharged in medically stable condition, with no subsequent hospital readmissions (Table 5).

TABLE 5. Maternal outcomes stratified by mode of delivery

Characteristic	Total ($n = 92$)	Vaginal ($n = 49$)	Scheduled Caesarean ($n = 14$)	Unscheduled Caesarean ($n = 29$)	*P*-value
	No./total no. (%)				
Complications					
Preeclampsia					
Total	26/92 (28)	12/49 (24)	3/14 (21)	11/29 (38)	0.37
Preeclampsia w/o SF	12/92 (13)	7/49 (14)	0/14 (0)	5/29 (17)	0.30
Preeclampsia w/ SF	6/92 (7)	2/49 (4)	2/14 (14)	2/29 (7)	0.29
Superimposed preeclampsia w/o SF	3/92 (3)	1/49 (2)	0/14 (0)	2/29 (7)	0.57
Superimposed preeclampsia w/ SF	5/92 (5)	2/49 (4)	1/14 (7)	2/29 (7)	0.70
Gestational diabetes	17/92 (19)	9/49 (18)	2/14 (14)	6/29 (21)	0.87
Stroke	0/92 (0)	0/49 (0)	0/14 (0)	0/29 (0)	1
Pulmonary embolism	0/92 (0)	0/49 (0)	0/14 (0)	0/29 (0)	1
PPROM	5/92 (5)	2/49 (4)	0/14 (0)	3/29 (10)	0.43
Placental abruption	2/92 (2.3)	1/49 (2)	0/14 (0)	1/29 (3)	0.99
Placenta previa	1/92 (1.1)	0/49 (0)	0/14 (0)	1/29 (3)	0.47
Chorioamnionitis	7/92 (7.6)	6/49 (12)	0/14 (0)	1/29 (3)	0.30
Endometritis	3/92 (3.3)	3/49 (6)	0/14 (0)	0/29 (0)	0.41
Postpartum haemorrhage	14/92 (15.2)	5/49 (10)	3/14 (21)	6/29 (21)	0.37
Sepsis	1/92 (1.1)	0/49 (0)	0/14 (0)	1/29 (3)	0.47
DIC	0/92 (0)	0/49 (0)	0/14 (0)	0/29 (0)	1
ARDS	2/92 (2.3)	0/49 (0)	0/14 (0)	2/29 (7)	0.12
Acute kidney injury	3/92 (3.3)	1/49 (2)	1/14 (7)	1/29 (3)	0.57
Pneumonia	10/92 (10.9)	2/49 (4)	0/14 (0)	8/29 (28)	0.0029*
ICU admission	3/92 (3.3)	0/49 (0)	0/14 (0)	3/29 (10)	0.053
Mechanical ventilation	3/92 (3.3)	0/49 (0)	0/14 (0)	3/29 (10)	0.053
Hospital re-admission	2/92 (2.3)	0/49 (0)	1/14 (7)	1/29 (3)	0.22
Maternal death	0/92 (0)	0/49 (0)	0/14 (0)	0/29 (0)	1
Pregnancy length					
Term (> 37 weeks)	67/92 (73)	42/49 (86)	12/14 (86)	14/29 (48)	< 0.001*
Preterm (34–37 weeks)	25/92 (27)	2/49 (4)	2/14 (14)	6/29 (21)	0.053
Preterm (< 34 weeks)	17/92 (19)	5/49 (10)	0/14 (0)	9/29 (31)	0.015*
	Median (25^{th} - 75^{th} percentile; range)				
Length of stay, days	3 (2–4; 2–19)	3 (2–3; 2–5)	3 (2–3; 2–5)	4 (3–6; 2–19)	0.0017*

*$P \leq 0.05$

SF – severe features, PPROM – preterm premature rupture of membranes, DIC – disseminated intravascular coagulation, ARDS – acute respiratory distress syndrome, ICU – intensive care unit

Antepartum corticosteroids, intrapartum antibiotics, and anticoagulants were used in 10 (11%), 74 (80%), and 27 (29%) patients, respectively (Table 4). There was no significant difference in frequency of usage of these medications between groups when stratified by disease severity.

Maternal and fetal outcomes

The most common obstetric complication was preeclampsia (26 patients [28%]) (Table 5). Other common obstetric complications included gestational diabetes (17 patients [19%]) and postpartum haemorrhage (14 patients [15%]). Ten patients (11%) were diagnosed with pneumonia, most of whom underwent unscheduled caesarean delivery. No patient in our cohort suffered from stroke, deep vein thrombosis (DVT), pulmonary embolism (PE), or disseminated intravascular coagulation (DIC) during delivery hospitalization. After discharge, 2 patients (2%) were readmitted to the hospital, both for complications of preeclampsia. No maternal deaths occurred during delivery hospitalization and all patients were ultimately discharged home.

Of the 92 deliveries, 25 newborn infants (27%) required admission to the neonatal intensive care unit (NICU) (Table 6). Eight infants (9%) were diag-

nosed with intrauterine growth restriction (IUGR) and 4 (4%) had a 5-minute Apgar score less than 7. Two infants (2%) experienced respiratory distress after delivery. Infants born to patients in the unscheduled caesarean group were more likely to have been preterm deliveries, with 31% of unscheduled caesarean deliveries (9/29 deliveries) occurring prior to 34 weeks gestation compared to 10% of vaginal deliveries (5/49 deliveries) (Table 5). There were 0 (0%) documented instances of SARS-CoV-2 vertical transmission amongst our cohort, and 2 (2%) fetal deaths. The first fetal death was an intrauterine fetal demise at 29 weeks gestation secondary to chronic hypertension and superimposed preeclampsia complicated by HELLP syndrome. The second fetal death was a miscarriage at 19 weeks gestation. Both patients who experienced fetal deaths underwent inductions of labour with DPE for labour analgesia.

Eight patients in the unscheduled caesarean group had a length of stay (LOS) greater than 5 days, including the 3 patients who were intubated for caesarean delivery under GA for rapidly worsening COVID-19 disease. Details of their presentation, anaesthetic management, laboratory test results, and outcomes are shown in Appendix 2.

TABLE 6. Fetal outcomes

Complication	No./total no. (%)
NICU admission	25/92 (27)
IUGR	8/92 (9)
5-minute Apgar score < 7	4/92 (4)
Respiratory distress	2/92 (2)
SARS-CoV-2 vertical transmission	0/92 (0)
Fetal death	2/92 (2)

NICU – neonatal intensive care unit, IUGR – intrauterine growth restriction

DISCUSSION

In this study, we report the anaesthetic management and short-term maternal-fetal outcomes in a cohort of 92 obstetric patients in the Bronx, New York, USA who tested positive for SARS-CoV-2.

Outcomes and complications

Caesarean section was the primary mode of delivery in the symptomatic COVID-19 patients within our cohort, with a greater caesarean delivery rate than the New York State (NYS) average [16]. A significant number of these caesarean deliveries were unscheduled secondary to complications from preeclampsia, COVID-related pneumonia, or both. Nearly every patient with pneumonia underwent unscheduled caesarean delivery, 3 of whom experienced hypoxic respiratory decompensation ultimately necessitating intubation and delivery under GA.

Preeclampsia was the most common complication, with rates in our cohort greater than rates in the general population on a nationwide, statewide, and citywide level [17-19]. Existing literature has documented a potential association between preeclampsia and coronavirus infection in pregnancy [6]. Although higher rates of preeclampsia are seen among patients in the Bronx [20], SARS-CoV-2 infection must be considered as a potential contributor to the rates of preeclampsia above baseline levels in our cohort.

Increased rates of preterm delivery were also observed in our cohort compared to general populations without COVID-19 in NYS and NYC [20, 21]. A majority of these preterm births occurred in the unscheduled caesarean group, which had a higher proportion of patients with moderate to critical disease. These findings support existing studies documenting an increase in preterm deliveries in patients with symptomatic COVID-19 disease [7, 8]. Likely attributable to the increased rate of preterm births, NICU admissions were also elevated compared to NICU admission rates in the general population [22].

Existing research has demonstrated possible evidence for vertical transmission of SARS-CoV-2 infection [23]. Within our cohort, SARS-CoV-2 was not detected in any newborn following delivery.

Asthma, hypertension, and diabetes were the most common comorbidities among patients in our cohort. Rates of these comorbidities were consistent with rates of asthma, hypertension, and diabetes in the general population of adults without COVID-19 aged 18-49 in NYC [24–26]. Although it is well established that these comorbidities are associated with increased mortality and decreased survival in COVID-19 disease [27], they were not correlated with an increased frequency of negative outcomes in our obstetric patient cohort.

Anaesthetic management

Nearly every patient in our obstetric cohort received neuraxial anaesthesia. Given the risks associated with SARS-CoV-2 aerosol transmission during invasive endotracheal procedures [28], GA was avoided in all but the most critically ill of patients. Since reliance on spinal anaesthesia confers the additional risk of conversion to GA if the block wears off intraoperatively, CSE and DPE (in which epidural catheters are maintained for the duration of anaesthetic delivery) were the preferred techniques in patients who underwent caesarean delivery. When compared to plain epidural analgesia/anaesthesia (which was rarely used in our cohort), CSE and DPE have lower rates of maternal and fetal side effects,

decreased time to analgesia, and improved quality of block [29]. Catheter failure is also less common in CSE and DPE compared to epidural anaesthesia wherein CSF confirmation is not obtained [30]. Although CSE and DPE have similarly low failure rates, placement success of CSE catheters remains uncertain in the first 1–2 hours after the patient receives an immediate intrathecal provision of analgesia. Thus, we found added security in performing DPE – especially at a teaching institution – wherein failed catheters can be promptly identified, troubleshot, and replaced if necessary.

Anticoagulation protocol

Postpartum D-dimer levels were elevated in our cohort, raising concern for an increased risk of coagulopathy and thromboembolic events – already a heightened concern given the physiologic hypercoagulable state of pregnancy. Despite having no formalized anticoagulation protocol for COVID-positive patients during the timeframe studied (Montefiore protocols were ultimately implemented on 4 May 2020), none of our cohort patients developed thrombotic complications such as deep vein thrombosis (DVT), pulmonary embolus (PE), or stroke. Anticoagulation protocols for pregnant patients carrying a COVID-positive diagnosis are at the institutions' discretion. However, many have used low-molecular weight heparin or other anticoagulant medications carrying the potential to preclude the safe provision of neuraxial analgesia in urgent situations. Multidisciplinary collaboration is pivotal whenever anticoagulation is introduced in the pregnant population, and even more so in the context of COVID-19, where concerns for appropriate anaesthetic management have considerable implications for both patient and healthcare worker safety. COVID-positive patients who have received prophylactic and/or therapeutic anticoagulation may ultimately require emergency provision of GA (with subsequent potential for increased SARS-CoV-2 exposure to healthcare workers via aerosolization), or could be given neuraxial placement in close proximity to having received anticoagulation agents (portending increased risk of spinal and/or epidural hematoma). Given our findings of zero COVID-positive patients in our cohort developing thrombotic complications during their peripartum stay, we recommend further study examining the overall utility of anticoagulation protocols for the entirety of COVID-positive pregnant patients (i.e. the necessity of anticoagulating those with asymptomatic presentations), and suggest that future decisions to initiate anticoagulation in this context be made on a case-by-case basis.

Limitations

Our findings must be interpreted in the context of several limitations. The evolving nature of the COVID-19 pandemic and the disproportionate burden it placed on hospitals in NYC meant that testing protocols and availability of testing materials and personal protective equipment changed on a near-daily basis. Unsurprisingly, the implantation of universal testing protocols midway through the investigation period increased the detection of asymptomatic COVID patients within our obstetric population. Had these protocols been implemented from the beginning of the study, it is likely that more patients would have been included, and a greater proportion of these may likely have been asymptomatic carriers.

We did not compare our cohort with a control group, and the number of patients with severe or critical COVID disease was limited. Further analysis with a larger sample size and a control group will be necessary to account for confounding variables. Additionally, D-dimer and fibrinogen were not obtained among all patients. Given their elevated risk for thromboembolic events, obtaining D-dimer and fibrinogen for every obstetric patient who tested positive for SARS-CoV-2 would have been beneficial.

Finally, due to the demands of the pandemic, most patients and newborn infants did not receive in-person follow-up after their hospital stay, and greater follow-up will be necessary to ascertain the long-term sequelae of COVID-19 disease in pregnancy. Medical records confirmed the zero rate of hospital readmissions to Montefiore Medical Center, though we cannot confirm that any of these patients may have presented to another institution.

CONCLUSIONS

Given the number of patients discovered to be asymptomatic carriers of COVID-19, universal testing is critical for the containment of the disease and protection of patients and staff in settings with high disease prevalence. Pregnant patients and their families must be advised to take extreme caution in avoiding SARS-CoV-2 infection due to the increased risk for adverse outcomes including preeclampsia, preterm labour, unscheduled caesarean delivery, and invasive mechanical ventilation. Regular check-ups of pregnant women are warranted during the prenatal period and in L&D to identify those most vulnerable to contracting COVID-19 and suffering disease complications. Considering the number of obstetric patients who will likely be infected with SARS-CoV-2 in the future, reporting the details of their anaesthetic management and outcomes carries significant importance for the provision of effective and evidence-based care.

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APPENDIX 1. World Health Organization (WHO) COVID-19 disease severity

Mild disease		Symptomatic patients meeting the case definition for COVID-19 without evidence of viral pneumonia or hypoxia. See the WHO website for most up-to-date case definitions.
Moderate disease	**Pneumonia**	Adolescent or adult with clinical signs of pneumonia (fever, cough, dyspnoea, fast breathing) but no signs of severe pneumonia; including $SpO_2 \geq 90\%$ on room air. While the diagnosis can be made on clinical grounds, chest imaging (radiograph, CT scan, ultrasound) may assist in diagnosis and identify or exclude pulmonary complications.
Severe disease	**Severe pneumonia**	Adolescent or adult with clinical signs of pneumonia (fever, cough, dyspnoea, fast breathing) plus one of the following: respiratory rate > 30 breaths min^{-1}; severe respiratory distress; or $SpO_2 < 90\%$ on room air. While the diagnosis can be made on clinical grounds, chest imaging (radiograph, CT scan, ultrasound) may assist in diagnosis and identify or exclude pulmonary complications.
Critical disease	**Acute respiratory distress syndrome (ARDS)**	**Onset:** within 1 week of a known clinical insult (i.e. pneumonia) or new or worsening respiratory symptoms. **Chest imaging:** (radiograph, CT scan, or lung ultrasound): bilateral opacities, not fully explain by volume overload, lobar or lung collapse, or nodules. **Origin of pulmonary infiltrates:** respiratory failure not fully explained by cardiac failure or fluid overload. Objective assessment (e.g. echocardiography) necessary to exclude hydrostatic cause of infiltrates/oedema if no risk factor present. **Oxygen impairment in adults:** • **Mild ARDS:** 200 mm Hg $< PaO_2/FiO_2$[a] $\leq$ 300 mm Hg (with PEEP or CPAP ≥ 5 cm H_2O). • **Moderate ARDS:** 100 mm Hg $< PaO_2/FiO_2 \leq$ 200 mm Hg (with PEEP ≥ 5 cm H_2O)[b]. • **Severe ARDS:** $PaO_2/FiO_2 \leq$ 100 mm Hg (with PEEP > 5 cm H_2O)[b].
Critical disease	**Sepsis**	**Adults:** acute life-threatening organ dysfunction caused by a dysregulated host response to suspected or proven infection. Signs of organ dysfunction include: altered mental status, difficult or fast breathing, low oxygen saturation, reduced urine output, fast heart rate, weak pulse, cold extremities or low blood pressure, skin mottling, laboratory evidence of coagulopathy, thrombocytopenia, acidosis, high lactate, or hyperbilirubinemia.
	Septic shock	**Adults:** persistent hypotension despite volume resuscitation, requiring vasopressors to maintain MAP $\geq$ 65 mm Hg and serum lactate level > 2 mmoL L^{-1}.
Other complications that have been described in COVID-19 patients include acute, life-threatening conditions such as acute pulmonary embolism, acute coronary syndrome, acute stroke and delirium. Clinical suspicion for these complications should be heightened when caring for COVID-19 patients, and appropriate diagnostic and treatment protocols should be available.		

Obtained from "Clinical management of COVID-19: interim guidance" published by WHO on 27 May 2020.

[a]If altitude is higher than 1000 m, then the correction factor should be calculated as follows: PaO_2/FiO_2 x barometric pressure/760. [b]When PaO2 is not available, $SpO_2/FiO_2 \leq 315$ suggests ARDS (including in non-ventilated patients).

CT – computed tomography, PaO_2 – partial pressure arterial oxygen, FiO_2 – fraction of inspired oxygen, PEEP – positive end-expiratory pressure, CPAP – continuous positive airway pressure, MAP – mean arterial pressure, SpO_2 – oxygen saturation

APPENDIX 2. Profile of 8 obstetric patients with symptomatic COVID-19 disease and LOS > 5 days

Factor	1	2	3	4	5	6	7	8
Age (years)	42	35	30	41	31	23	39	32
BMI	34.36	50.13	33.66	31.34	30.21	29.69	43.6	30.11
Race	Black/non-Hispanic or Latino	White/non-Hispanic or Latino	Black/non-Hispanic or Latino	Black/non-Hispanic or Latino	Hispanic or Latino	Hispanic or Latino	Declined to report	Hispanic or Latino
Gravida, Para	G5P4004	G6P3023	G4P2012	G5P3104	G1P0000	G2P1001	G11P4064	G1P0000
Gestational age	34w0d	33w3d	34w2d	36w0d	39w0d	40w0d	34w2d	36w1d
Comorbidities	HTN, T2DM	Asthma, DVT w/ IVC filter, seizures	None	T2DM	None	None	HTN, T2DM	None
ASA score	3	3	4	4	3	3	3	4
COVID-19 disease severity	Mild	Severe	Severe	Critical	Moderate	Moderate	Mild	Moderate
Mode of delivery	Unscheduled caesarean	Unscheduled caesarean	Unscheduled caesarean	Unscheduled caesarean	Unscheduled caesarean	Unscheduled caesarean	Unscheduled caesarean	Unscheduled caesarean
Reason for IOL	Worsening COVID	Worsening COVID	Worsening COVID	Worsening COVID	Worsening COVID	Existing COVID pneumonia & contractions (no labour)	Worsening PEC w/ SF	Worsening COVID
Labour analgesia	N	N	N	N	N	N	N	N
Surgical anaesthesia	Y (spinal)	Y (GA)	Y (GA)	Y (GA)	Y (spinal)	Y (CSE)	Y (CSE)	Y (spinal)
Respiratory support	None	Invasive mechanical ventilation	Invasive mechanical ventilation	Invasive mechanical ventilation	None	4L NC	None	2L NC
Hydroxychloroquine	Y	Y	Y	Y	Y	Y	N	Y
Remdesivir	N	N	N	N	N	N	N	N
Anticoagulation	Y	Y	Y	Y	Y	Y	Y	Y
Albumin	3	2.4	2.7	None	3	2.9	3	3.5
Creatinine	0.65	0.44	0.58	0.4	0.7	0.76	0.51	0.79
D-dimer	None	1.49	None	None	None	None	None	1.71
Fibrinogen	430	None	472	None	None	None	None	673
WBC	5.1	6	4.5	5.1	6.4	10	6.6	13
Haemoglobin	11.6	10.4	9.8	7.8	9.7	10.9	9.7	10.8
Platelets	156	135	113	308	398	157	347	261
Pneumonia	N	Y	Y	Y	Y	Y	N	Y
Sepsis	N	N	N	Y	N	N	N	N
Respiratory failure	N	N	Y	Y	N	N	N	N
AKI	N	N	N	N	N	N	N	N
DIC	N	N	N	N	N	N	N	N
Preeclampsia	Y (superimposed PEC w/o SF)	N	N	N	N	Y (PEC w/o SF)	Y (Superimposed PEC w/ SF)	N
Gestational diabetes	Y	N	N	Y	N	N	Y	N
Fetal complications	None	None	None	None	None	None	None	None
LOS	10	6	7	6	5	8	5	6
Outcome	Home	Home	Home	Home	Home	Home	Home	Home

LOS – length of stay, BMI – body mass index, N/A – not applicable, HTN – hypertension, T2DM – type II diabetes mellitus, IVC – inferior vena cava, ASA – American Society of Anesthesiologists, IOL – induction of labour, PEC – preeclampsia, SF – severe features, w/ – with; w/o – without, GA – general anaesthesia, SE – combined spinal-epidural, Y – yes, N – no, NC – nasal cannula, WBC – white blood cells, AKI – acute kidney injury, DIC – disseminated intravascular coagulation