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Original Article

Hemodynamic changes in patients with SARS-CoV-2 infection presenting for cesarean delivery under spinal anesthesia: a retrospective case-control study

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ABSTRACT

Background: Coronavirus disease 2019 (COVID-19) is associated with adverse maternal and neonatal outcomes. Early studies suggested that COVID-19 was associated with a higher incidence of hypotension following neuraxial anesthesia in parturients. We explored the hemodynamic response to spinal anesthesia for cesarean delivery in pregnant severe respiratory distress syndrome-coronavirus-2 (SARS-CoV-2) positive patients, using a retrospective case-control design.

Methods: We searched our electronic medical records for patients who received spinal anesthesia for cesarean delivery, and were SARS-CoV-2 positive or recovered at delivery, and used historical and SARS-CoV-2 negative controls from two tertiary care hospitals. We compared the demographic, clinical, and hemodynamic variables between patients who were SARS-CoV-2 positive at delivery, those who were positive during pregnancy and recovered before delivery, and controls. Analyses were stratified by normotensive versus hypertensive status of the patients at delivery.

Results: We identified 22 SARS-CoV-2 positive, 73 SARS-CoV-2 recovered, and 1517 controls. The SARS-CoV-2 positive, and recovered pregnant patients, had on average 5.6 and 2.2 mmHg, respectively, higher post-spinal mean arterial pressures (MAPs) than control patients, adjusting for covariates. Additionally, the lowest post-spinal MAP was negatively correlated with the number of days between the onset of COVID-19 symptoms and delivery in patients with hypertension (correlation −0.55, 95% CI −0.81 to −0.09).

Conclusions: Patients with SARS-CoV-2 infection during pregnancy exhibit less spinal hypotension than non-infected patients. While the clinical significance of this finding is unknown, it points to important cardiovascular effects of the virus.

Introduction

Coronavirus disease 2019 (COVID-19) in pregnancy, caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is associated with adverse maternal and neonatal outcomes, including increased risk for preterm delivery, cesarean delivery, and overall maternal morbidity and mortality.[1–6] The increased cesarean delivery rate has been attributed to critical maternal status, especially severe COVID-19 and preeclampsia.[4,6] Increased COVID-19 severity is associated with higher odds of adverse peripartum outcomes.[5]

Neuraxial anesthesia is the preferred mode of anesthesia for cesarean delivery, and this is especially true for pregnant patients with COVID-19. Neuraxial anesthesia has a superior maternal and neonatal safety profile and avoids the risks of SARS-CoV-2 aerosolization associated with tracheal intubation and extubation.[7,8] Early studies from China reported a higher incidence of hypotension with neuraxial anesthesia in pregnant patients with COVID-19 compared with non-

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infected individuals, however, detailed hemodynamic data are not available.[9,10] COVID-19 is characterized by systemic inflammatory symptoms and multi-organ involvement, including abnormal cardiovascular and hypertensive responses. Spinal anesthesia, the anesthetic technique of choice for elective cesarean delivery, can cause maternal hypotension in up to 74% of cases.[11] While spinal anesthesia is safe in patients with COVID-19,[12] no detailed data are available regarding the hemodynamic response to spinal anesthesia in SARS-CoV-2 positive pregnant patients.

In this study, we investigated if there are any differences in blood pressure responses (primary outcome) associated with spinal anesthesia in pregnant patients positive for SARS-CoV-2 at delivery or during pregnancy, compared with historical and SARS-CoV-2 negative controls, at two tertiary care hospitals in Boston and using a retrospective case-control study design. We also investigated vasopressor use, demographic and clinical covariates (secondary outcomes). As published studies have reported an increased incidence of hypotension, we hypothesized that patients positive for SARS-CoV-2 at delivery would have lower blood pressure and a higher likelihood of hemodynamic instability following spinal anesthesia.

Methods

This study was approved by the Mass General Brigham Institutional Review Board (#2020P001573) with a waiver of patient consent.

We conducted a retrospective electronic health record (EHR) review of all patients who tested positive for SARS-CoV-2 during their pregnancy or at the time of admission for delivery. The institutions implemented universal SARS-CoV-2 testing on all admitted patients, starting on April 19, 2020. Patients were identified from the group of individuals who delivered at Brigham and Women's and Massachusetts General Hospitals from March 2020 to August 2021. In addition, the hospital's research data repository was searched for patients with pregnancy or delivery, hyperbaric bupivacaine, cesarean delivery, and SARS-CoV-2 positive status. Patients with neuraxial labor analgesia were not included. SARS-CoV-2 positivity was ascertained by the evidence of a laboratory-confirmed positive SARS-CoV-2 result on reverse transcription polymerase chain reaction (RT-PCR) nasal swab before and up to three days after delivery. We reviewed the entire record, including the six-week postpartum visit, to classify patients with SARS-CoV-2 infection accurately.

All patients having spinal anesthesia for cesarean delivery and testing SARS-CoV-2 positive status during pregnancy or at the time of admission for delivery were included. Controls were pregnant patients who delivered in the period from October 2018 to August 2021, for whom data from prior unpublished studies was available.[13] Patients were excluded if modes of anesthesia other than spinal (general, epidural, or combined spinal-epidural anesthesia with activation of the epidural) were used. We reviewed and excluded patients with inaccuracies in their records, such as unexplained changes in the vital signs with no corresponding vasopressor charted. In addition, we excluded patients who had other causes for blood pressure changes, such as receipt of intra-operative labetalol or syncope during spinal placement.

The routine anesthesia care for cesarean delivery in our hospitals is provided as follows. Upon admission, an 18-gauge peripheral intravenous catheter is placed. Premedication is administered, including oral sodium citrate 30 mL, metoclopramide 10–20 mg, and lactated Ringer's solution 500 mL given over 20 min intravenously. On arrival in the operating room, patients are positioned upright and standard monitors are applied, including non-invasive blood pressure measured every 1–2 min. Vital signs data are recorded automatically into the EHR. Spinal or combined spinal-epidural (CSE) anesthesia is administered through a 25-gauge Whitacre (and 17-gauge Weiss epidural respectively) needle using 0.75% hyperbaric bupivacaine 1.2 mL (9 mg) - 2.0 mL (15 mg) with fentanyl 0.3 mL (15 μg) and preservative-free morphine 0.1 mL (100 μg) - 0.2 mL (200 μg). The patient is placed supine with a left lateral tilt created by a wedge placed under the right hip, and the adequacy of the tilt is determined by at least two clinicians. At the time of the spinal injection, a rapid bolus of 500 mL lactated Ringer's solution is administered. A T4 sensory level to pinprick is achieved before surgery commences. Administration of vasopressors is at the anesthesiologist's discretion. The patients receive either a prophylactic phenylephrine infusion or boluses of phenylephrine and/or ephedrine. Phenylephrine is the first-choice vasopressor administered, with ephedrine given primarily when hypotension is accompanied by bradycardia.

The following demographic and clinical data were collected from the admission history and physical notes: age, height, weight, race, ethnicity, gravidity, parity, gestational age (in weeks and days), presence of contractions, or spontaneous rupture of membranes (documented in the obstetrician's note), comorbidities, and outpatient medications. The anesthesia record was used to obtain hemodynamic variables, recorded as time series data in intervals of one minute of systolic blood pressure, diastolic blood pressure, and heart rate from the pulse oximeter; and medications bupivacaine, phenylephrine, and ephedrine with doses recorded as the total amount of medication (both bolus and infusion) administered in periods of one minute. Intraoperative data taken from the anesthesia record included the period of 5 min before the spinal injection and 20 min after injection or until delivery, whichever came first.

Data analyses were performed using R version 4.1.0 (https://www.R-project.org). Given the retrospective nature of the investigation, no sample size analysis was performed, and we included all patients who met the study criteria. We analyzed the cohort and subsequently performed sensitivity analyses for the normotensive and hypertensive patients. The hypertensive patients had any of the following diagnoses: chronic hypertension, gestational hypertension, and preeclampsia, as determined by their clinician based on the standard of care.[14]

All analyses were performed globally and then separately on each cohort due to the differential response of each cohort to vasopressors.[15] In each cohort, there were three groups: (1) patients who were SARS-CoV-2 positive at the time of the delivery (SARS-CoV-2 +); (2) patients who were SARS-CoV-2 positive during the pregnancy but recovered before the delivery (SARS-CoV-2 R); (3) patients who delivered prior to the pandemic or were SARS-CoV-2 negative (Control). The severity of COVID-19 was abstracted from the medical chart as determined by the clinician based on the World Health Organization (WHO) COVID-19 disease severity classification.[16] Missing blood pressure values were interpolated or extended at the end. Continuous variables were expressed as median (25th-75th percentile), and categorical variables were expressed as number (%). Comparisons of continuous variables between groups were performed using the Kruskal-Wallis Rank Sum test, and categorical variables were based on Fisher's exact test. The pre-delivery mean arterial pressure (MAP) and heart rate were averaged over the five-minute period before the intrathecal injection. Vasopressor use was expressed in phenylephrine equivalents, which was the total amount of phenylephrine with ephedrine, using the potency ratio of 81 between phenylephrine and ephedrine.[17] Linear mixed-effects models were used to evaluate the relationship between time, measured blood pressure, administered phenylephrine, and clinical covariates. Correlations between highest/lowest MAP after the spinal and lowest heart rate values with COVID-19 severity, days since positive SARS-CoV-2 result, or the days since COVID-19 was diagnosed, were analyzed using the Pearson correlation coefficient.

Results

Between March 2020 and August 2021, 98 patients received spinal anesthesia for cesarean delivery and tested positive for SARS-CoV-2

either during pregnancy or at the time of admission for delivery. Of those, two patients were excluded due to unsuccessful spinal anesthesia and the need to convert to epidural anesthesia, and one patient was excluded due to an incomplete medical record. The remaining 95 patients were included in the study. Of those, 78 patients were normotensive, and 17 were hypertensive. Of all 95 patients, 38 (40.0%) patients self-identified as White, 18 (19.0%) as Black, 2 (2.1%) as Asian and 37 (38.9%) as other/unknown. The self-identified ethnicity was 36 (37.9%) Hispanic, 51 (53.7%) non-Hispanic, and eight (8.4%) other/unknown. During the pregnancy and postpartum period, 20 patients had asymptomatic disease, 68 patients had mild disease, and six had severe COVID-19 with inpatient hospitalization.

The characteristics of all patients are summarized in Table 1. Of the 95 SARS-CoV-2 patients included in the study, 22 patients were SARS-CoV-2 positive at delivery, and 73 were SARS-CoV-2 recovered. Of the controls, there were 1436 SARS-CoV-2 presumed negative patients who delivered before and 81 SARS-CoV-2 negative patients who delivered during the pandemic. The SARS-CoV-2 positive and recovered patients had a higher body mass index (BMI) ($P < 0.001$), parity ($P = 0.001$), gestational diabetes incidence ($P = 0.0017$), and delivered earlier than the controls ($P = 0.005$). A linear mixed-effects model of the mean arterial pressure (MAP) (Table 2) demonstrated that the SARS-CoV-2 positive and recovered patients had 5.6 mmHg and 2.2 mmHg higher MAP, respectively, compared with the control patients. There was also a significant effect of the hypertensive status, and we performed sensitivity analyses for normotensive and hypertensive patients.

Normotensive patient cohort

The characteristics of the normotensive patients are listed in Supplemental Table 1. There were 17 patients who were SARS-CoV-2 positive at delivery and 61 who were SARS-CoV-2 recovered. The SARS-CoV-2 recovered patients had a higher BMI ($P = 0.001$) and higher parity ($P = 0.007$) than the control patients.

Hemodynamically, the SARS-CoV-2 positive and recovered patients exhibited higher average MAPs compared with the control patients (Fig. 1A). In addition, for the SARS-CoV-2 positive and recovered patients, the lowest MAP after spinal anesthesia was higher than that of the control patients ($P < 0.001$, Fig. 1B). A linear mixed-effects regression model demonstrated that the SARS-CoV-2 positive and recovered patients had 5.3 and 2.5 mmHg higher MAPs, respectively,

Table 1
Study patient characteristics

	SARS-CoV-2+ (n = 22)	SARS-CoV-2R (n = 73)	Control (n = 1517)	*P*-value
Age (y)	33.5 (28.2–35.0)	33.0 (30.0–37.0)	34.0 (32.0–37.0)	0.07
Body mass index (kg/m^2)	32.6 (30.5–36.8)	32.6 (29.1–37.3)	30.0 (26.9–33.8)	<0.001*#
Gravidity	3.0 (2.0–4.0)	3.0 (2.0–4.0)	2.0 (2.0–4.0)	0.171
Parity	1.5 (1.0–2.0)	1.0 (1.0–2.0)	1.0 (0.0–1.0)	0.001*#
Gestational age at delivery (weeks)	38.1 (35.5–39.0)	38.1 (37.0–39.1)	39.0 (37.4–39.3)	0.005*#
Contractions	3 (13.6%)	8 (11.0%)	285 (18.8%)	0.215
Spontaneous rupture of membranes	4 (18.2%)	7 (9.6%)	144 (9.5%)	0.349
Gestational diabetes	3 (13.6%)	15 (20.5%)	151 (10.0%)	0.017*#
Diabetes type 2	0 (0.0%)	2 (2.7%)	11 (0.7%)	0.185
Insulin use	0 (0.0%)	10 (13.7%)	81 (5.3%)	0.002#
Depression/anxiety	5 (22.7%)	20 (27.4%)	309 (20.4%)	0.029#
Intrathecal bupivacaine (mg)	13.5 (12 – 13.5)	13.5 (12 – 13.5)	13.5 (12 – 13.5)	0.213
Number of patients on phenylephrine infusion	20 (90.9%)	68 (93.2%)	1346 (88.7%)	0.715

Median (IQR) for continuous variables; n (%) for categorical variables; *P*-values for continuous variables based on Kruskal-Wallis Rank Sum test; for categorical variables based on Fisher's exact test.
SARS-CoV-2 +: patients who were SARS-CoV-2 positive at the time of the delivery.
SARS-CoV-2 R: patients who were SARS-CoV-2 positive during pregnancy and recovered before delivery.
Control: patients who delivered prior to the pandemic or were SARS-CoV-2 negative.
Post-hoc analysis based on pair-wise comparison with *P*-value < 0.05: * SARS-CoV-2 + vs Control and SARS-CoV-2 R vs Control. # significant comparing all three groups.

Table 2
Linear mixed-effects regression model of mean arterial pressures

	Coefficient (difference in MAP)	95% CI	*P*-value
Control (n = 1517) vs SARS-CoV-2 + (n = 22)	−5.626	−8.386 to −2.865	<0.001
SARS-CoV-2 R (n = 73) vs SARS-CoV-2 + (n = 22)	−3.385	−6.408 to −0.362	0.006
SARS-CoV-2 R (n = 73) vs Control (n = 1517)	2.240	0.642 to 3.839	0.006
Hypertensive status	9.299	6.182 to 12.415	<0.001
Bupivacaine intrathecal dose	−4.504	−7.513 to −1.494	0.003
Body mass index	0.173	0.115 to 0.232	<0.001
Parity	−0.479	−0.808 to −0.150	0.004
Contractions	−0.597	−1.479 to 0.285	0.185
Spontaneous rupture of membranes	0.747	−0.398 to 1.893	0.201
Gestational diabetes	0.748	−0.552 to 2.048	0.260
Time since spinal administration	−0.582	−0.593 to −0.571	<0.001
Total phenylephrine per 1000 μg increase	−2.284	−3.041 to −1.528	<0.001
Insulin use	−0.311	−2.016 to 1.394	0.721
Depression/anxiety	0.558	−0.212 to 1.328	0.155

SARS-CoV-2 +: patients who were SARS-CoV-2 positive at the time of the delivery.
SARS-CoV-2 R: patients who were SARS-CoV-2 positive during pregnancy and recovered before delivery. Control: patients who delivered prior to the pandemic or were SARS-CoV-2 negative.

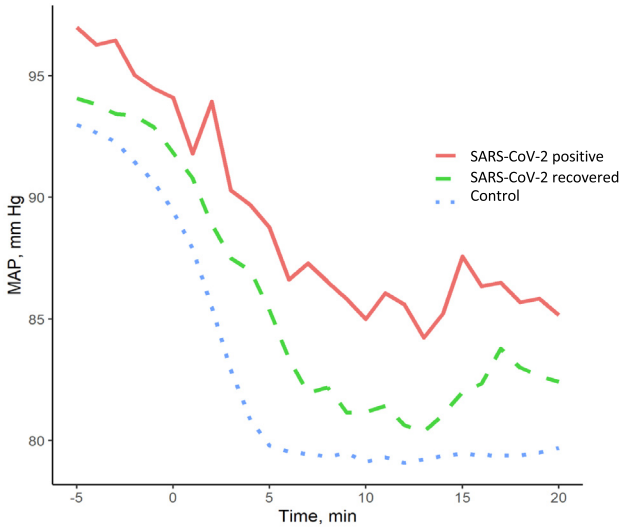

Fig. 1A. Intra-operative blood pressure course in the normotensive cohort. Mean arterial pressures (MAP) in the three groups, averaged for all patients in each group: the spinal anesthesia is administered at time 0. SARS-CoV-2 positive: patients who were SARS-CoV-2 positive at the time of the delivery. SARS-CoV-2 recovered: patients who were SARS-CoV-2 positive during pregnancy and recovered before delivery. Control: patients who delivered prior to the pandemic or were SARS-CoV-2 negative

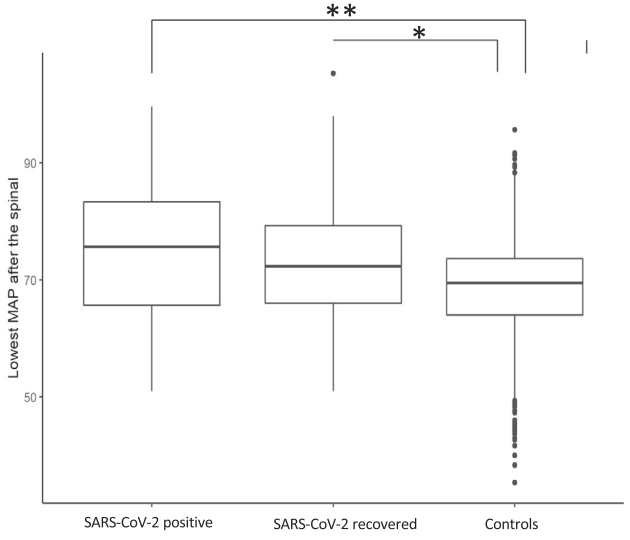

Fig. 1B. Comparison of the lowest mean arterial pressures (MAP) after spinal anesthesia in the normotensive patient cohort. SARS-CoV-2 positive: patients who were SARS-CoV-2 positive at the time of the delivery. SARS-CoV-2 recovered: patients who were SARS-CoV-2 positive during pregnancy and recovered before delivery. Control: patients who delivered prior to the pandemic or were SARS-CoV-2 negative. Comparison based on Kruskal-Wallis Rank Sum test comparison between all three groups ($P = 0.0003$); Pairwise comparisons: SARS-CoV-2 positive vs SARS-CoV-2 recovered ($P = 0.420$), SARS-CoV-2 positive vs Control ($P = 0.015$) SARS-CoV-2 recovered vs. Control ($P = 0.001$)

compared with the control patients, adjusted for multiple covariates (Supplemental Table 2).

Further analysis of the hemodynamic variables showed that the highest measured MAP after spinal anesthesia was highest in the SARS-CoV-2 positive patients ($P < 0.05$, Supplemental Table 3). There was no association between the hemodynamic variables and COVID-19 severity, the days since a positive SARS-CoV-2 result, or the days since COVID-19 was diagnosed.

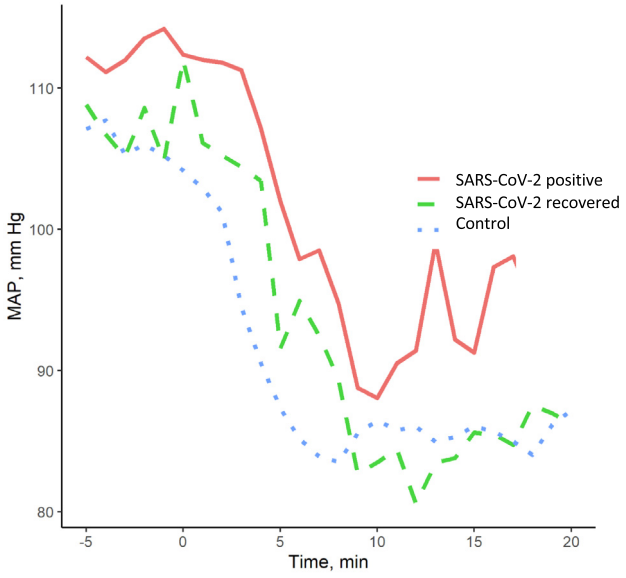

Fig. 2A. Intra-operative blood pressure course in the hypertensive cohort. Mean arterial pressures (MAP) in the three groups, averaged for all patients in each group: the spinal anesthesia is administered at time 0. SARS-CoV-2 positive: patients who were SARS-CoV-2 positive at the time of the delivery. SARS-CoV-2 recovered: patients who were SARS-CoV-2 positive during pregnancy and recovered before delivery. Control: patients who delivered prior to the pandemic

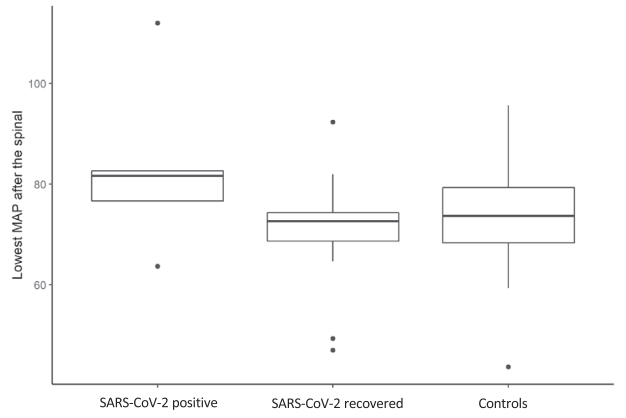

Fig. 2B. Comparison of the lowest mean arterial pressures (MAP) after spinal anesthesia in the hypertensive patient cohort. SARS-CoV-2 positive: patients who were SARS-CoV-2 positive at the time of the delivery. SARS-CoV-2 recovered: patients who were SARS-CoV-2 positive during pregnancy and recovered before delivery. Control: patients who delivered prior to the pandemic

Hypertensive patient cohort

Characteristics of the hypertensive patients are listed in Supplemental Table 4. This group includes five patients who were SARS-CoV-2 positive at delivery, 12 who were SARS-CoV-2 recovered, and 49 who were SARS-CoV-2 presumed negative controls. The SARS-CoV-2 positive and recovered patients had a higher incidence of contractions ($P < 0.001$) and a higher incidence of gestational diabetes, depression, and anxiety ($P = 0.02$). There was no significant differ-

ence between the groups for the average MAP after the spinal anesthetic (Fig. 2A and Fig. 2B). A linear mixed-effects regression model of the MAPs did not reach significance (Supplemental Table 5). There was also no difference in the hemodynamic variables (Supplemental Table 6). There was a negative correlation between the lowest MAP after the spinal anesthetic and the days between the onset of SARS-CoV-2 infectious symptoms and delivery, such that the patients with more recent infection had higher MAPs (correlation −0.55, 95% CI −0.81 to −0.09).

Discussion

In this study, we report the patient characteristics and hemodynamic response to spinal anesthesia for cesarean delivery in 95 obstetric patients with SARS-CoV-2 infection during pregnancy attending two tertiary care hospitals.

We report a milder degree of post-spinal hypotension in patients with SARS-CoV-2 infection during pregnancy compared with control patients. These results contrast with two studies from China done early in the pandemic that included presumed unvaccinated patients. A small study reported that 86% of the COVID-19 patients (n = 12) who received epidural anesthesia experienced severe hypotension.[9] Another study reported a 15.5% higher incidence of hypotension with neuraxial anesthesia in parturients with COVID-19 compared with propensity score-matched control parturients.[10] Lack of detailed hemodynamic and vasopressor data in both studies makes comparisons with our results difficult, and it is possible that those differences are due to different methodological, technical, and pharmacological approaches to spinal anesthesia, as well as prevention and treatment of hypotension. In addition, these studies were done early in the pandemic when patients had more severe disease, while our patients had a primarily mild or asymptomatic infection.

Our findings of less post-spinal hypotension in patients with SARS-CoV-2 infection may be related to the overall effect of the virus on the cardiovascular system, resulting in blood pressure elevation due to endothelial damage. Sudden blood pressure surges have been reported in pregnant or postpartum normotensive SARS-CoV-2 positive patients.[18] Another possible explanation of the observed differences in blood pressure response to spinal anesthesia is anxiety. In healthy patients, anxiety is associated with a more significant reduction in blood pressure after spinal anesthesia.[19] In non-pregnant hypertensive patients, pandemic-related stress led to higher blood pressure.[20] In pregnant patients, COVID-19 has been associated with increased generalized anxiety scores.[21] Further studies are needed to elucidate the role of COVID-associated anxiety and its effect on post-spinal hypotension.

Both lowest and highest MAP after the onset of spinal anesthesia was higher in SARS-CoV-2 positive patients compared with controls, but the total number of vasopressor doses did not differ significantly between the groups, suggesting that the effect on MAP was not due to over-treatment of the infected group. Both the SARS-CoV-2 positive and recovered patients followed similar hemodynamic trajectories, implying that the viral effects on the blood pressure may persist even after the active infection is resolved. A similar pattern was observed in the hypertensive cohort, however the comparisons did not reach statistical significance due to the small number of patients. The effect of the viral infection on the MAP was small, and the clinical significance is unknown. One possible implication of this finding is that there may be a slightly lower vasopressor requirements in SARS-CoV-2 positive or recovered patients.

The effects of COVID-19 on blood pressure control have been studied both in pregnant women and non-pregnant adults. In addition to the higher risk of preeclampsia associated with COVID-19, other hypertensive disorders also have been described. Preeclampsia-like syndrome, [22] postpartum atypical posterior reversible encephalopathy syndrome (PRES),[18] and eclampsia/PRES[23] have also been described in patients with COVID-19 and seem to share a common pathophysiology. Similarly, in normotensive patients infected with SARS-CoV-2, systolic and diastolic blood pressure increased more than that of non-infected adults during exercise.[24] Chronic hypertension may be a sequela of COVID-19.[25] A possible mechanism for SARS-CoV-2-associated vascular injury and hypertension is vasoconstriction resulting from the dysfunction of the renin-angiotensin system.[26–28] Moreover, SARS-CoV-2 infection may lead to changes in numerous signaling pathways associated with increased blood pressure in pregnant women.[29].

Strengths of this study include a large patient sample from two tertiary care centers and data obtained directly from the EHR. The information about SARS-CoV-2-positivity was based on RT-PCR nasal swab testing, and patients had detailed documentation about the type and onset of COVID-19 symptoms, pregnancy history, and comorbidities. The hemodynamic data, also obtained from EHR, were highly accurate since, in both institutions, vital signs are inserted automatically from the monitors into the patient's chart.

This study also has some limitations. We initiated universal screening for all pregnant patients on April 19, 2020, so we may have missed several early patients with asymptomatic or mild infection. While most patients had regular blood pressure monitoring either during office visits or at home, 5% of patients considered normotensive did not have blood pressures measured in the office prenatally. Thus, it is possible that diagnosis of mild hypertensive diseases of pregnancy may have been missed. To ensure precise phenotyping of hypertensive patients, the records of all patients were screened for postpartum preeclampsia or any elevated blood pressures, and no additional cases were identified. The effects of asymptomatic SARS-CoV-2 infection are unknown;[30] 21% of the study patients were asymptomatic, with the diagnosis ascertained only as a result of universal screening. Similarly, COVID-19 symptoms may persist up to 12 weeks during pregnancy,[31] and the pathophysiology of long COVID-19 is not yet well understood. Due to the study's retrospective nature, the management of spinal hypotension was at the discretion of the anesthesiologist. To account for the differences in the clinical management, the difference in MAPs before the administration of spinal anesthesia, and comorbidities, we adjusted for these variables in the linear mixed-effects models. It is unknown if there were any differences in the fluid load of the patients. There were no exclusions of patients from the study based on the intrathecal morphine dose. We acknowledge the selection of a historical control group in which most patients delivered before the pandemic (overlap of 81 normotensive SARS-CoV-2 negative patients) as a limitation. However, this was done to minimize the risk of misclassification of asymptomatic patients who were not tested and the advantage of a large control patient sample that was already available. The patients in this study were managed differently regarding the anesthesia staffing: the SARS-CoV-2 positive-at-delivery patients were managed by attending anesthesiologists or senior residents, while the SARS-CoV-2 recovered received routine care, similar to the historical controls. While it is possible that providers managed blood pressure in patients with SARS-CoV-2 infection more aggressively, we did not find higher doses of vasopressor use in those patients, and we believe that the records are accurate based on our chart review. Thus, we suspect that there were no significant clinical management differences in the administration of spinal anesthesia and management of hypotension between the patients in all cohorts.

In summary, patients with SARS-CoV-2 infection during pregnancy exhibit slightly less spinal hypotension at delivery than non-infected patients. While the clinical significance of this finding is unknown, it points to important cardiovascular effects of the virus. Clinicians should consider the risk of higher intra-operative blood pressure to avoid overtreatment with vasopressors. Further studies are needed to investigate the mechanisms by which SARS-CoV-2 infection affects blood pressure regulation, response to spinal anesthesia, and vasopres-

sors during pregnancy. Future research should also explore the long-term sequelae of SARS-CoV-2 infection and the association with hemodynamic variables.

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Declaration of interests

KJG has served as a consultant to Illumina Inc., Aetion, Roche, and BillionToOne outside the scope of the submitted work. VPK reports consulting fees from Avania CRO unrelated to the current work.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijoa.2022.103624.

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