# Spinal Anesthesia-Induced Hypotension: A Risk Comparison Between Patients with Severe Preeclampsia and Healthy Women Undergoing Preterm Cesarean Delivery

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We previously showed that, in comparison with term healthy parturients, patients with severe preeclampsia had a less frequent incidence of spinal hypotension, which was less severe and required less ephedrine. In the present study, we hypothesized that these findings were attributable to preeclampsia-associated factors rather than to a smaller uterine mass. The incidence and severity of hypotension were compared between severe preeclamptics ($n = 65$) and parturients with preterm pregnancies ($n = 71$), undergoing spinal anesthesia for cesarean delivery (0.5% bupivacaine, sufentanil, morphine). Hypotension was defined as the need for ephedrine (systolic blood pressure <100 mm Hg in parturients with preterm fetuses or 30% decrease in mean blood pressure in both groups). Apgar scores and umbilical arterial blood pH were also studied. Neonatal and placental weights were similar between the groups. Hypotension was less frequent in preeclamptic patients than in women with preterm pregnancies (24.6% versus 40.8%, respectively, $P = 0.044$). Although the magnitude of the decrease in systolic, diastolic, and mean arterial blood pressure was similar between groups, preeclamptic patients required less ephedrine than women in the preterm group to restore blood pressure to baseline levels (9.8 ± 4.6 mg versus 15.8 ± 6.2 mg, respectively, $P = 0.031$). The risk of hypotension in the preeclamptic group was almost 2 times less than that in the preterm group (relative risk = 0.603; 95% confidence interval, 0.362–1.003; $P = 0.044$). The impact of Apgar scores was minor, and umbilical arterial blood pH was not affected. We conclude that preeclampsia-associated factors, rather than a smaller uterine mass, account for the infrequent incidence of spinal hypotension in preeclamptic patients.

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Spinal anesthesia is often the preferred technique of anesthesia for cesarean delivery (1). Although there is some controversy, it has been reported that it is suitable for use in preeclamptic patients (2,3), even in cases with a nonreassuring fetal heart rate (HR) pattern (4). Hypotension may occur as a side effect of this anesthetic technique. In a previous study, we compared the incidence and magnitude of spinal anesthesia-associated hypotension in severely preeclamptic versus healthy parturients undergoing cesarean delivery (5). Although the study had some limitations arising from the perioperative management of preeclamptic patients (6), this group had a decreased incidence and magnitude of hypotension and smaller ephedrine requirement compared with healthy parturients. Two major factors were advocated to explain these findings (5,6). First, physiological changes induce a vasodilation and confer a relative resistance to vasopressor drugs in normal pregnancy, whereas preeclampsia is characterized by vasospasm and an increased sensitivity to vasopressors. Second, preeclamptic women had babies of smaller birth weight than healthy pregnant women at term, which could have resulted in less aortocaval compression by the uterine mass in the preeclamptic group, and therefore less impact on arterial blood pressure (BP). As both physiological changes and aortocaval compression were implicated in our previous findings, the present study was performed to evaluate the hemodynamic effects of spinal anesthesia in preeclamptic versus normotensive women when aortocaval compression was considered, for example by controlling fetal weight. For this purpose, we compared

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the incidence and magnitude of spinal hypotension in preeclamptic patients, with normotensive women carrying preterm fetuses, undergoing cesarean delivery.

## Methods

After institutional ethics committee approval and informed consent, consecutive severely preeclamptic patients cared for in our unit over a 28-mo period constituted the case cohort (preeclamptic group). Severe preeclampsia was defined according to the criteria of the National High Blood Pressure Education Program Working Group on High Blood Pressure in Pregnancy (7), but only patients with severe hypertension, defined as systolic blood pressure (SBP) ≥160 mm Hg or diastolic blood pressure (DBP) ≥110 mm Hg, were enrolled. Pharmacologic treatment of hypertension before inclusion in the protocol was recommended when mean arterial BP (MAP) was >130 mm Hg, with associated symptoms of end-organ involvement. IV nicardipine was the first-line antihypertensive treatment, according to the guidelines published by the French Society of Anesthesiology and Critical Care Medicine in collaboration with the French Society of Perinatology and the French College of Obstetricians and Gynecologists (8). The goal of acute treatment was to reduce the MAP by 20% (9). According to French guidelines, IV $MgSO_4$ (4.5 g initial dose over 20–30 min followed by 1–2 g/h continuous maintenance infusion) was given as seizure prophylaxis in patients with neuromuscular hyperexcitability (8). Over the inclusion period, consecutive normotensive women undergoing preterm cesarean delivery (before 35 wk gestation) were enrolled as a control group (preterm group), provided that the neonatal weight ranged from 1100 g to 1900 g. This group was designed to control the uterine mass and therefore the aortocaval compression. The range of neonatal weight defined was based on the 99% confidence interval of the neonatal weight in the preeclamptic group in our previous report (1124–1868 g) (5). Patients in labor, those with chronic hypertension, multiple gestation, diabetes, coagulopathy, or those given β-tocolytic drugs were not included in the study. Nevertheless, because cesarean delivery is indicated in up to one third of preterm women in our practice as a result of failed tocolysis, we also included all women who had only atosiban for tocolysis. Atosiban is a selective oxytocin receptor antagonist capable of inhibiting uterine contractions in animals and humans. Comparative trials showed that it is at least as effective for tocolysis as β-agonists but induces fewer side effects (10–12).

All patients were given an IV infusion of 1500 to 2000 mL lactated Ringer's solution over 20 min before the anesthetic. The volume of preload administered to severely preeclamptic patients was not decreased, as we expected that their intravascular volume contraction could cause severe hypotension in the setting of sympathetic blockade-induced vasodilation (13). MAP and HR were monitored using a Datex-Ohmeda S/5 monitor (Datex-Ohmeda S.A.S., Limonest, France). Intravascular fluid administration was performed with the patient in the supine position with a 10°–15° left lateral tilt of the operative table. Baseline MAP and HR were obtained in the operating room as the mean of three consecutive measurements taken 2 min apart immediately before spinal anesthesia. The patient was then placed in the sitting position and spinal anesthesia was administered. After skin infiltration with lidocaine, a 25- or 27-gauge Whitacre needle was inserted at the L2-3 or L3-4 vertebral interspace, and hyperbaric 0.5% bupivacaine (8–12 mg at the discretion of the anesthesiologist), sufentanil (3–5 μg), and preservative-free morphine hydrochloride (100 μg) were injected intrathecally. The patient was then returned to the supine position with a left lateral tilt of the operating table. The upper sensory level was checked at 10 min after the spinal injection using loss of cold sensation to ice, and a 10°–15° head down-tilt (Trendelenburg position) was initiated if a T4 sensory level was not achieved.

Maternal MAP and HR were recorded at 2-min intervals from the spinal injection for 30 min and then at 5-min intervals until the end of surgery. Hypotension was treated with IV ephedrine (6 mg every 2 min). Although hypotension in normotensive women is usually defined as a 20% decrease in MAP, given that a 20% decrease in MAP is usually a therapeutic goal in severely hypertensive patients (9), we defined hypotension in both study groups as a decrease in MAP to <70% of the baseline value over the time interval from spinal injection to delivery. An additional definition of hypotension in healthy parturients with preterm pregnancies was a decrease in SBP to <100 mm Hg over the same time interval. Therefore, for intergroup comparisons, we considered the incidence of ephedrine administration, the mean dosage of ephedrine given, and the time from spinal puncture to ephedrine administration. The largest and smallest values of maternal HR and the incidence of 20% changes in HR from the baseline values were also compared. The other study variables included demographic data, gestational age, spinal puncture to skin incision, skin incision to skin closure, and uterine incision to delivery intervals, the upper sensory level at 10 min after the spinal injection, neonatal and placental weights, 1- and 5-min Apgar scores, and umbilical artery blood pH.

Based on the findings of our previous study (5), we calculated that at least 65 patients per group were required to show a 25% difference in the incidence of hypotension with a 90% power at the 5% level. Data are presented as number, median and range, mean ±

**Table 1.** Maternal, Neonatal, and Anesthetic Characteristics

| | Preeclamptic ($n = 65$) | Preterm ($n = 71$) | $P$ value |
|---|---|---|---|
| Age (yr) | 30 ± 5 | 30 ± 6 | 0.879 |
| Weight (kg) | 74 ± 14 | 69 ± 14 | 0.034 |
| Height (cm) | 163 ± 6 | 164 ± 7 | 0.727 |
| Gestational age (wk) | 32.4 ± 2.4 | 31.9 ± 1.9 | 0.154 |
| Nulliparous | 42 (64.6) | 28 (39.4) | 0.003 |
| Dose of 0.5% bupivacaine (mg) | 10.6 ± 0.9 | 10.7 ± 0.9 | 0.582 |
| Volume preload (mL) | 1658 ± 308 | 1690 ± 242 | 0.511 |
| Upper sensory level at 10 min | T4 (T2 to T5) | T4 (T3 to T5) | 0.538 |
| Incidence of hypotension | 16 (24.6) | 29 (40.8) | 0.044 |
| Spinal puncture to skin incision interval (min) | 16.7 ± 4.1 | 15.6 ± 4.7 | 0.138 |
| Skin incision to skin closure interval (min) | 40.6 ± 10.1 | 39.4 ± 9.5 | 0.472 |
| Uterine incision to delivery interval (min) | 2.3 ± 1.2 | 2.3 ± 1.4 | 0.801 |
| Neonatal weight (g) | 1563 ± 523 | 1598 ± 297 | 0.664 |
| Placental weight (g) | 213 ± 84 | 232 ± 78 | 0.167 |
| Apgar score at 1 min | 7 (1–10) | 8 (2–10) | 0.380 |
| Apgar score < 7 at 1 min | 11 (16.9) | 18 (25.3) | 0.230 |
| Apgar score at 5 min | 10 (8–10) | 10 (6–10) | 0.143 |
| Apgar score < 7 at 5 min | 0 (0) | 1 (1.4) | 0.337 |
| Umbilical arterial Ph | 7.29 ± 0.03 | 7.28 ± 0.10 | 0.713 |
| Umbilical arterial pH < 7.20 | 3 (5.7) | 6 (9.7) | 0.367 |
| Tracheal intubation at birth | 3 (4.6) | 4 (5.6) | 0.788 |

Data are presented as mean ± SD, $n$ (%), or median (range).

SD, or percentage, as appropriate. $\chi^2$ test was used for intergroup comparisons of the number of nulliparous parturients, the upper sensory level, the incidence of hypotension, and the incidence of 20% changes in HR. Relative risk (RR) of hypotension between the preeclamptic group and the preterm group was calculated. Mean values of most quantitative study variables were compared by using unpaired Student's $t$-test. In addition, the largest and smallest values of MAP and HR were compared with corresponding baseline values in each study group by using the paired Student's $t$-test. A $P$ value of $< 0.05$ was considered to indicate statistical significance.

## Results

Sixty-five preeclamptic patients and 71 healthy women with preterm pregnancies (including 24 receiving tocolysis) were studied. All patients had effective anesthesia, allowing cesarean delivery. However, head-down tilt was needed in 34 preeclamptic patients and 28 women with preterm fetuses to reach a T4 sensory level ($P = 0.132$). Maternal and neonatal characteristics and anesthetic and surgical data are summarized in Table 1. Most study variables were similar between groups, including the IV fluid administration, bupivacaine dose, upper sensory level, operative time intervals, neonatal and placental weights, Apgar scores, and cord pH. However, preeclamptic patients had higher weight, and this group included more nullipara than the preterm group.

Thirty-six patients with severe preeclampsia were treated, 7 with only $MgSO_4$, 11 with only nicardipine, and 18 with both drugs. After the initial dose, the median maintenance dosage of $MgSO_4$ given was 1 g/h (range, 1–2.5 g/h). $MgSO_4$ was discontinued just before initiation of the spinal block in 10 of the 25 patients receiving this drug. The mean nicardipine dose was 1.7 ± 0.9 mg/h, and this drug was also discontinued at the time of spinal anesthesia in 25 of the 29 patients treated with it. No difference was observed among patients treated with only $MgSO_4$, nicardipine only, or both drugs with regard to baseline MAP (126.7 ± 8.2 mm Hg, 130.5 ± 12.3 mm Hg, and 124.8 ± 10.7 mm Hg, respectively, $P = 0.421$), nadir MAP (103.5 ± 20.8 mm Hg, 101.0 ± 13.9 mm Hg, and 96.2 ± 12.7 mm Hg, respectively, $P = 0.479$), as well as the percentage decrease in MAP (−18.6% ± 13.0%, −21.9% ± 13.1%, and −22.5% ± 10.6%, respectively, $P = 0.754$). The incidence of hypotension also was not different (28.6%, 27.3%, and 16.6%, respectively, $P = 0.723$). Baseline MAP values were similar in untreated severely preeclamptic patients and those given nicardipine and/or $MgSO_4$ (124.2 ± 8.2 mm Hg versus 126.8 ± 10.9 mm Hg, respectively, $P = 0.300$), as were the decrease in MAP (−24.5% ± 10.7% versus −21.6% ± 11.7%, respectively, $P = 0.305$), and the incidence of hypotension (26.6% versus 22.9%, respectively, $P = 0.722$).

MAP and HR values of preeclamptic patients and women with preterm cesarean delivery are shown in Table 2. Mean baseline values of SBP, DBP, and MAP were higher in the severely preeclamptic group. These three variables decreased significantly in both study groups after the spinal block (paired Student's $t$-test, $P$

**Table 2.** Changes in Blood Pressure and Heart Rate After Spinal Anesthesia

| | Preeclamptic ($n$ = 65) | Preterm ($n$ = 71) | $P$ value |
|---|---|---|---|
| Systolic blood pressure (mm Hg) | | | |
| Baseline | 165.8 ± 14.1 | 130.2 ± 9.6 | <0.0001 |
| Lowest after spinal anesthesia | 130.9 ± 16.9 | 102.9 ± 16.4 | <0.0001 |
| Decrease from baseline at the nadir (%) | −20.7 ± 10.7 | −20.8 ± 11.7 | 0.923 |
| Diastolic blood pressure (mm Hg) | | | |
| Baseline | 105.5 ± 10.0 | 78.4 ± 11.0 | <0.0001 |
| Lowest after spinal anesthesia | 79.0 ± 12.9 | 56.9 ± 13.0 | <0.0001 |
| Decrease from baseline at the nadir (%) | −24.6 ± 12.9 | −27.1 ± 14.0 | 0.284 |
| Mean arterial blood pressure (mm Hg) | | | |
| Baseline | 125.6 ± 9.7 | 95.7 ± 9.7 | <0.0001 |
| Lowest after spinal anesthesia | 96.3 ± 13.3 | 72.2 ± 13.3 | <0.0001 |
| Decrease from baseline at the nadir (%) | −23.0 ± 11.3 | −24.4 ± 11.7 | 0.468 |
| Time interval to the nadir (min) | 19.0 ± 8.1 | 16.4 ± 6.0 | 0.038 |
| Heart rate (beats/min) | | | |
| Baseline | 99.1 ± 20.9 | 92.6 ± 14.1 | 0.035 |
| Lowest after spinal anesthesia | 80.4 ± 16.9 | 80.7 ± 13.1 | 0.917 |
| Decrease from baseline at the nadir (%) | −17.9 ± 11.6 | −12.6 ± 8.7 | 0.003 |
| Highest after spinal anesthesia | 106.3 ± 21.4 | 100.7 ± 14.0 | 0.061 |
| Increase from baseline at the highest value (%) | 7.8 ± 9.8 | 9.1 ± 9.5 | 0.432 |
| Incidence of 20% increase in heart rate | 6 (9.2) | 12 (16.9) | 0.187 |
| Incidence of 20% decrease in heart rate | 17 (26.1) | 12 (16.9) | 0.188 |

Data are presented as mean ± SD or $n$ (%).

< 0.05). The incidence of clinically relevant hypotension leading to ephedrine treatment was lower in the severely preeclamptic group compared with the preterm group (24.4% versus 40.8%, $P$ = 0.044) (Table 1). The magnitude of the decrease in SBP, DBP, and MAP was similar in both groups (Table 2), even when data from patients having hypotension were analyzed separately (Table 3). However, the time to the nadir of MAP was longer in the preeclamptic group. All patients in the study groups had symptoms such as nausea, vomiting, or dizziness at the time of hypotension, except for three preeclamptic patients, and four parturients in the preterm group. These symptoms disappeared after effective treatment with ephedrine. Preeclamptic patients required less ephedrine than women in the preterm group (9.8 ± 4.6 mg versus 15.8 ± 6.2 mg, $P$ = 0.031) (Table 4). With regard to the incidence of hypotension, the risk of hypotension was almost 2 times less in patients with severe preeclampsia than that in pregnant patients with preterm fetuses (RR = 0.603, 95% confidence interval 0.362 to 1.003, $P$ = 0.044). Baseline values of HR were higher in preeclamptic patients than in the preterm group, but the incidence of 20% changes in HR was similar between both study groups (Table 2). Neonatal data also were similar (Tables 1 and 4).

## Discussion

This study shows that, when neonatal weight is controlled, the incidence of significant spinal anesthesia-induced hypotension leading to ephedrine treatment is less frequent in patients with severe preeclampsia undergoing spinal anesthesia for cesarean section than in healthy women with preterm fetuses. However, the magnitude of the decrease in SBP, DBP, and MAP was similar in both groups, even when subgroups of patients having hypotension were considered separately.

We previously reported that spinal hypotension was less frequent and less severe in preeclamptic patients compared with normotensive term women (5). However, the study had several limitations (6), and some of them have not been overcome in the present study. Although treatment with nicardipine and/or $MgSO_4$ could have biased the results in our previous and present studies with regard to hypotension, we consider that decreasing MAP in very severely hypertensive patients and treating neuromuscular hyperexcitability is part of the optimal preparation of these patients to the anesthetic procedure and is in agreement with the French guidelines (8). As previously shown (5), treated and untreated preeclamptic patients had similar baseline MAP and a similar incidence of hypotension. In addition, although some patients with severe preeclampsia may benefit from crystalloid intravascular fluid administration (i.e., those with oliguria), this should be balanced against the risk of pulmonary edema. Therefore, our findings must be interpreted with reference to clinical practice conditions. It should be noted that although the current definitions of severe preeclampsia include many other clinical or biologic criteria, we enrolled only patients with severe hypertension because of the common belief that patients with the highest MAP values

**Table 3.** Changes in Blood Pressure After Spinal Anesthesia in Parturients with Hypotension

| | Preeclamptic ($n$ = 16) | Preterm ($n$ = 29) | $P$ value |
|---|---|---|---|
| Systolic blood pressure (mm Hg) | | | |
| Baseline | 176.1 ± 13.3 | 129.3 ± 10.0 | <0.0001 |
| Lowest after spinal anesthesia | 114.6 ± 12.2 | 87.0 ± 9.1 | <0.0001 |
| Decrease from baseline at the nadir (%) | −34.7 ± 7.8 | −32.5 ± 7.3 | 0.350 |
| Diastolic blood pressure (mm Hg) | | | |
| Baseline | 110.8 ± 8.0 | 75.4 ± 10.2 | <0.0001 |
| Lowest after spinal anesthesia | 63.8 ± 6.2 | 46.5 ± 6.0 | <0.0001 |
| Decrease from baseline at the nadir (%) | −42.3 ± 4.3 | −37.3 ± 11.4 | 0.097 |
| Mean arterial blood pressure (mm Hg) | | | |
| Baseline | 132.6 ± 9.2 | 93.4 ± 9.4 | <0.0001 |
| Lowest after spinal anesthesia | 80.7 ± 6.8 | 60.0 ± 6.5 | <0.0001 |
| Decrease from baseline at the nadir (%) | −39.0 ± 4.6 | −35.2 ± 8.6 | 0.111 |

Data are presented as mean ± SD.

**Table 4.** Anesthetic and Neonatal Data in the Subgroup of Parturients with Hypotension

| | Preeclamptic ($n$ = 16) | Preterm ($n$ = 29) | $P$ value |
|---|---|---|---|
| Volume preload (mL) | 1588 ± 442 | 1641 ± 279 | 0.619 |
| Dose of 0.5% bupivacaine (mg) | 10.6 ± 0.9 | 10.8 ± 0.9 | 0.430 |
| Ephedrine dosage (mg) | 9.8 ± 4.6 | 15.8 ± 6.2 | 0.031 |
| Time to ephedrine administration (min) | 17.5 ± 7.6 | 15.2 ± 5.4 | 0.248 |
| Gestational age (wk) | 32.2 ± 2.0 | 31.7 ± 1.4 | 0.306 |
| Neonatal weight (g) | 1576 ± 312 | 1576 ± 199 | 0.997 |
| Apgar score at 1 min | 9 (1–10) | 8 (4–10) | 0.858 |
| Apgar score < 7 at 1 min | 4 (25) | 7 (24.1) | 0.428 |
| Apgar score at 5 min | 10 (8–10) | 10 (7–10) | 0.517 |
| Apgar score < 7 at 5 min | 0 (0) | 0 (0) | |
| Umbilical arterial PH | 7.29 (7.21–7.33) | 7.27 (6.90–7.33) | 0.784 |
| Umbilical arterial pH < 7.20 | 0 (0) | 1 (3.4) | 0.337 |
| Tracheal intubation at birth | 0 (0) | 1 (3.4) | 0.337 |

Data are presented as mean ± SD, median (range), or $n$ (%).

may have the greatest risk of spinal hypotension in terms of both incidence and severity. Consequently, our findings apply mainly to preeclamptic patients with severe hypertension.

The incidence and magnitude of spinal hypotension in patients with severe preeclampsia, including those undergoing cesarean delivery, was investigated previously (2–4,14–16). Despite the respective limitations of these studies, on the whole, their findings support the fact that the incidence of spinal hypotension in preeclamptic parturients is infrequent, and MAP may be restored to baseline with minimal doses of ephedrine. The findings of our previous report (5) and our current study are in total agreement with these statements. We previously showed a decreased incidence, a lower magnitude, and smaller ephedrine doses in preeclamptic parturients. This could be accounted for by two main factors, a less profound aortocaval compression by the uterine mass that can be expected in preeclamptic patients carrying small fetuses and pathophysiological changes favoring hypertension in preeclamptic patients and hypotension in normal pregnancy. We evaluated the role of pathophysiological factors in the present study by using a control group with a small uterine mass and normal MAP. The demonstration of a different incidence of hypotension between preeclamptic patients and women with preterm pregnancies suggests that preeclampsia-associated factors rather than reduced aortocaval compression may play a major role.

Vascular pathophysiological changes may be different during normal pregnancy versus preeclampsia. Decreased responses to exogenous and endogenous vasodilating and vasoconstricting substances are part of the adaptation of women to normal pregnancy to meet the metabolic needs of the mother and fetus. Investigators showed a decreased pressor response and vascular reactivity to vasoconstrictors such as angiotensin II (17). It was also shown that $\alpha_1$-adrenoceptor-mediated vasoconstriction was impaired more than $\beta$-adrenoceptor-mediated vasodilatation, shifting the balance toward a vasodilated state (18). Therefore, it appears that reduced vascular responsiveness contributes to the decrease in MAP occurring during normal pregnancy, when plasma renin concentration, renin activity, and angiotensin II levels are all increased (19). This decreased reactivity to vasopressors has been attributed to increased synthesis/

release of nitric oxide (20). The sympathetic block from spinal anesthesia may aggravate this vasodilated state, resulting in hypotension. Because atosiban was shown to impair adaptive responses to drug-induced hypotension in rats (21), it is possible that atosiban could have contributed to hypotension in some women in the present study. However, although some cases of hypotension were reported, atosiban was used without significant cardiovascular side effects (10–12). Experimental studies also support the lack of significant effect of atosiban on maternal HR and MAP (22–24).

Unlike the normal pregnancy, preeclampsia is characterized by increased vascular resistance leading to hypertension (25). This vasospasm may be attributable to an excessive inflammatory response to pregnancy, including activation of granulocytes, increased release of inflammatory cytokines such as tumor necrosis factor-$\alpha$, abnormal activation of clotting system and complement system (20,26). The associated endothelial dysfunction leads to enhanced formation of endothelin and thromboxane and decreased synthesis of vasodilators such as nitric oxide, prostacyclin, and endothelial-derived hyperpolarizing factor. In addition, damage and dysfunction of endothelium and vascular smooth muscle cells result in an increased vascular sensitivity to vasoconstricting substances such as angiotensin II (20). Whether this is attributable to modified affinity or in changes in density of receptors implicated in vascular tone remains to be specified. Nevertheless, the combination of these humoral and vascular factors may shift the vascular tone toward vasoconstriction. Because these factors are not altered by the sympathetic block from spinal anesthesia, they could maintain a high vascular tone that, finally, contributes to limiting the decrease in MAP during spinal block. The increased vascular sensitivity to vasoconstrictors, as suggested by the demonstration of enhanced vascular responsiveness to angiotensin II in vessels from women with preeclampsia (19), may explain the decreased requirement in vasopressors for the treatment of hypotension in preeclamptic patients. However, we must note that hypotension had a similar magnitude in the preeclamptic and the preterm groups. This suggests that, as noted by Santos and Birnbach (6) in the editorial accompanying our previous study, the difference in magnitude of hypotension may have been mainly the result of a difference in the aortocaval compression, as reflected by different neonatal weights between preeclamptic and term pregnant women (5). Indeed, this difference disappeared when the neonatal weight was controlled, as done in the present study, even when data from patients with hypotension were analyzed separately. Despite a decrease in the incidence of hypotension, as shown by others and in our previous and present studies, it should be emphasized that patients with severe preeclampsia can also experience severe hypotension after spinal anesthesia.

In the available literature, hypotension in preeclamptic patients has been treated with boluses of ephedrine, and most investigators showed that small doses of ephedrine were sufficient to restore MAP to baseline values. Although the choice among ephedrine, phenylephrine, their combination, or other drugs for prophylaxis or treatment of spinal hypotension in healthy parturients is debated (27–30), we believe that until further evidence is available ephedrine should remain the first-line vasopressor drug in preeclamptic patients and should be given only for treatment—and as small incremental bolus injections. Indeed, because of the increased sensitivity of preeclamptic patients to the effects of vasopressors, using more potent pressor drugs such as phenylephrine could lead to transient hypertensive responses as observed in healthy parturients (31), events which can be detrimental to the patient with severe preeclampsia and her fetus. Further studies are required, however, to support these statements.

Neonatal weights and Apgar scores were similar between the groups. Only one neonate in the preterm group had a 5-min Apgar score $<7$ and was therefore at risk of poor neonatal outcome (32). Umbilical artery acid-base status is also used to assess the fetal condition. $Pco_2$, $Po_2$, standard bicarbonate, and base deficit are widely used in addition to umbilical arterial pH. Because of material limitation within our labor ward, and because our study was not primarily focused on fetal and neonatal well being, we measured only neonatal umbilical arterial pH. No difference in pH values was observed between the groups. Some neonates had umbilical arterial blood pH $<7.20$, but only one preterm newborn's mother had hypotension. This suggests that the risk of severe fetal acidemia is small when spinal hypotension is promptly and effectively treated, even when using ephedrine, provided that the fetus is not already compromised.

In summary, the present study shows that the incidence of hypotension during spinal anesthesia for cesarean delivery is infrequent in preeclamptic patients, and that this is primarily attributable to preeclampsia-associated factors. Like normotensive patients, however, preeclamptics may also experience hypotension after spinal anesthesia for cesarean delivery. When hypotension occurs, the magnitude does not appear to be decreased in preeclamptic patients as compared to healthy women with preterm fetuses, suggesting that fetal weight and aortocaval compression may also play a role.

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