Spinal Anesthesia in Severe Preeclampsia

Vanessa G. Henke, MD,*† Brian T. Bateman, MD,† and Lisa R. Leffert, MD†

Spinal anesthesia is widely regarded as a reasonable anesthetic option for cesarean delivery in severe preeclampsia, provided there is no indwelling epidural catheter or contraindication to neuraxial anesthesia. Compared with healthy parturients, those with severe preeclampsia experience less frequent, less severe spinal-induced hypotension. In severe preeclampsia, spinal anesthesia may cause a higher incidence of hypotension than epidural anesthesia; however, this hypotension is typically easily treated and short lived and has not been linked to clinically significant differences in outcomes. In this review, we describe the advantages and limitations of spinal anesthesia in the setting of severe preeclampsia and the evidence guiding intraoperative hemodynamic management. (Anesth Analg 2013;117:686–93)

Preeclampsia, which affects 5% to 7% of pregnancies, is a significant cause of maternal and neonatal morbidity and mortality[1] and was implicated in 54 of 569 maternal deaths in the United States in 2006.[2] Characterized by hypertension and proteinuria after 20 weeks' gestation, the pathophysiologic basis of preeclampsia is deranged angiogenesis with incomplete trophoblastic invasion leading to small, constricted myometrial spiral arteries with exaggerated vasomotor responsiveness, superficial placentation, and placental hypoperfusion. Symptomatic preeclampsia reflects widespread endothelial dysfunction, in which placenta-derived mediators cause multisystem organ dysfunction.[3]

Preeclamptic parturients whose hypertension has been treated antepartum generally present for delivery with contracted plasma volume, normal or increased cardiac output, vasoconstriction, and hyperdynamic left ventricular function (although left ventricular systolic and diastolic dysfunction may develop). Additional manifestations include increased airway edema, decreased glomerular filtration, platelet dysfunction, and a spectrum of hemostatic derangements (typically accentuated hypercoagulability).[4,5] In severe preeclampsia, chronic placental hypoperfusion is often significant. Since the uteroplacental circulation is not autoregulated, further decreases in perfusion may be poorly tolerated by the fetus. Primary peripartum goals in the severely preeclamptic parturient are the optimization of maternal blood pressure, cardiac output, and uteroplacental perfusion and the prevention of seizures and stroke.

Historically, a pervasive belief that spinal anesthesia in patients with severe preeclampsia causes severe hypotension and decreased uteroplacental perfusion prevented the widespread use of spinal anesthesia in these patients. However, studies show that parturients with severe preeclampsia experience less frequent, less severe hypotension than healthy parturients. Among patients with severe preeclampsia, spinal anesthesia may cause a greater degree of hypotension than epidural anesthesia; however, this hypotension is typically easily treated and short lived, and no studies have demonstrated clinically significant differences in outcomes when spinal anesthesia is compared with epidural or general anesthesia. Risk–benefit considerations strongly favor neuraxial techniques over general anesthesia for cesarean delivery in the setting of severe preeclampsia as long as neuraxial anesthesia is not contraindicated. Therefore, spinal anesthesia is a reasonable anesthetic option in severe preeclampsia when cesarean delivery is indicated, and there is no indwelling epidural catheter or contraindication to spinal anesthesia.

SPINAL ANESTHESIA AND HYPOTENSION IN SEVERE PREECLAMPSIA

Hypotension after spinal anesthesia in severely preeclamptic patients may reflect the rapid onset of sympathetic blockade, underlying intravascular volume depletion, and possible left ventricular dysfunction. Longstanding obstacles to widespread use of spinal anesthesia for patients with preeclampsia were concerns about (1) precipitous spinal anesthesia–induced hypotension, superimposed on (2) preexisting uteroplacental hypoperfusion and (3) the risk of inducing hypertension or pulmonary edema with subsequent efforts to correct the hypotension.[6] While there was evidence as early as 1950 that preeclampsia actually attenuates spinal anesthesia–induced hypotension,[7,8] it was not until the mid-1990s, when clinical trials demonstrated the safety of spinal and combined spinal–epidural (CSE) anesthesia in this patient population,[9–11] that spinal anesthesia gained acceptance as an alternative to epidural and general anesthesia for preeclamptic patients.

Most trials assessing the severity of hypotension after spinal anesthesia among severely preeclamptic parturients exclude patients in active labor because labor itself attenuates the frequency and severity of the hypotensive response to neuraxial anesthesia during cesarean delivery.[12] Most studies are relatively small ($n < 150$), and the details of preoperative antihypertensive and magnesium regimens vary.

Three prospective trials have demonstrated that preeclamptic parturients experience less frequent and less severe hypotension and require smaller doses of vasopressors than normotensive controls after the initiation of spinal

From the *Department of Anesthesia, Stanford University School of Medicine, Stanford, California; and †Department of Anesthesia, Critical Care and Pain Medicine, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts.

Accepted for publication May 7, 2013.

Funding: Departmental.

The authors declare no conflicts of interest.

Reprints will not be available from the authors.

Address correspondence to Vanessa G. Henke, MD, UCLA Department of Anesthesiology, Ronald Reagan UCLA Medical Center, 757 Westwood Plaza, Suite 3325, Los Angeles, CA 90095-7403. Address e-mail to vanessagiselle@gmail.com.

DOI: 10.1213/ANE.0b013e31829eeef5

anesthesia (Table 1). A potential limitation of an initial study by Aya et al.[14] was that mean gestational age and fetal weight were significantly lower in the severely preeclamptic group compared with the normotensive group. Resulting intergroup differences in degree of aortocaval compression could have contributed to the finding that hypotension was less severe in the preeclamptic group. Similarly, a study by Clark et al.[15] did not control for fetal weight or gestational age. To correct for this limitation, a follow-up study by Aya et al.[13] studied preterm parturients presenting for nonemergency cesarean delivery and matched the normotensive and preeclamptic patients for gestational age (neonatal and placental weights were also comparable). The severely preeclamptic group experienced a lower incidence of hypotension requiring treatment (25% vs 41%, $P = 0.044$) and received a lower mean cumulative ephedrine dose (10 vs 16 mg, $P = 0.031$) compared with the normotensive control group. These findings indicate that spinal anesthesia can be safely administered to severely preeclamptic parturients undergoing nonemergency cesarean delivery and that spinal anesthesia–induced hypotension can generally be treated safely.

SPINAL VERSUS EPIDURAL ANESTHESIA IN SEVERE PREECLAMPSIA

It was traditionally believed that epidural is safer than spinal anesthesia in the setting of severe preeclampsia because epidural anesthesia was expected to confer a lower risk of clinically significant hypotension.[6] Studies are inconsistent as to whether hypotension is more severe after spinal anesthesia as compared with epidural anesthesia. However, the most rigorous study addressing this question, by Visalyaputra et al.,[16] concluded that although severely preeclamptic patients did experience more severe hypotension after spinal anesthesia than after epidural anesthesia, that difference was unlikely to be clinically significant.

Earlier studies had reported that vasopressor requirements for severely preeclamptic parturients were similar when comparing spinal with epidural anesthesia[11,17,18] (Table 2) and when comparing CSE with epidural anesthesia (Table 3).[9] Limitations of these early studies included small sample size,[17] retrospective design[11,18] and heterogeneous populations, and approaches to fluid[11,17,18] and vasopressor[11,18] administration. In contrast, Visalyaputra et al.[16] conducted a larger, multicenter randomized controlled trial involving 100 severely preeclamptic parturients (Table 2). Spinal anesthesia was associated with a higher incidence (51% vs 23%, $P < 0.001$) of hypotension (defined as systolic blood pressure <100 mm Hg) during the 20 minutes after induction of anesthesia. However, the difference in median cumulative ephedrine dose was small (epidural group: 6 mg vs spinal group: 12 mg; $P = 0.025$). In both groups, hypotension was easily treated and short lived, with the median duration of hypotension 1 minute or less in both groups. Furthermore, some of the intergroup differences may have been magnified by institutional differences in clinical practice and the ephedrine dosing scales that were used.[19] No study has reported clinically significant differences in markers of neonatal well-being, such as Apgar scores or umbilical artery pH.[9,16–18]

As emphasized by practice guidelines from the American Society of Anesthesiologists (ASA)[20] and the American

Table 1. Prospective Trials Comparing Hemodynamic Changes in Severely Preeclamptic with Normotensive Parturients

Author, study type	Sample size	Spinal dose	Ephedrine dose	Fluid management	Conclusions	Important characteristics
Aya et al.,[13] prospective case-control	Severely preeclamptic (n = 65); normotensive (n = 71)	Hyperbaric bupivacaine (8–12 mg) + sufentanil (3–5 µg) + morphine (100 µg)	For SBP <70% of baseline, or (for healthy group) for SBP <100 mm Hg: ephedrine 6 mg (every 2 min before, every 5 min after delivery)	1.5–2.0 L crystalloid preload	Lower incidence of hypotension (25% vs 41%, $P = 0.04$) and less ephedrine used (10 ± 5 vs 16 ± 6 mg, $P = 0.03$) in severely preeclamptic versus healthy group	Matched for gestational age Different ephedrine dosing criteria for each group
Aya et al.,[14] prospective cohort	Severely preeclamptic (n = 30); normotensive (n = 30)	Same doses as in Ref. 13	Same ephedrine dose criteria as in Ref. 13	1.5–2.0 L crystalloid preload	Lower incidence of hypotension requiring treatment in preeclamptic group (17% vs 53%, $P = 0.006$) and less ephedrine given (6 ± 0 vs 13 ± 7 mg, $P = 0.003$)	Significantly lower gestational age in preeclamptic group versus healthy group (32 ± 3 vs 38 ± 2 wk; $P < 0.0001$) Different ephedrine dosing criteria for each group
Clark et al.,[15] prospective case-control	Preeclamptic (n = 20); normotensive (n = 20)	Hyperbaric bupivacaine 13 mg + fentanyl 13 µg	For <80% baseline SBP, or for nausea/vomiting: ephedrine 5 mg every 2 min	250 mL crystalloid	Less ephedrine used in severely preeclamptic versus healthy group (16 ± 15 vs 28 ± 12 mg; $P < 0.01$)	Lower gestational age in preeclamptic versus healthy group: 35 ± 3.0 vs 39 ± 1.2 wk

Data are presented as incidence (%), mean ± SD.
SBP = systolic blood pressure.

Table 2. Prospective Trials Comparing Spinal Anesthesia with Epidural Anesthesia in Severely Preeclamptic Parturients

Author, study type	Sample size	Spinal dose	Epidural dose	Prehydration	Ephedrine dosing	Conclusions	Important characteristics
Visalyaputra et al.,[16] prospective randomized	Spinal (n = 53); epidural (n = 47)	Hyperbaric bupivacaine 11 mg + preservative-free morphine 200 µg	Lidocaine 2% with epinephrine 1:400,000 (18–23 mL) + fentanyl 50 µg (T6 level); after delivery, preservative-free morphine 3 mg	500 mL colloid over 20 min	For SBP 100–120 mm Hg: ephedrine 3 mg; for SBP <100 mm Hg: ephedrine 6 mg (every 2 min)	Higher incidence of hypotension (SBP <100 mm Hg) and larger median ephedrine doses in spinal anesthesia group (51% vs 23%, P < 0.001; ephedrine 6 mg [range: 0–42 mg] vs 12 mg [range: 0–60 mg] P = 0.025)	In both groups, the median duration of hypotension (SBP <100 mm Hg) was ≤ 1 min No patient had SBP ≤80 mm Hg for >1 min
Sharwood-Smith et al.,[17] prospective randomized	Spinal (n = 11); epidural (n = 10)	Hyperbaric 0.5% bupivacaine 14 mg	Lidocaine 80 mg, then bupivacaine (up to 80 mg) to achieve T5 level) ± fentanyl 75 µg	250 mL crystalloid	For SBP <70% of baseline, or nausea, vomiting, or dizziness: ephedrine 6 mg every 2 min	Similar incidence of hypotension and mean ephedrine dose in groups receiving epidural and spinal anesthetics	Nonemergent deliveries only; no P-values reported; inferior analgesia in the epidural group

Data are presented as median [range] or incidence (%).
SBP = systolic blood pressure.

Table 3. Prospective Trial Comparing CSE Anesthesia with Epidural Anesthesia and General Anesthesia Among Severely Preeclamptic Parturients

Author, study type	Sample size	CSE dose	Epidural/GA doses	Prehydration	Ephedrine dosing	Pertinent conclusions	Important characteristics
Wallace et al.,[9] prospective randomized	CSE (n = 27); epidural (n = 27); general (n = 26)	Hyperbaric bupivacaine 11 mg, epidural bupivacaine (15 mg doses) as needed	Epidural: lidocaine 2% or chloroprocaine 3% (18–23 mL), T4 level; GA: pentothal 4–5 mg/kg, lidocaine 1.5 mg/kg, succinylcholine 1.5 mg/kg, end-tidal isoflurane (0.75%), nitrous oxide (50%)	GA group: 400 ± 80 mL; CSE: 990 ± 60 mL; epidural: 1020 ± 60 mL	For SBP <100 mm Hg: ephedrine 5 mg and/or crystalloid	Ephedrine given to 22% patients in CSE group, 30% in epidural group, and no patients in GA group (significant difference P = 0.009)	CSE: intrathecal doses comparable with spinal doses in other studies comparing spinal with epidural anesthesia. Ephedrine doses not reported

Data are presented as mean ± SD or incidence (%).
CSE = combined spinal–epidural; GA = general anesthesia; SBP = systolic blood pressure.

College of Obstetricians and Gynecologists (ACOG),[4] neuraxial anesthetic techniques, when feasible, are strongly preferred to general anesthesia for preeclamptic parturients. Early epidural catheter placement in laboring preeclamptic parturients is encouraged, since it secures a means of delivering neuraxial anesthesia (avoiding the risks of general anesthesia) in the event that an emergency cesarean delivery is required. Additional benefits of epidural labor analgesia are reduced oxygen consumption and minute ventilation during the first and second stages of labor[21] and, in preeclamptic parturients, improved intervillous blood flow[22] (provided that hypotension is avoided) and decreased maternal plasma catecholamines.[23] Consequently, for complicated cases such as parturients with preeclampsia, the ASA practice guideline recommends early epidural or spinal catheter placement, "which may even precede onset of labor or the patient's request for analgesia."[20]

In preeclampsia, spinal anesthesia is generally considered for cesarean delivery when there is no indwelling epidural catheter or there is a contraindication to neuraxial anesthesia (e.g., coagulopathy, eclampsia with persistent neurologic deficits). Spinal anesthesia affords quicker onset of anesthesia than epidural or CSE anesthesia, which is a critical advantage in emergency situations. In the setting of severe hemodynamic instability or if a particularly long operative time is anticipated, an alternative titratable neuraxial technique such as epidural, CSE, or continuous spinal anesthesia should be considered.

SPINAL VERSUS GENERAL ANESTHESIA

For most of the severely preeclamptic population, the risk–benefit profiles of spinal anesthesia and general anesthesia strongly favor the use of spinal anesthesia when feasible. Important factors to consider are the risks of clinically significant maternal hemodynamic derangements, difficult airway management, stroke, spinal/epidural hematoma, and adverse neonatal outcomes. As described earlier, in severely preeclamptic patients, spinal anesthesia–induced hypotension is typically easily treated, the risk of spinal/epidural hematoma is low, and there is no evidence that neonatal outcomes are compromised. In contrast, potential complications of general anesthesia, such as hypertensive crisis, stroke, and difficult airway management, are leading causes of morbidity and mortality in the preeclamptic population. Therefore, in the majority of severely preeclamptic patients, who are not coagulopathic or thrombocytopenic, the risk of difficult or failed airway management and delayed recognition of maternal stroke during a general anesthetic are felt to exceed the risk of adverse outcomes from spinal anesthesia–induced hypotension or spinal/epidural hematoma.[19]

Peripartum pharyngeal and glottic edema are accentuated in preeclamptic parturients,[24] and the risks of difficult/failed laryngoscopy and intubation are greater among preeclamptic parturients than healthy parturients.[25] Traumatic laryngoscopy may trigger pharyngeal or hypopharyngeal bleeding, further obscuring visualization of the airway. Although the absolute risks of general anesthesia (failed/difficult airway management, hypertension with direct laryngoscopy, delayed recognition of stroke under general anesthesia, and aspiration) are low even among preeclamptic parturients, the risk of difficult airway management is a compelling reason to favor neuraxial anesthesia. Closed claims analysis from the United Kingdom from 2006 to 2008 identified poor management of preeclampsia as one of the main categories in which poor perioperative management may have contributed to maternal death.[26]

Severe preeclampsia is also a leading cause of peripartum hemorrhagic stroke.[27] During direct laryngoscopy and intubation, severely preeclamptic parturients experience significantly larger increases in arterial blood pressure and middle cerebral artery velocity compared with healthy parturients.[28] Cerebral hypertension may, in turn, precipitate hemorrhagic stroke. Hemorrhagic stroke was the leading direct cause of mortality in patients with severe preeclampsia according to the most recent analysis by the United Kingdom Center for Maternal and Child Enquiries.[29] If general anesthesia is necessary, equipment should be immediately available to manage a difficult airway, and every effort should be made to blunt the hemodynamic response to laryngoscopy (e.g., via a bolus of an antihypertensive drug or remifentanil).[30,31]

One study has been designed to detect differences in maternal or neonatal outcomes associated with the use of spinal anesthesia compared with general anesthesia in severe preeclampsia. Dyer et al.[32] prospectively compared umbilical arterial fetal base deficit and other markers of maternal and neonatal well-being in 70 preeclamptic patients undergoing cesarean delivery due to nonreassuring fetal heart rate tracings, randomized to receive either spinal or general anesthesia (Table 4). The study was powered to detect an intergroup difference in the primary outcome, the incidence of umbilical arterial base deficit >8 mEq/L. In both groups, mean umbilical arterial base deficit values were within the range considered normal for vaginal delivery (<10), although the spinal group had a higher mean umbilical arterial base deficit (7.1 vs 4.7 mEq/L, $P = 0.02$) and a lower median umbilical arterial pH (7.20 vs 7.23, $P = 0.046$). There were no significant intergroup differences in other markers of neonatal compromise, including requirement for neonatal resuscitation, Apgar score <7, umbilical arterial pH <7.2, and need for neonatal intermittent positive pressure ventilation. Maternal heart rate and arterial blood pressure values were also acceptable in both groups.

Notably, in the Dyer et al.[32] study, the mean ephedrine dose (14 vs 3 mg, $P = 0.002$) was significantly higher in the spinal anesthesia group. The authors point out that there was no correlation between ephedrine use and neonatal base deficit in either group. Of note, post hoc analysis showed that unless diastolic blood pressure exceeded 110 mm Hg, there was no intergroup difference in neonatal base deficit. However, the clinical significance of this observation remains unknown, especially since the study was not powered to assess this subset of patients. The trend toward lower umbilical arterial pH in the spinal group, in which ephedrine doses were higher, has prompted some authors[33] to recommend phenylephrine as the first-line vasopressor in severe preeclampsia. This recommendation is consistent with the finding that, in some studies, ephedrine is associated with greater fetal acidemia than phenylephrine among healthy parturients presenting for cesarean delivery.[33]

Table 4. Prospective Trial Comparing Spinal Anesthesia with General Anesthesia Among Parturients with Preeclampsia Undergoing Emergent Cesarean Delivery due to Nonreassuring Fetal Heart Rate

Author, study type	Sample size	Spinal dose	General anesthesia dose	Prehydration	Ephedrine dosing	Conclusions	Important characteristics
Dyer et al.,[32] prospective randomized	Spinal (n = 35) versus general (n = 35)	Hyperbaric bupivacaine 9 mg + fentanyl 10 µg	Thiopentone 5 mg/kg, suxamethonium 1.5 mg/kg, magnesium sulfate 30–45 mg/kg; end-tidal isoflurane (0.75–1.5), nitrous oxide (50%); after delivery: morphine 0.05–0.10 mg/kg	<750 mL crystalloid	For SBP <100 mm Hg, or SBP <75% baseline: ephedrine 5 mg every minute, until SBP ± 25% of baseline	Spinal anesthesia group: lower median umbilical artery pH (7.20 [range: 6.93–7.34] vs 7.23 [range: 7.05–7.4], P = 0.046) and larger mean umbilical artery base deficit (7.1 ± 4.0 vs 4.7 ± 3.3 mEq/L, P = 0.02)	Spinal anesthesia group received more ephedrine (14 ± 18 vs 3 ± 9 mg, P = 0.002)

Data are presented as mean ± SD, median [range], or as a percentage.
SBP = systolic blood pressure.

STRATEGIES TO REDUCE NEURAXIAL ANESTHESIA–INDUCED HYPOTENSION

In preeclamptic women, a prophylactic crystalloid bolus before spinal anesthesia increases central venous pressure for <2 minutes.[10] Preeclamptic parturients are at increased risk of pulmonary edema due to increased capillary permeability, decreased colloid oncotic pressure, increased hydrostatic pressure, and, in some cases, left ventricular dysfunction. Given the transient impact of IV fluid boluses on central venous pressure and the increased susceptibility of preeclamptic parturients to pulmonary edema, trials involving severely preeclamptic parturients have used judicious crystalloid doses (Table 2). This practice is consistent with the shift toward less perioperative crystalloid administration to healthy parturients,[34] which reflects evidence that fluid boluses, by themselves, do not prevent hypotension. No studies have specifically addressed fluid management for spinal anesthesia in preeclampsia. Prophylactic phenylephrine infusions have not been studied in the setting of uteroplacental insufficiency, and there is insufficient evidence to suggest their evidence-based use in the preeclamptic population.

One strategy to minimize hemodynamic disruption (in cases of significant fetal compromise, with reversal of umbilical artery end-diastolic flow) is CSE anesthesia using a small intrathecal local anesthetic dose.[35] The incidence of spinal anesthesia–induced hypotension is local anesthetic dose dependent, thus CSE compared with single-shot spinal anesthesia has been shown to be associated with a lower risk of hypotension.[36] However, no studies have compared CSE with spinal anesthesia in severe preeclampsia.

HEMODYNAMIC MONITORING DURING SPINAL ANESTHESIA IN SEVERE PREECLAMPSIA

The spectrum of hemodynamic profiles observed in severe preeclampsia reflects disease severity,[37] whether hypertension has been treated[38,39] and varied approaches to antihypertensive therapy and comorbidities. Among nonlaboring, term preeclamptic parturients, the incidence of global diastolic dysfunction, typically mild, is 40%.[40] The ASA practice guidelines for obstetric anesthesia state that the literature is silent or insufficient to determine whether invasive hemodynamic monitoring improves outcomes in women with pregnancy-related hypertensive disorders. No specific monitor has been proven to impact maternal or fetal outcomes in the setting of preeclampsia.[20] An arterial catheter can facilitate detection and treatment of blood pressure changes, especially in patients with severe or volatile hypertension. Echocardiography can provide information about volume status and cardiac function. In preeclampsia, central venous pressure often does not correlate with pulmonary capillary wedge pressure,[41] which in turn may not reflect left ventricular stroke work.[39] Also, pulmonary artery and central venous catheters confer a reported 4% risk of complications among hypertensive parturients.[42] Proponents of less invasive monitors that estimate stroke volume, such as arterial waveform analysis[43] and impedance cardiography, highlight the favorable risk–benefit ratio and the correlation of these data (in the early postpartum period among severely preeclamptic patients)[44] with thermodilution-derived measurements. Further evaluation

of these monitors in the peripartum management of severe preeclampsia is ongoing.[45,46]

COAGULOPATHY

In preeclampsia, endothelial dysfunction can stimulate excessive platelet activation and consumption, which may contribute to the increased incidence of thrombocytopenia. The incidence of spinal–epidural hematoma among preeclamptic patients undergoing neuraxial procedures is unknown. Large survey studies have found that the incidence of spinal–epidural hematoma after neuraxial anesthesia is lower among parturients than the general population.[47–49] These studies have also shown that whether[47] or not[47,49] analysis is limited to parturients, spinal–epidural hematoma is less common after spinal anesthesia than CSE or epidural anesthesia. However, retrospective studies may underestimate the incidence of spinal–epidural hematoma and/or the number of neuraxial techniques performed. Evidence suggests that the incidence of spinal–epidural hematoma has increased since the 1990s.[50] In large retrospective reviews[47,48] and case reports,[50] laboratory evidence of deranged hemostasis was found in a large proportion of pregnant and nonpregnant patients who developed spinal–epidural hematomas after neuraxial procedures. In 1 large retrospective study,[47] the only 2 cases of obstetric spinal–epidural hematoma occurred in patients with the syndrome of hemolysis, elevated liver enzymes, and low platelets. Spinal anesthesia may confer a lower risk of spinal/epidural hematoma than CSE or epidural anesthesia, since smaller caliber needles are associated with a lower incidence of spinal hematoma[51] and single-shot spinal anesthesia avoids the risks of an indwelling catheter.

While there is no definitive data for a "safe" platelet count, based on a consensus statement from the American Society of Regional Anesthesia[50] and case series data,[52] expert opinions from the hematology literature[53] and from the American Society of Hematologists pertaining to immune thrombocytopenia,[54] many anesthesiologists require a platelet count of at least 75,000 or 80,000/μL (and, if the platelet count is <150,000/μL, normal partial thromboplastin [PTT] and prothrombin [PT] times) before initiating spinal anesthesia in patients with severe preeclampsia.[55] The ASA practice guidelines advise that "the use of a platelet count may reduce the risk of anesthesia-related complications" in preeclampsia.[20] In a prospective study by Leduc et al.[56] involving 100 women with severe preeclampsia or chronic hypertension with preeclampsia (26 of whom developed hemolysis, elevated liver enzymes, and low platelets syndrome), no parturient had an elevated PT or PTT or a low fibrinogen level in the absence of a platelet count <150,000/μL. Of the patients whose initial platelet count was <150,000/μL, 75% went on to develop a platelet count <100,000/μL. On the basis of these findings, the authors recommended following serial platelet counts for intrapartum preeclamptic parturients and checking PT, PTT, and fibrinogen levels only if the platelet count decreases below 100,000/μL. While the Leduc et al.[56] study monitored hemostasis labs every 6 hours, for patients with clinical signs of worsening coagulopathy, a more recent assessment of platelet count and coagulation indices should be considered. Clinical judgment is critical in selecting the anesthetic approach for a preeclamptic patient with a marginal platelet count or coagulation profile.

AREAS FOR FURTHER RESEARCH

Further research is needed to elucidate strategies to optimize hemodynamics and uteroplacental perfusion among severely preeclamptic parturients during spinal anesthesia for cesarean delivery. Specific areas of interest include the effect of prophylactic phenylephrine infusions on neonatal outcomes, optimal strategies for fluid management for severely preeclamptic parturients during spinal anesthesia, and the role of minimally invasive cardiac output monitors in tailoring hemodynamic therapy.

DISCLOSURES

Name: Vanessa G. Henke, MD.
Contribution: This author helped design and conduct the study, analyze the data, and write the manuscript.
Attestation: Vanessa G. Henke approved the final manuscript.
Name: Brian T. Bateman, MD.
Contribution: This author helped design the study and write the manuscript.
Attestation: Brian T. Bateman approved the final manuscript.
Name: Lisa R. Leffert, MD.
Contribution: This author helped design and conduct the study and write the manuscript.
Attestation: Lisa R. Leffert approved the final manuscript.
This manuscript was handled by: Cynthia A. Wong, MD.

REFERENCES

1. Steegers EA, von Dadelszen P, Duvekot JJ, Pijnenborg R. Preeclampsia. Lancet 2010;376:631–44
2. Heron MP, Hoyert DL, Murphy SL, Xu J. Deaths: final data for 2006. National Vital Statistics Reports; vol 57, No 14. Available at: http://www.cdc.gov/nchs/data/nvsr/nvsr57/nvsr57_14.pdf. Accessed December 11, 2010
3. Gogarten W. Preeclampsia and anaesthesia. Curr Opin Anaesthesiol 2009;22:347–51
4. Diagnosis and management of preeclampsia and eclampsia. ACOG Practice Bulletin No. 33. American College of Obstetricians and Gynecologists. Obstet Gynecol 2002;99:159–67
5. Lindheimer MD, Taler SJ, Cunningham FG. Hypertension in pregnancy. J Am Soc Hypertens 2008;2:484–94
6. Pritchard JA, Cunningham FG, Pritchard SA. The Parkland Memorial Hospital protocol for treatment of eclampsia: evaluation of 245 cases. Am J Obstet Gynecol 1984;148:951–63
7. Assali NS, Prystowsky H. Studies on autonomic blockade. I. Comparison between the effects of tetraethylammonium chloride (TEAC) and high selective spinal anesthesia on blood pressure of normal and toxemic pregnancy. J Clin Invest 1950;29:1354–66
8. Jones GR, Ware HH, Garber EC, McElrath PJ. Continuous spinal anesthesia in the treatment of severe preeclampsia and eclampsia. Southern Med J 1952;45:34–41
9. Wallace DH, Leveno KJ, Cunningham FG, Giesecke AH, Shearer VE, Sidawi JE. Randomized comparison of general and regional anesthesia for cesarean delivery in pregnancies complicated by severe preeclampsia. Obstet Gynecol 1995;86:193–9
10. Karinen J, Rasanen J, Alahuhta S, Jouppila R, Jouppila P. Maternal and uteroplacental haemodynamic state in preeclamptic patients during spinal anesthesia for cesarean section. Br J Anasth 1996;76:616–20
11. Hood DD, Curry R. Spinal versus epidural anesthesia for cesarean section in severely preeclamptic patients: a retrospective survey. Anesthesiology 1999;90:1276–82
12. Brizgys RV, Dailey PA, Shnider SM, Kotelko DM, Levinson G. The incidence and neonatal effects of maternal hypotension during epidural anesthesia for cesarean section. Anesthesiology 1987;67:782–6
13. Aya AG, Vialles N, Tanoubi I, Mangin R, Ferrer JM, Robert C, Ripart J, de La Coussaye JE. Spinal anesthesia-induced hypotension: a risk comparison between patients with severe

preeclampsia and healthy women undergoing preterm cesarean delivery. Anesth Analg 2005;101:869–75
14. Aya AG, Mangin R, Vialles N, Ferrer JM, Robert C, Ripart J, de La Coussaye JE. Patients with severe preeclampsia experience less hypotension during spinal anesthesia for elective cesarean delivery than healthy parturients: a prospective cohort comparison. Anesth Analg 2003;97:867–72
15. Clark VA, Sharwood-Smith GH, Stewart AV. Ephedrine requirements are reduced during spinal anaesthesia for caesarean section in preeclampsia. Int J Obstet Anesth 2005;14:9–13
16. Visalyaputra S, Rodanant O, Somboonviboon W, Tantivitayatan K, Thienthong S, Saengchote W. Spinal versus epidural anesthesia for cesarean delivery in severe preeclampsia: a prospective randomized, multicenter study. Anesth Analg 2005;101:862–8
17. Sharwood-Smith G, Clark V, Watson E. Regional anesthesia for cesarean section in severe preeclampsia: spinal anesthesia is the preferred choice. Int J Obstet Anesth 1999;8:85–9
18. Chiu CL, Mansor M, Ng KP, Chan YK. Retrospective review of spinal versus epidural anaesthesia for caesarean section in preeclamptic patients. Int J Obstet Anesth 2003;12:23–7
19. Santos AC, Birnbach DJ. Spinal anesthesia for cesarean delivery in severely preeclamptic women: don't throw out the baby with the bathwater! Anesth Analg 2005;101:859–61
20. American Society of Anesthesiologists Task Force on Obstetric Anesthesia. Practice guidelines for obstetric anesthesia: an updated report by the American Society of Anesthesiologists Task Force on Obstetric Anesthesia. Anesthesiology 2007; 106:843–63
21. Hägerdal M, Morgan CW, Sumner AE, Gutsche BB. Minute ventilation and oxygen consumption during labor with epidural analgesia. Anesthesiology 1983;59:425–7
22. Jouppila P, Jouppila R, Hollmén A, Koivula A. Lumbar epidural analgesia to improve intervillous blood flow during labor in severe preeclampsia. Obstet Gynecol 1982;59:158–61
23. Abboud T, Artal R, Sarkis F, Henriksen EH, Kammula RK. Sympathoadrenal activity, maternal, fetal, and neonatal responses after epidural anesthesia in the preeclamptic patient. Am J Obstet Gynecol 1982;144:915–8
24. Izci B, Riha RL, Martin SE, Vennelle M, Liston WA, Dundas KC, Calder AA, Douglas NJ. The upper airway in pregnancy and pre-eclampsia. Am J Respir Crit Care Med 2003;167:137–40
25. Munnur U, de Boisblanc B, Suresh MS. Airway problems in pregnancy. Crit Care Med 2005;33:S259–68
26. McClure J, Cooper G; on behalf of the Centre for Maternal and Child Enquiries. Chapter 8: Anaesthesia. In: Lewis G, ed. Saving Mothers' Lives: Reviewing Maternal Deaths to Make Motherhood Safer: 2006–2008. The Eighth Report of the Confidential Enquiries into Maternal Deaths in the United Kingdom. Br J Obstet Gynecol 2011;118 (Suppl 1):1–203
27. Bateman BT, Schumacher HC, Bushnell CD, Pile-Spellman J, Simpson LL, Sacco RL, Berman MF. Intracerebral hemorrhage in pregnancy: frequency, risk factors, and outcome. Neurology 2006;67:424–9
28. Ramanathan J, Angel JJ, Bush AJ, Lawson P, Sibai B. Changes in maternal middle cerebral artery blood flow velocity associated with general anesthesia in severe preeclampsia. Anesth Analg 1999;88:357–61
29. Neilson J; on behalf of the Centre for Maternal and Child Enquiries. Chapter 3: Pre-eclampsia and eclampsia. In: Lewis G, ed. Saving Mothers' Lives: Reviewing maternal deaths to make motherhood safer: 2006–2008. The Eighth Report of the Confidential Enquiries into Maternal Deaths in the United Kingdom. Br J Obstet Gynecol 2011;118 (Suppl 1):1–203
30. Park BY, Jeong CW, Jang EA, Kim SJ, Jeong ST, Shin MH, Lee J, Yoo KY. Dose-related attenuation of cardiovascular responses to tracheal intubation by intravenous remifentanil bolus in severe pre-eclamptic patients undergoing Caesarean delivery. Br J Anaesth 2011;106:82–7
31. Yoo KY, Jeong CW, Park BY, Kim SJ, Jeong ST, Shin MH, Lee J. Effects of remifentanil on cardiovascular and bispectral index responses to endotracheal intubation in severe pre-eclamptic patients undergoing caesarean delivery under general anesthesia. Br J Anesth 2009;102:812–9
32. Dyer RA, Els I, Farbas J, Torr GJ, Schoeman LK, James MF. Prospective, randomized trial comparing general with spinal anesthesia for cesarean delivery in preeclamptic patients with a nonreassuring fetal heart trace. Anesthesiology 2003;99:561–9
33. Smiley RM. Burden of proof. Anesthesiology 2009;111:470–2
34. Habib AS. A review of the impact of phenylephrine administration on maternal hemodynamics and maternal and neonatal outcomes in women undergoing cesarean delivery under spinal anesthesia. Anesth Analg 2012;114:377–90
35. Ramanathan J, Vaddadi AK, Arheart KL. Combined spinal and epidural anesthesia with low doses of intrathecal bupivacaine in women with severe preeclampsia: a preliminary report. Reg Anesth Pain Med 2001;26:46–51
36. Rawal N, Schollin J, Wesström G. Epidural versus combined spinal epidural block for cesarean section. Acta Anaesthesiol Scand 1988;32:61–6
37. Bosio PM, McKenna PJ, Conroy R, O'Herlihy C. Maternal central hemodynamics in hypertensive disorders of pregnancy. Obstet Gynecol 1999;94:978–84
38. Groenendijk R, Trimbos JB, Wallenburg HC. Hemodynamic measurements in preeclampsia: preliminary observations. Am J Obstet Gynecol 1984;150:232–6
39. Visser W, Wallenburg HC. Central hemodynamic observations in untreated preeclamptic patients. Hypertension 1991;17:1072–7
40. Melchiorre K, Sutherland GR, Baltabaeva A, Liberati M, Thilaganathan B. Maternal cardiac dysfunction and remodeling in women with preeclampsia at term. Hypertension 2011;57:85–93
41. Bolte AC, Dekker GA, van Eyck J, van Schijndel RS, van Geijn HP. Lack of agreement between central venous pressure and pulmonary capillary wedge pressure in preeclampsia. Hypertens Pregnancy 2000;19:261–71
42. Young P, Johanson R. Haemodynamic, invasive and echocardiographic monitoring in the hypertensive parturient. Best Pract Res Clin Obstet Gynaecol 2001;15:605–22
43. Montenij LJ, de Waal EE, Buhre WF. Arterial waveform analysis in anesthesia and critical care. Curr Opin Anaesthesiol 2011;24:651–6
44. Dyer RA, Piercy JL, Reed AR, Strathie GW, Lombard CJ, Anthony JA, James MF. Comparison between pulse waveform analysis and thermodilution cardiac output determination in patients with severe pre-eclampsia. Br J Anaesth 2011;106:77–81
45. Pauca AL. Pressure wave analysis is useful to understand the pathophysiology of preeclampsia, but perhaps not the rapid changes during cesarean delivery. Anesthesiology 2008;108:773–4
46. Dyer RA, Piercy JL, Reed AR. The role of the anaesthetist in the management of the pre-eclamptic patient. Curr Opin Anaesthesiol 2007;20:168–74
47. Moen V, Dahlgren N, Irestedt L. Severe neurological complications after central neuraxial blockades in Sweden 1990-1999. Anesthesiology 2004;101:950–9
48. Bateman BT, Mhyre JM, Ehrenfeld J, Kheterpal S, Abbey KR, Argalious M, Berman MF, Jacques PS, Levy W, Loeb RG, Paganelli W, Smith KW, Wethington KL, Wax D, Pace NL, Tremper K, Sandberg WS. Brief report: the risk and outcomes of epidural hematomas after perioperative and obstetric epidural catheterization: a report from the multicenter perioperative outcomes group research consortium. Anesth Analg 2013;116:1380–5
49. Cook TM, Counsell D, Wildsmith JA; Royal College of Anaesthetists Third National Audit Project. Major complications of central neuraxial block: report on the Third National Audit Project of the Royal College of Anaesthetists. Br J Anaesth 2009;102:179–90
50. Horlocker TT, Wedel DJ, Rowlingson JC, Enneking FK, Kopp SL, Benzon HT, Brown DL, Heit JA, Mulroy MF, Rosenquist RW, Tryba M, Yuan CS. Regional anesthesia in the patient receiving antithrombotic or thrombolytic therapy: American Society of Regional Anesthesia and Pain Medicine Evidence-Based Guidelines (Third Edition). Reg Anesth Pain Med 2010;35:64–101

51. Horlocker TT, Wedel DJ, Schroeder DR, Rose SH, Elliott BA, McGregor DG, Wong GY. Preoperative antiplatelet therapy does not increase the risk of spinal hematoma associated with regional anesthesia. Anesth Analg 1995;80:303–9
52. Douglas MJ. Platelets, the parturient and regional anesthesia. Int J Obstet Anesth 2001;10:113–20
53. van Veen JJ, Nokes TJ, Makris M. The risk of spinal haematoma following neuraxial anaesthesia or lumbar puncture in thrombocytopenic individuals. Br J Haematol 2010;148:15–25
54. Neunert C, Lim W, Crowther M, Cohen A, Solberg L Jr, Crowther MA; American Society of Hematology. The American Society of Hematology 2011 evidence-based practice guideline for immune thrombocytopenia. Blood 2011;117:4190–207
55. Douglas MJ. Platelets, the parturient and regional anesthesia. Int J Obstet Anesth 2001;10:113–120
56. Leduc L, Wheeler JM, Kirshon B, Mitchell P, Cotton DB. Coagulation profile in severe preeclampsia. Obstet Gynecol 1992;79:14–8