ORIGINAL RESEARCH ARTICLE

Dose-response relationship of prophylactic norepinephrine infusion for prevention of spinal anesthesia-induced hypotension during caesarean delivery: A comparative study of normal weight and obese parturients

DOI: 10.29063/ajrh2026/v30i14.8

Xiaoping Chen[1], Zhenyu Gao[2], Cuicui Jiao[1], Jialin Wang[1], Lihong Sun[1], Xiaowei Qian[1], and Shuqun Liu[3]*

Department of Anesthesiology, Women's Hospital, School of Medicine, Zhejiang University, Hangzhou, China[1]; Department of Anesthesiology, Branch, Women's Hospital, School of Medicine, Zhejiang University, Linhai, China[2]; Department of Anesthesiology, the First Affiliated Hospital of Wenzhou Medical University, Wenzhou, China[3]

***For Correspondence:** Email: *liushuqun25@163.com*; Phone: +86-571-87061501; +86-13566265369

Abstract

Obese parturients are at increased risk of spinal anesthesia–induced hypotension during cesarean delivery, but optimal prophylactic norepinephrine dosing remains unclear. In this randomized, double-blind, dose–response study, 200 parturients undergoing elective cesarean delivery were stratified into obese (BMI ≥30 kg/m²) and normal weight (BMI 18.5–24.9 kg/m²) groups. Within each group, patients received norepinephrine infusion at 0.02–0.06 μg·kg⁻¹·min⁻¹. Standardized combined spinal–epidural anesthesia with 16 mg hyperbaric ropivacaine was used, and infusion was started immediately after spinal injection. Hypotension was defined as SBP <90 mmHg or >20% decrease from baseline, and success as absence of hypotension. Probit regression was used to estimate ED50 and ED95. ED50 and ED95 were 0.022 (95% CI 0.015–0.029) and 0.051 (0.041–0.061) μg·kg⁻¹·min⁻¹ in normal weight, compared with 0.036 (0.029–0.043) and 0.080 (0.058–0.102) μg·kg⁻¹·min⁻¹ in obese parturients. The relative potency ratio was 1.597 (95% CI 1.007–2.187; P=0.013). Neonatal outcomes and maternal adverse effects were comparable. Obese parturients require higher weight-adjusted norepinephrine infusion rates to prevent spinal anesthesia–induced hypotension during cesarean delivery. *(Afr J Reprod Health 2026; 30 [14]: 66-74).*

Keywords: norepinephrine; hypotension; spinal anesthesia; caesarean delivery; obesity; parturients

Résumé

Les parturientes obèses présentent un risque accru d'hypotension induite par l'anesthésie rachidienne lors de la césarienne, mais la posologie optimale de noradrénaline en prophylaxie reste mal définie. Dans cette étude randomisée, en double aveugle et de type dose–réponse, 200 parturientes programmées pour une césarienne élective ont été réparties en un groupe obèse (IMC ≥30 kg/m²) et un groupe de poids normal (IMC 18,5–24,9 kg/m²). Dans chaque groupe, les patientes ont reçu une perfusion de noradrénaline à des doses de 0,02 à 0,06 μg·kg⁻¹·min⁻¹. Une anesthésie combinée rachidienne–péridurale standardisée avec 16 mg de ropivacaïne hyperbare a été réalisée, et la perfusion a été débutée immédiatement après l'injection rachidienne. L'hypotension était définie par une pression artérielle systolique <90 mmHg ou une diminution >20 % par rapport à la valeur de base, et le succès par l'absence d'hypotension. Une analyse de régression probit a permis d'estimer les ED50 et ED95. Les ED50 et ED95 étaient de 0,022 (IC 95 % 0,015–0,029) et 0,051 (0,041–0,061) μg·kg⁻¹·min⁻¹ chez les parturientes de poids normal, contre 0,036 (0,029–0,043) et 0,080 (0,058–0,102) μg·kg⁻¹·min⁻¹ chez les parturientes obèses. Le rapport de puissance relative était de 1,597 (IC 95 % 1,007–2,187; p=0,013). Les résultats néonataux et les effets indésirables maternels étaient comparables entre les groupes. Les parturientes obèses nécessitent des doses de perfusion de noradrénaline plus élevées, ajustées au poids, pour prévenir efficacement l'hypotension induite par l'anesthésie rachidienne lors de la césarienne. *(Afr J Reprod Health 2026; 30 [14]: 66-74).*

Mots-clés: noradrénaline ; hypotension ; anesthésie rachidienne ; césarienne ; obésité ; parturientes

Introduction

Hypotension following spinal induction is a frequent complication of caesarean section and is associated with adverse effect on both the mother and neonate, including maternal dizziness, nausea, vomiting, impaired uteroplacental perfusion, and fetal academia.[1,2] Given these risks, prophylactic

vasopressor use is strongly recommended.[3-5] Among the available agents, norepinephrine has gained prominence in obstetric anesthesia owing to its favorable hemodynamic profile, characterized by minimal depression of cardiac output and weak β-adrenergic activity.[6,7] Previous studies for dose determination, including work from our group, have established effective continuous infusion regimens of norepinephrine for normotensive maintenance.[8,9] However, these dosing guidelines are derived predominantly from studies involving normal weight populations, and their applicability to obese parturients remains unclear.Maternal obesity is not only a global health concern but also a significant risk factor for peripartum complications such as gestational diabetes, preeclampsia, and cardiovascular disease.[10-12] Physiologically, obese parturients exhibit elevated peripheral resistance and altered vascular compliance, which may modify their cardiovascular responses to vasopressors.[13] Consistent with this, obesity is recognized as a predictor for more frequent hypotension following spinal anesthesia and greater vasopressor requirements.[14] Supporting the need for dosing adjusted for weight, evidence indicates that the optimal prophylactic dose of vasopressor is dependent on body mass index (BMI).[15] Moreover, there is an independent association between obesity and the increased risk of fetal acidosis during caesarean delivery under neuraxial anesthesia[16], and this risk potentially exacerbated by reductions in placental perfusion that are related to hypotension. Consequently, the reliable prevention of hypotension in this vulnerable population is critically important. Precise administration of norepinephrine can prevent maternal hypertension or hypotension, and may improve the outcomes for both the maternal and the neonatal. The dose of norepinephrine to keep the obesity parturients from hypotension may be different from the normal weight parturients. The potency of norepinephrine to prevent hypotension is quantified by 50% effective dose (ED50) and 95% effective dose (ED95) value, which is defined as the concentration required to prevent hypotension in 50% or 95% of parturients during spinal anesthesia.

The objective of this study was to compare the optimal prophylactic dose of norepinephrine for obese and normal weight parturients undergoing elective caesarean delivery. Specifically, we sought to establish the ED50 and ED95 using an infusion regimen based on patient weight. We hypothesized that both ED50 and ED95 would be higher in the obese group.

Methods

Hypotension following spinal induction is a frequent complication of caesarean section and is associated with adverse effect on both the mother and neonate, including maternal dizziness, nausea, vomiting, impaired uteroplacental perfusion, and fetal academia.[1,2] Given these risks, prophylactic vasopressor use is strongly recommended.[3-5] Among the available agents, norepinephrine has gained prominence in obstetric anesthesia owing to its favorable hemodynamic profile, characterized by minimal depression of cardiac output and weak β-adrenergic activity.[6,7]

Previous studies for dose determination, including work from our group, have established effective continuous infusion regimens of norepinephrine for normotensive maintenance.[8,9] However, these dosing guidelines are derived predominantly from studies involving normal weight populations, and their applicability to obese parturients remains unclear.Maternal obesity is not only a global health concern but also a significant risk factor for peripartum complications such as gestational diabetes, preeclampsia, and cardiovascular disease.[10-12] Physiologically, obese parturients exhibit elevated peripheral resistance and altered vascular compliance, which may modify their cardiovascular responses to vasopressors.[13] Consistent with this, obesity is recognized as a predictor for more frequent hypotension following spinal anesthesia and greater vasopressor requirements.[14] Supporting the need for dosing adjusted for weight, evidence indicates that the optimal prophylactic dose of vasopressor is dependent on body mass index (BMI).[15] Moreover, there is an independent association between obesity and the increased risk of fetal acidosis during caesarean delivery under neuraxial anesthesia[16], and this risk potentially exacerbated by reductions in placental perfusion that are related to hypotension. Consequently, the reliable prevention

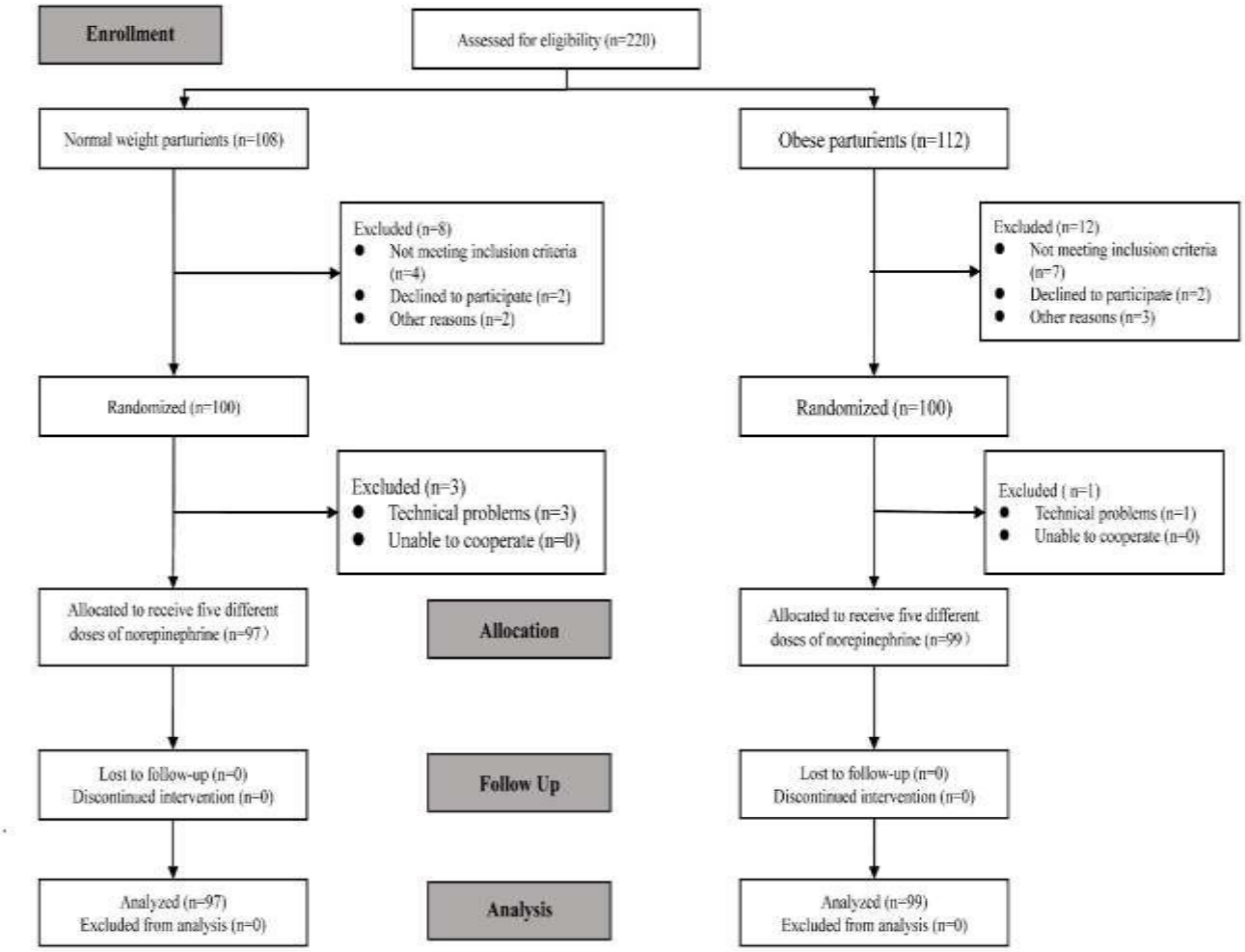

Figure 1: CONSORT flow diagram of recruitment

of hypotension in this vulnerable population is critically important. Precise administration of norepinephrine can prevent maternal hypertension or hypotension, and may improve the outcomes for both the maternal and the neonatal. The dose of norepinephrine to keep the obesity parturients from hypotension may be different from the normal weight parturients. The potency of norepinephrine to prevent hypotension is quantified by 50% effective dose (ED50) and 95% effective dose (ED95) value, which is defined as the concentration required to prevent hypotension in 50% or 95% of parturients during spinal anesthesia.

The objective of this study was to compare the optimal prophylactic dose of norepinephrine for obese and normal weight parturients undergoing elective caesarean delivery. Specifically, we sought to establish the ED50 and ED95 using an infusion regimen based on patient weight. We hypothesized that both ED50 and ED95 would be higher in the obese group.

Results

Participant recruitment is shown in Figure 1. A total of 200 parturients were enrolled in this study. Three participants in Group C, who had a sensory block level below T6, and one participant in Group O, who had failed spinal anesthesia, were excluded from the analysis. Finally, 97 participants in Group

Table 1: Demographic characteristics, sensory block levels, surgical data, and rescue dose data are presented as mean±SD or median [IQR].

	Group N(n=97)	Group O(n=99)	P value
Age (yr)	33 (6)	31 (7)	0.283
Height (cm)	161.07 ± 5.25	159.72 ± 4.75	0.060
weight (kg)	60.68 ± 4.99	82.02 ± 6.94	<0.0001
BMI (kg m^{-2})	23.76 (1.93)	31.65 (2.69)	<0.0001
Gestation (weeks)	38 (1)	38 (1)	0.855
Upper sensory block level (T4/T5)	14.4%/23.7%	32.3%/43.4%	<0.001
Induction-delivery interval (min)	15 (5)	15 (4)	0.076
Uterine incision-delivery interval (min)	1 (1)	2 (2)	0.145
Intravenous fluid volume given before delivery (ml)	500 (200)	500 (100)	0.026
Norepinephrine total rescue dose (ug/kg)	1.90 (22.6%)	4.80 (45.4%)	<0.0001

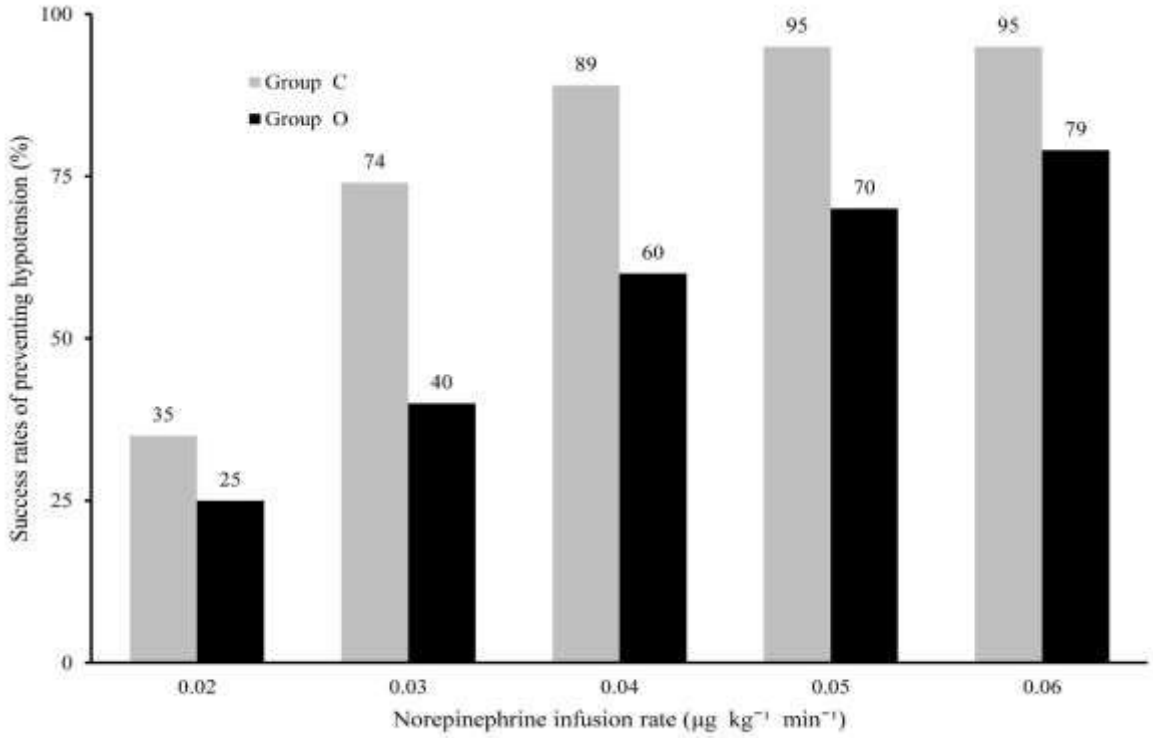

Figure 2: Success rates for preventing hypotension following spinal induction at different norepinephrine infusion rates. Grey bars (Group C), black bars (Group O) (Success was defined as maintaining systolic blood pressure (SBP) ≥80% of baseline throughout the interval from induction to delivery).

C and 99 in Group O completed this study and could be used for the final analysis.The demographic characteristics and baseline data were shown in Table 1. There were significant differences in weight, BMI, upper sensory block level (T4/T5), and total rescue doses of norepinephrine among the groups (P<0.05). Other demographic and baseline data were comparable between groups.

Figure 2 shows the success rates of preventing spinal anesthesia induced hypotension in both groups under different norepinephrine infusion rates. The incidence rate of hypotension after the induction of spinal anesthesia was greater

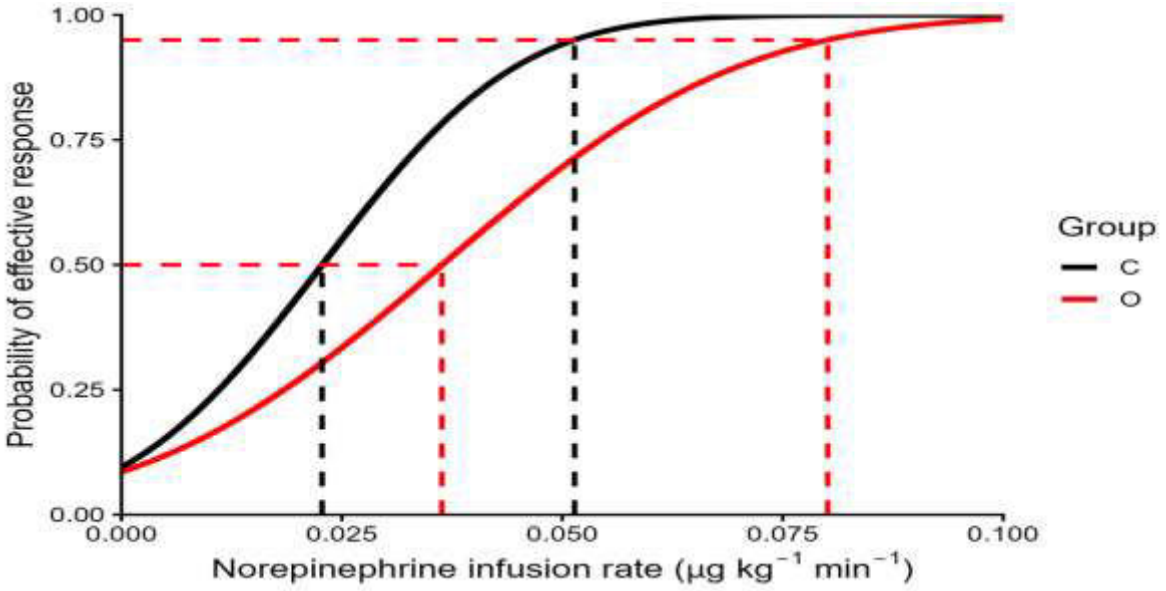

Figure 3: Dose-response curves for norepinephrine infusion in preventing hypotension, derived from probit regression analysis of response probabilities in normal weight versus obese parturients

in Group O than in Group C across all five infusion rates. The rate of hypotension following spinal anesthesia was negatively correlated with increasing norepinephrine infusion rates in both the groups.

Figure 3 showed the derived dose-response curves when using prophylactic infusion of norepinephrine to prevent hypotension after spinal anesthesia in two groups. The ED50 and ED95 values for prophylactic infusion of norepinephrine derived from probit analysis were 0.022 (95%CI, 0.015 to 0.029) and 0.051 (95%CI, 0.041 to 0.061) ug $kg^{-1}min^{-1}$ for Group C, and 0.036 (95%CI, 0.029 to 0.043) and 0.080 (95%CI, 0.058 to 0.102) ug $kg^{-1}min^{-1}$ for Group O, respectively. The relative median potency for norepinephrine infusion between groups was 1.597 (95%CI, 1.007 to 2.187), *P*=0.013, indicating a significant difference in prophylactic infusion rates between groups C and O. There was no significant difference observed in neonatal outcomes or maternal adverse effects between groups.

Discussion

This randomized, double-blind, prospective dose-response study demonstrates that obese parturients require significantly higher prophylactic doses of norepinephrine than their normal weight counterparts to prevent spinal hypotension during elective cesarean delivery. The estimated ED50 and ED95 values were substantially higher in obese parturients, highlighting the direct influence of maternal BMI on vasopressor requirements and the increased intrinsic risk of hypotension in this population. These findings provide robust, evidence-based guidance for individualized hemodynamic management.

Norepinephrine remains a first-line vasopressor in obstetric anesthesia due to its predominant α-adrenergic activity and minimal β-adrenergic effects.[6,7,20,21] Consistent with the 2018 consensus recommendation,[3] our data confirmed that higher infusion rates correlate with a reduced incidence of hypotension, emphasizing the benefit of weight-adjusted dosing strategies for precise hemodynamic control. In alignment with prior research, Sheng et al. employed weight-based dosing to determine effective norepinephrine doses (ED50 and ED90) for twin pregnancies,[22] which informed the dosing gradient used in our study.

Obesity, prevalent among a significant proportion of parturients globally,[23] presents distinct physiological challenges for anesthesia. It

not only increases the baseline risk of obstetric complications but also modifies responses to neuraxial anesthesia. Obese women are more likely to undergo cesarean section due to labor abnormalities, shoulder dystocia, and maternal comorbidities.[12,24] Mechanistically, obesity contributes to heightened susceptibility to spinal hypotension through reduced lumbosacral cerebrospinal fluid volume,[25] altered spinal anatomy,[26] and increased cephalad spread of local anesthetics,[27,28] leading to a more profound sympathetic blockade. Additionally, obesity-related cardiovascular changes, such as elevated baseline sympathetic tone[29] and attenuated vascular responsiveness,[30,31] may further compromise hemodynamic compensation. Consequently, maternal obesity is a well-established independent risk factor for hypotension following spinal anesthesia.[14,32,33]

Our study systematically quantified the increased norepinephrine requirements in obese parturients. Compared with normal weight parturients, ED50 and ED95 values were approximately 64% and 57% higher, respectively, providing a concrete basis for individualized prophylactic dosing. The recommended initial target dose of 0.036 μg·kg^-1·min^-1 and a fully protective dose of 0.080 μg·kg^-1·min^-1 offer practical guidance for clinical application. Unlike previous studies that primarily focused on general or twin pregnancy populations,[8,22] this work specifically addresses high-risk obese parturients under standardized, weight-adjusted dosing conditions, enhancing its clinical relevance.

Preoperative fluid administration likely contributed to the lower ED50 and ED95 values observed compared to prior studies using epinephrine.[35] Rapid crystalloid cohydration has been shown to increase intravascular volume, optimize venous return, and reduce vasopressor requirements.[17,36-39] While higher doses of vasopressors can prevent hypotension more effectively, they also increase the risk of reactive hypertension, emphasizing the importance of precise, individualized dosing.

Strengths of this study include its prospective, randomized, double-blind design, weight-standardized dosing approach, and direct comparison between obese and normal weight parturients. These factors enhance the validity and clinical applicability of our findings. Limitations include the upper cap of 0.06 μg·kg^-1·min^-1 for norepinephrine, which may not reflect optimal doses for morbidly obese parturients (BMI ≥40 kg·m^-2), the use of standard noninvasive blood pressure monitoring without advanced hemodynamic assessment, and the exclusion of parturients with obesity-related comorbidities. Therefore, our conclusions are most applicable to otherwise healthy parturients with BMI 30–40 kg·m^-2 undergoing elective cesarean delivery.

Clinically, these results support individualized, weight-adjusted norepinephrine dosing to improve maternal hemodynamic stability and potentially optimize neonatal outcomes. From a policy perspective, our findings justify incorporating BMI-based vasopressor protocols into obstetric anesthesia guidelines to standardize care for high-risk populations.

Conclusion

Obese parturients (BMI ≥30 kg·m^-2) require significantly higher prophylactic doses of norepinephrine than normal weight parturients to prevent spinal anesthesia-induced hypotension during cesarean delivery. The quantified ED50 and ED95 values provide an evidence-based framework for individualized hemodynamic management. These findings underscore the importance of weight-adjusted vasopressor protocols in obstetric anesthesia and inform both clinical practice and policy. Future studies should validate these doses in more diverse populations, including morbidly obese parturients and those with comorbidities, and investigate long-term maternal and neonatal outcomes.

Ethical approval

Ethics approval and consent to participate: This study was approved (IRB-20240122-R) by the Ethics Committee of Women's Hospital, School of Medicine, Zhejiang University (Chairperson Prof Yumin. Jin) on 22 April 2024.

Consent for publication

Not applicable.

Availability of data and materials

Data for the study are available on reasonable request from the first author or the corresponding author.

Conflict of interests

None

Funding

None.

Authors' contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Cuicui Jiao, Xiaoping Chen, Zhenyu Gao and Jialin Wang. The first draft of the manuscript was written by Xiaoping Chen and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Acknowledgements

Not applicable

References

1. Skillman CA, Plessinger MA, Woods JR, Clark KE. Effect of graded reductions in uteroplacental blood flow on the fetal lamb, *Am J Physiol*, 1985;249(6 Pt 2):H1098-105. https://doi.org/10.1152/ajpheart.1985.249.6.H1098
2. Langesæter E, Dyer RA. Maternal haemodynamic changes during spinal anaesthesia for caesarean section, *Curr Opin Anaesthesiol*, 2011;24(3):242-8. https://doi.org/10.1097/ACO.0b013e32834588c5
3. Kinsella SM, Carvalho B, Dyer RA, Fernando R, McDonnell N, Mercier FJ, Palanisamy A, Sia ATH, Van de Velde M, Vercueil A, Consensus SC. International consensus statement on the management of hypotension with vasopressors during caesarean section under spinal anaesthesia, *Anaesthesia*, 2018;73(1):71-92. https://doi.org/10.1111/anae.14080
4. Ngan Kee WD. Prevention of maternal hypotension after regional anaesthesia for caesarean section, *Curr Opin Anaesthesiol*, 2010;23(3):304-9. https://doi.org/10.1097/ACO.0b013e328337ffc65.
Singh PM, Singh NP, Reschke M, Ngan Kee WD, Palanisamy A, Monks DT. Vasopressor drugs for the prevention and treatment of hypotension during neuraxial anaesthesia for Caesarean delivery: a Bayesian network meta-analysis of fetal and maternal outcomes, *Brit J Anaesth*, 2020;124(3):e95-107. https://doi.org/10.1016/j.bja.2019.09.045
6. Ngan Kee WD, Lee SWY, Ng FF, Tan PE, Khaw KS. Randomized double-blinded comparison of norepinephrine and phenylephrine for maintenance of blood pressure during spinal anesthesia for cesarean delivery, *Anesthesiology*, 2015;122(4):736-45. https://doi.org/10.1097/ALN.0000000000000601
7. Heesen M, Hilber N, Rijs K, Rossaint R, Girard T, Mercier FJ, Klimek M. A systematic review of phenylephrine vs. noradrenaline for the management of hypotension associated with neuraxial anaesthesia in women undergoing caesarean section, *Anaesthesia*, 2020;75(6):800-8. https://doi.org/10.1111/anae.14976
8. Vallejo MC, Attaallah AF, Elzamzamy OM, Cifarelli DT, Phelps AL, Hobbs GR, Shapiro RE, Ranganathan P. An open-label randomized controlled clinical trial for comparison of continuous phenylephrine versus norepinephrine infusion in prevention of spinal hypotension during cesarean delivery, *Int J Obstet Anesth*, 2017;29:18-25. https://doi.org/10.1016/j.ijoa.2016.08.005
9. Fu F, Xiao F, Chen W, Yang M, Zhou Y, Ngan Kee WD, Chen X. A randomised double-blind dose-response study of weight-adjusted infusions of norepinephrine for preventing hypotension during combined spinal-epidural anaesthesia for Caesarean delivery, *Brit J Anaesth*, 2020;124(3):e108-14. https://doi.org/10.1016/j.bja.2019.12.019
10. Ituk US, Ha N, Ravindranath S, Wu C. The association of maternal obesity with fetal pH in parturients undergoing cesarean delivery under spinal anesthesia, *Curr Med Res Opin*, 2022;38(8):1467-72. https://doi.org/10.1080/03007995.2022.2088717
11. Creanga AA, Catalano PM, Bateman BT. Obesity in Pregnancy, *N Engl J Med*, 2022;387(3):248-59. https://doi.org/10.1056/NEJMra1801040
12. Taylor CR, Dominguez JE, Habib AS. Obesity And Obstetric Anesthesia: Current Insights, *Local Reg Anesth*, 2019;12:111-24. https://doi.org/10.2147/LRA.S186530
13. George RB, McKeen DM, Dominguez JE, Allen TK, Doyle PA, Habib AS. A randomized trial of phenylephrine infusion versus bolus dosing for nausea and vomiting during Cesarean delivery in obese women, *Can J Anaesth*, 2018;65(3):254-62. https://doi.org/10.1007/s12630-017-1034-6
14. Ngaka TC, Coetzee JF, Dyer RA. The Influence of Body Mass Index on Sensorimotor Block and Vasopressor Requirement During Spinal Anesthesia for Elective Cesarean Delivery, *Anesth Analg*, 2016;123(6):1527-34. https://doi.org/10.1213/ANE.0000000000001568
15. Yang C, Meng Q, Cheng Y, Huang S, Yu X. Effect of maternal body mass index on the prophylactic dose

of phenylephrine for preventing hypotension in parturients after spinal anaesthesia, *Anaesth Crit Care Pa*, 2022;41(2):101035. https://doi.org/10.1016/j.accpm.2022.101035

16. DeBolt CA, Sarker M, Trejo FE, Feldman K, Kaplowitz E, Rattner P, Paul K, Jagannatham S, Ferrara L, Doulaveris G, Bernstein PS, Brustman L, Glazer KB, Stone J, Bianco A. Association Between Obesity and Fetal Acidosis at Scheduled Cesarean Delivery, *Obstet Gynecol*, 2022;140(6):950-7. https://doi.org/10.1097/AOG.0000000000004968
17. Ngan Kee WD, Khaw KS, Ng FF. Prevention of hypotension during spinal anesthesia for cesarean delivery: an effective technique using combination phenylephrine infusion and crystalloid cohydration, *Anesthesiology*, 2005;103(4):744-50. https://doi.org/10.1097/00000542-200510000-00012
18. Capogna G, Celleno D, Fusco P, Lyons G, Columb M. Relative potencies of bupivacaine and ropivacaine for analgesia in labour, *Brit J Anaesth a*, 1999;82(3):371-3. https://doi.org/10.1093/bja/82.3.371
19. Carvalho B, Collins J, Drover DR, Atkinson Ralls L, Riley ET. ED(50) and ED(95) of intrathecal bupivacaine in morbidly obese patients undergoing cesarean delivery, *Anesthesiology*, 2011;114(3):529-35. https://doi.org/10.1097/ALN.0b013e318209a92d
20. Carvalho B, Dyer RA. Norepinephrine for Spinal Hypotension during Cesarean Delivery: Another Paradigm Shift? *Anesthesiology*, 2015;122(4):728-30. https://doi.org/10.1097/ALN.0000000000000602
21. Mercier FJ, Soued M, Morau E, Ngan Kee WD. Noradrenaline for haemodynamic control in obstetric anaesthesia: Is it now a suitable alternative to phenylephrine? *Anaesth Crit Care Pa*, 2019;38(6):591-3. https://doi.org/10.1016/j.accpm.2019.10.006
22. Sheng Z, Sun H, Liu J, Qian X. Comparative dose--response study on norepinephrine infusion for preventing hypotension during spinal anaesthesia for caesarean delivery in singleton versus twin pregnancies: A randomized, double-blind, controlled, dose-finding trial, *Eur J Anaesth*, 2021;38(8):895-7. https://doi.org/10.1097/EJA.0000000000001404
23. American COOA. ACOG Committee opinion no. 549: obesity in pregnancy, *Obstet Gynecol*, 2013;121(1):213-7. https://doi.org/10.1097/01.aog.0000425667.10377.60
24. Tonidandel A, Booth J, D'Angelo R, Harris L, Tonidandel S. Anesthetic and obstetric outcomes in morbidly obese parturients: a 20-year follow-up retrospective cohort study, *Int J Obstet Anesth*, 2014;23(4):357-64. https://doi.org/10.1016/j.ijoa.2014.05.004
25. Hogan QH, Prost R, Kulier A, Taylor ML, Liu S, Mark L. Magnetic resonance imaging of cerebrospinal fluid volume and the influence of body habitus and abdominal pressure, *Anesthesiology*, 1996;84(6):1341-9. https://doi.org/10.1097/00000542-199606000-00010
26. Broadbent CR, Maxwell WB, Ferrie R, Wilson DJ, Gawne-Cain M, Russell R. Ability of anaesthetists to identify a marked lumbar interspace, *Anaesthesia*, 2000;55(11):1122-6. https://doi.org/10.1046/j.1365-2044.2000.01547-4.x
27. Taivainen T, Tuominen M, Rosenberg PH. Influence of obesity on the spread of spinal analgesia after injection of plain 0.5% bupivacaine at the L3-4 or L4-5 interspace, *Brit J Anaesth*, 1990;64(5):542-6. https://doi.org/10.1093/bja/64.5.542
28. McCulloch WJ, Littlewood DG. Influence of obesity on spinal analgesia with isobaric 0.5% bupivacaine, *Brit J Anaesth*, 1986;58(6):610-4. https://doi.org/10.1093/bja/58.6.610
29. Lewinsky RM, Riskin-Mashiah S. Autonomic imbalance in preeclampsia: evidence for increased sympathetic tone in response to the supine-pressor test, *Obstet Gynecol*, 1998;91(6):935-9. https://doi.org/10.1016/s0029-7844(98)00105-7
30. Saravanakumar K, Rao SG, Cooper GM. Obesity and obstetric anaesthesia, *Anaesthesia*, 2006;61(1):36-48. https://doi.org/10.1111/j.1365-2044.2005.04433.x
31. Soens MA, Birnbach DJ, Ranasinghe JS, van Zundert A. Obstetric anesthesia for the obese and morbidly obese patient: an ounce of prevention is worth more than a pound of treatment, *Acta Anaesth Scand*, 2008;52(1):6-19. https://doi.org/10.1111/j.1399-6576.2007.01483.x
32. Lamon AM, Einhorn LM, Cooter M, Habib AS. The impact of body mass index on the risk of high spinal block in parturients undergoing cesarean delivery: a retrospective cohort study, *J Anesth*, 2017;31(4):552-8. https://doi.org/10.1007/s00540-017-2352-0
33. Nani FS, Torres MLA. Correlation between the body mass index (BMI) of pregnant women and the development of hypotension after spinal anesthesia for cesarean section, *Rev Bras Anestesiol*, 2011;61(1):21-30. https://doi.org/10.1016/S0034-7094(11)70003-4
34. Subedi A, Tripathi M, Bhattarai BK, Gupta PK, Pokharel K, Regmi MC. The effect of height and weight adjusted dose of intrathecal hyperbaric bupivacaine for elective caesarean section, *J Nepal Med Assoc*, 2011;51(181):1-6.
35. Wei C, Qian J, Zhang Y, Chang X, Hu H, Xiao F. Norepinephrine for the prevention of spinal-induced hypotension during caesarean delivery under combined spinal-epidural anaesthesia: Randomised, double-blind, dose-finding study, *Eur J Anaesth*, 2020;37(4):309-15. https://doi.org/10.1097/EJA.0000000000001152
36. Tamilselvan P, Fernando R, Bray J, Sodhi M, Columb M. The effects of crystalloid and colloid preload on cardiac output in the parturient undergoing planned

cesarean delivery under spinal anesthesia: a randomized trial, *Anesth Analg*, 2009;109(6):1916-21. https://doi.org/10.1213/ANE.0b013e3181bbfdf6

37. Siddik-Sayyid SM, Nasr VG, Taha SK, Zbeide RA, Shehade JMREA, Al Alami AA, Mokadem FH, Abdallah FW, Baraka AS, Aouad MT. A randomized trial comparing colloid preload to coload during spinal anesthesia for elective cesarean delivery, *Anesth Analg*, 2009;109(4):1219-24. https://doi.org/10.1213/ane.0b013e3181b2bd6b
38. Banerjee A, Stocche RM, Angle P, Halpern SH. Preload or coload for spinal anesthesia for elective Cesarean delivery: a meta-analysis, *Can J Anaesth*, 2010;57(1):24-31. https://doi.org/10.1007/s12630-009-9206-7
39. Teoh WHL, Sia ATH. Colloid preload versus coload for spinal anesthesia for cesarean delivery: the effects on maternal cardiac output, *Anesth Analg*, 2009;108(5):1592-8. https://doi.org/10.1213/ane.0b013e31819e016d

: