Supplementary Information

Supplementary Table 1. Overview of perinatal anesthesia techniques and their clinical applications

Anesthesia Techniques	Areas of Application	Clinical Advantages	Potential Risks/ Limitations	Development Trends/ Innovative Directions	References
Intrathecal Morphine (ITM) Analgesia	Postoperative Analgesia Following Cesarean Section	Improves Obstetric Recovery, Reduces Opioid Consumption	Opioid-Related Side Effects, Requires Monitoring	Optimizing Maternal Recovery in Multimodal Analgesia Strategies	[1]
Combined Spinal-Epidural Anesthesia (CSEA) vs Continuous Epidural Anesthesia (CEA) (Ropivacaine+Sufentanil)	Labor analgesia	Rapid onset, significant pain relief, high satisfaction	Higher adverse reactions with CEA, requires skilled operation CEA	Clinical promotion and optimization of application	[2]
CSEA	Labor analgesia for natural childbirth	Reduces anxiety, significant pain relief, low stress response	Low risk of motor blockade, fewer complications	Improving pain relief safety and optimizing application	[3]
CSEA+Acupoint Injection	Labor analgesia	Significant pain relief, reduced medication usage	Hypotension, nausea, vomiting, and other adverse events require monitoring	Combination technique to optimize maternal-fetal inflammatory response	[4]
Dural Puncture Epidural (DPE) Anesthesia	Cesarean section analgesia	Cesarean section analgesia	Rapid onset, excellent blockade, high satisfaction	Risk of hypotension and intraoperative pain requires monitoring	[5]
CSEA	Labor analgesia	Effective pain relief, controlled induction time	Increased incidence of numbness in the lateral position, increased demand for ephedrine	Optimize positioning to reduce complications	[6]
CSE Anesthesia	Labor analgesia	Rapid onset, high safety	Slight increase in maternal uterine artery resistance, fetal heart rate monitoring required	Safe analgesia strategy with low-dose local anesthetics and precise monitoring	[7]
Combined Subarachnoid-Epidural Anesthesia	Labor analgesia	Rapid onset of pain relief, high safety	Increases the risk of maternal fever during labor	Develop predictive models for early identification of high-risk parturients	[8]
Patient-Controlled Epidural Analgesia (PCEA) (Ropivacaine)	Labor analgesia	Effective pain relief, high satisfaction	Frequent pain breakthrough with low concentration	Optimize concentration and dosage regimen	[9]
PIEB+PCEA	Labor analgesia	Reduced intervention, high satisfaction	No significant increase in adverse events	Reduce medical interventions, optimize drug administration	[10]
PIEB Epidural Analgesia	Labor analgesia	Significant pain relief, low breakthrough pain	Prolonged second stage of labor	Optimize bolus volume and individualized dosing	[11]
DPE Epidural Anesthesia	Labor analgesia	Good pain relief for breakthrough pain	Experience-dependent, high technical requirements	Enhance analgesia precision and effectiveness	[12]
PIEB+PCEA	Labor analgesia	Reduced drug dosage	Increased staff workload	Optimize the balance between analgesia and workload	[13]
CSE (Low-dose Ropivacaine - Sufentanil)	Labor analgesia	Rapid onset, significant pain relief, low demand for supplemental analgesia	Spinal opioid dose-related adverse reactions	Optimize analgesia, reduce breakthrough pain, multi-center validation	[14]
ClearSight guided Goal-Directed Fluid Therapy (GDFT)	Spinal anesthesia for cesarean section	Reduces nausea	Does not improve hypotension	Optimize fluid management strategies	[15]

REFERENCES

[1] van den Bosch OFC, Rijsdijk M, Rosier SE, van Baal L, Schaap TP, Sultan P, et al. The implementation of intrathecal morphine for caesarean delivery into clinical practice, and assessment of its impact on patient-reported quality of recovery using the ObsQoR-10-Dutch scale: A single-centre cohort study. Eur J Anaesthesiol. 2025 Apr 1;42(4):332-339. https://doi.org/10.1097/EJA.0000000000002127

[2] Wang Y, Xu M. Comparison of ropivacaine combined with sufentanil for epidural anesthesia and spinal-epidural anesthesia in labor analgesia. BMC Anesthesiol. 2020 Jan 2;20(1):1. https://doi.org/10.1186/s12871-019-0855-y

[3] Cai L, Jiang J, Wang T, Cao S. Effects of combined spinal-epidural anesthesia on anxiety, labor analgesia and motor blocks in women during natural delivery. World J Psychiatry. 2023 Nov 19;13(11):838-847. https://doi.org/10.5498/wjp.v13.i11.838

[4] Wu L, Zhao H, Zhang Z, Huang M, Wu S, Fang C, et al. Combined spinal-epidural anesthesia with acupoint injection for labor anesthesia reduces IL-1β/IL-10 ratio in maternal peripheral blood, umbilical cord blood and improves the labor outcomes: A prospective randomized controlled trial. Clin Immunol. 2022 Mar;236:108935. https://doi.org/10.1016/j.clim.2022.108935

[5] Rao WY, Xu F, Dai SB, Mei Z, Chen XP, Lv CC, et al. Comparison of dural puncture epidural, epidural and combined spinal-epidural anesthesia for cesarean delivery: A randomized controlled trial. Drug Des Devel Ther. 2023 Jul 18;17:2077-2085. https://doi.org/10.2147/DDDT.S415684

[6] Sawasaki F, Takeshita J, Tachibana K. Influence of maternal position during combined spinal-epidural anesthesia for labor analgesia on technical difficulties and complications. J Anesth. 2023 Jun;37(3):426-432. https://doi.org/10.1007/s00540-023-03182-8

[7] Vargas J, Hirano A, Arzola C, Hobson SR, Kunpalin Y, Downey K, et al. Changes in velocimetric indices of uterine and umbilical arteries before and after combined spinal epidural analgesia in laboring women: a prospective cohort study. Int J Obstet Anesth. 2025 Nov;64:104770. https://doi.org/10.1016/j.ijoa.2025.104770

[8] Liu B, Ling L, Wei D, Li Y, Jia F, Li H, et al. Predictive models for intrapartum maternal fever: Development and validation of pre-analgesia and labor process indicators. Medicine (Baltimore). 2025;104(25):e42939. https://doi.org/10.1097/MD.0000000000042939

[9] Bihani P, Vyas M, Soni S, Jaju R, Janweja S, Choudhary U. Comparison of efficacy and safety of three different concentrations of ropivacaine for labor pain management using patient-controlled epidural analgesia (PCEA): A double-blind, randomized controlled trial. J Anaesthesiol Clin Pharmacol. 2024 Jul-Sep;40(3):463-469. https://doi.org/10.4103/joacp.joacp_159_23

[10] Liu SK, Wu SC, Hung SC, Chen KB, Illias AM, Tsai YF. Combined programmed intermittent bolus and patient-controlled bolus is a more favorable setting for epidural pain relief than continuous infusion. Healthcare (Basel). 2023 May 8;11(9):1350. https://doi.org/10.3390/healthcare11091350

[11] Zuo RH, Dang JJ, Zhuang JW, Chen QM, Zhang JY, Zheng HW, et al. The incidence of breakthrough pain associated with programmed intermittent bolus volumes for labor epidural analgesia: a randomized controlled trial. Int J Obstet Anesth. 2022 Aug;51:103571. https://doi.org/10.1016/j.ijoa.2022.103571

[12] Tsunoda Y, Osumi M, Matsushima T, Ishikawa M, Suzuki S. Effect of dural puncture epidural technique on management of breakthrough pain for parous women receiving labor analgesia during induced labor: A retrospective cohort study. J Nippon Med Sch. 2024;91(5):426-431. https://doi.org/10.1272/jnms.JNMS.2024_91-506

[13] Tsao SL, Li WT, Chang LY, Yeh PH, Yeh LT, Liu LJ, et al. Assessing continuous epidural infusion and programmed intermittent epidural bolus for their effectiveness in providing labor analgesia: A mono-centric retrospective comparative study. Medicina (Kaunas). 2023 Aug 30;59(9):1579. https://doi.org/10.3390/medicina59091579

[14] Ji T, Xie L, Zhao T, Chen Z, Sun X, Zhang Y, et al. Elevating labor analgesia: The impact of low-dose intrathecal ropivacaine-sufentanil in combined spinal-epidural analgesia: A prospective double-blinded randomized trial. Drug Des Devel Ther. 2025 Sep 5;19:7763-7775. https://doi.org/10.2147/DDDT.S532237

[15] Yang SH, Lin YS, Lee CN, Cheng YJ, Chen YH, Chiu HC, et al. Implications of continuous noninvasive finger cuff arterial pressure device use during cesarean delivery for goal-directed fluid therapy preload optimization: A randomized controlled trial. Biomed Res Int. 2021 Mar 28;2021:6685584. https://doi.org/10.1155/2021/6685584