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Effect of Dural Puncture Epidural Technique on Management of Breakthrough Pain for Parous Women Receiving Labor Analgesia during Induced Labor: A Retrospective Cohort Study

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Background: This study assessed the effectiveness of the dural puncture epidural (DPE) technique in managing breakthrough pain in parous women receiving labor analgesia during induced labor.
Methods: This single-center retrospective cohort study included term pregnant women with singleton pregnancies who received treatment for breakthrough pain during labor. All participants underwent induced labor, and some parous women among them underwent DPE. The DPE technique consisted of placing an epidural catheter after dural puncture with a 27-gauge spinal needle. Eligible women were allocated into a DPE group and conventional epidural (CE) anesthesia group. Pain was assessed with a numerical rating scale (NRS), and a patient-controlled epidural analgesia (PCEA) bolus was administered when the NRS score was ≥3. Breakthrough pain was defined as an NRS score ≥3 during PCEA management. The primary outcome was the efficacy of rescue interventions in managing breakthrough pain, as determined by a reduction in pain intensity to an NRS score <3 before birth.
Results: Among the 55 parous women who received labor analgesia, 44 required additional rescue administration for breakthrough pain. Of the remaining women, 23 received DPE and 19 received CE anesthesia. The DPE group experienced significantly more effective relief of breakthrough pain before birth than did the CE group (DPE: 100%; CE: 68.4%; p=0.005).
Conclusion: In parous women, DPE anesthesia was more effective than CE anesthesia in providing analgesia for breakthrough pain immediately before delivery during induced labor.
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Key words: breakthrough pain, epidural anesthesia, analgesia

Introduction

Neuraxial techniques such as epidural anesthesia are associated with enhanced analgesia and decreased motor block[1]. The patient-controlled epidural analgesia (PCEA) method has been demonstrated to provide effective pain relief during labor[2]. However, a recent study found that 14.3% of 10,170 patients receiving PCEA experienced breakthrough pain[3], defined as pain or pressure that necessitates unscheduled supplemental epidural medication. Therefore, to optimize labor analgesia and enhance patient comfort, it is imperative to explore rapid, effective pain relief strategies for breakthrough pain.

Rapid progression of labor is associated with a higher probability of breakthrough pain while undergoing analgesia for labor[4]. A recent study found that the active phase was more rapid for induced labor than for spontaneous labor in parous women[5]. Labor induction in parous women may hasten progression of labor during

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the active phase, which can complicate management of breakthrough pain in labor analgesia cases.

The dural puncture epidural (DPE) technique involves puncturing the dura mater with a spinal needle without administering intrathecal drugs, followed by insertion of an epidural catheter. Dural puncture facilitates passage of local anesthetics from the epidural space to the subarachnoid space. Radiological evidence indicates that a dural hole allows translocation of epidural medications into the subarachnoid space[6]. In addition, several studies have demonstrated that DPE is associated with faster onset of analgesia, improved sacral spread, and a lower rate of unilateral or patchy sensory blockade than conventional epidural anesthesia[7–9]. Moreover, the DPE technique is associated with fewer adverse effects, including reduced blood pressure, pruritus, and fetal bradycardia, as compared with the combined spinal epidural (CSE) technique[7]. However, it is unclear whether the DPE technique has a more rapid effect on breakthrough pain than the conventional epidural technique.

The efficacy of the DPE technique in managing breakthrough pain in parous women during induced labor has not been determined. We hypothesized that the DPE technique would be better than conventional epidural technique for managing breakthrough pain in parous women during induced labor. This study evaluated the efficacy of the DPE technique in treating breakthrough pain during labor analgesia in parous women.

Materials and Methods

This single-center retrospective cohort study analyzed data for the period from September 2021 through March 2023. The participants were full-term parous pregnant women with singleton gestation who received analgesics for breakthrough pain during labor. Cases were excluded when a 25-gauge spinal needle was used for puncture and when the reliability of the epidural catheter was uncertain while administering analgesic medications for breakthrough pain and the catheter could not be replaced in time for delivery. Labor was induced in all participants, and some multiparous women underwent the DPE technique. Eligible women were divided into two groups: a DPE group and a conventional epidural anesthesia group (CE group). Informed consent was obtained for medical treatment before initiation of labor analgesia for epidural anesthesia during labor, including for the DPE technique. When informed consent for medical treatment was requested, the participants were provided with information on the risks and benefits of conventional epidural anesthesia and DPE technique, and they chose the method of labor analgesia. This study was approved by the Ethics Committee of Nippon Medical School Musashi Kosugi Hospital (approval number: 687-4-62; February 16, 2023). All participants provided informed consent before inclusion in the study. Informed consent for this study was obtained by means of an opt-out on our website.

The neuraxial analgesia procedure was performed at the L3-L4 interspace with a 17-gauge Tuohy needle (UNISET disposable epidural anesthesia minitray; UNISIS Corp., Japan) and loss-of-resistance technique. In the DPE group, a 27-gauge spinal needle (disposable spinal anesthesia pencil point needles; UNISIS Corp., Japan) was used for dural puncture before placement of an epidural catheter through the extradural space. The approach to the epidural space was made using the paramedian method, and the catheter was placed 5 cm into the space. After confirming negative aspiration of blood and cerebrospinal fluid, a test dose of 3 mL of 1% lidocaine was administered. Labor analgesia was initiated by administering 12 mL of 0.125% levobupivacaine at a rate of 3 mL every 5 min. The women were maintained on labor analgesia by means of a programmed intermittent epidural bolus (PIEB) in conjunction with PCEA. The PCEA reservoir contained a mixture of 0.08% levobupivacaine and 2 μg/mL fentanyl. The PCEA system was configured to deliver a bolus of 5 mL with a lockout period of 15 min. Furthermore, the PIEB was set to administer an initial bolus of 5 mL, followed by subsequent doses every 45 min. Participant pain levels were assessed with a numerical rating scale (NRS), and they received a PCEA bolus when their NRS score was ≥3. NRS assessment was performed hourly by trained medical staff. Boluses administered by pregnant women were recorded and referenced in the PCEA pump system. Breakthrough pain was defined as an NRS >3 after 15 min of PCEA bolus administration, prompting the participant to contact medical staff if the NRS exceeded 3. Breakthrough pain was managed with additional boluses of either 5 mL of 0.125% levobupivacaine combined with 100 μg of fentanyl or 5 mL of 1% mepivacaine. The method of labor induction involved administering oxytocin combined with amniotomy in all cases when the cervix was dilated more than 3 cm.

The data collected from each clinical record were maternal age, maternal height, parity, body mass index (BMI) at delivery, gestational age at delivery, artificial reproductive technology, delivery mode, time required to

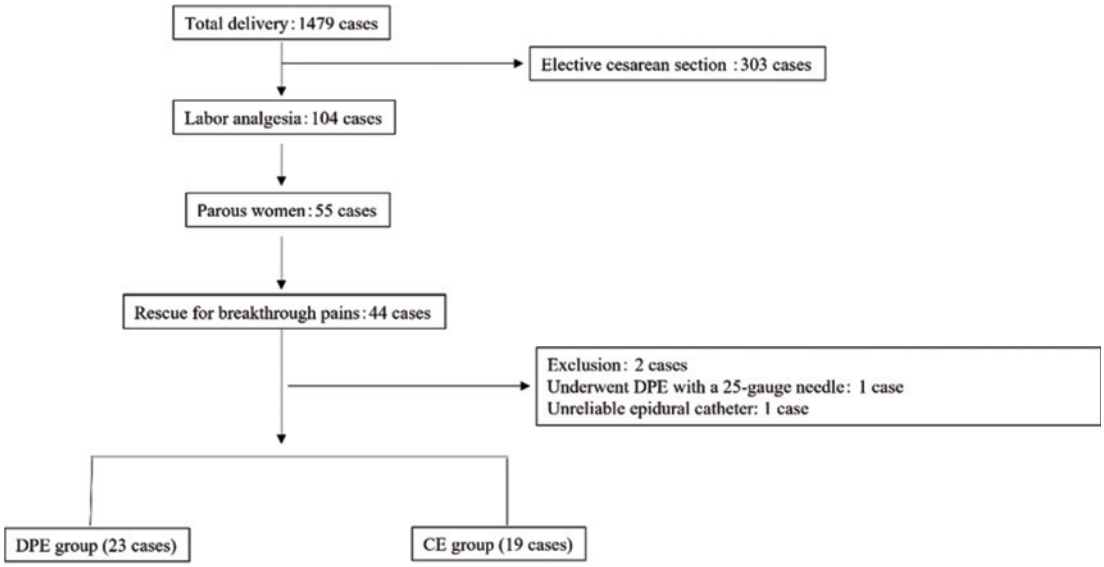

Fig. 1 Flowchart for participant selection

deliver (defined as interval from labor onset to infant delivery), amount of bleeding within 2 h after delivery, number of PCEA, number of rescue administrations for breakthrough pain, total volume of PCEA and PIEB boluses, and time required to achieve an NRS score of <3 after administering the first rescue medication for breakthrough pain. The NRS was also used to record the pain level immediately after induction of anesthesia. In addition, the limits of the upper sensory block and lower sensory block analgesic effects were recorded through cold testing to evaluate the extent of analgesic effect immediately after induction of anesthesia. The following complications of epidural anesthesia were recorded: hypotension requiring use of hypertensive agents, pruritus, fever during labor, total spinal anesthesia, headache, neuropathy, epidural hematoma, epidural abscess, local anesthetic intoxication, and anaphylaxis.

The primary outcome was the effectiveness of rescue interventions in relieving breakthrough pain, defined as an NRS score of <3 at delivery. The secondary outcomes included the number of PCEA, number of rescue administrations for breakthrough pain, total volume of PCEA and PIEB boluses, and time required for achieving an NRS score of <3 after the first rescue medication for breakthrough pain. When administration of rescue medication had no effect on pain during delivery, the interval from the administration of rescue medication to delivery was recorded.

Before the analysis, the normality of continuous variables was verified with the Shapiro-Wilk test. The Mann-Whitney U test and Student t test were used for continuous variables, and the χ^2 test and Fisher exact test were used for qualitative variables. All statistical analyses were performed by using IBM SPSS Statistics 23. The threshold for statistical significance was set at $P<0.05$.

Results

During the study period, labor analgesia was administered to 104 women, 55 of whom were parous (**Fig. 1**). Of these, 44 received rescue administration for breakthrough pain. Two pregnant women were excluded: one had undergone DPE with a 25-gauge needle and another had a patchy sensory blockade due to an unreliable epidural catheter immediately before delivery. Of the women included in the study, 23 received DPE and 19 received conventional epidural anesthesia. **Table 1** shows the maternal characteristics of the DPE and CE groups. There was no significant between-group difference in any maternal characteristic, except lower sensory block level analgesic effects.

Table 2 shows the primary study outcomes. Notably, management of breakthrough pain before birth was significantly better in the DPE group than in the CE group ($P=0.005$). However, the two groups did not significantly differ in the total dose of PCEA and PIEB, the number of PCEA, the number of rescue administrations, or the time required for effective rescue. No pregnant women required emergency cesarean section in the present study. In addition, there were no complications associated with the epidural anesthesia.

Table 1 Maternal characteristics

	DPE group (n = 23)	CE group (n = 19)	p
Age	35.2 ± 3.71	34.7 ± 4.40	0.698
Parous women who have given birth only once	20 (87.0)	18 (94.7)	0.38
Biparous women	3 (13.0)	1 (5.26)	0.38
Maternal height (cm)	159 ± 4.74	159 ± 5.60	0.972
BMI at delivery	21.9 ± 3.01	20.9 ± 2.28	0.232
ART	3 (13.0)	5 (26.3)	0.243
Gestational age at delivery (weeks)	39 [38-39]	39 [38-39]	0.296
Upper sensory block level	T10 [T10-T10]	T10 [T9-T11]	0.294
Lower sensory block level	S2 [S2-S2]	S2 [S2-S2]	0.032
Pain after induction of analgesia (NRS)	1 [0-2]	1 [0-2]	0.716
Time to delivery (minutes)	270 [182-396]	289 [256-383]	0.306
Instrumental delivery	5 (21.7)	3 (15.8)	0.466
Total postpartum bleeding (mL)	520 [375-640]	495 [355-945]	0.99

Data are presented as n (%) or median [interquartile range].
DPE: Dural puncture epidural technique, CE: Conventional epidural anesthesia, BMI: Body mass index, ART: Artificial reproductive technology, T: Thoracic spine, S: Sacral spine

Table 2 Outcomes for parous women

	DPE group (n = 23)	CE group (n = 19)	p
Effective rescue for breakthrough pain	23 (100)	13 (68.4)	0.005
Total dose of PCEA and PIEB (mL)	35 [25-45]	40 [30-45]	0.467
Number of PCEA	3 [1-4]	3 [2-4]	0.347
Number of rescue administrations	2 [1-2]	2 [1-3]	0.214
Time required to achieve effective rescue (minutes)	20 [13-35]	40 [20-52]	0.1

Data are presented as n (%) or median [interquartile range].
DPE: Dural puncture epidural technique, CE: Conventional epidural anesthesia, PCEA: Patient-controlled epidural analgesia, PIEB: Programmed intermittent epidural bolus, effective rescue for breakthrough pain defined as achieving a numerical rating scale score of <3 at delivery.

Discussion

DPE was significantly better than CE for relieving breakthrough pain immediately before delivery. No adverse events related to epidural anesthesia were observed in either group in the present study.

Although few studies have examined the effects of DPE on breakthrough pain, a previous study reported that CSE reduced the incidence of breakthrough pain[10]. However, a systematic review of the effect of CSE on breakthrough pain did not conclusively support this finding[11]. Similar to CSE, DPE is a technique in which a spinal needle is used to puncture the dura mater, which suggests that it might be effective for treating breakthrough pain. In our study, although there was no clear advantage in the interval from local anesthetic administration to achieving an NRS score of <3 for breakthrough pain, the DPE group experienced greater pain relief during the second stage of labor, ie, immediately before delivery, than did the CE group.

Some studies reported that the onset of the analgesic effect of DPE was faster when a 25- or 26-gauge spinal needle was used for the dural puncture technique[7,8,12]. However, a randomized controlled trial comparing the efficacies of epidural analgesia and DPE with a 27-gauge Whitacre spinal needle found no significant difference in analgesia effectiveness or catheter replacement rate between the two groups[13]. Moreover, a recent pilot study indicated that DPE with a 27-gauge needle provided faster pain relief than did the conventional epidural technique[14]. In our study, dural puncture was performed using a 27-gauge needle, and the analgesic effect of the drug on breakthrough pain was significantly greater than that of conventional epidural anesthesia.

Among women who gave birth, the effect of local anesthetics on pain immediately before delivery was greater in the DPE group than in the CE group. Additionally, the onset of the drug's effects tended to be quicker in the DPE group than in the CE group. A previous study re-

ported that although multiparity was significantly associated with inadequate epidural anesthesia, it was not identified as a significant predictor of outcomes in logistic regression analyses[15]. Rapid progression of labor is associated with an increased likelihood of breakthrough pain during labor analgesia[3], and women experiencing rapid labor progression frequently report insufficient sacral analgesia[16]. A comparative study on labor progression found that women undergoing elective induction of labor without cervical ripening had a shorter active phase of labor than did those admitted for spontaneous labor[17]. Furthermore, the study found that parous women who underwent pre-induction cervical ripening also experienced a shorter active phase of labor than did those who were admitted for spontaneous labor. In parous women, labor induction might lead to rapid progression of delivery in the active phase, potentially resulting in breakthrough pain and inadequate sacral analgesia. A systematic review has demonstrated that the DPE technique provides better sacral spread than the conventional epidural technique[18]. The present study also found that the DPE technique improved control of breakthrough pain and enhanced pain relief, particularly in parous women undergoing induced labor, who are more likely to experience rapid pain progression during labor. Our study found that management with the DPE technique was superior to that with the CE regarding the effect on breakthrough pain immediately before delivery, thus suggesting that the DPE technique is effective in treating breakthrough pain immediately before delivery for parous women with potential rapid labor progression.

The strength of our study is that it showed that the DPE technique was more effective for breakthrough pain before delivery, specifically in parous women undergoing induced labor. This effect was achieved using the DPE technique with a 27-gauge spinal needle, unlike some previous studies that primarily focused on the use of 25-gauge or 26-gauge needles. Furthermore, a previous study reported that decreased maternal satisfaction was independently associated with breakthrough pain[19]. Therefore, the DPE technique may be useful for achieving more satisfactory labor analgesia in parturient women.

Our study has limitations. It was a retrospective study with a small sample size. Randomized controlled studies are required in order to more conclusively determine the effects of DPE on breakthrough pain.

The present study showed that the DPE technique provided more effective analgesia for breakthrough pain immediately before delivery than did the CE approach in parous women during induced labor. The DPE technique might be particularly effective for women who have previously given birth, as they may have faster labor progression.

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