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Total failure of spinal anesthesia for cesarean delivery, associated factors, and outcomes

A retrospective case–control study

Wiruntri Punchuklang, BNs[a], Patchareya Nivatpumin, MD[a,*], Thatchanan Jintadawong, BNs[a]

Abstract

Spinal anesthesia is the anesthetic technique of choice for patients undergoing cesarean delivery. In the present study, total spinal anesthesia failure was defined as a case when an absent blockade or inadequate surgery required general anesthesia administration with an endotracheal tube. This study aimed to investigate factors related to this condition and report its maternal and neonatal outcomes.

This retrospective matched case–control study was conducted by recruiting 110 patients with failed spinal anesthesia and 330 control patients from September 1, 2016, to April 30, 2020, in the largest university hospital, Thailand.

Of 12,914 cesarean deliveries, 12,001 patients received single-shot spinal anesthesia (92.9%) during the study period. Total spinal anesthesia failure was experienced by 110/12,001 patients, giving an incidence of 0.9%. Factors related to the failures were a patient body mass index (BMI) ≤29.5 kg/m^2 (adjusted odds ratio 1.9; 95% confidence interval 1.2–3.1; $P = .010$) and a third-year resident (the most senior trainee) performing the spinal block (adjusted odds ratio 2.4; 95% confidence interval 1.5–3.7; $P < .001$). In the group with failed spinal anesthesia, neonatal Apgar scores at 1 and 5 minutes were lower than those of the control group (both $P < .001$). Two patients in the failed spinal anesthesia group (2/110; 1.8%) had difficult airways and desaturation.

Independent factors associated with total spinal anesthesia failure were a BMI of ≤29.5 kg/m^2 and a third-year resident performing the spinal block. Although the incidence of total failure was infrequent, there were negative consequences for the mothers and neonates. Adjusting the dose of bupivacaine according to the weight and height of a patient is recommended, with a higher dose appropriate for patients with a lower BMI.

Abbreviations: BMI = body mass index, USA = United states of America.

Keywords: Apgar score, cesarean delivery, failed spinal anesthesia, general anesthesia

1. Introduction

Spinal anesthesia is the anesthetic technique of choice for patients undergoing cesarean delivery due to its predictability, rapid onset, and good postoperative pain control.[1] It also has a lower maternal mortality rate than general anesthesia.[2] However, inadequate or failed spinal anesthesia can occur unexpectedly. There is a wide range of definitions for the term "failed spinal anesthesia," but many publications reported 2 main categories. First, partial failure was defined as pain or discomfort that occurs during surgery and requires additional intravenous or inhalational analgesia.[3–7] Furthermore, total failure was defined as the failure to achieve adequate sensory blockade, making general anesthesia necessary.[3–8] Previous studies revealed that the incidence of total failure of spinal anesthesia requiring conversion to general anesthesia with an endotracheal tube in cesarean delivery was as high as 0.5% to 6.4%.[3,5–7] Such conversions frustrate attending anesthesiologists and all other personnel in the operating theater. Additionally, the conversions can cause numerous adverse maternal consequences, such as maternal hypoxia, difficult intubation, failed intubation, and pulmonary aspiration, as well as negative effects on neonatal outcomes.

Factors associated with partial and total failure of spinal anesthesia in cesarean delivery have been widely studied. They included maternal body mass index (BMI), spinal needle size, exteriorization of the uterus, postpartum sterilization, and surgical complications. The level of experience of the spinal block anesthesiologists also influenced the failure of spinal anesthesia.[3,5,7,9] The current investigation focused exclusively on the total failure of spinal anesthesia (inadequate or absent sensory blockade) and sought to identify the factors that required

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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The study was approved by Siriraj Institutional Review Board, Mahidol University, Bangkok (protocol number 290/2563 (EC1), approval number Si 445/2020, May 28, 2020).

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[a] Division of Obstetric Anesthesia, Department of Anesthesiology, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand.

**Correspondence: Patchareya Nivatpumin, Division of Obstetric Anesthesia, Department of Anesthesiology, Faculty of Medicine Siriraj Hospital, Mahidol University2 Wanglang Road, Bangkok Noi, Bangkok 10700, Thailand (e-mail: patchareya.niv@mahidol.ac.th).*

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conversion to general anesthesia during cesarean delivery in our setting. Additionally, we collected information on the perioperative outcomes of the parturients and their neonates after failed spinal anesthesia.

2. Materials and Methods

2.1. Study design, study site, and ethical aspect

This retrospective matched case–control study was conducted at Siriraj Hospital, Mahidol University, the largest university hospital in Bangkok, the capital of Thailand. It was approved by the Siriraj Institutional Review Board (protocol number 290/2563 [EC1]; approval number Si 445/2020; May 28, 2020). The study was registered with www.clinicaltrials.gov (protocol number: NCT04685980).

2.2. Identification of cases

Parturients were studied if they had undergone cesarean delivery with the total failure of single-shot spinal anesthesia. A failed spinal anesthesia was defined as one in which there was an inadequate level, or absence, of spinal anesthesia blockade during cesarean delivery. This directly resulted in the patient receiving general anesthesia with an endotracheal tube.

2.3. Identification of controls

Controls were obtained from a random list of patients who underwent cesarean delivery with the 3 controls per case. All controls were parturients undergoing cesarean delivery under spinal anesthesia who did not receive any intraoperative supplemental analgesia or sedative medication. The controls were matched by the year of delivery. We excluded patients who had a gestational age <24 weeks and those who received combined epidural anesthesia, transversus abdominis plane nerve block, or quadratus lumborum nerve blocks.

2.4. Data collection

The hospital numbers of the failed spinal anesthesia cases were recovered from the incidence reports held by the obstetric anesthesia service unit at our hospital. We then searched and collected detailed patient information from our hospital's electronic medical record center. Our study included 110 consecutive patients who had cesarean delivery with failed spinal anesthesia between September 1, 2016, and April 30, 2020. Patients whose anesthetic records could not be recovered were withdrawn from the study. For both cases and controls, medical records were reviewed to extract details of demographic characteristics, underlying diseases, preoperative obstetric data, and histories of surgery and cesarean deliveries. Intraoperative anesthetic management and neonatal Apgar scores were collected.

The included patients received spinal anesthesia with 10 to 11.5 mg of 0.5% hyperbaric bupivacaine (Marcaine, AstraZeneca, Sweden; Marcaine, Aspen, France; or Regivell, Novell Pharmaceutical Laboratories, Indonesia) with intrathecal morphine sulfate (Morphine; M&H Manufacturing, Thailand). The needle types used in our hospital were a 25-gauge Whitacre spinal needle (Becton Dickinson, NJ) and a 26- or 27-gauge Quincke spinal needle (Becton Dickinson). If an anesthetic record indicated that >1 type of needle was used, we recorded the final type for analysis purposes. The method of sensory testing was not documented; however, the popular method used at our hospital was the absence of a cold sensation from alcohol pads. The positions of the patients during the spinal anesthesia were not recorded; nevertheless, almost all of our patients receive spinal anesthesia for cesarean delivery in the lateral position.

2.5. Sample size calculation

The sample size calculation was derived from the findings of Rukewe et al,[7] which revealed that 29.6% cases of failed spinal anesthesia were performed by senior registrars. We assumed that the proportion of our patients with spinal block failure performed by our third-year residents (the senior trainee) was 50% ($\pi 1 = 0.5$), whereas the proportion of successful spinal blocks performed by third-year residents was 30% ($\pi 2 = 0.3$). The sample size calculation used nQuery Advisor version 6 (Cork, Ireland) with a power of 95%, an alpha error of 0.05, and a 1:3 ratio of cases to controls. It revealed that 101 cases, 303 controls, and 404 patients were required. After adjusting for an expected 10% drop-off, 440 patients were included in this study.

2.6. Data analysis

All analyses were performed using PASW (Predictive Analytics software) Statistics for Windows (version 18.0; SPSS Inc., Chicago, IL). Data were presented as mean ± standard deviation, range, and number with percentage, as appropriate. The chi-square test or Fisher exact test was used to analyze categorical data. Comparisons between continuous data were made using an independent *t* test. Univariate analysis was used to compare the variables of the failed spinal anesthesia and the control groups. A receiver operating characteristic curve was used to determine the cutoff point of continuous data, including patient age and BMI. The significant *P* value of <.2 from the univariate analysis was selected for multiple logistic regression using the forward-stepwise method. The associated factors are presented as crude odds ratios, adjusted odds ratios, and 95% confidence interval. Significance was defined at a *P* value of <.05 (2-sided).

2.7. Definition

In this study, difficult intubation was defined as ≥3 attempts at intubation. Desaturation was defined as oxygen saturation of <90% that lasted for ≥5 minutes. A failed intubation was defined as one in which tracheal intubation was not achieved, necessitating the insertion of other instruments, such as a laryngeal mask airway. Repeated spinal block was defined as the failure to achieve blockade in the first spinal block test with the patient in the supine position, therefore requiring a second spinal anesthesia. Birth asphyxia was defined as a neonatal Apgar score of <7 at 5 minutes after delivery. Our center performed spinal anesthesia in the operating room; thus, the duration of the anesthesia was from the beginning of the anesthesia to the removal of the patient from the operating room. The duration of the operation was recorded from the skin incision to the completion of the closure of the cesarean wound. The primary outcome was the associated factors involving total failure of spinal anesthesia.

3. Results

There were 12,914 cesarean deliveries between September 1, 2016, and April 30, 2020, of which 12,001 patients received single-shot spinal anesthesia. Total spinal anesthesia failure occurred in 110 cases, giving an incidence of 0.9%. Those 110 cases and another 330 controls meant that 440 patients were available for analysis. The demographic and obstetric data of the case and control groups did not differ (Table 1). All patients were of Asian ethnicity. Details of the spinal anesthesia failure cases are listed in Table 2. The average total volume of bupivacaine with morphine that was injected was 2.19 ± 0.04 mL (range: 10–11.5 mg of 0.5% hyperbaric bupivacaine). All patients received intrathecal morphine (150–200 mcg). None of the patients received intrathecal fentanyl or other adjuvant medication. Even though 5 of the 110 patients (4.5%) received a second spinal block, all 5 were still unable to achieve an adequate sensory blockade. Before general anesthesia, 18 of

Table 1

Demographic and obstetric characteristics (N = 440).

Parameters	Failed spinal anesthesia (n = 110)	Control (n = 330)	*P* value
Age (yrs)	31.7 ± 5.3 20–43	32.2 ± 5.5 18–44	.401
Weight (kg)	71.8 ± 15.4 45.3–146.9	73.2 ± 13.6 49.0–136.0	.367
Height (cm)	158.8 ± 6.1 143.0–173.0	158.6 ± 5.6 145.0–178.0	.717
BMI (kg/m^2)	28.44 ± 6.09 18.55–57.38	29.09 ± 5.07 19.41–57.64	.255
Primigravida	49 (44.5%)	140 (42.4%)	.697
Gestational age (wk)	37.4 ± 1.6	37.7 ± 1.7	.100
Twin	5 (4.5)	13 (3.9)	.783
History of previous normal labor	15 (13.6)	36 (10.9)	.439
History of previous cesarean delivery	40 (36.4)	122 (37.0)	.909
Pregnancy associated problems			
- Gestational diabetes	14 (12.7)	39 (11.8)	.800
- Hypertension in pregnancy	8 (7.3)	28 (8.5)	.688

Data presented as mean ± SD, minimum–maximum value, and number (percentage) [n(%)].
BMI = body mass index, SD = standard deviation.

Table 2

Detailed intraoperative data of failed spinal anesthesia patients (n = 110).

Parameters	Number (%)
Level of performed spinal block	
- L2–L3	13 (11.8)
- L3–L4	95 (86.4)
- L4–L5	2 (1.8)
Needle type*	
- Whitacre No. 25	10 (9.1)
- Quincke No. 26	9 (8.2)
- Quincke No. 27	91 (82.7)
Number of passes	
- 1	56 (50.9)
- 2	14 (12.7)
- 3	2 (1.8)
- 4	1 (0.9)
- >5	5 (4.5)
-- Unknown	32 (29.1)
Total volume of hyperbaric bupivacaine 0.5% (mL)	
- 2.0	3 (2.7)
- 2.1	1 (0.9)
- 2.15	2 (1.8)
- 2.2	103 (93.6)
- 2.3	1 (0.9)
Anesthetic sensory block level	
- T4–T9	61 (55.5)
- T10–T12	16 (14.5)
- Lumbar	1 (0.9)
- Absent of block or no CSF aspirated	32 (29.1)
Repeated spinal block/successful repeated block	5 (4.5)/ 0 (0)
Sedation administration before general anesthesia	18 (16.4)
Conversion to general anesthesia	
Before delivery	100 (90.9)
After delivery	10 (9.1)

Data presented as n (%).
CSF = cerebrospinal fluid, L = lumbar, T = thoracic.
*The final level of performing spinal block and needle type were used to analyze (in cases where the medical records presented multiple levels of block and numerous needles).

10 patients (16.4%) received sedation medications. These were intravenous ketamine (before or after delivery) and/or intravenous fentanyl or pethidine (after delivery). The vast majority of the patients (100/110; 90.9%) received general anesthesia before delivery.

Two patients experienced difficult intubations, both of which caused maternal desaturation. One patient had severe preeclampsia. The first 2 intubation attempts failed, and her oxygen saturation dropped to 85%. Subsequent tracheal intubation was successful with the help of a video laryngoscope (GlideScope Ranger Single-Use, Verathon Inc, Bothell, WA). The second patient underwent multiple intubation attempts by several anesthesiologists. The prior 3 esophageal intubations and 5 tracheal intubations failed. However, a senior consultant anesthesiologist subsequently achieved immediate success using conventional laryngoscopy. The nadir level of oxygen saturation was 43%.

Regarding the 110 patients with total spinal anesthesia failure, there were no reports of failed intubations or pulmonary aspiration. None of the patients in the case or control groups suffered postpartum hemorrhage or received peripartum hysterectomy. Although 5 of the 110 patients (4.5%) reported multiple spinal block passes, none of the patients in the failed spinal anesthesia group developed a postdural puncture headache. All 110 spinal anesthesia failure patients were extubated in the operating theater, and none required admission to the postoperative intensive care unit. Medical records of cases undergoing emergency operations noted the following indications: previous cesarean delivery with labor pain; cephalopelvic disproportion; National Institute of Child Health and Human Development criteria for category II fetal heart rate; antepartum hemorrhage; prolonged premature membrane rupture; and severe preeclampsia. Exteriorization of the uterus for repair of the hysterotomy after delivery was not recorded in the operative notes. However, almost all patients at our center receive this surgical technique as routine practice. Anesthesia training at our center involves a 3-year curriculum divided into first- to third-year residents. Third-year residents are considered senior trainees.

Table 3 presents the results of univariate analysis of factors associated with failed spinal anesthesia. No association was found with patient age, history of cesarean delivery, twin pregnancies, operations performed outside of office hours, and type of spinal needle. Multivariate analysis revealed the 2 independent factors associated with spinal anesthesia failure (Table 4). The perioperative data of the case and control groups (Table 5) showed significantly lower neonatal Apgar scores for the failed spinal anesthesia group at 1 and 5 minutes ($P < .001$). The proportion of neonates with asphyxia at birth was also higher for the failed spinal anesthesia group, but the difference was not statistically significant.

4. Discussion

The incidence of total spinal anesthesia failure that required general anesthesia for cesarean delivery at our institute was 0.9%. Previously reported incidences of failed spinal anesthesia have

Table 3

Univariate analysis of factors associated with failed anesthesia (N = 440).

Factors	Failed spinal anesthesia (n = 110)	Control (n = 330)	*P* value	Crude OR (95% CI)
Age				
≤30 yr	49 (44.5)	123 (37.3)	.176	1.4 (0.9–2.1)
> 30 yr	61 (55.5)	207 (62.7)		1
BMI				
≤29.5 kg/m^2	82 (74.5)	203 (41.5)	.013	
>29.5 kg/m^2	28 (25.5)	127 (38.5)		1.8 (1.1–2.9)
History of cesarean delivery			.909	
Yes	40 (63.6)	122(37)		1
No	70 (36.4)	208(63)		1.1 (0.7–1.6)
Twin				
Yes	5 (4.5)	13 (3.9)	.783	1.2 (0.4–3.3)
No	105 (95.5)	137 (96.1)		1
Emergency cesarean delivery				
Yes	66 (60)	166 (50.3)	.078	1.5 (0.9–2.3)
No	44 (40)	164 (49.7)		1
Out of office hours				
Yes	53 (48.2)	149 (45.2)	.581	1.1 (0.7–1.7)
No	57 (51.8)	181(54.8)		1
Anesthesiologist				
First- and second-year resident	45 (40.9)	202 (61.2)	<.001	1
Third-year resident	64 (58.2)	124 (38.6)		2.3 (1.5–3.6)
Consultant	1 (0.9)	4 (1.2)		1.1 (0.1–10.3)
Needle type				
Whitacre no. 25	10 (9.1)	46 (13.9)	.413	1
Quincke no. 26	9 (8.2)	27 (8.2)		1.5 (0.6–4.2)
Quincke no. 27	91 (82.7)	257 (77.9)		1.6 (0.8–3.4)
Tubal sterilization				
Yes	31 (28.2)	81 (24.5)	.448	1
No	79 (71.8)	249 (75.4)		1.2 (0.7–1.9)

The cutpoint of patient age and BMI used receiver operating characteristic curve (ROC curve).

BMI = body mass index, CI = confidence interval, OR = odd ratio, ROC = receiver operating characteristic.

Table 4

Multivariate analysis of factors associated with failed anesthesia (N = 440).

Factors	*P* value	Adjusted OR (95% CI)
BMI ≤29.5 kg/m^2	.010	1.9 (1.2–3.1)
Third-year resident	<.001	2.4 (1.5–3.7)

BMI = body mass index, CI = confidence interval, OR = odd ratio.

varied considerably, consistent with the range of definitions used for the term "failure." Our study focused on total failure of spinal anesthesia, which we deemed to be one in which general anesthesia was required. With that definition, our incidence was comparable to those reported for obstetric patients in Singapore (4/800; 0.5%),[3] France (12/270; 4.4%),[6] and Nigeria (25/389; 6.4%).[5] Thailand has not yet established a maximum acceptable rate for the conversion of spinal anesthesia to general anesthesia in cesarean delivery. However, our incidence is consistent with the British targets developed by the Royal College of Anaesthetists.[10] The target rates for the United Kingdom depend on the urgency of cesarean delivery. Specifically, they are <5% for categories 1 to 3 (maternal or fetal compromise, or no maternal or fetal compromise but early delivery is required) and <1% for category 4 (delivery at a time that suits the woman and maternity services).[10] The current work did not include patients with partial failure in cesarean delivery. This was because partial failure requires only the use of supplemental analgesia or sedation, not general anesthesia. Therefore, this study did not identify the incidence of partial failure or the factors associated with it.

The results of our study showed that a patient BMI of ≤29.5 kg/m^2 was associated with total spinal anesthesia failure. Rukewe et al reported a lower weight and a lower BMI in the failed spinal anesthesia group of obstetric patients. However, those researchers did not find a significant association between failed spinal anesthesia and either weight or BMI.[7] Furthermore, Sng and coauthors[3] reported that patients with a higher height were more likely to have partial failure than no failure. Miyoshi and associates[11] found that a maternal BMI of <23 kg/m^2 resulted in an inadequate spinal block height (a block-level lower than T6) immediately after spinal anesthesia. However, their study did not find differences in the requirements for supplementary analgesic or anesthetics.[11] Although the average BMI resulting in inadequate block in the work of Miyoshi and colleagues (23.4 kg/m^2) in Japan was lower than that found by our study (28.4 kg/m^2), the present investigation showed that a lower BMI was associated with failed spinal block. This implies that the structure of a patient (that is, weight and height) affects the spread of spinal anesthesia. A possible mechanism is that the volume of cerebrospinal fluid varies depending on the intra-abdominal pressure and the pressure of the epidural space. In patients with a lower BMI, due to a lower weight or a higher height, there may be a lower epidural space pressure and thus a lower extension of the blockade. In addition, earlier research found that there was an inverse relationship between the length of the vertebral column and the cephalad spread of spinal anesthesia, which could be due to the larger volume of lumbosacral cerebrospinal fluid.[12] A study also found that the volume of lumbosacral cerebrospinal fluid was inversely proportional to BMI.[13] The common dose of 0.5% bupivacaine used in our institute was 11 mg, which was used for 103 of 110 patients (93.6%). There was a very narrow range for the amount of bupivacaine used in our practice. Additionally, our results showed that the common dose of bupivacaine used was only marginally below the ED95 dose of the drug (the dose with a 95% probability of response). When no supplemental epidural anesthesia is required during an operation, the ED95 of bupivacaine is 11.2 mg (plus fentanyl 10 mcg

Table 5

Data comparing failed spinal anesthesia group and control group (N = 440).

Parameters	Failed spinal anesthesia (n = 110)	Control (n = 330)	*P* value
Neonatal birth*weight (g)	2950.6 ± 482.9	3042.9 ± 551.6	.118
Uterine incision to delivery time (min)*	2.0 ± 1.4	2.0 ± 1.4	.936
Apgar score 1 min*	7.5 ± 1.8	8.3 ± 0.9	<.001†
Apgar score 5 min*	9.2 ± 0.9	9.5 ± 0.7	<.001†
Birth asphyxia*	3 (2.7)	2 (0.6)	.102
Anesthetic duration (min)	105.7 ± 33.6	83.3 ± 19.1	<.001†
Operative duration (min)	61.3 ± 31.9	53.1 ± 15.74	.011†

Data presented as mean ± SD or n (%).

SD = standard deviation.

*Data presented only for the first born of twins.

and morphine 200 mcg).[14] However, the dose that is regularly used in our institute can be problematic in patients with low BMI as it can lead to partial or total failure of spinal anesthesia.

The level of the anesthesia provider has been broadly studied in terms of spinal anesthesia failure in obstetric patients. Sng et al[3] did not find a difference between the rates of partial failure of spinal block for anesthesiologist specialists and residents who performed spinal anesthesia. In contrast, several studies determined that the performance of spinal blocks by personnel with less clinical experience administering anesthesia was an independent risk factor for partial or total failure of spinal anesthesia.[4,5,9] Our study found that anesthesia administration by a third-year resident was an associated risk factor. This was consistent with the work of Rukewe and colleagues,[7] which revealed that a spinal block performed by a senior registrar was a risk factor for partial or total anesthesia failure. As our center is a teaching hospital, third-year residents have the main responsibility for the obstetric theaters after office hours. We therefore sought to see whether the timing of the operations was associated with spinal anesthesia failure, but there was no difference between the hours. Data indicated that most of the failed spinal anesthesia patients (58.2%) were performed by third-year residents. This finding can be explained by the closer supervision by consultant anesthesiologists of junior residents than third-year residents while performing spinal anesthesia. Furthermore, there may be differences in case management after the initial failure of spinal anesthesia. During office hours, a repeated spinal block or epidural block can be done by a consultant anesthesiologist. After hours, it is more likely that a senior resident will convert from spinal anesthesia to general anesthesia.

Although our study did not obtain statistically significant results, emergency cesarean delivery tended to show the highest rate of total spinal anesthesia failure. Intrapartum cesarean delivery due to National Institute of Child Health and Human Development category II or previous cesarean delivery with labor pain puts patients in a state of discomfort and suffering. As a result, patients are difficult to immobilize while anesthesiologists perform the spinal block. A prospective study from the United Kingdom involving >5000 cesarean deliveries showed a higher rate of conversion from regional to general anesthesia for emergency (4.9%) than nonemergency (0.8%) cesarean deliveries.[8] This finding is consistent with the position of the British Royal College of Anaesthetists, which is that the acceptable rate of conversion to general anesthesia for emergency cesareans is higher than that for elective cesarean deliveries.[10] However, conflicting results for elective and emergency surgery emerged between previous cohort studies. Alabi et al[4] reported that emergency cesarean delivery was a factor related to partial and total failure of spinal anesthesia. In comparison, Rukewe and associates[9] did not find a significant relationship between partial or total failure and emergency cesarean delivery.

Approximately 10% of our failed spinal anesthesia patients received general anesthesia after delivery. Exteriorization of the uterus contributed to intraoperative pain, nausea and vomiting, discomfort from stretching of the uterine ligaments and the parietal peritoneum, and increased postoperative pain in patients.[15–17] However, exteriorization is the usual surgical technique at our center. Visceral pain and discomfort that resulted from the procedure explained the need for additional analgesia or general anesthesia after delivery. At and So found that exteriorization of the uterus and intraoperative tubal sterilization were factors related to partial failure of spinal anesthesia.[5] Similarly, Sng and associates.[3] reported that postpartum sterilization was the independent factor associated with partial failure of spinal anesthesia, making patients require supplemental fentanyl or nitrous oxide. However, our study could not demonstrate that tubal sterilization was associated with total failure of spinal block. The duration of surgery may also be 1 reason patients receive general anesthesia after delivery. The operative period of the failed spinal group was significantly longer than that of the control group. The recession of the sensory blockade can be explained by the local anesthetic drugs wearing off with time.

With the exception of intrathecal morphine, none of our patients received adjuvant spinal medications, such as intrathecal fentanyl or clonidine, as the staff at our center were not familiar with the usage of these medications. Fuzier et al[6] reported that the absence of an adjuvant medication in addition to local anesthesia was a factor contributing to spinal anesthesia failure and the need for general anesthesia in obstetric, abdominal, urologic, orthopedic, traumatic, and vascular surgery. The systematic review and meta-analysis concluded that adjuvant intrathecal fentanyl significantly reduced the need for supplemental intraoperative analgesia and decreased nausea and vomiting.[18] However, intrathecal fentanyl did not lower the rate of conversion to general anesthesia.[18]

Although not all patients in the failed spinal anesthesia group required general anesthesia before delivery, the results showed that the neonatal Apgar scores at 1 and 5 minutes were significantly lower than those of the control group. It is generally acknowledged that the use of general anesthesia results in patients needing intravenous and inhalational anesthetic agents, which are subsequently transferred to the intrauterine fetuses. Many studies have described the consequences of fetal exposure to anesthetic agents through maternal general anesthesia, but with some inconsistent conclusions.[19,20] However, another study revealed that the unplanned conversion from spinal to general anesthesia caused delayed neonatal respiration (respiration not achieved within 1 minute of delivery).[21] A network meta-analysis showed that the neonatal Apgar scores at 1 and 5 minutes of the spinal anesthesia group were significantly higher than those of the general anesthesia group.[22] Additionally, a recent systematic review reported that regional anesthesia provided higher neonatal Apgar scores at 1 and 5 minutes than general anesthesia, with an Apgar score of <7 at 1 minute being more common with general anesthesia.[23] Our results support the finding that conversion from spinal to general anesthesia causes significantly lower neonatal Apgar scores.

Two of our total spinal anesthesia failure cases exhibited unexpectedly difficult intubation with maternal desaturation. Preparation for a difficult airway after failed spinal anesthesia is

suggested. The clinical practice guidelines of both the American Society of Anesthesiologists Task Force on Obstetric Anesthesia and the Society for Obstetric Anesthesia and Perinatology 2016 recommend that equipment facilities be made available in an operating theater and supporting personnel be on hand in the event of inadequate regional anesthesia.[24] Therefore, it is essential to identify patients with a high risk of failed spinal anesthesia to allow anesthetic personnel to prepare for the provision of appropriate treatment, with difficult intubation equipment in place. To deal with a likely situation, all anesthesiologists should be familiar with the range of airway drills. Maternal and neonatal complications that result from the conversion of failed spinal anesthesia to general anesthesia should be the main concerns.

One of the limitations of our study was the lack of data on neonatal umbilical cord blood gas. This is because our institute did not routinely measure blood gas from the umbilical cord. Therefore, there were insufficient data to conduct a detailed analysis of the effects of failed spinal anesthesia on neonates. Second, the precise level of sensory blockade before general anesthesia was not recorded; therefore, the receding level of block by time is unknown. In addition, the exact number of spinal passes was not recorded in the surgical notes of approximately 30% of the patients in the failed spinal anesthesia group. This is pertinent as multiple spinal block passes were found to be a risk factor for spinal anesthesia failure. Lastly, the decisions to convert from spinal anesthesia to general anesthesia were based on the discretion of each consultant anesthesiologist on duty. We were unable to determine the actual reasons for the conversions to general anesthesia.

5. Conclusion

Total spinal anesthesia failure at our institute was uncommon, but it produced negative maternal and neonatal effects. A BMI of <29.5 kg/m^2 and the level of the anesthesia provider (specifically, third-year resident) performing the spinal block were the associated risk factors. Adjusting the dose of bupivacaine by patient structure (weight and height) is recommended, bearing in mind that a higher dose is appropriate for patients with a lower BMI. Adjuvant drugs for spinal anesthesia or combined spinal–epidural anesthesia were also beneficial for patients requiring prolonged operations, such as in cases intended for the teaching of operation techniques or intraoperative tubal sterilization. Finally, we emphasize the need for proficiency on the part of anesthetic trainees before they are authorized to perform spinal anesthesia on obstetric patients.

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Author contributions

Conceptualization: Wiruntri Punchuklang, Patchareya Nivatpumin
Data curation: Wiruntri Punchuklang, Patchareya Nivatpumin, Thatchanan Jintadawong
Formal analysis: Wiruntri Punchuklang, Patchareya Nivatpumin, Thatchanan Jintadawong
Methodology: Wiruntri Punchuklang, Patchareya Nivatpumin
Project administration: Wiruntri Punchuklang, Patchareya Nivatpumin
Resources: Wiruntri Punchuklang, Patchareya Nivatpumin
Supervision: Patchareya Nivatpumin
Validation: Wiruntri Punchuklang, Patchareya Nivatpumin
Writing – original draft: Wiruntri Punchuklang, Patchareya Nivatpumin
Writing – review & editing: Wiruntri Punchuklang, Patchareya Nivatpumi

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