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REPORTS OF ORIGINAL INVESTIGATIONS

Evaluation of failed and high blocks associated with spinal anesthesia for Cesarean delivery following inadequate labour epidural: a retrospective cohort study

Évaluation des blocs inadéquats et élevés associés à la rachianesthésie pour une césarienne après une péridurale inefficace pour le travail obstétrical: une étude de cohorte rétrospective

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Abstract

Purpose *The purpose of this retrospective cohort study was to investigate factors associated with failed and high spinal blocks in patients who received spinal anesthesia for Cesarean delivery following a labour epidural that was inadequate for surgical anesthesia.*

Methods *We searched our perioperative database for women with a labour epidural who received spinal or combined spinal-epidural anesthesia for Cesarean delivery due to the inadequacy of the existing epidural. The primary outcome was the occurrence of failed spinal blocks, and the secondary outcome was the occurrence of high blocks following spinal administration.*

Results *Of the 263 patients in the analysis, there were 29 (11%) failed spinals and nine (3%) high spinals. There was a significant difference between patients with failed spinals and those with successful spinals with regards to receipt of an epidural top-up dose for Cesarean delivery within 30 min of the spinal, type of neuraxial block, body mass index, age, and dose of hyperbaric bupivacaine. In a multivariable analysis, only receipt of an epidural top-up dose was associated with failure (OR, 6.0; 95% CI, 2.1 to 17.0; $P < 0.001$). As for the risk of a high spinal, patient characteristics and block details were not different amongst patients, except for a younger age in those with a high block.*

Conclusions *Administration of spinal anesthesia within 30 min of an epidural top-up dose is associated with increased risk of failure. We speculate that this may be due in part to the presence of a large volume of local anesthetic in the epidural space, which may be mistaken for cerebrospinal fluid during spinal placement.*

Résumé

Objectif *L'objectif de cette étude de cohorte rétrospective était d'explorer les facteurs associés aux blocs rachidiens inefficaces ou élevés chez les patientes ayant reçu une rachianesthésie pour une césarienne après une péridurale pour le travail qui ne convenait pas à une anesthésie chirurgicale.*

Méthode *Nous avons effectué une recherche dans notre base de données périopératoire et recueilli les données des femmes ayant reçu une péridurale pour le travail et qui ont reçu une anesthésie rachidienne ou une péridurale et rachidienne combinée pour un accouchement par césarienne en raison de l'inefficacité de la péridurale en place. Le critère d'évaluation principal était la survenue de blocs rachidiens inadéquats, et le critère secondaire était la survenue de blocs élevés suite à l'administration rachidienne.*

Résultats *Parmi les 263 patientes analysées, on a dénombré 29 (11 %) rachianesthésies inadéquates et neuf (3 %) rachianesthésies élevées. Une différence significative a été observée à plusieurs égards entre les patientes chez lesquelles la rachianesthésie avait échoué et celles chez lesquelles elle avait réussi, soit : la réception d'une dose complémentaire de péridurale pour la césarienne dans les 30 minutes avant la rachianesthésie, le type de bloc neuraxial, l'indice de masse corporel, l'âge et la dose de bupivacaïne hyperbare. Dans une analyse*

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multivariée, seule la réception d'une dose supplémentaire de péridurale était associée à un échec (RC, 6,0; IC 95 %, 2,1 à 17,0; P < 0,001). En ce qui touche au risque de rachianesthésie élevée, les caractéristiques des patientes et les spécificités du bloc n'ont pas joué de rôle significatif chez les patientes, hormis l'âge plus jeune des femmes chez lesquelles le bloc était élevé.

Conclusion *L'administration d'une rachianesthésie dans les 30 minutes suivant une dose péridurale supplémentaire est associée à un risque accru d'échec du bloc. Nous pensons que cela pourrait être en partie dû à la présence d'un important volume d'anesthésique local dans l'espace péridural, lequel pourrait être interprété comme du liquide céphalorachidien pendant la mise en place de la rachianesthésie.*

Controversy remains regarding the management of patients with an existing labour epidural that is deemed inadequate to provide surgical anesthesia for Cesarean delivery. Retrospective cohort studies have reported a 1.7-19.8% incidence of failure to convert an existing satisfactory labour epidural to surgical anesthesia with a top-up dose, and this often requires conversion to general anesthesia.[1,2] Risk factors associated with failed conversion of labour epidural analgesia to surgical anesthesia for Cesarean delivery were investigated in a recent meta-analysis. Such factors included an increased number of boluses delivered during labour, urgent need for Cesarean delivery, and care provided by a non-obstetric anesthesiologist.[3]

To avoid known complications associated with general anesthesia in parturients, spinal anesthesia is frequently performed if an existing labour epidural fails to provide adequate surgical anesthesia. Nevertheless, a number of case reports and retrospective studies have suggested that there may be an increased risk of a high block from a single intrathecal dose of local anesthetic following epidural anesthesia,[4-7] sometimes necessitating endotracheal intubation. While previous studies have evaluated the incidence of both failed epidural top ups and high spinal blocks in this situation,[1,2,4-7] there is a paucity of data analyzing the incidence of failed spinals in the setting of spinal anesthesia in women with an existing labour epidural. One previous study examined the rate of failed spinals for Cesarean delivery following labour epidurals,[8] but none of the patients in that study received an epidural top-up dose for the Cesarean delivery. Furthermore, that study did not examine the factors associated with failed blocks in this situation.

In our practice, we anecdotally observed a higher rate of failed spinal blocks following attempts to convert an existing labour epidural to surgical anesthesia with a top-up dose which proved inadequate. We speculated that this increase in observed failures may be due to either the presence of local anesthetic in the epidural space, which might be mistaken for cerebrospinal fluid (CSF) when performing a subsequent spinal anesthetic, or an underdosing of the spinal due to clinician concern regarding a greater risk of high block. Therefore, the purpose of this study was to investigate the incidence and factors associated with failed blocks in patients receiving a spinal anesthetic for Cesarean delivery following an existing labour epidural that was unable to be adequately topped up for surgical anesthesia. A secondary objective was to assess the incidence of high spinal blocks in this setting.

Methods

Our Institutional Review Board approved this study and waived the requirement for written informed consent. This was a secondary analysis of data extracted from our Duke Perioperative Anesthesia Database for a different study.[9] Duke University Hospital is an academic teaching institution with approximately 3,500 deliveries per year, including a mix of high- and low-risk parturients. A dedicated group of nine obstetric anesthesiologists provide 24-hr coverage for the labour and delivery unit and make all final decisions regarding anesthetic management of patients. Anesthesia residents in their first, second, or third year, a certified registered nurse anesthetist (CRNA), and an obstetric anesthesia fellow staff the labour and delivery ward. Residents and CRNAs perform the majority of the neuraxial procedures.

We retrospectively retrieved data from the Duke Perioperative Anesthesia Database using the following criteria: labouring women with an existing labour epidural requiring a Cesarean delivery and receiving either a single-shot spinal or a combined spinal-epidural (CSE) anesthesia due to inadequacy of the labour epidural to provide surgical anesthesia, either after a top up for Cesarean delivery or without receipt of a top-up dose. The database is derived from patients' electronic medical records documented in the electronic charting system (Innovian®; Dräger Medical Systems Inc., Telford, PA, USA) and used for research purposes. The database includes data about all patients irrespective of billing, insurance, or patient characteristics. Patient information, including demographic data, presence of a labour epidural, and intraoperative management during Cesarean delivery, was collected starting August 19, 2003, when an electronic charting system was installed at the labour and delivery unit at Duke University Hospital, and extracted on May 30, 2013 when the hospital changed electronic health record systems. There were no

significant institutional changes in the patient population, care delivery, or staffing model over the period of data collection. All labour epidurals were maintained with a continuous infusion and patient-controlled epidural analgesia with a solution consisting of 0.125% bupivacaine with fentanyl 2 $\mu g \cdot mL^{-1}$.

We initially searched the database for all women who received a spinal or a CSE anesthetic for Cesarean delivery. We then identified women who had an existing labour epidural prior to the spinal or CSE performed for the Cesarean delivery. We looked for patients who received repeat spinal dosing, those who needed intraoperative analgesic supplementation, and those who received a general anesthetic after the neuraxial block for the Cesarean delivery. The database, which was constructed from anesthetic records, captured all times and doses of the medications administered, the surgical incision and end of surgery times, as well as the time and type of neuraxial blockade. Once we identified our cohort, we manually reviewed the individual record of each woman who met the inclusion criteria to confirm success or failure of the block. In addition, we manually reviewed all cases of free-text documentation by providers for specific clinical decisions in our cohort, such as repeating the block or converting to general anesthesia. We also examined the operative record of all included patients to extract data about the indication and degree of urgency of the Cesarean delivery.

The primary outcome was inadequate surgical anesthesia (i.e., failed block) following the spinal anesthetic, and the secondary outcome was the occurrence of a high spinal block. A failed block was defined as the need to repeat the neuraxial technique to obtain an adequate block height, convert to general anesthesia secondary to pain within 60 min of incision, or supplement with at least two of the following within 60 min of incision: nitrous oxide, fentanyl ($>$ 100 μg *iv*), intravenous ketamine, intravenous midazolam or propofol (in addition to epidural lidocaine if the CSE technique was used). A high spinal was defined as the need to convert to general anesthesia within the first 20 min after the initial block due to weakness, altered mentation, respiratory distress, or a recorded block height $\geq$ the T1 dermatome.

We collected information about patient demographics, receipt of an epidural top-up dose (defined as a bolus of epidural lidocaine $\geq$ 200 mg within 30 min prior to spinal or CSE administration), type of block performed (single-shot spinal or CSE), dose of hyperbaric bupivacaine, indication for Cesarean delivery, provider performing the block (resident, CRNA, or attending), number of top ups needed during labour, documented block level prior to and after spinal or CSE, and highest documented sensory level for all patients.

Statistical analysis

We used the Kolmogrov-Smirnov test to assess for normality of distribution of the data. Normally distributed data are presented as mean (standard deviation [SD]), and non-normally distributed data are presented as median [interquartile range (IQR)]. Wilcoxon rank-sum test, Student's *t* test, Fisher's exact test, and Chi square test were used as appropriate to compare variables in patients with a failed spinal *vs* those with a successful spinal (i.e., primary outcome) and those with a high spinal *vs* those without a high block (i.e., secondary outcome). *P* values and confidence intervals were not adjusted for the use of the same control group in the two analyses. Variables with a $P < 0.1$ in univariate analysis were subsequently tested in multivariate analysis with block failure as the outcome. Statistical analyses were conducted using SAS® v9.3 software (SAS Institute Inc., Cary, NC, USA). All reported *P* values are two sided.

Results

There were 5,570 patients who received either a spinal or CSE for Cesarean delivery during the study period. Of these patients, 263 had an existing labour epidural and were included in the analysis. Of those, 90 (34%) received epidural top-up doses for Cesarean delivery within 30 min prior to placement of a spinal or CSE technique. No patient in this cohort had more than one delivery, and there were no obstetrical emergencies requiring general anesthesia. One patient had a failed spinal, followed by a repeat spinal 20 min later that subsequently resulted in a high block. This patient was included in both analyses. The most common dose of hyperbaric bupivacaine administered with the spinal technique was 12 mg (38%), followed by 10.5 mg (25%), 7.5-9.75 mg (17%), 11.25 mg (17%), $\geq$ 12.75 mg (2%), and $<$ 7.5 mg (1%). The most common dose of hyperbaric bupivacaine administered with the CSE technique was 7.5 mg (31%), followed by 12 mg (25%), 9-10.5 mg (25%), and $<$ 7.5 mg (19%).

Primary outcome: failed blocks

Overall, there were 29 (11%) failed blocks. A single-shot spinal was used in 24 cases, and a CSE was used in five cases. Eighteen (62%) of the 29 failed blocks required general anesthesia; eight failures (28%) required additional pain control with supplemental intravenous adjuvants (with or without nitrous oxide), and three failures (10%) required repeating the spinal technique with a second dose. The following doses of hyperbaric bupivacaine were used in the 29 patients who had failed blocks: 4.5 mg (n = 1), 5.25 mg

(n = 1), 7.5 mg (n = 7), 8.25 mg (n = 2), 9 mg (n = 1), 10.5 mg (n = 8), 11.25 mg (n = 4), and 12 mg (n = 5). The dermatomal levels in 14 patients were recorded prior to spinal placement. Five patients (36%) had levels documented as below T10 bilaterally; four patients (29%) had levels of T7-T10 bilaterally; four patients (29%) had one-sided blocks; and one patient had a T6 level (7%) bilaterally.

Following the spinal placement, 15 (52%) of the 29 patients had no block level detected, as documented in the anesthetic record. In five of those cases, the providers specifically noted that they could freely aspirate fluid prior to and at the end of spinal injection. The remaining 14 patients with failed blocks had a documented sensory level, but they developed pain when the surgeon tested them with surgical forceps prior to incision or immediately following incision.

Table 1 summarizes patient characteristics, indications for Cesarean delivery, provider level, and type of block in patients with a failed spinal *vs* those with a successful block following an inadequate epidural. Of the failed blocks, 22 of 29 (76%) had an epidural top-up dose in the preceding 30 min compared with only 68 of 234 (29%) in the non-failure group ($P < 0.001$). The mean (SD) time from top-up dose to new neuraxial technique was 25 (3) min and the median [IQR] lidocaine dose used for top up was 400 [300-500] mg.

There was also a significant difference in the type of block used for Cesarean delivery between patients who had a failed block *vs* those with a successful block; five patients (21%) had CSEs in the failure group compared with 11 patients (5%) in the non-failure group ($P = 0.02$). Details regarding the management of the CSEs are summarized in Table 2.

In addition to differences regarding receipt of an epidural top up and type of block between patients with a failed block *vs* those with a successful block, there was a significant difference between groups in weight, body mass index (BMI), age, and bupivacaine dose (Table 1). In the multivariable model with failed block as an outcome, BMI, age, bupivacaine dose, type of block, and receipt of an epidural top up were used as predictors. The final model (C-index = 0.774) is shown in Table 3. Receipt of a top-up dose was significantly associated with a failed block, with an adjusted odds ratio of 6.0 (95% confidence interval, 2.1 to 17.0; $P < 0.001$). The BMI, type of block, age, and bupivacaine dose were not associated with a failed block. There was no difference in results in a model when using weight instead of BMI.

Secondary outcome: high block

There were nine (3%) high spinals. Five (56%) were converted to general anesthesia due to weakness, altered mentation, or respiratory distress, and the remaining four (44%) had recorded block levels $\geq$ T1 without conversion to general anesthesia. The doses of hyperbaric bupivacaine used in patients who had high blocks were 7.5 mg (one), 9 mg (one), 9.75 mg (one), 10.5 mg (one), 11.25 mg (one), and 12 mg (four). Three patients had an epidural sensory block level recorded prior to spinal placement: two patients (67%) had levels documented as $\leq$ T10 bilaterally, and one patient (33%) had a level at T9 bilaterally. Table 4 shows patient characteristics, indications for Cesarean delivery, and type of block in patients with a high spinal following an inadequate epidural *vs* those without a high block. Patients were significantly younger in the high spinal group, but other patient demographics, block characteristics, and receipt of an epidural top-up dose were not different between those patients with *vs* without a high block.

Discussion

Concerns regarding the safety of using spinal anesthesia in the setting of an existing labour epidural have been well described in the literature. Multiple case reports published as early as 1989 document high spinal block in parturients who underwent spinal anesthesia following an inadequate labour epidural for Cesarean delivery.[10] Although a variety of mechanisms have been postulated, the leading theory suggests that compression of the dural sac by residual anesthetic in the epidural space may result in cephalad displacement of the intrathecal dose within the CSF.[7,11]

In contrast, other more recent cohort studies have shown no difference in the rate of high block between *de novo* spinals for Cesarean delivery and those placed after an existing labour epidural, if certain precautions are used.[8,12,13] These precautions include using a lower intrathecal dose, limiting top-up doses to > 30 min prior to the spinal administration, and delaying supine positioning for two minutes following spinal placement. Recently, Vaida *et al.* suggested an algorithm for the anesthetic management of patients requiring Cesarean delivery with unsatisfactory labour epidurals.[14] This algorithm includes the option of a single-shot spinal, if appropriate, based on the urgency of Cesarean delivery, but does not specify dosing regimens. The controversy regarding safety remains, as a standardized intrathecal dose of local anesthetic has not been described for these patients and there is no ability to titrate a single dose.[15,16]

At the standard doses of local anesthetic used in our practice (0.75% hyperbaric bupivacaine 10.5-12 mg), the block failure and high spinal rates for *de novo* spinals at our institution are 5.0%[9] and 0.6%,[17] respectively. In this retrospective database analysis, our results show that the

Table 1 Univariate analysis based on a failed block

	Failure (*n*=29)	No failure (*n*=226)	*P* value	OR (95% CI)
Age, yr	25 (6)	28 (7)	0.05	0.94 (0.88 to 1.00)
Height, cm	162 (8)	162 (8)	0.18	0.97 (0.92 to 1.01)
Weight, kg	78 (18)	88 (22)	0.02	0.97 (0.95 to 1.00)
BMI, $kg \cdot m^{-2}$	30 (5)	33 (8)	0.03	0.93 (0.87 to 1.00)
Gestational age, weeks	38 (3)	39 (2)	0.43	0.92 (0.80 to 1.06)
Block type, spinal / CSE	24 (83%)/5 (21%)	215 (95%)/11 (5%)	0.02	0.24 (0.08 to 0.77)
Hyperbaric bupivacaine dose, mg				
All cases combined	10.5 (2)	11.3 (1)	<0.001	0.67 (0.54 to 0.82)
Spinal cases	10.1 (2)	10.9 (1)	0.05	0.68 (0.52 to 0.89)
CSE cases	7.1 (2)	9.2 (3)	0.42	0.72 (0.46 to 1.15)
Provider level*			0.60	
Attending	7 (32%)	43 (24%)		1.57 (0.59 to 4.2)
CRNA	2 (9%)	13 (7%)		1.48 (0.3 to 7.3)
Resident	13 (59%)	125 (69%)		Reference
Number of clinician top ups needed during labour	1.4 (1.5)	1.1 (1.4)	0.26	1.15 (0.90 to 1.47)
Epidural Topped Up for Cesarean, yes / no	22 (76%)†/7(24%)††	66 (29%)/160(71%)	<0.001	7.62 (3.1 to 18.7)
Year of delivery			0.20	1.13 (0.95 to 1.45)
2003-2004	3 (10%)	17 (8%)		
2005-2006	12 (41%)	45 (20%)		
2007-2008	4 (14%)	65 (29%)		
2009-2010	7 (24%)	60 (27%)		
2011-2012	3 (10%)	29 (13%)		
2013	0 (0%)	10 (4%)		
Indications for Cesarean delivery			0.81	
Chorioamnionitis	0 (0%)	2 (1%)		0.02 (0 to 2.7×10^{-10})
FTP	19 (66%)	166 (74%)		1.03 (0.12 to 8.6)
FTP with NRFHT	3 (6%)	15 (7%)		1.8 (0.16 to 20.0)
Malpresentation	2 (6%)	7 (3%)		2.6 (0.19 to 34.5)
NRFHT	4 (14%)	27 (12%)		1.33 (0.13, to 13.5)
Severe preeclampsia	1 (4%)	9 (4%)		Reference

Data are mean (SD) or number (%). BMI = body mass index; CI = confidence interval; CRNA = certified registered nurse anesthetist; CSE = combined spinal epidural; GA= general anesthesia; FTP = failure to progress; NRFHT = non-reassuring fetal heart tracing; OR = odds ratio. *Data missing in 52 cases, †general anesthesia in 14, analgesic supplementation in seven, and block repeated in one, †† general anesthesia in three, analgesic supplementation in two, and block repeated in two

administration of a spinal anesthetic following an inadequate labour epidural is associated with an increased risk of block failure (11.0%) and high blocks (3.4%) compared with *de novo* techniques.

In a previous retrospective cohort study, Visser *et al.* examined spinal anesthesia for Cesarean delivery following epidural labour analgesia in 128 patients. The authors reported that three patients (2.3%) needed conversion to general anesthesia—two of these cases were due to insufficient anesthesia (1.2%). There are a number of differences between the study by Visser *et al.* and our study. First, none of the patients in Visser's study received an epidural top-up dose for Cesarean delivery. Second, they did not report on the need for intraoperative supplemental analgesics, which we included in our definition of failure. Although our results indicate a higher overall rate of failed spinals, the majority of these failures occurred following an epidural top-up dose for Cesarean delivery. In fact, examination of the 167 patients in our analysis who did not receive an epidural top up reveals that three patients (1.8%) required conversion to general anesthesia due to an inadequate block. These

Table 2 Analysis of combined spinal epidurals based on failed block

	Failed CSE (n=5)	No Failed CSE (n=11)	P value	OR (95% CI)
Labour epidural top up for Cesarean,* yes/no	5 (100%)/0 (0%)	6 (55%)/5 (45%)	0.10	
Labour epidural lidocaine top up dose before CSE, mg†	480 (91)	327 (114)	0.04	1.01 (1.00 to 1.03)
Spinal Dose for CSE, mg	7.1 (2)	9.2 (3)	0.45	0.72 (0.46 to 1.15)
Epidural lidocaine after CSE, yes/no	2 (40%)/3 (60%)	5 (45%)/6 (55%)	0.11	1.25 (0.15 to 10.7)
Epidural lidocaine dose after CSE, mg†	150 (71)	112 (52)	0.46	1.01 (0.99 to 1.05)

Data are mean (SD) or number (%). CSE = combined spinal epidural; OR = odds ratio. *Given the observed rates of no top up, the odds ratio estimates are not informative and therefore not presented. †These data are for patients who received lidocaine. Top-up doses before Cesarean included doses of at least 200 mg lidocaine given within 30 min of CSE placement

Table 3 Multivariate analysis of factors associated with a failed spinal

Covariable	Adjusted Odds Ratio (95% Confidence Interval)	P value
Epidural top up	6.0 (2.1 to 17.0)	<0.001
Block type, spinal *vs* CSE	0.34 (0.08 to 1.53)	0.17
BMI, $kg{\cdot}m^{-2}$	0.93 (0.87 to 1.00)	0.06
Hyperbaric bupivacaine, mg	0.93 (0.87 to 1.27)	0.76
Age, yr	0.98 (0.92 to 1.05)	0.61

BMI = body mass index; CSE = combined spinal epidural

results are comparable with the rates reported in Visser's study.

The risk of block failure in our study was significantly higher if the epidural had been topped up within 30 min prior to spinal administration. In keeping with previous studies,[8,12-14] we used a 30-min cut-off to ensure that we could adequately capture a top-up dose for surgical anesthesia. During the performance of a spinal anesthetic, the traditional endpoint for confirmation of proper needle placement is the free flow of clear fluid from the needle hub. Under normal circumstances, it is unusual for spinal anesthesia to fail when this endpoint is obtained.[18] Nevertheless, the inaccurate assumption that CSF is the clear fluid being aspirated during spinal placement may lead to failure of the neuraxial block, particularly in the setting of prior fluid in the epidural space.[13,19] The increased incidence of failed spinals that we report, particularly in patients who received a recent top-up dose, may be due to the presence of a large volume of local anesthetic within the lumbar epidural space which may be mistaken for CSF during spinal administration. Indeed, in five cases with no block documented following spinal administration, the providers specifically charted that they could freely aspirate fluid prior to injection of the intrathecal local anesthetic. In these cases, it may be appropriate to consider using a CSF glucose test to ensure that the clear fluid is not residual local anesthetic in the epidural space.[20]

The above explanation may account for the 15 cases in which it was documented that no block was detected following spinal placement. Nevertheless, surgery was allowed to proceed in 14 cases, and it was ultimately converted to general anesthesia or required analgesic supplementation due to pain immediately following testing with surgical forceps or skin incision. Therefore, the spinal dose in those cases might have been inadequate or the patient may have developed an incomplete or patchy block which made the documented level unreliable. It is difficult to determine appropriate spinal dosing in these situations with no available data to guide dosing. Consequently, the chosen dose is often based on the individual clinician's decision, which is also likely influenced by the sensory level prior to spinal administration.

The overall incidence of high spinal block in our study (3%) was greater than that in Visser's study (0.8%) and in another previous retrospective study where no epidural top ups were given (1.5%).[21] Nevertheless, the overall incidence was lower than reported in that same study in patients who received an epidural top-up dose (9.9%) as well as in another previous study (11%) where at least two of the three patients who developed a high block received an epidural top-up dose.[4] It is difficult to make comparisons between those studies due to differences in spinal dosing and receipt of epidural top-up doses. It is possible that providers in our practice have an increased

Table 4 Univariate analysis based on high block

	High Block (*n*=9)	No high block (*n*=226)	*P* value	OR (95% CI)
Age, yr	22 (4)	28 (7)	0.01	0.85 (0.74 to 0.98)
Height, cm	164 (9)	162 (8)	0.51	1.04 (0.95 to1.13)
Weight, kg	85 (15)	88 (22)	0.89	0.99 (0.96 to 1.03)
BMI, $kg \cdot m^{-2}$	32 (5)	33 (8)	0.75	0.97 (0.87 to 1.07)
Gestational age, weeks	40 (1)	39 (2)	0.32	1.28 (0.83 to 2.0)
Block type,† spinal/CSE	9 (100%)/0 (0%)	215 (95%)/11 (5%)	1.0	
Hyperbaric bupivacaine, mg	11 (2)	11 (2)	0.73	0.93 (0.61 to 1.41)
Provider level*†			0.81	
Attending	1 (14%)	43 (24%)		
CRNA	0 (0 %)	13 (7%)		
Resident	6 (86%)	125 (69%)		
Epidural Topped Up, yes/no	2 (22%)/7 (78%)	66 (29%)/160 (71%)	1.0	1.44 (0.29 to 7.1)
Year of delivery			0.24	1.07 (0.79 to 1.45)
2003-2004	1 (11%)	17 (8%)		
2005-2006	0 (0%)	45 (20%)		
2007-2008	1 (11%)	65 (29%)		
2009-2010	5 (56%)	60 (27%)		
2011-2012	2 (22%)	29 (13%)		
2013	0 (0%)	10 (4%)		
Indications for Cesarean delivery†			1.0	
Chorioamnionitis	0 (0%)	2 (0.9%)		
FTP	8 (89%)	166 (74%)		
FTP with NRFHT	0 (0%)	15 (7%)		
Malpresentation	0 (0%)	7 (3%)		
NRFHT	1 (11%)	27 (12%)		
Severe preeclampsia	0 (0%)	9 (4%)		

Data are mean (SD) or number (%). BMI = body mass index; CI = confidence interval; CSE = combined spinal epidural; CRNA = certified registered nurse anesthetist; GA = general anesthesia; FTP = failure to progress; NRFHT = non-reassuring fetal heart tracing; OR = odds ratio. *Data missing in 47 cases, †given the observed rates of high block for these variables, the odds ratio estimates are not informative and therefore not presented

awareness of the risk of high spinals following epidural top up and employed different techniques, such as a longer sitting time, before placing the patient in a supine position.

Due to the uncertainty about the appropriate dosing of a spinal anesthetic in the setting of an existing inadequate epidural and concerns about both high block and failed block, performance of a CSE rather than a single-shot spinal might be the preferred technique. While our results seem to indicate a higher failure rate with a CSE *vs* spinal anesthesia, all five of the failed CSEs in our cohort received a top-up dose prior to placement of the spinal, and only two received local anesthetic through their new epidural catheter. This was likely due to concern about local anesthetic toxicity given that a mean top-up dose of 480 mg of lidocaine was administered prior to placing the new CSE. Theoretically, a CSE would allow for the administration of a lower spinal dose, which might reduce the risk of a high block and would also provide a backup in case the spinal dose failed. Therefore, if there are concerns whether a labour epidural can be converted successfully to surgical anesthesia, we recommend CSE placement without a preceding epidural top-up dose. Indeed, some have recommended performing a CSE in this situation,[16] but a CSE might be more time-consuming compared with a single-shot spinal, especially if there was an urgency to the Cesarean delivery. Most of the cases in this series were in fact single-shot spinals rather than CSEs. Of importance, however, our data do not provide support for the recommendation to perform a CSE in this situation, partly due to the small number of CSEs used in our series, and future data are needed to examine the success of this proposed strategy. Alternatively, a repeat epidural might be performed, allowing for incremental dosing and reducing the risk of a high block. Nevertheless, this option might be limited in cases where there is an urgency to the Cesarean delivery or if a large top-up dose was already

administered through the inadequate labour epidural catheter. This strategy, however, was not investigated in our study and needs to be assessed in future studies.

There are limitations to our study. As this is a retrospective analysis, we cannot ascertain from the patients' charts the reasoning behind every clinical decision made by the responsible attending anesthesiologist. The determination regarding the adequacy of a labour epidural might have varied between different attending anesthesiologists. Additionally, sensory block levels before and after top-up doses and prior to spinal administration were not consistently documented and might have varied between different patients. Therefore, we are unable to control for initial block levels prior to spinal administration or to determine the effect this may have had on both failed and high blocks. Also, guidelines are lacking regarding the spinal dose to use in this scenario, and a range of doses were used in the cases included in this analysis. The urgency of the Cesarean delivery could have varied among the included cases; however, in all cases, there was enough time available to replace the epidural with a new block.

Like many major United States academic centres, Duke is a teaching institution where residents and CRNAs perform the majority of the neuraxial procedures. There was no difference between the failure and non-failure groups in the level of provider performing the block, but these data were missing in 18% of the included cases. Of importance, however, is the fact that the failure rate in this cohort is higher than the 5% failure rate in *de novo* blocks reported in parturients undergoing Cesarean delivery at term at our institution. Residents performed about 70% of those procedures.[9] Finally, we have no way to account for patients who might have a genetic predisposition for an inadequate labour epidural or spinal failure, such as resistance to local anesthetics or hyperalgesia related to abnormal neural signalling.[22,23] Despite those limitations, our study highlights that spinal anesthetics performed after an existing inadequate labour epidural have a high risk of failure. This could be due to mistaking local anesthetic in the epidural space for CSF during performance of a spinal anesthetic.

In conclusion, careful consideration regarding management of anesthesia must be given to patients with an existing inadequate labour epidural who require Cesarean delivery. This attention is necessary due to the risks of failed and high blocks associated with subsequent spinal anesthesia. There is a higher risk of a failed spinal anesthetic if an epidural top-up dose has been administered within 30 min of the Cesarean delivery. Early recognition of an inadequate labour epidural is essential in order to avoid future complications associated with a failed top-up dose.

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References

1. *Paech MJ*, *Godkin R*, *Webster S*. Complications of obstetric epidural analgesia and anaesthesia: a prospective analysis of 10,995 cases. Int J Obstet Anesth 1998; 7: 5-11.
2. *Orbach-Zinger S*, *Friedman L*, *Avramovich A*, *et al*. Risk factors for failure to extend labor epidural analgesia to epidural anesthesia for cesarean section. Acta Anaesthesiol Scand 2006; 50: 1014-8.
3. *Bauer ME*, *Kountanis JA*, *Tsen LC*, *Greenfield ML*, *Mhyre JM*. Risk factors for failed conversion of labor epidural analgesia to cesarean delivery anesthesia: a systematic review and meta-analysis of observational trials. Int J Obstet Anesth 2012; 21: 294-309.
4. *Furst SR*, *Reisner LS*. Risk of high spinal anesthesia following failed epidural block for cesarean delivery. J Clin Anesth 1995; 7: 71-4.
5. *Gupta A*, *Enlund G*, *Bengtsson M*, *Sjoberg F*. Spinal anaesthesia for caesarean section following epidural analgesia in labour: a relative contraindication. Int J Obstet Anesth 1994; 3: 153-6.
6. *Mets B*, *Broccoli E*, *Brown AR*. Is spinal anesthesia after failed epidural anesthesia contraindicated for cesarean section? Anesth Analg 1993; 77: 629-31.
7. *Beck GN*, *Griffiths AG*. Failed extradural anaesthesia for caesarean section. Complication of subsequent spinal block. Anaesthesia 1992; 47: 690-2.
8. *Visser WA*, *Dijkstra A*, *Albayrak M*, *Gielen MJ*, *Boersma E*, *Vonsee HJ*. Spinal anesthesia for intrapartum cesarean delivery following epidural labor analgesia: a retrospective cohort study. Can J Anesth 2009; 56: 577-83.
9. *Adesope OA*, *Einhorn LM*, *Olufolabi AJ*, *Cooter M*, *Habib AS*. The impact of gestational age and fetal weight on the risk of failure of spinal anesthesia for cesarean delivery. Int J Obstet Anesth 2016; 26: 8-14.
10. *Stone PA*, *Thorburn J*, *Lamb KS*. Complications of spinal anaesthesia following extradural block for caesarean section. Br J Anaesth 1989; 62: 335-7.
11. *Blumgart CH*, *Ryall D*, *Dennison B*, *Thompson-Hill LM*. Mechanism of extension of spinal anaesthesia by extradural injection of local anaesthetic. Br J Anaesth 1992; 69: 457-60.
12. *Dadarkar P*, *Philip J*, *Weidner C*, *et al*. Spinal anesthesia for cesarean section following inadequate labor epidural analgesia: a retrospective audit. Int J Obstet Anesth 2004; 13: 239-43.
13. *Portnoy D*, *Vadhera RB*. Mechanisms and management of an incomplete epidural block for cesarean section. Anesthesiol Clin North America 2003; 21: 39-57.
14. *Vaida S, Cattano D, Hurwitz D, Mets B.* Algorithm for the anesthetic management of cesarean delivery in patients with unsatisfactory labor epidural analgesia. F1000Res 2015; 4: 98.

15. *Wilson MJ*. When using spinal anaesthesia for caesarean section after the epidural has failed, the normal dose of spinal anaesthetic should be used. Int J Obstet Anesth 2005; 14: 53-5.
16. *Carvalho B*. Failed epidural top-up for cesarean delivery for failure to progress in labor: the case against single-shot spinal anesthesia. Int J Obstet Anesth 2012; 21: 357-9.
17. *Einhorn LM, Akushevich I, Habib AS.* Intrathecal bupivacaine dose for cesarean delivery is not reduced in obese compared to non-obese parturients. American Society of Anesthesiologists Annual Meeting; New Orleans, 2014: A4206 (abstract).
18. *Levy JH*, *Islas JA*, *Ghia JN*, *Turnbull C*. A retrospective study of the incidence and causes of failed spinal anesthetics in a university hospital. Anesth Analg 1985; 64: 705-10.
19. *Lang SA*, *Prusinkiewicz C*, *Tsui BC*. Failed spinal anesthesia after a psoas compartment block. Can J Anesth 2005; 52: 74-8.
20. *Fah A*, *Sutton J*, *Cohen V*, *Dowling K*, *Cyna AM*. A comparison of epidural and cerebrospinal fluid glucose in parturients at term: an observational study. Int J Obstet Anesth 2012; 21: 242-4.
21. *Kinsella SM*. A prospective audit of regional anaesthesia failure in 5080 caesarean sections. Anaesthesia 2008; 63: 822-32.
22. *Kavlock R*, *Ting PH*. Local anesthetic resistance in a pregnant patient with lumbosacral plexopathy. BMC Anesthesiol 2004; 4: 1.
23. *Bevacqua BK*, *Cleary WF*. Relative resistance to intrathecal local anesthetics. Anesth Analg 1994; 78: 1024-6.