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REPORTS OF ORIGINAL INVESTIGATIONS

Anesthetic management of patients with class 3 obesity undergoing elective Cesarean delivery: a single-centre historical cohort study

Prise en charge anesthésique de patientes obèses de classe 3 bénéficiant d'un accouchement par césarienne programmée : une étude de cohorte historique monocentrique

Oscar F. C. van den Bosch, MD · Marie-Eve Fiset, MD · Kristi Downey, MSc · Cynthia Maxwell, MD · Jose C. A. Carvalho, MD, PhD

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Abstract

Purpose *The preferred neuraxial anesthetic technique for patients with class 3 obesity undergoing elective Cesarean delivery is still under debate. We aimed to describe the anesthetic technique used in our tertiary institution across body mass index (BMI) groups and different surgical incisions.*

Method *In this historical cohort study, we reviewed medical records of patients with a BMI* $\geq$ *40 kg·m*$^{-2}$ *undergoing elective Cesarean delivery between July 2014 and December 2020. We collected data on patient characteristics, anesthetic and surgical technique, and procedural times. For data analysis, we stratified patients by BMI into three different groups: 40.0–49.9 kg·m*$^{-2}$*, 50.0–59.9 kg·m*$^{-2}$*, and* $\geq$ *60.0 kg·m*$^{-2}$*.*

Results *We included 396 deliveries, distributed as follows: 258 with a BMI 40.0–49.9 kg·m*$^{-2}$*, 112 with a BMI 50.0–59.9 kg·m*$^{-2}$*, and 26 with a BMI* $\geq$ *60.0 kg·m*$^{-2}$*. For patients with a BMI 40.0–49.9 kg·m*$^{-2}$*, the anesthetic technique of first choice was predominantly spinal anesthesia (71%), whereas for those with a BMI* $\geq$ *60.0 kg·m*$^{-2}$*, spinal anesthesia was never used as the anesthetic of first choice. With regard to the surgical incision, spinal anesthesia was almost exclusively used for patients undergoing Pfannenstiel incision and was rarely used for a higher supra- or infraumbilical transverse or midline incision. The overall incidence of general anesthesia was low (7/396, 1.8%). Anesthetic time, surgical time, and operating room time increased almost twofold in patients with a BMI* $\geq$ *60.0 kg·m*$^{-2}$ *compared with those with a BMI of 40.0–49.9 kg·m*$^{-2}$*.*

Conclusion *Neuraxial anesthesia was successfully used in approximately 98% of patients with class 3 obesity undergoing elective Cesarean delivery. The choice of regional anesthesia technique varied with increasing BMI and with the planned surgical incision. Procedural times increased with increasing BMI. This information should prove useful for comparing anesthetic choices and outcomes in this challenging population.*

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O. F. C. van den Bosch, MD (✉) · M.-E. Fiset, MD · K. Downey, MSc
Department of Anesthesiology and Pain Medicine, Mount Sinai Hospital, University of Toronto, 600 University Ave, Room 7-400, Toronto, ON M5G 1X5, Canada
e-mail: o.f.c.vandenbosch@umcutrecht.nl

C. Maxwell, MD
Department of Obstetrics and Gynecology, Mount Sinai Hospital, University of Toronto, Toronto, ON, Canada

J. C. A. Carvalho, MD, PhD
Department of Anesthesiology and Pain Medicine, Mount Sinai Hospital, University of Toronto, 600 University Ave, Room 7-400, Toronto, ON M5G 1X5, Canada

Department of Obstetrics and Gynecology, Mount Sinai Hospital, University of Toronto, Toronto, ON, Canada

Résumé

Objectif *La technique d'anesthésie neuraxiale préférée pour les patientes atteintes d'obésité de classe 3 bénéficiant d'un accouchement par césarienne* *programmée n'a pas encore été déterminée. Nous avons cherché à décrire la technique d'anesthésie utilisée dans notre établissement d'enseignement supérieur à travers les groupes d'indice de masse corporelle (IMC) et les différentes incisions chirurgicales.*

Méthode *Dans cette étude de cohorte historique, nous avons examiné les dossiers médicaux de patientes ayant un IMC ≥ 40 kg·m^{-2} ayant bénéficié d'un accouchement par césarienne programmée entre juillet 2014 et décembre 2020. Nous avons recueilli des données sur les caractéristiques des patientes, la technique anesthésique et chirurgicale et les délais de procédure. Pour l'analyse des données, nous avons stratifié les patientes par IMC en trois groupes différents, soit : 40,0–49,9 kg·m^{-2}, 50,0–59,9 kg·m^{-2}, et ≥ 60,0 kg·m^{-2}.*

Résultats *Nous avons inclus 396 accouchements, répartis comme suit : 258 pour un IMC de 40,0 à 49,9 kg·m^{-2}, 112 pour un IMC de 50,0 à 59,9 kg·m^{-2}, et 26 pour un IMC ≥ 60,0 kg·m^{-2}. Pour les patientes ayant un IMC de 40,0 à 49,9 kg·m^{-2}, la technique anesthésique de premier choix était principalement la rachianesthésie (71 %), alors que pour celles dont l'IMC ≥ de 60,0 kg·m^{-2}, la rachianesthésie n'a jamais été utilisée comme modalité anesthésique de premier choix. En ce qui concerne l'incision chirurgicale, la rachianesthésie était presque exclusivement utilisée pour les patientes bénéficiant d'une incision de Pfannenstiel et était rarement utilisée pour une incision transversale ou médiane supra- ou infra-ombilicale supérieure. L'incidence globale d'anesthésie générale était faible (7/396, 1,8 %). Le temps d'anesthésie, le temps chirurgical et le temps passé en salle d'opération ont presque doublé chez les patientes ayant un IMC ≥ 60,0 kg·m^{-2} par rapport à celles ayant un IMC de 40,0 à 49,9 kg·m^{-2}.*

Conclusion *L'anesthésie neuraxiale a été utilisée avec succès chez environ 98 % des patientes atteintes d'obésité de classe 3 bénéficiant d'un accouchement par césarienne programmée. Le choix de la technique d'anesthésie régionale variait en fonction de l'augmentation de l'IMC et de l'incision chirurgicale prévue. Les temps procéduraux augmentaient avec l'augmentation de l'IMC. Ces informations devraient s'avérer utiles pour comparer les choix et les issues en matière d'anesthésie dans cette population difficile.*

Keywords Cesarean delivery · epidural anesthesia · obesity · obstetrical anesthesia · spinal anesthesia

The worldwide prevalence of obesity has increased dramatically over the past two decades, reaching an unprecedented level of one in three adults in the USA and one in four adults in Canada.[1,2] As a result, an increasing number of patients with obesity require anesthetic care for labor and delivery.[3] Also, Cesarean deliveries are more common in patients with obesity.[4] Even though neuraxial anesthesia is usually preferred for Cesarean delivery, obesity increases the risk of neuraxial anesthesia failure and longer procedural times.[5] Complications from anesthesia, as well as overall morbidity and mortality, are higher in patients with obesity than in the general population.[2,6,7]

Most studies regarding obstetric anesthesia for patients with obesity use the World Health Organization definition of obesity, which is a body mass index (BMI) of 30.0 kg·m^{-2} or more. Nevertheless, this universal definition of obesity does not recognize the subtleties related to management of this group of patients. Previous studies have proposed defining a BMI of 50.0–59.9 kg·m^{-2} as "super morbid obesity" and 60.0 kg·m^{-2} or more as "super-super morbid obesity,"[8] even though these terms may be considered derogatory. No study has offered a comprehensive overview of the anesthetic management for elective Cesarean delivery of patients with class 3 obesity (i.e., BMI ≥ 40 kg·m^{-2}) across different BMI strata.

The aim of this study was to describe the anesthetic techniques and outcomes in different categories of patients with class 3 obesity undergoing elective Cesarean delivery, specifically those with BMIs of 40.0–49.9 kg·m^{-2}, 50.0–59.9 kg·m^{-2}, and ≥ 60.0 kg·m^{-2}.

Methods

Study design

Ethical approval for this historical cohort study was provided by the Mount Sinai Hospital Research Ethics Board on 27 November 2020 (Toronto, ON, Canada; reference 20-0279-C). The need for written informed consent was waived.

Our institution is an academic hospital and a tertiary referral centre, with 7,000 deliveries per year. Most centres in Ontario seek tertiary consultation for patients with a BMI of 40 kg·m^{-2} or more.

We searched the electronic delivery log of our institution for patients with a BMI ≥ 40.0 kg·m^{-2} undergoing Cesarean delivery between July 2014 and December 2020. Each record was manually assessed to include only elective Cesarean deliveries. Patients with planned combined surgery (i.e., Cesarean-appendectomy or Cesarean-hysterectomy) were excluded. This study was reported in adherence with the STROBE statement for observational studies.[9]

Anesthetic management

At Mount Sinai Hospital, all patients undergo a detailed preanesthetic evaluation. We administer metoclopramide 10 mg and famotidine 20 mg *iv* 30–60 min prior to surgery, and sodium citrate 0.3M 30 mL on the way to the operating room (OR). We routinely discuss the planned surgical incision with the obstetrician prior to selecting the anesthetic technique. The patient is placed in the sitting position, using an Epidural Positioning Device (MEDITEK, Winnipeg, MB, Canada). The anesthetic technique is performed by a fellow in obstetric anesthesia and/or an obstetric anesthesiologist. We typically perform a preprocedural ultrasound assessment to determine the exact spinal interspace level, the ideal insertion point, the angle of the puncture, and the depth to the epidural and/or intrathecal space. In case of single-shot spinal anesthesia, a 27G or 25G Whitacre spinal needle is used below the L2–L3 interspace. Our typical intrathecal medication regimen is hyperbaric bupivacaine 13.5 mg, fentanyl 10 µg, and preservative-free morphine 100 µg. In case of epidural anesthesia, we typically place a catheter at a higher lumbar or lower thoracic interspace, given the presence of less adipose tissue and shorter distance from skin to the epidural space. Prior to injection of local anesthetics, we typically perform an electric stimulation of the epidural catheter (Tsui test)[10] and/or epidural waveform analysis to ascertain the position of the catheter in the epidural space. Our typical epidural medication regimen is lidocaine 2% with epinephrine 1:200,000 plus fentanyl 5 $\mu g \cdot mL^{-1}$ titrated to effect; some clinicians use a mixture of 2% lidocaine and 0.5% bupivacaine with epinephrine 1:200,000 plus fentanyl 5 $\mu g \cdot mL^{-1}$. Upon assessment of the neuraxial block, a T4 block to ice would be considered satisfactory for proceeding to Cesarean delivery. Some clinicians also use pinprick as a second modality of testing of the sensory block. In case of unsatisfactory neuraxial block, a secondary neuraxial technique would be applied at the discretion of the attending anesthesiologist.

Data collection

All data were collected from our electronic medical record system. Data were gathered from the antenatal and peripartum obstetric records, anesthesia records, anesthesia consultation notes, delivery notes, and nursing notes.

We recorded patient characteristics including age, height, weight prior to pregnancy as well as at time of delivery, gestational age, gravidity, parity, and whether this was a primary or repeat Cesarean delivery. All patients had a preanesthetic evaluation and we recorded details regarding airway assessment.

We recorded the first anesthetic technique that was used (i.e., spinal, epidural, combined spinal-epidural, or general anesthesia), and defined this as the *initial anesthetic technique*. If the initial anesthetic technique did not lead to satisfactory conditions for proceeding to the Cesarean delivery, we also recorded the anesthetic technique under which the Cesarean delivery was effectively performed. This was defined as the *final anesthetic technique*.

We recorded the type of surgical skin incision (i.e., Pfannenstiel, infraumbilical transverse, supraumbilical transverse, or midline). We also recorded the need for secondary uterotonic drugs in addition to oxytocin and whether the estimated blood loss exceeded 1,000 mL.

We recorded the time taken to establish adequate anesthesia (anesthesia time), the time from skin incision to skin closure (surgical time) and the time from entering to leaving the OR (OR time).

Statistical analysis

Statistical analysis was performed using R (R Foundation for Statistical Computing, Vienna, Austria; http://www.R-project.org). Data are presented as mean (standard deviation [SD]), median [interquartile range (IQR)], or *n* (%). Patients were stratified into three prespecified groups according to their BMI at time of delivery: 40.0 to 49.9 $kg \cdot m^{-2}$, 50.0 to 59.9 $kg \cdot m^{-2}$, and 60.0 $kg \cdot m^{-2}$ or more. Binomial confidence intervals (CIs) were calculated with the Clopper–Pearson method.

Results

We identified 1,853 deliveries in patients with class 3 obesity between July 2014 and December 2020. After excluding vaginal deliveries, nonelective Cesarean deliveries, and combined surgeries (i.e., Cesarean-appendectomy or Cesarean-hysterectomy), we included 396 elective Cesarean deliveries in 371 unique patients for analysis (Electronic Supplementary Material, eFigure).

In these 396 deliveries, the mean (SD) maternal age was 34.2 (4.8) yr and weight at time of delivery was 129.9 (8.2) kg, with a mean BMI of 48.1 (7.0) $kg \cdot m^{-2}$. The mean gestational age was 38.4 (1.0) weeks. We included 258, 112, and 26 patients with a BMI 40.0–49.9 $kg \cdot m^{-2}$, 50–59.9 $kg \cdot m^{-2}$, and $\geq$ 60.0 $kg \cdot m^{-2}$, respectively.

The patient characteristics, obstetric data, and airway assessments across the BMI groups are shown in Table 1.

Table 1 Characteristics of patients with class 3 obesity undergoing elective Cesarean delivery

Characteristic	BMI 40.0–49.9 kg·m^{-2} *N* = 258	BMI 50.0–59.9 kg·m^{-2} *N* = 112	BMI ≥ 60.0 kg·m^{-2} *N* = 26
Age (yr), mean (SD)	34.4 (4.9)	34.0 (4.5)	33.3 (4.7)
Height (cm), mean (SD)	164 (8.3)	165 (8.1)	163 (7.7)
Weight prepregnancy (kg), mean (SD)[a]	101 (17)	134 (20)	152 (22)
BMI prepregnancy (kg·m^{-2}), mean (SD)[a]	37.5 (5.8)	48.1 (7.6)	57.0 (8.6)
Weight at delivery (kg), mean (SD)	117 (14)	149 (16)	171 (18)
BMI at delivery (kg·m^{-2}), mean (SD)	43.8 (2.8)	54.4 (2.6)	64.1 (4.7)
Gravidity, median [IQR]	2[2–4]	2 [2, 3]	3 [1–4]
Parity, median [IQR]	1 [1, 2]	1 [0–1]	1 [0–2]
Gestation age (weeks), mean (SD)	38.5 (0.9)	38.4 (1.0)	37.9 (1.2)
Repeat Cesarean delivery, *n*/total *N* (%)	175/258 (68%)	78/112 (70%)	15/26 (58%)
Airway assessment,[b] *n*/total *N* (%)			
Mallampati class 1/2	144/256 (56%)	50/108 (46%)	12/25 (48%)
Mallampati class 3/4	112/256 (44%)	58/108 (54%)	13/25 (52%)
Abnormal thyromental distance	13/257 (5%)	10/108 (9%)	1/23 (4%)
Abnormal mandibular protrusion	4/253 (1.6%)	2/107 (2%)	0/25 (0%)
Abnormal cervical mobility	2/255 (0.8%)	4/109 (4%)	1/24 (4%)
Abnormal mouth opening	2/257 (0.8%)	0/107 (0%)	1/24 (4%)

[a] Prepregnancy weight missing in 85 patients

[b] *N* values vary because of missing data

BMI = body mass index; IQR = interquartile range; SD = standard deviation

Success of neuraxial anesthesia and management of failed neuraxial anesthesia

A neuraxial technique was planned in 394/396 patients (99.5%). The overall success rate of neuraxial anesthesia was 389/394 (98.7%; 95% CI, 97.1 to 99.6).

Failure of the initial anesthetic technique occurred in 36/394 (9.1%) of all deliveries (95% CI, 6.5 to 12.4). The failure rate of anesthetic technique in patients undergoing a spinal, epidural, or combined spinal-epidural technique was 6.1% (95% CI, 3.2 to 10.4), 8.6% (95% CI, 3.5 to 17.0), and 14.7% (95% CI, 8.8 to 22.4), respectively.

In the 34 patients with failed initial neuraxial anesthesia, a secondary neuraxial technique was successfully used in 29 patients. The final anesthetic technique in case of initial failure was mostly epidural (18/36, 50%), spinal (4/36, 11%), or combined spinal-epidural (9/36, 25%). Five of these 34 patients (15%) underwent general anesthesia. The general anesthesia conversion rate was therefore 1.3% (95% CI, 0.4 to 2.9; 5/394 patients).

General anesthesia

The incidence of general anesthesia was low (7/396, 1.8%; 95% CI, 0.7 to 3.6). Two patients underwent planned general anesthesia. Two patients required conversion to general anesthesia prior to skin incision, and three patients required intraoperative conversion to general anesthesia. More details regarding the indications for general anesthesia are listed in Table 2.

Anesthetic technique and body mass index

The anesthetic technique varied across BMI groups (Fig. 1A). For patients with a BMI of 40.0–49.9 kg·m^{-2}, the anesthetic technique was predominantly spinal anesthesia (71%), and less often combined spinal-epidural (CSE) technique (21%) or epidural anesthesia (7%) . For patients with a BMI ≥ 60.0 kg·m^{-2}, spinal anesthesia was never used as an anesthetic of first choice, whereas epidural anesthesia and CSE were used in 58% and 42%, respectively. Further details regarding anesthetic and obstetric management are shown in Table 3.

Anesthetic technique and surgical incision

The surgical incision varied across BMI groups (Fig. 2). The anesthetic technique of choice varied with regard to the surgical incision (Fig. 1B). Patients undergoing a Pfannenstiel incision were mostly managed with spinal anesthesia (186/281, 66%) and less frequently with CSE, epidural, or general anesthesia (23%, 10%, and 0.4%, respectively). A modified surgical incision was mostly managed with epidural anesthesia or CSE, particularly

Table 2 Indications for general anesthesia for elective Cesarean delivery in patients with class 3 obesity

Timing	Indication	BMI
Planned	Myelomeningocele C8–T1 with neurologic sequelae	46.9 $kg \cdot m^{-2}$
Planned	Patient declined neuraxial anesthesia	40.1 $kg \cdot m^{-2}$
Prior to incision	Multiple spinal and epidural attempts without success	41.2 $kg \cdot m^{-2}$
Prior to incision	Significant discomfort due to high epidural block	57.1 $kg \cdot m^{-2}$
Intraoperative	Pain during procedure	49.5 $kg \cdot m^{-2}$
Intraoperative	Hemorrhagic shock requiring massive transfusion	60.1 $kg \cdot m^{-2}$
Intraoperative	Unexpected concerns for invasive placenta	40.2 $kg \cdot m^{-2}$

BMI = body mass index

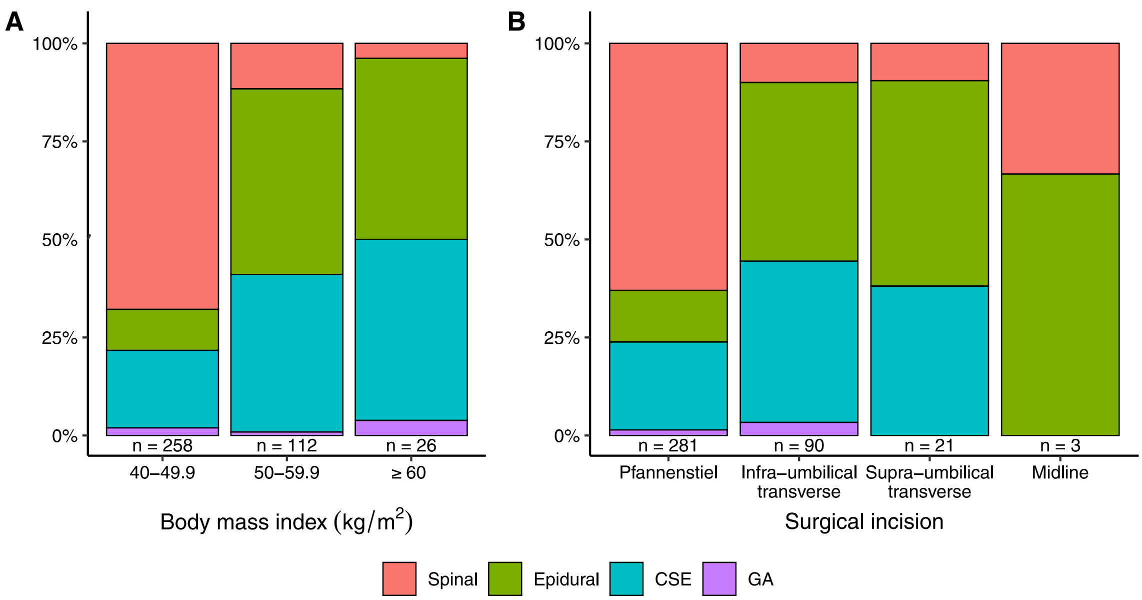

Fig. 1 Anesthetic technique to establish adequate anesthesia for elective Cesarean delivery in patients with class 3 obesity according to body mass index (A) and surgical incision (B). CSE = combined spinal-epidural technique; GA = general anesthesia

when a supra- or infraumbilical transverse incision was used.

Anesthetic and surgical times

The time taken to establish adequate anesthesia (anesthesia time) and the time from incision to skin closure (surgical time) increased in higher BMI groups. Details regarding anesthesia time, surgical time, and OR time are shown in Table 3.

Discussion

Our results show that neuraxial anesthesia was effective in patients with class 3 obesity undergoing elective Cesarean delivery, with only 1.8% (95% CI, 0.7 to 3.6) requiring general anesthesia. Our results also show that the choice of the anesthetic technique varied with BMI and surgical incision, with single-shot spinal anesthesia mostly used in patients with a lower BMI and Pfannenstiel incision. Furthermore, procedural times increased with increasing BMI.

High neuraxial block requiring tracheal intubation has been identified as the most common serious complication related to obstetric anesthesia.[11] High neuraxial block should be avoided unequivocally in patients with class 3 obesity, given that obesity is a known predictor of difficult tracheal intubation, face mask ventilation, supraglottic airway device insertion, and front-of-neck airway access.[12] Whether patients with obesity should receive a reduced dose of intrathecal drug to reduce the risk of high neuraxial block remains controversial. Given the two-fold increase in surgical time in patients with a higher BMI, as shown in

Table 3 Anesthetic and obstetric management for Cesarean delivery in patients with class 3 obesity

	BMI 40.0–49.9 kg·m^{-2} *N* = 258	BMI 50.0–59.9 kg·m^{-2} *N* = 112	BMI ≥ 60.0 kg·m^{-2} *N* = 26
Preprocedural ultrasound, *n*/total *N* (%)	166/258 (64%)	82/112 (73%)	24/26 (92%)
Initial anesthetic technique, *n*/total *N* (%)			
Spinal	183/258 (71%)	14/112 (12%)	0/26 (0%)
Epidural	18/258 (7%)	48/112 (43%)	15/26 (58%)
CSE	55/258 (21%)	50/112 (45%)	11/26 (42%)
General anesthesia	2/258 (1%)	0/112 (0%)	0/26 (0%)
Failed initial neuraxial technique	20/256 (8%)	13/112 (12%)	3/26 (12%)
Final anesthetic technique, *n*/total *N* (%)			
Spinal	175/258 (68%)	13/112 (12%)	1/26 (4%)
Epidural	27/258 (11%)	53/112 (47%)	12/26 (46%)
CSE	51/258 (20%)	45/112 (40%)	12/26 (46%)
General anesthesia	5/258 (2%)	1/112 (1%)	1/26 (4%)
Intrathecal drug dose,[a] mean (SD)			
Hyperbaric bupivacaine (mg)	13 (1)	13 (1)	N/A
Fentanyl (µg)	11 (2)	11 (2)	N/A
Preservative-free morphine (µg)	100 (0)	100 (0)	N/A
Skin incision,[b] *n*/total *N* (%)			
Pfannenstiel	225/258 (87%)	49/111 (44%)	7/26 (27%)
Infraumbilical transverse	26/258 (10%)	49/111 (44%)	15/26 (58%)
Supraumbilical transverse	5/258 (2%)	12/111 (11%)	4/26 (15%)
Midline	2/258 (1%)	1/111 (1%)	0/26 (0%)
Additional uterotonic drugs	20/258 (8%)	5/112 (5%)	4/26 (15%)
Estimated blood loss > 1,000 mL	10/258 (4%)	7/112 (6%)	5/26 (19%)
Procedural times			
Anesthetic time (min[c]), median [IQR]	20 [15–28]	33 [25–50]	38 [27–51]
Surgical time (min[d]), median [IQR]	53 [43–66]	76 [61–88]	96 [82–114]
OR time (min[e]), median [IQR]	92 [78–111]	136 [119–162]	158 [139–188]

[a] Intrathecal drug dose reported for patients undergoing successful single-shot spinal anesthesia

[b] *N* values vary because of missing data in one patient

[c] Time between patient and anesthesiologist in the room and establishment of adequate anesthesia for the procedure

[d] Time between skin incision and closure of skin

[e] Time between entering and leaving the operating room

BMI = body mass index; CSE = combined spinal-epidural technique; GA = general anesthesia; IQR = interquartile range; OR = operating room

our study, a reduced intrathecal dose of local anesthetic in a single-shot spinal technique could lead to insufficient anesthetic during surgery. In fact, the literature suggests that the required intrathecal dose for Cesarean delivery is similar for patients with and without obesity.[13,14] These data, however, are limited to patients with a BMI of 30–50 kg·m^{-2}; therefore, the findings cannot be extrapolated to patients with a BMI above 50 kg·m^{-2}. Our data suggests that most patients with a BMI of 40.0–49.9 kg·m^{-2} undergoing Pfannenstiel incision can be managed safely with single-shot spinal anesthesia. Nevertheless, we believe that it is wise to abstain from single-shot spinal anesthesia in patients with a higher BMI, and instead plan for placement of an epidural catheter that will allow slow titration to the required sensory block. This practice is also recommended by others.[15,16] The choice of neuraxial technique remains a case-by-case decision, based on BMI, adipose tissue distribution, and surgical technique.

A modified surgical incision was used in 21% of all patients; this percentage increased with increasing BMI. Nevertheless, and importantly, BMI is not the only variable dictating the choice of surgical incision. The surgical approach with regard to the incision is mostly defined by the panniculus. A Pfannenstiel incision for entry beneath

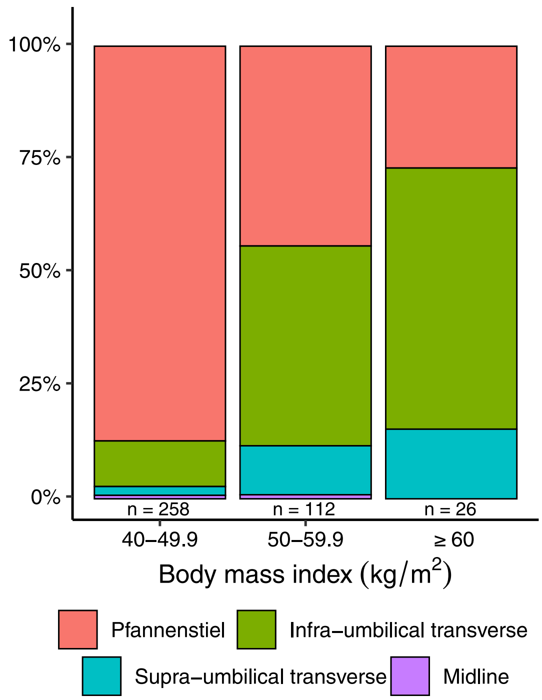

Fig. 2 Choice of surgical incision for elective Cesarean delivery in patients with class 3 obesity according to body mass index. Data were missing for 1/368 deliveries

the panniculus has important benefits. However, there is concern regarding an overhanging panniculus, likely increasing wound exposure to microbial flora and low oxygen tension.[17] When the panniculus is too large, infected, or edematous, an incision above it can be considered.[18] As the type of incision affects the dermatomes that are to be anesthetized, it is important to discuss the surgical technique with the surgical team and to make an anesthetic plan accordingly. In our cohort, we did not see a clear preference for CSE or epidural anesthesia, although there was a trend toward more frequent use of epidural anesthesia in patients with a BMI of 60.0 $kg \cdot m^{-2}$ and above. One advantage of epidural anesthesia is that it can be performed at a higher spinal level. Although we did not capture the insertion site in our study, when epidural anesthesia is used in these patients, we typically use the T12–L1 or L1–L2 interspaces, which makes the epidural catheter placement easier, given the presence of less adipose tissue and the shorter distance from skin to the epidural space, which typically avoids the need for longer epidural needles. Furthermore, the epidural catheter placed at a higher intervertebral level may provide denser blocks for modified incisions that may be sometimes supraumbilical.

Patients with class 3 obesity are at risk of several technical difficulties during neuraxial procedures. Firstly, anatomical landmarks such as the midline, iliac crest, and spinous processes are often obscured by adiposity. Secondly, the distance from the skin to the epidural space increases with increasing BMI.[19] These two challenges can be addressed with a preprocedural spinal ultrasound, which can determine the exact interspace level for insertion, the ideal insertion point, the angle of the puncture, the depth to the epidural space, and any anatomical abnormalities such as scoliosis.[20] A preprocedural ultrasound reduces the number of neuraxial attempts and the duration of the procedure in patients with obesity.[21] In our study, the use of ultrasound was high in all groups and increased with higher BMI. Given the paramount importance of successful neuraxial anesthesia in these patients, we routinely use additional tests to confirm the accurate placement of the epidural catheter. The electrical stimulation test of the epidural catheter (Tsui test)[10] and the epidural waveform analysis through the needle[22] and/or the catheter[23] allow objective assessment of the catheter position prior to injection of local anesthetics, hence minimizing chances of a failed epidural anesthetic. Unfortunately, the use of these tests was not routinely charted, so we could not report their use across the BMI groups.

We found a rate of insufficient initial neuraxial anesthesia of 9.1%, which was reduced to 1.3% after a subsequent regional technique. This highlights the need for careful, extensive testing of the anesthetic block prior to incision, to facilitate a subsequent regional technique. Factors that may have influenced the success of a subsequent regional technique include the use of ultrasound, a more experienced operator, and the use of a different neuraxial technique.

Interestingly, more than half of the general anesthetics were administered for reasons other than regional anesthesia failure, such as unexpected invasive placentation or severe hemorrhage. Therefore, our approach reduced the rate of failed neuraxial anesthesia to a rare event.

A recent systematic review into inadequate anesthesia for Cesarean delivery showed a prevalence of general anesthesia conversion of only 0.1% (2/3,497).[24] This is considerably less than the rate in the present study of 1.3% (95% CI, 0.4 to 2.9). The difference may partly be explained by reporting bias but also highlights the technical challenges as well as the higher risk of anesthesia-related adverse events in this population.

Every patient undergoing Cesarean delivery should have an airway assessment to allow appropriate planning of resources. A Mallampati class of 3–4, which is strongly associated with difficult laryngoscopy and difficult face mask ventilation, was found in 44%–54% of our patients in the three BMI groups. This is considerably higher than the previously reported rate of 10.3% in patients without obesity at eight months of gestational age.[25] Other predictors of difficult airway management, i.e., abnormal thyromental distance, mandibular protrusion, cervical mobility, and mouth opening, were infrequent across all BMI groups (0%–9.1%). This reflects that difficult laryngoscopy in patients with class 3 obesity mostly arises from excessive adipose depositions in soft tissues such as the velopalate, retropharynx, and submandibular regions.[26] We believe general anesthesia should be avoided in this population regardless of the airway assessment, unless there is a strong indication for a general anesthetic (Table 2).

Our study identified important considerations for planning of OR resources. Mandatory additional equipment would include width extenders for the operating table, a Troop Elevation Pillow, appropriate arm supports, as well as an ultrasound machine and longer epidural needles. Because of the technical difficulties previously described, the time taken to establish effective anesthesia was 1.9 times longer in patients with a BMI ≥ 60.0 kg·m^{-2} when compared with patients with a BMI of 40.0–49.9 kg·m^{-2}. Similarly, the time taken from skin incision until skin closure was 1.7 times longer. We incorporated this into our practice by booking longer OR slots for this patient population. Additional staffing resources should be available to help position the patient and to help manage any emergency situation that may occur.

The limitations of this study are inherent to the retrospective use of routinely collected data. For instance, we were unable to elaborate on the rationale behind the choice of anesthetic technique, as those considerations are not routinely charted. It should therefore not be interpreted as a guide for decision-making, but should allow other providers to compare their approach and outcomes. Even though race and socioeconomic status are known to be associated with differences in anesthetic management, we were unable to collect these as they are not routinely charted. Other factors that were not collected include practitioner clustering, the used spinal interspace level, the depth at loss of resistance, and the use of intravenous and/or inhaled anxiolytics and analgesics. Furthermore, the population in this single-centre cohort may not necessarily reflect an average practice, even though our approach may prove useful to those less familiar with managing patients with class 3 obesity.

In conclusion, management of patients with class 3 obesity undergoing elective Cesarean delivery is complex and requires careful planning of the anesthetic technique. The choice of neuraxial technique varied with the degree of obesity and with the type of surgical incision. Failure of the initial neuraxial technique was successfully managed with a secondary neuraxial technique in most cases, with a low overall rate of general anesthesia of 1.8% (95% CI, 0.7 to 3.6). Longer procedural times are common in this patient population and OR resources should be planned accordingly. This information should allow other anesthesiologists to compare their practice and outcomes in patients with class 3 obesity undergoing elective Cesarean delivery.

Author contributions *Oscar van den Bosch* contributed to all aspects of this manuscript, including conception and design; acquisition, analysis, and interpretation of data; and drafting the article. *Marie-Eve Fiest* and *Kristi Downey* contributed to the study design and acquisition of data. *Cynthia Maxwell* contributed to the study design and interpretation of data. *Jose Carvalho* contributed to the conception and design of the study, analysis and interpretation of data, and drafting the article.

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