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Anesthetic management in obese parturients

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Introduction

Obesity is one of the common nutritional disorders in industrialized countries. Among various definitions for obesity, body mass index (BMI = weight [kg] / height $[m]^2$) has been most commonly employed to define the extent of overweight (Fig. 1) [1]. The normal value of BMI is 25, whereas people with BMI between 26 and 29 are classified as overweight. Morbid obesity is defined as a body weight more than twice the ideal weight or a BMI of more than 35 [2,3]. The proportion of obese people varies among countries. For instance, in the United States, one-third of the population is estimated to be overweight, and the proportion of overweight people has dramatically increased in all sex, race, and age groups in the past decade (Table 1) [2,4]. Although BMI is derived from a simple calculation and therefore may be a useful measure to describe the degree of overweight, the pathophysiologic nature of obesity cannot be accurately predicted from the BMI alone. In addition, android obesity, which is characterized by a primarily truncal distribution of fat, is associated with a high incidence of cardiovascular disorders, whereas gynecoid obesity, in which fat is primarily distributed in the thighs and the buttocks, is not tightly linked with an increased incidence of cardiovascular complications [5]. Moreover, many persons classified as obese on the basis of the BMI may have no apparent respiratory, cardiovascular, or metabolic pathology, implying that the clinical relevance of obesity should be carefully sought in individual cases.

On the other hand, the prevalences of certain anatomical abnormalities, pathologic functions, and alterations of pharmacologic responses are considerably higher in the obese population. An increased incidence of hypertension, coronary artery disease, impaired pulmonary function, adult-onset diabetes mellitus, and gastrointestinal abnormalities in obese patients could complicate anesthetic management and postoperative care [6,7]. As a result, morbidly obese patients have at least a twofold increase in surgical mortality in general [6]. Moreover, a positive correlation has been found between gestational weight gain and increased risks of poor laryngoscopic view, abnormal labor, certain fetal abnormalities, and unscheduled cesarean section [8,9]. In this article, we discuss some important aspects of obesity-induced pathophysiology relevant in anesthetic practice and review the limited available literature regarding the clinical implications of obesity in parturients.

Pathophysiology of obesity

Respiratory system

Although the basal metabolic rate usually remains within the normal range, obese persons have increased oxygen consumption ($\dot{V}O_2$) and carbon dioxide production ($\dot{V}CO_2$) in proportion to the extent of overweight [10–12]. This is caused by the metabolic activity of adipose tissue as well as the increased energy expenditure due to locomotive and respiratory efforts. Obese patients, therefore, require high minute ventilation to meet their energy requirements and to maintain normocarbia in spite of the reduced chest wall compliance due to the fat-loaded chest cage (restrictive lung disease). The compliance of the lung parenchyma,

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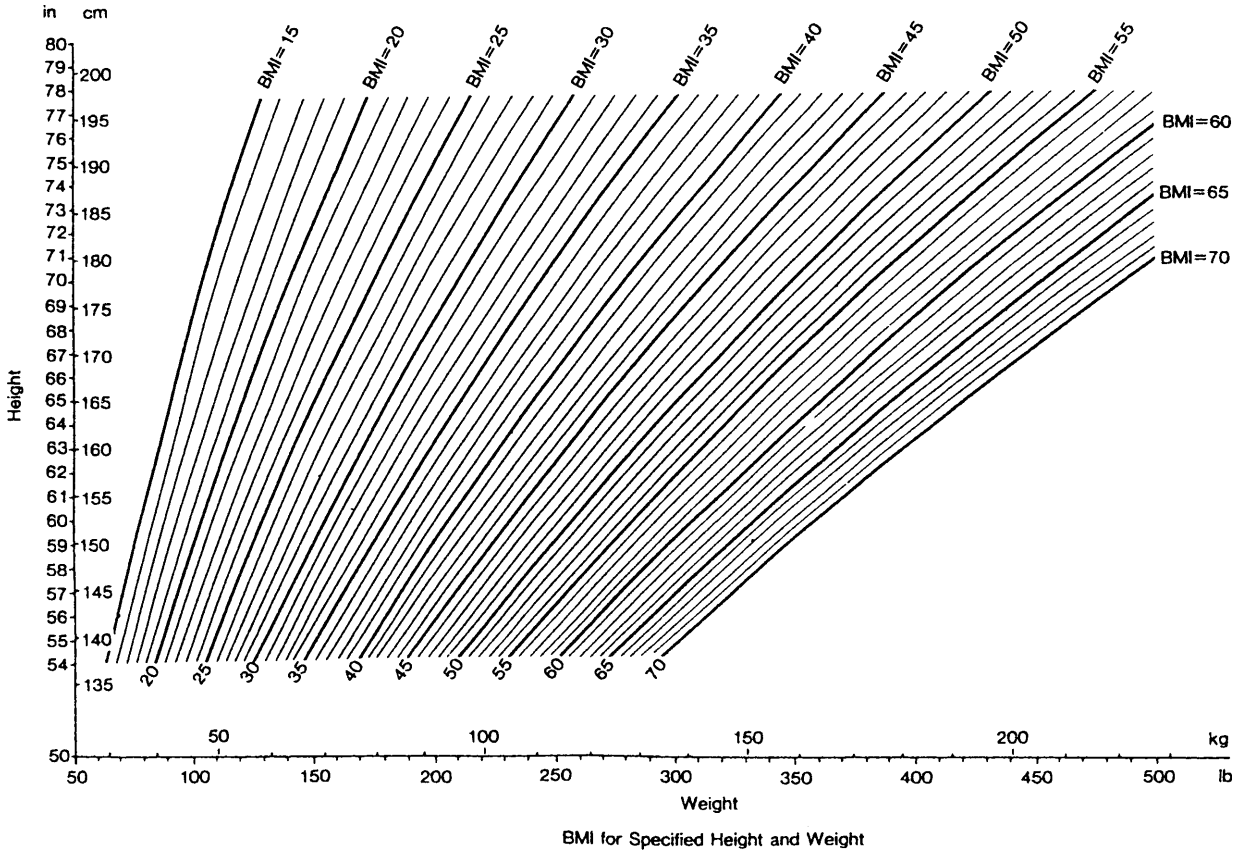

Fig. 1. Body mass index (BMI) (body weight in kilograms/height in meters^2) for specified height and weight. (From Frankel [1])

however, is usually normal unless underlying lung pathology, such as atelectasis and pneumonia, is present [6]. Increases in $\dot{V}O_2$ and $\dot{V}CO_2$ are even more pronounced during labor and delivery in obese than in lean parturients [10,12].

More importantly, obese patients have a dramatic reduction of residual volume and functional residual capacity (FRC) as compared with lean patients. Even in the upright position, tidal respiration may fall within the closing capacity during the expiratory phase, resulting in ventilation/perfusion mismatching or intrapulmonary right-to-left shunt. This is accentuated in the supine or Trendelenburg position, when FRC is further reduced. This is the major cause of arterial hypoxemia seen in the operating room in this population.

Although most healthy obese subjects can maintain adequate minute ventilation and present with normal pulmonary function test results, in some extreme cases the patient may present with the condition known as the Pickwickian syndrome (obesity hypoventilation syndrome). This syndrome, seen in 8% of the obese population, is characterized by alveolar hypoventilation, daytime somnolence, and morbid obesity [13]. Chronic arterial hypoxemia and ensuing polycythemia are present. Hypercarbia is considered to be caused by decreased sensitivity of the brainstem respiratory center to carbon dioxide. Chronic hypoxemia and hypercarbia may cause pulmonary hypertension and ultimately cor pulmonale and right ventricular failure. The soft tissue mass of the oropharynx is increased, predisposing these patients to intermittent obstruction of the upper airway when the pharyngeal musculature is relaxed during sleep [14]. These patients are deprived of sleep and have daytime hypersomnolence. Pulmonary embolism and pneumonia are also common in patients with the Pickwickian syndrome.

Airway

Limited flexion of the cervical spine, limited mouth opening, and narrowed view of the pharyngeal opening are all common in obese patients. These findings are due, at least in part, to the cervical, upper thoracic, breast, and mental subcutaneous adipose tissue. All these anatomic alterations may cause difficulty in visualizing the larynx. Furthermore, obese parturients have a much higher incidence of failed intubation (0.35%) than obese nonpregnant surgical patients

Table 1. Age-adjusted and age-specific prevalence of overweight, US population 20 through 74 years of age[a]

Population Group	Prevalence of overweight by study, %			
	NHES I (1960–1962)†	NHANES I (1971–1974)	NHANES II (1976–1980)	NHANES III Phase 1 (1988–1991)
Age 20–74 yr	24.3	25.0	25.4	33.3
Race/sex				
White				
Men	23.0	23.8	24.2	32.0
Women	23.6	24.0	24.4	33.5
Black				
Men	22.1	23.9	26.2	31.8
Women	41.6	43.1	44.5	49.2
Sex/age, yr				
Men				
20–74	22.8	23.7	24.1	31.7
20–29	18.4	15.7	15.1	20.2
30–39	21.8	28.4	24.4	27.4
40–49	25.5	30.2	32.4	37.0
50–59	28.8	27.1	28.2	42.1
60–74	23.0	21.6	26.8	40.9
Women				
20–74	25.7	26.0	26.5	34.9
20–29	10.1	12.6	14.7	20.2
30–39	21.9	22.9	23.8	34.3
40–49	26.8	29.7	29.0	37.6
50–59	35.0	35.5	36.5	52.0
60–74	45.6	39.0	37.3	41.3

[a] Pregnant women were excluded. NHES, National Health Examination Survey; NHANES, National Health and Nutrition Examination Survey. A total of 0.9 kg was subtracted from measured weight to adjust for weight of clothing. (From Kuczmarski et al. [2]).

(0.04%), indicating that obesity and pregnancy can additively worsen the intubating condition [8]. Indeed, when the gestational weight gain is more than 15 kg, a suboptimal laryngoscopic view is four times as frequent as among nonpregnant women at the corresponding age [9].

Cardiovascular system

The circulating blood volume, plasma volume, and cardiac output increase in proportion to weight in obese subjects [15,16]. An increase in cardiac output is due in part to the blood flow through the adipose tissue, which accounts for 2–3 $ml \cdot min^{-1} \cdot 100\,g^{-1}$ at rest, and parallels that of $\dot{V}O_2$. An abrupt rise in cardiac output occurs in obese patients in comparison with lean patients during exercise [17], and this change can be augmented during labor, causing a profound increase in oxygen consumption by the heart as well as by the whole body. The heart rate at rest is usually unaltered in obese patients, indicating that the increase in stroke volume accounts for the increase in cardiac output [16].

Hypertension is a frequent coexisting disorder in obese patients. Elevated blood pressure and increased circulating blood volume indicate that both the afterload and the preload of the heart are elevated, even at rest. As a result of this pressure and volume loading, left ventricular end-diastolic pressure is increased, cardiac diameter is increased on the chest radiograph, and left ventricular hypertrophy ensues [17]. This is why labor- and delivery-induced changes in blood pressure in obese parturients frequently require continuous infusion of a vasodilatory drug. It is, however, clinically challenging to obtain satisfactory blood pressure control within an acceptable range because of the contraction-induced abrupt surges in blood pressure owing to sudden augmentation of both preload and afterload. Obese parturients are also vulnerable to pulmonary hypertension [18]. The pulmonary artery occluded pressure becomes elevated during labor and delivery and may be accentuated by hypoxic pulmonary vasoconstriction in patients with morbid obesity or preexisting pulmonary pathology.

Endocrine and metabolic systems

Glucose tolerance is frequently impaired in obese patients as a result of resistance to insulin [19].

Hypertrophy of the islets of Langerhans in the pancreas is found, and hyperinsulinemia ensues. This reflects a marked increase in the incidence of adult-onset diabetes mellitus in the morbidly obese population. During pregnancy, relative insulin deficiency may further impair glucose tolerance [20]. These patients may also have high serum triglyceride and cholesterol levels, which may be the cause of the increased prevalence of ischemic heart disease, although they have not been proved to be the cause.

Gastrointestinal system

The intraabdominal pressure and the prevalence of hiatal hernia increase in proportion to the degree of overweight. Classically, gastric volume was said to be increased and the pH of the gastric fluid to be decreased by obesity [21]. Indeed, nearly 90% of fasting morbidly obese patients present with gastric volume greater than 25 ml and pH less than 2.5, a condition associated with a high risk of aspiration pneumonitis should gastric fluid reach the airway. Our routine practice is to administer antacid with or without a gastric prokinetic drug preoperatively to obese patients. However, a recent clinical study questioned these classical findings and in fact demonstrated a decreased incidence of high-volume, low-pH gastric content among nonmedicated, nondiabetic, fasting obese (BMI $>$ 30) patients free of gastroesophageal pathology than among nonobese (BMI $<$ 30) surgical patients [22]. The major difference between this recent study and the classical one is that a greater proportion of the obese patients in the classical study received narcotic premedication than nonobese patients.

The finding of Vaughan et al. that almost 90% of obese nonpregnant patients had high-volume, low-pH gastric contents is similar to findings in healthy pregnant patients [23]. Whether the combination of obesity and pregnancy produces an even greater risk of aspiration remains to be seen [24]. There is no doubt that pregnancy is associated with an increased incidence of symptomatic hiatal hernia and decreased sphincter tone of the lower esophagus [25,26]. Since the effects of obesity may be superimposed on gastric fluid volume, pH, and/or lower esophageal sphincter tone during pregnancy, emphasis should be placed on the benefits of an antacid and a gastric prokinetic drug to decrease the likelihood of aspiration pneumonitis in this population.

Problems associated with pregnancy

The specific problems of obese subjects during pregnancy are four: an increased incidence of some prepregnancy medical problems [27–30], abnormal labor [26,31], cesarean delivery [29–31], and fetal abnormalities [27,29,31,32].

Pregnancy has a striking effect on the incidence of chronic hypertension (Fig. 2). A 14-fold increase in the incidence of chronic hypertension has been observed in comparison with nonobese subjects, whereas the increase in the incidence of pregnancy-induced hypertension (PIH) remains minimal [27–30]. The diabetogenic state of pregnancy also puts obese parturients at risk for insulin-dependent diabetes, whereas nonpregnant obese patients are already in the insulin-resistant state [29,30,32]. Indeed, the pregnancy-induced increase in the incidence of diabetes is two- to eightfold. More importantly, the rate of anesthesia- and surgery-related maternal death is higher in obese than in nonobese parturients [33–35].

Some studies also suggest that obese patients have a increased likelihood of abnormal labor, such as meconium-stained amniotic fluid and late decelerations during labor [26,31]. Failure to progress, a prolonged second stage of labor, and a failed response to elective induction of labor have also been reported to occur more frequently in obese than in nonobese parturients [27]. Dystocia is more frequent in obese than in nonobese parturients, all of which most likely contribute to the increased risk of cesarean section. Other factors associated with the likelihood of cesarean delivery may be abnormal presentations, including shoulder dystocia, fetal macrosomatia, and multiple gestation, which are all more frequent among fetuses of obese patients [27,29,32]. Although macrosomatia may be associated with a high incidence of cesarean section, Johnson et al. reported that an increased incidence of cesarean section among obese parturients occurred

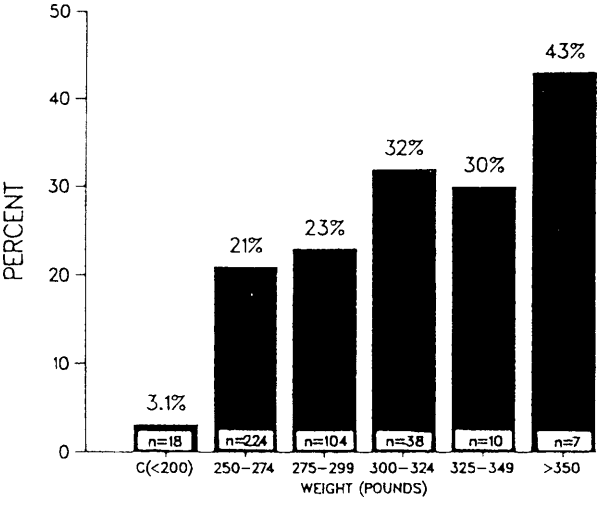

Fig. 2. Incidence of chronic hypertension in obese parturients stratified in increments of 25 pounds. (From Johnson et al. [27])

independently of the presence of hypertension, diabetes, and macrosomatia [27]. It has been speculated that intrapelvic fat tissue and perineal and vaginal wall adipose deposits may cause anatomic distortion of the birth canal, resulting in prolonged labor and the frequent diagnosis of dystocia in this population.

Maternal obesity, increased gestational weight gain, and diabetes are independent risk factors for macrosomatia [29,31,32]. On the other hand, the incidences of preterm delivery and low-birthweight infants are decreased in obese patients [27,31,32]. Most importantly, the incidence of neonatal admission to the intensive care unit is higher, and infants of obese patients have a 10-fold higher perinatal mortality [30,36].

Pharmacokinetic and pharmacodynamic alterations in obese patients

Physiologic and pathophysiologic alterations that require pharmacokinetic and pharmacodynamic considerations include increases in circulating blood volume, cardiac output, organ size, and adipose tissue. Most importantly, the increase in fat tissue affects the pharmacokinetic properties of lipophilic drugs, as opposed to hydrophilic drugs, whose pharmacokinetic properties are less affected [37,38]. A classical belief that obese patients have a prolonged recovery from volatile anesthetic agents, which also have a high affinity for adipose tissue, has been proved not to be applicable after short procedures such as cesarean section (less than 4 h) [39].

Lipid-soluble drugs tend to have an increased volume of distribution. The concentrations of albumin and total protein are unaffected by obesity, whereas the increased concentrations of triglycerides, cholesterol, free fatty acids, and α_1-acid glycoprotein may influence plasma protein binding and the free fraction of active drug. Increased kidney size, renal blood flow, and glomerular filtration rate facilitate renal clearance. Increased splanchnic blood flow and hypertrophy of the hepatic parenchymal cells may also affect the hepatic clearance of drugs. Obesity, however, is not associated with changes in phase I metabolism of the liver (oxidation, reduction, and hydrolysis), whereas elimination through phase II metabolism (conjugation pathway) seems to be faster.

Thiopental and benzodiazepines are highly lipophilic and hence have larger volumes of distribution [40, 41]. Their longer elimination half-lives despite the unchanged clearance values, indicates that these lipid-soluble drugs are more selectively distributed in the fat tissue. These findings imply that obese patients require larger induction doses of lipid-soluble drugs for general anesthesia, even though a decreased anesthetic requirement during pregnancy should also be considered. At the authors' institution, 4–5 $mg \cdot kg^{-1}$ of thiopental is used for obese parturients to avoid intraoperative awareness and to not delay emergence should endotracheal intubation fail. Propofol is also a lipophilic agent with a fast onset and a short duration. Even though pharmacokinetic data on propofol in obese patients are limited, the initial volume of distribution of propofol does not seem to be modified as compared with that in nonobese subjects [42]. The total body clearance and volume of distribution in the steady state are also correlated with body weight. The pharmacokinetic features of propofol do not seem to be altered during pregnancy, suggesting that accumulation of propofol does not occur and that the dosage (in milligrams per kilograms) does not need to be altered in morbidly obese parturients. Ketamine is the induction agent of choice for those with a history of bronchial asthma as well as for those presenting with hypotension [43]. However, the ideal dose of ketamine for obese pregnant patients has not yet been determined.

Fentanyl, when given in doses of micrograms per kilogram, has comparable pharmacokinetic properties in obese and nonobese patients [44]. On the other hand, sufentanil is associated with a larger volume of distribution and unchanged plasma clearance, resulting in a prolonged elimination half-life [45]. Alfentanil is associated with a longer elimination half-life in obese than in nonobese patients, secondary to decreased drug clearance, but the volume of distribution at steady state is unaltered [46].

Fat tissue serves as a reservoir for volatile anesthetic agents, and there is an increased fear of biotransformation of volatile agents in obese patients. Increased serum inorganic fluoride concentrations have been reported after halothane anesthesia in obese patients compared with nonobese patients [47]. The peak plasma fluoride concentration after administration of enflurane was three times greater than after isoflurane [48]. However, no prospective study has demonstrated an increased incidence of renal toxicity after brief exposure to enflurane in obese patients. Similarly, although halothane hepatitis is epidemiologically associated with obesity, no evidence suggests increased hepatocellular damage as detected enzymatically after halothane anesthesia in obese patients [47]. Similarly, sevoflurane biotransformation and plasma inorganic fluoride concentrations seem not to be increased in obese patients, and thus postoperative hepatic or renal test results do not appear to be different [49]. From these viewpoints, for brief procedures such as cesarean section, the choice of volatile anesthetic agent may not be clinically important.

Plasma cholinesterase activity increases in proportion to BMI [50], whereas a reduction of cholinesterase activity of 25% to 30% occurs during the first trimester and continues during the remainder of pregnancy and the postpartum period [51,52]. Whether the combination of these pathophysiologic states yields more or less pseudocholinesterase activity, and whether the dosing regimen of succinylcholine should therefore be increased or decreased, remains undetermined. Some anesthesiologists are reluctant to administer a large dose of succinylcholine ($2\,mg \cdot kg^{-1}$) at the time of induction of general anesthesia for fear of prolonged paralysis should endotracheal intubation fail. At the author's institution, at least $1\,mg \cdot kg^{-1}$ of succinylcholine is administered to ensure optimal conditions for endotracheal intubation, which is indispensable for those with anticipated difficult intubation. In obese pregnant patients, vecuronium produces muscle relaxation lasting far longer than in lean nonpregnant patients. On the other hand, the metabolism and recovery of atracurium-induced muscle relaxation are not affected by obesity. To date, atracurium has not been reported to cause adverse responses in pregnant women indicative of altered pharmacokinetic parameters, unless a high dose is administered as a bolus, which can cause release of histamine and resultant hypotension. In theory, atracurium may be the muscle relaxant of choice for short procedures such as cesarean section. Regardless of the choice of muscle relaxant, use of a nerve stimulator is essential to assess objectively the onset and duration of paralysis.

Preoperative evaluation

In addition to routine preoperative evaluation for parturients, including prepregnancy medical disorders and pregnancy-associated problems such as PIH, assessment of the airway should be performed carefully in obese parturients. Any history of previous anesthesia and surgeries should be obtained in detail. If an adverse reaction was noted in association with anesthetics, the strategy should be thoroughly discussed a sufficient time before the induction of anesthesia. The anesthesiologist should anticipate the worst possible event at the time of inducing general or regional anesthesia, and must be fully equipped to minimize intra- and postoperative morbidity and mortality. It is also essential that the patients be informed of every possible consequence in case cooperation is a key to success (e.g., for awake intubation). Another important aspect of the preoperative visit is to administer, in a timely fashion, medications that are mandatory to optimize the patient's condition for surgery and anesthesia. We recommend that morbidly obese parturients be placed on NPO status earlier because of the increased likelihood of proceeding to cesarean section. The interval between the last oral intake and the start of labor should be noted. Prophylaxis for aspiration of gastric contents should be performed aggressively in all obese pregnant patients. Cardiovascular medication is usually continued up to the time of surgery.

Respiratory system and airway

Information on preexisting respiratory disorders, their treatment, and their current status should be carefully collected. Physical examination and chest radiograms are mandatory for morbidly obese patients, and determination of arterial blood gas tensions provides important information regarding both ventilation and oxygenation. Oxygen saturation measured by a pulse oximeter in both the sitting and the supine positions may help to assess the degree of compromised pulmonary function due to obesity. A decrease in oxygen saturation on movement from the recumbent to the supine position suggests airway closing at tidal respiration and provides a guideline for the requirement of postoperative oxygen therapy. In symptom-free, healthy obese patients, however, only oxygen saturation by a pulse oximeter is routinely determined in our institution under room air in both the recumbent and the supine positions. Detailed pulmonary investigations are reserved for those with more severe respiratory diseases.

Airway examination in relation to endotracheal intubation is by far the most important part of the preoperative visit. Obesity and pregnancy may additively worsen the conditions for laryngoscopy and intubation [8]. A history of sleep obstruction is an ominous sign suggestive of a poor laryngoscopic view. An increased fat pad on the back of the neck and the shoulder and fatty anterior chest tissue limit the extension and flexion of the neck so that placing the patient's head in the optimal position for laryngoscopy may be difficult. Increased chest diameter, enlarged breasts, and decreased chin-to-chest distance all increase the likelihood of difficult laryngoscopy. Furthermore, the laryngoscopic view may be narrowed owing to the enlarged tongue and fleshy pharyngeal and supralaryngeal soft tissue. A recent study demonstrated that a weight gain of more than 15 kg during pregnancy is associated with a threefold increase in the incidence of suboptimal laryngoscopic views, as compared with nonpregnant women at the corresponding age [9]. Only through a complete preoperative evaluation of the airway can a possibly difficult laryngoscopy or failed intubation be predicted and a step-by-step strategy for airway management be planned.

Cardiovascular system

Prepregnancy cardiovascular disorders should be thoroughly evaluated, in addition to pregnancy-induced changes such as PIH. Especially in morbidly obese parturients, possible signs of left or right ventricular failure, pulmonary hypertension, and ischemic heart disease should be sought from the history, electrocardiogram, and chest radiogram. In patients with a long history of diabetes, typical symptoms indicative of angina pectoris may be absent. In healthy obese patients without evidence of cardiovascular disease, however, the electrocardiogram and chest radiogram may not be routinely obtained in our institution. Cardiovascular medication should not be discontinued until oral intake is prohibited. Caution should be exercised when blood pressure is measured noninvasively in obese patients. The sphygmomanometric cuff should be of an appropriate size, since otherwise systolic and diastolic blood pressure may be overestimated.

Gastrointestinal and endocrine systems

The patient should be carefully questioned for symptoms of esophageal reflux, and medication for the symptoms should be continued up to anesthesia and surgery. Previous laboratory test results, including fasting blood glucose levels and liver function, should be closely examined. The history and treatment of diabetes should be obtained. If abnormal liver function is present, the HELLP syndrome should be ruled out.

Other considerations

When regional analgesia using a central neuraxial block is being considered, the needle insertion site should be examined to determine whether local infection exists and bony landmarks are easily identified. The anesthesiologist should anticipate using a longer epidural or spinal needle in the morbidly obese patient [53]. However, this has seldom been necessary in our institution. The patient should be examined for signs and symptoms of bleeding tendency. Establishment of peripheral venous access may also be difficult in obese patients. In such cases, our preference is to insert a large-bore, single-lumen central venous catheter rather than a multilumen catheter, because of the increased likelihood of longer duration of surgery and more operative bleeding during cesarean section in the obese parturient. Administration of medication by either the oral or the intravenous route is recommended, but not by the intramuscular route, since attempts to give intramuscular injection may result in intrafat or subcutaneous injection, resulting in unreliable drug absorption.

Premedication

Prophylaxis against aspiration pneumonitis is by far the most important aspect of premedication in the morbidly obese parturient. Routine medications for this purpose include H_2–blockers (famotidine 20 mg PO or IV, ranitidine 50–75 mg IV) and a prokinetic drug (metoclopramide 10 mg IV) [54,55]. H_2–blockers have long durations of pharmacologic action and thus should be given earlier rather than later. In case of an emergency that does not allow sufficient time for an intravenous H_2–blocker to exert its effect, 30 ml of 0.3 M sodium citrate solution given orally rapidly increases the pH of the gastric contents [56]. It should be noted, however, that its pH-increasing effect dissipates rapidly and its duration of action varies tremendously among individuals. Therefore, it should be given within 10 min before the induction of general anesthesia. Also, repeated administration through an orogastric tube before extubation should be considered in obese parturients [23]. An anxiolytic drug is usually not required and, if possible, should be avoided preoperatively and intraoperatively. These drugs have a mild respiratory depressant effect and, more importantly, suppress the upper airway protective reflex.

Anesthetic management

The following are general principles for delivering anesthesia to obese parturients. First, on the basis of previous epidemiologic evidence (Fig. 3) [33,35,57], regional anesthesia or peripheral nerve block should be chosen unless general anesthesia is the last resort

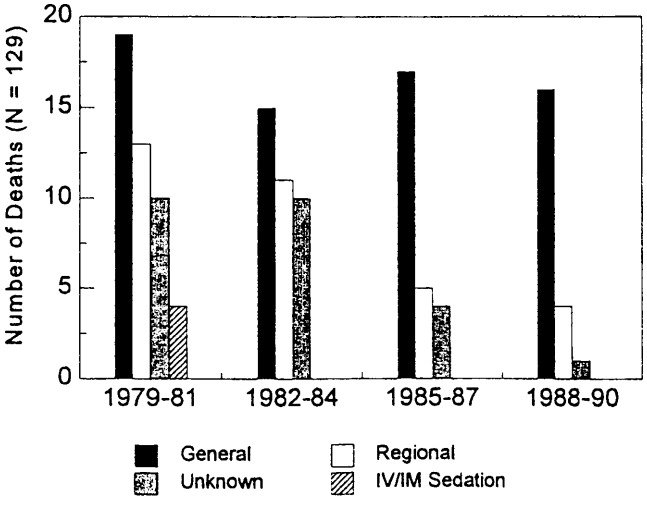

Fig. 3. Anesthesia-related maternal deaths by type of anesthesia, US, 1979–1990. (From Hawkins et al. [57])

to save the mother, the fetus, or both. Second, it is essential that at least two experienced anesthesiologists attend in the case of morbidly obese parturients undergoing labor and delivery or cesarean section. Third, general anesthesia, if absolutely indicated, should be delivered via an endotracheal tube rather than a mask, and ventilation should be controlled. Fourth, every attempt should be made to avoid aspiration of the gastric contents. Fifth, sedation should be minimized or, ideally, avoided unless respiration is closely monitored by experienced anesthesiologists.

Monitors, anesthesia machine, airway equipments, and drugs for emergency cesarean section and airway management should always be available in the labor and delivery room. An appropriately sized labor bed and operating table may be required for obese parturients. A sufficient number of personnel is mandatory to transport oversized patients, especially when they are unable to move themselves due to contraction pain and motor weakness from neural blockade. Preparation for airway management should include a short-handled laryngoscope; assorted blades, such as Macintosh and Miller blades, of different sizes; endotracheal tubes of three different sizes with a stylet in each tube; oropharyngeal airways; laryngeal masks; and equipment for transtracheal intubation, jet ventilation, and fiberoptic intubation. A suction device, preferably the Yankauer type, should be readily available in duplicate, since devices of this type can be operated with one hand, the direction of the tip is easily controlled, and the lumen is not obstructed even if the patient is uncooperative.

Anesthesia for labor and delivery

Despite anticipated technical difficulties, epidural analgesia for labor and delivery has theoretical advantages for obese parturients. Relief of pain during contractions would reduce oxygen consumption and attenuate the hypertensive response. The increase in cardiac output would also be lessened. Limited data suggest that administration of epidural anesthesia, per se, does not increase the likelihood of cesarean section in obese patients [58]. In contrast with a single-shot intrathecal opioid, drugs can be administered repeatedly through the epidural catheter. Neonatal depression is usually not an issue with epidural analgesia, unlike systemic opioids. Hence, anesthesiologists should not be reluctant to perform epidural anesthesia simply because of the anticipated technical difficulties in obese parturients. In the face of the increased likelihood of cesarean section in obese parturients [29–31], placing a functional epidural catheter in advance is a definite advantage. In addition, epidural analgesia can be extended for postoperative analgesia, when adequate pain relief and optimal care are thought to decrease maternal morbidity.

Identification of the midline of the back can be problematic in some morbidly obese parturients. The fat pad over the thoracic region on the back is usually thinner than that over the lumbar region. If the thoracic spinous process can be identified, a lumbar midline can be assumed between the thoracic midline and the coccygeal bone. Alternatively, it may be easier to have the obese patient sit up rather than lie on her side to identify the midline of the spinal column. In theory, an increase in the distance from the skin to the epidural space causes greater deviation of the angle along which the needle is to be advanced. As a result, the likelihood of introducing the epidural catheter into the lateral part of the epidural space would be increased. Indeed, a higher incidence of failed epidural anesthesia and unilateral block and more attempts to identify the epidural space have been reported in morbidly obese patients [53]. A length of catheter longer than the usual should be left in the epidural space, because the epidural catheter is taped on the skin and its position relative to the epidural space is more likely to change due to the excessive fatty subcutaneous tissue. Given the fact that more obese patients will eventually proceed to cesarean section, epidural anesthesia should be checked frequently for its analgesic effect, and a malfunctioning catheter should be replaced immediately.

Intrathecal (fentanyl or sufentanil) and intravenous (meperidine or butorphanol) opioids can also be effective for the relief of labor pain and may be provided to obese parturients in our institution. Pudendal block during stage II labor is technically difficult, especially in morbidly obese parturients. Inhalational anesthetics are of less clinical value for analgesia during labor and delivery. Nitrous oxide does not have sufficient potency to provide satisfactory analgesia as a single agent. Volatile agents may cause loss of consciousness and suppression of the airway protective reflex, both of which may increase the risk of aspiration pneumonitis. Furthermore, loss of consciousness may precipitate upper airway obstruction in morbidly obese patients in whom intubation may be difficult. In summary, our fundamental approach to obese patients requiring analgesia for labor and delivery is similar to that for nonobese parturients, but a functional epidural catheter would be imperative to make further anesthetic management of cesarean section and postoperative care safer and smoother.

Regional anesthesia for cesarean section

Among parturients presenting for labor and delivery, cesarean section and morbid obesity are independent

risk factors for increased morbidity and mortality [33–35]. A higher percentage of morbidly obese parturients than of nonobese parturients eventually undergo cesarean delivery, since morbidly obese parturients have exaggerated pathophysiologic deviations from normality as compared with the nonobese. Given that a considerable proportion of maternal mortality is associated with general anesthesia during cesarean section (Fig. 3) [57], it is rational to administer general anesthesia only when it is indispensable to save the mother, the fetus, or both. General anesthetic should not be administered to save the fetus at the cost of endangering the mother.

Compared with spinal anesthesia, epidural anesthesia offers several advantages: an easily titratable dose and level of analgesia, the ability to extend analgesia for prolonged surgery, a lower incidence and perhaps a slower speed of development of hypotension, a decreased likelihood of excess motor blockade, and utilization for postoperative analgesia. There are limited data showing that both pregnant and nonpregnant obese patients undergoing abdominal surgery require smaller doses for induction of epidural anesthesia [53,59]. However, administration of local anesthetic should be closely titrated, with the use of smaller incremental doses for obese parturients. Epidural anesthesia alone is usually well tolerated in obese parturients [60]. However, sedating obese patients during cesarean section requires vigilance. Whatever sedative drug is used, the airway protective reflex should be considered to be impaired. In addition, relaxation of the pharyngeal musculature and a narrower than usual oropharyngeal and supraglottic space may increase the likelihood of upper airway obstruction in sedated obese parturients. Given the potential for difficult bag-and-mask ventilation and failed intubation in these parturients, excessive sedation in theory places these patients at tremendous risk for aspiration pneumonitis and life-threatening complications.

Extending labor epidural analgesia for cesarean section usually requires additional local anesthetic at a higher concentration. Dilute local anesthetic, with or without a narcotic, for labor analgesia is usually not adequate in terms of quality as well as the level of analgesia. The level of analgesia required for cesarean section is at least T4–5, whereas analgesia higher than T10 is rarely required during stage I and II labor. The dose of epidural or intrathecal local anesthetic needed to produce denser and higher block, where some analgesia preexists from the epidural combination of a local anesthetic and a narcotic, remains undetermined.

Previous reports produced conflicting results regarding the dose requirement during spinal anesthesia for obese patients. Some studies demonstrated a negative correlation between the degree of obesity and the dose requirement for intrathecally administered local anesthetic; that is, the larger the BMI, the greater the spread of sensory analgesia produced by spinal anesthesia [61]. Other studies failed to demonstrate any significant correlation [62]. Greene has suggested that the dose requirement is unaltered, but the spread is affected by obesity [63]. Larger buttocks, engorged epidural veins resulting in a reduced subarachnoid space, exaggerated curvature of the lumbar spinal column, and hormonal changes may all contribute to the changes seen in obese patients. Caution should, therefore, be exercised for the consequences of extensive high block when a single-shot spinal anesthesia is selected for obese parturients. Our practice is to administer a local anesthetic dose comparable to that for nonobese parturients, but the level of analgesia is more frequently determined and adjusted by tilting the operating table appropriately. Also, a longer time is ensured for obese than nonobese parturients before incision because subarachnoid blockade may extend in the cephalad direction more slowly and insidiously. Even though high thoracic spinal anesthesia produces more profound motor blockade than epidural anesthesia, spinal anesthesia produces either no change in arterial gas tensions or only a slight worsening of oxygenation in obese parturients [64]. Rather, cardiovascular compromise may be of greater concern in obese parturients undergoing spinal anesthesia because of a higher incidence of systemic hypotension. A higher and variable extension of autonomic blockade is known to occur in obese patients [65]. In addition, panniculus retraction may exaggerate cardiovascular compromise [66]. Another concern associated with single-shot spinal anesthesia is the potential for prolonged surgery in obese parturients. Continuous spinal anesthesia would alleviate some of those concerns associated with single-shot spinal anesthesia, and the desired level of surgical analgesia would be obtained in a more titratable manner.

General anesthesia for cesarean section

Whenever general anesthesia is anticipated in obese patients, prophylaxis against regurgitation or aspiration of gastric contents should be initiated in a timely fashion. Thorough preoperative assessment of the airway is mandatory. Anesthetic equipment and medications should be prepared for the worst possible scenario. It is imperative that the airway be secured with an endotracheal tube whenever general anesthesia is administered to an obese parturient. However, the standard technique of endotracheal intubation should not be expected to be successful, because anatomic deviation of the upper airway from normality may

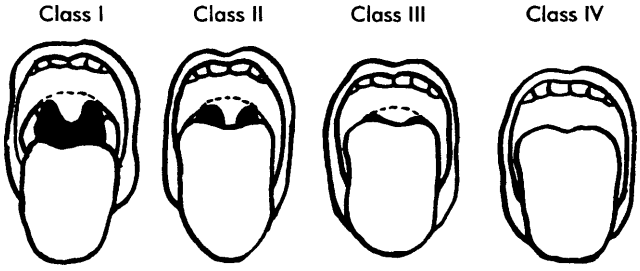

Fig. 4. Classification of the upper airway in terms of the size of the tongue and the pharyngeal structures when the mouth is widely opened. Class I, the glottis (including anterior and posterior commissures) can be fully exposed; class II, the glottis can be partly exposed (anterior commissure not visualized); class III, the glottis cannot be exposed (corniculate cartilages only can be visualized); class IV, the glottis including corniculate cartilages cannot be exposed. (Modified from Mallampati et al. [67])

be exaggerated by the combination of obesity and pregnancy. Indeed, Buckley et al. estimated that 13% of obese patients and 30% of obese parturients pose difficulties in tracheal intubation [53]. Furthermore, as expected, the degree of overweight is positively correlated with the incidence of difficult intubation [67].

If the Mallampati classification (Fig. 4) suggests that intubation will probably be difficult (class III or IV), awake oral intubation is recommended for obese parturients [68]. It is our policy to perform direct laryngoscopy in all obese patients after topical anesthesia, with the use of 4% lidocaine over the base of the tongue, epiglottis, larynx, and posterior pharyngeal wall, while attention is paid to the possibility of regurgitation of the gastric contents. If all or most of the glottis is visualized, subsequent endotracheal intubation is usually easier than expected. Then, an induction dose of intravenous agent and succinylcholine is administered with cricoid pressure (rapid sequence induction) after denitrogenation by either technique: tidal respiration of 100% oxygen for 3 min, or four maximal inspirations of 100% oxygen [69–71]. No previous data have clearly demonstrated that one technique of denitrogenation is considerably better than the other. It is reasonable that the urgency of cesarean section should dictate one of those techniques. If it is impossible to visualize the larynx, awake intubation should be accomplished by either direct laryngoscopy or fiberoptic guidance. Nasal intubation is not recommended because of the characteristic mucosal edema during pregnancy. Bear in mind that multiple attempts at direct laryngoscopy may cause further mucosal swelling and bleeding, rendering subsequent maneuvers extremely difficult.

Failure to intubate the trachea after the rapid sequence induction usually necessitates bag-and-mask ventilation with extra personnel applying cricoid pressure continuously, since desaturation occurs rapidly in obese parturients [72]. If general anesthesia is chosen because of failed regional anesthesia or contraindications to regional anesthesia (i.e., neither the mother or fetus is compromised), awakening the patient may be a reasonable alternative. Otherwise, cesarean section should be performed while the patient undergoes ventilation by an anesthetic mask, bearing in mind that the risk of aspiration continues during the entire course of the surgical procedure. If mask ventilation is found to be difficult, the laryngeal mask airway may be a valuable aid to establishing the airway.

Tracheal intubation should be confirmed by the repetitive and characteristic waveform of capnography in addition to auscultation, since the breath sounds may be distant in morbidly obese patients. Once the tracheal intubation has been confirmed, general anesthesia should be maintained by intermittent positive pressure ventilation rather than by spontaneous respiration. Most anesthesiologists use supplemental nitrous oxide as long as the mother can maintain adequate oxygenation. In morbidly obese patients, however, higher inspired concentrations of oxygen may be required than in nonobese patients, necessitating relatively high concentrations of volatile anesthetic agents [73]. Higher than normal tidal volume and application of positive end-expiratory pressure (PEEP) have been suggested to raise PaO_2 and lower the alveolar–arterial oxygen tension difference in extremely obese patients [74]. However, increasing the PEEP may progressively decrease cardiac output and oxygen availability in such a population [75]. Whether application of PEEP increases or decreases oxygen delivery to the fetus in obese parturients remains to be determined. A volatile agent, irrespective of the choice, dose-dependently relaxes uterine smooth muscle and, in theory, may increase postpartum hemorrhage. In addition, volatile agents and muscle relaxants decrease FRC, which is further compromised in the supine position in obese patients. In order to decrease the general anesthetic requirement, therefore, most anesthesiologists administer supplemental narcotics, such as fentanyl 3–5 $\mu g \cdot kg^{-1}$, once the umbilical cord has been clamped. Such a practice would alleviate pain in the immediate postoperative period. At the end of surgery, neuromuscular blockade should be antagonized completely, as confirmed by responses to peripheral nerve stimulation. Bear in mind that the effect of muscle relaxants during surgery may be overestimated, whereas the reversal effect may be underestimated due to the thickened subcutaneous soft tissue in obese patients. Routine criteria for tracheal extubation should also be strictly followed.

Postoperative considerations

Morbidly obese patients have increased postoperative morbidity after cesarean delivery, but not after vaginal delivery. Among morbidly obese patients undergoing cesarean section, prolonged surgery and intraoperative blood loss are associated with the increase in post operative morbidity [27]. As expected, obese parturients are more likely to develop postoperative pulmonary complications, such as hypoxemia, atelectasis, and pneumonia [76,77]. Even in healthy obese patients, postoperative hypoxemia occurs universally after cesarean section under general anesthesia. A vertical abdominal incision is more likely to cause postoperative hypoxemia than a horizontal incision [78]. The patient should be placed in a semi-recumbent position as soon after surgery as possible. In addition to aggressive physiotherapy, supplemental oxygen should be continued, possibly for several days in morbidly obese parturients, until hypoxemia is no longer of concern. Whether abnormal preoperative results of respiratory function tests are indicative of postoperative pulmonary complications remains to be determined in obese parturients.

Previous literature indicates that obese patients are at increased risk of developing deep vein thrombosis and pulmonary thromboembolism [79]. On the other hand, pregnancy-induced anemia and the resultant decrease in blood viscosity may decrease the likelihood of such complications. However, a recent governmental report from Japan documented that the majority of pulmonary thromboembolisms occurred in obese parturients, and that 76% of such complications occurred after cesarean section, suggesting that obesity still remains a risk factor for thromboembolism during pregnancy [80]. The clinical efficacy of low-dose heparin, compression stockings, and regional anesthesia as compared with general anesthesia for the prevention of thromboembolic episodes remains to be proved in obese parturients.

In theory, early mobilization is essential for obese parturients to decrease the likelihood of developing postoperative pulmonary complications and thromboembolic episodes. A sufficient dose of analgesic medication should be administered for postoperative analgesia, since adequate pain control is one of the determinants of decreased postoperative maternal morbidity. For those who underwent cesarean section under single-shot spinal or general anesthesia, intravenous patient-controlled analgesia (PCA) with morphine or fentanyl is most often utilized in our institution. However, anecdotal reports suggest that PCA could be hazardous in patients with a history of sleep apnea [81], whereas others have demonstrated that PCA can be used safely for postoperative analgesia in morbidly obese patients [82]. For those who received epidural anesthesia intraoperatively, continuous epidural analgesia or epidural PCA with fentanyl usually provides excellent pain relief. Alternatively, epidural morphine may be given intermittently, because the analgesic action of epidural morphine is much longer than that of epidural fentanyl [83]. However, respiratory depression of delayed onset may occur after epidural morphine [84]. Therefore, monitoring of respiratory variables is mandatory to avoid or detect respiratory depression at the earliest possible time, because the respiratory reserve is already marginal in morbidly obese patients. Routine use of a pulse oximeter and frequent determination of the respiratory rate and the level of consciousness may facilitate early detection of clinically significant respiratory depression.

Summary

As the proportion of obese patients increases in the general population, anesthetizing obese parturients for labor and delivery and for cesarean section is no longer rare in industrialized countries. Because of the different types of obesity, inter-individual variations in pathophysiology, and pharmacokinetic and pharmacodynamic alterations associated with obesity, individualized evaluation is a key to maximize the predictability of intraoperative and postoperative untoward sequelae. Examination of the upper airway, prophylaxis of aspiration pneumonitis, and discussion of every possible consequence with the patient are perhaps the most important aspects of the preoperative visit.

The fundamental approach to obese parturients presenting for labor and delivery or for cesarean section is similar to that for nonobese parturients. However, in the face of an increased likelihood of abnormal labor and cesarean section, and for optimal postoperative care, a functioning epidural catheter is essential for the subsequent management of obese parturients. It is mandatory that the operating and delivery rooms be fully equipped with appropriate monitors, an anesthesia machine, airway equipment, and drugs for emergency situations. Postoperative analgesia and early mobilization are the most important measures to prevent certain types of complications likely to occur in obese parturients, such as pulmonary complications and thromboembolism.

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