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Review

Morbid obesity in pregnant women

MARC VAN DE VELDE
EVA ROOFTHOOFT

Department of Anesthesiology
University Hospitals Gasthuisberg
Katholieke Universiteit Leuven
Herestraat 49
B-3000 Leuven
Belgium

Correspondence:
Marc Van de Velde
Director Obstetric Anesthesia and Extra Muros Anesthesia
Department of Anesthesiology
University Hospitals Gasthuisberg
Herestraat 49, B – 3000 Leuven, Belgium
E-mail: marc.vandevelde@uz.kuleuven.ac.be

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INTRODUCTION

Obesity is a global health care problem with increasing prevalence. The World Health Organisation (WHO) characterizes obesity as a pandemic with a higher prevalence in women than in men. Therefore, anaesthesiologists are increasingly faced with the care for obese parturients.

Obesity in the pregnant woman is considered a high risk state because it is associated with many complications *(1, 2, 3, 4, 5, 6)*. Compared with normal-weight patients, obese women have more infertility, more early miscarriage and more congenital abnormalities *(5, 6)*. Besides the co-existence of preexisting diabetes mellitus and chronic hypertension, obese women are more likely to have pregnancy-induced hypertension, pre-eclampsia, gestational diabetes, thrombo-embolism, macrosomia, and spontaneous late intrauterine demise *(1, 2)*. Obese women also require more instrumental deliveries and Cesarean sections, with a higher incidence of postoperative wound infections. Children born of obese mothers have a higher incidence of macrosomia and associated shoulder dystocia, and in addition of being large at birth, these children are also more susceptable to obesity in adolescence and adulthood *(1, 2, 3)*. Ray et al. showed that obese women required more medical involvement and had more complications then lean patients *(7)*. Chu et al. published a large study in over 13000 pregnant patients showing that obese parturients increasingly used health care resources (8). Despite the clear evidence that obese pregnancy is more expensive and associated with more risks then normal weight pregnancy, obstetric health care providers fail to communicate this information to their patients *(9)*.

The World Health Organisation (WHO) and the National Institutes of Health (NIH) collaboratively define normal weight as a body mass index (BMI) of 18.5 to 24.9 kg/m^2, overweight as a BMI of 25 to 29.9 and obesity from a BMI of > 30 kg/m^2, which is further devided into three classes.

Obesity is also a risk factor for anesthesia related maternal mortality. The Confidential Enquiry into Maternal and Child Health (CEMACH) reported that in the period 2000–2002, 30% of all mothers who died were obese; by 2003–2005 more than half were overweight or obese and over 15% were morbidly or super morbidly obese (>50 kg/m^2). In the latter report there were six maternal deaths in direct relation to anesthesia, four of them were obese, two morbidly obese *(10, 11)*.

EPIDEMIOLOGY

The prevalence of obesity has increased at an alarming rate. Fortunately, possibly as a result of increased awareness of the problem, at least in developed countries such as the United States, the dramatic in-

crease seems to be halted. The latest Center for Disease Control and Prevention report shows that in the United States (US) the prevalence of obesity has not measurably risen in the past few years. However the levels remains high, with 34 % of adults aged 20 or more being considered obese *(2)*.

The dramatically increasing rate of obesity in the general population also extends on women of reproductive age. During pregnancy the BMI is calculated using pre-pregnant weight, or if not known, the first weight measured at prenatal care. The National Health and Nutrition Examination Survey (NHNES) cited the prevalence of overweight US women in traditional childbaring ages (20–39) as 54.3% and obese women in the age categories of 20–29, 30–39, 10–49, as 23.3%, 32.5% and 35.4% respectively *(3)*. Three United Kingdom (UK) studies show the rate of maternal obesity have risen from 9.9% to 16% between 1990 and 2004 in Middlesbrough *(12),* from 3.2% to 8.9% between 1990 and 1999 in Cardiff *(13)* and from 9.4% to 18.9% between 1990 and 2002/4 in Glasgow *(14)*. A National Survey for England in 2003 shows that the prevalence of obesity in women of childbearing age is 17.8% *(15)*. A similar survey published in 2002 reported on the BMI over the previous ten years, which showed that the percentage of obese and morbide obese women in the reproductive age group had doubled during this period *(16)*.

Trends in maternal obesity on an international level are difficult to compare directly owing to different measurement criteria used. However, Guelinckx et al. summarized the literature and reported that obesity varies from 1.8 to 25.3% of the pregnancy population using a BMI > 30 kg/m^2 cut-off point.

PHYSIOLOGICAL CHANGES IN OBESITY AND PREGNANCY

Both obesity and pregnancy are associated with physiologic changes and many of these changes have a similar impact. The most important changes are in the airway, the respiratory and the cardiovascular sytems. Many of the effects of pregnancy and obesity are additive, and lead to significant functional impairment, decreased physiologic reserve, and increased anaesthetic and obstetric risk.

Airway

Pregnancy carries an increased risk for aspiration of gastric content and the so-called Mendelson's syndrome. Whether the combination of pregnancy and obesity increases the risk for pulmonary aspiration remains controversial. Older studies found that weight was a significant factor in gastric content volume during pregnancy *(18)* and that obese non-pregnant women scheduled for elective surgery had both a larger volume and a lower gastric pH than non-obese patients *(19)*. Recently however Maltby *et al.* showed that the intake of 300 mL of clear liquids in obese, surgical patients had no effect on the gastric content or pH when compared to patients who had fasted for more than 6 hours *(20)*. Similarly Juvin et al. compared obese patients with normal weight patients and found comparable results *(21)*. Wong *et al.* studied gastric emptying of water in obese term pregnant patients and found gastric emptying not delayed following ingestion of 300 mL water compared to the ingestion of 50 mL *(22)*. Obese patients however have a higher incidence of hiatus hernia, gastro-oesophageal reflux and elevated intra-gastric pressure compared to normal weight patients *(21, 23)*. Obesity is also one of the major risk factors for diabetes, which in turn can cause delayed gastric emptying, increasing the risk for aspiration. This togheter with the fact that obesity is associated with more difficult mask ventilation, intubation and difficult airway management, can make obesity a risk factor for aspiration during C-section independent of gastric emptying time *(22)*. A rapid sequence induction with succinylcholine remains the golden standard for a general anaesthesia for C-section.

Obesity and pregnancy each increase the risk for difficult intubation. In the literature an incidence of failed tracheal intubation of approximately 1:280 in the obstetric population is reported versus 1:2230 in a general surgical population *(24, 25, 26)*. In an obese population with BMI > 35 kg/m^2, Juvin *et al.* found an incidence as high as 15.5% *(27)* Rahman *et al.* reported difficult intubation in obstetric general anaesthesia to be 1:238 over a 5-year period from 1999 to 2003. The mean body mass index in their study population was 31.9 kg/m^2 and most of the cases were emergencies *(28)*. Several other authors reported on an incidence as high as 33% for morbidly obese pregnant patients *(29, 30)*. Also a six year review of obstetric patients in a UK region reported a high failed intubation rate in women whose BMI was found to be over 33 *(25)*. So it is clear that difficult or failed tracheal intubation in obese parturients occurs frequently and optimal assessment and management of the airway is of extreme importance. A careful airway evaluation should be completed before any anesthetic procedure including Mallampati score, mouth opening and neck mobility. Merah *et al.* found that among obstetric patients, the combination of Mallampati score and thyromental distance has a sensitivity of 100% and positive predictive value of 61.5% to predict difficult laryngoscopy *(31)*. Further airway imaging is questionable as it only improves the predictability of a difficult airway by 0.04% *(32)*. Juvin *et al.* found in both obese and non-obese and in both pregnant and non-pregnant women that only a Mallampati score of III–IV was an independent risk factor for difficult intubation, not range of head and neck motion, width of mouth opening, the presence of buck teeth, the presence of mandibular recession or BMI score *(27)*. Although there are no bony differences between obese, non-obese, pregnant or non-pregnant patients, the changes in airway can be explained by fat deposition in obese and soft tissue changes during pregnancy. Poor head position in the obese and cricoid pressure, although necessary for a rapid sequence induction, can contribute to the difficulty. Optimal positioning before induction of

general anesthesia remains critical for the morbidly obese parturient, although not always easy to achieve in an emergency situation. Symptoms such as stridor or hoarseness may suggest airway oedema. A pre-operative anesthetic consultation when an obese patient arrives in the hospital for labor gives the anesthetist time to emphasize this problem and plan the management of a possible difficult intubation, and gives him the opportunity to choose for other possibilities, like early placement of neuraxial analgesia *(33)*.

Respiratory system

All aspects of oxygenation and ventilation are affected during pregnancy. The mechanical effects of the growing uterus produce a progressive decrease in expiratory reserve volume (ERV), residual volume (RV), and functional residual capacity (FRC). In the past, studies have shown that obesity on itself is also associated with decrease in ERV, RV and FRC caused by the added weight and the decreased compliance of the chest wall *(34)*. In an obese woman who becomes pregnant there may however be some improvement on the respiratory system, especially on the FRC *(35)*. Hormonal changes decrease the airway resistance, through the relaxing effect of progesterone on smooth muscle, reducing some of the negative effects of obesity on the respiratory system *(36)*. Studies that have shown the respiratory effect of obesity in pregnancy to be minimal were carried out in the sitting position. When FRC is furhter reduced by assuming the supine position or by induction of general anesthesia, FRC drops below closing capacity, leading to airway closure and shunting.

The work of breathing is increased in obese parturients due to chest wall weight, leading to higher ventilatory requirements and oxygen cost of breathing. Dempsey *et al. (37)* showed that excess body weight increases oxygen consumption and CO2 production in a linear fashion. Thus the obese parturient is particulary susceptible to rapid desaturation for instance by induction of general anesthesia. This underlines the importance of adequate pre-oxygenation.

Cardiovascular system

Pregnancy is associated withwide-ranging cardiovascular changes. Obesity induced pathological changes have profound effects on cardiac, endothelial and vascular function. Unlike the respiratory system, where pregnancy offers some favorable effects in obese patients, the cardiovascular system is further stressed when pregnancy is associated with obesity *(38, 39)*.

Pregnancy is associated with a significant increase in cardiac output, which is further increased during labor and in the immediate post-partum period when cardiac output peaks up to 75% above pre-delivery values *(40)*. Obesity increases cardiac output even further because every extra 100g of fat increases the cardiac output by up to50 mL/min *(41)*. Blood volume is increased during pregnancy and even more when the pregnant women is obese. In non-obese women, pregnancy is associated with a significant reduction in afterload. When pregnancy is associated with obesity however, afterload reduction is significantly impaired due to increased peripheral resistance *(42)*. Volume load initially brings left ventricular hypertrophy and subsequently the myocardium starts to dilate against increased pressure overload, eventually leading systolic dysfunction. Prepregnancy hypertension may become accentuated and an increase in heart rate in line with the increase in cardiac output may lead to diastolic dysfunction. Pulmonary blood flow increases in proportion to the increase in cardiac output and pulmonary hypertension and right ventricular failure may develop. These can be exacerbated by the supine position, airway obstruction, sleep apnea and hypoxemia.

During pregnancy the adverse effects of obesity are exacerbated due to hormonal changes. Insulin resistance occurs as well as hyperinsulinemia, resulting in increased fat disposition. If fat deposition occurs in myocardial tissue, conduction and contractility can be seriously affected *(40, 42)*. Morbidly obese patients are more susceptible to develop fatal arrhythmias. Even minor or borderline Q-T interval prolongation can result in sudden cardiac death in these patients. Therefore, medications known to prolong the Q-T interval, such as methadone, droperidol, granisetron and others, are best avoided.

Obesity results in endothelial function due to dyslipidemia and increased vascular inflammation *(39)*. Endothelial dysfunction in pregnant woman may predispose to the development of pregnancy-induced hypertension *(39)*. Additionally, obesity itself is associated with hypertension, diabetes mellitus, hyperlipidemia and poor cardiac function and is one of the leading risk factors for coronary artery disease and cerebrovascular accidents *(43)*. In addition, obesity has been mentioned as a risk factor for peripartum cardiomyopathy, a potentially lethal disease *(44, 45)*.

It is important to stress the risks of obesity combined with assuming certain perioperative positional changes. Two cases of sudden death on assuming the supine position in morbidly obese patients were attributed to the obese supine hypotensive syndrome, comparable to the phenomenon of aortacaval compression *(46)*. The well-know effect of an enlarged uterus compressing major abdominal vessels in the supine position leading to severe reduced cardiac output and placental perfusion can be exacerbated by obesity where a large abdominal panniculus adds to uterine and vascular compression. In fact, obese pregnant women often demonstrate resting tachycardia in the sitting position which resolves in the left lateral position *(47)*.

Anesthetic management for labor

Obesity is associated with an increased incidence of fetal macrosomia and labor abnormalities such as shoulder dystocia, which are known risk factors for more painfull contractions and complicated labor *(48)*. Wether obesity alone has an influence on the severity of labor pain, is

controversial. Melzack *et al.* found a positive correlation between BMI and the severity of labour pain *(49)*. Findings which could not be confirmed in a later study by Ranta *et al.* (50). Anyway, obese parturients most likely have a higher need to receive good analgesia.

Nitrous oxide or systemic opioids have been proven to lead to maternal drowsiness, airway obstruction and hypoxemia *(51)*. Most authors would agree that neuraxial labor analgesia is the most optimal mode of providing analgesia during labor and delivery. This was confirmed by a recent Cochrane review *(52)*. Moreover, effective pain relief during labor can improve maternal respiratory function and attenuate sympathetically mediated cardiovascular response, an effect which is even more important in obese parturients *(53)*. Obesity also increases the need for Cesarean section, so having a functional epidural catheter in place is advantageous should an urgent operative procedure be necessary. Furthermore, general anesthesia during pregnancy, especially in obese women, is associated with increased risks such as aspiration and failed intubation *(54)*. One way to avoid these complications is to place a functional catheter in early labor, which can be used in case of emergency Cesarean section and for pain relief in the postoperative period.

Although regional anaesthesia offers many advantages in the obstetric parturient, these techniques can be very challenging, because anatomical landmarks are obscured. Clincksales *et al.* showed that with increasing BMI the depth of the epidural space is increased *(55)*. Jordan et al. showed that almost 75% of massively obese parturients require multiple placement attempts, and 14 % require more than 3 attempts for successful epidural placement *(56)*. Whether the lateral decubitus or sitting position is preferred during puncture is matter of considerable debate. Some authors prefer the lateral recumbent head-down position because of lower incidence of intravascular catheter placement due to reduced venous congestion in epidural veins *(57),* however others prefer the sitting position because landmarks are more easily identified. Hamza *et al.* demonstrated that the depth of the epidural space is greater in the lateral position compared to sitting because gravity pulls down the pad of fat obscuring the midline *(58)*. These authors also reported that weight and BMI were positively correlated to the epidural space. This was confirmed by Bahk et al. who used computed tomography to measure the depth of the epidural space in non-pregnant patients *(59),* and by Clincksales *et al. (55)* who derived a simple formula to predict the depth of the epidural space based on BMI and maternal age. Interestingly, despite an increased epidural space depth with increasing weight and BMI, very few patients actually have an epidural space which is deeper then 8 cm *(58)*.

The identification of the midline can be difficult. Using the sitting position can be helpfull. In recent years ultrasound has become a very usefull tool which is growing in popularity. It can be used to identify the midline and the depth to the epidural space. Different studies have been published to show the usefulness of this technique *(60, 61, 62)*.

In obese patients, a correctly placed epidural catheter can easily be dislodged by the drag of fat when parturients turn in bed or change their position. Several authors described movement as much as 2 cm out of the epidural space *(63, 64)*. This should be taken into consideration when deciding at which depth the catheter should be left into the epidural space. With an increased risk for Cesarean section, one should make sure that the epidural catheter is working well, and if not, replace it when possible.

Anaesthetic management for Cesarean section

The risk of Cesarean section is significantly increased in obese parturients. A recent meta-analysis showed a significantly increased risk of Cesarean section as compared to normal weight patients *(65, 66)*. Maternal mortality and morbidity is also increased following Cesarean section in obese patients (more blood loss, more wound infections, longer surgery, etc…) *(66)*. Not only the obstetric risks are increased, also the anesthetic complications are more frequent. Hawkins *et al.* reported that general anesthesia for Cesarean section is associated with a much higher risk of maternal mortality compared to regional anesthesia *(67)*. Also obesity was found in several studies to be a major risk factor for maternal mortality, with failed intubation and aspiration as the cause of death in the majority of cases *(54)*. The combination of obesity and pregnancy is a significant risk factor for what we already highlighted, difficult intubation and aspiration *(10, 11, 54)*. It is of course best to avoid these problems by having a good functioning epidural catheter in place during labor. Therefore early catheter placement is recommended by various opinion leaders *(38, 39)*. To achieve this goal, early and good multidisciplinary communication between midwife, obstetrician and anesthetist is mandatory.

If however, general anesthesia can not be avoided the anesthetist should be aware of it's significant risks. Aspiration, failed intubation and rapid desaturation have been discussed previously. Therefore good aspiration prophylaxis, using the combination of a non-particulate antacid (such as 0.3M sodium citrate), an H2-antagonist and metoclopramide, should be standard in these patients *(38)*. Good pre-oxygenation should always be performed, while an extra pair of skilled hands should be readily available i fairway management becomes difficult. To facilitate laryngoscopy, a so-called »ramped« position with blankets under the patients thorax and head was described by Collins *et al. (68)*. Careful attention to left lateral tilt, even during general anesthesia, is mandatory. If general anesthesia in induced using penthotal a higher initial dose should be used, but because of prolonged elimination care should be taken with repetitive dosing. Propofol's pharmacokinetics change less in obese patients and initial dosing should be calculated on lean body weight *(38)*.

For elective Cessarean section regional techniques are, as already, stated preferred. While single shot spinal anesthesia is probably worldwide the most practized technique of anesthesia for Cesarean section, we prefer to use a combined spinal epidural (CSE) technique in these patients *(69)*. In obese patients the block can be unpredictable and often exaggerated. Thus usually dose reductions are required in obese patients *(70)*. Not only the need for anesthetics is unpredictable, also the duration of surgery might be prolonged. As already mentioned obese patients are also susceptible to aortocaval compression. Reducing the dose will help to control the hemodynamic side-effects of the Block. Therefore having a back-up epidural catheter is useful. This allows for dose reductions to titrate the need of anesthetics to the specific needs of that individual patient. But it also guarantees flexibility to prolong regional anesthesia if surgery is prolonged.

SUMMARY

A thorough understanding of physiology, pathofysiology, associated conditions, their complications and the implications for analgesia and anaesthesia, should place the anaesthesiologist in a better position to take care of these patients. Neuraxial blockade with an indwelling catheter is the prefered method for labor analgesia in obese or morbidly obese patients. An early placement in labor is necessary to give adequate analgesia and to avoid general anesthesia in case of emergency Cesarean section. Therefore, anesthesiology consultation on arrival of the obese parturient in the hospital is of absolute importance to give the anesthesiologist time to place a catheter and to plan the management of a possible difficult intubation.

If Cesarean section is required, using the epidural catheter is preferred. CSE is our preferred technique if planned operative delivery is performed. Both the flexibility of reducing the dose and being able to sustain anesthesia when surgery is prolonged are appealing features of the CSE technique.Whenever general anesthesia becomes necessary, careful positioning (ramped head position and adequate left lateral tilt), good denitrogenation and acid aspiration prophylaxis are absolutely mandatory.

REFERENCES

1. SAPATHY H K, FLEMING A, FREY D BARSOOM M, SAPATHY C H, KHANDALAVALA J 2008 Maternal Obesity and Pregnancy. *Postgraduate Medicine 120 (3)*
2. OGDEN C L, CARROLL M D, MCDOWELL M A, FLEGAL K M 2007 Obesity among adults in the United States-no change since 2003–2004. NCHS data brief no 1. Hyattsville MD: National Center for Health Statistics.
3. FLEGAL K M, CARROLL M D, OGDEN C L, JOHNSON C L 2002 Prevalence and trends in obesity among US adults, 1999–2000. *JAMA 288:* 1723–7
4. ARENDAS K, QIU Q, GRUSLIN A 2008 Obesity in pregnancy: pre-conceptional to postpartum consequences. *J Obstet Gynaecol Can 30:* 477–488
5. RAY A, HILDRETH A, ESEN U I 2008 Morbid obesity and intrapartum care. *J Obstet Gynaecol 28:* 301–304
6. DIXIT A, GIRLING J C 2008 Obesity and pregnancy. *J Obstet Gynaecol 28:* 14–23
7. RASMUSSEN S A, CHU SY KIM SY, SCHMID C H, LAU J 2008 Maternal obesity and risk of neural tube defects: a metaanalysis. *Am J Obstet Gynecol (june):* 611–619
8. CHU S Y, BACHMAN D J, CALLAGHAN W M, WHITLOCK E P, DIETZ P M, BERG C J, O'KEEFFE-ROSETTI M, BRUCE F C, HORNBROOK M C 2008 Association between obesity during pregnancy and increased use of health care. *N Engl J Med 358:* 1444–1453
9. MHYRE J M, GREENFIELD M L V H, POLLEY L S 2007 Survey of obstetric providers' views on the anesthetic risks of maternal obesity. *Int J Obstet Anesth 16:* 316–322
10. Confidential Enquiry into Maternal and Child Health, 2004 Why mothers die 2000–2002. RCOG, London.
11. LEWIS G 2007 The Confidential Enquiry into Maternal and Child Health (CEMACH). Saving Mother's Lives: Reviewing Maternal Deaths to Make Motherhood Safer – 2003–2005. The seventh report on Confidential Enquiries into Maternal Deaths in the United Kingdom *(ed.)*. CEMACH, London.
12. HESLEHURST N, ELLS L J, SIMPSON H, BATTERHAM A, WILKINSON J, SUMMERBELL C D 2007 Trends in Maternal obesity incidence rates, demographic predictors, and health inequalities in 36 821 women over a 15 year period. *BJOG 114:* 187–194
13. KIRAN T S U, HEMMADI S, BETHAL J, EVANS J 2005 Outcome of pregnancy in a woman with an increased body mass index. *Br J Obstet Gynaecol 112:* 768–772
14. KANAGALINGAM M G, FOROUHI N G, GREER I A, SATTAR N 2005 Changes in booking body mass index over a decade: retrospective analysis from a Glasgow Maternity Hospital. *BJOG 112:* 1431–1433
15. Department of Health. Health Survey for England 2003 HMSO, London, 2003.
16. Department of Health, London. Health Survey for England 2002-trends. http://www.dh.gov.uk/assetRoot/04/06/60/70/04066070.xls
17. GUELINCKX I, DEVLIEGER R, BECJERS K, VANSANT G 2008 Maternal obesity: pregnancy complications, gestational weight gain and nutrition. *Obes Rev 9:* 140–150
18. ROBERTS R B, SHIRLEY M A 1974 Reducing the risk of acid aspiration during cesarian section. *Anest Analg 53:* 859–68
19. VAUGHAN R W, BAUER S, WISE L 1975 Volume and pH of gastric juice in obese patients. *Anesthesiology 43:* 686–9
20. MALTBY J R, PYTKA S, WATSON N C, COWAN R A, FICK G H Drinking 300 ml of clear fluid two hours before surgery has no effect on gastric fluid volume and pH in fasting and non-fasting obese patients. *Can J Anaesth 51:* 111–15
21. JUVIN P, FEVRE G, MEROUCHE M, VALLOT T, DESMONTS J M 2001 Gastric residu is not more copious in obese patients. *Anesth Analg 93:* 1621–1622
22. WONG C A, MCCARTHY R J, FITZGERALD P C, RAIKOFF K, AVRAM M J 2007 *Anesth Analg 105:* 751–5
23. BARAK N, EHRENPREIS E D, HARRISON J R, SITRIN M D 2002 Gastro-oesophagal reflux disease in obesity: pathophysiological and therapeutic considerations. *Obes Rev 3:* 9–15
24. HAWTHORNE L, WILSON R, LYONS G, DRESNER M 1996 Failed intubation revisited: a 17-yr experience in a teaching Maternity unit. *Br J Anaesth 76:* 680–4
25. BERNARDO P D, JENKINS J G 2000 Failed tracheal intubation in obstetrics: a 6 year review in a UK region. *Anaesthesia 55:* 685–94
26. SAMSOON G L, YOUNG J R 1987 Difficult tracheal intubation: a retrospective study. *Anaesthesia 42:* 487–90
27. JUVIN P H, LAVAUT E, DUPONT H, LEFEVRE P, DEMETRIOU M, DUMOULIN J L, DESMONTS J M 2003 Difficult tracheal intubation is more common in obese than in lean patients. *Anesth Analg 97:* 595–600
28. RAHMAN K, JENKINS J G 2005 Failed tracheal intubation in obtetrics: no more frequent but still badly managed. *Anaesthesia 60:* 168–171
29. D' ANGELO R, DEWAN D D 2004 Obesity. *In:* Chestnut D H *(ed.)* Obstetric Anaesthesia: Principles and Practice. Elsevier Mosby, Philadelphia, p 893–903
30. HOOD D D, DEWAN D M 1993 Anesthetic and obstetric outcome in morbidly obese parturients. *Anesthesiology 79:* 1210–8
31. MERAH N A, FOULKES-CRABBE D J, KUSHIMO O T 2004 *et al.* Prediction of difficult laryngoscopy in a population of Nigerian obstetric patients. *West Afr J Med 23:* 38–41

32. NAGUIB M, MALABAREY T, ALSATLI R A, DAMEGH S A, SAMARKANDI A H 1999 Predictive models for difficult laryngoscopy and intubation. A clinical, radiologic and three-dimensional computer imaging study. *Can J Anesth 46:* 748–59
33. WISSLER R N 2008 Obesity in the parturient: an increasing burden. *Int J Obstet Anesth 17:* 1–2
34. LEE J J, LARSEN R H, BUCKLEY J J *et al.* 1981 Pulmonary function and its correlation to the degree of obesity in 294 patients. *Anesth Rev 54:* 325–8
35. ENG M, BUTLER J, BONICA J J 1975 Respiratory function in pregnant obese women. *Am J Obstet Gynecol 123:* 241–5
36. UNTERBORN J 2001 Pumonary function testing in obesity, pregnancy and extremes of body habitus. *Clinics in chest medicine 22:* 759–67
37. DEMPSEY J A, REDDAN W, RANKIN J *et al.* 1996 Alveoalr arterial gas exchange during muscle work in obesity. *J Appl Physiol 21:* 1807–14
38. SOENS M A, BIRNBACH D J, RANASINGHE J S, VAN ZUNDERT A 2008 Obstetric anaesthesia for the obese and morbidly obese patient: an ounce of prevention is worth more than a pound of treatment: review article. *Acta anaestesiol scand 52:* 6–19
39. SARAVANAKUMAR K, RAO S G, COOPER G M 2006 Obesity and obstetric anaesthesia: review article. *Anaesthesia 61:* 36–48
40. CHANG A B 2004 Physiologic changes of pregnancy *In:* Chesthut D H *(ed.)* Obstetric anesthesia: principles and practice, 3rd edn. Elsevier Mosby, Philadelphia, 15–36
41. VEILLE J C, HANSON R 1994 Obesity, pregnancy, ans left ventricular functioning during the third trimester. *Am J Obstet Gynaecol 171:* 980–3
42. VASAN R S 2003 Cardiac function and obesity. *Heart 89:* 1127–9
43. TOMODA S, TAMURA T, SUDO Y *et al.* 1996 Effects of obesity on pregnant women: maternal hemodynamic change. *Am J Perinat 13:* 73–8
44. RAMSAY J E, FERRELL W R, CRAWFORD L, WALLACE AM, GREER I A, SATTAR N 2002 Maternal obesity is associated with dysregulation of metabolic, vascular and inflammatory pathways. *Journal of Clinical endocrinology and metabolism 87:* 4231–7
45. KAUFMAN I, BONDY R, BENJAMIN A 2003 Peripartum cardiomyopathy and thromboembolism; anesthetic management and clinical cause of an obese, diabetic patient. *Can J Anaesth 50:* 161–165
46. TSEUDA K, DEBRAND M, ZEOK S S, WRIGHT B D, GRIFFIN W O 1979 Obesity supine death syndrome: reports of two morbidly obese patients. *Anaesth Analg 58:* 345–7
47. CARSON M P, POWRIE R O, ROSENE-MONTELLA K 2002 The effect of obesity and position on heart rate in pregnancy. *J Matern Fetal Neonatal Med 11:* 40–45
48. HESS P E, PRATT S D, LUCA T P *et al.* 2001 Predictors of breakthrough pain during labour epidural analgesia. *Anesth Analg 93:* 414–8
49. MELZACK R, KINCH R, DOBKIN P *et al*. 1984 Severity of labour pain: influence of physical as well as physiologic variables. *Can Med Assoc J 130:* 579–84
50. RANTA P, JOUPPILA P, SPALDING M *et al.* 1995 The effect of maternal obesity on labor and labor pain. *Anaesthesia 50:* 322–6
51. ELBOURNE D, WISEMAN R A 2004 Types of intra-muscular opioids for maternal pain relief in labour (Cochrane review). *In:* The Cochrane Library, Issue 4. John Wiley & Sons, Ltd, Chichester
52. HOWELL C J 2004 Epidural versus non-epidural analgesia for pain relief in labour (cochrane review). *In:* The Cochrane Library, Issue 4. John Wiley & Sons Ltd., Chichester.
53. VON UNGERN-STERNBERG B S, REGLI A, BUCHER E, REBER A, SCHNEIDER M C 2004 The effect of epidural analgesia in labour on maternal respiratory function. *Anaesthesia 59:* 350–3
54. COOPER G M, MCCLURE J H 2008 Anaesthesia chapter from Saving Mothers' Lives; reviewing maternal deaths to make pregnancy safer. *Brit J Anaesth 100:* 17 – 22
55. CLINCKSALES C P, GREENFIELD M L V H, VANARASE M, POLLEY L S 2007 An observational study of the relationship between lumbar epidural space depth and body mass index in Michigan parturients. *Int J Obstet Anesth 16:* 323–7
56. JORDAN
57. BAHAR M, CHANIMOV M, COHEN M L *et al.* 2004 The lateral recumbent head-down position decreases the incidence of epidural venous puncture during catheter insertion in obese parturients. *Can J Anaesth 51:* 577–80
58. HAMZA J, SMIDA H, BENHAMOU D, COHEN S E 1995 Parturient's posture during epidural puncture affects the distance from skin to epidural space. *J Clin Anaesth 7:* 1–4
59. BAHK J H, KIM J H, LEE J S *et al*. 1998 Computed tomography study of the lumbar (L3–L4) epidural depth and its relationship to physical measurements in young adult men. *Reg Anaesth Pain Med 23:* 262–5
60. GRAU T, BARTUSSECK E, CONRADI R, MARTIN E, MOTSCH J 2003 Ultrasound imaging improves learning curves in obstetric epidural anesthesia: a preliminary study. *Can J Anesth 50:* 1047–1050
61. GRAU T, LEOPLOD R W, HORTER J, CONRADI R, MARTIN E, MOTSCH J 2001 The lumbar epidural space in pregnancy: visualisation by ultrasonography. *Brit J Anaesth 86:* 798–804
62. CARVALHO J C A 2008 Ultrasound-facilitated epidurals and spinals in obstetrics. *Anesthesiology Clinics 26:* 145–158
63. WASSON C 2000 Failed epidural in an obese patient-blame it on Pythagoras. *Anaesthesia 56:* 585–610
64. FAHEEM N, SARWAR N. 2002 Sliding of the skin over subcutaneous tissue is another important factor in epidural catheter migration. *Can J Anesrh 49:* 634
65. HESLEHURST N, SIMPSON H, ELLS L J, RANKIN J, WILKINSON J, LANG R, BROWN T J, SUMMERBELL C D 2008 The impact of maternal BMI status on pregnancy outcomes with immediate short-term obstetric resource implications: a meta-analysis. *Obesity reviews 9:* 635–683
66. DIXIT A, GIRLING J C 2008 Obesity and pregnancy. *J Obstet Gynaecol 28:* 14–23
67. HAWKINS J L 2003 Anaesthesia-related maternal mortality. *Clin Obstet Gynecol 46:* 679–87
68. COLLINS J S, LEMMENS H J, BRODSKY J B *et al.* 2004 Laryngoscopy and morbid obesity: a comparison of the sniff and ramped positions. *Obes Surg 14:* 1171–1175
69. MCDONNELL N J, PAECH M 2007 The management of a super morbidly obese parturient delivering twins by caesarean section. *Anaesth Intensiv Care 35:* 979–983
70. PANNI M K, COLUMB M O 2006 Obese parturients have lower epidural local anaesthetic requirements for analgesia in labour. *Brit J Anaesth 96:* 106–110