Obstetrical sonography in obese women: A review

Jan Weichert, Rafael David Hartge

Journal of Clinical Ultrasound

Obstetrical sonography in obese women: A review

Journal:	*Journal of Clinical Ultrasound*
Manuscript ID:	JCU-09-175.R2
Wiley - Manuscript type:	Review
Keywords:	obesity, ultrasound, pregnancy, image quality, body mass index

Obstetrical sonography in obese women: A review

Abstract

The prevalence of overweight and obese women of childbearing age poses a major challenge to obstetric practice, because increased maternal size is associated with a number of pregnancy complications affecting both mother and the developing fetus. Obstetrical ultrasound imaging in pregnant women is adversely affected by obesity with negative impact on the detection rate of congenital anomalies. This review aims to tabulate relevant data dealing this issue and to discuss clinical as well as technical problems accompanied with ultrasound examination of the obese gravida.

Introduction

The World Health Organization (WHO) stated in 2005 that an estimated number of 1.6 billion adults (aged 15 years and older) were overweighted (body mass index, BMI ≥ 25-29.9) and additional 400 million adults were obese (BMI ≥ 30) by definition. By 2015 it is expected that one third of the world's population (2.3 billion) will be overweighted and more than 700 million people (9 %) will match the criteria of obesity[1,2]. The incidence of obesity among pregnant women in the United States ranges from 18.5 to over 38 %[3,4]. These alarming data constitute a significant public health concern not only for obstetrical care providers and is likely to remain so for the forseeable future. A recently published study of more than 13.000 pregnant women clearly demonstrated that obese parturients increasingly use healthcare resources[5].

Obese women, especially those who show abdominal adiposity, are at increased risk of adverse pregnancy outcome including gestational diabetes, hypertension, infectious morbidity, postpartum haemorrhage, fetal macrosomia and stillbirth[6-13]. In a large retrospective study Sebire et al. reviewed the database records of 290.000 pregnancies of the North West Thames Region and highlighted the association of obesity and maternal and fetal pregnancy complications in relation to the degree of obesity[14]. Similar data were previously published by Cnattingius et al. and Nohr et al. who analysed records derived from Scandinavian birth registers[15,16]. Furthermore, maternal obesity has been established as a potential risk factor for congenital malformations even in the absence of gestational diabetes. Several population-based studies have reported the likelihood of structural abnormalities of the offspring of obese mothers, such as neural tube defects, congenital heart defects, anorectal atresia, hydrocephaly, hypospadias and limb reduction defects[17-22].

Although considerable technical advances in obstetrical ultrasonography have been achieved over the last 3 decades, ultrasound imaging of obese patients remains challenging due to adverse effects of obesity on propagating sound waves. This review tabulates the available data on these conditions regarding imaging options in obese pregnant women and clinical importance for the detection of fetal abnormalities to provide a framework for a proper parental counseling.

Quantification of obesity

For the estimation of the degree of fat accumulation, assessment of the body mass index (BMI - calculated as weight in kilograms divided by height in meters squared) has been established as the principal standard method to diagnose overweight and obesity. By definition the World Health Organization (WHO) and the National Institutes of Health (NIH) both define normal weight comprising a BMI of 18.5–24.9, overweight as a BMI of 25–29.9, and obesity as a BMI of 30 or greater. Obesity is further categorized by BMI into Class I (30–34.9), Class II (35–39.9), and Class III or morbid obesity (≥ 40)[2,23]. In pregnancy, BMI is calculated using pre-pregnant weight or the weight measured during the initial visit at the prenatal care provider. Due to the fact that BMI is an indirect measure reflecting the overall fatness without distinguishing between fat and fat-free components it is not as useful in predicting the difficulties encountered with ultrasound visualization and putative obesity-related risks during advancing pregnancy. In the past few years, a number of studies have called attention to the importance of abdominal obesity and its measuring modalities. A strong relation between increase in abdominal girth and cardiovascular disease among adults has recently been demonstrated[24]. Other publications stressed the association of abdominal obesity and poor respiratory function or the increased risk of chronic kidney disease in the general population[25,26]. However, from an obstetric perspective Yamamoto et al. in 2001 were the first who reported a higher waist-to-hip ratio (WHR) prior to 9 gestational weeks to be significantly linked to an increased risk for pre-eclampsia[27]. Similar findings were published by Sattar et al., who found a significant correlation of increased waist-circumference prior to 16 weeks' gestation and pregnancy-induced hypertension (Odds Ratio - OR 1.8, 95% confidence intervall - CI 1.1, 2.9) and pre-eclampsia (OR 2.7, 95% CI 1.1, 6.8)[28]. In a prior series an impact of maternal WHR on elevated fetal growth was established[29]. Both waist-to-hip ratio (WHR) and waist circumference (WC) have been additionally used as proxy measures for body fat distribution when investigating health concerns evolving from (maternal) obesity[30-32]. Bartha and colleagues introduced an ultrasonographic measurement of maternal visceral fat thickness (VFT) during early pregnancy and were able to demonstrate a better correlation of the VFT estimate compared to BMI with metabolic and cardiovascular risk factors such as hyperinsulinaemia, insulin resistance, high blood pressure or dyslipidaemia in pregnancy[33].

Obstetrical ultrasound

Pre-examination counseling of the obese gravida has to point out the likely impact of adiposity on image clarity and diagnostic accuracy[34]. This should be communicated to the patient in a sensitive but appropriate way, because it allows earlier abandonment of a technically difficult study and enables to set realistic expectations regarding the scan[35]. It seems reasonable to claim an informed consent signed by the gravida in advance of the anatomic survey. Furthermore, the first prenatal visit should focus on dating the pregnancy and confirming viability of the fetus. In fact, obese women are more likely to have anovulatory or irregular cycles, so that the utility of determining the last menstrual period for establishing gestational age may be limited[36]. To improve the accuracy of pregnancy-dating during the early first trimester, transvaginal assessment of the crown-rump-length should be performed.

Image clarity

In addition to the arithmetic indices, measuring the distance from skin surface to the intrauterine region of interest (e.g. key fetal structures) allows simple documentation of the fat layer, thereby conveying the grade of image clarity impairment (figure 1)[35]. Excess of abdominal (subcutaneous or intraabdominal) fat results in an increased number of interfaces and consecutively in marked attenuation of the signal. Attenuation encompasses absorption, reflection, reverberation and scatter[37]. The overall visualization of fetal organs with respect to increasing maternal size has been previously addressed by several studies[38,39]. Reduction in successful image generation was most marked for cardiac and cerebrospinal structures as well as the umbilical cord[40,41]. Catanzarite et al. postulated five categories of potential barriers to complete fetal anatomic survey. In addition to maternal body habitus, other confounding variables such as gestational age, fetal spine-up position, resolution/penetration of ultrasound equipment and sonographer skills evidently exert influence on image clarity. The authors also described a strong relation of scanning duration and completion of the anatomical survey in the non-obese population. For each 5-minute time increment up to 30 minutes, the rate of complete morphological assessment improved in their study[42].

The impact of sonographer's experience on the rate of suboptimal visualization in the obese gravida is obvious and was previously reported[43,44]. Rates of completed anatomic surveys rise with advancing gestational age. The preferred timing of midtrimester ultrasound examination of the obese gravida appears to be between 18-20 weeks' gestation in order to achieve maximum efficiency with respect to the potential duration of the scan and need for repeated scans[45,46]. This is slightly different to the findings of Wolfe et al. who stated an optimal overall organ visualization at 21-23 weeks for a mean maternal BMI of 27.3 of the women enrolled in their study[40].

Hendler et al. described an inverse relationship between the severity of maternal obesity and the ability to adequately visualize the fetal heart (37.3 % obese vs. 18.7 % non-obese, $p < 0.001$) and craniospinal structures (42.8 % obese vs. 29.5 % non-obese, $p < 0.001$). They found a degradation in image quality by 10 % for every further step in obesity classification[41]. Wolfe et al reported a 14.5 % reduction in visualization rates in the markedly obese patient[40]. Similar observations were recently published with respect to suboptimal visualization of facial soft tissue (39.1 % obese vs. 19.3 % non-obese, $p < 0.001$) and abdominal wall (2.7 % obese vs. 0 % non-obese, $p < 0.001$)[47]. Series assessing the potential impact of maternal obesity[48] on optimal visualization and completion of anatomic survey[49] are summarized in table 1.

Due to this poor transmission of ultrasound waves in adipose tissue there were several attempts to optimize in image quality. A transvaginal approach is beneficial for assessment of fetal structures close to the lower uterine segment and therefore mainly limited to ultrasound examinations throughout the first trimester. Measurement of fetal nuchal translucency between 11-13+6 weeks most often performed transabdominally as this allows a wider range of scanning angles, may substantially be hampered by increasing maternal size[50,51]. In the obese patient therefore, a transvaginal assessment to facilitate a better resolution of the skin line, perispinal tissue or amniotic sheet as separate structures, should be considered[35]. This approach enables proper assessment of fetal limbs and extremities and is feasible to perform early fetal echocardiography as well. Recently, it has been postulated that most of the anomalies detectable during standard 18-week scan can be seen at 12 to 13 weeks with appropriate imaging even in obese women[52]. However, this has been challenged by other authors, which concordantly emphasize that a number of anomalies are not amenable to first trimester detection (regardless recent promising findings, such as intracranial translucency)[53-55]. Further studies are needed to systematically investigate the diagnostic capability of a first trimester anatomic sonogram and to establish reliable standards taking into account increased maternal size and limited acoustic window[56].

Beyond 14-15 weeks' gestation ultrasonic scans are preferentially performed by transabdominal imaging, thereby utilizing appropriate anatomic regions (e. g. lower transverse abdominal crease). Morbidly obese women often have an abnormally lowered, ptotic apron. Elevating and retracting the fatty apron (panniculus) towards the patient's head enables optimized access to the fetal areas of interest by placing the probe near the arcus tendineus superior to the pubis[35,36]. This is of particular importance with regard to diagnostic procedures such as chorionic villous sampling (CVS), amniocentesis (AC) or cordocentesis (CS). In later gestation it may also be helpful to get access to the gravid uterus from a subcostal approach with the women in a lateral position which shifts the abdomen towards the examination table. In general, the higher the degree of maternal obesity, the higher will be the pressure exerted on the abdominal wall to reduce the depth of insonation thereby trying to achieve an acceptable acoustic window.

Alternative approaches

In obese patients, in whom a successful fetal anatomic survey has apparently failed, the maternal umbilicus, the thinnest section of the abdominal wall potentially affords improved image resolution. A previous series by Davidoff et al. revealed an optimized image clarity in most of the 68 included women, but the relatively large curvilinear transducer may have limited the ultrasonic sector view[37]. Based on these findings Rosenberg et al. and later McCoy and co-workers established a transumbilical use of the endovaginal probe in the obese gravida[57,58]. Placement of the transvaginal transducer in the umbilicus resulted in improved resolution and satisfactory fetal cardiac survey in 95 % and 87 % respectively. The authors resumed, that transumbilical use of the transvaginal probe is a beneficial, well-tolerated technique, which clearly improves gray-scale imaging. In addition, color and pulsed Doppler interrogation of fetal vessels may also be optimized. Similar observations were made by Paladini, who assumed that improved cardiac visualization (with the fetus in breech presentation) may be achieved when the scan is performed with filled maternal bladder pushing the uterus cephalad, allowing the sonographer to explore the heart via the periumbilical region[59].

On the contrary, a transrectal approach has been undertaken in those patients undergoing assisted reproduction where difficult embryo transfer was anticipated and transabdominal ultrasound guidance was hampered by increased BMI[60]. However, these procedures have not been regularly implemented in routine obstetrical ultrasound practice.

Tissue harmonic imaging

Tissue harmonic imaging (THI), nowadays commonly implemented into commercially available ultrasound systems, constitutes a real-time imaging technique that relies on the detection of so-called harmonics created by non-linear propagation of the fundamental ultrasonic beam through tissue[61]. The generation of harmonics by tissue itself increases with depth up to a point where attenuation causes them to decrease. Modern ultrasound transducers are able to isolate the second harmonic frequency in the detected echo, enabling image rendering of harmonic reflection. This relatively novel method of echo processing is useful while scanning technically difficult patients to improve image quality and confidence of diagnosis[62,63]. Treadwell and colleagues found that tissue harmonic imaging was able to improve resolution of at least one fetal structure in more than 50 % of patients enrolled in their study[64]. Whether the use of THI may result in improved detection of fetal abnormalities this study was not able to confirm, because the included patients had normal fetuses. Nevertheless, the advantages of THI in fetal cardiac examination were recently addressed by three studies[65-67]. The differences in image clarity obtained by using THI in a morbidly obese gravida compared to inconclusive images depicted without technical adjuncts are illustrated in figure 2. Other technical advances facilitating improved ultrasound assessment of fetal morphology in obese mothers include pre- and postprocessing techniques such as compound imaging, speckle reduction filters and multi-Hertz transducer technology.

Other imaging modalities

In recent years, three- and four-dimensional ultrasound applications have become clinically valuable in obstetrics as well as in gynecology. Comparative studies addressing the beneficial value of 3D ultrasound are contradictory. In a review of 11 studies comparing conventional 2D imaging and 3D ultrasound for the diagnosis of facial anomalies, seven studies reported additional information using 3D while four found similar findings achieved by these two modalities[68]. Many of the studies on the accuracy of 3D ultrasonography in prenatal diagnosis are biased by the availability of information from the initial 2D scan. Nevertheless, a previous study suggests three-dimensional ultrasound as being capable of improving visualization of fetal anatomy even in fetuses in anterior spine position[69]. In spite of the apparent advantages of 3D obstetrical imaging, non-favourable scanning conditions, such as oligohydramnios, severe obesity and the absence of tissue borderlines, cause the same problems in 3D as in 2D scanning so far.

Although ultrasound is the primary imaging modality for the evaluation of the fetus, because of proven utility, relatively low cost and widespread availability, fetal magnetic resonance imaging (MRI) has grown in popularity over the past two decades as a complementary tool for antenatal assessment of fetal abnormalities[70,71]. MRI has been useful in confirming abnormalities seen on ultrasound scan or determining the underlying cause of nonspecific sonographic anomalies and may add incremental information that might have influence on prognosis or management at birth[72-74]. Faster scanning techniques allow studies to be performed without sedation in the second and third trimester with minimal motion artefacts[75]. Moreover, MRI is not hampered by maternal obesity, fetal position, overlying bones or oligohydramnios, so that fetal MRI has emerged as a clinically valuable diagnostic supplement to ultrasound in case of inconclusive findings or degraded image.

Detection of malformations

Infants of obese parturients are reported to be at elevated risk for congenital malformations (11.1 %) compared with those of mothers of average prepregnancy weight (7.9 %). Queisser-Luft et al. reported significant odds for major malformations (OR 1.3, 95 % CI 1.0-1.7)[76]. Similar findings were recently published by two meta-analyses in which the authors systematically assessed the attributable risk for anomalies in the offspring of obese mothers[21,22]. Based on these pooled data, obese women are at significantly increased odds of a pregnancy affected by a neural tube defect (OR 1.87, 95 % CI 1.62-2.15). The statistically strongest correlation was found for spina bifida (OR 2.24, 95 % CI 1.86-2.69). Moreover, an association of maternal adiposity and cardiovascular anomalies (OR 1.30, 95 % CI 1.12-1.51) with significant odds for septal anomalies (OR 1.20, 95 % CI 1.09-1.31); orofacial clefts, e.g. cleft palate (OR 1.23, 95 % CI 1.03-1.47) or cleft lip and palate (OR 1.20, 95 % CI 1.03-1.40); anorectal atresia (OR 1.48, 95 % CI 1.12-1.97); hydrocephaly (OR 1.68, 95 % CI 1.19-2.36) and limb reduction (OR 1.34, 95 % CI 1.03-1.73) has been described. On the other hand, the relative risk for gastroschisis among obese mothers was significantly lower (OR 0.17, 95 % CI 0.10-0.30) compared with women of recommended BMI[77]. An opposite effect has been found for offspring with omphalocele, with increased odds (OR 1.63, 95 % CI 1.01-2.47) when the mother was classified as obese. These data emphasize the superior importance of detailed sonographic examination of fetuses of obese pregnant women[78,79].

According to the findings of the FaSTER (First and Second Trimester Evaluation of Risk) trial in an unselected obstetric population, it has been stated that maternal obesity significantly decreased the likelihood of sonographic detection of common anomalies (adjusted OR 0.7, 95 % CI 0.6-0.9)[80]. In a recent paper Dashe et al. assessed the impact of maternal body habitus on the detection of major structural abnormalities during second-trimester standard and targeted sonographic scan[81]. Detection of anomalous fetuses with standard ultrasound decreased substantially from 66 % in women having a normal BMI to only 25 % in morbidly obese women. In high risk pregnancies receiving targeted scans detection of malformations ranged from 83 % (lean patients) to 67 % (class III obesity). Within the targeted group the detection rate was significantly lower among women with pre-gestational diabetes than in women with other high-risk indications. These data are consistent with previous findings. In order to facilitate proper counseling, the residual risk of an undetected anomaly was calculated to be 0.4 % among women of normal BMI compared to 1.0 % in obese gravida ($p < 0.001$). However the authors did not address the issue whether follow up ultrasonography could have improved anomaly detection in obese women. Hendler et al. noted that 64 % of their included study population, who were scheduled for an additional fetal heart examination due to the initial inability to complete morphology assessment of the fetus, were obese[82]. The rate of persistent suboptimal visualization of cardiac structures even after recalled exam increased in a BMI-dependent manner from 1.5 % (non-obese) up to 20 % in morbidly obese women ($p < 0.001$). In conclusion the authors stated that the rate of initially inadaequate image clarity could be reduced by at least 80 % by repeating sonographic scans, thereby improving the prenatal diagnosis of congenital heart defects in an obstetric setting. In accordance to these observations, which are similar to previous reports, maternal obesity limits the likelihood of adequate ultrasound visualization even when advanced ultrasound systems for assessing fetal structures are used[83].

Summary

Given the continuing rise in prevalence of overall obesity, and in particular maternal obesity with impact on ultrasound imaging of fetal anatomy, obstetricians have to face new challenges in the antenatal and peripartal management of complications during pregnancy, labor, delivery and beyond. Obtaining adequate sonographic images in obese patients is of particular concern because of the increased rate of congenital anomalies. Considering the findings of sensitivity studies on mixed populations or obese gravid patients, it is reasonable that the anomaly scan at 20 weeks' gestation should be left to experienced sonographers. Moreover, obese mothers will benefit from repeated ultrasonic scans.

The main determinants of signal intensity and consecutive image clarity remain the depth of the part to be depicted as well as the specific tissue characteristics. Thus, future additions to the imaging efforts should include optimized signal processing, further advances in transducer technology or the adjunctive use of complementary image modalities such as fetal MRI to resolve associated shortcomings of obesity in obstetric practice.

An appropriate counseling prior to the commencement of the sonographic exam of overweight and obese patients allowing for the limitations of the study is advisable. The greater potential for delayed or missed diagnoses in obese patients constitutes one of the major medicolegal issues in obstetric care.

References

1. World Health Organization. Obesity and overweight. http://www.who.int/mediacentre/factsheets/fs311/en/index.html

2. World Health Organization. Obesity: preventing and managing a global epidemic. World Health Organ Tech Rep Ser 2000;894:1

3. Centers of Disease Control and Prevention Obesity and overweight. http://www.surgeongeneral.gov/topics/obesity/calltoaction/fact_glance.html

4. Reece EA. Perspectives on obesity, pregnancy and birth outcomes in the United States: the scope of the problem. Am J Obstet Gynecol 2008;198:23.

5. Chu SY, Bachman DJ, Callaghan WM, et al. Association between obesity during pregnancy and increased use of health care. N Engl J Med 2008;358:1444.

6. Committee on the impact of pregnancy weight on maternal and child health, National Research Council. Influence of pregnancy weight on maternal and child health: workshop report. Washington (DC): The National Academies Press; 2007.

7. Stotland NE. Obesity and pregnancy. BMJ 2008;338:107.

8. Chu SY, Kim SY, Lau J, et al. Maternal obesity and risk of stillbirth: a metaanalysis. Am J Obstet Gynecol 2007;197:223.

9. Phillips J, Henderson J. Delivery and postpartum concerns in the obese gravida. OBG Management 2009;21:51.

10. Catalano PM. Management of obesity in pregnancy. Obstet Gynecol 2007;109:419.

11. Cedergren MI. Maternal morbid obesity and the risk of adverse pregnancy outcome. Obstet Gynecol 2004;103:219.

12. Andreasen KR, Andersen ML, Schantz AL. Obesity and pregnancy. Acta Obstet Gynecol Scand 2004;83:1022.

13. Obesity in pregnancy. ACOG Committee Opinion No. 315. American College of Obstetricians and Gynecologists. Obstet Gynecol 2005;106:671.

14. Sebire NJ, Jolly M, Harris JP, et al. Maternal obesity and pregnancy outcome: a study of 287.213 pregnancies in London. Int J Obes Relat Metab Disord 2001;25:1175.

15. Cnattingius S, Bergström R, Lipworth L, et al. Prepregnancy weight and the risk of adverse pregnancy outcomes. N Engl J Med 1998;338:147.

16. Nohr EA, Bech BH, Vaeth M, et al. Obesity, gestational weight gain and preterm birth: a study within the Danish National Birth Cohort. Paediatr Perinat Epidemiol 2007;21:5.

17. Cedergren MI, Källén BA. Maternal obesity and infant heart defects. Obes Res 2003;11:1065.

18. Waller DK, Shaw GM, Rasmussen SA, et al. National Birth Defects Prevention Study. Prepregnancy obesity as a risk factor for structural birth defects. Arch Pediatr Adolesc Med 2007;161:745.

19. Watkins ML, Rasmussen SA, Honein MA, et al. Maternal obesity and risk for birth defects. Pediatrics 2003;111:1152.

20. Queisser-Luft A, Kieninger-Baum D, Menger H, et al. Does maternal obesity increase the risk of fetal abnormalities? Analysis of 20.248 newborn infants of the Mainz Birth Register for detecting congenital abnormalities. Ultraschall in Med 1998;19:40.

21. Stothard KJ, Tennant PW, Bell R, et al. Maternal overweight and obesity and the risk of congenital anomalies: a systematic review and meta-analysis. JAMA 2009;301:636.

22. Rasmussen SA, Chu SY, Kim SY, et al. Maternal obesity and risk of neural tube defects: a metaanalysis. Am J Obstet Gynecol 2008;198:611.

23. National Institutes of Health. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. Bethesda 1998, NIH publication No. 98-4083, http://www.nhlbi.nih.gov/guidelines/obesity/ob_gdlns.pdf

24. Bergman RN, Kim SP, Hsu IR, et al. Abdominal obesity: role in the pathophysiology of metabolic disease and cardiovascular risk. Am J Med 2007;120:S3.

25. Noori N, Hosseinpanah F, Nasiri AA, et al. Comparison of overall obesity and abdominal adiposity in predicting chronic kidney disease incidence among adults. J Ren Nutr 2009;19:228.

26. Ochs-Balcom HM, Grant BJ, Muti P, et al. Pulmonary function and abdominal adiposity in the general population. Chest 2006;129:853.

27. Yamamoto S, Douchi T, Yoshimitsu N, et al. Waist to hip circumference ratio as a significant predictor of preeclampsia, irrespective of overall adiposity. J Obstet Gynaecol Res 2001;27:27.

28. Sattar N, Clark P, Holmes A, et al. Antenatal waist circumference and hypertension risk. Obstet Gynecol 2001;97;268.

29. Brown JE, Potter JD, Jacobs DR Jr, et al. Maternal waist-to-hip ratio as a predictor of newborn size: Results of the Diana Project. Epidemiology 1996;7:62.

30. Neovius M, Linné Y, Rossner S. BMI, waist-circumference and waist-hip-ratio as diagnostic tests for fatness in adolescents. Int J Obes 2005;29:163.

31. Molarius A, Seidell JC, Sans S, et al. Waist and hip circumferences, and waist-hip ratio in 19 populations of the WHO MONICA Project. Int J Obes Relat Metab Disord 1999;23:116.

32. Welborn TA, Dhaliwal SS. Preferred clinical measures of central obesity for predicting mortality. Eur J Clin Nutr 2007;61:1373.

33. Bartha JL, Marín-Segura P, González-González NL, et al. Ultrasound evaluation of visceral fat and metabolic risk factors during early pregnancy. Obesity 2007;15:2233.

34. Dashe JS, McIntire DD, Twickler DM. Maternal obesity limits the ultrasound evaluation of fetal anatomy. J Ultrasound Med 2009;28:1025.

35. Siva S, McLennan A. The impact of obesity on obstetrical and gynaecological ultrasound. OGMagazine 2008;10:26.

36. Phillips J, Henderson J. For the obese gravida, try strong counselling and close follow-up. OBG Management 2009;21:42.

37. Davidoff A, Reuter K, Karellas A, et al. Maternal umbilicus: ultrasound window to the gravid uterus. J Clin Ultrasound 1994;22:263.

38. Zador IE, Bottoms SF, Tse GM, et al. Nomograms for ultrasound visualization of fetal organs. J Ultrasound Med 1988;7:197.

39. Wolfe HM, Zador IE, Bottoms SF, et al. Trends in sonographic fetal organ visualization. Ultrasound Obstet Gynecol 1993;3:97.

40. Wolfe HM, Sokol RJ, Martier SM, et al. Maternal obesity: a potential source of error in sonographic prenatal diagnosis. Obstet Gynecol 1990;76:339.

41. Hendler I, Blackwell SC, Bujold E, et al. The impact of maternal obesity on midtrimester sonographic visualization of fetal cardiac and craniospinal structures. Int J Obes Relat Metab Disord 2004;28:1607.

42. Catanzarite V, Delaney K, Wolfe S, et al. Targeted mid-trimester ultrasound examination: how does fetal anatomic visualization depend upon the duration of the scan? Ultrasound Obstet Gynecol 2005;26:521.

43. Hendler I, Blackwell SC, Treadwell MC, et al. Does sonographer's experience impact the rate of suboptimal visualization in the obese gravida [abstract]? Am J Obstet Gynecol 2004;189:S239.

44. Troya-Nutt M, Hendler I, Blackwell SC, et al. The accuracy of prenatal diagnosis of fetal heart anomalies in the obese gravida [abstract]. Am J Obstet Gynecol 2004;189:S239.

45. Lantz ME, Chisholm CA. The preferred timing of second-trimester obstetric sonography based on maternal body mass index. J Ultrasound Med 2004;23:1019.

46. Schwärzler P, Senat MV, Holden D, et al. Feasibility of the second-trimester fetal ultrasound examination in an unselected population at 18, 20 or 22 weeks of pregnancy: a randomized trial. Ultrasound Obstet Gynecol 1999;14:92.

47. Khoury FR, Ehrenberg HM, Mercer BM. The impact of maternal obesity on satisfactory detailed anatomic ultrasound image acquisition. J Matern Fetal Neonatal Med 2009;22:337.

48. Wong SF, Chan FY, Cincotta RB, et al. Routine ultrasound screening in diabetic pregnancies. Ultrasound Obstet Gynecol 2002;19:171.

49. Maxwell C, Dunn E, Tomlinson G, et al. How does maternal obesity affect the routine fetal anatomic ultrasound? J Matern Fetal Neonatal Med 2010; (Epub ahead of print).

50. Gandhi M, Fox N, Pozharny Y, et al. The effect of increased body mass index on the 1st trimester ultrasound for aneuploidy risk assessment [abstract]. Am J Obstet Gynecol 2008;199:S130.

51. Thornburg LL, Miles K, Ho M, et al. Fetal anatomic evaluation in the overweight and obese gravida. Ultrasound Obstet Gynecol 2009a;33:670.

52. Hershey D. Effect of maternal obesity on the ultrasound detection of anomalous fetuses. Obstet Gynecol 2009;114:694.

53. Thornburg LL, Mulconry M, Post A, et al. Fetal nuchal translucency thickness evaluation in the overweight and obese gravida. Ultrasound Obstet Gynecol 2009b;33:665.

54. Ebrashy A, El Kateb A, Momtaz M, et al. 13-14-week fetal anatomy scan: a 5-year prospective study. Ultrasound Obstet Gynecol 2010;35:292.

55. Chaoui R, Benoit B, Mitkowska-Wozniak H, et al. Assessment of intracranial translucency (IT) in the detection of spina bifida at the 11-13-week scan. Ultrasound Obstet Gynecol 2009;34:249.

56. Timor-Tritsch IE, Fuchs KM, Monteagudo A, et al. Performing a fetal anatomy scan at the time of first-trimester screening. Obstet Gynecol 2009;113:402.

57. Rosenberg JC, Guzman ER, Vintzileos AM, et al. Transumbilical placement of the vaginal probe in obese pregnant women. Obstet Gynecol 1995;85:132.

58. McCoy MC, Watson WJ, Chescheir NC, et al. Transumbilical use of the endovaginal probe. Am J Perinatol 1996;13:395.

59. Paladini D. Sonography in obese and overweight pregnant women: clinical, medicolegal and technical issues. Ultrasound Obstet Gynecol 2009;33:720.

60. Sohan K, Woodward B, Ramsewak SS. Successful use of transrectal ultrasound for embryo transfer in obese women. J Obstet Gynaecol 2004;24:839.

61. Hedrick WR, Metzger L. Tissue Harmonic Imaging: A Review. J Diagn Med Sonogr 2005;21:183.

62. Tranquart F, Grenier N, Eder V, et al. Clinical use of ultrasound tissue harmonic imaging. Ultrasound Med Biol 1999;25:889.

63. Choudhry S, Gorman B, Charboneau JW, et al. Comparison of tissue harmonic imaging with conventional US in abdominal disease. Radiographics 2000;20:1127.

64. Treadwell MC, Seubert DE, Zador I, et al. Benefits associated with harmonic tissue imaging in the obstetric patient. Am J Obstet Gynecol 2000;182:1620.

65. Kovalchin JP, Lewin MB, Bezold LI, et al. Harmonic imaging in fetal echocardiography. J Am Soc Echocardiogr 2001;14:1025.

66. Zhao BW, Tang FG, Shou JD, et al. Comparison study of harmonic imaging (HI) and fundamental imaging (FI) in fetal echocardiography. J Zhejiang Univ Sci 2003;4:374.

67. Paladini D, Vassallo M, Tartaglione A, et al. The role of tissue harmonic imaging in fetal echocardiography. Ultrasound Obstet Gynecol 2004;23:159.

68. Lee YM, Simpson LL. Major fetal structural malformations: the role of new imaging modalities. Am J Med Genet C Semin Med Genet 2007;145C:33.

69. Timor-Tritsch IE, Monteagudo A. Three and four-dimensional ultrasound in obstetrics and gynecology. Curr Opin Obstet Gynecol 2007;19:157.

70. Gonçalves LF, Nien JK, Espinoza J, et al. What does 2-dimensional imaging add to 3- and 4-dimensional obstetric ultrasonography? J Ultrasound Med 2006;25:691.

71. Wang PH, Chen GD, Lin LY. Imaging comparison of basic cardiac views between two- and three-dimensional ultrasound in normal fetuses in anterior spine positions. Int J Cardiovasc Imaging 2002;18:17.

72. Behairy NH, Talaat S, Saleem SN, et al. Magnetic resonance imaging in fetal anomalies: What does it add to 3D and 4D US? Eur J Radiol 2010;74:250.

73. Frates MC, Kumar AJ, Benson CB, et al. Fetal anomalies: comparison of MR imaging and US for diagnosis. Radiology 2004;232:398.

74. Whitby E, Paley MN, Davies N, et al. Ultrafast magnetic resonance imaging of central nervous system abnormalities in utero in the second and third trimester of pregnancy: comparison with ultrasound. BJOG 2001;108:519.

75. Hubbard AM. Ultrafast fetal MRI and prenatal diagnosis. Semin Pediatr Surg 2003;12:143.

76. Queisser-Luft A, Stolz G, Wiesel A, et al. Malformations in newborn: results based on 30.940 infants and fetuses from the Mainz congenital birth defect monitoring system (1990-1998). Arch Gynecol Obstet 2002;266:163.

77. Siega-Riz AM, Herring AH, Olshan AF, et al. National Birth Defects Prevention Study. The joint effects of maternal prepregnancy body mass index and age on the risk of gastroschisis. Paediatr Perinat Epidemiol 2009;23:51.

78. Wong SF, Chan FY, Cincotta RB, et al. Factors influencing the prenatal detection of structural congenital heart diseases. Ultrasound Obstet Gynecol 2003;21:19.

79. Ehrenberg HM, Fischer RL, Hediger ML, et al. Are maternal and sonographic factors associated with the detection of a fetal echogenic cardiac focus? J Ultrasound Med 2001;20:1047.

80. Aagaard-Tillery KM, Flint Porter T, Malone FD, et al. Influence of maternal BMI on genetic sonography in the FaSTER trial. Prenat Diagn 2010;30:14.

81. Dashe JS, McIntire DD, Twickler DM. Effect of maternal obesity on the ultrasound detection of anomalous fetuses. Obstet Gynecol 2009;113:1001.

82. Hendler I, Blackwell SC, Bujold E, et al. Suboptimal second-trimester ultrasonographic visualization of the fetal heart in obese women: should we repeat the examination? J Ultrasound Med 2005;24:1205.

83. Hendler I, Blackwell SC, Treadwell MC, et al. Does advanced ultrasound equipment improve the adequacy of ultrasound visualization of fetal cardiac structures in the obese gravid woman? Am J Obstet Gynecol 2004;190:1616.

TABLE 1. Published studies investigating the deleterious impact of maternal obesity on optimal visualization and completion of anatomic survey according to BMI classification. SUV, suboptimal ultrasound visualization.

Reference	**No. of cases**	**Gestational age**	**Target value**	**Non-obese**	**Obese**			**p-value**
				≤ 29.9 kg/m²	30-34.9 kg/m²	35-39.9 kg/m²	≥ 40 kg/m²	
	(n)	(weeks)		(%)	Class I (%)	Class II (%)	Class III (%)	
Wolfe et al.[40]	1.622	15-40	SUV (overall)	12.9		———— 25.5 ————		0.00001
Wong et al.[48]	130	16	SUV (overall)	37		———— 65.4 ————		< 0.0001
Hendler et al.[41]	11.019	14.0-23.9	SUV (heart)	18.7	29.6	39	49.6	< 0.0001
Lantz et al.[45]	1.444	18.0-19.6	Completed Survey	85.7		———— 67.9 ————		n/a
Ghandi et al.[50]	435	11.0-13.9	SUV (nasal bone)	3		———— 11.5 ————		0.002
Thornburg et al. [51]	2.508	11.0-13.9	Completed Survey	77.6	72	61	49	< 0.00001
Khoury et al.[47]	814	18.0-24.9	Completed Survey	51.3		———— 35.4 ————		0.0005
Dashe et al.[34]	10.112	18.0-23.9	Completed Survey	70	57	41	30	< 0.001
Maxwell et al.[49]	100	17.5-20.5	Completed Survey	97.5		———— 74 ————		< 0.001
Total	28.184	11.0-40	-	-	-	-	-	-

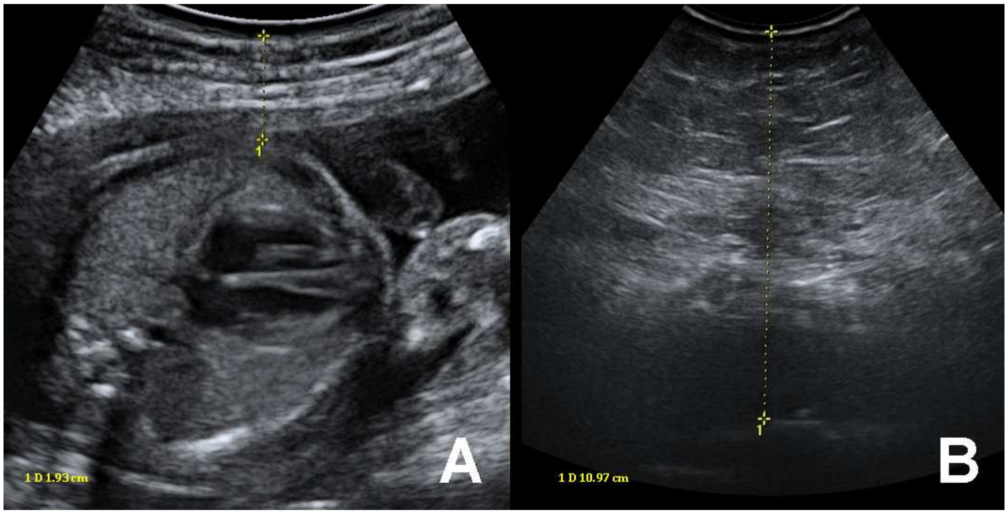

FIGURE 1. Documentation of the depth of insonation in a lean (BMI 21.8 kg/m2) pregnant woman (A), compared to a gravida with morbid obesity (BMI > 40 kg/m2) at 22 weeks of gestation.
180x91mm (150 x 150 DPI)

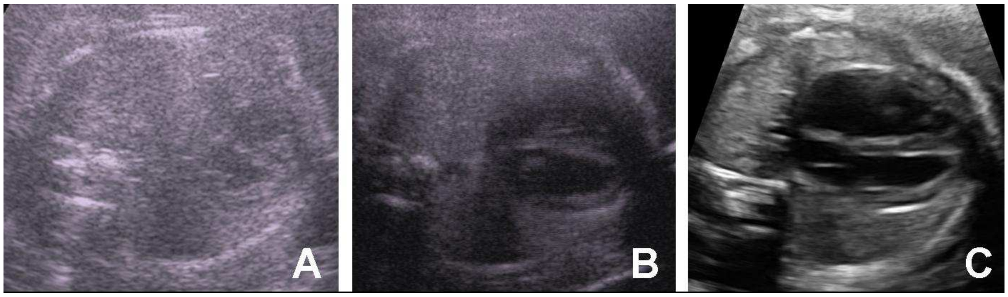

FIGURE 2: Comparison of the lateral 4-chamber view of the fetal heart in a morbidly obese mother (BMI > 40 kg/m2)
obtained with fundamental frequency ultrasound (A), with additional tissue harmonic imaging (B) and corresponding imaging by use of technical tools (tissue harmonic imaging, compound imaging, speckle reduction filter) usually implemented in high-end ultrasound equipment (C).

237x68mm (150 x 150 DPI)

Obstetrical sonography in obese women: A review

Abstract

The prevalence of overweight and obese women of childbearing age poses a major challenge to obstetric practice, because increased maternal size is associated with a number of pregnancy complications affecting both mother and the developing fetus. Obstetrical ultrasound imaging in pregnant women is adversely affected by obesity with negative impact on the detection rate of congenital anomalies. This review aims to tabulate relevant data dealing this issue and to discuss clinical as well as technical problems accompanied with ultrasound examination of the obese gravida.

Introduction

The World Health Organization (WHO) stated in 2005 that an estimated number of 1.6 billion adults (aged 15 years and older) were overweighted (body mass index, BMI ≥ 25-29.9) and additional 400 million adults were obese (BMI ≥ 30) by definition. By 2015 it is expected that one third of the world's population (2.3 billion) will be overweighted and more than 700 million people (9 %) will match the criteria of obesity[1,2]. The incidence of obesity among pregnant women in the United States ranges from 18.5 to over 38 %[3,4]. These alarming data constitute a significant public health concern not only for obstetrical care providers and is likely to remain so for the forseeable future. A recently published study of more than 13.000 pregnant women clearly demonstrated that obese parturients increasingly use healthcare resources[5].

Obese women, especially those who show abdominal adiposity, are at increased risk of adverse pregnancy outcome including gestational diabetes, hypertension, infectious morbidity, postpartum haemorrhage, fetal macrosomia and stillbirth[6-13]. In a large retrospective study Sebire et al. reviewed the database records of 290.000 pregnancies of the North West Thames Region and highlighted the association of obesity and maternal and fetal pregnancy complications in relation to the degree of obesity[14]. Similar data were previously published by Cnattingius et al. and Nohr et al. who analysed records derived from Scandinavian birth registers[15,16]. Furthermore, maternal obesity has been established as a potential risk factor for congenital malformations even in the absence of gestational diabetes. Several population-based studies have reported the likelihood of structural abnormalities of the offspring of obese mothers, such as neural tube defects, congenital heart defects, anorectal atresia, hydrocephaly, hypospadias and limb reduction defects[17-22].

Although considerable technical advances in obstetrical ultrasonography have been achieved over the last 3 decades, ultrasound imaging of obese patients remains challenging due to adverse effects of obesity on propagating sound waves. This review tabulates the available data on these conditions regarding imaging options in obese pregnant women and clinical importance for the detection of fetal abnormalities to provide a framework for a proper parental counseling.

Quantification of obesity

For the estimation of the degree of fat accumulation, assessment of the body mass index (BMI - calculated as weight in kilograms divided by height in meters squared) has been established as the principal standard method to diagnose overweight and obesity. By definition the World Health Organization (WHO) and the National Institutes of Health (NIH) both define normal weight comprising a BMI of 18.5–24.9, overweight as a BMI of 25–29.9, and obesity as a BMI of 30 or greater. Obesity is further categorized by BMI into Class I (30–34.9), Class II (35–39.9), and Class III or morbid obesity (≥ 40)[2,23]. In pregnancy, BMI is calculated using pre-pregnant weight or the weight measured during the initial visit at the prenatal care provider. Due to the fact that BMI is an indirect measure reflecting the overall fatness without distinguishing between fat and fat-free components it is not as useful in predicting the difficulties encountered with ultrasound visualization and putative obesity-related risks during advancing pregnancy. In the past few years, a number of studies have called attention to the importance of abdominal obesity and its measuring modalities. A strong relation between increase in abdominal girth and cardiovascular disease among adults has recently been demonstrated[24]. Other publications stressed the association of abdominal obesity and poor respiratory function or the increased risk of chronic kidney disease in the general population[25,26]. However, from an obstetric perspective Yamamoto et al. in 2001 were the first who reported a higher waist-to-hip ratio (WHR) prior to 9 gestational weeks to be significantly linked to an increased risk for pre-eclampsia[27]. Similar findings were published by Sattar et al., who found a significant correlation of increased waist-circumference prior to 16 weeks' gestation and pregnancy-induced hypertension (Odds Ratio - OR 1.8, 95% confidence intervall - CI 1.1, 2.9) and pre-eclampsia (OR 2.7, 95% CI 1.1, 6.8)[28]. In a prior series an impact of maternal WHR on elevated fetal growth was established[29]. Both waist-to-hip ratio (WHR) and waist circumference (WC) have been additionally used as proxy measures for body fat distribution when investigating health concerns evolving from (maternal) obesity[30-32]. Bartha and colleagues introduced an ultrasonographic measurement of maternal visceral fat thickness (VFT) during early pregnancy and were able to demonstrate a better correlation of the VFT estimate compared to BMI with metabolic and cardiovascular risk factors such as hyperinsulinaemia, insulin resistance, high blood pressure or dyslipidaemia in pregnancy[33].

Obstetrical ultrasound

Pre-examination counseling of the obese gravida has to point out the likely impact of adiposity on image clarity and diagnostic accuracy[34]. This should be communicated to the patient in a sensitive but appropriate way, because it allows earlier abandonment of a technically difficult study and enables to set realistic expectations regarding the scan[35]. It seems reasonable to claim an informed consent signed by the gravida in advance of the anatomic survey. Furthermore, the first prenatal visit should focus on dating the pregnancy and confirming viability of the fetus. In fact, obese women are more likely to have anovulatory or irregular cycles, so that the utility of determining the last menstrual period for establishing gestational age may be limited[36]. To improve the accuracy of pregnancy-dating during the early first trimester, transvaginal assessment of the crown-rump-length should be performed.

Image clarity

In addition to the arithmetic indices, measuring the distance from skin surface to the intrauterine region of interest (e.g. key fetal structures) allows simple documentation of the fat layer, thereby conveying the grade of image clarity impairment (figure 1)[35]. Excess of abdominal (subcutaneous or intraabdominal) fat results in an increased number of interfaces and consecutively in marked attenuation of the signal. Attenuation encompasses absorption, reflection, reverberation and scatter[37]. The overall visualization of fetal organs with respect to increasing maternal size has been previously addressed by several studies[38,39]. Reduction in successful image generation was most marked for cardiac and cerebrospinal structures as well as the umbilical cord[40,41]. Catanzarite et al. postulated five categories of potential barriers to complete fetal anatomic survey. In addition to maternal body habitus, other confounding variables such as gestational age, fetal spine-up position, resolution/penetration of ultrasound equipment and sonographer skills evidently exert influence on image clarity. The authors also described a strong relation of scanning duration and completion of the anatomical survey in the non-obese population. For each 5-minute time increment up to 30 minutes, the rate of complete morphological assessment improved in their study[42].

The impact of sonographer's experience on the rate of suboptimal visualization in the obese gravida is obvious and was previously reported[43,44]. Rates of completed anatomic surveys rise with advancing gestational age. The preferred timing of midtrimester ultrasound examination of the obese gravida appears to be between 18-20 weeks' gestation in order to achieve maximum efficiency with respect to the potential duration of the scan and need for repeated scans[45,46]. This is slightly different to the findings of Wolfe et al. who stated an optimal overall organ visualization at 21-23 weeks for a mean maternal BMI of 27.3 of the women enrolled in their study[40].

Hendler et al. described an inverse relationship between the severity of maternal obesity and the ability to adequately visualize the fetal heart (37.3 % obese vs. 18.7 % non-obese, $p < 0.001$) and craniospinal structures (42.8 % obese vs. 29.5 % non-obese, $p < 0.001$). They found a degradation in image quality by 10 % for every further step in obesity classification[41]. Wolfe et al reported a 14.5 % reduction in visualization rates in the markedly obese patient[40]. Similar observations were recently published with respect to suboptimal visualization of facial soft tissue (39.1 % obese vs. 19.3 % non-obese, $p < 0.001$) and abdominal wall (2.7 % obese vs. 0 % non-obese, $p < 0.001$)[47]. Series assessing the potential impact of maternal obesity[48] on optimal visualization and completion of anatomic survey[49] are summarized in table 1.

Due to this poor transmission of ultrasound waves in adipose tissue there were several attempts to optimize in image quality. A transvaginal approach is beneficial for assessment of fetal structures close to the lower uterine segment and therefore mainly limited to ultrasound examinations throughout the first trimester. Measurement of fetal nuchal translucency between 11-13+6 weeks most often performed transabdominally as this allows a wider range of scanning angles, may substantially be hampered by increasing maternal size[50,51]. In the obese patient therefore, a transvaginal assessment to facilitate a better resolution of the skin line, perispinal tissue or amniotic sheet as separate structures, should be considered[35]. This approach enables proper assessment of fetal limbs and extremities and is feasible to perform early fetal echocardiography as well. Recently, it has been postulated that most of the anomalies detectable during standard 18-week scan can be seen at 12 to 13 weeks with appropriate imaging even in obese women[52]. However, this has been challenged by other authors, which concordantly emphasize that a number of anomalies are not amenable to first trimester detection (regardless recent promising findings, such as intracranial translucency)[53-55]. Further studies are needed to systematically investigate the diagnostic capability of a first trimester anatomic sonogram and to establish reliable standards taking into account increased maternal size and limited acoustic window[56].

Beyond 14-15 weeks' gestation ultrasonic scans are preferentially performed by transabdominal imaging, thereby utilizing appropriate anatomic regions (e. g. lower transverse abdominal crease). Morbidly obese women often have an abnormally lowered, ptotic apron. Elevating and retracting the fatty apron (panniculus) towards the patient's head enables optimized access to the fetal areas of interest by placing the probe near the arcus tendineus superior to the pubis[35,36]. This is of particular importance with regard to diagnostic procedures such as chorionic villous sampling (CVS), amniocentesis (AC) or cordocentesis (CS). In later gestation it may also be helpful to get access to the gravid uterus from a subcostal approach with the women in a lateral position which shifts the abdomen towards the examination table. In general, the higher the degree of maternal obesity, the higher will be the pressure exerted on the abdominal wall to reduce the depth of insonation thereby trying to achieve an acceptable acoustic window.

Alternative approaches

In obese patients, in whom a successful fetal anatomic survey has apparently failed, the maternal umbilicus, the thinnest section of the abdominal wall potentially affords improved image resolution. A previous series by Davidoff et al. revealed an optimized image clarity in most of the 68 included women, but the relatively large curvilinear transducer may have limited the ultrasonic sector view[37]. Based on these findings Rosenberg et al. and later McCoy and co-workers established a transumbilical use of the endovaginal probe in the obese gravida[57,58]. Placement of the transvaginal transducer in the umbilicus resulted in improved resolution and satisfactory fetal cardiac survey in 95 % and 87 % respectively. The authors resumed, that transumbilical use of the transvaginal probe is a beneficial, well-tolerated technique, which clearly improves gray-scale imaging. In addition, color and pulsed Doppler interrogation of fetal vessels may also be optimized. Similar observations were made by Paladini, who assumed that improved cardiac visualization (with the fetus in breech presentation) may be achieved when the scan is performed with filled maternal bladder pushing the uterus cephalad, allowing the sonographer to explore the heart via the periumbilical region[59].

On the contrary, a transrectal approach has been undertaken in those patients undergoing assisted reproduction where difficult embryo transfer was anticipated and transabdominal ultrasound guidance was hampered by increased BMI[60]. However, these procedures have not been regularly implemented in routine obstetrical ultrasound practice.

Tissue harmonic imaging

Tissue harmonic imaging (THI), nowadays commonly implemented into commercially available ultrasound systems, constitutes a real-time imaging technique that relies on the detection of so-called harmonics created by non-linear propagation of the fundamental ultrasonic beam through tissue[61]. The generation of harmonics by tissue itself increases with depth up to a point where attenuation causes them to decrease. Modern ultrasound transducers are able to isolate the second harmonic frequency in the detected echo, enabling image rendering of harmonic reflection. This relatively novel method of echo processing is useful while scanning technically difficult patients to improve image quality and confidence of diagnosis[62,63]. Treadwell and colleagues found that tissue harmonic imaging was able to improve resolution of at least one fetal structure in more than 50 % of patients enrolled in their study[64]. Whether the use of THI may result in improved detection of fetal abnormalities this study was not able to confirm, because the included patients had normal fetuses. Nevertheless, the advantages of THI in fetal cardiac examination were recently addressed by three studies[65-67]. The differences in image clarity obtained by using THI in a morbidly obese gravida compared to inconclusive images depicted without technical adjuncts are illustrated in figure 2. Other technical advances facilitating improved ultrasound assessment of fetal morphology in obese mothers include pre- and postprocessing techniques such as compound imaging, speckle reduction filters and multi-Hertz transducer technology.

Other imaging modalities

In recent years, three- and four-dimensional ultrasound applications have become clinically valuable in obstetrics as well as in gynecology. Comparative studies addressing the beneficial value of 3D ultrasound are contradictory. In a review of 11 studies comparing conventional 2D imaging and 3D ultrasound for the diagnosis of facial anomalies, seven studies reported additional information using 3D while four found similar findings achieved by these two modalities[68]. Many of the studies on the accuracy of 3D ultrasonography in prenatal diagnosis are biased by the availability of information from the initial 2D scan. Nevertheless, a previous study suggests three-dimensional ultrasound as being capable of improving visualization of fetal anatomy even in fetuses in anterior spine position[69]. In spite of the apparent advantages of 3D obstetrical imaging, non-favourable scanning conditions, such as oligohydramnios, severe obesity and the absence of tissue borderlines, cause the same problems in 3D as in 2D scanning so far.

Although ultrasound is the primary imaging modality for the evaluation of the fetus, because of proven utility, relatively low cost and widespread availability, fetal magnetic resonance imaging (MRI) has grown in popularity over the past two decades as a complementary tool for antenatal assessment of fetal abnormalities[70,71]. MRI has been useful in confirming abnormalities seen on ultrasound scan or determining the underlying cause of nonspecific sonographic anomalies and may add incremental information that might have influence on prognosis or management at birth[72-74]. Faster scanning techniques allow studies to be performed without sedation in the second and third trimester with minimal motion artefacts[75]. Moreover, MRI is not hampered by maternal obesity, fetal position, overlying bones or oligohydramnios, so that fetal MRI has emerged as a clinically valuable diagnostic supplement to ultrasound in case of inconclusive findings or degraded image.

Detection of malformations

Infants of obese parturients are reported to be at elevated risk for congenital malformations (11.1 %) compared with those of mothers of average prepregnancy weight (7.9 %). Queisser-Luft et al. reported significant odds for major malformations (OR 1.3, 95 % CI 1.0-1.7)[76]. Similar findings were recently published by two meta-analyses in which the authors systematically assessed the attributable risk for anomalies in the offspring of obese mothers[21,22]. Based on these pooled data, obese women are at significantly increased odds of a pregnancy affected by a neural tube defect (OR 1.87, 95 % CI 1.62-2.15). The statistically strongest correlation was found for spina bifida (OR 2.24, 95 % CI 1.86-2.69). Moreover, an association of maternal adiposity and cardiovascular anomalies (OR 1.30, 95 % CI 1.12-1.51) with significant odds for septal anomalies (OR 1.20, 95 % CI 1.09-1.31); orofacial clefts, e.g. cleft palate (OR 1.23, 95 % CI 1.03-1.47) or cleft lip and palate (OR 1.20, 95 % CI 1.03-1.40); anorectal atresia (OR 1.48, 95 % CI 1.12-1.97); hydrocephaly (OR 1.68, 95 % CI 1.19-2.36) and limb reduction (OR 1.34, 95 % CI 1.03-1.73) has been described. On the other hand, the relative risk for gastroschisis among obese mothers was significantly lower (OR 0.17, 95 % CI 0.10-0.30) compared with women of recommended BMI[77]. An opposite effect has been found for offspring with omphalocele, with increased odds (OR 1.63, 95 % CI 1.01-2.47) when the mother was classified as obese. These data emphasize the superior importance of detailed sonographic examination of fetuses of obese pregnant women[78,79].

According to the findings of the FaSTER (First and Second Trimester Evaluation of Risk) trial in an unselected obstetric population, it has been stated that maternal obesity significantly decreased the likelihood of sonographic detection of common anomalies (adjusted OR 0.7, 95 % CI 0.6-0.9)[80]. In a recent paper Dashe et al. assessed the impact of maternal body habitus on the detection of major structural abnormalities during second-trimester standard and targeted sonographic scan[81]. Detection of anomalous fetuses with standard ultrasound decreased substantially from 66 % in women having a normal BMI to only 25 % in morbidly obese women. In high risk pregnancies receiving targeted scans detection of malformations ranged from 83 % (lean patients) to 67 % (class III obesity). Within the targeted group the detection rate was significantly lower among women with pre-gestational diabetes than in women with other high-risk indications. These data are consistent with previous findings. In order to facilitate proper counseling, the residual risk of an undetected anomaly was calculated to be 0.4 % among women of normal BMI compared to 1.0 % in obese gravida ($p < 0.001$). However the authors did not address the issue whether follow up ultrasonography could have improved anomaly detection in obese women. Hendler et al. noted that 64 % of their included study population, who were scheduled for an additional fetal heart examination due to the initial inability to complete morphology assessment of the fetus, were obese[82]. The rate of persistent suboptimal visualization of cardiac structures even after recalled exam increased in a BMI-dependent manner from 1.5 % (non-obese) up to 20 % in morbidly obese women ($p < 0.001$). In conclusion the authors stated that the rate of initially inadaequate image clarity could be reduced by at least 80 % by repeating sonographic scans, thereby improving the prenatal diagnosis of congenital heart defects in an obstetric setting. In accordance to these observations, which are similar to previous reports, maternal obesity limits the likelihood of adequate ultrasound visualization even when advanced ultrasound systems for assessing fetal structures are used[83].

Summary

Given the continuing rise in prevalence of overall obesity, and in particular maternal obesity with impact on ultrasound imaging of fetal anatomy, obstetricians have to face new challenges in the antenatal and peripartal management of complications during pregnancy, labor, delivery and beyond. Obtaining adequate sonographic images in obese patients is of particular concern because of the increased rate of congenital anomalies. Considering the findings of sensitivity studies on mixed populations or obese gravid patients, it is reasonable that the anomaly scan at 20 weeks' gestation should be left to experienced sonographers. Moreover, obese mothers will benefit from repeated ultrasonic scans.

The main determinants of signal intensity and consecutive image clarity remain the depth of the part to be depicted as well as the specific tissue characteristics. Thus, future additions to the imaging efforts should include optimized signal processing, further advances in transducer technology or the adjunctive use of complementary image modalities such as fetal MRI to resolve associated shortcomings of obesity in obstetric practice.

An appropriate counseling prior to the commencement of the sonographic exam of overweight and obese patients allowing for the limitations of the study is advisable. The greater potential for delayed or missed diagnoses in obese patients constitutes one of the major medicolegal issues in obstetric care.

References

1. World Health Organization. Obesity and overweight. http://www.who.int/mediacentre/factsheets/fs311/en/index.html

2. World Health Organization. Obesity: preventing and managing a global epidemic. World Health Organ Tech Rep Ser 2000;894:1

3. Centers of Disease Control and Prevention Obesity and overweight. http://www.surgeongeneral.gov/topics/obesity/calltoaction/fact_glance.html

4. Reece EA. Perspectives on obesity, pregnancy and birth outcomes in the United States: the scope of the problem. Am J Obstet Gynecol 2008;198:23.

5. Chu SY, Bachman DJ, Callaghan WM, et al. Association between obesity during pregnancy and increased use of health care. N Engl J Med 2008;358:1444.

6. Committee on the impact of pregnancy weight on maternal and child health, National Research Council. Influence of pregnancy weight on maternal and child health: workshop report. Washington (DC): The National Academies Press; 2007.

7. Stotland NE. Obesity and pregnancy. BMJ 2008;338:107.

8. Chu SY, Kim SY, Lau J, et al. Maternal obesity and risk of stillbirth: a metaanalysis. Am J Obstet Gynecol 2007;197:223.

9. Phillips J, Henderson J. Delivery and postpartum concerns in the obese gravida. OBG Management 2009;21:51.

10. Catalano PM. Management of obesity in pregnancy. Obstet Gynecol 2007;109:419.

11. Cedergren MI. Maternal morbid obesity and the risk of adverse pregnancy outcome. Obstet Gynecol 2004;103:219.

12. Andreasen KR, Andersen ML, Schantz AL. Obesity and pregnancy. Acta Obstet Gynecol Scand 2004;83:1022.

13. Obesity in pregnancy. ACOG Committee Opinion No. 315. American College of Obstetricians and Gynecologists. Obstet Gynecol 2005;106:671.

14. Sebire NJ, Jolly M, Harris JP, et al. Maternal obesity and pregnancy outcome: a study of 287.213 pregnancies in London. Int J Obes Relat Metab Disord 2001;25:1175.

15. Cnattingius S, Bergström R, Lipworth L, et al. Prepregnancy weight and the risk of adverse pregnancy outcomes. N Engl J Med 1998;338:147.

16. Nohr EA, Bech BH, Vaeth M, et al. Obesity, gestational weight gain and preterm birth: a study within the Danish National Birth Cohort. Paediatr Perinat Epidemiol 2007;21:5.

17. Cedergren MI, Källén BA. Maternal obesity and infant heart defects. Obes Res 2003;11:1065.

18. Waller DK, Shaw GM, Rasmussen SA, et al. National Birth Defects Prevention Study. Prepregnancy obesity as a risk factor for structural birth defects. Arch Pediatr Adolesc Med 2007;161:745.

19. Watkins ML, Rasmussen SA, Honein MA, et al. Maternal obesity and risk for birth defects. Pediatrics 2003;111:1152.

20. Queisser-Luft A, Kieninger-Baum D, Menger H, et al. Does maternal obesity increase the risk of fetal abnormalities? Analysis of 20.248 newborn infants of the Mainz Birth Register for detecting congenital abnormalities. Ultraschall in Med 1998;19:40.

21. Stothard KJ, Tennant PW, Bell R, et al. Maternal overweight and obesity and the risk of congenital anomalies: a systematic review and meta-analysis. JAMA 2009;301:636.

22. Rasmussen SA, Chu SY, Kim SY, et al. Maternal obesity and risk of neural tube defects: a metaanalysis. Am J Obstet Gynecol 2008;198:611.

23. National Institutes of Health. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. Bethesda 1998, NIH publication No. 98-4083, http://www.nhlbi.nih.gov/guidelines/obesity/ob_gdlns.pdf

24. Bergman RN, Kim SP, Hsu IR, et al. Abdominal obesity: role in the pathophysiology of metabolic disease and cardiovascular risk. Am J Med 2007;120:S3.

25. Noori N, Hosseinpanah F, Nasiri AA, et al. Comparison of overall obesity and abdominal adiposity in predicting chronic kidney disease incidence among adults. J Ren Nutr 2009;19:228.

26. Ochs-Balcom HM, Grant BJ, Muti P, et al. Pulmonary function and abdominal adiposity in the general population. Chest 2006;129:853.

27. Yamamoto S, Douchi T, Yoshimitsu N, et al. Waist to hip circumference ratio as a significant predictor of preeclampsia, irrespective of overall adiposity. J Obstet Gynaecol Res 2001;27:27.

28. Sattar N, Clark P, Holmes A, et al. Antenatal waist circumference and hypertension risk. Obstet Gynecol 2001;97;268.

29. Brown JE, Potter JD, Jacobs DR Jr, et al. Maternal waist-to-hip ratio as a predictor of newborn size: Results of the Diana Project. Epidemiology 1996;7:62.

30. Neovius M, Linné Y, Rossner S. BMI, waist-circumference and waist-hip-ratio as diagnostic tests for fatness in adolescents. Int J Obes 2005;29:163.

31. Molarius A, Seidell JC, Sans S, et al. Waist and hip circumferences, and waist-hip ratio in 19 populations of the WHO MONICA Project. Int J Obes Relat Metab Disord 1999;23:116.

32. Welborn TA, Dhaliwal SS. Preferred clinical measures of central obesity for predicting mortality. Eur J Clin Nutr 2007;61:1373.

33. Bartha JL, Marín-Segura P, González-González NL, et al. Ultrasound evaluation of visceral fat and metabolic risk factors during early pregnancy. Obesity 2007;15:2233.

34. Dashe JS, McIntire DD, Twickler DM. Maternal obesity limits the ultrasound evaluation of fetal anatomy. J Ultrasound Med 2009;28:1025.

35. Siva S, McLennan A. The impact of obesity on obstetrical and gynaecological ultrasound. OGMagazine 2008;10:26.

36. Phillips J, Henderson J. For the obese gravida, try strong counselling and close follow-up. OBG Management 2009;21:42.

37. Davidoff A, Reuter K, Karellas A, et al. Maternal umbilicus: ultrasound window to the gravid uterus. J Clin Ultrasound 1994;22:263.

38. Zador IE, Bottoms SF, Tse GM, et al. Nomograms for ultrasound visualization of fetal organs. J Ultrasound Med 1988;7:197.

39. Wolfe HM, Zador IE, Bottoms SF, et al. Trends in sonographic fetal organ visualization. Ultrasound Obstet Gynecol 1993;3:97.

40. Wolfe HM, Sokol RJ, Martier SM, et al. Maternal obesity: a potential source of error in sonographic prenatal diagnosis. Obstet Gynecol 1990;76:339.

41. Hendler I, Blackwell SC, Bujold E, et al. The impact of maternal obesity on midtrimester sonographic visualization of fetal cardiac and craniospinal structures. Int J Obes Relat Metab Disord 2004;28:1607.

42. Catanzarite V, Delaney K, Wolfe S, et al. Targeted mid-trimester ultrasound examination: how does fetal anatomic visualization depend upon the duration of the scan? Ultrasound Obstet Gynecol 2005;26:521.

43. Hendler I, Blackwell SC, Treadwell MC, et al. Does sonographer's experience impact the rate of suboptimal visualization in the obese gravida [abstract]? Am J Obstet Gynecol 2004;189:S239.

44. Troya-Nutt M, Hendler I, Blackwell SC, et al. The accuracy of prenatal diagnosis of fetal heart anomalies in the obese gravida [abstract]. Am J Obstet Gynecol 2004;189:S239.

45. Lantz ME, Chisholm CA. The preferred timing of second-trimester obstetric sonography based on maternal body mass index. J Ultrasound Med 2004;23:1019.

46. Schwärzler P, Senat MV, Holden D, et al. Feasibility of the second-trimester fetal ultrasound examination in an unselected population at 18, 20 or 22 weeks of pregnancy: a randomized trial. Ultrasound Obstet Gynecol 1999;14:92.

47. Khoury FR, Ehrenberg HM, Mercer BM. The impact of maternal obesity on satisfactory detailed anatomic ultrasound image acquisition. J Matern Fetal Neonatal Med 2009;22:337.

48. Wong SF, Chan FY, Cincotta RB, et al. Routine ultrasound screening in diabetic pregnancies. Ultrasound Obstet Gynecol 2002;19:171.

49. Maxwell C, Dunn E, Tomlinson G, et al. How does maternal obesity affect the routine fetal anatomic ultrasound? J Matern Fetal Neonatal Med 2010. (Epub ahead of print).

50. Gandhi M, Fox N, Pozharny Y, et al. The effect of increased body mass index on the 1st trimester ultrasound for aneuploidy risk assessment [abstract]. Am J Obstet Gynecol 2008;199:S130.

51. Thornburg LL, Miles K, Ho M, et al. Fetal anatomic evaluation in the overweight and obese gravida. Ultrasound Obstet Gynecol 2009a;33:670.

52. Hershey D. Effect of maternal obesity on the ultrasound detection of anomalous fetuses. Obstet Gynecol 2009;114:694.

53. Thornburg LL, Mulconry M, Post A, et al. Fetal nuchal translucency thickness evaluation in the overweight and obese gravida. Ultrasound Obstet Gynecol 2009b;33:665.

54. Ebrashy A, El Kateb A, Momtaz M, et al. 13-14-week fetal anatomy scan: a 5-year prospective study. Ultrasound Obstet Gynecol 2010;35:292.

55. Chaoui R, Benoit B, Mitkowska-Wozniak H, et al. Assessment of intracranial translucency (IT) in the detection of spina bifida at the 11-13-week scan. Ultrasound Obstet Gynecol 2009;34:249.

56. Timor-Tritsch IE, Fuchs KM, Monteagudo A, et al. Performing a fetal anatomy scan at the time of first-trimester screening. Obstet Gynecol 2009;113:402.

57. Rosenberg JC, Guzman ER, Vintzileos AM, et al. Transumbilical placement of the vaginal probe in obese pregnant women. Obstet Gynecol 1995;85:132.

58. McCoy MC, Watson WJ, Chescheir NC, et al. Transumbilical use of the endovaginal probe. Am J Perinatol 1996;13:395.

59. Paladini D. Sonography in obese and overweight pregnant women: clinical, medicolegal and technical issues. Ultrasound Obstet Gynecol 2009;33:720.

60. Sohan K, Woodward B, Ramsewak SS. Successful use of transrectal ultrasound for embryo transfer in obese women. J Obstet Gynaecol 2004;24:839.

61. Hedrick WR, Metzger L. Tissue Harmonic Imaging: A Review. J Diagn Med Sonogr 2005;21:183.

62. Tranquart F, Grenier N, Eder V, et al. Clinical use of ultrasound tissue harmonic imaging. Ultrasound Med Biol 1999;25:889.

63. Choudhry S, Gorman B, Charboneau JW, et al. Comparison of tissue harmonic imaging with conventional US in abdominal disease. Radiographics 2000;20:1127.

64. Treadwell MC, Seubert DE, Zador I, et al. Benefits associated with harmonic tissue imaging in the obstetric patient. Am J Obstet Gynecol 2000;182:1620.

65. Kovalchin JP, Lewin MB, Bezold LI, et al. Harmonic imaging in fetal echocardiography. J Am Soc Echocardiogr 2001;14:1025.

66. Zhao BW, Tang FG, Shou JD, et al. Comparison study of harmonic imaging (HI) and fundamental imaging (FI) in fetal echocardiography. J Zhejiang Univ Sci 2003;4:374.

67. Paladini D, Vassallo M, Tartaglione A, et al. The role of tissue harmonic imaging in fetal echocardiography. Ultrasound Obstet Gynecol 2004;23:159.

68. Lee YM, Simpson LL. Major fetal structural malformations: the role of new imaging modalities. Am J Med Genet C Semin Med Genet 2007;145C:33.

69. Timor-Tritsch IE, Monteagudo A. Three and four-dimensional ultrasound in obstetrics and gynecology. Curr Opin Obstet Gynecol 2007;19:157.

70. Gonçalves LF, Nien JK, Espinoza J, et al. What does 2-dimensional imaging add to 3- and 4-dimensional obstetric ultrasonography? J Ultrasound Med 2006;25:691.

71. Wang PH, Chen GD, Lin LY. Imaging comparison of basic cardiac views between two- and three-dimensional ultrasound in normal fetuses in anterior spine positions. Int J Cardiovasc Imaging 2002;18:17.

72. Behairy NH, Talaat S, Saleem SN, et al. Magnetic resonance imaging in fetal anomalies: What does it add to 3D and 4D US? Eur J Radiol 2009. (Epub ahead of print).

73. Frates MC, Kumar AJ, Benson CB, et al. Fetal anomalies: comparison of MR imaging and US for diagnosis. Radiology 2004;232:398.

74. Whitby E, Paley MN, Davies N, et al. Ultrafast magnetic resonance imaging of central nervous system abnormalities in utero in the second and third trimester of pregnancy: comparison with ultrasound. BJOG 2001;108:519.

75. Hubbard AM. Ultrafast fetal MRI and prenatal diagnosis. Semin Pediatr Surg 2003;12:143.

76. Queisser-Luft A, Stolz G, Wiesel A, et al. Malformations in newborn: results based on 30.940 infants and fetuses from the Mainz congenital birth defect monitoring system (1990-1998). Arch Gynecol Obstet 2002;266:163.

77. Siega-Riz AM, Herring AH, Olshan AF, et al. National Birth Defects Prevention Study. The joint effects of maternal prepregnancy body mass index and age on the risk of gastroschisis. Paediatr Perinat Epidemiol 2009;23:51.

78. Wong SF, Chan FY, Cincotta RB, et al. Factors influencing the prenatal detection of structural congenital heart diseases. Ultrasound Obstet Gynecol 2003;21:19.

79. Ehrenberg HM, Fischer RL, Hediger ML, et al. Are maternal and sonographic factors associated with the detection of a fetal echogenic cardiac focus? J Ultrasound Med 2001;20:1047.

80. Aagaard-Tillery KM, Flint Porter T, Malone FD, et al. Influence of maternal BMI on genetic sonography in the FaSTER trial. Prenat Diagn 2010;30:14.

81. Dashe JS, McIntire DD, Twickler DM. Effect of maternal obesity on the ultrasound detection of anomalous fetuses. Obstet Gynecol 2009;113:1001.

82. Hendler I, Blackwell SC, Bujold E, et al. Suboptimal second-trimester ultrasonographic visualization of the fetal heart in obese women: should we repeat the examination? J Ultrasound Med 2005;24:1205.

83. Hendler I, Blackwell SC, Treadwell MC, et al. Does advanced ultrasound equipment improve the adequacy of ultrasound visualization of fetal cardiac structures in the obese gravid woman? Am J Obstet Gynecol 2004;190:1616.