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Jan Weichert, Rafael David Hartge

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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.
Obstetrical ultrasound and obesity

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. The incidence of obesity among pregnant women in the United States ranges from 18.5 to over 38 %. These alarming data constitute a significant public health concern not only for obstetrical care providers and is likely to remain so for the foreseeable future. A recently published study of more than 13,000 pregnant women clearly demonstrated that obese parturients increasingly use healthcare resources.

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. 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. Similar data were previously published by Cnattingius et al. and Nohr et al. who analysed records derived from Scandinavian birth registers. 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.

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
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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). 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. Other publications stressed the association of abdominal obesity and poor respiratory function or the increased risk of chronic kidney disease in the general population. 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. 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 interval - CI 1.1, 2.9) and pre-eclampsia (OR 2.7, 95% CI 1.1, 6.8). In a prior series an impact of maternal WHR on elevated fetal growth was established. Both waist-to-hip ratio (WHR) and waist circumference (WC) have been additionally used as proxy
Obstetrical ultrasound and obesity measures for body fat distribution when investigating health concerns evolving from (maternal) obesity\textsuperscript{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\textsuperscript{33}.

\textbf{Obstetrical ultrasound}

Pre-examination counseling of the obese gravida has to point out the likely impact of adiposity on image clarity and diagnostic accuracy\textsuperscript{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\textsuperscript{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\textsuperscript{36}. To improve the accuracy of pregnancy-dating during the early first trimester, transvaginal assessment of the crown-rump-length should be performed.

\textit{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)\textsuperscript{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\textsuperscript{37}. The overall visualization of fetal organs with respect to
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increasing maternal size has been previously addressed by several studies\textsuperscript{38,39}. Reduction in successful image generation was most marked for cardiac and cerebrospinal structures as well as the umbilical cord\textsuperscript{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\textsuperscript{42}.

The impact of sonographer's experience on the rate of suboptimal visualization in the obese gravida is obvious and was previously reported\textsuperscript{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\textsuperscript{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\textsuperscript{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\textsuperscript{41}. Wolfe et al reported a 14.5 % reduction in visualization rates in the markedly obese patient\textsuperscript{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, \(p < 0.001\))\textsuperscript{47}. Series assessing the potential impact of maternal obesity\textsuperscript{48} on optimal visualization and completion of anatomic survey\textsuperscript{49} are summarized in table 1.
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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. 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. 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. 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). 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.

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. 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. 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. 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.

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. 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
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tissue. 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. 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. 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. 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. 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. In spite of the apparent advantages of 3D obstetrical imaging, non-favourable scanning conditions, such as oligohydramnios, severe
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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. 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. Faster scanning techniques allow studies to be performed without sedation in the second and third trimester with minimal motion artefacts. 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). 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. 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
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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. 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.

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). 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. 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. 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 inadequate 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
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previous reports, maternal obesity limits the likelihood of adequate ultrasound visualization even when advanced ultrasound systems for assessing fetal structures are used[63].

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

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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.

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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.

180x91 mm (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).
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Obstetrical ultrasound and obesity increasing maternal size has been previously addressed by several studies. Reduction in successful image generation was most marked for cardiac and cerebrospinal structures as well as the umbilical cord. 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.

The impact of sonographer’s experience on the rate of suboptimal visualization in the obese gravida is obvious and was previously reported. 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. 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.

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. Wolfe et al reported a 14.5% reduction in visualization rates in the markedly obese patient. 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). Series assessing the potential impact of maternal obesity on optimal visualization and completion of anatomic survey are summarized in table 1.
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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. 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. 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. 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). 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.

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. 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
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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. 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. 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.

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. 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
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tissue. 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. 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. 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. 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. 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. In spite of the apparent advantages of 3D obstetrical imaging, non-favourable scanning conditions, such as oligohydramnios, severe...
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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\textsuperscript{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\textsuperscript{72-74}. Faster scanning techniques allow studies to be performed without sedation in the second and third trimester with minimal motion artefacts\textsuperscript{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 pre-pregnancy weight (7.9 \%). Queisser-Luft et al. reported significant odds for major malformations (OR 1.3, 95 \% CI 1.0-1.7)\textsuperscript{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\textsuperscript{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
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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\textsuperscript{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\textsuperscript{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)\textsuperscript{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 scans\textsuperscript{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\textsuperscript{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 inadequate 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
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previous reports, maternal obesity limits the likelihood of adequate ultrasound visualization even when advanced ultrasound systems for assessing fetal structures are used\(^\text{[83]}\).

**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**

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