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**Obstetrical sonography in obese women: A review**

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Review

## 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.

## 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  $\geq$  25-29.9) and additional 400 million adults were obese (BMI  $\geq$  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<sup>1,2</sup>. The incidence of obesity among pregnant women in the United States ranges from 18.5 to over 38 %<sup>3,4</sup>. 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<sup>5</sup>.

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<sup>6-13</sup>. 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<sup>14</sup>. Similar data were previously published by Cnattingius et al. and Nohr et al. who analysed records derived from Scandinavian birth registers<sup>15,16</sup>. 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<sup>17-22</sup>.

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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2  
3 importance for the detection of fetal abnormalities to provide a framework for a proper parental  
4  
5 counseling.  
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### 8 9 ***Quantification of obesity***

10 For the estimation of the degree of fat accumulation, assessment of the body mass index (BMI -  
11  
12 calculated as weight in kilograms divided by height in meters squared) has been established as  
13  
14 the principal standard method to diagnose overweight and obesity. By definition the World  
15  
16 Health Organization (WHO) and the National Institutes of Health (NIH) both define normal  
17  
18 weight comprising a BMI of 18.5–24.9, overweight as a BMI of 25–29.9, and obesity as a BMI of  
19  
20 30 or greater. Obesity is further categorized by BMI into Class I (30–34.9), Class II (35–39.9), and  
21  
22 Class III or morbid obesity ( $\geq 40$ )<sup>2,23</sup>. In pregnancy, BMI is calculated using pre-pregnant weight  
23  
24 or the weight measured during the initial visit at the prenatal care provider. Due to the fact that  
25  
26 BMI is an indirect measure reflecting the overall fatness without distinguishing between fat and  
27  
28 fat-free components it is not as useful in predicting the difficulties encountered with ultrasound  
29  
30 visualization and putative obesity-related risks during advancing pregnancy. In the past few  
31  
32 years, a number of studies have called attention to the importance of abdominal obesity and its  
33  
34 measuring modalities. A strong relation between increase in abdominal girth and cardiovascular  
35  
36 disease among adults has recently been demonstrated<sup>24</sup>. Other publications stressed the  
37  
38 association of abdominal obesity and poor respiratory function or the increased risk of chronic  
39  
40 kidney disease in the general population<sup>25,26</sup>. However, from an obstetric perspective Yamamoto  
41  
42 et al. in 2001 were the first who reported a higher waist-to-hip ratio (WHR) prior to 9  
43  
44 gestational weeks to be significantly linked to an increased risk for pre-eclampsia<sup>27</sup>. Similar  
45  
46 findings were published by Sattar et al., who found a significant correlation of increased waist-  
47  
48 circumference prior to 16 weeks' gestation and pregnancy-induced hypertension (Odds Ratio -  
49  
50 OR 1.8, 95% confidence interval - CI 1.1, 2.9) and pre-eclampsia (OR 2.7, 95% CI 1.1, 6.8)<sup>28</sup>. In a  
51  
52 prior series an impact of maternal WHR on elevated fetal growth was established<sup>29</sup>. Both waist-  
53  
54 to-hip ratio (WHR) and waist circumference (WC) have been additionally used as proxy  
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## Obstetrical ultrasound and obesity

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2  
3 measures for body fat distribution when investigating health concerns evolving from (maternal)  
4  
5 obesity<sup>30-32</sup>. Bartha and colleagues introduced an ultrasonographic measurement of maternal  
6  
7 visceral fat thickness (VFT) during early pregnancy and were able to demonstrate a better  
8  
9 correlation of the VFT estimate compared to BMI with metabolic and cardiovascular risk factors  
10  
11 such as hyperinsulinaemia, insulin resistance, high blood pressure or dyslipidaemia in  
12  
13 pregnancy<sup>33</sup>.

***Obstetrical ultrasound***

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19  
20 Pre-examination counseling of the obese gravida has to point out the likely impact of adiposity  
21  
22 on image clarity and diagnostic accuracy<sup>34</sup>. This should be communicated to the patient in a  
23  
24 sensitive but appropriate way, because it allows earlier abandonment of a technically difficult  
25  
26 study and enables to set realistic expectations regarding the scan<sup>35</sup>. It seems reasonable to claim  
27  
28 an informed consent signed by the gravida in advance of the anatomic survey. Furthermore, the  
29  
30 first prenatal visit should focus on dating the pregnancy and confirming viability of the fetus. In  
31  
32 fact, obese women are more likely to have anovulatory or irregular cycles, so that the utility of  
33  
34 determining the last menstrual period for establishing gestational age may be limited<sup>36</sup>. To  
35  
36 improve the accuracy of pregnancy-dating during the early first trimester, transvaginal  
37  
38 assessment of the crown-rump-length should be performed.  
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***Image clarity***

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52 In addition to the arithmetic indices, measuring the distance from skin surface to the  
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54 intrauterine region of interest (e.g. key fetal structures) allows simple documentation of the fat  
55  
56 layer, thereby conveying the grade of image clarity impairment (figure 1)<sup>35</sup>. Excess of abdominal  
57  
58 (subcutaneous or intraabdominal) fat results in an increased number of interfaces and  
59  
60 consecutively in marked attenuation of the signal. Attenuation encompasses absorption,  
reflection, reverberation and scatter<sup>37</sup>. The overall visualization of fetal organs with respect to

1  
2  
3 increasing maternal size has been previously addressed by several studies<sup>38,39</sup>. Reduction in  
4  
5 successful image generation was most marked for cardiac and cerebrospinal structures as well  
6  
7 as the umbilical cord<sup>40,41</sup>. Catanzarite et al. postulated five categories of potential barriers to  
8  
9 complete fetal anatomic survey. In addition to maternal body habitus, other confounding  
10  
11 variables such as gestational age, fetal spine-up position, resolution/penetration of ultrasound  
12  
13 equipment and sonographer skills evidently exert influence on image clarity. The authors also  
14  
15 described a strong relation of scanning duration and completion of the anatomical survey in the  
16  
17 non-obese population. For each 5-minute time increment up to 30 minutes, the rate of complete  
18  
19 morphological assessment improved in their study<sup>42</sup>.

20  
21  
22  
23 The impact of sonographer's experience on the rate of suboptimal visualization in the obese  
24  
25 gravida is obvious and was previously reported<sup>43,44</sup>. Rates of completed anatomic surveys rise  
26  
27 with advancing gestational age. The preferred timing of midtrimester ultrasound examination of  
28  
29 the obese gravida appears to be between 18-20 weeks' gestation in order to achieve maximum  
30  
31 efficiency with respect to the potential duration of the scan and need for repeated scans<sup>45,46</sup>. This  
32  
33 is slightly different to the findings of Wolfe et al. who stated an optimal overall organ  
34  
35 visualization at 21-23 weeks for a mean maternal BMI of 27.3 of the women enrolled in their  
36  
37 study<sup>40</sup>.

38  
39  
40 Hendler et al. described an inverse relationship between the severity of maternal obesity and the  
41  
42 ability to adequately visualize the fetal heart (37.3 % obese vs. 18.7 % non-obese,  
43  
44  $p < 0.001$ ) and craniospinal structures (42.8 % obese vs. 29.5 % non-obese,  $p < 0.001$ ). They  
45  
46 found a degradation in image quality by 10 % for every further step in obesity classification<sup>41</sup>.

47  
48  
49 Wolfe et al reported a 14.5 % reduction in visualization rates in the markedly obese patient<sup>40</sup>.  
50  
51 Similar observations were recently published with respect to suboptimal visualization of facial  
52  
53 soft tissue (39.1 % obese vs. 19.3 % non-obese,  $p < 0.001$ ) and abdominal wall (2.7 % obese vs. 0  
54  
55 % non-obese,  $p < 0.001$ )<sup>47</sup>. Series assessing the potential impact of maternal obesity<sup>48</sup> on optimal  
56  
57 visualization and completion of anatomic survey<sup>49</sup> are summarized in table 1.  
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60

## Obstetrical ultrasound and obesity

1  
2  
3 Due to this poor transmission of ultrasound waves in adipose tissue there were several attempts  
4 to optimize in image quality. A transvaginal approach is beneficial for assessment of fetal  
5 structures close to the lower uterine segment and therefore mainly limited to ultrasound  
6 examinations throughout the first trimester. Measurement of fetal nuchal translucency between  
7 11-13+6 weeks most often performed transabdominally as this allows a wider range of scanning  
8 angles, may substantially be hampered by increasing maternal size<sup>50,51</sup>. In the obese patient  
9 therefore, a transvaginal assessment to facilitate a better resolution of the skin line, perispinal  
10 tissue or amniotic sheet as separate structures, should be considered<sup>35</sup>. This approach enables  
11 proper assessment of fetal limbs and extremities and is feasible to perform early fetal  
12 echocardiography as well. Recently, it has been postulated that most of the anomalies detectable  
13 during standard 18-week scan can be seen at 12 to 13 weeks with appropriate imaging even in  
14 obese women<sup>52</sup>. However, this has been challenged by other authors, which concordantly  
15 emphasize that a number of anomalies are not amenable to first trimester detection (regardless  
16 recent promising findings, such as intracranial translucency)<sup>53-55</sup>. Further studies are needed to  
17 systematically investigate the diagnostic capability of a first trimester anatomic sonogram and to  
18 establish reliable standards taking into account increased maternal size and limited acoustic  
19 window<sup>56</sup>.

20  
21 Beyond 14-15 weeks' gestation ultrasonic scans are preferentially performed by transabdominal  
22 imaging, thereby utilizing appropriate anatomic regions (e. g. lower transverse abdominal  
23 crease). Morbidly obese women often have an abnormally lowered, ptotic apron. Elevating and  
24 retracting the fatty apron (panniculus) towards the patient's head enables optimized access to  
25 the fetal areas of interest by placing the probe near the arcus tendineus superior to the pubis<sup>35,36</sup>.  
26 This is of particular importance with regard to diagnostic procedures such as chorionic villous  
27 sampling (CVS), amniocentesis (AC) or cordocentesis (CS). In later gestation it may also be  
28 helpful to get access to the gravid uterus from a subcostal approach with the women in a lateral  
29 position which shifts the abdomen towards the examination table. In general, the higher the  
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3 degree of maternal obesity, the higher will be the pressure exerted on the abdominal wall to  
4  
5 reduce the depth of insonation thereby trying to achieve an acceptable acoustic window.  
6  
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#### 8 9 *Alternative approaches*

10  
11 In obese patients, in whom a successful fetal anatomic survey has apparently failed, the maternal  
12  
13 umbilicus, the thinnest section of the abdominal wall potentially affords improved image  
14  
15 resolution. A previous series by Davidoff et al. revealed an optimized image clarity in most of the  
16  
17 68 included women, but the relatively large curvilinear transducer may have limited the  
18  
19 ultrasonic sector view<sup>37</sup>. Based on these findings Rosenberg et al. and later McCoy and co-  
20  
21 workers established a transumbilical use of the endovaginal probe in the obese gravida<sup>57,58</sup>.  
22  
23 Placement of the transvaginal transducer in the umbilicus resulted in improved resolution and  
24  
25 satisfactory fetal cardiac survey in 95 % and 87 % respectively. The authors resumed, that  
26  
27 transumbilical use of the transvaginal probe is a beneficial, well-tolerated technique, which  
28  
29 clearly improves gray-scale imaging. In addition, color and pulsed Doppler interrogation of fetal  
30  
31 vessels may also be optimized. Similar observations were made by Paladini, who assumed that  
32  
33 improved cardiac visualization (with the fetus in breech presentation) may be achieved when  
34  
35 the scan is performed with filled maternal bladder pushing the uterus cephalad, allowing the  
36  
37 sonographer to explore the heart via the periumbilical region<sup>59</sup>.  
38  
39

40  
41 On the contrary, a transrectal approach has been undertaken in those patients undergoing  
42  
43 assisted reproduction where difficult embryo transfer was anticipated and transabdominal  
44  
45 ultrasound guidance was hampered by increased BMI<sup>60</sup>. However, these procedures have not  
46  
47 been regularly implemented in routine obstetrical ultrasound practice.  
48  
49

#### 50 51 52 53 *Tissue harmonic imaging*

54  
55 Tissue harmonic imaging (THI), nowadays commonly implemented into commercially available  
56  
57 ultrasound systems, constitutes a real-time imaging technique that relies on the detection of so-  
58  
59 called harmonics created by non-linear propagation of the fundamental ultrasonic beam through  
60

## Obstetrical ultrasound and obesity

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3 tissue<sup>61</sup>. The generation of harmonics by tissue itself increases with depth up to a point where  
4  
5  
6 attenuation causes them to decrease. Modern ultrasound transducers are able to isolate the  
7  
8 second harmonic frequency in the detected echo, enabling image rendering of harmonic  
9  
10 reflection. This relatively novel method of echo processing is useful while scanning technically  
11  
12 difficult patients to improve image quality and confidence of diagnosis<sup>62,63</sup>. Treadwell and  
13  
14 colleagues found that tissue harmonic imaging was able to improve resolution of at least one  
15  
16 fetal structure in more than 50 % of patients enrolled in their study<sup>64</sup>. Whether the use of THI  
17  
18 may result in improved detection of fetal abnormalities this study was not able to confirm,  
19  
20 because the included patients had normal fetuses. Nevertheless, the advantages of THI in fetal  
21  
22 cardiac examination were recently addressed by three studies<sup>65-67</sup>. The differences in image  
23  
24 clarity obtained by using THI in a morbidly obese gravida compared to inconclusive images  
25  
26 depicted without technical adjuncts are illustrated in figure 2. Other technical advances  
27  
28 facilitating improved ultrasound assessment of fetal morphology in obese mothers include pre-  
29  
30 and postprocessing techniques such as compound imaging, speckle reduction filters and multi-  
31  
32 Hertz transducer technology.  
33  
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*Other imaging modalities*

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40 In recent years, three- and four-dimensional ultrasound applications have become clinically  
41  
42 valuable in obstetrics as well as in gynecology. Comparative studies addressing the beneficial  
43  
44 value of 3D ultrasound are contradictory. In a review of 11 studies comparing conventional 2D  
45  
46 imaging and 3D ultrasound for the diagnosis of facial anomalies, seven studies reported  
47  
48 additional information using 3D while four found similar findings achieved by these two  
49  
50 modalities<sup>68</sup>. Many of the studies on the accuracy of 3D ultrasonography in prenatal diagnosis  
51  
52 are biased by the availability of information from the initial 2D scan. Nevertheless, a previous  
53  
54 study suggests three-dimensional ultrasound as being capable of improving visualization of fetal  
55  
56 anatomy even in fetuses in anterior spine position<sup>69</sup>. In spite of the apparent advantages of 3D  
57  
58 obstetrical imaging, non-favourable scanning conditions, such as oligohydramnios, severe  
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1  
2  
3 obesity and the absence of tissue borderlines, cause the same problems in 3D as in 2D scanning  
4  
5 so far.

6  
7 Although ultrasound is the primary imaging modality for the evaluation of the fetus, because of  
8  
9 proven utility, relatively low cost and widespread availability, fetal magnetic resonance imaging  
10  
11 (MRI) has grown in popularity over the past two decades as a complementary tool for antenatal  
12  
13 assessment of fetal abnormalities<sup>70,71</sup>. MRI has been useful in confirming abnormalities seen on  
14  
15 ultrasound scan or determining the underlying cause of nonspecific sonographic anomalies and  
16  
17 may add incremental information that might have influence on prognosis or management at  
18  
19 birth<sup>72-74</sup>. Faster scanning techniques allow studies to be performed without sedation in the  
20  
21 second and third trimester with minimal motion artefacts<sup>75</sup>. Moreover, MRI is not hampered by  
22  
23 maternal obesity, fetal position, overlying bones or oligohydramnios, so that fetal MRI has  
24  
25 emerged as a clinically valuable diagnostic supplement to ultrasound in case of inconclusive  
26  
27 findings or degraded image.  
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### 34 ***Detection of malformations***

35  
36 Infants of obese parturients are reported to be at elevated risk for congenital malformations  
37  
38 (11.1 %) compared with those of mothers of average prepregnancy weight (7.9 %). Queisser-  
39  
40 Luft et al. reported significant odds for major malformations (OR 1.3, 95 % CI 1.0-1.7)<sup>76</sup>. Similar  
41  
42 findings were recently published by two meta-analyses in which the authors systematically  
43  
44 assessed the attributable risk for anomalies in the offspring of obese mothers<sup>21,22</sup>. Based on these  
45  
46 pooled data, obese women are at significantly increased odds of a pregnancy affected by a neural  
47  
48 tube defect (OR 1.87, 95 % CI 1.62-2.15). The statistically strongest correlation was found for  
49  
50 spina bifida (OR 2.24, 95 % CI 1.86-2.69). Moreover, an association of maternal adiposity and  
51  
52 cardiovascular anomalies (OR 1.30, 95 % CI 1.12-1.51) with significant odds for septal anomalies  
53  
54 (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  
55  
56 lip and palate (OR 1.20, 95 % CI 1.03-1.40); anorectal atresia (OR 1.48, 95 % CI 1.12-1.97);  
57  
58 hydrocephaly (OR 1.68, 95 % CI 1.19-2.36) and limb reduction (OR 1.34, 95 % CI 1.03-1.73) has  
59  
60

## Obstetrical ultrasound and obesity

1  
2  
3 been described. On the other hand, the relative risk for gastroschisis among obese mothers was  
4 significantly lower (OR 0.17, 95 % CI 0.10-0.30) compared with women of recommended BMI<sup>77</sup>.  
5  
6 An opposite effect has been found for offspring with omphalocele, with increased odds (OR 1.63,  
7 95 % CI 1.01-2.47) when the mother was classified as obese. These data emphasize the superior  
8 importance of detailed sonographic examination of fetuses of obese pregnant women<sup>78,79</sup>.  
9  
10 According to the findings of the FaSTER (First and Second Trimester Evaluation of Risk) trial in  
11 an unselected obstetric population, it has been stated that maternal obesity significantly  
12 decreased the likelihood of sonographic detection of common anomalies (adjusted OR 0.7, 95 %  
13 CI 0.6-0.9)<sup>80</sup>. In a recent paper Dashe et al. assessed the impact of maternal body habitus on the  
14 detection of major structural abnormalities during second-trimester standard and targeted  
15 sonographic scan<sup>81</sup>. Detection of anomalous fetuses with standard ultrasound decreased  
16 substantially from 66 % in women having a normal BMI to only 25 % in morbidly obese women.  
17  
18 In high risk pregnancies receiving targeted scans detection of malformations ranged from 83 %  
19 (lean patients) to 67 % (class III obesity). Within the targeted group the detection rate was  
20 significantly lower among women with pre-gestational diabetes than in women with other high-  
21 risk indications. These data are consistent with previous findings. In order to facilitate proper  
22 counseling, the residual risk of an undetected anomaly was calculated to be 0.4 % among women  
23 of normal BMI compared to 1.0 % in obese gravida ( $p < 0.001$ ). However the authors did not  
24 address the issue whether follow up ultrasonography could have improved anomaly detection in  
25 obese women. Hendler et al. noted that 64 % of their included study population, who were  
26 scheduled for an additional fetal heart examination due to the initial inability to complete  
27 morphology assessment of the fetus, were obese<sup>82</sup>. The rate of persistent suboptimal  
28 visualization of cardiac structures even after recalled exam increased in a BMI-dependent  
29 manner from 1.5 % (non-obese) up to 20 % in morbidly obese women ( $p < 0.001$ ). In conclusion  
30 the authors stated that the rate of initially inadequate image clarity could be reduced by at least  
31 80 % by repeating sonographic scans, thereby improving the prenatal diagnosis of congenital  
32 heart defects in an obstetric setting. In accordance to these observations, which are similar to  
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3 previous reports, maternal obesity limits the likelihood of adequate ultrasound visualization  
4  
5 even when advanced ultrasound systems for assessing fetal structures are used<sup>83</sup>.  
6  
7

### 8 9 **Summary**

10 Given the continuing rise in prevalence of overall obesity, and in particular maternal obesity  
11  
12 with impact on ultrasound imaging of fetal anatomy, obstetricians have to face new challenges in  
13  
14 the antenatal and peripartal management of complications during pregnancy, labor, delivery and  
15  
16 beyond. Obtaining adequate sonographic images in obese patients is of particular concern  
17  
18 because of the increased rate of congenital anomalies. Considering the findings of sensitivity  
19  
20 studies on mixed populations or obese gravid patients, it is reasonable that the anomaly scan at  
21  
22 20 weeks' gestation should be left to experienced sonographers. Moreover, obese mothers will  
23  
24 benefit from repeated ultrasonic scans.  
25  
26

27 The main determinants of signal intensity and consecutive image clarity remain the depth of the  
28  
29 part to be depicted as well as the specific tissue characteristics. Thus, future additions to the  
30  
31 imaging efforts should include optimized signal processing, further advances in transducer  
32  
33 technology or the adjunctive use of complementary image modalities such as fetal MRI to  
34  
35 resolve associated shortcomings of obesity in obstetric practice.  
36  
37

38 An appropriate counseling prior to the commencement of the sonographic exam of overweight  
39  
40 and obese patients allowing for the limitations of the study is advisable. The greater potential for  
41  
42 delayed or missed diagnoses in obese patients constitutes one of the major medicolegal issues in  
43  
44 obstetric care.  
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## Obstetrical ultrasound and obesity

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## Obstetrical ultrasound and obesity

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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.

Reference	No. of cases	Gestational age	Target value	Non-obese	Obese			p-value
				≤ 29.9 kg/m <sup>2</sup>	30-34.9 kg/m <sup>2</sup>	35-39.9 kg/m <sup>2</sup>	≥ 40 kg/m <sup>2</sup>	
	(n)	(weeks)		(%)	Class I (%)	Class II (%)	Class III (%)	
Wolfe et al. <sup>40</sup>	1.622	15-40	SUV (overall)	12.9	----- 25.5 -----			0.00001
Wong et al. <sup>48</sup>	130	16	SUV (overall)	37	----- 65.4 -----			< 0.0001
Hendler et al. <sup>41</sup>	11.019	14.0-23.9	SUV (heart)	18.7	29.6	39	49.6	< 0.0001
Lantz et al. <sup>45</sup>	1.444	18.0-19.6	Completed Survey	85.7	----- 67.9 -----			n/a
Ghandi et al. <sup>50</sup>	435	11.0-13.9	SUV (nasal bone)	3	----- 11.5 -----			0.002
Thornburg et al. <sup>51</sup>	2.508	11.0-13.9	Completed Survey	77.6	72	61	49	< 0.00001
Khoury et al. <sup>47</sup>	814	18.0-24.9	Completed Survey	51.3	----- 35.4 -----			0.0005
Dashe et al. <sup>34</sup>	10.112	18.0-23.9	Completed Survey	70	57	41	30	< 0.001
Maxwell et al. <sup>49</sup>	100	17.5-20.5	Completed Survey	97.5	----- 74 -----			< 0.001
Total	28.184	11.0-40	-	-	-	-	-	-



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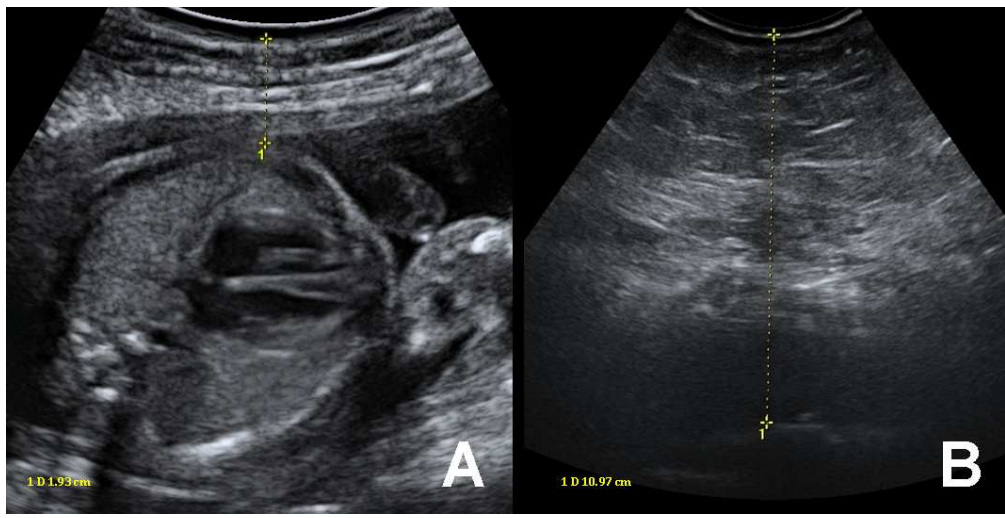


FIGURE 1. Documentation of the depth of insonation in a lean (BMI 21.8 kg/m<sup>2</sup>) pregnant woman (A), compared to a gravida with morbid obesity (BMI > 40 kg/m<sup>2</sup>) at 22 weeks of gestation. 180x91mm (150 x 150 DPI)

Peer Review



FIGURE 2: Comparison of the lateral 4-chamber view of the fetal heart in a morbidly obese mother (BMI > 40 kg/m<sup>2</sup>) 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)

Peer Review

## 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.

## 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  $\geq$  25-29.9) and additional 400 million adults were obese (BMI  $\geq$  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<sup>1,2</sup>. The incidence of obesity among pregnant women in the United States ranges from 18.5 to over 38 %<sup>3,4</sup>. 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<sup>5</sup>.

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<sup>6-13</sup>. 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<sup>14</sup>. Similar data were previously published by Cnattingius et al. and Nohr et al. who analysed records derived from Scandinavian birth registers<sup>15,16</sup>. 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<sup>17-22</sup>.

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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3 importance for the detection of fetal abnormalities to provide a framework for a proper parental  
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5 counseling.  
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### 8 9 ***Quantification of obesity***

10 For the estimation of the degree of fat accumulation, assessment of the body mass index (BMI -  
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12 calculated as weight in kilograms divided by height in meters squared) has been established as  
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14 the principal standard method to diagnose overweight and obesity. By definition the World  
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16 Health Organization (WHO) and the National Institutes of Health (NIH) both define normal  
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18 weight comprising a BMI of 18.5–24.9, overweight as a BMI of 25–29.9, and obesity as a BMI of  
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20 30 or greater. Obesity is further categorized by BMI into Class I (30–34.9), Class II (35–39.9), and  
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22 Class III or morbid obesity ( $\geq 40$ )<sup>2,23</sup>. In pregnancy, BMI is calculated using pre-pregnant weight  
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24 or the weight measured during the initial visit at the prenatal care provider. Due to the fact that  
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26 BMI is an indirect measure reflecting the overall fatness without distinguishing between fat and  
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28 fat-free components it is not as useful in predicting the difficulties encountered with ultrasound  
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30 visualization and putative obesity-related risks during advancing pregnancy. In the past few  
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32 years, a number of studies have called attention to the importance of abdominal obesity and its  
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34 measuring modalities. A strong relation between increase in abdominal girth and cardiovascular  
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36 disease among adults has recently been demonstrated<sup>24</sup>. Other publications stressed the  
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38 association of abdominal obesity and poor respiratory function or the increased risk of chronic  
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40 kidney disease in the general population<sup>25,26</sup>. However, from an obstetric perspective Yamamoto  
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42 et al. in 2001 were the first who reported a higher waist-to-hip ratio (WHR) prior to 9  
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44 gestational weeks to be significantly linked to an increased risk for pre-eclampsia<sup>27</sup>. Similar  
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46 findings were published by Sattar et al., who found a significant correlation of increased waist-  
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48 circumference prior to 16 weeks' gestation and pregnancy-induced hypertension (Odds Ratio -  
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50 OR 1.8, 95% confidence interval - CI 1.1, 2.9) and pre-eclampsia (OR 2.7, 95% CI 1.1, 6.8)<sup>28</sup>. In a  
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52 prior series an impact of maternal WHR on elevated fetal growth was established<sup>29</sup>. Both waist-  
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54 to-hip ratio (WHR) and waist circumference (WC) have been additionally used as proxy  
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## Obstetrical ultrasound and obesity

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3 measures for body fat distribution when investigating health concerns evolving from (maternal)  
4  
5 obesity<sup>30-32</sup>. Bartha and colleagues introduced an ultrasonographic measurement of maternal  
6  
7 visceral fat thickness (VFT) during early pregnancy and were able to demonstrate a better  
8  
9 correlation of the VFT estimate compared to BMI with metabolic and cardiovascular risk factors  
10  
11 such as hyperinsulinaemia, insulin resistance, high blood pressure or dyslipidaemia in  
12  
13 pregnancy<sup>33</sup>.

***Obstetrical ultrasound***

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20 Pre-examination counseling of the obese gravida has to point out the likely impact of adiposity  
21  
22 on image clarity and diagnostic accuracy<sup>34</sup>. This should be communicated to the patient in a  
23  
24 sensitive but appropriate way, because it allows earlier abandonment of a technically difficult  
25  
26 study and enables to set realistic expectations regarding the scan<sup>35</sup>. It seems reasonable to claim  
27  
28 an informed consent signed by the gravida in advance of the anatomic survey. Furthermore, the  
29  
30 first prenatal visit should focus on dating the pregnancy and confirming viability of the fetus. In  
31  
32 fact, obese women are more likely to have anovulatory or irregular cycles, so that the utility of  
33  
34 determining the last menstrual period for establishing gestational age may be limited<sup>36</sup>. To  
35  
36 improve the accuracy of pregnancy-dating during the early first trimester, transvaginal  
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38 assessment of the crown-rump-length should be performed.  
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***Image clarity***

51  
52 In addition to the arithmetic indices, measuring the distance from skin surface to the  
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54 intrauterine region of interest (e.g. key fetal structures) allows simple documentation of the fat  
55  
56 layer, thereby conveying the grade of image clarity impairment (figure 1)<sup>35</sup>. Excess of abdominal  
57  
58 (subcutaneous or intraabdominal) fat results in an increased number of interfaces and  
59  
60 consecutively in marked attenuation of the signal. Attenuation encompasses absorption,  
reflection, reverberation and scatter<sup>37</sup>. The overall visualization of fetal organs with respect to

## Obstetrical ultrasound and obesity

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2  
3 increasing maternal size has been previously addressed by several studies<sup>38,39</sup>. Reduction in  
4  
5 successful image generation was most marked for cardiac and cerebrospinal structures as well  
6  
7 as the umbilical cord<sup>40,41</sup>. Catanzarite et al. postulated five categories of potential barriers to  
8  
9 complete fetal anatomic survey. In addition to maternal body habitus, other confounding  
10  
11 variables such as gestational age, fetal spine-up position, resolution/penetration of ultrasound  
12  
13 equipment and sonographer skills evidently exert influence on image clarity. The authors also  
14  
15 described a strong relation of scanning duration and completion of the anatomical survey in the  
16  
17 non-obese population. For each 5-minute time increment up to 30 minutes, the rate of complete  
18  
19 morphological assessment improved in their study<sup>42</sup>.

20  
21  
22 The impact of sonographer's experience on the rate of suboptimal visualization in the obese  
23  
24 gravida is obvious and was previously reported<sup>43,44</sup>. Rates of completed anatomic surveys rise  
25  
26 with advancing gestational age. The preferred timing of midtrimester ultrasound examination of  
27  
28 the obese gravida appears to be between 18-20 weeks' gestation in order to achieve maximum  
29  
30 efficiency with respect to the potential duration of the scan and need for repeated scans<sup>45,46</sup>. This  
31  
32 is slightly different to the findings of Wolfe et al. who stated an optimal overall organ  
33  
34 visualization at 21-23 weeks for a mean maternal BMI of 27.3 of the women enrolled in their  
35  
36 study<sup>40</sup>.

37  
38  
39 Hendler et al. described an inverse relationship between the severity of maternal obesity and the  
40  
41 ability to adequately visualize the fetal heart (37.3 % obese vs. 18.7 % non-obese,  
42  
43  $p < 0.001$ ) and craniospinal structures (42.8 % obese vs. 29.5 % non-obese,  $p < 0.001$ ). They  
44  
45 found a degradation in image quality by 10 % for every further step in obesity classification<sup>41</sup>.

46  
47  
48 Wolfe et al reported a 14.5 % reduction in visualization rates in the markedly obese patient<sup>40</sup>.  
49  
50 Similar observations were recently published with respect to suboptimal visualization of facial  
51  
52 soft tissue (39.1 % obese vs. 19.3 % non-obese,  $p < 0.001$ ) and abdominal wall (2.7 % obese vs. 0  
53  
54 % non-obese,  $p < 0.001$ )<sup>47</sup>. Series assessing the potential impact of maternal obesity<sup>48</sup> on optimal  
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56 visualization and completion of anatomic survey<sup>49</sup> are summarized in table 1.  
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## Obstetrical ultrasound and obesity

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3 Due to this poor transmission of ultrasound waves in adipose tissue there were several attempts  
4 to optimize in image quality. A transvaginal approach is beneficial for assessment of fetal  
5 structures close to the lower uterine segment and therefore mainly limited to ultrasound  
6 examinations throughout the first trimester. Measurement of fetal nuchal translucency between  
7 11-13+6 weeks most often performed transabdominally as this allows a wider range of scanning  
8 angles, may substantially be hampered by increasing maternal size<sup>50,51</sup>. In the obese patient  
9 therefore, a transvaginal assessment to facilitate a better resolution of the skin line, perispinal  
10 tissue or amniotic sheet as separate structures, should be considered<sup>35</sup>. This approach enables  
11 proper assessment of fetal limbs and extremities and is feasible to perform early fetal  
12 echocardiography as well. Recently, it has been postulated that most of the anomalies detectable  
13 during standard 18-week scan can be seen at 12 to 13 weeks with appropriate imaging even in  
14 obese women<sup>52</sup>. However, this has been challenged by other authors, which concordantly  
15 emphasize that a number of anomalies are not amenable to first trimester detection (regardless  
16 recent promising findings, such as intracranial translucency)<sup>53-55</sup>. Further studies are needed to  
17 systematically investigate the diagnostic capability of a first trimester anatomic sonogram and to  
18 establish reliable standards taking into account increased maternal size and limited acoustic  
19 window<sup>56</sup>.

20  
21 Beyond 14-15 weeks' gestation ultrasonic scans are preferentially performed by transabdominal  
22 imaging, thereby utilizing appropriate anatomic regions (e. g. lower transverse abdominal  
23 crease). Morbidly obese women often have an abnormally lowered, ptotic apron. Elevating and  
24 retracting the fatty apron (panniculus) towards the patient's head enables optimized access to  
25 the fetal areas of interest by placing the probe near the arcus tendineus superior to the pubis<sup>35,36</sup>.  
26 This is of particular importance with regard to diagnostic procedures such as chorionic villous  
27 sampling (CVS), amniocentesis (AC) or cordocentesis (CS). In later gestation it may also be  
28 helpful to get access to the gravid uterus from a subcostal approach with the women in a lateral  
29 position which shifts the abdomen towards the examination table. In general, the higher the  
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3 degree of maternal obesity, the higher will be the pressure exerted on the abdominal wall to  
4  
5 reduce the depth of insonation thereby trying to achieve an acceptable acoustic window.  
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#### 8 9 10 *Alternative approaches*

11 In obese patients, in whom a successful fetal anatomic survey has apparently failed, the maternal  
12 umbilicus, the thinnest section of the abdominal wall potentially affords improved image  
13 resolution. A previous series by Davidoff et al. revealed an optimized image clarity in most of the  
14 68 included women, but the relatively large curvilinear transducer may have limited the  
15 ultrasonic sector view<sup>37</sup>. Based on these findings Rosenberg et al. and later McCoy and co-  
16 workers established a transumbilical use of the endovaginal probe in the obese gravida<sup>57,58</sup>.  
17 Placement of the transvaginal transducer in the umbilicus resulted in improved resolution and  
18 satisfactory fetal cardiac survey in 95 % and 87 % respectively. The authors resumed, that  
19 transumbilical use of the transvaginal probe is a beneficial, well-tolerated technique, which  
20 clearly improves gray-scale imaging. In addition, color and pulsed Doppler interrogation of fetal  
21 vessels may also be optimized. Similar observations were made by Paladini, who assumed that  
22 improved cardiac visualization (with the fetus in breech presentation) may be achieved when  
23 the scan is performed with filled maternal bladder pushing the uterus cephalad, allowing the  
24 sonographer to explore the heart via the periumbilical region<sup>59</sup>.  
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43 On the contrary, a transrectal approach has been undertaken in those patients undergoing  
44 assisted reproduction where difficult embryo transfer was anticipated and transabdominal  
45 ultrasound guidance was hampered by increased BMI<sup>60</sup>. However, these procedures have not  
46 been regularly implemented in routine obstetrical ultrasound practice.  
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#### 51 52 53 54 *Tissue harmonic imaging*

55 Tissue harmonic imaging (THI), nowadays commonly implemented into commercially available  
56 ultrasound systems, constitutes a real-time imaging technique that relies on the detection of so-  
57 called harmonics created by non-linear propagation of the fundamental ultrasonic beam through  
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## Obstetrical ultrasound and obesity

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3 tissue<sup>61</sup>. The generation of harmonics by tissue itself increases with depth up to a point where  
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5  
6 attenuation causes them to decrease. Modern ultrasound transducers are able to isolate the  
7  
8 second harmonic frequency in the detected echo, enabling image rendering of harmonic  
9  
10 reflection. This relatively novel method of echo processing is useful while scanning technically  
11  
12 difficult patients to improve image quality and confidence of diagnosis<sup>62,63</sup>. Treadwell and  
13  
14 colleagues found that tissue harmonic imaging was able to improve resolution of at least one  
15  
16 fetal structure in more than 50 % of patients enrolled in their study<sup>64</sup>. Whether the use of THI  
17  
18 may result in improved detection of fetal abnormalities this study was not able to confirm,  
19  
20 because the included patients had normal fetuses. Nevertheless, the advantages of THI in fetal  
21  
22 cardiac examination were recently addressed by three studies<sup>65-67</sup>. The differences in image  
23  
24 clarity obtained by using THI in a morbidly obese gravida compared to inconclusive images  
25  
26 depicted without technical adjuncts are illustrated in figure 2. Other technical advances  
27  
28 facilitating improved ultrasound assessment of fetal morphology in obese mothers include pre-  
29  
30 and postprocessing techniques such as compound imaging, speckle reduction filters and multi-  
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32 Hertz transducer technology.  
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*Other imaging modalities*

39  
40 In recent years, three- and four-dimensional ultrasound applications have become clinically  
41  
42 valuable in obstetrics as well as in gynecology. Comparative studies addressing the beneficial  
43  
44 value of 3D ultrasound are contradictory. In a review of 11 studies comparing conventional 2D  
45  
46 imaging and 3D ultrasound for the diagnosis of facial anomalies, seven studies reported  
47  
48 additional information using 3D while four found similar findings achieved by these two  
49  
50 modalities<sup>68</sup>. Many of the studies on the accuracy of 3D ultrasonography in prenatal diagnosis  
51  
52 are biased by the availability of information from the initial 2D scan. Nevertheless, a previous  
53  
54 study suggests three-dimensional ultrasound as being capable of improving visualization of fetal  
55  
56 anatomy even in fetuses in anterior spine position<sup>69</sup>. In spite of the apparent advantages of 3D  
57  
58 obstetrical imaging, non-favourable scanning conditions, such as oligohydramnios, severe  
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3 obesity and the absence of tissue borderlines, cause the same problems in 3D as in 2D scanning  
4  
5 so far.

6  
7 Although ultrasound is the primary imaging modality for the evaluation of the fetus, because of  
8  
9 proven utility, relatively low cost and widespread availability, fetal magnetic resonance imaging  
10  
11 (MRI) has grown in popularity over the past two decades as a complementary tool for antenatal  
12  
13 assessment of fetal abnormalities<sup>70,71</sup>. MRI has been useful in confirming abnormalities seen on  
14  
15 ultrasound scan or determining the underlying cause of nonspecific sonographic anomalies and  
16  
17 may add incremental information that might have influence on prognosis or management at  
18  
19 birth<sup>72-74</sup>. Faster scanning techniques allow studies to be performed without sedation in the  
20  
21 second and third trimester with minimal motion artefacts<sup>75</sup>. Moreover, MRI is not hampered by  
22  
23 maternal obesity, fetal position, overlying bones or oligohydramnios, so that fetal MRI has  
24  
25 emerged as a clinically valuable diagnostic supplement to ultrasound in case of inconclusive  
26  
27 findings or degraded image.  
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### 34 ***Detection of malformations***

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36 Infants of obese parturients are reported to be at elevated risk for congenital malformations  
37  
38 (11.1 %) compared with those of mothers of average prepregnancy weight (7.9 %). Queisser-  
39  
40 Luft et al. reported significant odds for major malformations (OR 1.3, 95 % CI 1.0-1.7)<sup>76</sup>. Similar  
41  
42 findings were recently published by two meta-analyses in which the authors systematically  
43  
44 assessed the attributable risk for anomalies in the offspring of obese mothers<sup>21,22</sup>. Based on these  
45  
46 pooled data, obese women are at significantly increased odds of a pregnancy affected by a neural  
47  
48 tube defect (OR 1.87, 95 % CI 1.62-2.15). The statistically strongest correlation was found for  
49  
50 spina bifida (OR 2.24, 95 % CI 1.86-2.69). Moreover, an association of maternal adiposity and  
51  
52 cardiovascular anomalies (OR 1.30, 95 % CI 1.12-1.51) with significant odds for septal anomalies  
53  
54 (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  
55  
56 lip and palate (OR 1.20, 95 % CI 1.03-1.40); anorectal atresia (OR 1.48, 95 % CI 1.12-1.97);  
57  
58 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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## Obstetrical ultrasound and obesity

1  
2  
3 been described. On the other hand, the relative risk for gastroschisis among obese mothers was  
4 significantly lower (OR 0.17, 95 % CI 0.10-0.30) compared with women of recommended BMI<sup>77</sup>.  
5  
6 An opposite effect has been found for offspring with omphalocele, with increased odds (OR 1.63,  
7 95 % CI 1.01-2.47) when the mother was classified as obese. These data emphasize the superior  
8 importance of detailed sonographic examination of fetuses of obese pregnant women<sup>78,79</sup>.  
9  
10 According to the findings of the FaSTER (First and Second Trimester Evaluation of Risk) trial in  
11 an unselected obstetric population, it has been stated that maternal obesity significantly  
12 decreased the likelihood of sonographic detection of common anomalies (adjusted OR 0.7, 95 %  
13 CI 0.6-0.9)<sup>80</sup>. In a recent paper Dashe et al. assessed the impact of maternal body habitus on the  
14 detection of major structural abnormalities during second-trimester standard and targeted  
15 sonographic scan<sup>81</sup>. Detection of anomalous fetuses with standard ultrasound decreased  
16 substantially from 66 % in women having a normal BMI to only 25 % in morbidly obese women.  
17  
18 In high risk pregnancies receiving targeted scans detection of malformations ranged from 83 %  
19 (lean patients) to 67 % (class III obesity). Within the targeted group the detection rate was  
20 significantly lower among women with pre-gestational diabetes than in women with other high-  
21 risk indications. These data are consistent with previous findings. In order to facilitate proper  
22 counseling, the residual risk of an undetected anomaly was calculated to be 0.4 % among women  
23 of normal BMI compared to 1.0 % in obese gravida ( $p < 0.001$ ). However the authors did not  
24 address the issue whether follow up ultrasonography could have improved anomaly detection in  
25 obese women. Hendler et al. noted that 64 % of their included study population, who were  
26 scheduled for an additional fetal heart examination due to the initial inability to complete  
27 morphology assessment of the fetus, were obese<sup>82</sup>. The rate of persistent suboptimal  
28 visualization of cardiac structures even after recalled exam increased in a BMI-dependent  
29 manner from 1.5 % (non-obese) up to 20 % in morbidly obese women ( $p < 0.001$ ). In conclusion  
30 the authors stated that the rate of initially inadequate image clarity could be reduced by at least  
31 80 % by repeating sonographic scans, thereby improving the prenatal diagnosis of congenital  
32 heart defects in an obstetric setting. In accordance to these observations, which are similar to  
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3 previous reports, maternal obesity limits the likelihood of adequate ultrasound visualization  
4  
5 even when advanced ultrasound systems for assessing fetal structures are used<sup>83</sup>.  
6  
7

### 8 9 **Summary**

10 Given the continuing rise in prevalence of overall obesity, and in particular maternal obesity  
11 with impact on ultrasound imaging of fetal anatomy, obstetricians have to face new challenges in  
12 the antenatal and peripartal management of complications during pregnancy, labor, delivery and  
13 beyond. Obtaining adequate sonographic images in obese patients is of particular concern  
14 because of the increased rate of congenital anomalies. Considering the findings of sensitivity  
15 studies on mixed populations or obese gravid patients, it is reasonable that the anomaly scan at  
16 20 weeks' gestation should be left to experienced sonographers. Moreover, obese mothers will  
17 benefit from repeated ultrasonic scans.  
18

19 The main determinants of signal intensity and consecutive image clarity remain the depth of the  
20 part to be depicted as well as the specific tissue characteristics. Thus, future additions to the  
21 imaging efforts should include optimized signal processing, further advances in transducer  
22 technology or the adjunctive use of complementary image modalities such as fetal MRI to  
23 resolve associated shortcomings of obesity in obstetric practice.  
24

25 An appropriate counseling prior to the commencement of the sonographic exam of overweight  
26 and obese patients allowing for the limitations of the study is advisable. The greater potential for  
27 delayed or missed diagnoses in obese patients constitutes one of the major medicolegal issues in  
28 obstetric care.  
29

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## Obstetrical ultrasound and obesity

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