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Sonography in obese and overweight pregnant women: clinical, medicolegal and technical issues

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KEYWORDS: congenital anomalies; detection rate; obesity; overweight; screening; ultrasound

ABSTRACT

Obesity has increased dramatically worldwide over the last two decades, becoming a social concern. In pregnancy, obesity is associated with increased risk of maternal death and of significant complications, such as pre-eclampsia, diabetes and postpartum hemorrhage. Several papers have also reported an increased risk of major anomalies in the offspring of obese pregnant women. At the same time, carrying out an ultrasound examination on an obese pregnant woman is a difficult task, due to the impaired acoustic window. This Review discusses the clinical, technical and medicolegal problems associated with ultrasound examination in obese and/or overweight women and provides tips for performing these examinations. Copyright © 2009 ISUOG. Published by John Wiley & Sons, Ltd.

INTRODUCTION

Obesity is generally defined as 'a condition characterized by excess of body fat frequently resulting in a significant impairment of health and longevity'[1]. According to guidelines published in 1990 by the Institute of Medicine (IOM)[1] and acknowledged later by the World Health Organization[2], a woman is defined as obese if her body mass index (BMI, employed universally to assess body weight based on height and calculated using the formula weight/height^2) is in the range of 30.0–34.9 kg/m^2 and morbidly obese if her BMI is $\geq$35.0 kg/m^2.

The National Institute for Health and Clinical Excellence has further sub-categorized obesity into Classes I, II and III according to the BMI range (30.0–34.9, 35.0–39.9 and $\geq$40.0 kg/m^2, respectively)[3]. Women with a BMI ranging from 20.0 to 24.9 kg/m^2 are considered to have a normal weight, whereas those with a BMI $<$20.0 kg/m^2 are underweight. Being overweight is defined by a BMI higher than the normal range but below the threshold for frank obesity, i.e. in the range of 25.0–29.9 kg/m^2.

Recommendations for normal weight gain in pregnancy have been controversial, though the guidelines published by the IOM and reported in Table 1 were shown to be associated with the best reproductive fetomaternal outcome[4].

EPIDEMIOLOGY: DIMENSIONS OF THE PROBLEM (TABLE 2)

Obesity represents a growing social concern worldwide, its prevalence having doubled or even tripled in some places in under 20 years[2]. In Western countries, 28% of pregnant women are overweight and 11% are obese, and a worrying increase in the prevalence of obesity is now appearing in developing countries too[5–7]. In the USA, approximately 61–64.5% of the total population is classified as either overweight or obese; in the UK, 33% of women are overweight and 23% are obese, giving a total of 56% of women over the recommended BMI[2]. The Health Survey for England 2004 revealed a steady rise in the prevalence of obesity in women, from 16.4% in 1993 to 23.8% in 2004[8], and similar statistics have been published for most Western countries over the last decade. In France, the numbers are also creeping up, especially in young women aged 20–29 years[9]. Obesity affects about 20% of the German population and at least 28% of the Russian one[10]. In the islands of the Southern Pacific the prevalence of obesity is enormous, at 44–79%. In Brazil more than one third of females are obese[11]. Studies analyzing risk factors for obesity in women have demonstrated that African-American ethnicity, low level of school education and low-income households are all associated with an increased incidence of obesity[12,13].

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Table 1 Recommended total weight gain ranges for pregnant women according to prepregnancy body mass index (BMI)

	Recommended weight gain	
Prepregnancy BMI (kg/m²)	*kg*	*lb*
< 19.8, underweight	12.5–18.0	28–40
19.8–24.9, normal weight	11.5–16.0	25–35
25–29.9, overweight	7.0–11.5	15–25
> 29.9, obese	At least 6.8*	At least 15*

Modified from National Institute for Health and Clinical Excellence[2]. *Higher limit not specified.

MATERNAL AND FETONEONATAL CONSEQUENCES

Obesity, being overweight, high interpregnancy weight gain and high weight gain in pregnancy are all associated with an increased risk of important maternal and fetoneonatal complications[11,14–16] (Table 3). Obesity in women is associated with a higher incidence of amenorrhea and, hence, of infertility. The incidence of miscarriage in obese women undergoing *in-vitro* fertilization and egg-donation procedures is at least threefold higher than it is in non-obese ones[17,18]. In addition, obesity and being overweight in pregnancy have been associated with an increased risk of hypertensive complications, diabetes, thromboembolism, postpartum hemorrhage and, consequently, of maternal mortality[14–16]. Adverse fetoneonatal effects of maternal obesity include increased risk of macrosomia, prematurity and stillbirth, neonatal death and congenital anomalies.

INCREASED RISK OF CONGENITAL ANOMALIES IN FETUSES OF OBESE WOMEN (TABLE 4)

Several epidemiological studies have demonstrated an increased incidence of congenital anomalies in the offspring of obese pregnant women. In an interesting case–control study[19], the authors demonstrated that the neonatal incidence of a series of malformations was significantly increased in women with BMI > 30 kg/m². These anomalies included neural tube defects (NTD) and central nervous system malformations, conotruncal heart defects, ventral wall anomalies and other intestinal defects. Although other studies have not found such an association[20], a recent meta-analysis reviewed all available data published in peer-reviewed journals since 1980 and showed that the unadjusted odds ratios for an NTD-affected pregnancy were 1.22 (95% CI, 0.99–1.49), 1.70 (95% CI, 1.34–2.15), and 3.11 (95% CI, 1.75–5.46) among overweight, obese and morbidly obese women, respectively, compared with women of normal weight[21]. Another multicenter case–control study showed a weak to moderate positive association of maternal obesity with seven of 16 categories of birth defect and a strong inverse association with gastroschisis[22]. In this study, the malformation categories for which the odds ratios were increased in obese women were: spina bifida (not anencephaly), congenital heart disease, diaphragmatic hernia, omphalocele, anorectal atresia, hypospadia and limb reduction defects. The odds ratios for heart defects and omphalocele were also significantly increased in overweight women. Swedish[23] and a American[21] case–control studies confirmed the positive association between maternal obesity in early pregnancy and congenital heart defects in the offspring, the latter study also showing an increased risk for spina bifida, omphalocele and multiple anomalies. Another report from the same American research group demonstrated that women who are overweight or obese are more likely to conceive an infant with an obstructive renal anomaly[24]. Additional evidence of an increased risk of congenital anomalies in the offspring of obese and overweight women is provided by various studies demonstrating such an association[25–29]. It is important to emphasize that there are other significant studies, not listed in Table 4, that failed to demonstrate any association between pregnant women being obese/overweight and increased risk of malformations in the offspring. However, the amount of epidemiological research showing such an association is considerable, as evident in Table 4.

MECHANISM FOR THE ASSOCIATION BETWEEN OBESITY AND BIRTH DEFECTS

A number of theories have been put forward to explain the increased incidence of malformations in the offspring of overweight and obese women. The metabolic abnormalities of obesity, which include increased serum insulin, triglycerides, uric acid and endogenous estrogens, may have the same teratogenic 'fuel-mediated' effect as maternal insulin-dependent diabetes[30]. Chronic hypoxia and hypercapnia have also been considered as additional teratogenic factors in obese pregnant women. Obesity is associated with pre-existing diabetes mellitus, but most studies demonstrating an increased risk of congenital anomalies in obese women have adjusted their odds ratios for diabetes. Finally, another possibility is that the folic acid supplementation dose usually considered adequate to reduce the incidence of NTD in the normal-weight pregnant woman might be insufficient in the obese pregnant woman, due to lower gastrointestinal absorption and higher metabolic demands[31]. This hypothesis is supported by a case–control study on birth defects which demonstrated a daily intake of 400 μg folate to be protective against NTD in infants of women with a body weight ≤ 70 kg but not in infants of women weighing > 70 kg[31]. This concept is confirmed by another study demonstrating lower serum folate levels in women of childbearing age with a higher than normal BMI, even after control for intake[32].

SCANNING THE OBESE/OVERWEIGHT PREGNANT WOMAN: A REAL CHALLENGE

Scanning obese pregnant women is difficult, and on some occasions it may become a real challenge, as every medical

Table 2 Prevalence of obese and overweight females in selected countries

Country	Year of data collection	Population studied (n)	Age category (years)	% Overweight (BMI 25.0–29.9 kg/m²)	% Obese (BMI ≥ 30 kg/m²)	Total: % overweight/obese (BMI ≥ 25.0)
Argentina	2003	1100	18–65	10.8	17.5	28.3
Australia	2000	11 067	25+	29.9	22.2	52.1
Austria	1999	841	25–64	27	14	41
Bahamas	1988–89	1771	15–64	25.6	28	53.6
Belgium	1994–7	21 356	35–59	28	13	41
Brazil	1997	N/A	20+	26.5	12.5	39
Canada	2000/01	50 801	20–64	25	14	39
China	1998–2000	2776	20–94	28.9	5.5	34.4
Colombia	2000	3070	15–49	30.3	10.5	40.8
Czech Republic	1997/8	3068	25+	31.4	26.2	57.6
Denmark	1992	1624	30–60	26	11.3	37.3
Egypt	2000	6751	15–49	38.8	32.4	71.2
England	2004	5579	16+	34.7	23.8	58.5
Finland	1997	4394	25–64	33	19.4	52.4
France	2006	23 747	15+	23.3	13.0	36.3
Germany	2002	3807	25+	35.6	23.3	58.9
Ghana	1997	4731	25+	26.9	20.2	47.1
Greece	2001–2	3042	20–89	31	15	46
Guatemala	1998/9	2199	15–49	31.7	12.1	43.8
Hungary	1992–4	2559	18+	27.9	21.2	49.1
Iceland	1991–6	6178	18+	35.2	18.3	53.5
Iran	2000	10 145	20+	45	30	75
Ireland	1997–99	1379	18–64	32.5	15.9	48.4
Israel	1999–2001	2782	25–64	33.1	25.7	58.8
Italy	2003		18+	25.8	8.7	34.5
Jamaica	1999	1935	18+	30.3	23.9	54.2
Mexico	2000	41 188	20–69	36.2	29	65.2
Morocco	2000	1797	20+	29.8	21.7	51.5
Netherlands	1998–2002	3691	20–59	28.5	10.1	38.6
New Zealand	1997	4420	15+		19.2	
Norway (Limited area)	1995–97	66 140	20+	40	21	61
Peru	1998–2000	2337	18–60	40	23	63
Philippines	1998	9299	20+	18.9	4.4	23.3
Poland	2002		18–94	29	20	49
Portugal	2003–5	5123	18–64	31.9	14.6	46.5
Russia	2000	9006	19–55	27.4	21.6	49
Saudi Arabia	1995–2000	17 223	30+	31.8	44	75.8
Scotland	2003	6675	16+	33.8	26	59.8
Singapore	2004	4168	18–69	22.6	7.3	29.9
South Africa	1998	13 585	15+	25.9	27.9	53.8
Spain	1990–2000	9885	25–60	32.2	15.8	48
Sweden (Goteburg)	2002	1032	25–64	26.6	11	37.6
Switzerland	2000–1	2482	35–74	27.6	10.4	38
Turkey	2001–2	5016	20+	28.6	29.4	58
UAE	2000	1286	20–79	28.4	31.4	59.8
USA	2003–4		20–74	28.6	33.2	61.8
Venezuela	1981–87	7042	20–50	23	6.8	29.8
Wales	2003	7800	16+	30	18	48

Modified from the International Obesity TaskForce[5]. N/A, not available.

sonologist or sonographer knows. However, despite the widespread use of diagnostic ultrasound in pregnancy and the increasing rate of maternal obesity, there is little evidence in the literature of the fact that visualization of fetal anatomy in such circumstances is significantly impaired. With respect to the 20-week anomaly scan, which is probably the most important obstetric ultrasound examination, there are a few studies addressing the issue of suboptimal visualization of fetal anatomy in obese pregnant women. The first paper addressing this problem dates back to 1990, when Wolfe *et al.*[33] demonstrated that visualization rates of fetal anatomy fell by 14.5% if the BMI was > 90th centile. The authors pointed out that the heart and spine were the anatomical structures most difficult to visualize in obese women and that there was no improvement in the visualization rate with advancing gestational age. Unfortunately, despite 20 years of research and technical advances in the field of diagnostic ultrasound, the situation has barely changed. An interesting report published in 2004 compared the visualization rate for the different

Table 3 Risks related to obesity in pregnancy

Maternal	
	Maternal death or severe morbidity
	Cardiac disease
	Spontaneous first-trimester and recurrent miscarriage
	Pre-eclampsia
	Gestational diabetes
	Thromboembolism
	Post Cesarean wound infection
	Infection from other causes
	Postpartum hemorrhage
	Low breast-feeding rates
Fetal	
	Stillbirth and neonatal death
	Congenital abnormalities
	Prematurity
	Macrosomia

anatomical structures at the mid-trimester anomaly scan in the obese (BMI ≥ 30 kg/m^2) vs. non-obese (BMI < 30 kg/m^2) pregnant population undergoing ultrasound examination at a referral center[34]. The obese population, which accounted for 39% of the sample, was further subdivided into Class I (BMI ≥ 30 and < 35 kg/m^2), Class II (BMI ≥ 35 and < 40 kg/m^2) and Class III (BMI ≥ 40 kg/m^2). The rate of suboptimal visualization was significantly increased in the obese group for both the fetal heart (37% vs. 19%) and spine (43% vs. 29%), and was correlated linearly with degree of obesity (Table 5). The same researchers successively demonstrated that if the scan was repeated at 21 gestational weeks, 2 weeks after the former scan, which was performed at a mean of 19.1 weeks, there was a significant improvement in the visualization of cardiac anatomy in all classes of obesity[35] (Table 5). However, neither the 19-week nor the 21-week cardiac structure visualization rates can be regarded as acceptable in clinical practice, considering that the heart could not be properly assessed in 12–20% of the obese pregnant population. Hence, taking into account the increased risk of congenital heart disease in women who are overweight or obese[19,21–23,28] (Table 4) and the frustratingly low visualization rates, it would probably be best to consider maternal obesity *per se* as an indication for fetal echocardiography. Also, in view of the similarly increased risk of extracardiac anomalies, especially of NTD[19,21,22,25–28] (Table 4), one might wonder whether obese pregnant women should be referred directly from the onset of pregnancy to tertiary referral centers for fetal anatomical assessment. An early anatomy scan

Table 4 Literature review of epidemiological studies demonstrating an increased risk of congenital anomalies in the offspring of obese/overweight women

Reference	*Congenital anomaly*	*BMI category**	*Study design*	*Odds ratio*	*95% CI*
Rasmussen *et al.*[45] (2008)	Spina bifida	Obese	Meta-analysis	1.70	1.34–2.15
Waller *et al.*[22] (2007)	Spina bifida	Obese	Case–control	2.10	1.63–2.71
Waller *et al.*[19] (1994)	Spina bifida	Obese	Case–control	2.60	1.50–4.50
Watkins *et al.*[21] (2003)	Spina bifida	Obese	Case–control	3.50	1.20–10.3
Shaw *et al.*[25] (1996)	NTD	Obese	Case–control	1.90	1.30–2.90
Watkins *et al.*[26] (1996)	NTD	Obese	Case–control	1.92	1.08–3.40
Hendricks *et al.*[27] (2001)	NTD	Obese	Case–control	1.73	1.03–2.92
Queisser-Luft *et al.*[28] (1998)	Encephalocele	Obese	Case–control	7.30	1.70–50.6
Waller *et al.*[19] (1994)	Other CNS	Obese	Case–control	4.20	1.20–14.6
Queisser-Luft *et al.*[28] (1998)	Eye anomalies†	Obese	Case–control	5.00	1.30–20.0
Waller *et al.*[22] (2007)	Heart defects	Obese	Case–control	1.40	1.24–1.59
Waller *et al.*[22] (2007)	Heart defects	Overweight	Case–control	1.13	1.01–1.26
Watkins *et al.*[21] (2003)	Heart defects	Obese	Case–control	2.00	1.20–3.40
Watkins *et al.*[21] (2003)	Heart defects	Overweight	Case–control	2.00	1.20–3.10
Mikhail *et al.*[29] (2002)	Heart defects	BMI > 27	Retrospective cohort	6.50	1.20–34.9
Cedergren and Kallen[23] (2003)	Heart defects	Obese	Case–control	1.41	1.22–1.64
Cedergren and Kallen[23] (2003)	Heart defects	Overweight	Case–control	1.18	1.09–1.27
Waller *et al.*[19] (1994)	GA defect	Obese	Case–control	6.20	1.40–27.4
Queisser-Luft *et al.*[28] (1998)	GA defect	Obese	Case–control	4.40	1.10–17.7
Queisser-Luft *et al.*[28] (1998)	CAT	Obese	Case–control	6.30	1.60–24.8
Waller *et al.*[22] (2007)	Anorectal atresia	Obese	Case–control	1.46	1.10–1.95
Queisser-Luft *et al.*[28] (1998)	Urogenital system	Obese	Case–control	1.70	1.10–2.80
Waller *et al.*[22] (2007)	Hypospadia‡	Obese	Case–control	1.33	1.03–1.72
Waller *et al.*[22] (2007)	Hypospadia‡	Overweight	Case–control	1.25	1.01–1.54
Waller *et al.*[22] (2007)	Limb reduction	Obese	Case–control	1.36	1.05–1.77
Waller *et al.*[22] (2007)	CDH	Obese	Case–control	1.42	1.03–1.98
Waller *et al.*[22] (2007)	Omphalocele	Obese	Case–control	1.63	1.07–2.47
Waller *et al.*[22] (2007)	Omphalocele	Overweight	Case–control	1.50	1.04–2.17
Waller *et al.*[19] (1994)	Omphalocele	Obese	Case–control	4.20	1.20–14.6

*Obesity defined as BMI > 29.9 kg/m^2 and overweight as BMI = 25.0–29.9 kg/m^2. †Including anophthalmia and microphthalmia. ‡High-grade hypospadia. CAT, common arterial trunk; CDH, congenital diaphragmatic hernia; CNS, central nervous system; GA, great arteries; NTD, neural tube defects.

Table 5 Suboptimal visualization rates according to anatomical structure at the mid-trimester anomaly scan in the obese vs. normal-weight pregnant woman

		Suboptimal visualization rate (%) for BMI category:				
Anatomical structure	*Mean GA (weeks)*	*Normal weight < 30 kg/m^2*	*All obese ≥ 30 kg/m^2*	*Obese Class I 30–34.9 kg/m^2*	*Obese Class II 35–39.9 kg/m^2*	*Obese Class III ≥ 40 kg/m^2*
Heart	19	19	37	30	39	49
Heart; rescan*	21	2		12	17	20
Craniospinal†	36	29	43	37	44	53

Adapted from Hendler *et al.*[34,35]. $P < 0.001$ for all differences vs. normal weight (BMI < 30 kg/m^2). *Rate of suboptimal visualization at recall ultrasound 2 weeks later[35]. †Includes cerebellar diameter and posterior fossa, midline, cavum septi pellucidi, lateral ventricle atrial width and spine. GA, gestational age.

performed transvaginally would significantly reduce the suboptimal visualization rates, at least for limbs and extremities.

Regrettably, such a policy probably cannot be implemented, due to the numbers entailed: by definition, high-risk pregnancies, due to maternal and/or fetal problems, represent 10–20% of the total pregnant population, without taking obesity into account. Even though it is true that the two groups tend to overlap, due to the association between maternal obesity and such conditions as pre-eclampsia and diabetes (Table 3), transferring pregnancy care of all obese women to referral centers would mean that these advanced units would manage some 25–40% of all pregnancies, depending upon local obesity rates. This is simply not feasible, because there are not enough units and experts worldwide; it would require several years and substantial funds to train an adequate number of professionals.

TECHNICAL ISSUES

This section will aim to illustrate the technical factors responsible for the inadequate visualization rate of fetal anatomy in cases of maternal obesity and suggest possible ways to enhance visualization. The two major acoustic limiting factors in these cases are the depth of insonation required and the absorption of ultrasound energy (drop-out) by the abdominal adipose tissue. By definition, the mean depth of insonation at mid-trimester is of course deeper for obese women than it is for non-obese ones and the greater distance that the ultrasound waves have to travel means greater absorption and dispersion in the surrounding tissues. At the end of their journey, the ultrasound waves are weaker, having lost a significant amount of energy, and the backscatter from refraction is much higher. As a consequence, the signal-to-background noise ratio is also decreased.

To deal with these problems, ultrasound equipment producers have followed two lines of action. The first involves reducing the mean array emission frequency to warrant better penetration – obviously within the range of output energy levels recommended by the Food and Drug Administration in the USA and by the corresponding European community healthcare bodies. The second involves using all possible pre- and postprocessing filters and techniques to increase the signal-to-background noise ratio. The latter measures include tissue (not contrast) harmonic imaging, compound imaging and speckle reduction filters. Harmonic imaging exploits the generation of harmonic frequencies by an ultrasound wave as it propagates through tissue. Harmonic frequencies are created in relation to wave distortion caused by slight nonlinearities in sound propagation; these gradually deform the shape of the wave and result in development of harmonic frequencies not present in the initial wave. As a consequence, tissue harmonics increase with depth, being virtually absent at skin level and increasing up to the point at which tissue attenuation makes them decrease again. Therefore, their behavior is completely different from the fundamental frequency harmonic, the energy of which decreases linearly with depth[36,37]. This basic difference is the reason why the use of tissue harmonic imaging has been shown to improve image quality in obese individuals. In fact, our group has confirmed that in obese pregnant women tissue harmonic imaging improves the visualization of cardiac anatomy[38]. Compound imaging represents a broad bandwidth technology that combines multiple coplanar images captured from different beam angles to form a single real-time image. Spatial compounding reduces speckle artifacts and improves contrast resolution. Speckle reduction filters are post-processing tools that further improve image quality and contrast. These all represent technical advances that are thought to facilitate the ultrasound assessment of fetal anatomy in obese women, determining better edge recognition.

A clear demonstration of how dramatic the effects of such tools can be is shown in Figures 1 and 2. In these images, the heart and the cerebellum of the fetuses of two obese women are displayed with (Figures 1a and c and 2a and c) and without (Figures 1b and d and 2b and d) harmonic imaging, compound imaging and speckle reduction filter. The difference in the clinical information obtained is immense. However, despite these demonstrations and with the exception of harmonic imaging[38], one study claims that using high-end ultrasound equipment contributes only marginally to ameliorate the adequacy of ultrasound visualization of

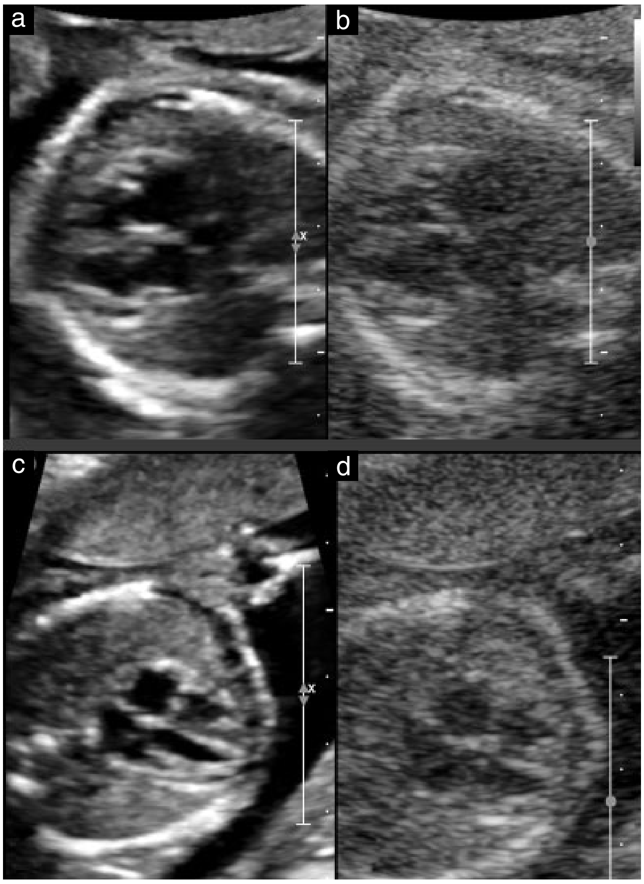

Figure 1 Four-chamber view of the fetal heart in an obese woman with a body mass index (BMI) of 35 kg/m^2 at 22 weeks (a,b) and in another obese woman (BMI, 33 kg/m^2) at 20 weeks (c,d). Images (a) and (c) were taken using technical tools: harmonic frequency, compound imaging and speckle reduction filter; (b) and (d) are corresponding images taken without technical tools. The different quality of the pairs of images is evident, especially at solid–fluid interfaces.

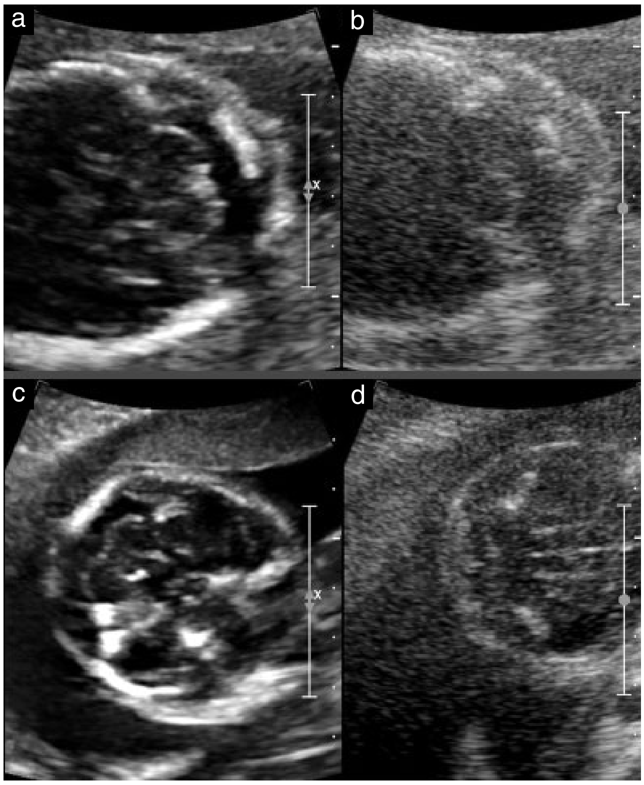

Figure 2 Transcerebellar view of the fetal head in the same women as in Figure 1. Images (a) and (c) were taken using technical tools: harmonic frequency, compound imaging and speckle reduction filter; (b) and (d) are corresponding images taken without technical tools. The different quality of the pairs of images is evident, especially at solid–fluid interfaces.

fetal cardiac structures in the obese pregnant woman[39]. Considering the evidence shown in Figures 1 and 2, there are two possible explanations for the results of that study: either the use of sophisticated scanners requires more experience in adapting the different settings to the actual depth of insonation and type of examination; or, more probably, the study is too old to have benefited from the most recent advances in ultrasound technology. Furthermore, the ultrasound devices used in the study, which was published in 2004, were not the latest releases available at that time.

COFACTORS IMPAIRING THE ACOUSTIC WINDOW

In this era of obesity epidemics there are, unfortunately, additional factors which impair even further the acoustic window: the increased rates of multiple pregnancies and of Cesarean sections. Multiple births have increased over the last few decades because of the higher demand for assisted-reproduction techniques[40]. Furthermore, infertility due to metabolic and/or hormonal problems is much more frequent in the obese female population[17,18], and it is therefore not uncommon to have to deal with an obese pregnant woman and a multiple pregnancy at the same time. Similarly, the rate of Cesarean births has increased due to several factors, including the increase in multiple pregnancies and an increase in age at first pregnancy[41]. All of these factors contribute to the lower accuracy of diagnostic ultrasound in obese pregnant women.

FINANCIAL ISSUES

As discussed above, due to the numbers involved, the community screening setting should remain in charge of screening ultrasound examinations of obese pregnant women. However, considering the significant technical limitations and the fact that more time is required per examination in difficult cases, healthcare managers should be aware that the widespread increase in maternal obesity will determine a slowdown in turnover at ultrasound clinics worldwide, with fewer examinations booked per time unit and, consequently, higher costs per single examination. The cost per single anomaly detected will consequently increase, considering both the higher cost of the examination and the lower detection rates demonstrated for obese women.

Another cost that scanning a larger number of obese pregnant women is likely to generate is related to

Table 6 Tips for the mid-trimester anomaly scan in obese women

Use all available technical tools improving image quality in obesity
Lower transducer emission frequencies
Harmonic imaging
Compound imaging
Speckle reduction filters
Consider approaching fetus through the four major abdominal areas with least subcutaneous fat:
Periumbilical area
Suprapubic area
Right and left iliac fossae
Consider using the transvaginal approach for assessment of the central nervous system in fetuses in vertex presentation
Wait for the fetus to be in optimal position, with a posterior spine
Become familiar with the use of color Doppler to check cardiac inflows and outflows
Gently inform the patient and her partner that obesity will reduce the diagnostic accuracy of the scan
Include a statement to this purpose in the information sheet provided with the ultrasound report, possibly supported by the references cited in this review
Consider including body mass index value in the demographic part of the report, to document presence or absence of maternal obesity
Report other cofactors of limited acoustic window, such as previous Cesarean section (for the scar), twinning and myomata

the probable increase of professional illnesses among obstetric sonologists[42,43]. In fact, the operator's arm joints, namely the shoulder girdle, the elbow and the wrist, are continuously under tension during the obstetric ultrasound examination, and muscular fatigue is known to increase with the degree and duration of muscle contraction. The higher is the degree of obesity, the higher will be the pressure needed to reduce the depth of insonation and/or to achieve an acceptable acoustic window; an increase in orthopedic illness is therefore predictable in the exposed category of professionals in the near-to-midterm future.

TIPS FOR SCANNING OBESE PREGNANT WOMEN (TABLE 6)

To overcome the acoustic window impairment problem in obese or overweight mothers, all the technical features discussed (lower emission frequencies, harmonic and compound imaging and speckle reduction filters) should be used: sometimes selectively and on other occasions in combination. However, another issue needs consideration. Usually, due to the high acoustic impedance, there is no problem in visualizing most of the gross fetal skeleton even in cases of maternal obesity. The major problem arising when the mid-trimester anomaly scan checklist is considered regards the visualization of low-impedance anatomical structures, such as the heart, cerebellum, lips and kidneys[33–35], and of the skeletal extremities, due to their small size. The best way to visualize the extremities is to perform a transvaginal scan at 12–15 weeks of gestation. This modality reduces the problem of the acoustic window, though in some cases the depth of insonation may be remarkable even with this approach. At the same time, it ensures an adequate assessment of limbs and extremities, especially as at this gestational age the fetal hands are often wide open. It may be worth also trying an initial evaluation of the fetal heart, if this is feasible and the operator is able to perform such a scan. Visualization of soft tissue parenchymatous organs should be dealt with at the time of the mid-trimester anomaly scan. At this gestational age, the key issue contributing to a sufficient, if not particularly good, examination of an obese woman is the choice of the best abdominal port of entry. It is well known that the abdominal adipose tissue tends to accumulate in the area between the umbilicus and the pubis, on the midline, while the umbilical area, the iliac fossae and the area just above the symphisis are less prone to fat accumulation. Hence, considering that the uterine fundus at the time of the mid-trimester anomaly scan is 5–10 cm below the umbilical transverse line, the best way to perform the examination is by combining these four entry sites (periumbilical, suprapubic and right and left iliac fossae). A trick worth considering is shown in Figure 3: considering the size of the pregnant uterus at 20 weeks of gestation, with the fetus in breech presentation, the heart is likely to lie just outside the transducer field when the maternal bladder is empty (Figure 3a); in contrast, a relatively full maternal bladder will push the uterus upwards, allowing the operator to explore the fetal heart through the periumbilical area (Figure 3b). In some cases, however, gray-scale imaging fails to demonstrate central cardiac connections, no matter what the approach. In these cases, the employment of color Doppler examination that is properly set up may at the very least demonstrate the inflows, outflows and crossover (Figure 4). It may be advisable to practice using color Doppler for basic evaluation of cardiac connections on lean women; becoming familiar with the expected color pattern of inflows and outflows will help in recognizing the same normal patterns in obese pregnant women.

LIMITING LIABILITY FOR OVERLOOKED ANOMALIES IN OBESE PREGNANT WOMEN

The aim of this section is not to address the thorny issue of medicolegal litigation for overlooked fetal anomalies. That would warrant another review by itself, considering the worldwide increase in lawsuits against healthcare professionals for this specific reason. The purpose here is

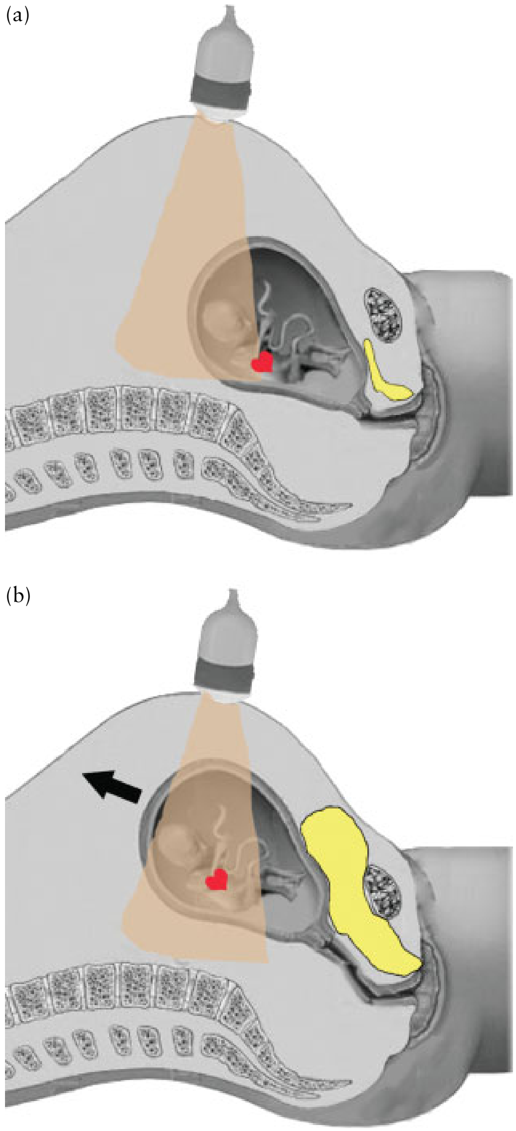

Figure 3 Field of view on ultrasound using a transabdominal periumbilical approach at 20 weeks of gestation. (a) With an empty maternal bladder (yellow) and the fetus in breech presentation, the heart (red) is just outside the field of view of the convex probe and can hardly be evaluated; (b) if the scan is performed with a full maternal bladder (yellow), the uterus is pushed upwards, allowing the operator to explore the fetal heart (red) through the periumbilical area.

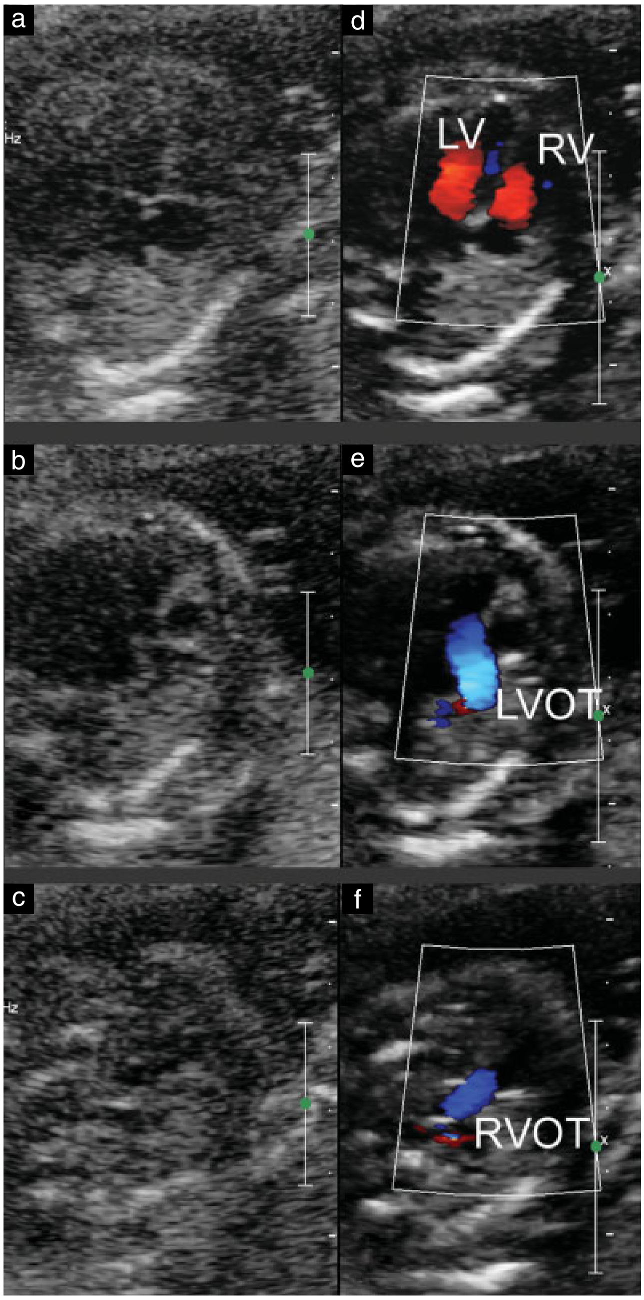

Figure 4 Color Doppler evaluation may help in demonstrating normal atrioventricular and ventriculoarterial connections in cases in which gray-scale ultrasound does not allow a conclusive examination due to maternal obesity. (a,b,c) Inconclusive gray-scale images of four-chamber view, left outflow tract view and right outflow tract view, respectively. (d,e,f) Corresponding color Doppler images demonstrating two normal ventricular inflows (d), an unremarkable left outflow tract (e) and an unremarkable main pulmonary artery crossing over the aorta (f), the direction of the aorta having been checked on the previous image. Normal, laminar blood flow, excluding inflow and outflow obstructions, is seen in all color Doppler images. LV, left ventricle; LVOT, left ventricular outflow tract; RV, right ventricle; RVOT, right ventricular outflow tract).

to suggest a few simple ways to try to prevent this problem (Table 6). The first thing is to talk to patients and husbands, kindly and sensitively pointing out the direct relationship between maternal BMI, impaired acoustic window and consequent increased chance of missing important fetal anomalies at ultrasound. The second and most important piece of advice is to include in the information leaflet that is usually attached to the ultrasound report a detailed explanation of the fact that obesity, as well as scars from prior Cesarean sections, twinning and/or the presence of myomata, may cause a reduction in the detection rate of congenital anomalies due to acoustic impairment. Adding a few references among those cited in this article may further support the concept. These measures will not be able to prevent all lawsuits, but may reduce their incidence, because the awareness of the parents of the decreased resolution of the ultrasound examination is important in the mechanism of the legal action.

Table 7 Hierarchy of evidence and grading of recommendations proposed by the United Kingdom National Institute for Health and Clinical Excellence[44]

Grading of evidence
- Ia: systematic review or meta-analysis of randomized controlled trials
- Ib: at least one randomized controlled trial
- IIa: at least one well-designed controlled study without randomization
- IIb: at least one well-designed quasi-experimental study, such as a cohort study
- III: well-designed non-experimental descriptive studies, such as comparative studies, correlation studies, case–control studies and case series
- IV: expert committee reports, opinions and/or clinical experience of respected authorities

Grading of recommendations
- A: based on hierarchy I evidence
- B: based on hierarchy II evidence or extrapolated from hierarchy I evidence
- C: based on hierarchy III evidence or extrapolated from hierarchy I or II evidence
- D: directly based on hierarchy IV evidence or extrapolated from hierarchy I, II or III evidence

Table 8 Levels of evidence and recommendation for the relationships between obesity and malformations and for the use of obstetric ultrasound in obese pregnant women

Obesity, pregnancy and malformations – Evidence and recommendations
- The prevalence of obesity is increasing worldwide (*Level of Evidence IIa*)
- Obesity, being overweight, high interpregnancy weight gain, and high weight gain in pregnancy are all associated with an increased risk of important maternal and fetoneonatal complications (*Level of Evidence IIa*)

Obesity, ultrasound and malformations – Evidence and recommendations
- Maternal obesity is associated with an increased risk of congenital anomalies in the offspring (*Level of Evidence IIa*)
- Visualization of fetal anatomy is more difficult in obese women and is linearly correlated with degree of obesity (*Level of Evidence III*)
- Lower ultrasound frequency emission, harmonic imaging, compound imaging and postprocessing filters (e.g. speckle reduction) improve visualization of fetal anatomy in cases of maternal obesity (*Level of Evidence III*)
- Abdominal scars from previous Cesarean birth(s) may further reduce the acoustic window (*Level of Evidence IV*)
- In obese pregnant women, it is advisable to perform an early anatomy evaluation, transvaginally, at 12–14 weeks of gestation (*Level of Evidence IV – Level of Recommendation D*)
- In obese pregnant women, the use of color Doppler may contribute to assessment of fetal cardiac anatomy also at screening level (*Level of Evidence IV – Level of Recommendation D*)
- It is advisable to include in the information sheet attached to the ultrasound report a note underscoring the fact that maternal obesity/being overweight and/or high weight gain in pregnancy are all associated with decreased image resolution and so a reduced detection rate for fetal anomalies (*Level of Evidence IV – Level of Recommendation D*)

In some countries in which the medicolegal pressure is higher, the couple sign an informed consent regarding the diagnostic limitations of prenatal ultrasound. Finally, to document the fact that the patient is obese/overweight or has undergone excessive pregnancy-related weight gain, it may be worth including in the report's demographic data the BMI of the patient, expressed as such or as height and weight. This simple figure will demonstrate objectively the difficulty of the examination.

GRADING OF EVIDENCE AND RECOMMENDATIONS

The level of evidence and recommendations for all data and procedures mentioned in this review have been assessed according to the hierarchy scale proposed by the United Kingdom National Institute for Health and Clinical Excellence[44] (Table 7), and are reported in Table 8.

CONCLUSIONS

The purpose of this review was not to solve the medicolegal and technical problems related to diagnostic ultrasound in obese and overweight pregnant women. Everybody performing such diagnostic examinations, from sonographers to medical sonologists and fetal medicine experts, is fully aware of the frustration and the difficulties experienced when performing a 20-week anomaly scan or a fetal echocardiogram in an obese pregnant woman. However, fetal medicine experts and fetal medicine doctors, have a duty to draw the attention of healthcare professionals, patients, lawyers, insurers and health-policy makers to yet another negative and costly effect of the irreversible and mounting wave of obesity: a significant reduction in the detection rate of congenital anomalies at the mid-trimester screening ultrasound examination.

REFERENCES

1. Institute of Medicine. *Nutrition During Pregnancy: Part I: Weight Gain, Part II: Nutrient Supplements*. The National Academy of Sciences: Washington, DC, 1990.
2. WHO: Controlling the global obesity epidemic. WHO health topics, 2004; http://www.who.int/nutrition/topics/obesity/en/index.html [Accessed 8 May 2009].
3. National Institute for Health and Clinical Excellence. Obesity: the prevention, identification, assessment and management of overweight and obesity in adults and children. National Institute for Health and Clinical Excellence (NICE), 2006; http://www.nice.org.uk/guidance/CG43 [Accessed 21 March 2009].

4. Abrams B, Altman SL, Pickett KE. Pregnancy weight gain: still controversial. *Am J Clin Nutr* 2000; **71**: 1233S–1242S.
5. International Association for the Study of Obesity. International Obesity Taskforce. http://www.iotf.org/database/GlobalAdults August2005.asp [Accessed December 2008].
6. James PT, Leach R, Kalamara E, Shayeghi M. The worldwide obesity epidemic. *Obes Res* 2001; **9**: S228–S233.
7. Katzmarzyk PT. The Canadian obesity epidemic, 1985–1998. *CMAJ* 2002; **166**: 1039–1040.
8. Health Survey for England. Updating of Trend Tables to Include 2004 Data.: Health and Social Care Information Centre, Part of the Government Statistical Service: Leeds, UK, 2004; ISBN: 1-84636-033-1.
9. Maillard G, Charles MA, Thibult N, Forhan A, Sermet C, Basdevant A, Eschwège E. Trends in the prevalence of obesity in the French adult population between 1980 and 1991. *Int J Obes Relat Metab Disord* 1999; **23**: 389–394.
10. Popkin BM, Doak CM. The obesity epidemic is a worldwide phenomenon. *Nutr Rev* 1998; **56**: 106–114.
11. Lev-Ran A. Human obesity: an evolutionary approach to understanding our bulging waistline. *Diabetes Metab Res Rev* 2001; **17**: 347–362.
12. Siega-Riz AM, Laraia B. The implications of maternal overweight and obesity on the course of pregnancy and birth outcomes. *Matern Child Health J* 2006; **10**: S153–S156.
13. Heslehurst N, Ells LJ, Simpson L, Batterham A, Wilkinson J, Summerbella CD. Trends in maternal obesity incidence rates, demographic predictors, and health inequalities in 36 821 women over a 15-year period. *BJOG* 2007; **114**: 187–194.
14. Abrams B, Parker J. Overweight and pregnancy complications. *Int J Obesity* 1988; **12**: 293–303.
15. Villamor E, Cnattingius S. Interpregnancy weight change and risk of adverse pregnancy outcomes: a population-based study. *Lancet* 2006; **368**: 1164–1170.
16. Yu CKH, Teoh TG, Robinson S. Obesity in pregnancy. *BJOG* 2006; **113**: 1117–1125.
17. Bellver J, Rossal LP, Bosch E, Zuniga A, Corona JT, Melendez F, Gómez E, Simón C, Remohí J, Pellicer A. Obesity and the risk of spontaneous abortion after oocyte donation. *Fertil Steril* 2003; **79**: 1136–1140.
18. Wang JX, Davies MJ, Norman RJ. Polycystic ovarian syndrome and the risk of spontaneous abortion following assisted reproductive technology treatment. *Hum Reprod* 2001; **16**: 2606–2609.
19. Waller DK, Mills JL, Simpson JL, Cunningham GC, Conley MR, Lassman MR, Rhoads GG. Are obese women at higher risk for producing malformed offspring? *Am J Obstet Gynecol* 1994; **170**: 541–548.
20. Moore LL, Singer MR, Bradlee ML, Rothman KJ, Milunsky A. A prospective study of the risk of congenital defects associated with maternal obesity and diabetes mellitus. *Epidemiology* 2000; **11**: 689–694.
21. Watkins ML, Rasmussen SA, Honein MA, Botto LD, Moore CA. Maternal obesity and risk for birth defects. *Pediatrics* 2003; **111**: 1152–1158.
22. Waller DK, Shaw GM, Rasmussen SA, Hobbs CA, Canfield MA, Siega-Riz AM, Gallaway MS, Correa A. Prepregnancy obesity as a risk factor for structural birth defects. *Arch Pediatr Adolesc Med* 2007; **161**: 745–750.
23. Cedergren MI, Kallen BAJ. Maternal obesity and infant heart defects. *Obes Res* 2003; **11**: 1065–1071.
24. Honein MA, Moore CA, Watkins ML. Subfertility and prepregnancy overweight/obesity: possible interaction between these risk factors in the etiology of congenital renal anomalies. *Birth Defects Res A Clin Mol Teratol* 2003; **67**: 572–577.
25. Shaw GM, Velie EM, Schaffer D. Risk of neural tube defect-affected pregnancies among obese women. *JAMA* 1996; **275**: 1093–1096.
26. Watkins ML, Scanlon KS, Mulinare J, Khoury MJ. Is maternal obesity a risk factor for anencephaly and spina bifida? *Epidemiology* 1996; **7**: 507–512.
27. Hendricks KA, Nuno OM, Suarez L, Larsen R. Effects of hyperinsulinemia and obesity on risk of neural tube defects among Mexican Americans. *Epidemiology* 2001; **12**: 630–635.
28. Queisser-Luft A, Kieninger-Baum D, Menger H, Stolz G, Schlaefer K, Merz E. [Does maternal obesity increase the risk of fetal abnormalities? Analysis of 20,248 newborn infants of the Mainz Birth Register for detecting congenital abnormalities.] *Ultraschall Med* 1998; **19**: 40–44.
29. Mikhail LN, Walker CK, Mittendorf R. Association between maternal obesity and fetal cardiac malformations in African Americans. *J Natl Med Assoc* 2002; **94**: 695–700.
30. Metzger BE. Biphasic effects of maternal metabolism on fetal growth. Quintessential expression of fuel-mediated teratogenesis. *Diabetes* 1991; **40**: 99–105.
31. Werler MM, Louik C, Shapiro S, Mitchell AA. Prepregnant weight in relation to risk of neural tube defects. *JAMA* 1996; **275**: 1089–1092.
32. Mojtabai R. Body mass index and serum folate in childbearing age women. *Eur J Epidemiol* 2004; **19**: 1029–1036.
33. Wolfe HM, Sokol RJ, Martier SM, Zador IE. Maternal obesity: a potential source of error in sonographic prenatal diagnosis. *Obstet Gynecol* 1990; **76**: 339–342.
34. Hendler I, Blackwelll SC, Bujold E, Treadwelll MC, Wolfe HM, Sokoll RJ, Sorokin J. The impact of maternal obesity on midtrimester sonographic visualization of fetal cardiac and craniospinal structures. *Int J Obesity* 2004; **28**: 1607–1611.
35. Hendler I, Blackwell SC, Bujold E, Treadwell MC, Mittal P, Sokol RJ, Sorokin Y. Suboptimal second-trimester ultrasonographic visualization of the fetal heart in obese women: should we repeat the examination? *J Ultrasound Med* 2005; **24**: 1205–1209.
36. Muir TG, Cartensen EL. Prediction of nonlinear acoustic effects at biomedical frequencies and intensities. *Ultrasound Med Biol* 1997; **6**: 345–357.
37. Tranquart F, Grenier N, Eder V, Pourcelot L. Clinical use of ultrasound tissue harmonic imaging. *Ultrasound Med Biol* 1999; **25**: 889–894.
38. Paladini D, Vassallo M, Tartaglione A, Lapadula C, Martinelli P. The role of tissue harmonic imaging in fetal echocardiography. *Ultrasound Obstet Gynecol* 2004; **23**: 159–164.
39. Hendler I, Blackwell SC, Treadwell MC, Bujold E, Sokol RJ, Sorokin Y. Does advanced ultrasound equipment improve the adequacy of ultrasound visualization of fetal cardiac structures in the obese gravid woman? *Am J Obstet Gynecol* 2004; **190**: 1616–1620.
40. Tomassini C, Grundy E, Skytthe A, Christensen K. Twins and their health cost: consequences of multiple births on parental health and mortality in Denmark and England and Wales. *Twin Res Hum Genet* 2006; **9**: 444–449.
41. Leung TY, Leung TN, Sahota DS, Chan OK, Chan LW, Fung TY, Lau TK. Trends in maternal obesity and associated risks of adverse pregnancy outcomes in a population of Chinese women. *BJOG* 2008; **115**: 1529–1537.
42. Schoenfeld A, Goverman J, Weiss DM, Meizner I. Transducer user syndrome: an occupational hazard of the ultrasonographer. *Eur J Ultrasound* 1999; **10**: 41–45.
43. Magnavita N, Bevilacqua L, Mirk P, Fileni A, Castellino N. Work-related musculoskeletal complaints in sonologists. *J Occup Environ Med* 1999; **41**: 981–988.
44. Harbour R, Miller J. A new system for grading recommendations in evidence based guidelines. *BMJ* 2001; **323**: 334–336.
45. Rasmussen SA, Chu SY, Kim SY, Schmid CH, Lau J. Maternal obesity and risk of neural tube defects: a metaanalysis *Am J Obstet Gynecol* 2008; **198**: 611–619.

