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Impact of ultrasound speed choice on the quality of the second-trimester fetal ultrasound examination in obese women

Running title

Ultrasound speed choice and fetal sonography quality in obese women

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List of abbreviations

4CV: four chambers view,

BMI: body mass index

GA: gestational age

RVO: right ventricular outlet

SD: standard deviation

Abstract

Purpose. The purpose of this study was to assess the impact of the free choice of ultrasound propagation velocity on ultrasound image construction to improve the completion rate and anatomical quality of fetal second-trimester ultrasound examination in obese women.

Materials and methods. This repeated cross-sectional single-center study retrospectively collected second-trimester ultrasound images of 88 obese women. During the first period, ultrasound examinations were performed in 44 women (mean age, 31.4 ± 5.9 [SD] years; range: 21.1 - 45.3 years) applying only the standard 1540 m/s tissue ultrasound velocity (group 1). During the second period, ultrasound examinations were performed in other 44 women (mean age, 31.4 ± 5.1 [SD] years; range: 20.6 - 41.6 years) with the operator free to choose among three available velocity settings (1420 m/s, 1480 m/s or 1540 m/s) for the scanning planes for the morphological images (group 2). All women underwent mid-trimester ultrasound examination at 20 to 24 gestational weeks. Two observers assessed the examinations in both groups for completeness, quality, and duration of fetal ultrasound examinations.

Results. No differences in age ($P > 0.99$), body mass index ($P = 0.67$), prevalence of previous cesarean delivery ($P = 0.30$), or gestational age at the second-trimester scan ($P = 0.20$) were found between the two groups. The mean cumulative duration of these ultrasound examinations was longer in group 1 than in group 2 (for both the complete ($P = 0.04$) and incomplete ($P = 0.03$) examinations). The quality of the anatomic images according to Salomon's criteria was less often acceptable in group 1 (5/44, 11.4%) than in group 2 (15/44, 34.1%) ($P = 0.02$).

Conclusion. Free choice of ultrasound velocity improves the overall performance of fetal

second-trimester ultrasound examinations in obese women.

Keywords: Ultrasonography, prenatal; Pregnancy trimester, second; Ultrasound propagation velocity; Image quality; Obesity

Introduction

Obesity affects 10% of women of childbearing age in Europe and up to 25.6% in the United States of America [1,2]. Maternal obesity is associated with increased use of health care [3] and increased risk of fetal abnormalities, in particular of the heart and spine [4–6]. Studies have shown that the degree of impairment of fetal ultrasound is directly correlated with maternal body mass index (BMI). Dashe et al. demonstrated that the visualization of fetal anatomy decreases significantly with increasing maternal BMI [7], most markedly for the heart, the spine, and the abdominal wall. They also showed that the higher the maternal BMI, the higher the risk of false negative findings for the diagnosis of fetal malformations, both for screening ultrasound examinations (detection rate 66% for BMI < 25 vs. 25% for BMI > 40) and more importantly in target or referral ultrasound examinations (*i.e.*, in women at high-risk or with a fetal abnormality observed in standard ultrasound), when the operator should be especially alert (97% for BMIs < 25 vs. 75% for BMI > 40) [7].

Second-trimester fetal ultrasound examinations have been standardized and several objective image quality criteria have been developed [8,9]. Both completion rates and the quality of anatomical visualization are lower in the obese population, mainly because of the thickness of the subcutaneous fatty layer [10]. The literature suggests that repeating and/or increasing the duration of the ultrasound scan may improve its completion [10–12].

Ultrasound image construction is based on equations that contain the value of the propagation velocity of sound waves; this velocity is assumed conventionally to be constant and equal to 1540 m/s in the human body, and this value is used by virtually all manufacturers [13–15]. In fatty tissue, however, the actual propagation velocity is 1450 m/s [14]. The superiority of this ultrasound velocity value for the construction of images in the presence of fat was initially suggested for breast imaging, as the breast is a predominantly adipose organ [16]. Because ultrasound velocity in fat tissue is slower than in other soft tissues (*i.e.*, 1450 m/s vs. 1540 m/s), the intrinsic image quality in terms of sharpness and precision is improved when the slower value is applied to image construction [17].

The purpose of this study was to assess the impact of the choice of ultrasound velocity in the

image construction calculations on the completion and anatomical quality of the images from fetal ultrasound examinations of obese women.

Material and methods

Patients

This repeated cross-sectional single-center study retrospectively collected second-trimester ultrasound images of women with obesity (*i.e.*, BMI ≥ 30 kg/m²) during two separate periods. The first period ran from January 1, 2014, to May 31, 2015, and the second from January 1, 2016, to May 31, 2017. This study was approved by our Institutional Review Board (IRB approval 5921).

Eligible files were selected from among pregnant women who underwent their second-trimester ultrasound examination for fetal anomalies, in compliance with French national recommendations (at 20-24 gestational weeks) [9]. Women with multiple pregnancies and those with BMI < 30 were excluded. Patients were extracted from our database through the ICOGEM[®] electronic medical file used in our department (Medicode[™], 13390 Auriol, France) by two investigators (A.P. and N.S.). Patients of the two periods were matched to 1:1 for BMI category (Figure 1). The fetal images for each woman were available from the picture archiving and communication system) and reporting software (GE Medical Systems).

Ultrasound protocol

Two ultrasound devices were used: Voluson[™] VE-8 (GE Medical Systems) equipped with real-time four-dimensional abdominal transducers supporting a bandwidth of 2–8 MHz and two-dimensional abdominal transducers supporting a bandwidth of 2–5 MHz) and Aixplorer[™] (SuperSonic Imagine[®]), equipped with two-dimensional abdominal transducers supporting a bandwidth of 1-6 MHz. During the first period, ultrasound image construction applied the conventional 1540 m/s ultrasound velocity (group 1). During the second period, the device was able to offer several calculations of ultrasound propagation speed (1420 m/s, 1480 m/s or 1540 m/s), choice available on the control screen at the touch of a button, with the operator able to choose between these for morphological ultrasound examinations while biometric images continued to be acquired at the conventional ultrasound velocity (1540 m/s), in view of the current absence of guidelines for ultrasound measurements using nonconventional velocities (group 2). All ultrasound examinations were performed by five

experienced practitioners (≥ 10 years of experience) (M.A., D.G., D.J., D.L., and H.L.) in both groups.

Image analysis

Two investigators (A.P. and N.S.), who were not involved in ultrasound examinations, independently reviewed each image. For each ultrasound examination, the evaluation criteria included: (i), Completeness of fetal ultrasound examination; (ii), Quality score; (iii), Maternal age; (iv), BMI; (vi), Previous cesarean section; (vii), Duration of each ultrasound examination; and (viii), Number of attempts to obtain acceptable ultrasound examination.

The completeness of the fetal ultrasound examination, defined as the presence of the nine images included in the French fetal ultrasound scan screening guidelines recommended until July 2016 [18] and included in the 13 recommended images since July 2016 [9]. These guidelines include three biometric images (head and abdominal circumferences and femur length measurement) and six images to assess key anatomical features (four-chamber view, right ventricular outlet, kidneys, diaphragm, spine, and face/lips) [19]. The quality score proposed by Salomon et al. applied to the 6 morphological images [20]. This score varied from 4 to 6 depending on the anatomical plane in question. The maximum score including 3 biometric and 6 morphological items was 48 and 32 when the biometric planes were excluded. The threshold for considering each image as “acceptable” was 33% of its maximum possible score [20]. Duration of each ultrasound examination was defined by the interval between the clock time provided by the machine at the first and last image of each ultrasound examination. The number of attempts to obtain acceptable ultrasound examination was defined by the number of attempts to complete (or fail to complete) the screening at an acceptable quality level. If there were several attempts, the cumulative duration was considered.

Statistical analysis

Both groups were matched for BMI, in three classes (30-34.9; 35-39.9; ≥ 40) (1:1 matching). Group 1 included women from the first period and group 2 from the second period. Quantitative variables and results are reported as means \pm SD and ranges, and categorical variables as raw numbers, proportions, and percentages. The demographic characteristics of the two samples were compared with the Chi-2 or Fisher exact test, as appropriate, for the categorical variables, and Student's t test or the Mann-Whitney test for the

continuous variables. Results were expressed as means \pm standard deviations (SD) and ranges. The completion rates and quality of the ultrasound scans between the two groups were assessed by the McNemar and Pearson tests or the Friedman test for categorical variables and by paired Student's t tests for continuous variables. The analysis was performed with SAS software (version 9.4, SAS Institute, Inc.). A P value < 0.05 was considered significant.

Results

The study includes 88 patients: 44 in group 1 and 44 in group 2. Table 1 summarizes the maternal characteristics in each group. The groups did not differ significantly for age ($P = 0.99$), prevalence of previous cesarean delivery ($P = 0.30$) and gestational age at second-trimester fetal ultrasound ($P = 0.20$). No fetal or neonatal abnormality was observed.

No difference in completeness of first fetal ultrasound examination was found between group 1 (18/44, 40.9%) and group 2 (26/44, 59.1%) ($P = 0.14$) (Table 2). No difference in mean duration of the first attempt was found between group 1 (16.9 ± 8.8 [SD] min; range: 6.0 - 58.0 min) and group 2 (18.4 ± 5.3 [SD] min; range: 10.0 - 30.0 min) ($P = 0.29$). Whether or not the ultrasound examination was completed and regardless of the number of attempts, the overall cumulative duration was shorter in group 2 than in group 1 ($P = 0.03$). The result was similar when only complete fetal ultrasound examinations were considered ($P = 0.04$) (Table 3). The groups did not differ significantly in their successes in obtaining each recommended plane (Table 4). No differences in acquisition were observed for the diaphragm, right ventricular outlet, kidneys and other structures. According to Salomon's quality score, it was more difficult to obtain anatomical images of acceptable quality in group 1 (5/44, 11.4%) than in group 2 (15/44, 34.1%) ($P = 0.02$) (Table 5) [20]. The mean Salomon quality score (maximum 32) for all 6 images was lower in group 1 (16.4 ± 4.3 [SD]; range: 1.0-24.0) than in group 2 (19.8 ± 4.6 [SD]; range: 7.0 - 28.0) ($P < 0.001$).

Discussion

Our results show that completeness of morphological images on fetal ultrasound is better when the operator can choose the ultrasound velocity to be used to construct them. Meeting the anatomical criteria for the images produces higher scores and less cumulative time spent on ultrasound examinations, regardless of the number of attempts. These points are important, even if fetal ultrasound scans are necessarily longer in mothers with obesity and even though some remain incomplete [10–12]. Adaptation of the ultrasound velocity used to construct the

images appears to improve the overall quality of the examination rather than that of each item, considered alone, since adjustments are required for each woman, adapted to the distribution of her adipose tissue and distance between probe and target. It has previously been shown that sharpness and precision are both better when a lower propagation velocity in adipose tissue is applied for image formation [21]. It therefore enhances the visibility of each anatomical element studied and improves the operator's ability to meet the standard criteria. Therefore the main interest of this work was to study the completion rate and the anatomical quality of fetal second-trimester ultrasound scans of women with obesity when the sonographer had a free choice of ultrasound velocities. The modification of the calculation of ultrasound propagation velocity does not change intrinsic ultrasound properties such as mechanical and thermal indexes.

This study was conducted retrospectively on data previously collected under routine working conditions. This explains why indicators such as Salomon's score and examination duration may look suboptimal compared with those obtained in prospective studies designed to evaluate image quality [8,20]. The bias of trying to obtain, as closely as possible, an image meeting all the anatomical criteria of the score selected for the evaluation may artificially lead to optimization of this score, while a retrospective rating, such as here, describes unbiased routine practices [22]. On the other hand, in routine practice, operators who fail to obtain the "academic" image recommended always seek alternative means of acquiring the equivalent clinical information and, consequently, are unlikely to spend too much extra time. Here we consider only recommended published scanning planes and scores. It would be interesting to evaluate elsewhere how and when practitioners use such alternative strategies. To date, the literature is inadequate to enable an assessment of the potential consequences on the variability of the biometric measurements of taking the tissue propagation speed into account for image construction [17]. This is why, in routine practice, fetal biometric measurements in both groups were assessed at a presumed velocity of 1540 m/s. Thus, the possible impact of the criterion "ultrasound celerity" (or "proper velocity") on the quality of an anatomical image, which is what Salomon's score seeks to assess, can be assessed only from the 6 morphological, that is, non-biometric images comprising the score. Choice of ultrasound speed might also be useful in improving the quality of first-trimester ultrasound images. The qualitative evaluation would then be performed with the Herman score [23,24]. In this context, it will also be necessary to study other technical alternatives for obtaining images of sufficient quality in obese women, such as the use of transvaginal ultrasound [25].

In conclusion, the difficulties for performing obstetric ultrasound examination in obese women and fully verifying fetal morphology impair the effectiveness and efficacy of fetal abnormality screening [4–6]. These limitations have led operators to modify their practices. They can use unusual acoustic windows and increase the duration and repetition of ultrasound examinations but these changes have substantial functional, organizational, and financial impacts [10,11,26,27]. In this context, the possibility of fine-tuning image formation by adapting it to the true ultrasound propagation velocity in adipose tissue is a helpful adjunct for improving the overall performance and cost effectiveness of ultrasound; that is, it makes fetal morphological assessment more complete, improves its quality, and results in faster performance and less need for repeat ultrasound examinations.

Disclosure of interest

The authors declare that they have no competing interest.

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Author contributions

All authors attest that they meet the current International Committee of Medical Journal Editors (ICMJE) criteria for Authorship.

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Legends for figures

Figure 1. Study flow chart. BMI indicates body mass index. WG indicates weeks of gestation.

Table 1: Women's characteristics.

Table 2: Completeness of mid-trimester fetal ultrasound examination.

Table 3: Duration of ultrasound examinations.

Table 4: Presence of expected images regarding the number of ultrasound examinations.

Table 5. Ability to obtain planes of acceptable quality (i.e., Salomon score \geq 33% of maximum).

First period (January 2014 - May 2015)
2103 second trimester ultrasound examinations by
experienced operators

Excluded patients (1974)
442 multiple pregnancies
1484 non obese women
48 ultrasound before 20 WG or after 24 WG

129 obese women with ultrasound
examination between 20 and 24 WG

Second period (January 2016-May 2017)
1658 second trimester ultrasound examinations by
experienced operators

Excluded patients (1539)
351 multiple pregnancies
1109 non obese women
79 ultrasound before 20 WG or after 24 WG

119 obese women with ultrasound examination
between 20 and 24 WG
53 examinations with free choice ultrasound
velocity

44 women from first period (group 1) and 44 women
from second period (group 2)
matched 1:1 for BMI category

	Group 1 (n = 44)	Group 2 (n = 44)	<i>P</i>
GA at first ultrasound examination	22.4 ± 1 [20.3 -24.4]	22.7 ± 0.9 [20.6 - 24.3]	0.20
Maternal age (years)	31.4 ± 5.9 [21.1 - 45.3]	31.4 ±5.1 [20.6 - 41.6]	0.99
Previous cesarean section			0.30
1	11 (11/44; 25.0%)	8 (8/44; 18.1%)	
≥ 2	5 (5/44; 11.4%)	9 (9/44; 20.5%)	

Group 1: Ultrasound examinations were performed using the single conventional 1540 m/s ultrasound velocity for image construction

Group 2: Ultrasound examinations performed with the operator's choice of ultrasound velocities to calculate image construction (1420 m/s, 1480 m/s or 1540 m/s)

GA: gestational age

Quantitative variables are expressed as means ± standard deviations; numbers in brackets are ranges. Qualitative variables are expressed as raw numbers; numbers in parentheses are proportions followed by percentages.

	Group 1 n = 44	Group 2 n = 44	<i>P</i>
Completeness at first ultrasound examination	18 (18/44; 40.9%)	26 (26/44; 59.1%)	0.14
Final completeness	25 (25/44; 56.8%)	27 (27/44; 61.4%)	0.83

Group 1: Ultrasound examinations performed with the conventional 1540 m/s ultrasound velocity calculation

Group 2: Ultrasound examinations performed with the operator's choice of ultrasound velocities to calculate image construction (1420 m/s, 1480 m/s or 1540 m/s)

	Group 1	Group 2	<i>P</i>
Duration of first ultrasound examination (complete or not) (min)	n = 44 16.9 ± 8.8 [6 - 58]	n = 44 18.4 ± 5.3 [10 - 30]	0.29
Cumulative duration of ultrasound examination (complete or not)	n = 44	n = 44	0.03
< 20 min	20 (20/44; 45.5%)	27 (27/44; 61.4%)	
20-29 min	14 (14/44; 31.2%)	13 (13/44; 29.6%)	
≥ 30 min	9 (9/44; 20.5%)	4 (4/44, 9.1%)	
Cumulative duration of ultrasound examination (complete only)	n = 25	n = 27	0.04
< 20 min	12 (18/25; 48.0%)	18 (18/27; 66.4%)	
20-29 min	8 (8/25; 32.0%)	8 (8/27; 29.6%)	
≥ 30 min	5 (5/25; 20.0%)	1 (1/27; 3.7%)	

Group 1: Ultrasound examinations performed using the single conventional 1540 m/s ultrasound velocity for image construction

Group 2: Ultrasound examinations performed with the operator choice of ultrasound velocities to calculate image construction (1420 m/s, 1480 m/s or 1540 m/s)

Quantitative variables are expressed as means ± standard deviations; numbers in brackets are ranges. Qualitative variables are expressed as raw numbers; numbers in parentheses are proportions followed by percentages. Bold indicates significant *P* value.

	First ultrasound examination			Several ultrasound examinations		
	Group 1 n = 44	Group 2 n = 44	<i>P</i>	Group 1 n = 44	Group 2 n = 44	<i>P</i>
BPD	44 (44/44; 100%)	44 (44/44; 100%)	> 0.99	44 (44/44; 100%)	44 (44/44; 100%)	> 0.99
AC	44 (44/44; 100%)	42 (42/44; 95.5%)	> 0.99	44 (44/44; 100%)	44 (44/44; 100%)	> 0.99
FL	44 (44/44; 100%)	44 (44/44; 100%)	> 0.99	44 (44/44; 100%)	44 (44/44; 100%)	> 0.99
Face/lips	36 (36/44; 81.8%)	39 (39/44; 88.6%)	0.55	40 (40/44; 90.9%)	40 (40/44; 90.9%)	> 0.99
4CV	36 (36/44; 81.8%)	42 (42/44; 95.5%)	0.08	44 (44/44; 100%)	44 (44/44; 100%)	> 0.99
RVO	31 (31/44; 70.5%)	39 (39/44; 88.6%)	0.08	41 (41/44; 93.2%)	40 (40/44; 90.9%)	> 0.99
Diaphragm	31 (31/44; 70.5%)	37 (37/44; 84.1%)	0.21	33 (33/44; 75.0)	37 (37/44; 84.1%)	0.42
Kidneys	36 (36/44; 81.8%)	34 (34/44; 77.3%)	0.77	40 (40/44; 90.9%)	37 (37/44; 84.1%)	0.55
Spine	35 (35/44; 79.6%)	41 (41/44; 93.2%)	0.11	40 (40/44; 90.9%)	42 (42/44 ; 95.5%)	0.69

Group 1: Ultrasound examinations performed using the single conventional 1540 m/s ultrasound velocity for image construction

Group 2: Ultrasound examinations performed with the operator's choice of ultrasound velocities to calculate image construction (1420-1480-1540 m/s)

BPD: biparietal diameter, AC: abdominal circumference, FL: femur length, 4CV: four chambers view, RVO: right ventricular outlet.

Face/lips			
	Group 1 (n = 40)	Group 2 (n = 40)	P
Acceptable	9 (9/40; 22.5%)	11 (11/40; 27.5%)	> 0.99
4CV			
	Group 1 (n = 44)	Group 2 (n = 44)	
Acceptable	27 (27/44; 61.4%)	27 (27/44; 61.4%)	> 0.99
RVO			
	Group 1 (n = 41)	Group 2 (n = 40)	
Acceptable	20 (20/41; 40.8%)	16 (16/40; 40.0%)	0.42
Diaphragm			
	Group 1 (n = 33)	Group 2 (n = 37)	
Acceptable	8 (8/33; 24.2%)	16 (16/37; 43.2%)	0.33
Kidneys			
	Group 1 (n = 40)	Group 2 (n = 37)	
Acceptable	16 (16/40; 40.0%)	17 (17/44; 46.0%)	0.55
Spine			
	Group 1 (n = 40)	Group 2 (n = 42)	
Acceptable	27 (17/40; 67.5%)	27 (27/42; 64.3%)	1.0
All planes			
	Group 1 (n = 44)	Group 2 (n = 44)	
Acceptable	5 (5/44; 11.4%)	15 (15/44; 34.1%)	0.02

Group 1: Ultrasound examinations performed using the single conventional 1540 m/s ultrasound velocity for image construction

Group 2: Ultrasound examinations performed with the operator's choice of ultrasound velocities to calculate image construction (1420 m/s, 1480 m/s or 1540 m/s)

Data are expressed as raw numbers; numbers in parentheses are proportions followed by percentages. Bold indicates significant *P* value.

4CV: four chambers view, RVO: right ventricular outlet