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Frontal tangential coronal view two-dimensional ultrasonography in assessment of fetal face [mouth and nose] in comparison with four-dimensional ultrasonography

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Abstract

Background: The fetal face reflects strictly the development of the fetal brain during its growth. Four-dimensional (4D) examination permits continuous monitoring of the examined parts of fetal face and surface. The final performance of obstetric sonographic images depends upon multiple factors, such as fetal lie, uterine wall, abdominal wall fat, amniotic fluid, and the number of gestations which may limit the optimum performance of (4D) ultrasound. The two-dimensional (2D) ultrasound is the first choice due to its wide availability, low cost, and real-time capabilities. The tangential view obtained by (2D) ultrasound coronal sections through the face showed the nose, nostril, lips, eye, lens, and hard palate.

Results: One hundred and sixty fetuses showed straight forwards obstetric examination by both 2D and 4D examinations with identical final reports. While the total number of fetuses with clear images by 2D frontal tangential coronal examination was 191 cases, only 29 cases failed, whereas 170 cases obtained clear images by 4D examination, and 50 cases failed. Both 2D and 4D ultrasound failed to obtain clear images of 19 cases, while 4D failed for 31 cases, and 2D failed for 10 cases. 2D imaging was found to be significantly better than 4D imaging, with a *P* value of 0.009.

Conclusion: 2D ultrasound using the frontal tangential coronal view is an essential part of the fetal examination and more superior than 4D ultrasound in assessing facial anatomy and anomalies, as well comparable to 4D ultrasound as regards fascial expression.

Keywords: 2D, 4D, Fetal face

Background

Prenatal diagnosis of malformations, such as lip/palate clefts, involves no immediate risk to life and can be operated on during the neonatal period. The impact of the prenatal diagnosis can be beneficial and can help the parents prepare to welcome their future child by meeting the pediatricians and the surgeons, as well as facilitating better integration of the child into the family, society and school [1].

There is a strong correlation between orofacial clefting and other structural anomalies, as well the genetic and chromosomal disorders [1]. The fetal face movement and its expressions reflect strictly the development of the fetal brain during its growth and might be the clue of brain functions [2].

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At mid-pregnancy; one sonographic examination at least between 18 and 22 weeks is usually a routine in most countries [3]. For assessing fetal well-being, the (2D) ultrasound is the first choice due to its wide availability, low cost, real-time capabilities, and absence of radiation [2]. 2D sonography is operator dependent and requires training to assess fetal anatomy properly.

Accordingly, there is usually a continuous need for a new modality that has advanced imaging capabilities, which can detect fetal malformations [4].

4D examination is generated by sequential three-dimensional (3D) images, which permit continuous monitoring of the examined parts of fetal face and surface [4]. The final performance of obstetric sonographic images depends upon multiple factors, such as fetal lie, uterine wall, abdominal wall fat, amniotic fluid, and the number of gesation [5].

According to the recommendations of the National Technical Committee of Prenatal Ultrasound Screening (CNTE) elaborated in 2005, the second semester (22–24 weeks of pregnancy) is an essential time for analyzing the face and performing screening of morphological abnormalities of the fetus. Long training is needed to assess the continuity of the lips by the tangential frontal view of the lower face through various fetal anatomy and orientations [5, 6].

During the second trimester and using the frontal view tangentially, we can depict fascial cleft, if any [5]. We can classify the degree of lip interruption as clearly visualized by the tip of the nose using the anterior coronal plane [7]. The tangential view obtained by 2D ultrasound coronal sections through the face showed the nose, nostril, lips, eye, lens, and hard palate. Thus, we can assess the orientation and size of the palpebral fissures, hypertelorism or hypotelorism, microphthalmia or anophthalmia, shape of the nose, microstomia or macrostomia, tongue (possible macroglossia), and lips (discard fissures). Reference values were published for the majority of these measurements (width of the eyelids, area of the ears, the height of the front, size of the philtrum, etc.) [8].

The study aims to emphasize the value of 2D sonography as an easy, rapid, and accurate technique in the assessment of fetal mouth and nose, as well as the detection of their anomalies in comparison with 4D examination.

Methods

Patients

This prospective study was done upon 220 pregnant females after obtaining ethical approval from our Institutional Review Board (IRB) and the Committee of Ethics in agreement with the declaration of Helsinki 1975 that was as revised in 2013. Informed written consent was obtained from all participants. The study was conducted from January 2016 to January 2019 for the assessment of fetal well-being at different age groups with a mean gestational age of (23 weeks). Inclusion criteria included any pregnancy with a single viable fetus. Exclusion criteria included multiple gestations, first-trimester pregnancy, and fetal demise.

Imaging protocol

All ultrasonographic images were obtained using a SIEMENS ACUSON X700 ultrasound device, with Curved Array probe 2.0–5.0 MHz used for 2D imaging and broadband volume curved ultrasound transducer of 2–6 MHz used for 4D imaging. No time limit was predetermined for performing the examination. First, all pregnant women underwent 2D ultrasound examination in the second and third trimesters to assess fetal presentation and lie, the presence of fetal cardiac activity, the number of fetuses within the uterus, the adequacy of the amniotic fluid, the localization of the placenta, and pregnancy dating/estimation of fetal weight following the 2D ultrasound. 4D ultrasound is performed in the same manner during the same session. To create a region of interest box that was fitted to the area of interest, the volume images were obtained by 4D sonography. The 4D real-time option and acquisition times were under 20 s per cine volume, with scan angles ranging from 30° to 60°.

B-mode 2D examination used either the 2D convex transducer or the 4D transducer with acquiring tangential coronal anterior views for the fetal face. It attempted the perpendicular coronal plan upon the easily obtained axial view at any level and from any fetal orientation through the angulation of the transducer 90-degree posteroanterior or anteroposterior direction relative to the face. The transducer was moved gently and slowly toward the face direction till reaching the amniotic fluid and returning. This action was repeated with some angulation to the coronal plane mainly until obtaining the desired views and clear images. There was a gentle slow movement to get more fine details of the mouth, lip, tongue, eyes, and cheek as possible (Figs. 1, 2). Many factors and obstacles were overcome during examination by some gentle movement and angulations that resulted in image quality degradation and were mostly related to decreased amniotic fluid (Fig. 3), which may be associated with other causes of close proximity to the uterine wall, hands (Fig. 4), limbs (Fig. 5), placenta (Fig. 6), umbilical cord, or motions of the amniotic fluid (Fig. 7).

The sustained examination was conducted to assess the movement of the mouth and tongue and any fascial expression (Fig. 8).

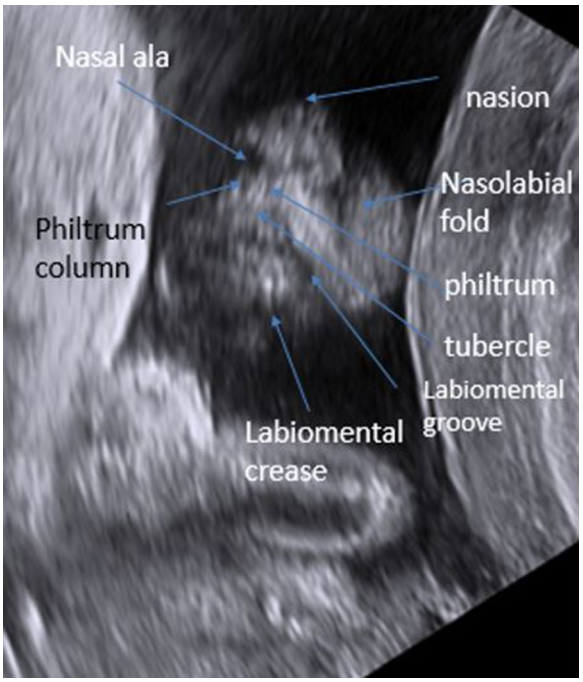

Fig. 1 Anatomy of the face; detailed nasolabial external anatomical landmarks

Examination performed by two expert radiologists with more than 15 years of experience in obstetric ultrasound. Both used the same ultrasound system and the same setting, but everyone was blinded to the results obtained by the other one. The intraobserver and interobserver reliability indexes for this method ranged from 0.905 to 0.945 and from 0.880 to 0.915, respectively.

Imaging analysis

Efforts and repeated trials for both techniques were made to acquire clear diagnostic images as possible. The diagnostic image is clear informative images that show anatomical details and superficial landmarks of the lips and nose without masked or hidden areas.

Statistical analysis

Data were analyzed using the Statistical Package of Social Sciences (SPSS) version 25 software (IBM Corporation, Chicago, USA, August 2017). Qualitative data were expressed as numbers and percentages. Pearson χ^2 was used to compare the percentages of the qualitative variables, and Fisher Exact test was used instead of Pearson χ^2 in the cases of nonparametric data. The P value of less than 0.05 was considered significant.

Results

In this study, we examined 220 fetuses: 121 males and 99 females. One hundred and sixty fetuses showed straight forwards obstetric examination by 2D and 4D ultrasound with identical final reports.

The total number of 2D frontal tangential coronal examinations that obtained clear images was 191 cases. This technique failed in only 29 cases compared to 50 cases for 4D ultrasound that obtained clear images in 170 cases only. Both 2D and 4D ultrasound failed to obtain clear images in 19 cases, while 4D failed in 31 cases and 2D failed in 10 cases. 2D was found significantly better than 4D imaging, with a P value of 0.009 (Table 1).

From all examined fetuses, 60 fetuses had an imaging problem and obstacle with the facial view to acquire clear informative diagnostic images that demonstrate the anatomical details of the mouth and lip. Thirty fetuses were associated with decreased amniotic fluid, 36 fetuses

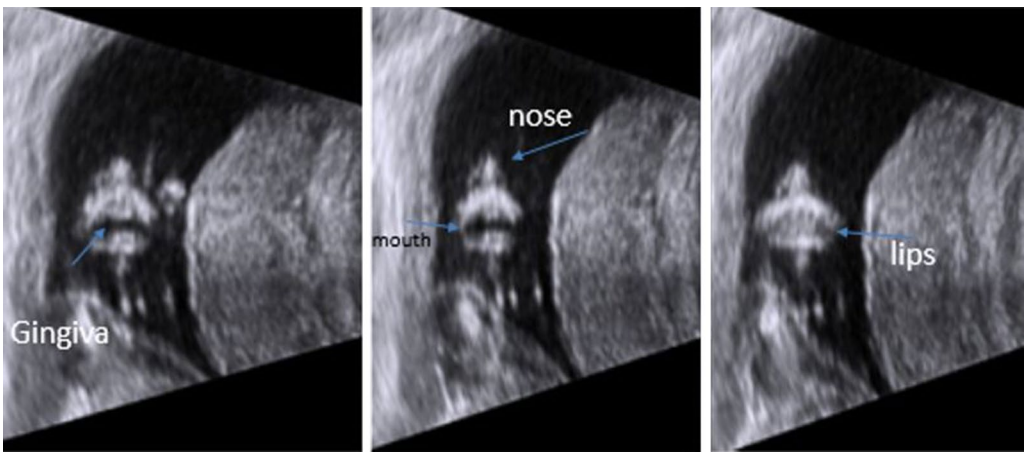

Fig. 2 21-week fetus shows the opening of the mouth and integrity of the lips and nose [arrows]

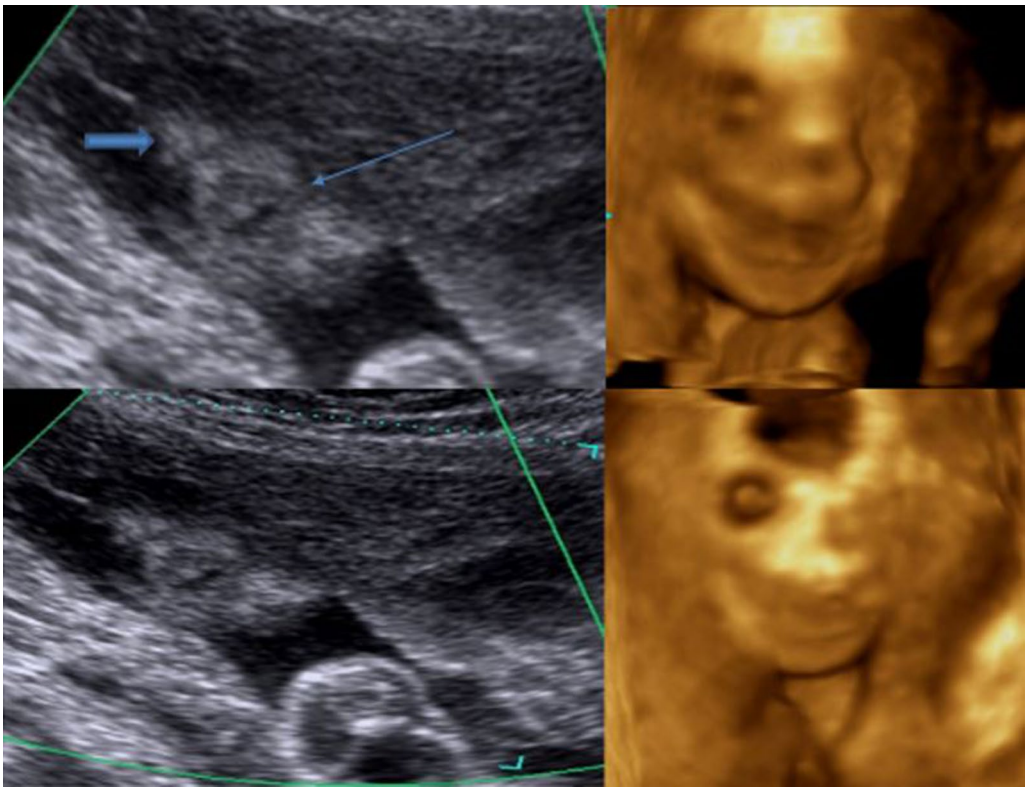

Fig. 3 Decreased amniotic fluid effect; 24 weeks gestational age fetus shows that the nose [arrow head] and lips [arrow] could be seen in the 2D image, and no details could be depicted from the 4D images

showed close proximity to adjacent structures, and 17 fetuses had difficult access either due to posterior deep orientation or deeply seated head at the pelvis. Moreover, 2 fetuses had exaggerated movement. From these 60 fetuses, 39 fetuses had only one obstacle (decreased amniotic fluid in 15 fetuses, close proximity in 17 fetuses, difficult accessibility in 5 fetuses, and exaggerated movement in 2 cases). On the other hand, 17 fetuses had a combination of two obstacles (9 fetuses shared decreased amniotic fluid and close proximity; 6 fetuses shared close proximity and difficult accessibility, and 2 fetuses shared decreased amniotic fluid and difficult accessibility). Finally, 4 fetuses shared the three obstacles (Figs. 9, 10). The 2 fetuses facing difficulty in imaging of the face due to exaggerated movement both were associated with increased amniotic fluid and were within the second trimester [22–23 week].

Most of the causes of image quality degradation were related to decreased amniotic fluid (Fig. 3), which may be associated with other causes of close proximity to the uterine wall, hands (Fig. 4), limbs (Fig. 5), placenta (Fig. 6), or umbilical cord.

The amniotic fluid is essential to get a 3D or 4D image. Otherwise, ill-defined shadows have no diagnostic values. This was reflected in the highly significant worse data obtained by 4D in comparison with 2D in the case of the decreased amniotic fluid, with a P value of < 0.001 (Table 2). Table 2 also shows that 4D was significantly worse also in the cases of close proximity to the placenta (P value $= 0.014$) and close proximity to limbs (P value $= 0.049$). Otherwise, there were no significant differences between 2D and 4D imaging.

The physics in 4D examination stays upon the reflected image upon the adjacent amniotic fluid, not the face itself. In the 2D examination, we examine the fascial components per se not the water; however, we need a small amount of fluid rim around the face for better image quality. As mentioned in Table 2, 2D sonography examination has less difficulty in obtaining a good image in decreased amniotic fluid and the close proximity of any structure. It does not need space to obtain the views. The second important obstacle to both techniques is the posterior deep orientation of the head and the deeply seated head.

Fetal movements in a repeated manner resulted in movements of the amniotic fluid and image degradation of 4D examination. On the other hand, it presented no significant problem for 2D examination. Two cases of 4D

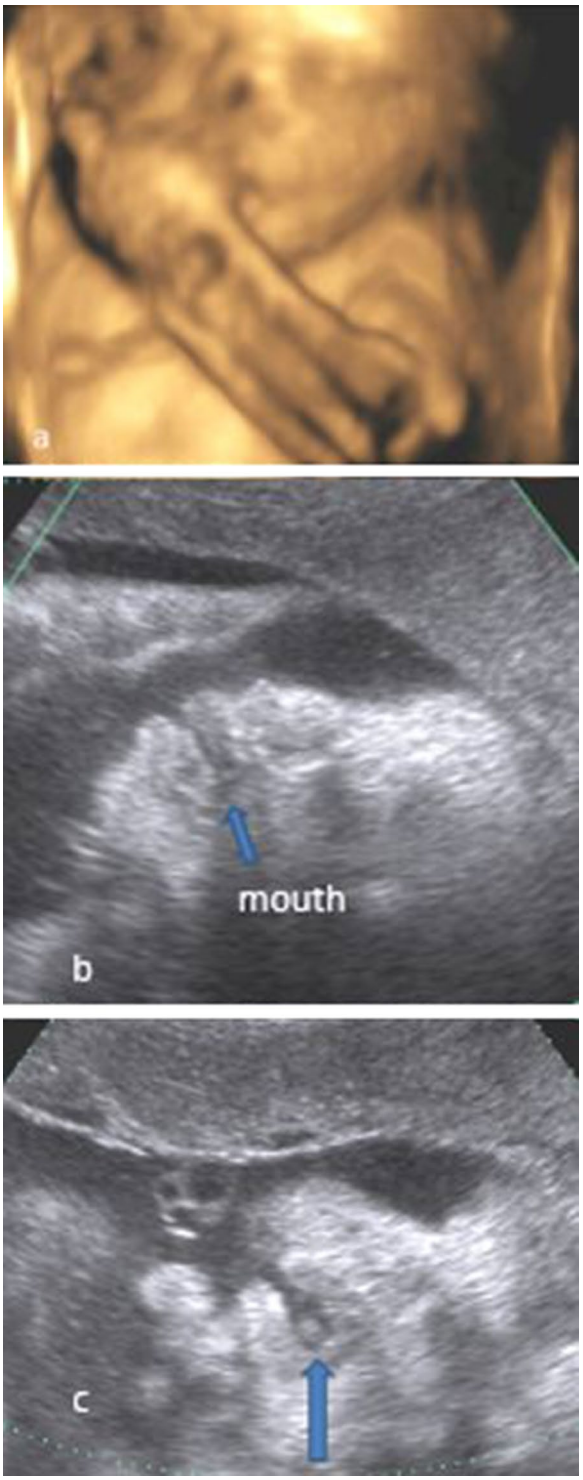

Fig. 4 Close proximity to hand; 4D image **a** shows the left upper limb and hand cover the mouth and nose, and no enough details could be depicted from the image in contrast to 2D tangential images, **b** and **c** that show the lips the tongue protruding from the open mouth [arrow]

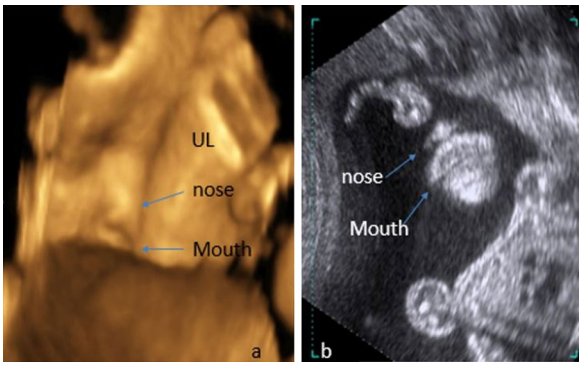

Fig. 5 Close proximity to upper limb; 31 weeks gestational age fetus shows close proximity of UL to fetal mouth and nose; some details from 4D image (**a**) and good details from 2D images (**b**)

examination encountered difficulty in obtaining a clear image or better assessment of the mouth opening due to the motion of the amniotic fluid that associated with the motion (Fig. 7). Facial expressions were noted during examinations (Fig. 8). The most common expression was mouthing encountered in 22 fetuses, as shown in Table 3.

Discussion

A comparative study was conducted on 4D sonographic and tangential coronal view of 2D sonography coronal plane in the assessment of fetus face mainly the mouth and nose anatomy and their movements. Most of the reviewed literature assessed only fetal behavior using 4D ultrasound. Only the study of Ocal et al. compared 4D and 2D ultrasound concerning the detection of fetal anomalies [4].

To the best of our knowledge, the current research is the first study that compares 4D with 2D in the tangential anterior coronal plan. The view of the nose and lips is obtained by 2D scanning of the face in an anterior coronal plane, in which the tip of the nose and the details of the lip are seen in the same view [7].

This study concluded that 2D sonography tangential views are better and more rapid and accurate in comparison with 4D examination in the anatomical delineation of the mouth and nose due to the following causes.

The first cause

The tangential view obtained by coronal, direct, or oblique views in more or less tangential axis to the face by slow movements to get a slice thickness to include the nose and mouth in details with to and fro movement getting more information about the structures and morphology and with sustained images will observe the movement of the lips, mouth opening, and tongue

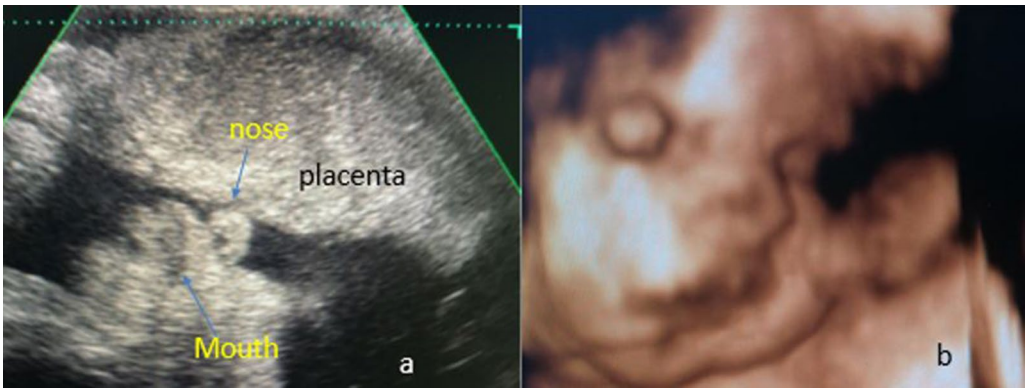

Fig. 6 Close proximity to the placenta, good details are better appreciated from the 2D image (**a**) regarding the lips and nose in comparison with the corresponding 4D image (**b**); however, in the latter, the entire face is could be assessed

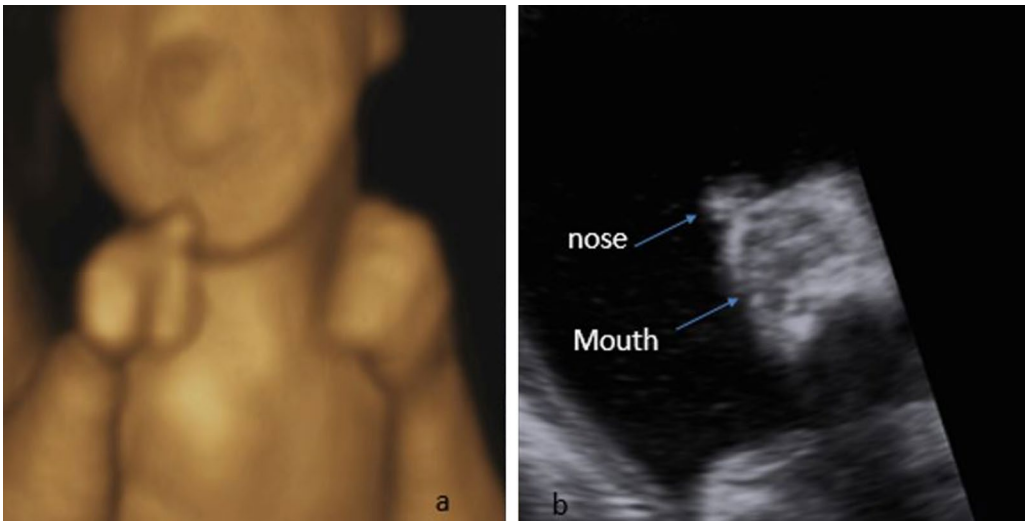

Fig. 7 18-week pregnancy; movement results in poor image quality in the 4D image (**a**) exaggerated by increased amniotic fluid in comparison with 2D image (**b**) that still shows good details [arrows]

movement and size, as well the overall facial expressions, if any. It is real-time imaging.

The 4D sonographic image presents a surface rendering image of the structures by the reflection of the amniotic fluid around the fetus. The presence of amniotic fluid is essential to obtain a clear and informative image. Increasing the amniotic fluid helps the operator to get more detailed findings, so we obtained the image of a fluid, not the face itself.

The observation of fetal faces by 4D sonography was hampered as the images were only near-real-time [9, 10]. Azumendi et al. ensured that the examination of the fetal face is facilitated by the presence of the surrounding fluid [11].

The second cause

One of 4D examination preconditions is sufficient amniotic fluid around the examined part to obtain an optimal 4D image. Thus, the lack of amniotic fluid around the intra-fetal structures makes it impossible to obtain diagnostic 4D ultrasound examination [4].

In coronal tangential images, we do not need much amniotic fluid to clarify the target site, even minimal or trace amount; 22 cases showing decreased amniotic fluid [AFI 7–9 cm] and 8 showing oligohydramnios [AFI 1–5 cm] in about 26 cases. 4D sonography was less informative and showed poor image quality in comparison with 2D, which was also less informative in 7 cases only.

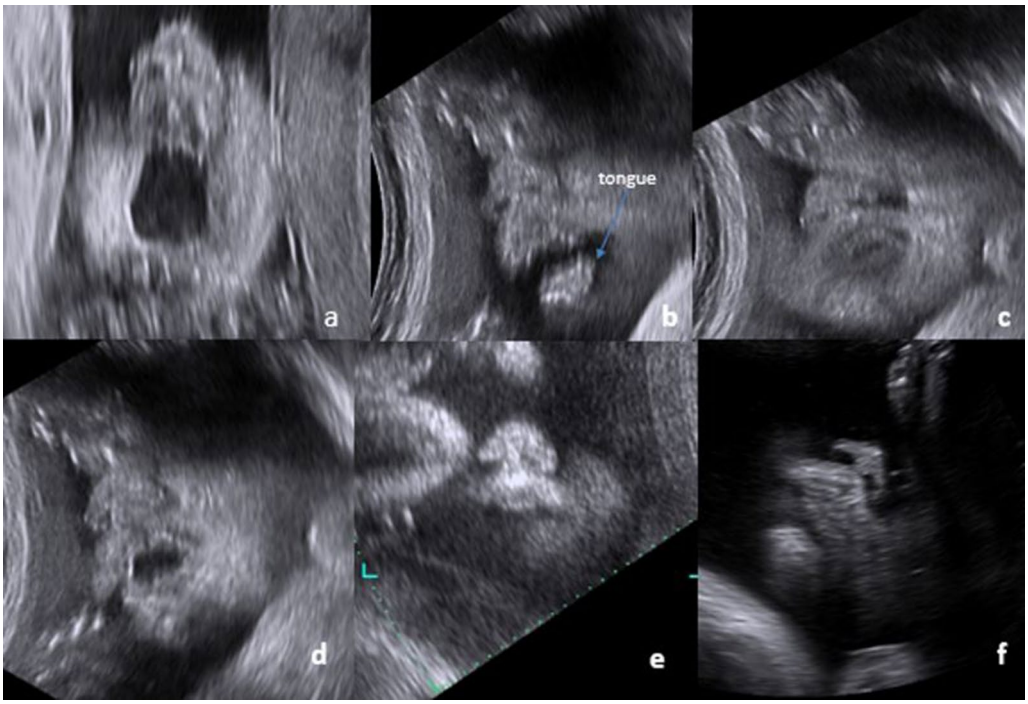

Fig. 8 Different facial expressions at different fetal age groups; yawing, tongue expulsion, scowling, mouthing, smiling, suckling; image (**a**–**f**), respectively

Table 1 About the clear diagnostic view, which is an image that has an enface orientation and shows details of the face

	Clear diagnostic view	Otherwise no
2D	191	29
4D	170	50

$\chi^2 = 6.804$, *P* value = 0.009 (S)

The third cause

4D sonography gets enface image after the adjustment of the probes to en-profile images. We need mid-sagittal images to get a clear 4D image, which looks tedious in many cases either due to low lying or deeply impacted head, or posterior enfacement of the face toward the posterior wall not toward the anterior side or otherwise marked flexion of the neck or complex head direction. All are difficult positions that need a long time to access the mid-sagittal view and for optimizing fetal position and lastly may not be accessed.

The case is different in 2D images. We just access the head in the coronal view and move toward the face, even when image quality may be suboptimum, but we will get some diagnostic data. From 17 cases in whom the posterior deep fetal head orientation or deeply seated fetal head at the pelvis, 4D could not show a clear diagnostic image in 14 cases, compared to only 11 cases in the 2D, but with a non-significant difference (*P* value 1.000 and 0.564, respectively).

Fetal lie, presentation, and position can all affect the configuration of standard diagnostic planes. Informative images can be obtained successfully when the fetus offers an optimal window (e.g., spine down); however, when the fetus moves to a different position (e.g., spine up), the same informative images may not be obtained [12].

The fourth cause is close proximity to adjacent structures, such as hand, limbs, umbilical cord, placenta, or uterine wall to the face. Therefore, the amniotic fluid layers are thinned to obtain a good 4D image. We do not need excess amniotic fluid to obtain coronal 2D views. From 36 fetuses' structures that intervene in the face, 4D could not show clear images in 27 fetuses, compared to 11 cases for 2D. The most common cause is close proximity to hand and limbs seen in 13 fetuses from whom 4D examinations failed in 9 cases, and 2D examinations could not present clear images in four cases only with a significant difference (*P* value = 0.049).

Clear 4D ultrasound examination needs the field around the fetal face empty of any fetal parts or cord, just amniotic fluid in adequate amount [4]. Kanenishi et al. published an observation that the fetal face was difficult during 4D examination when fetal extremities or the

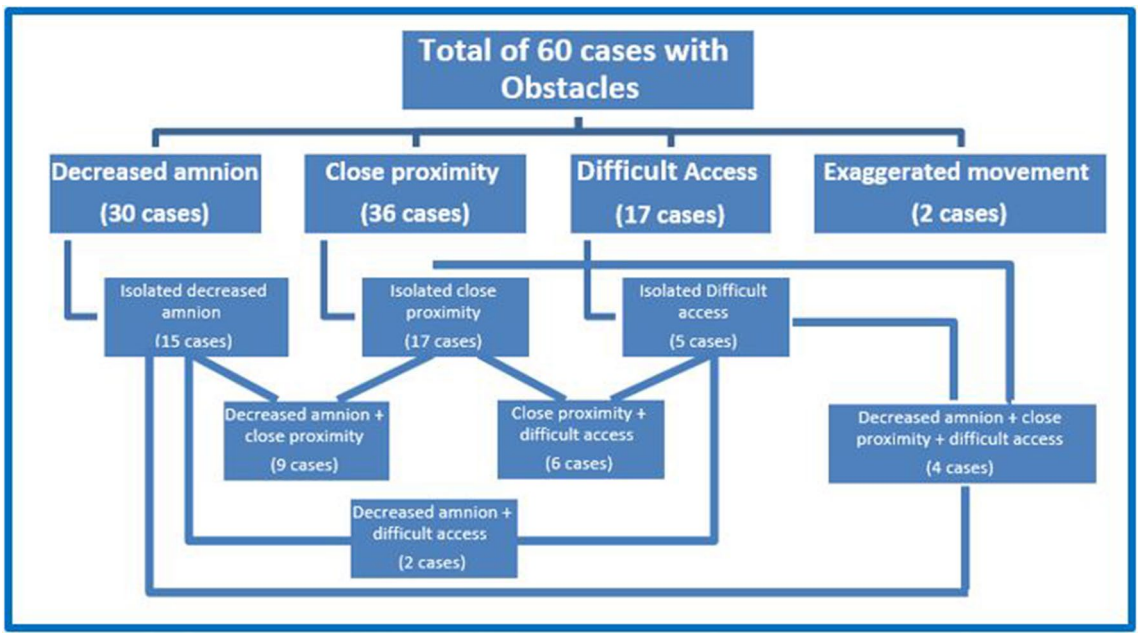

Fig. 9 A diagram shows the distribution of cases with obstacles

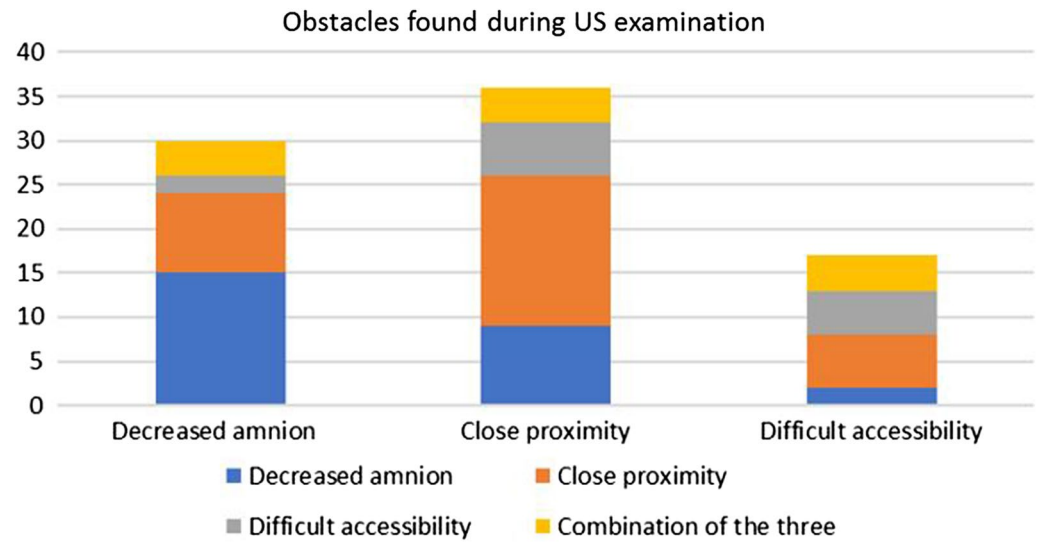

Fig. 10 A diagram shows the distribution and causes of obstacles

umbilical cord were in front of the face, or the fetal face was facing the uterine wall or the placenta [13].

The fifth cause

Volumetric sonography requires dedicated software and a special transducer. In contrast, 2D is not dependent on specific ultrasound platforms and applicable by the commonly curved array transducer [12].

The sixth cause is the assessment of the movements of the lips and tongue as well some of the facial expressions. 4D examination results in some image degradation by the movement of any structures that affect the stagnation of the amniotic fluid, so with lips or tongue movements the amniotic fluid moves, and the acquisition of the reconstructed image is of variable quality in comparison with the 2D image, which is not affected by the movement of

Table 2 Causes of poor image quality or non-diagnostic view

Cause	No	No. in 2D exam	No. in 4D exam	*P* value
Decreased amniotic fluid	30	9	26	**< 0.001**
Close proximity to placenta	12	3	9	**0.014**
Close proximity to uterine wall	9	4	6	0.635[a]
Close proximity to limbs	13	4	9	**0.049**
Close Proximity to umbilical cord	2	1	2	1.000[a]
Posterior deep fetal head orientation	9	6	7	1.000[a]
Deeply seated fetal head at the pelvis	8	5	7	0.564[a]
Fetal movement	2	0	2	0.317[a]

Values of statistically significant *p* values were marked in blod

[a] Fisher exact test was used instead of Pearson χ^2 due to nonparametric data

Table 3 Common facial expression

Facial expression	Number
Mouthing	22
Yawing	16
Tongue expulsion	15
Smiling	3
Suckling	3
Scowling	3

No fascial anomalies were depicted in any examined fetus

the structure or the adjacent amniotic fluid. Thus, the image is not hazy. So 2D ultrasound presents a good sufficient job as regards facial expression.

The seventh (last) cause is the wide availability and the low cost of 2D sonographic machines relative to 4D, making 2D examination more available and easily accessible for a very pregnant lady.

In this study of 220 fetuses, the face is not seen in 21 by 2D and 39 by 4D. This finding agrees with Pretorius et al. who studied 71 fetuses of whom faces were seen in 68 and not seen in 3 by either 2D or 3D sonography [14].

In this study, the mouth movement is the commonest facial expression. It agreed with the findings of Kanenishi et al. that the mouthing movement was the most common facial expression at 20–34 weeks of gestation followed by tongue expulsion [13]. Fetal mouthing is considered the most frequent facial expression observed by 4D ultrasound [15].

Still, 4D sonography is superior in some cases and conditions regarding the face. The entire face assessment of 4D is well impressive for facial expression rather than 2D coronal view.

According to Lebit et al., the most benefits of 4D ultrasound could be a real-time assessment of fetal face, grimacing, breathing movements, swallowing, mouthing, isolated eye-blinking, and the direction of the limbs [15]. In seven studies, 2D was more diagnostic in comparison with 3D, whereas in another four studies, both 2D and 3D had the same diagnostic capability [4].

Öcal et al. reported that 2D US was significantly better than 4D USG in detecting anomalies ($P < 0.001$). However, 4D US was superior to 2D US in terms of intelligibility among the cases with a superficial anomaly ($P < 0.005$) [4].

Conclusion

Frontal tangential coronal view, 2D sonography is an essential part of fetal examination during fetal screening. It is considered a well informative view about facial anatomy and dysmorphology, as well mouth movements and some of the facial expressions in comparison with 4D examination.

Abbreviations

4D: Four dimensional; 2D: Two dimensional; 3D: Three dimensional; CNTE: National Technical Committee of Prenatal Ultrasound Screening; IRB: Institutional Review Board.

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Authors' contributions

The guarantor of this publication is H.A.A.E. Study concept and design were contributed by H.A.A.E., M.H., M.A. Literature research was contributed by H.A.A.E., M.H., M.A. Patient enrollment was contributed by M.H., M.A. Data analysis was contributed by H.A.A.E. Manuscript preparation was contributed by all authors. All authors read and approved the final manuscript.

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Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent of participate

The study was approved by ethical committee of Sohag university hospital. The authors declare that they obtained a written informed consent from the patients included in the article. The authors also confirm that the personal details of the patients have been removed.

Consent of publication

Not applicable.

Competing interests

The authors of this manuscript declare that there is no conflict of interest to disclose.

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