

# Fetal neurobehavior assessed by three-dimensional/four-dimensional sonography

Ocenjevanje nevroloških vedenjskih vzorcev pri plodu s pomočjo tridimenzionalne in štiridimenzionalne sonografije

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## Abstract

Recent development of three-dimensional (3D) and four-dimensional ultrasound (4D) provided us with new possibilities to study fetal movements and behavior. Many studies have been conducted in order to provide information on specific movement patterns in normal and high-risk fetuses. This was the base for a multicenter study on the use of new scoring system for fetal neurobehavior the purpose of which is to recognize fetuses at increased risk for a poor neurological outcome. The purpose of this paper is to give a brief review on the use of 3D and 4D ultrasound in the assessment of fetal behavior.

## Izvleček

Nedavni razvoj tridimenzionalne (3D) in štiridimenzionalne (4D) ultrasonografije nam odpira nove možnosti za raziskovanje gibanja in obnašanja ploda. Veliko študij je bilo opravljenih z namenom, da bi pridobili informacije o določenih vzorcih gibanja pri normalnih in visoko-rizičnih plodovih. To je bila osnova za multicentrično raziskavo o uporabi novega sistema ocenjevanja plodovega nevrološkega vedenjskega vzorca, katerega namen je bil prepoznati plodove s povečanim tveganjem za slab nevrološki izid. Namen tega članka je podati kratek pregled uporabe 3D in 4D ultrasonografije za oceno plodovega vedenja.

## Introduction

Fetal behavior could be described as any fetal movement felt by the mother or observed by more objective method, such as ultrasonography. Since recently, maternal registration of fetal movements and obstetrician auscultation of fetal heartbeats were the only methods for assessment of fetal status *in utero*. This was changed with the development of real time two-dimensional (2D) ultrasound that enabled direct visualization of fetal anatomy and monitoring of fetal activity. Investigators used this great accomplishment as a starting point for analysis of fetal behaviour in comparison with morphological studies, which led to the conclusion that fetal behavioural patterns directly reflect developmental and maturation processes of fetal central nervous system.<sup>1,2</sup> Therefore, it was suggested that the assessment of fetal behavior in different periods of gestation may provide the possibility to distinguish between normal and ab-

normal brain development, as well as early diagnose various structural or functional abnormalities.<sup>1</sup> However, 2D ultrasound with poor quality of image, especially in the beginning, was considered to be somewhat subjective because the information needed observer's interpretation. The latest development of three-dimensional (3D) and four dimensional (4D) sonography and their implementation in clinical practice enable precise study of fetal and even embryonic activity. The use of these new technologies has shown that fetal activity appears as early as in the late embryonic period, which is far earlier than a mother can sense it. This could be potentially used in early embryonic neurobehavior assessment with great implications for termination of pregnancy in a case of an abnormal finding. Since now the investigations of fetal neurobehavior seem inconceivable without the use of ultrasound, fetal behavior can be defined as any fetal activity observed or recorded with ultrasonographic equipment.

## Fetal motility and four-dimensional ultrasound

Although 2D sonography enhanced our understanding of fetal neuromuscular development, the real breakthrough in studying fetal neurobehavior was achieved by 3D/4D ultrasound. This technique has important advantages, such as the ability to study fetal activity in the surface-rendered mode, it is particularly superior for fast fetal movements and it is better in visualization of the fetal face.<sup>3</sup> Fetal movements such as yawning, swallowing and eyelid movements cannot be displayed simultaneously, whereas with 4D sonography, the simultaneous facial movements can be clearly depicted.<sup>4</sup> An additional advantage in comparison with 2D ultrasound is its ability to visualize the whole fetus continuously. The key benefit of 4D ultrasound lies in providing real-time 3D images of embryonic or fetal movements, previously limited by technological possibilities. The introduction of high-frequency transvaginal transducers has resulted in remarkable progress in ultrasonographic visualization of early embryos and fetuses and in the development of sonoembryology. For the first time, parallel analyses of structural and functional parameters in the first 12 weeks of gestation become possible.

3D ultrasound has been extensively used for more than ten years with the development of several different kinds of modes that have been created for different purposes. These include multiplanar imaging, volume rendering, surface rendering, 3D color Doppler, and 3D volumetry, cine-loop animation, post-processing and cutting. However, the 3D image freezes the object and therefore does not provide information on movements or any information about the dynamic changes of the object of interest. A technique was needed that would enable 3D imaging to be performed in a real-time mode. This technique can be called live 3D ultrasound (3D-US) or 4D ultrasound (4D-US), as coined by a manufacturer, because time becomes a parameter within the 3D imaging sequence. Human eyes are known to be able to differentiate between images up to a frequency of about 12 images per

second, and therefore production of an appropriate frame rate with specially designed probes and a fast computer rendering device is required. At the moment, 4D-US scanning is not real-time, and the available machines can reach up to about 20 images per second, depending on volume size, resolution and the mechanics of the probe. Nevertheless, even at these relatively slow frame rates the ability to study fetal activity is strikingly good, enabling the continuous monitoring of the fetal face and other surface features of the fetus, such as fetal extremities. This was the beginning of investigation of the relatively unexplored area of fetal behaviour as a possible measure of neurological maturation.

In the early second trimester 4D-US provides simultaneous visualization of all four extremities and enables a reliable recognition of isolated arm movements and their direction. Because of the limitations of 2D-US only five types of isolated hand movements can be described. They include: hand to head, hand to trunk, hand to foot, hand to fluid and hand to the uterine wall. If one performs 4D-US, hand to head movement can be differentiated into seven subgroups: hand to head, hand to mouth, hand near mouth, hand to face, hand near face, hand to eye and hand to ear.

With 4D-US, it is now feasible to study a full range of facial expressions including smiling, crying, scowling and eyelid movements.<sup>4,5</sup> The observation of facial expression may be of scientific and diagnostic value and such scientific approach opens an entirely new field. Recently, multicentric studies of fetal brain function have been carried out,<sup>6,7,8</sup> the aim of which was to establish the standards of fetal peripheral and body movements, and facial expressions as additional diagnostic criteria for prenatal brain impairment. It is our belief that 4D ultrasound will have its place in everyday obstetric practice, combining patient acceptance and sensitivity of diagnosis.

## Classification of movement patterns

Based on the first analysis of fetal movements by 2D ultrasonography, de Vries classified movements into different patterns as follows:<sup>9,10</sup>

1. Sideways bending. Between 7 and 8 weeks postmenstrual age, slow and small displacements at one or two poles of the fetus occur, lasting from half a second to two seconds, which usually occur as a single event and disappear in the course of gestation.
2. Startle. A startle consists of a rapid phase contraction of all limb muscles. It often spreads to the trunk and neck. It occurs frequently in the first trimester from 8 weeks on.
3. General movements. These movements are complex movements including neck, trunk and limbs that are applicable if the whole body is moved but no distinctive patterning or sequencing of the body parts can be recognized. They wax and wane in intensity, force, and speed, and they have a gradual beginning and end. These movements are performed from 8 weeks on.
4. Hiccup. A hiccup consists of a jerky contraction of the diaphragm. Hiccups appear from 9 weeks and on, often in series, for up to several minutes, and isolated arm and leg movements can be observed.
5. Breathing. Fetal breathing movements are usually paradoxical in a way that every contraction of the diaphragm (which after birth leads to an inspiration) causes an inward movement of the torax. The onset of fetal breathing movements is around the 10<sup>th</sup> week of gestation. Early in gestation, they are present continually and are associated with activity in the postural muscles of the neck and limbs.
6. Isolated arm or leg movement. These movements appear around 10<sup>th</sup> week of gestation and they vary in speed and amplitude. They involve extension, flexion, external and internal rotation, or abduction and adduction of an extremity, without movements of other body parts.
7. Twitches. Twiches are quick extensions or flexions of a limb or the neck. They are not generalized or repetitive.
8. Clonic movements. These are repetitive movements of one or more limbs at a rate of about three per second.
9. Isolated retroflexion of the head. Retroflexions of the head are usually carried out slowly, but they can also be fast and jerky. These movements can be seen around 10<sup>th</sup> week and on.
10. Isolated rotation of the head. Rotation of the head is carried out at a slow velocity and only exceptionally at a higher speed. The head may turn from a midline position to one side and back.
11. Isolated anteflexion of the head. Anteflexion of the head is carried out only at a slow velocity. The displacement of the head is small. The duration is about 1 s.
12. Jaw movements. The onset of irregular jaw opening is at 11<sup>th</sup> week. The opening may be either slow or quick. The duration of opening varies from less than 1 s to 5 s.
13. Sucking and swallowing. At 13 weeks rhythmical sucking movements, often followed by swallowing, occur in bursts indicating that the fetus is drinking amniotic fluid.
14. Hand–head contact. In this pattern of movement, the hand slowly touches the face, and the fingers frequently extend and flex. These movements appear from 10<sup>th</sup> week on and at first they usually represent an accidental contact of a hand with the face or mouth. Subgroups of these movements are: a) 1. hand to head – when hand movement ends at contact of fingers with the parieto-occipitotemporal region of the head; b) hand to mouth – when hand movement ends at contact of thumb or finger with the mouth, lips or the immediate oral region; c) hand near mouth – when movement ends with fingers in fluid between the nose and shoulders/nipples or between both shoulders. Hands must be below eyes and within the area defined by the ears, less than a hand away from the mouth; d) hand to face – when movement ends with hand in contact with the face (cheeks, chin, forehe-

**Table 1:** Neurological scoring test for fetus

Sign	Score			Sign Score
	1	2	3	
Isolated head anteflexion 	Abrupt	Small range (0 – 3 times of movements)	Variable in full range, many alternation (> 3 times of movements)	
Cranial sutures and head circumference 	Overlapping of cranial sutures	Normal cranial sutures with measurement of HC below the normal limit (-2 SD) according to GA	Normal cranial sutures with normal measurement of HC according to GA	
Isolated eye blinking 		Not fluent (0 – 5 times of blinking)	Fluency (> 5 times of blinking)	
Facial alteration (grimace or tongue expulsion) 		Not fluent (0 – 5 times of alteration)	Fluency (> 5 times of alteration)	
Mouth opening (yawning or mouthing) 		Not fluent (0 – 3 times of alteration)	Fluency (> 3 times of alteration)	
Isolated hand movement 	Cramped	Poor repertoire	Variable and complex	
Isolated leg movement 	Cramped	Poor repertoire	Variable and complex	
Hand to face movements 	Abrupt	Small range (0 – 5 times of movement)	Variable in full range, many alternation (> 6 times of movements)	
Finger movements 	Unilateral or bilateral clenched fist, (neurological thumb)	Cramped invariable finger movements	Smooth and complex, variable finger movements	
Gestalt perception of GMs	Definitely abnormal	Borderline	Normal	
			Total score	

ad); e) hand near face – when movement ends with finger in fluid in front of the face but not in mouth region; f) hand to eye – when movement ends with hand or palm or fingers in the eye region; g) hand

to ear – when movement ends at hand contact with the ear.

15. Stretch. A stretch is a complex motor pattern, which is always carried out at a slow speed and consists of the following



**Figure 1:** Three-dimensional (3D) ultrasound assessment of fetus in the first trimester showing complex movements of body and limbs

components: forceful extension of the back, retroflexion of the head, and external rotation and elevation of the arms. It retains an identical movement form in adult life.

16. Yawn. This movement is similar to the yawn observed after birth: prolonged wide opening of the jaws followed by quick closure, often with retroflexion of the head and sometimes elevation of the arms. This movement pattern is non-repetitive and it appears around 11<sup>th</sup> week. The anatomical criterion for fetal yawning is retraction of the tongue, whereas yawning in adults is characterized by an extended tongue.
17. Rotation of the fetus. Rotation of the fetus occurs around the sagittal or transverse axis. A complete change in position around the transverse axis, usually with a backward somersault, is achieved by a complex general movement, including alternating leg movements, which resemble neonatal stepping.

## Onset of specific fetal behavioral patterns assessed by 3D/4D

### The first trimester

Beside 3D-US that allows precise morphological examinations of conceptus in the first trimester, 4D-US adds quanti-

tative assessment of fetal motility that can be performed almost equally precisely as by conventional 2D-US even at the very early period of gestation.<sup>11</sup> Our own study showed that both 2D and 4D sonography can be used to assess fetal movements in the first trimester.<sup>12</sup> Moreover, 4D-US offers an advantage of simultaneous visualization of the whole body.

The early embryonic development is characterized by the immobility of an embryo. Most types of movement pattern emerge between 7 and 15 weeks of gestation and from the 15<sup>th</sup> week onwards, distinct patterns can be seen.<sup>12</sup> One of the first studies from Zagreb group on fetal behavior assessed by 4D sonography showed that three types of movements can be visualized in the first trimester: gross body movements between seven and eight weeks, limb movements after 10 weeks, and complex movements after 11 weeks of gestation<sup>8,13</sup> (Figure 1). An alteration from the given pattern of motoric development should be considered as an indication for further investigation.<sup>13</sup> In another study by the same group body and limb movements were visualized by 4D sonography a week earlier than by 2D.<sup>14,15</sup>

In a little while, these first simple movements are replaced by different general movements (GMs).<sup>13</sup> At first, GMs are slow and of limited amplitude, and from 10 to 12 weeks GMs become more forceful but are smooth in appearance and of large amplitude. We can suppose that the generating neural network responsible for GMs is located in the brain stem and the spinal cord, higher structures of the brain playing more subtle role in modulating quality and, perhaps, time patterning of different movement patterns.<sup>16</sup> Isolated limb movements emerge almost simultaneously with the general movements and they could be seen from 8<sup>th</sup> to 9<sup>th</sup> weeks of gestation by 4D-US.<sup>16</sup> Organization of the appearance of the movement pattern occurs with increasing frequency. It seems that fetal arms explore the surrounding environment and cross the midline, while the palmar surface is oriented towards the uterine wall. The fetal legs are extended to the uterine wall. From the 10<sup>th</sup> week onwards, the number and frequency of fetal movements increase

and the repertoire of movements begins to expand. Breathing movements appear between 10.5 and 12 weeks, consisting of the opening of the jaw; bending forward of the head and complex stretch movements are added to the repertoire.<sup>17</sup>

To determine the accuracy of 4D sonography in the assessment of embryonic and early fetal motor activity in the first trimester of normal pregnancy the Zagreb group conducted a study with fifty pregnant women and performed 2D and 4D recordings. Several movement patterns, such as sideways bending, hiccup, fetal breathing movements and facial movements could not be observed by 4D-US imaging technique, although they were clearly visible by 2D-US. The authors concluded that at the time, both 2D and 4D methods were required for the assessment of early fetal motor development and motor behavior. It was reasonable to expect that such technological improvement may provide some new information about the intrauterine motor activity and facilitate the prenatal detection of some neurological disorders.<sup>17</sup>

Detailed observation of fetal hand and finger positioning 3D/4D ultrasound revealed that at the beginning of the 10th week, fetal hands are located in front of the chest without movements of wrists or fingers. Active arm movements can be visualized from the middle of 10th week of gestation with changes in finger positioning from the 11th week.<sup>18</sup>

In the first trimester one could notice a tendency towards an increased frequency of fetal movement patterns with increasing gestational age. Only the startle movement pattern seemed to occur stagnantly during early gestation.<sup>19</sup>

## The second trimester

Only a few studies are available on fetal movement patterns during the second trimester.<sup>15,35,36-40</sup> In this period of gestation the incidence of body movements increases considerably with longer periods of quiescence. The most active fetal behavioral pattern is arm movement, whereas the least active is mouth movement. Each fetal mo-

vement was shown to be synchronized and harmonized in this period of pregnancy.<sup>20</sup> Important movements that are most developed in the second trimester are eye movements with isolated eye blinking patterns seen as consolidate movements from the 24<sup>th</sup> to 26<sup>th</sup> week of gestation, while facial grimaces are seen as sporadic movements with a limited frequency.<sup>21</sup> From a developmental point of view, one could say that in the second trimester the development continues, but there are no new movements appearing for the first time.<sup>22</sup>

Using 4D sonography, the Zagreb group have found that from 13 gestational weeks onwards, a "goal orientation" of hand movements appears and a target point can be recognized for each hand movement.<sup>23,24</sup> All subtypes of hand to head movement could be seen from 13 weeks of gestation, with fluctuating incidence (Figure 2). Among facial expressions, two types could be easily differentiated: smiling and scowling. The authors concluded that 4D-US is superior over 2D real-time ultrasound for the qualitative, but inferior for quantitative analysis of hand movements. Thus 4D-US makes it possible to determine exactly the direction of the fetal hand, but the exact number of each type of hand movements still could not be determined. Two-dimensional sonography easily recognizes hand movements associated with body movements, but there are problems in the recognition and differentiation of isolated hand movements and hand movements associated with leg movements. In this situation 4D-US is the method of choice for the reliable recognition of the isolated hand movements. Additionally, 4D sonography provides surface rendered images of the fetal head and visualization of hand movements in three dimensions that allows further differentiation of hand to head movements.<sup>23,24</sup>

Kurjak et al. reported the first study with the 4D-US techniques used for obtaining longitudinal standard parameters of fetal neurological development in all trimesters of a normal pregnancy.<sup>25</sup> Valid reference ranges appropriate for gestational ages are essential for comparisons with previous measurements of the same patients and among patients as well. The authors found a tenden-



**Figure 2:** Example of three-dimensional (3D) ultrasound assessment of the fetal face and isolated hand movement in the second trimester

cy towards an increase in the frequency of fetal movement patterns at the beginning of the 2<sup>nd</sup> trimester. All types of facial expressions display a peak frequency at the end of the 2<sup>nd</sup> trimester, except in isolated eye blinking which increases at the beginning of 24<sup>th</sup> week. This longitudinal study establishes reference ranges with gestational age for suggestible used fetal neurobehavioral development parameters in respected number of normal singleton pregnancies. Results from Yigiter and co. are similar as they found a significant correlation between all head movements and hand to body contact patterns during the 2<sup>nd</sup> and the 3<sup>rd</sup> trimesters except for head anteflexion, which did not show a significant change during the second half of pregnancy.<sup>19</sup> It has also been suggested that there is a tendency towards decreased frequency of observed facial expressions and movement patterns with increasing gestational age.<sup>25</sup> All types of facial expressions display a peak frequency at the end of the 2<sup>nd</sup> trimester, except in isolated eye blinking which increases at the beginning of 24<sup>th</sup> week.<sup>25</sup>

### The third trimester

During this period of pregnancy, motor behavior becomes increasingly frequent and variable with an obvious developmental improvement in orienting responses. Precht showed that the development was intraindividually characteristic and consistent, but

interindividually variable.<sup>26</sup> In short, a rich variety of fetal and premature movements has been described and it has been shown that the repertoire of fetal movements consists exclusively of motor patterns which can also be observed postnatally and that there is a high degree of continuity of behavior before and after birth. However, the newborn's behavioral repertoire rapidly expands with patterns never observed in the fetus, such as the Moro response.

The concept of behavioral states has been used as a descriptive categorization of behavior in the third trimester as an explanatory concept in which states are considered to reflect particular modes of nervous activity that modify the responsiveness of the infant.<sup>27</sup> These states consist of fetal heart rate pattern, and eye and body movements.<sup>27</sup> The association of these movements increases steadily and, in the last weeks of pregnancy, authors stated that fetal behavior can be almost completely described in terms of behavioral states, which are stable over time and recur repeatedly, not only in the same infant, but also in similar forms in all infants.<sup>27,28</sup>

By term, number of generalized movements reduced as a result of cerebral maturation processes.<sup>29</sup> Simultaneously with this decrease, an increase in the facial movements, including opening/closing of the jaw, swallowing and chewing can be observed.<sup>29</sup> However, not only the changes in the quantity of movements, but also in their quality are shown to be the result of maturational processes.

The incorporation of 3D-US technology into clinical practice has resulted in remarkable progress in visualization and anatomic examination of the fetal face. 4D-US, in turn, provided for the first time an opportunity to evaluate subtle fetal facial expressions, which can be used to understand fetal behavior<sup>30</sup> (Figure 3). Because of its curvature and small anatomic details, the fetal face can be visualized and analyzed only to a limited extent with 2D-US, but 3D-US allows spatial reconstruction of the fetal face and simultaneous visualization of all facial structures such as the fetal nose, eyebrows, mouth, and eyelids. This technique does not replace conventional real-time 2D-US

imaging, but rather supplements it. 3D-US requires an investment of additional time in each case; therefore, it is predominately used, presently in conjunction with 2D-US, as a problem-solving tool.

Although facial movements, which are controlled by V and VII cranial nerves, appear around 10 and 11 weeks, the exact onset of facial expressions has not been determined and it is still unclear whether their appearance is gestational age related.<sup>30</sup> The possibility of studying such subtle movements might open a new area of investigation.

Zagreb group undertook the study to show the ability of 4D sonography to depict different facial expressions and grimacing which might represent fetal awareness.<sup>31</sup> This was based on the hypothesis that “the face predicts the brain” because of the same embryologic origin of many facial and encephalic structures.<sup>32</sup> A tendency towards increased frequency of observed facial expressions with increasing gestational age was noted, but the difference between second- and third-trimester fetuses was not significant due to the low frequency of movements. As at that time the images were only near real-time, they were only able to study the quantity and not the quality of facial movement patterns with the possibility that some very subtle facial movements may have been missed.

Recently, Yan and his group found that mouthing was the most active facial expression from 28 to 34 weeks.<sup>33</sup> However, the frequency of blinking was lower compared to other studies, which may be attributed to differences in the characteristics of the samples recruited and differences in interpreting the definition of each facial expression.<sup>23,31</sup>

### New scoring system for fetal neurobehavior assessed by 3D and 4D sonography

In their recent study, the Zagreb group attempted to develop a new scoring system for fetal neurobehavior based on prenatal assessment by 3D/4D sonography.<sup>34</sup> That scoring system is a combination of prena-

tally visualized parameters by 4D-US from other previously used tests, such as fetal GM assessment and postnatal ATNAT.<sup>35,36</sup> The parameters were chosen based on developmental approach to the neurological assessment and on the theory of central pattern generators of GM emergence, and were the product of multicentric studies conducted for several years<sup>24,25</sup> (Table 1). The authors developed a three-point scale for isolated head anteflexion, isolated hand, leg, hand to face and finger movements, while for the assessment of cranial sutures, isolated eye blinking, facial alterations and mouth opening two-point scale was applied. The distinction between scores 0 and 2 is evident, whereas uncertainty may exist with regards to the assignation of a score of 1, the latter indicating an abnormal result of moderate degree. The precise description of the moderate abnormal performance is included for each item in the record form.

To develop the new scoring test, the Zagreb group identified severely brain damaged infants and those with optimal neurological findings by comparing fetal with neonatal findings. In the group of 100 low-risk pregnancies they retrospectively applied new scoring system. After delivery, postnatal neurological assessment (ATNAT) was performed,<sup>37</sup> and all neonates assessed as normal reached a score between 14 and 20, which was assumed to be a score of optimal neurological development. New scoring system was applied in the group of 120 high-risk pregnancies in which, based on postnatal neurological findings, three subgroups of newborns were identified: normal, mildly or moderately abnormal and abnormal. Based on this, a neurological scoring system has been proposed. All normal fetuses reached a score in the range from 14 to 20. Ten fetuses who were postnatally described as mildly or moderately abnormal achieved a prenatal score of 5 to 13, while another ten fetuses postnatally assigned as neurologically abnormal had a prenatal score from 0 to 5. Among this group, four had lobar holoprosencephally, one had severe hypertensive hydrocephaly, one had tanatophoric dysplasia and four fetuses had multiple malformations.



**Figure 3:** Example of three-dimensional (3D) ultrasound assessment of the fetal face in the third trimester which provides the possibility to study a full range of facial expressions including smiling, crying, scowling and eyelid movements

That was a preliminary study that has already been continued in several collaborative centres. A future database formed using this new score for fetal neurological assessment will help in distinguishing fetal neurobehavioral impairments due to the early brain damage occurring *in utero*. It is hoped that the study of a large population will hopefully validate the value of the new test as a predictive marker for fetal neurodevelopmental outcome in both low-risk and high-risk populations.

### Conclusion

The new 3D/4D-US technology has been one of the most promising advances in the unknown field of prenatal behavior. The advance has been achieved by facilitating visualizations in almost real-time and producing standards for different movement patterns to appear and develop. The 4D study of fetal behavior provided us with a great possibility of understanding the hidden function of the developmental pathway of the fetal CNS and the potentialities of originating a neurological investigation *in utero*. By 4D technology we might be able to visualize an intrauterine neurological condition that would enable us to identify which fetus is at risk and which is not. The existence of motoric competence in the newborn, even in preterm infants, is assumed to have its origins in prenatal life. Behavioral perinatology assessed by 4D sonography

should be an interdisciplinary area of research involving concepts and conducting studies of the dynamic interplay between behavioral processes in fetal, neonatal, and infant life. The ultimate clinical application of fetal neurobehavioral assessment will be to identify functional characteristics of the fetus that predict a range of subsequent developmental dysfunctions. Establishing this link will require demonstration of positive and negative predictability to outcomes significantly beyond the immediate perinatal period. After standardization of valid reference ranges of movements appropriate for the gestational age, attempts have been made to develop a new scoring system for fetal neurobehavior based on prenatal assessment by 3D/4D sonography. That preliminary work may help in detecting fetal brain and neurodevelopmental alterations due to *in utero* brain impairment that is inaccessible by any other method.

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