Contribution of 3D power Doppler ultrasound to the evaluation of fetoplacental circulation

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Presentation:
Placental developmental abnormalities may be a cause of intrauterine growth retardation. 3D power Doppler ultrasound applied to the placenta may contribute to the evaluation of fetoplacental circulation.

Abstract

Three-dimensional ultrasound is a new method, based on the possibility of acquisition of a volume, in which the area of interest can be examined in various planes. The combination of 3D and power Doppler ultrasound provides important information on the spatial distribution of vessels in the studied organ.
3D power Doppler ultrasound applied to the placenta may contribute to the evaluation of fetoplacental circulation. The determination of placental vascularization indices makes ultrasound a quantitative method for the evaluation of placental vascularization. This type of examination can bring a real benefit in the monitoring of the evolution of pregnancies.
Keywords: *placenta, 3D Power Doppler ultrasound, vascularization indices*

Starting with 1996, modalities for the three-dimensional representation of ultrasound information have been developed[1]. Thus, 3D ultrasound has become an ideal instrument for distance medicine, opening new collaboration perspectives and ensuring high quality perinatal diagnosis[2].

3D ultrasound is a starting point for 4D ultrasound in perinatal medicine. This technique is still at a pioneering stage, but in a not too far future, 4D ultrasound might replace two-dimensional and Doppler ultrasound in the evaluation of fetoplacental circulation.

The past years have witnessed a spectacular development of imaging diagnosis in pregnancy, so that pregnancy monitoring without ultrasound diagnosis is inconceivable today. The progress from 2 to 3 dimensions has allowed the storage and processing of images, as well as a better evaluation of anatomical structures. 3D ultrasound has become comparable to computed tomographic and magnetic resonance examinations, having two major advantages: low cost and absence of radiation.

3D ultrasound represents a new group of methods used for decoding ultrasound reflection. Three-dimensional (3D) ultrasound explores and memorizes a volume, allowing to obtain some section planes that are inaccessible to conventional investigation[3].

3D ultrasound examination should be preceded by conventional investigation and can be associated with power Doppler examination. The association of 3D ultrasound with power Doppler examination provides additional information, by evidencing the vascular pattern of the examined organ. Vascular structures are better studied by the combination of the two techniques[4]. In obstetric pathology,

the role of the method is undeniable[5]. This exploration method can also be applied to the placenta. Thus, an exact evaluation of placental vascularization is possible[6]. The ultrasound evaluation of the placenta is currently considered as important as the morphofunctional study of the fetus[7].

Combined 3D and power Doppler ultrasound evidences vascular structures with an increasing accuracy, also showing their spatial distribution. The study of placental circulation is based on the fetal growth disorder-abnormal circulation relationship. 3D power Doppler ultrasound favors the in vivo evaluation of the pathophysiological status. Using these techniques, placental vascularization can be easily reconstructed, with the detection of possible vascular abnormalities[8]. The most important benefit of this method is the possibility of the three-dimensional evaluation of the placenta[9] (Figure 1).

The modalities for the obtaining of block ultrasound information allowing three-dimensional reconstruction differ depending on the device.

Data acquisition can be performed using specialized transducers or the „free hand" technique.

Ultrasound information can be represented by three orthogonal sections or by the three-dimensional spatial rendering (computerized representation) of the area of interest (Figure 2)[10].

The three orthogonal sections can be displayed separately or can be coupled dynamically in the so-called "niche" mode.

Three-dimensional ultrasound techniques may contain several types of information:

- information in the gray scale alone;
- information on vessels by power Doppler technique;
- information on vessels by color Doppler technique.

3D ultrasound requires a high resolution device, a specialized transducer, high calculation processor power, and the presence of specialized software.

The stored three-dimensional volume can then be processed, by eliminating a number of surrounding structures[10].

It can be concluded that 3D ultrasound is superior to two-dimensional ultrasound due to the following aspects:

- rapid volume acquisition;
- the examiner can choose between two examination modes: the flat mode or the three-dimensional image.

In the flat mode, the object is simultaneously projected in three perpendicular planes. There are no limitations in the rotation of the object.

The size of the placenta is an important aspect in three-dimensional evaluation. The extremely large or extremely small sizes are associated with obstetric pathology (hydrops fetalis, intrauterine growth retardation, maternal diabetes mellitus, chromosomal abnormalities, etc.)[11]. Prior to 3D ultrasound, the placenta can be assessed by the measurement of two dimensions. Studies on placental volume measured by 2D ultrasound in the first and second trimesters of pregnancy have been published. According to some authors, small placental volumes estimated by two-dimensional ultrasound are more frequent in pregnancies with vascular complications[12]. Other studies have demonstrated that low fetal birth weight is preceded by small placental volume, considered to be a more important predictive factor for intrauterine growth retardation than fetal measurements[13].

Three-dimensional imaging has many advantages in the examination, but also a number of limitations such as:

- appearance of fetal or even maternal movements during volume scanning;
- movement artifacts, which reduce the quality of the image or even make it impossible to interpret;
- oligohydramnios;
- the posterior location of the placenta is an impediment to the acquisition of a volume.

3D power Doppler ultrasound should become a routine procedure in the evaluation of the development of placental vascularization during pregnancy. This imaging method should be used at various gestational ages for the assessment of the evolution of the process of placentation.

For the performance of 3D ultrasound examination, it is recommended that patients should be examined in semiprone position. 2D and Doppler ultrasound examination is initially performed. In this way, information regarding the localization of the placenta, its thickness and the degree of placental maturation will be provided. Subsequently, the insertion of the umbilical cord is located and the umbilical artery flow is recor-

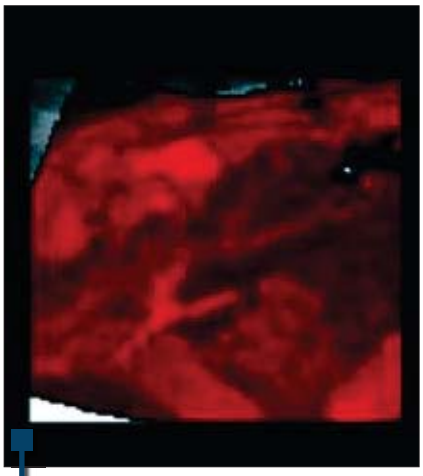

Figure 1. 3D and power Doppler ultrasound - placenta

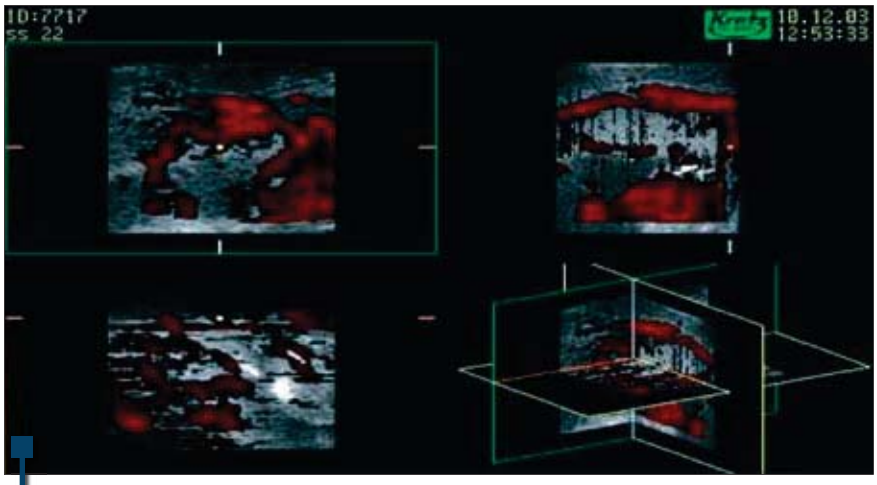

Figure 2. 3D ultrasound - placenta represented in the "niche" mode

ded. Umbilical RI will be measured, and this will be correlated with the vascularization indices in the placenta.

3D power Doppler ultrasound will be performed after the obtaining of all this information. Data on a representative placental vascularization volume will be obtained.

In the first trimester of pregnancy, the whole placental volume can be visualized, but the separation of placental vascularization from non-placental vascularization is difficult[14].

The measurement of placental volume between 11 and 14 weeks of amenorrhea is an indicator, but cannot be considered a predictive factor for chromosomal abnormalities[15]. A recent study case has described a potential role of 3D ultrasound and of the determination of placental volume in the detection of aneuploidy[16].

The possibility of the correlation of placental volume measured by 3D ultrasound at the end of the first trimester of pregnancy with placenta-associated plasma protein A levels and free βhCG has also been studied. This association might represent a higher stage in the diagnosing of the Down syndrome in the first trimester of pregnancy[17].

Figure 3. Two-dimensional placental ultrasound in power Doppler mode

Figure 4. Three-dimensional placental ultrasound in power Doppler mode

One more argument in favor of the use of 3D ultrasound might be represented by the literature data supporting the fact that the study of placental volume could be an effective, easy, early method for the identification of deficient trophoblast invasion[11].

Small placental volume, associated with a pathological uterine Doppler waveform pattern at 11-14 WA represents a predictive factor for pathological pregnancy.

In the second and third trimesters of pregnancy, the method is obviously superior to all the other ultrasound methods. 3D power Doppler ultrasound will allow the visualization of the vascular tree, including arteries of third order stem villi, structures that could not been evidenced with certainty using other ultrasound techniques[18]. However, the whole placenta cannot be visualized in this period. Thus, standardized methods are required, so that the data obtained can be clinically reproducible.

For this type of ultrasound examination, it is recommended that blood samples be taken from the central part of the placenta, if this is located anteriorly, laterally or in the uterine fundus. In the case of posteriorly inserted placentas, the most accessible area will be chosen. The volume device will be positioned in the area with the highest villous vascular density. There are also opinions supporting the fact that placental indices provide data on vascularization in a selected volume unit, which might not be representative of the entire organ. In the second and third trimesters of pregnancy, it is recommended that these indices be determined in several units, between which signifcant vascularization differences might occur[19].

The 3D power Doppler ultrasound study performed by the method of "placental vascular biopsy" represents a useful method for the evaluation of placental vascularization during pregnancy. This technique involves the acquisition of the 3D image using the VOCAL program (virtual organ computer-aided analysis), using the spherical mode in order to define the placental area of interest[20]. The reference image for the evaluation of the placenta is plane A. Volume is obtained using the VOCAL rotation technique, which draws the outline of the placenta, after which the image is rotated at a 30 degree angle. After the 6 rotations, the device software automatically provides placental volume. In this way, a representative model of placental vascularization is obtained, which will allow the evaluation of the placental vascular tree. The exploration is extremely important, also allowing the visualization of an abnormal vascular network, which is correlated with intrauterine growth retardation.

The determination of volume and the evidencing of blood vessels by power Doppler ultrasound is a first qualitative assessment stage. Placental vascularization can also be quantitatively evaluated by 3D power Doppler ultrasound, a method that studies and quantifies the Doppler signal in the whole placenta, unike 2D ultrasound combined with color or power Doppler, which allows the analysis of vascularization in an initially selected restrictive two-dimensional plane (Figure 3, Figure 4).

In order to eliminate the subjectivity of examination, 3 interplacental vascularization indices were defined[21]. After the estimation of placental volume, the histogram for the determination of vascular indices will be used. These will be calculated using the VOCAL program. The three planes of analysis of placental volume will have to locate the area with the highest vascular density.

The VOCAL program automatically calculates the gray scale and the significance of colors in the studied volume. 3D ultrasound uses voxels, which contain the gray-scale and color information on an intensity scale from 0 to 100. The degree of brightness, the gray scale and color Doppler are associated with voxels, and the information is represented in a 3D power Doppler histogram[20] (Figure 5, Figure 6). In this system, the 3 vascularization and flow indices in the placenta are measured:

- VI is the vascularization index, which determines the number of color voxels in the studied volume (percentage of color in the volume of interest), so it is the representation of blood vessels in the explored territory. It is expressed in percentage;

■ FI is the flow index, which represents the mean of color voxels, being the expression of blood flow intensity;

■ VFI is defined as the vascularization-flow index, being the mean of gray-scale and color voxels in the studied volume and evaluates both vascularization and blood flow.

The literature contains little information regarding the distribution of these placental vascular indices during the course of pregnancy.

A number of recent studies have represented vascularization indices depending on gestational age and placental volume. Distribution has been assessed by various statistical methods, which might also explain the considerable differences between the various studies. The majority of the authors recommend the evaluation of distribution indices by regression, histogram analysis and Shapiro-Wilk and Kolmogorov-Smirnov tests. The Pearson correlation test has been used in order to evaluate the correlation between placental indices and gestational age, placental volume, respectively. Other authors recommend the ANOVA tests or the SPSS program[7,19,20].

In the case of the correlation of placental vascularization indices with gestational age, there are studies reporting a constant maintenance of the three indices during the course of pregnancy[19]. Other authors show that FI increases progressively and linearly throughout the course of pregnancy. VI increases until 30 week of pregnancy and plateau values are maintained until 37 weeks of pregnancy. Subsequently, a slight decrease is found until delivery[20]. The vascularization-flow index reflects the combination of the two indices, based on the values of which this is calculated. The differences that occur can be explained by the modality of placental volume sampling. The majority of the studies support the fact that the 3D power Doppler ultrasound method allows the adequate study of placental circulation and the identification of the ramifications of villous vessels. The number of vessels can be assessed by the measurement of VI and the blood flow by the determination of FI and VFI. Thus, new information on the study of placental vascularization in both normal pregnancies and those with vascular pathology can be obtained[22].

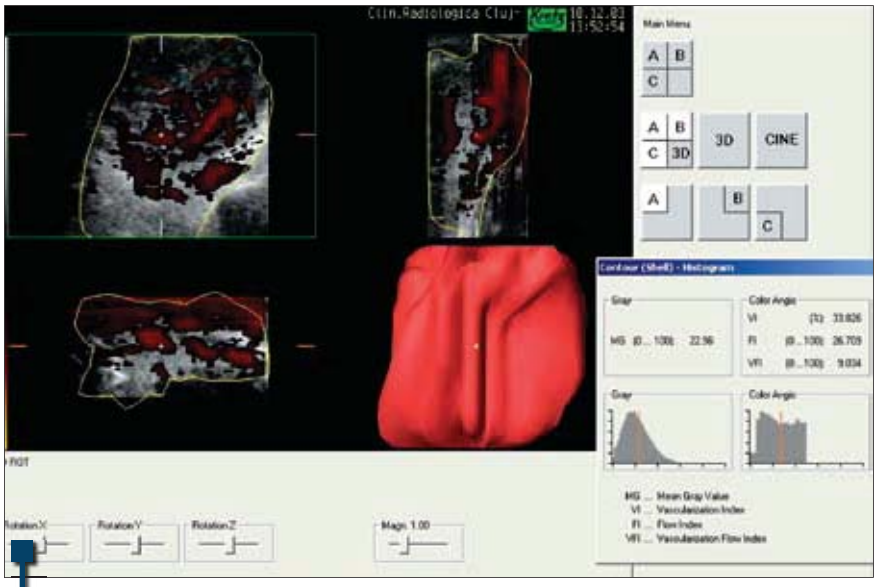

Figure 5. Determination of vascularization indices using the 3D power Doppler histogram

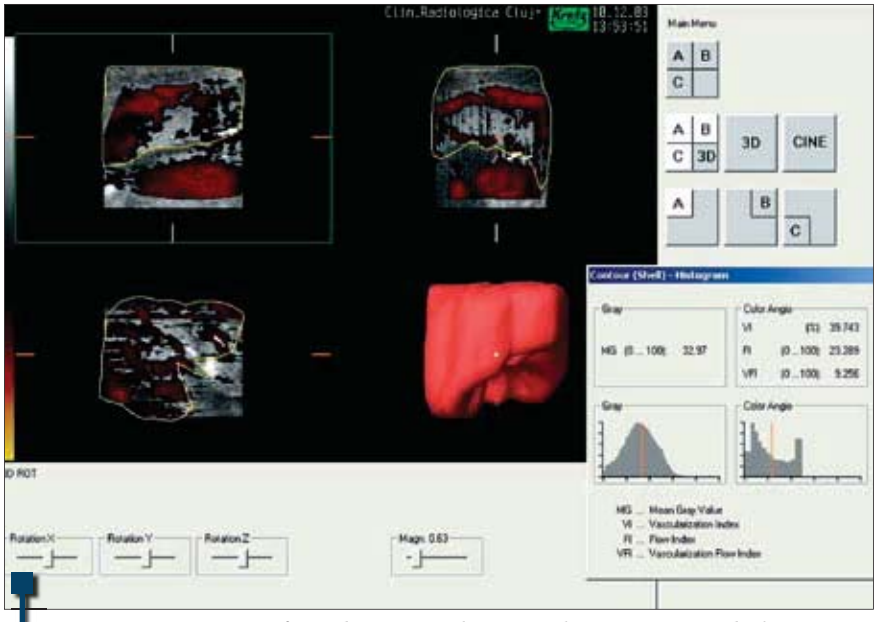

Figure 6. Determination of vascularization indices using the 3D power Doppler histogram

Some studies indicate in the case of the correlation of the 3 indices with placental volume a tendency to their decrease with the increase in placental volume. Other studies show that placental vascularization increases proportionally to placental volume, contributing to the constant maintenance of indices during pregnancy[23].

Placental vascularization indices can also be correlated with umbilical RI. Doppler velocimetry alterations in umbilical arteries indicate changes in villous vessels. An increase in umbilical RI occurs when 70% of placental vessels are affected. Consequently, normal umbilical RI values do not guarantee an adequate placental flow. In these cases, high intraplacental vascular resistance can determine pregnancy complications[20]. These statements support the importance of the determination of placental indices for the early detection of intrauterine growth disorders and fetal distress. It can be concluded that the reduction of placental flow evidenced by 3D power Doppler ultrasound can become an earlier marker than the increase of resistivity in the umbilical artery[20,25,26].

The 3 vascularization indices can also be correlated with fetal biometric parameters and fetal weight.

Recent studies show that placental volume and vascularization indices are not influenced by maternal age, in the absence of diseases associated with pregnancy. Parity influences all 3 indices, which have higher values in multiparous women[24].

Studies over the past years have increasingly focused on the normal or pathological aspect of the placenta. This is justified by the fact that the placenta, an organ created by pregnancy, ensures fetal-maternal exchanges, with direct implications in the development of the product of conception[27].

Conclusions

It can be concluded that 3D power Doppler ultrasound provides new important information on placental vascularization in both normal pregnancies and pregnancies with vascular pathology.

The majority of the published studies investigate normal pregnancies, within 14-25 weeks of amenorrhea, in which the mean values of placental vascularization indices are[23]:

- VI = 11.43- 14.63
- FI = 37.44- 40
- VFI = 4.77- 6.06

Placental developmental abnormalities may be a cause of intrauterine growth retardation. Using 3D power Doppler ultrasound, placental vascularization can be easily reconstructed. Maternal vessels, the vascular tree at the level of each cotyledon, as well as umbilical cord vessels can be examined in three-dimensions. Thus, new perspectives for the monitoring of pregnancies with vascular pathology are opened. The correlation of placental vascularization indices with other ultrasound parameters might provide valuable information allowing an improvement in the monitoring of these pregnancies. ■

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