Editorial

Asim Kurjak*

3D/4D Sonography

DOI 10.1515/jpm-2016-0431

Three-dimensional (3D) ultrasound has been the most rapidly evolving technique and technology in fetal ultrasound in the past few years [1–3]. In fact, it is fair to say that, the technology advances have been so profound that most sonologists have caught up with recent developments.

3D ultrasound has undergone dramatic changes since its inception 3 decades ago; the original cumbersome B-mode gantry system has evolved into a high resolution real-time imaging system. It is the most widely used imaging technology worldwide. Its popularity has greatly increased due to availability, speed and low cost. With enhancement in computer technology doing real-time processing, we are starting to get images that are so clear; patients do not even realize the images are ultrasound.

The tremendous technological advances developed by prenatal ultrasound diagnosis are unmatched in other areas of medicine. Today we have sophisticated equipment that allows us to obtain not only high quality images but also, 3D and 4D images rapidly. Moreover, current 3D ultrasound equipment can store the information obtained in 3D/4D for later processing, allowing shortened examinations of patients. This is very helpful when reviewing cases for teaching and research purposes.

Our journal has been following the explosive development of the clinical use of 3D/4D sonography. A few years ago, a large review of 575 papers published from 2000 to 2006 was reviewed. This editorial together with 12 papers from 10 countries published in this issue of the *Journal of Perinatal Medicine* is a continuation of our interest in critical multicentric evaluation of the routine use of 3D/4D sonography in all periods of perinatal medicine [4–13].

For 3D visualization of the fetal face, the surface mode is generally used. This normally needs a shorter training period with acceptable results in a relatively limited period of time [14, 15]. The appropriate gestational age is neither too early nor too late. It is our belief that the most favorable age for 3D scanning of the fetal face is from weeks 23 to 30.

Our experience shows that it is counterproductive to show the 3D image of the fetal face to parents during the first trimester. For most parents, the image appears to be strange and it can create a distorted image of their child, which will not reinforce the affective bonds.

Fetal anomalies are much better detected by 3D/4D which clearly makes a difference in areas such as anatomic anomalies (cleft lip, clubfoot, etc.), better assessment of the heart, and by giving a reassuring overview of limbs, face and body surface [16]. This is extensively discussed in the paper of Merz and Pashaj [4].

It is our belief that the future use of 4D ultrasound will expand greatly, making our assessment of the fetus in the first and second trimesters not only more complete, but also a more enjoyable experience. This is clearly illustrated in papers by Merz and Pashaj, and Spalldi Barisic et al. [4, 5].

It is possible to detect early complications of multifetal pregnancies such as a “vanishing” twin in the first trimester. It is important not to confuse this with a subchorionic hematoma, in which 3D ultrasound is very useful in imaging variable shape, internal low-level echoes and the absence of an echogenic rim of chorionic tissue.

Using 3D ultrasound, it is possible to calculate the volumes of the gestational sac, amniotic sac, and the embryo, allowing a better diagnosis of discordant fetal growth. Furthermore, it is possible to diagnose a variety of anomalies involving one of the twins. The type of malformation affecting twins can be divided into those unique to twins and acardiac twins, and those anomalies not unique to twins, such as neural tube defects and congenital heart defects. Wataganara [6] discussed in detail assessment of conjoined twins.

The “placental biopsy” technique with the 3D power Doppler was designed to obtain a representative sample of placental vascularization, which allows evaluation of the placental vascular tree as a whole. Power Doppler was sensitive enough to depict a vascular tree because it is based on Doppler signal amplitude instead of mean frequency values. Moreover, it does not show an aliasing effect and the color map is independent of the insonation angle. Yamasato and Zalud [7] discussed it in detail.

3D power Doppler ultrasound provides a 3D reconstruction of the blood vessels under analysis, and complex, subtle anatomic details may be visualized in real time. With the use of post-processing applications, the operator can delete the grayscale images surrounding the color

Doppler and 3D power Doppler acquisition. This isolates and allows examination and evaluation of the vascular tree. In concurrence with others, we show that visualization of the vessels seen with this mode gives us a better understanding of both normal and pathologic anatomy. Many more details and illustrations can be found in paper by Cali [8] and his team.

Silhouette ultrasound is a new promising tool [17, 18]. The device can actually create images of virtually any organ in the body. The Radiance System Architecture sets a new standard in imaging performance which gives more clarity, more depth penetration and high resolution with fast frames and with the processing power for advanced applications and efficient workflow.

Based on this 3D/4D platform many reformed images are being developed using a new software "HDlive Silhouette and HDlive Flow" [19–21]. It brings an unprecedented detail, bringing an end to an era of blurred grayscale images. One of the aim of these development is to detect the abnormalities in the fetuses early and to plan the treatment long before the baby is born.

The scanner's new HDlive Silhouette and HDlive Flow applications use the ultrasound data in new ways to calculate depth, shape and detail, removing noise, enhancing image and adding color and light, to the final 3D image. The incredible number-crunching power of the machines allows it to render these images in seconds so that what was once a grainy, grayscale, two-dimensional image has changed into a picture of crystal clear clarity in which ultrasonographers and patients can even "see a baby through ultrasound". This is elegantly illustrated in papers by Merz and Pashaj [4], Antsaklis et al. [9] and Spalldi Barisic et al. [5].

New technology has enabled insight into the fetal neuromotor development that is reflected by the repertoire of fetal activities or fetal behavior. Based on that new technology, the Zagreb group proposed a screening test called the Kurjak Antenatal Neurodevelopmental Test (KANET) [22–24]. Over 10 years, the KANET has been used to assess almost 3000 fetuses. Initial results are promising, and the test has demonstrated an ability to recognize normal, borderline, and abnormal behavior in fetuses from low risk and high risk pregnancies. However, further studies are necessary as well as long-term postnatal monitoring of children who were prenatally evaluated with the KANET in order to determine its clinical value in identification of children with neurological risk. This is discussed in detail in the papers on multicentric studies of KANET by Kurjak et al. [10].

In the history of 3D/4D ultrasound technology, one of the greatest achievements was HDlive technology. This technology is a novel ultrasound technique that improves the 3D/4D images. HDlive ultrasound has resulted in remarkable progress in visualization of early embryos and fetuses and in the development of sonoembryology. HDlive uses an adjustable light source and software that calculates the propagation of light through surface structures in relation to the light direction. The virtual light source produces selective illumination, and the respective shadows are created by the structures where the light is reflected. This combination of light and shadows increases depth perception and produces remarkable images that are more natural than those obtained with classic 3D ultrasound. The virtual light can be placed in the front, back, or lateral sides, where viewing is desired until the best image is achieved. A great advantage is that the software can be applied to all images stored in the machine's memory. With HDlive ultrasound, both structural and functional developments can be assessed from early pregnancy more objectively and reliably and indeed, the new technology has moved embryology from post-mortem studies to the *in vivo* environment. Practically in obstetrical ultrasound, HDlive could be used during all three trimesters of pregnancy. In the paper by AboEllail and Hata [11] HDlive image of the fetus is more clearly demonstrated by shadowing with virtual light than classic 3D image. There have been several reports on HDlive demonstration of fetal surface. 3D HDlive further "humanizes" the fetus, enables detailed observation of facial appearance even in the first trimester, and reveals that a small fetus is not a fetus but a "person" with a personality from the first trimester. Detailed structural abnormalities of face, fingers, toes and even amniotic membranes in the first trimester could be well demonstrated by HDlive technique. New applications of HDlive silhouette and HDlive flow were released at the end of 2014. The algorithm of HDlive silhouette creates a gradient at organ boundaries, fluid filled cavity and vessel walls, where an abrupt change of the acoustic impedance exists within tissues. By HDlive silhouette mode, an inner cystic structure with fluid collection can be depicted through the outer surface structure of the body and it can be appropriately named as "see-through fashion" [19].

The preimplantation ultrasound refers to targeted imaging of the uterus and adnexa prior to assisted reproduction techniques to optimize the infertility treatment outcomes. A systematic approach for 3D ultrasound examination consists of a detailed examination of the uterine shape, size and contour, evaluation of the endometrial thickness, volume, pattern and vascularity, and assessment of the junctional zone regularity, echogenicity and thickness. Color power Doppler ultrasound may be applied to evaluate the vascularity of the ovaries and pelvic lesions. The diagnostic possibilities with 3D/4D in this critical period of pregnancy are discussed by Arya and Kupesic [12] and Panchal et al. [13].

In conclusion, it is not an overstatement that in one generation advances in imaging have transformed perinatal medicine. Undoubtedly 3D ultrasound is becoming an important part of the state of art sonographic imaging in perinatal medicine. It is a problem solving tool in selected circumstances with further evidence needed that 3D ultrasound improves clinical outcomes. With this great technologic advance comes caution. 3D ultrasound enables our profession to visualize the fetal patient better than ever. With this ability comes the danger that patients believe that medicine can guarantee the “perfect baby”. Our colleague Frank Chervenak has appropriately warned us not to mislead our patients to this false conclusion.

References

[1] Kurjak A, Miskovic B, Andonotopo W, Stanojevic M, Azumendi G, Vrcic H. How useful is 3D and 4D ultrasound in perinatal medicine. J Perinat Med. 2007;35:10–27.
[2] Merz E. 25 Years of 3D ultrasound in prenatal diagnosis (1989–2014). Editorial. Ultraschall in Med. 2015;36:3–8.
[3] Kurjak A, Pooh RK, Merce LT, Carrera JM, Salihagic-Kadic A, Andonotopo W. Structural and functional early human development assessed by three-dimensional (3D) and four-dimensional (4D) sonography. Fertil Steril. 2005;84:1285–99.
[4] Merz E, Pashaj S. Advantages of 3D ultrasound in the assessment of fetal abnormalities. J Perinat Med. 2017;45:643–50.
[5] Spalldi Barišić L, Stanojević M, Kurjak A, Porović S, Gaber G. Diagnosis of fetal syndromes by three- and four-dimensional ultrasound: is there any improvement? J Perinat Med. 2017;45:651–65.
[6] Wataganara T, Ruangvutilert P, Sunsaneevithayakul P, Russameecharoen K, Nawapun K, Phithakwatchara N. Three-dimensional ultrasound for prenatal assessment of conjoined twins: additional advantages? J Perinat Med. 2017;45:667–91.
[7] Yamasato K, Zalud I. Three dimensional power Doppler of the placenta and its clinical applications. J Perinat Med. 2017;45:693–700.
[8] Calì G, Foti F, Minneci G. 3D power Doppler in the evaluation of abnormally invasive placenta. J Perinat Med. 2017;45:701–9.
[9] Antsaklis P, Porovic S, Daskalakis G, Kurjak A. 4D assessment of fetal brain function in diabetic patients. J Perinat Med. 2017;45:711–5.
[10] Kurjak A, Antsaklis P, Stanojevic M, Vladareanu R, Vladareanu S, Moreira Neto R, et al. Multicentric studies of the fetal neurobehavior by KANET test. J Perinat Med. 2017;45:717–27.
[11] AboEllail MAM, Hata T. Fetal face as important indicator of fetal brain function. J Perinat Med. 2017;45:729–36.
[12] Arya S, Kupesic Plavsic S. Preimplantation 3D ultrasound: current uses and challenges. J Perinat Med. 2017;45:745–58.
[13] Panchal S, Kurjak A, Nagori C. 3D and 4D studies from human reproduction to perinatal medicine. J Perinat Med. 2017;45:759–72.
[14] Azumendi G, Kurjak A. Three-dimensional and four-dimensional sonography in the study of the fetal face. Ultrasound Rev Obstet Gynecol. 2003;3:160–9.
[15] Kurjak A, Azumendi G, Andonotopo W, Salihagic-Kadic A. Three- and four-dimensional ultrasonography for the structural and functional evaluation of the fetal face. Am J Obstet Gynecol. 2007;196:16–28.
[16] Pooh RK, Kurjak A. Three-dimensional ultrasound in detection of fetal anomalies. Donald School J Ultrasound ObstetGynecol. 2016;10:214–34.
[17] Pooh RK, Shiota K, Kurjak A. Imaging of the human embryo with magnetic resonance imaging microscopy and high-resolution transvaginal 3-dimensional sonography: human embryology in the 21st century. Am J Obstet Gynecol. 2011;204:77.e1–16.
[18] Pooh RK, Kurjak A. Novel application of three-dimensional HDlive imaging in prenatal diagnosis from the first trimester. J Perinat Med. 2014;43:147–58.
[19] Pooh RK. “See-through Fashion” in prenatal diagnostic imaging. Donald School J Ultrasound Obstet Gynecol. 2015;9:111.
[20] Pooh RK. A new field of “Fetal Sono-ophthalmology by 3D HDlive silhouette and flow. Donald School JUltrasound ObstetGynecol. 2015;9:221–2
[21] AboEllail MAM, Kanenishi K, Mori N, Kurobe A, Hata T. HDlive imaging of circumvallate placenta. Ultrasound Obstet Gynecol. 2015;46:513–4.
[22] Kurjak A, Ahmed B, Abo-Yaquab S, Younis M, Saleh H, Shaddad AN, et al. An attempt to introduce neurological test for fetus based on 3D and 4D sonography. Donald School J Ultrasound ObstetGynecol. 2008;2:29–45.
[23] Salihagic Kadic S, Stanojevic M, Predojevic M, Poljak B, Grubisic-Cabo B, Kurjak A. Assessment of the fetal neuromotor development with the new KANET test. In: Reissland N, Kisilevsky BS, editors. Fetal development. Switzerland: Springer International Publishing; 2016. p. 177–88.
[24] Kurjak A, Miskovic B, Stanojevic M, Amiel Tison C, Ahmed B, Azumendi G, et al. New scoring system for fetal neurobehavior assessed by three- and four-dimensional sonography. J Perinat Med 2008;36:73–81.

***Corresponding author: Prof. Asim Kurjak,** MD, PhD, Department of Obstetrics and Gynecology, Medical School University of Zagreb, Sveti Duh 64, Zagreb 10000; and International Academy of Perinatal Medicine, Zagreb, Croatia, E-mail: asim.kurjak@public.carnet.hr