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EDITORIAL

1989–2019: 30 Years of 3D Ultrasound in Obstetrics and Gynecology

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ABSTRACT

Three-dimensional (3D)/four-dimensional (4D) ultrasound has profited greatly from the developments in computer and 3D probe technology. It has become such a sophisticated technique in the fields of prenatal diagnosis, gynecology, and breast diagnosis that it is indispensable for the skilled ultrasound operator. It represents a problem-solving tool in different circumstances, not only in the demonstration of pathological findings, but also in the verification of normal findings. This is particularly important in obstetrics in patients with an increased risk for a specific fetal malformation. In such a situation, the parents-to-be can easily be reassured by being shown the normal fetal anatomy. On the contrary, with the ability to demonstrate the fetus to the parents-to-be as in a photograph, there may be a risk that they believe 3D ultrasound to be able to detect any possible defect and can thus guarantee the "perfect baby." However, this would definitively be the wrong conclusion.

Keywords: Four-dimensional ultrasound, HDlive mode, Silhouette mode, Three-dimensional ultrasound.

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INTRODUCTION

Thirty years of 3D ultrasound in obstetrics and gynecology represents an extraordinary success story in recent ultrasound history. However, as with many new technologies, the beginning was anything but easy. Even though initial experimental *in vitro* ultrasound studies had already been published by 1974,[1] the clinical application of 3D ultrasound only started several years later with the first commercial 3D ultrasound unit (Combison 330) launched by Kretztechnik, Zipf, Austria, in 1989.[2,3] This system was already equipped with special 3D transducers that enabled automatic and precise volume acquisition, making it possible for the first time to display the three orthogonal two-dimensional (2D) image planes at the same time on the monitor (multiplanar or triplanar display).[3,4] Nevertheless, not a few experienced 2D ultrasound operators were initially skeptical regarding the clinical use of this new technique and viewed 3D ultrasound as a difficult, inconvenient, and even unnecessary method.[5] A turnaround occurred with the First World Congress on 3D Ultrasound in Obstetrics and Gynecology from September 5 to 6, 1997 in Mainz, Germany (Fig. 1),[3] and with the Second World Congress on 3D Ultrasound in Obstetrics and Gynecology from October 14 to 15, 1999 in Las Vegas, United States (Fig. 1).

A growing interest in the new technology, as well as factors, such as an increase in 3D publications, the development of new display modes, the simplification of the operation process, faster rendering due to greater computer processing power, in addition to the improvement of image quality, and the decrease in costs further contributed to this development and led to the global application of the technology. However, for economic reasons worldwide, only national 3D conferences and courses followed (Fig. 2), and until now, no further World Congresses have been organized.

Due to the rapidly evolving developments in 3D/4D ultrasound over the past few years, the need to organize a third World Congress on 3D Ultrasound in Obstetrics and Gynecology became apparent. Asim Kurjak and I therefore, decided to organize such a congress in Dubrovnik, Croatia in 2019.

The tremendous progress made in 3D ultrasound over the past 30 years has shown it to be not only a valuable supplementary method to conventional 2D ultrasound, but confirmed it as being essential for the precise demonstration of suspicious findings. In comparison with 2D ultrasound, 3D sonography provides the operator with a number of advantages: Several visualization modes, precise control of a certain anatomical plane, digital long-term storage of the volumes, and the possibility of performing virtual ultrasound examinations.[3-6]

In prenatal diagnosis, 3D ultrasound provides the operator with excellent multiplanar, surface, and transparent images of the embryo and the fetus, allowing the precise demonstration of a normal anatomy and

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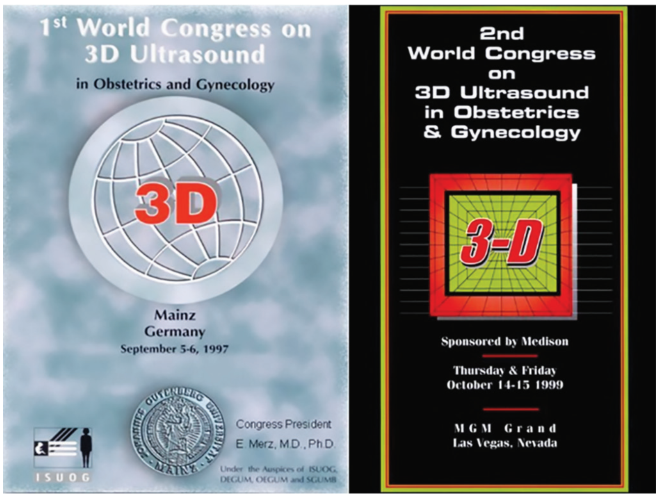

Fig. 1: Left: Announcement of the First World Congress on 3D Ultrasound in Obstetrics and Gynecology in Mainz, Germany. Right: Announcement of the Second World Congress on 3D Ultrasound in Obstetrics and Gynecology in Las Vegas, USA

anomalies of the brain, the face, thorax, heart and the vascular system, abdominal wall defects, spina bifida, and urogenital and limb malformations.[7-26] One of the latest developments in 3D ultrasound is the HDlive mode that enables a near photographic demonstration of the surface of the embryo and fetus.[19,25,27] HDlive uses a movable virtual light source for illumination of the object of interest. The combination of light and shadow increases depth perception and produces more natural pictures than those obtained with classic 3D surface modes. HDlive Studio allows illumination of the embryo/fetus with 3 different movable light sources, similar to the illumination of an actor on a stage. Another new technology is the Silhouette mode, in particular, the high Silhouette mode that allows demonstration of inner organs, such as the ventricle system of the brain[28] or the bowel in the umbilical cord during umbilical herniation.[29] With the different display modes, even subtle defects which are important in syndromes or chromosomal aberrations can be demonstrated. The 4D ultrasound enables the control of fetal movements in real time while observing the fetal surface. Normal and abnormal movements permit insights into fetal neurodevelopment.[30-32] Normal, borderline, and abnormal behavior in fetuses from low-risk and high-risk pregnancies can be differentiated by use of the Kurjak Antenatal Neurodevelopment Test.[33,34] Spatiotemporal image correlation (STIC) permits offline multiplanar analysis of the fetal heart in motion.[35,36] The combination of STIC and color Doppler provides the examiner with a detailed view of the cardiac blood flow. This allows the examiner to view complex anomalies of the fetal heart and to control the cardiac blood flow during the different heart cycles.[4,37-40]

In gynecology, 3D ultrasound[41,42] can be applied in the diagnosis of pelvic floor defects,[43,44] uterus anomalies,[42,45,46] or fertility problems as well as in the identification of tubal patency (HYCOSY)[47-53] or uterine device location[42,54,55] as well as in tumor evaluation and differentiation.[42,56-59] In particular, the combination of 3D

Fig. 2: Left: Announcement of the Second Asian Congress on 3D Ultrasound in Obstetrics and Gynecology in Tainan, Taiwan. Right: Announcement of the 11th Symposium on 3D Ultrasound in Obstetrics and Gynecology in Frankfurt, Germany

ultrasound and Color Doppler permits the demonstration of the spatial pattern of tumor vascularization.[42,60,61]

In breast diagnosis, 3D ultrasound[62-66] provides additional information in the multiplanar mode. The third plane parallel to the thorax enables the detection of the retraction pattern typical for malignant tumors.[62,63] The 3D ultrasound offers another important advantage during the puncture of breast tumors: Control of the needle in all three planes enables a precise puncture of the tumor.[67,68]

The digital storage of volumes permits a virtual examination, i.e., volumes can be reloaded at any time and examined in the absence of the patient.[4,25] With the help of a special computer program, all stored volumes can be loaded on a computer and thus be examined independently of the ultrasound unit.[3-6] Digital storing of volumes further enables a perfect teaching approach in medical education. Reviewing copies of a stored volume allows several trainees to be taught at the same time enabling them to recognize the fetal anatomy hidden within the volume.[3]

In conclusion, 3D/4D ultrasound has profited greatly from the developments in computer and 3D probe technology. It has become such a sophisticated technique in the fields of prenatal diagnosis, gynecology, and breast diagnosis that it is indispensable for the skilled ultrasound operator. It represents a problem-solving tool in different circumstances, not only in the demonstration of pathological findings, but also in the verification of normal findings. This is particularly important in obstetrics in patients with an increased risk for a specific fetal malformation. In such a situation, the parents-to-be can easily be reassured by being shown the normal fetal anatomy. On the contrary, with the ability to demonstrate the fetus to the parents-to-be as in a photograph, there may be a risk that they believe 3D ultrasound to be able to detect any possible defect and can thus guarantee the "perfect baby."[69] However, this would definitively be the wrong conclusion.

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