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3D and 4D Ultrasound for Fetal Airway Assessment: Prognostic Value and Delivery

Megan Gutierrez*

Department of Maternal Fetal Medicine Livingston, Saint Barnabas Medical Center, NJ, USA

***Corresponding author:** *Megan Gutierrez,* Department of OBGYN Division of Maternal Fetal Medicine Livingston, Saint Barnabas Medical Center, NJ, USA, E-mail: gutierrezm@yahoo.com

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Introduction

Advances in ultrasound technology have transformed our abilities in prenatal diagnosis. Specifically, the value of Three-Dimensional Ultrasound (3DUS) has profound clinical implications when diagnosing fetal craniofacial and nasopharyngeal anomalies with the potential for airway obstruction. Varying diagnoses carry different probabilities of neonatal breathing impairment, difficult intubation, asphyxia or neonatal death. In complement to 2D ultrasound, both 3D and 4D Ultrasound (4DUS) technologies promote clinically relevant, enhanced analysis of complex fetal anatomy. A thorough assessment using 3D and 4DUS providescrucial prognostic information regarding the need for special delivery.

Discussion advancing technologies in ultrasound are vital for evaluation of complex prenatal anatomy. For fetal anomalies with potential respiratory compromise and difficult intubation at birth, it may be the primary decision making tool in safe delivery planning. Through a comprehensive evaluation of the amniotic fluid volume, stomach bubble, oral and nasal passages, and nasopharynx- trachea using 3DUS and 4DUS, patency and pliability of the airway can be accurately predicted. Oral tumors and craniofacial malformations may cause obstruction of the fetal airway at time of birth, leading to potentially life-threatening respiratory distress. When fetal airway access is compromised, one technique for optimizing fetal oxygen status at birth is the Ex Utero Intrapartum Treatment procedure, or exit. Exit allows for prolonged maintenance of utero-placental circulation for fetal interventions at time of cesarean section through partial fetal delivery with continued placental flow. Once a fetal airway is secured, the infant may be fully delivered. However, exit introduces serious maternal risks. Aspiration pneumonitis is common as the lower esophageal sphincter pressure is reduced with increased compression by the gravid uterus on the stomach. Combining this natural physiology with increased gastric acid production poses a danger during general anesthesia. Additionally, due to the decreased preload during supine positioning, the compromised cardiovascular system may experience hypotension with decreased uterine artery perfusion. Lastly, the prolonged length of exit leads to increased blood loss during cesarean delivery. While exit is a valuable tool, its significant complications dictate that it should only be used if necessary. Through detailed views of fetal anatomy, 3DUS helped to predict airway patency in each case. While exit was considered for all due to concern for neonatal breathing impairment and difficult intubation, antenatal decision was made against exit due to reassuring US signs of patent airway. Multidisciplinary planning between obstetrical, anesthesia, pediatric ENT, and NICU teams concurred that fetal outcome would not benefit via exit while increasing unnecessary risks for the mother. However, multidisciplinary teams were present at delivery for precaution. Ultimately, all neonates projected vigorous, immediate cries upon delivery without obstructed breathing and did not require intubation. Compared to 2D ultrasonography, 3DUS has proven advantageous in the detection of abnormal fetal anatomy and airway obstruction. It is not only useful in predicting the severity of a defect, but also in providing more convincing evidence of a normal fetus in cases at increased risk of malformation . As an adjunct 2D ultrasonography, 3DUS adds value in diagnosing various fetal head and neck abnormalities, including micrognathia and other profile malformations, cleft lip and palate, metopic suture abnormalities, nasal bone, ear or orbit abnormalities, neural tube defects, and skeletal malformations.

In each case, various 3D technologies were applied for a complete anatomical assessment. 3DUS surface rendering allows for accurate depiction of the fetal face and profile. The electronic scalpel assists in removal of obstructing adjacent structures such as placenta or cord that obscure the area of interest. 3D volume acquisition and Tomographic Imaging (TUI) enable multi-slice analysis that extends MRI capability with volume rendering and plane manipulation. Multiplanar display allows images to be displayed at right angles to each other in sagittal, coronal, or axial planes. By choosing a single point of intersection and traversing the three planes, one facilitates an improved spatial relationship of complex anatomical defects. HD live imaging enables 3DUS reconstruction at a frame rate of up to 20 images per second, yielding a smooth and dynamic real time 3D image. With the addition of Doppler, it is possible to visualize real-time active streaming of unimpaired bidirectional fluid flow in the fetal body.

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