The Utility of Antenatal Three-Dimensional Printing for Ex Utero Intrapartum Treatment (EXIT) Procedure

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Introduction

- Routine antenatal ultrasonography (US) allows for the timely identification of fetal abnormalities including the risk for airway obstruction. Congenital airway obstruction may be secondary to multiple etiologies and poses life-threatening risks to the newborn[1].
- Securing the airway at time of delivery is often difficult given the disruption of the normal anatomy and limitations of conventional imaging modalities[1-2].
- We present two cases highlighting the novel utility of three-dimensional (3D) printing to plan ex utero intrapartum treatment (EXIT) procedure during cesarean section (CS) delivery.

Case #1: (Figure 1)

- 32-year-old G8P502 with a routine fetal US showing a 3 x 2 x 2 cm right and midline cystic neck mass with a lobulated contour and hyperechoic components displacing the fetal hypopharynx to the left.
- Fetal magnetic resonance (MRI) noted an anterior midline, mainly cystic neck mass measuring 3.5 x 2.7 x 3.2 cm with slight displacement of the esophagus and trachea. Delivery via CS and EXIT procedure was recommended.
- 29w3d US demonstrated growth to 8.23 x 4.42 x 5.95 cm; a hyperextended neck and mild polyhydramnios with an amniotic fluid index (AFI) of 26.2 cm. MRI at 33w3d noted a dominant cystic lobule accounting for approximately one third of the total mass volume. 35w3d US showed growth to 9.62 x 9.23 x 9.08 cm and AFI of 20.82 cm.
- CS was performed under general anesthesia at 37w1d without complications. Intra-operatively, 270 cc was removed from the cystic area via needle aspiration before the lower uterine segment was incised. Tissue pathology reported an immature teratoma, grade 3, with focal microscopic yolk sac tumor.

Case #2: (Figure 2)

- 21-year-old G1P0010 with a 3D US at 18w1d revealing a mass protruding from the fetal mouth measuring 1.1 x 0.8 x 1.2 cm. The cavum septi pellucidi (CSP) was not visualized, there was cerebellar hypoplasia, and a dilated third ventricle.
- Genetic screening resulted in maternal carrier of Zellweger spectrum disorder (ZSD), PEX-1 mutation, and father of the baby (FOB) with Fabry disease and a low-risk carrier for PEX1-related ZSD. FISH, Karyotype, alpha-feto protein levels, and microarray collected via amniocentesis were all negative for significant findings.
- Fetal MRI at 20w4d confirmed presence of cerebellar and vermis hypoplasia and a pedunculated cystic pharyngeal mass extending from the mouth. Delivery via CS and possibility for EXIT procedure were discussed.
- Growth remained stable. 33w5d US showed mass measuring 2.0 x 2.7 x 2.2 cm and normal AFI, deferring EXIT procedure. Delivery was via CS at 33w6d due to preterm premature rupture of membranes. Tissue pathology showed a mature teratoma.

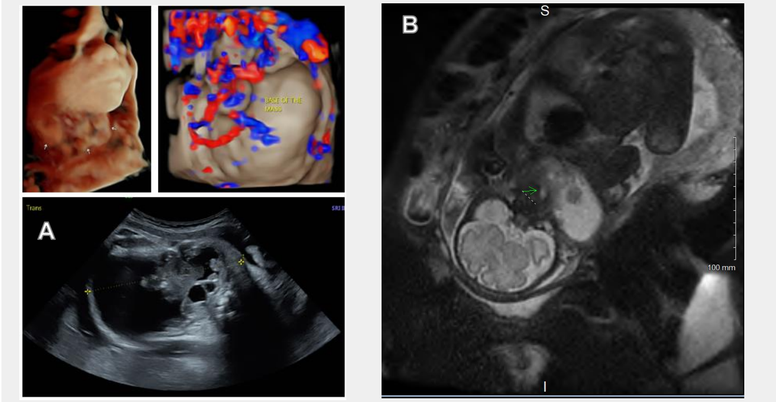

Figure 1. Imaging modalities utilized antenatally for teratoma characterization. (A) Upper left and right – 3D US volumes delineating the anatomical borders and vascularization at the base of the mass. Lower center – 35w3d 2D US illustrating mixed solid and cystic components representing 1/3 of total mass volume. (B) 33w3d Fetal MRI single coronal view which fails to clearly portray the anatomy. (C) Modeling Sequence starting from 3D US volume used as framework followed by the high-resolution virtual model, and final 3D-printed model of fetal neck mass with clear left displacement of fetal anatomy. Finally, patient after successful delivery and real-time large teratoma.

Figure 2. Similar sequence as shown in Figure 1 starting with the far left – 3D antenatal US volume utilized as skeleton for subsequent printing, followed by high-resolution virtual images and final 3D printed model delineating the oropharyngeal mass and lack of indication for EXIT procedure with room for potential intubation after delivery in case required. Far righ – newborn with real time 2.3 cm oropharyngeal mass extending from the fetal mouth as previously clearly illustrated on the 3D models.

Methods

- 3D US volumes from the fetal face/neck were acquired, edited, and exported from Voluson™ E10 Ultrasound System (GE Healthcare, Chicago, IL) in standard triangle language (STL) file format. 3-matic Medical (Materialise V, Leuven, Belgium) was utilized to prepare the imaging datasets for printing and included co-registration of multiple US volumes.
- The anatomic models were printed on F270 (Stratasys, Eden Praire, MN; Case 1-immature cervical teratoma), and Form 3B (Formlabs, Somerville, MA; Case 2-oropharyngeal mass).
- Post-processing of models included removal of support materials, sanding, and color and clear spray coatings.

Discussion

- The use of 3D printed models and computer aided designs techniques has been rapidly growing in the medical field. As such, 3D printing has become more cost-effective, efficient, and widely available.[3]
- Anatomical models and surgical guides have been utilized in multiple surgical fields, but that has not been the case for obstetrics and gynecology.[3]
- 3D printed models can be utilized for therapeutic planification, research, and the creation of library cases/anatomical atlas strengthening the training of providers and personalizing patient care.
- The development of guidelines to improve the reporting of experience with 3D printing in surgery is highly desirable.[4]

Conclusion

- Accurate and early antenatal diagnosis improves the prognosis and outcomes following EXIT procedures in fetuses with congenital airway obstructions at the time of cesarean section.
- This experience allowed the care team to proceed with or without an EXIT procedure having more confidence in the anatomy and potential interventions.
- 3D printing plays a vital role in the optimization of pre-surgical planning, prenatal parental counseling, and education of new medical professionals, and must be considered for fetuses with congenital airway obstructions.

References

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