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WILEY PRENATAL DIAGNOSIS

RESEARCH LETTER

Three-dimensional virtual cystoscopy: Noninvasive approach for the assessment of urinary tract in fetuses with lower urinary tract obstruction

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Fetal lower urinary tract obstruction (LUTO) is an obstructive uropathy beyond the level of the neck of the bladder for which the main cause is the posterior urethral valve. It shows an incidence of 2.2 per 10 000 births and is associated with high rates of morbidity and mortality as a consequence of pulmonary hypoplasia or renal failure.[1] Lower urinary tract obstruction can be an isolated condition or associated with some syndromes,[2] such as megacystis-microcolon syndrome, megacystis-megaureter syndrome, prune-belly syndrome, and trisomy 18.

Prenatal diagnosis of LUTO is possible since first trimester by the visualization of megacystics.[3] Prenatal ultrasound (US) provides high rates of detection of LUTO by means the identification of classical "key-hole sign," which represents the dilated posterior urethra.[4] Fetal cystoscopy is an invasive technique that allows direct diagnosis of the cause of the obstructive uropathy and then a specific prenatal therapy. If a membrane-like obstruction of the urethral lumen is seen, the diagnosis of posterior urethral valve will be confirmed, allowing the option of laser fulguration of the valves. However, if the membrane-like is not observed, laser fulguration is not possible, and the prognosis is considerably worse.[4]

The imaging fusion of real time US and MRI is feasible and may improve the fetal diagnosis.[5] Three-dimensional (3D) virtual navigation is a model created from overlapping image layers generated of US and/or magnetic resonance imaging (MRI) scan data. This technology provides an immersive virtual reality that allows for anatomic evaluation of fetal structure similarly to performing a real invasive procedure.[6]

In the present study, we describe a case of a prenatal diagnosis of LUTO with the 3D virtual cystoscopy that was obtained from MRI scan data. In the present case, this technology allowed a didactical and clear evaluation of the pathology.

The patient was a 22-year-old primigravida, referred to our tertiary fetal center, because of fetal US at 29 weeks of gestations that identified fetal renal abnormalities. We saw her in our clinic at 31 weeks of gestation. In our unit, a fetal US was performed using a Voluson E8 apparatus (General Electric Medical System, Milwaukee, Wisconsin), which showed moderate bilateral hydronephrosis, increased kidneys size, dilated bilateral ureters, dilated bladder with thickened wall, and dilated superior portion of urethra keyhole sign (Figure S1). Three-dimensional US in both conventional and HDlive rendering modes identified clearly the increased kidneys size and hydronephrosis (Figure S2). To obtain a better assessment of fetal morphology, a fetal MRI examination was performed using a 1.5-tesla magnet (Magnetom Aera, Siemens Healthcare, Erlangen, Germany) on the same day of the US examination. The MRI protocol was a T2-weighted sequence in the 3 planes of the fetal body (half-Fourier acquisition single-shot turbo spin echo with repetition time, shortest; echo time, 140 ms; field of view, 300-200 mm; 256 × 256 matrix; slice thickness, 4 mm; acquisition time, 17 s; and 40 slices). Additionally, to prepare the 3D virtual cystoscopy, we applied a 3D T2-weighted true fast imaging with steady-state precession sequence in the sagittal plane (repetition time, 3.02 ms; echo time, 1.34 ms; voxel size, 1.6 × 1.6 × 1.6 mm^3; FA, 70; PAT, 2; acquisition time, 0.26 s). The entire examination time did not exceed 30 minutes.

Magnetic resonance imaging confirmed bilateral hydronephrosis, dilated bilateral uterers, increased bladder volume, and dilatation of superior portion of urethra keyhole sign (Figure S3).

The construction process of the 3D accurate virtual model starts with the 3D modeling volume built through the MRI slices mounted sequentially, followed by the segmentation process where the physician selects the important body parts to be analyzed and reconstructed in 3D. Once the 3D model of the fetus and fetal urinary tract was generated accurately, the final step was to program the virtual navigation (Figure 1). The software adopted was the Slicer 3D (v.4.5.0) to segment the images to generate a polygon mesh model. Meshlab (v.1.3.3) was then used to treat the mesh to smooth the surface. To finalize, the file was then exported to Unreal Engine (v.4.16.2) to create the environment, material, colorize the model, and create a virtual camera and also to establish the path to animate it before export to the navigation in 360°.

Three-dimensional virtual cystoscopy allowed the clear visualization of urethral lumen, distended bladder, and hydroureter, suggesting the diagnosis of posterior urethral valve (Figure S4, Video S1). The clear visualization of the membrane-like could not be exactly demonstrated.

The patient was followed in our fetal medicine center (and had C-section at 39 + 3 weeks of gestation, delivering a male newborn, weighting 3020 grams, height 47 cm). Because of respiratory distress, newborn was interned in the neonatal intensive care and submitted to vesicostomy. Urinary cystourethrography at 10 days of life confirmed the diagnosis of posterior urethral valve and thickened wall bladder (Figure S5). At this moment (2 months after delivery), the newborn is clinically stable in the neonatal intensive care. This case report was approved by the Ethic Committee of Clínica de Diagnóstico por Imagem, and the woman gave the consent form for publication of the images.

Three-dimensional virtual navigation from MRI scan data has been described to assess the respiratory tract in both normal and abnormal fetuses, and this technique allowed the visualization the upper respiratory tract from the pharynx downwards through the trachea-bronchial tree with a quality similar to that which could be obtained by videotaped bronchoscopy.[6,7] In fetuses with cervical tumors, 3D virtual bronchoscopy predicted the patency of fetal airways, allowing the selection of cases with necessity of ex utero intrapartum therapy procedure.[6]

Three-dimensional virtual fetal cystoscopy in our patient provided noninvasive accurate images of the LUTO. In addition, this technology allowed a virtual navigation inside the fetal bladder and dilated posterior urethra with similar views that may be observed during real fetal cystoscopy. The main limitation of the method is to depend on the quality of the MRI file, being subject to the same artifacts. While the images produced are nice, the information is all derived from the MRI sequence that can be viewed before further postprocessing. Therefore, the real question for future studies should be what additional information does virtual cystoscopy provide over the acquired MRI and US viewed in the traditional way. Future studies comparing virtual vs real fetal cystoscopies in fetuses with LUTO are necessary to validate this technique.

What is already known about this topic?

- Lower urinary tract obstruction is associated with high morbidity and mortality.
- Fetal cystoscopy may allow the correct identification of the etiology of the obstruction and may provide the adequate treatment.

What does this study add?

- Three-dimensional virtual navigation is a noninvasive approach that provides an immersive virtual reality in the assessment of fetal structures.
- Three-dimensional virtual cystoscopy provides a noninvasive evaluation of fetal lower urinary tract obstruction that in the future may help in the selection of candidates for fetal cystoscopy.

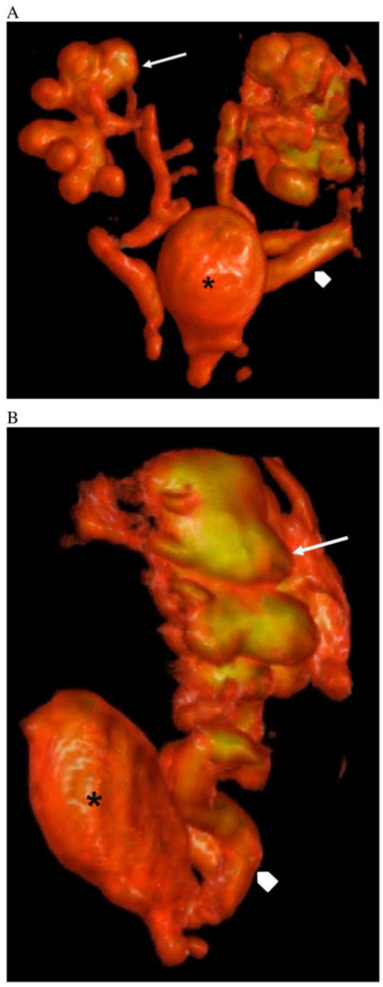

FIGURE 1 Three-dimensional virtual reconstruction of fetal urinary tract (31 weeks of gestation) from magnetic resonance imaging scan data at (A) coronal and (B) sagittal views showing the increased bladder volume (*), dilated ureters (head arrow), and hydronephrosis (arrow)

CONFLICTS OF INTEREST

None declared.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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