Original Article

Application of three-dimensional visualization technology in laparoscopic pyeloplasty for ureteropelvic junction obstruction caused by crossing vessels: a retrospective comparative cohort study

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Background: Ureteropelvic junction obstruction (UPJO) caused by crossing vessels is a common upper urinary tract abnormal development in which the vessels compress the upper segment of the ureter leading to different grades of hydronephrosis. Compared with routine computed tomography (CT) examination, three-dimensional visualization technology (3DVT) can help surgeons better understand the anatomical structure of the target surgical area. The aim of this study was to investigate the clinical value of 3DVT for the diagnosis, preoperative surgical planning, perioperative outcomes, and patient education of UPJO caused by crossing vessels.

Methods: In this study, we retrospectively analyzed the clinical data of 28 patients who were admitted to the Department of Urology in Xiangya Hospital between January 2016 and December 2021 presenting with UPJO caused by crossing vessel compression. Among the 28 patients included, 13 patients underwent preoperative 3DVT and 15 patients underwent routine computed tomography (CT) scans. After the initial evaluation, all patients received standardized dismembered LP. The 2 groups of patients were compared in terms of demographic parameters, intraoperative data, and perioperative results. After surgery, all patients were asked to complete a Likert scale questionnaire to gain insight into their understanding of the disease and surgery, as well as their satisfaction with the use of different imaging techniques.

Results: There were no statistically significant differences in age, gender, body mass index (BMI), side of obstruction, blood vessel compressing the ureteropelvic junction (UPJ), mean duration of hospitalization, and surgical efficacy between the 2 groups. However, the 3DVT group experienced a significant reduction in operation duration (120.8±7.0 versus 144.0±7.9 min, P=0.039), time required for dismemberment of the UPJ (14.8±1.7 versus 24.0±2.2 min, P=0.004), and the amount of intraoperative blood loss (60.8±10.5 versus 95.3±11.9 mL, P=0.041). The 3DVT group was also notably superior to the conventional CT group in terms of the overall levels of patient satisfaction and understanding of the disease and surgery.

Conclusions: 3DVT is a helpful preoperative examination tool which can clearly show the anatomical relationship between crossing vessels and the UPJ. In addition, 3DVT can also help patients better understand their conditions and surgical plans, thereby improving patient satisfaction.

Keywords: Three-dimensional visualization technology (3DVT); ureteropelvic junction obstruction (UPJO); crossing vessels; surgical plan; patient education

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Introduction

Ureteropelvic junction obstruction (UPJO) is a relatively common disease of the urinary system and is one of the common causes of hydronephrosis, with an overall incidence of approximately 67 cases per 100,000 adults each year (1-3). UPJO may also cause chronic infections or urolithiasis and can result in progressive deterioration of renal function (2,4). Vascular compression is a common cause of UPJO. UPJO caused by crossing vessel compression accounts for 10–28.1% of adult primary UPJO (5,6). Crossing vessels can produce mechanical compression or traction at the ureteropelvic junction (UPJ), causing obstruction and deformation of the local ureter which leads to poor drainage of urine, hydronephrosis, and renal dysfunction (7).

The crossing blood vessels compressing the UPJ are mainly composed of crossing renal vessels (also known as aberrant renal vessels), including crossing renal arteries and crossing renal veins (8). The crossing renal vessels are usually located at the ventral side of the UPJ and enter the kidney without passing through the renal hilum. Additionally, some of the crossing blood vessels directly enter the lower pole of the kidney (5). Since the UPJ is usually rich in blood vessels, especially in the case of crossing vessel compression, accurate preoperative assessment and understanding of the anatomical relationships at the UPJ are important factors in reducing surgical risk and difficulty, thereby reducing the incidence of postoperative complications.

Highlight box

Key findings

- 3DVT is an effective tool in pre-LP evaluation for UPJO caused by crossing vessel compression.

What is known and what is new?

- 3DVT can help surgeons better understand the anatomical structure of the target surgical area.
- 3DVT is a helpful preoperative examination tool which can clearly show the anatomical relationship between crossing vessels and the UPJ. In addition, 3DVT can also help patients better understand their conditions and surgical plans, thereby improving patient satisfaction.

What is the implication, and what should change now?

- 3DVT is of great value for the diagnosis, preoperative surgical planning, perioperative outcomes and patient education of UPJO caused by crossed vessels, and can be safely used for patients with UPJO caused by crossing vessel.

Laparoscopic pyeloplasty (LP) is currently the preferred treatment option for UPJO, including UPJO caused by crossing vessel compression. This is due to its advantages of intraoperative visualization, reduced blood loss, fewer postoperative complications, faster recovery, and better cosmetic effect (1). Computed tomography (CT), especially CT-based vascular reconstruction, can help surgeons to preliminarily observe the relationship between the UPJ and peripheral structures before surgery (9). However, image reconstruction using traditional CT is often unsatisfactory because of the complex structure around UPJ. Based on CT or magnetic resonance imaging (MRI), three-dimensional visualization technology (3DVT) is an emerging technology developed in recent years that allows a visual display of the anatomical relationships surrounding the surgical area on computers or mobile applications after 3D reconstruction using software (10-12). This technique can help surgeons better understand the anatomical structure of the target surgical area before surgery for early planning, and it can also help patients better understand their conditions (13,14).

At present, there is no literature showing 3DVT to be superior to conventional CT during LP for UPJO caused by crossing vessel. In this study, we evaluated the perioperative results following application of 3DVT in LP compared with those following conventional CT. We also evaluated whether this technique can improve the understanding of the disease and surgery among patients with UPJO caused by crossing vessel compression, as well as their levels of satisfaction. We present the following article in accordance with the STROBE reporting checklist (available at https://tau.amegroups.com/article/view/10.21037/tau-22-695/rc).

Methods

Study design

This study included 132 adult patients who were diagnosed with UPJO using CT scans and were admitted to Xiangya Hospital of Central South University to undergo LP between January 2016 and December 2021. Abdominal CT examination was completed because of waist pain or hydronephrosis found by B-ultrasound. Among the 132 included patients, 63 patients underwent preoperative 3DVT followed by laparoscopic surgery, and 69 patients underwent conventional CT scans followed by laparoscopic surgery. Among 132 UPJO patients, 28 patients were diagnosed as UPJO caused by crossing vessel compression after operation. The clinical data of

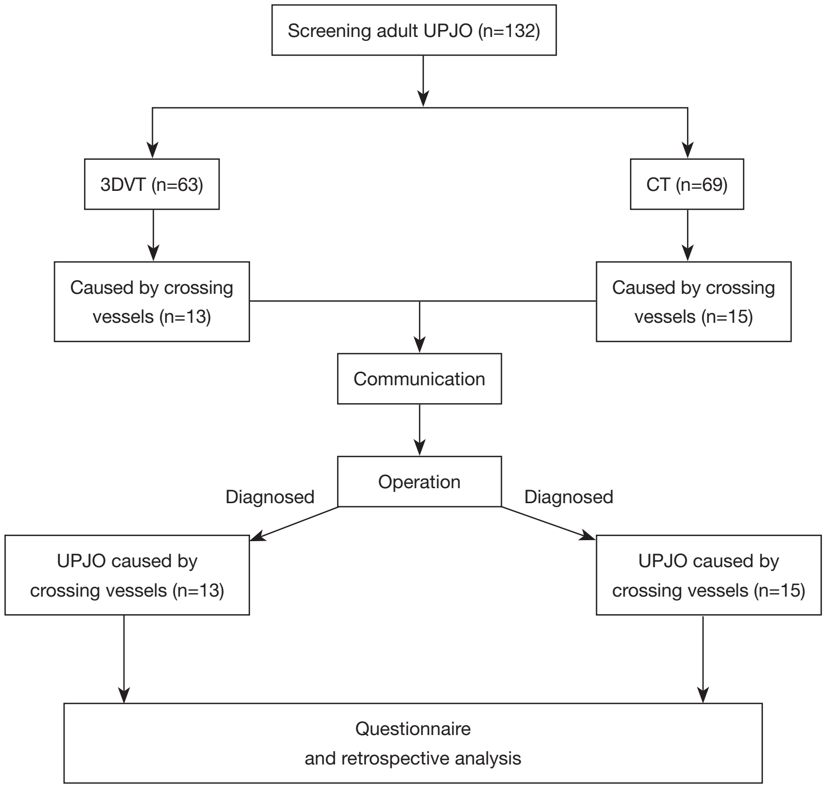

Figure 1 The flow chart of this study. 3DVT, three-dimensional visualization technology; UPJO, ureteropelvic junction obstruction; CT, computed tomography.

28 patients postoperatively diagnosed with UPJO caused by crossing vessel compression were retrospectively analyzed, including 13 patients undergoing preoperative 3DVT and 15 patients undergoing conventional CT scans (*Figure 1*). The study inclusion criteria were as follows: adult patients, unilateral UPJO, no other treatment prior to this surgery, diagnosis confirmed on intraoperative and postoperative pathology, and ≥6 months of postoperative follow-up. This study was approved by the Ethics Committee of Xiangya Hospital of Central South University (No. 202103503) and informed consent was obtained from all individual participants. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

3DVT

CT scans were performed with a 64-row spiral CT scanner at 5-mm intervals, and contrast-enhanced CT scans were acquired in the cortical, medullary, and excretory phases. All image data from CT scans were transmitted in Digital Imaging and Communications in Medicine format for segmentation and reconstruction before the medical image 3D visualization system (Yorktal, China) was used to generate 3D images. After the modeling data were imported for reconstruction, surgeons could use the E3D cloud-based digital health platform to observe the anatomical relationships surrounding the UPJ on a phone or computer. The kidneys, ureters, local arteries, and local veins in the images were marked with different colors (*Figure 2*). With the help of this system, surgeons could rotate, amplify, or delete the anatomical structures in the surgical area or make some of the structures transparent to better visualize the anatomical relationship between the UPJ and the compressing blood vessel before surgery.

Response evaluation criteria

On the day before surgery, the researcher used CT images and 3D visualization models to explain the disease condition and surgical regimen to patients. After surgery, a survey containing 5 questions on a 10-point Likert scale (Appendix 1) was administered to the patients with the

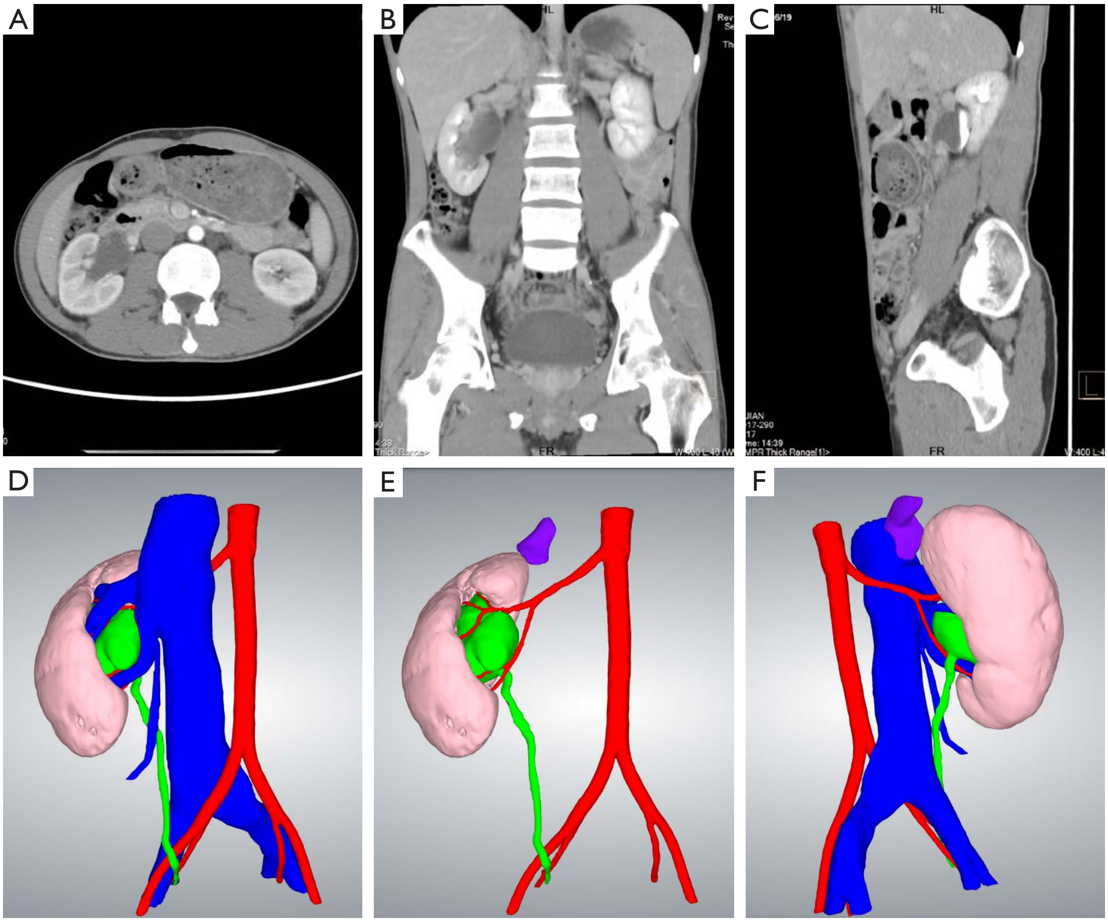

Figure 2 3DVT model of the urinary system based on CT. (A) CT transverse scan; (B) CT coronal scan; (C) CT median sagittal scan; (D) 3DVT model of the urinary system and vessels (view from the front); (E) 3DVT model of the urinary system and vessels (veins removed); (F) 3DVT model of the urinary system and vessels (view from behind). 3DVT, three-dimensional visualization technology; CT, computed tomography.

consent of the patients and their family members to evaluate their understanding of the disease and surgical regimens as well as their satisfaction levels.

Surgery, pathological examination, and follow-up

All 28 patients underwent LP, during which ureteral stricture at the level of the UPJ and localized compression of the UPJ by crossing blood vessels were observed. Laparoscopic Anderson-Hynes UPJ-dismembered pyeloplasty via the transabdominal approach was performed for all patients, and crossing blood vessels were retained for dorsal-side anastomotic reconstruction. Postoperative pathological examinations suggested chronic inflammatory changes at the UPJ in all patients. Patient follow-up was performed at 3 and 6 months post-surgery, and then annually. During follow-up visits, assessment of clinical symptoms, serological tests of renal function, renal ultrasound, and intravenous pyelography (IVP) or CT scans were performed. The criteria for surgical success included relief of subjective pain and improvement or stabilization of renal function and hydronephrosis.

Statistical analysis

SPSS 26.0 software was used for statistical analysis. Qualitative variables were analyzed using Fisher's exact test, and quantitative variables were compared using Student's

Table 1 Patient demographic characteristics

Characteristics	3DVT	CT	P value
Gender (male/female)	5/8	9/6	0.449
Age (years)	32.3±3.7	34.1±2.8	0.705
BMI (kg/m^2)	22.9±0.6	22.4±0.4	0.515

Continuous variables were presented as mean ± standard deviation. 3DVT, three-dimensional visualization technology; CT, computed tomography; BMI, body mass index.

Table 2 Crossing vessel characteristics

Characteristics	3DVT	CT	P value
Total vessels (n)	17	21	
Laterality (left/right)	7/6	8/7	1.000
Vessel type (artery/vein/artery and vein)	6/3/4	7/2/6	0.765
Vessel location (anterior/posterior)	13/0	14/1	1.000

3DVT, three-dimensional visualization technology; CT, computed tomography.

t-test after being tested for normality with Levene's test. All tests were two-sided, and P<0.05 was considered statistically significant.

Results

Patients and surgical outcomes

The 2 groups of patients were comparable in gender (5/8 versus 9/6, P=0.449), age (32.3±3.7 years versus 34.1±2.8 years, P=0.705), and body mass index (BMI) (22.9±0.6 versus 22.4±0.4 kg/m^2, P=0.515), with no statistically significant inter-group differences in these indicators (*Table 1*). All 28 patients underwent successful surgery without intraoperative conversion to open surgery, and none of the patients experienced postoperative bleeding or urine leakage. There were no statistically significant inter-group differences in the affected side and the type and location of the blood vessels compressing the UPJ (*Table 2*). We found that compression of the UPJ by a single crossing artery or double compression by both a crossing artery and a crossing vein was most common, and compression by only 1 vein was the least common. The site of compression was mostly at the anterior side of the UPJ. Only 1 patient experienced compression at the posterior side of the UPJ. The results of this study showed that the 3DVT group experienced a reduction in operation duration (120.8±7.0 versus 144.0±7.9 min, P=0.039), time required for dismembering the UPJ (14.8±1.7 versus 24.0±2.2 min, P=0.004), and amount of intraoperative blood loss (60.8±10.5 versus 95.3±11.9 mL, P=0.041) compared with the CT group. The inter-group differences in the mean hospital stay and surgical success rate were not significant (*Table 3*).

Patient understanding of the disease and surgery, and satisfaction level

A total of 28 patients with a mean age of 33.3 years participated in this study, and all patients who completed the questionnaire had obtained at least a high school diploma. The results of the Likert scale questionnaire suggested that patients in the 3DVT group had a better understanding of "pathology", "anatomy", and "surgical plans" than those in the conventional CT group based on scale scores. Overall patient satisfaction in the 3DVT group was significantly higher than that in the conventional CT group (*Table 4*). Patients generally believed that the 3DVT model could help them gain a clear understanding of the etiology of UPJO caused by crossing vessel compression and the surgical regimens of the physician.

Discussion

UPJO has a variety of causes, including abnormal

Table 3 Intraoperative and postoperative outcomes

Parameters	3DVT	CT	P value
Operating time (min)	120.8±7.0	144.0±7.9	0.039
Time of dissociating UPJ (min)	14.8±1.7	24.0±2.2	0.004
Estimated blood loss (mL)	60.8±10.5	95.3±11.9	0.041
Mean hospital stay (days)	6.5±0.2	6.7±0.3	0.481
Success rate	100%	100%	1.000

Continuous variables were presented as mean ± standard deviation. UPJ, ureteropelvic junction; 3DVT, three-dimensional visualization technology; CT, computed tomography.

Table 4 Patient understanding of the disease and surgery, and satisfaction level

Questions	3DVT	CT	P value
Understand the cause of UPJO	8.4±0.3	6.2±0.3	<0.001
Understand the anatomy of UPJ	7.3±0.3	5.6±0.3	0.001
Feel safe performing surgery	8.1±0.2	7.9±0.2	0.668
Understand the surgical plan	7.5±0.2	6.7± 0.2	0.020
Overall satisfaction	8.7±0.2	7.7±0.2	0.002

Continuous variables were presented as mean ± standard deviation. UPJO, ureteropelvic junction obstruction; 3DVT, three-dimensional visualization technology; CT, computed tomography.

development of muscle fibers at the UPJ, high insertion of the ureter, valves at the UPJ, compression of the UPJ by the surrounding crossing vessels, and fibrous cords and stricture caused by lithiasis, tumors, and inflammation (15,16). Crossing vessel compression is a common cause of UPJO and is mostly related to congenital development (17). At present, UPJO caused by crossing vessel compression is mainly diagnosed by CT and MRI (18). MRI can provide high sensitivity, specificity, and accuracy in the diagnosis of UPJO caused by crossing vessel compression (19). However, the longer time required for MRI scans leads to a lower spatial and temporal resolution than that of computed tomography angiography (CTA). Furthermore, the poor visualization of vessels <2 mm in diameter has restricted the wider application of MRI. CT scans can offer high spatial and temporal resolution but may not be completely accurate in visualizing the anatomical relationship between the surrounding crossing vessels and the UPJ. Mitterberger *et al.* reported an accuracy of approximately 93% (18). Of these 132 UPJO patients, the artery compressing the UPJ was not effectively detected by preoperative CT in 1 patient, and the radiologist failed to accurately capture that blood vessel, possibly because of its small diameter.

Nakada *et al.* found that the presence of crossing vessels lowered the success rate of endoluminal pyelotomy from 92% to 64% and significantly increased the incidence of postoperative bleeding and other complications (20). Most crossing vessels are located at the anterior side of the UPJ, and crossing vessels located at the posterior side are less commonly seen. Leavitt *et al.* found that the location of the crossing vessel relative to the UPJ varied and included anterior (25.8%), anterolateral (36.8%), medial (14.6%), anteromedial (2.5%), lateral (12.9%), and posterior (7.4%) (8). The UPJ is mostly compressed by arteries, veins, or both arteries and veins. Mitterberger *et al.* found that of 44 cases with UPJO caused by crossing vessel compression, 44 of the UPJ-compressing blood vessels were arteries, 4 were veins, and 32 were both arteries and veins (18). Among the 28 patients with UPJO caused by crossing vessel compression in this study, artery compression was the most common, followed by artery and vein double compression, and then vein compression.

Proper management of crossing blood vessels has always been a difficult challenge in pyeloplasty, and blind ligation of crossing blood vessels might lead to partial renal ischemia and consequent renal hypertension (21,22). Ellerkamp *et al.* found ureteral compression is usually accompanied by dysplasia or altered kinetics at the compressed ureteral segment, so the affected segment should be resected (5). In this study, we performed UPJ-dismembered pyeloplasty for all 28 patients and retained crossing blood vessels for dorsal-side anastomotic reconstruction. The results of long-term follow-up demonstrated high surgical success rates and good therapeutic efficacy.

Our study revealed that 3DVT facilitates not only the diagnosis of UPJO caused by crossing vessel compression but also preoperative evaluation. Preoperative 3DVT can provide detailed insight into the anatomical types and variations of renal arteries and veins, the presence of crossing vessels surrounding the UPJ, and the precise anatomical relationship between the crossing vessels and the UPJ. This understanding plays an important role in the selection of a surgical regimen, the improvement of the surgical success rate, and the reduction of surgical complications. Thirteen patients in the 3DVT group were preoperatively diagnosed with crossing vessel compression, all of which were consistent with postoperative confirmation. The results of this study showed that 3DVT can reduce the total operation duration, the time required for UPJ dismemberment, and the amount of intraoperative blood loss compared with conventional CT, and these factors are closely associated with accurate preoperative evaluation and surgical planning.

Perioperative communication with patients is also a crucial component of surgical care. Previous studies found that 3D technologies can improve patient understanding of spinal (14), cardiac (23), sinus (24), and kidney (25) surgeries, as well as their levels of subjective satisfaction. However, the significance and role of 3D technologies in the education of UPJO patients have yet to be studied. This study is the first to suggest that 3DVT can improve patients' understanding of the anatomy and physiology of UPJO, their disease conditions, and surgical plans. Individualized 3DVT may also improve the levels of subjective patient satisfaction.

However, the following limitations remain: (I) the study was retrospective and subject to recall bias; (II) the sample size was insufficient, and long-term follow-up of large samples is required; and (III) only adult patients were included in this study; hence, the effect of 3DVT on pediatric patients with UPJO caused by crossing vessel compression remains unclear.

Conclusions

In summary, 3DVT serves as an effective tool in pre-LP evaluation for UPJO caused by crossing vessel compression. It can accurately display the relationship between crossing blood vessels and the UPJ, helping surgeons to understand the anatomical structure of the target surgical area. This provides references for the planning of surgical strategies, helps reduce the operation duration and amount of intraoperative blood loss, and improves patient knowledge and satisfaction.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://tau.amegroups.com/article/view/10.21037/tau-22-695/rc

Data Sharing Statement: Available at https://tau.amegroups.com/article/view/10.21037/tau-22-695/dss

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Medical Ethics Committee of Xiangya Hospital of Central South University (No. 202103503) and informed consent was obtained from all individual participants.

References

1. Szavay P. Laparoscopic Pyeloplasty for Ureteropelvic Junction Obstruction. J Laparoendosc Adv Surg Tech A 2021;31:1214-8.
2. Krajewski W, Wojciechowska J, Dembowski J, et al. Hydronephrosis in the course of ureteropelvic junction obstruction: An underestimated problem? Current opinions on the pathogenesis, diagnosis and treatment. Adv Clin Exp Med 2017;26:857-64.
3. Khan F, Ahmed K, Lee N, et al. Management of ureteropelvic junction obstruction in adults. Nat Rev Urol 2014;11:629-38.
4. Sarhan O, Al Otay A, Al Faddagh A, et al. Pyeloplasty in children with low differential renal function: Functional recoverability. J Pediatr Urol 2021;17:658.e1-9.
5. Ellerkamp V, Kurth RR, Schmid E, et al. Differences between intrinsic and extrinsic ureteropelvic junction obstruction related to crossing vessels: histology and functional analyses. World J Urol 2016;34:577-83.
6. Helmy TE, Sarhan OM, Sharaf DE, et al. Critical analysis of outcome after open dismembered pyeloplasty in ectopic pelvic kidneys in a pediatric cohort. Urology 2012;80:1357-60.
7. Rosen S, Peters CA, Chevalier RL, et al. The kidney in congenital ureteropelvic junction obstruction: a spectrum from normal to nephrectomy. J Urol 2008;179:1257-63.
8. Leavitt DA, Nicholson AF, Ortiz-Alvarado O, et al. Nature of crossing vessels in patients with radiographically normal ureteropelvic junctions: prevalence and anatomic characteristics. Urology 2013;81:1168-72.
9. Rouvière O, Lyonnet D, Berger P, et al. Ureteropelvic junction obstruction: use of helical CT for preoperative assessment--comparison with intraarterial angiography. Radiology 1999;213:668-73.
10. Zhang B, Chen Z, Hu X, et al. Application of Three-Dimensional Visualization Technology in Laparoscopic Surgery for Pheochromocytoma/Paraganglioma: A Single-Center Experience. J Laparoendosc Adv Surg Tech A 2018;28:997-1002.
11. Bogomolova K, Hierck BP, Looijen AEM, et al. Stereoscopic three-dimensional visualisation technology in anatomy learning: A meta-analysis. Med Educ 2021;55:317-27.
12. Li XL, Xu B, Zhu XD, et al. Simulation of portal/hepatic vein associated remnant liver ischemia/congestion by three-dimensional visualization technology based on preoperative CT scan. Ann Transl Med 2021;9:756.
13. Patel P, Malik K, Khachemoune A. Patient education in Mohs surgery: a review and critical evaluation of techniques. Arch Dermatol Res 2021;313:217-24.
14. Zhuang YD, Zhou MC, Liu SC, et al. Effectiveness of personalized 3D printed models for patient education in degenerative lumbar disease. Patient Educ Couns 2019;102:1875-81.
15. Williams B, Tareen B, Resnick MI. Pathophysiology and treatment of ureteropelvic junction obstruction. Curr Urol Rep 2007;8:111-7.
16. Vemulakonda VM. Ureteropelvic junction obstruction: diagnosis and management. Curr Opin Pediatr 2021;33:227-34.
17. Rooks VJ, Lebowitz RL. Extrinsic ureteropelvic junction obstruction from a crossing renal vessel: demography and imaging. Pediatr Radiol 2001;31:120-4.
18. Mitterberger M, Pinggera GM, Neururer R, et al. Comparison of contrast-enhanced color Doppler imaging (CDI), computed tomography (CT), and magnetic resonance imaging (MRI) for the detection of crossing vessels in patients with ureteropelvic junction obstruction (UPJO). Eur Urol 2008;53:1254-60.
19. Payabvash S, Kajbafzadeh AM, Saeedi P, et al. Application of magnetic resonance urography in diagnosis of congenital urogenital anomalies in children. Pediatr Surg Int 2008;24:979-86.
20. Nakada SY, Wolf JS Jr, Brink JA, et al. Retrospective analysis of the effect of crossing vessels on successful retrograde endopyelotomy outcomes using spiral computerized tomography angiography. J Urol 1998;159:62-5.
21. Polok M, Toczewski K, Borselle D, et al. Hydronephrosis in Children Caused by Lower Pole Crossing Vessels-How to Choose the Proper Method of Treatment? Front Pediatr 2019;7:83.
22. Panek W, Jong TPVM, Szydełko T, et al. Management

of crossing vessels in children and adults: A multi-center experience with the transperitoneal laparoscopic approach. Adv Clin Exp Med 2019;28:777-82.

23. Wang DD, Qian Z, Vukicevic M, et al. 3D Printing, Computational Modeling, and Artificial Intelligence for Structural Heart Disease. JACC Cardiovasc Imaging 2021;14:41-60.
24. Sander IM, Liepert TT, Doney EL, et al. Patient Education for Endoscopic Sinus Surgery: Preliminary Experience Using 3D-Printed Clinical Imaging Data. J Funct Biomater 2017;8:13.
25. Schmit C, Matsumoto J, Yost K, et al. Impact of a 3D printed model on patients' understanding of renal cryoablation: a prospective pilot study. Abdom Radiol (NY) 2019;44:304-9.

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Supplementary

Appendix 1 Ureteropelvic junction obstruction patient communication in clinical practice

Questionnaire

Patient age (days/months/years)										
Sex (of parent)	Male			Female						
Education Level	< High School		High School			University graduate			Other	
	Not at all → Absolutely									
I understand the cause of UPJO caused by crossing vessels through the doctor's explanation.	1	2	3	4	5	6	7	8	9	10
I understand the anatomy of UPJ through the doctor's explanation.	1	2	3	4	5	6	7	8	9	10
I felt safe performing surgery while using this imaging tool.	1	2	3	4	5	6	7	8	9	10
I understand the doctor's surgical plan explanation.	1	2	3	4	5	6	7	8	9	10
Preoperative and surgical overall satisfaction.	1	2	3	4	5	6	7	8	9	10
Comments										

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