

Ultrasound evaluation for prediction of outcomes and surgical decision in fetal hydronephrosis

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Abstract. Fetal hydronephrosis (HY) is a frequent congenital condition, which may be detected by prenatal ultrasound. Society for Fetal Urology (SFU) and anterior-posterior diameter (APD) grading are two major grading systems based on ultrasonography. The present study aimed to assess the predictive value of the SFU and APD grades in patients with fetal HY. A total of 162 patients with 234 kidneys affected by HY were included in the present study. The SFU and APD grades were determined from the ultrasound images at 38 gestational weeks, and a 12-month follow-up was performed after birth. The associations of the SFU and APD grades with the outcome of fetal HY, including HY regression, and post-partum surgery were examined. In the present study, 16 patients with 17 kidneys were diagnosed with pathological HY, and stenosis at the ureteropelvic junction was demonstrated to be a leading cause of pathological HY. Among the 234 kidneys affected by HY, 161 kidneys were scored as SFU grade I, 57 as SFU grade II, 7 as SFU grade III and 9 kidneys as SFU grade IV. According to the APD grading system, 112 kidneys were determined as having low, 104 as having moderate and 18 as having severe HY. The SFU and APD grades were demonstrated to be independently associated with the occurrence of pathological HY by logistic regression analysis with a high diagnostic accuracy to distinguish pathological and physiological HY cases as evidenced by the results of ROC analysis. In addition, univariate and

multivariate logistic regression analysis indicated that patients with spontaneous HY regression usually had low SFU and APD grades. Furthermore, the rate of surgery was increased in the group of patients with high SFU or APD grades, and these two systems were identified as independent predictors for the requirement of surgery by Kaplan-Meier analysis. Patients with pathological HY had high SFU and APD grades, and these two grading systems may be used as reliable predictors for the outcome of fetal HY, including HY regression, and post-partum surgery.

Introduction

Fetal hydronephrosis (HY), a type of fetal malformation, is a common congenital condition (1). It may be determined by prenatal ultrasound and is characterized by abnormal dilatation of renal pelvis and calyces, as well as atrophy in renal parenchyma (2,3). The incidence rate of HY among all newborns detected by ultrasound is 0.6-5.4% (4). HY is more frequently diagnosed in fetuses of male gender and those in a unilateral position (5). Studies have demonstrated that vesicoureteral reflux and tract obstruction, particularly at the ureteropelvic junction, are the leading causes of HY, while HY caused by duplex renal system or hydroureteronephrosis is rare (6,7). HY may be divided into physiological and pathological types based on the post-partum conditions. HY that may spontaneously resolve after birth is classified as physiological HY, while the type that deteriorates and may lead to impaired renal function is referred to as pathological HY (8).

At present, fetal HY is mainly diagnosed based on prenatal ultrasound (9). The rate of clinical detection of HY has been increasing due to the development of ultrasonic technology and optimization of ultrasonic instruments (10). However, a dilemma is emerging with regard to the management of infants diagnosed with fetal HY (11,12). Society for Fetal Urology (SFU) grading and anterior-posterior diameter (APD) measurement are two major ultrasonography-based systems to evaluate HY. The SFU system consists of five grades (0, I, II, III and IV) according to the appearance of calices, pelvis and thinning of parenchyma (13). The APD system contains three grades (mild, moderate and severe) based on the anterior/posterior diameter of the pelvis (14). The severity of HY evaluated by ultrasound is closely associated with the prognosis of the

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affected pediatric patients. Thus, precise determination of HY grading is critical for optimal management.

To further investigate the diagnosis and achieve appropriate management of fetal HY, the present study focused on the predictive value of the SFU and APD grading systems regarding the post-partum outcome, and explored their associations with spontaneous regression of HY and requirement of surgery.

Materials and methods

Subjects. The present study retrospectively analyzed the ultrasonic data and clinical characteristics of 162 pregnant females who received antenatal examination and gave birth at the Second Affiliated Hospital of Wenzhou Medical University (Wenzhou, China) between January 2014 and December 2017. All of these subjects fulfilled the inclusion criteria: Singleton pregnancy; detection of fetal HY by ultrasound; no fetal malformation except HY; no consanguineous marriage; couples had no genetic disease. Prenatal ultrasound of these pregnant females at 20–40 gestational weeks identified 234 fetal kidneys affected by HY, including 72 cases of bilateral HY and 90 of unilateral HY. The protocols of the present study were approved by the Ethics Committee of the Second Affiliated Hospital of Wenzhou Medical University (Wenzhou, China) and written informed consent for the use of ultrasonic data and clinical characteristics was obtained from each participant.

Imaging. All of the pregnant females underwent assessment of fetal HY by ultrasonography with an ESAOTE Technos MYLAB 65 (Esaote) every 2–4 weeks prior to delivery. The neonates were re-examined by ultrasound at 7 days after delivery. The cases still exhibiting HY were followed up for 12 months, and those patients with persistent or progressive HY were further diagnosed by other adjuvant examinations, including intravenous pyelography (IVP), emission computed tomography (ECT) and magnetic resonance urography (MRU). An X-ray machine (Siemens AG, Munich, Germany) was used for IVP, a CT scanner (Siemens AG) was used for ECT, and a nuclear magnetic resonance detector (Philips NV, Amsterdam, Netherlands) was used for MRU examination. HY that spontaneously resolves after birth is referred to as physiological HY, while the type that becomes deteriorative and may lead to impaired renal function is called pathological HY. During the follow-up survey, the HY outcomes and rate of surgery were recorded for further analysis. The patients were graded using the SFU and APD systems based on their ultrasound images (15). The classifications of these two systems are listed in Table I and representative ultrasound images are provided in Fig. 1.

Statistical analysis. All the statistical analyses were performed using SPSS 20.0 software (IBM Corp.). Continuous variables are expressed as the mean \pm standard deviation. The association between SFU or APD grades and the clinical characteristics of the patients was assessed using the Chi-squared test. Univariate and multivariate logistic regression analysis was performed to examine the association of clinicopathological parameters, as well as SFU or APD grading, with the postpartum outcomes, HY regression and post-partum surgery

Table I. Classification criteria of SFU and APD grading systems.

A, SFU grading system	
Grade	Characteristics
0	No hydronephrosis
I	Renal pelvis is slightly separated
II	Renal pelvis is further separated and a single or a few dilated calices may be visualized
III	All calices are dilated
IV	All calices are dilated and the renal parenchyma over the calices is thinned
B, APD grading system	
Grade	Time window/APD (mm)
Mild	Second trimester: $4 < \text{APD} < 7$ Third trimester: $7 < \text{APD} < 9$
Moderate	Second trimester: $7 < \text{APD} < 10$ Third trimester: $9 < \text{APD} < 15$
Severe	Second trimester: $\text{APD} > 10$ Third trimester: $\text{APD} > 15$
SFU, Society for Fetal Urology; APD, anterior-posterior diameter.	

for fetal HY. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the predictive value of SFU and APD grading systems, and the sensitivity and specificity to distinguish pathological and physiological HY was determined. The Kaplan-Meier method was applied to analyze the rate of surgery among the patients with pathological HY and different SFU and APD grades, and log-rank test was adopted to compare the differences between curves. $P < 0.05$ was considered to indicate statistical significance.

Results

Characteristics of the patients and grading results. The characteristics of the patients are summarized in Table II. According to the prenatal ultrasound, a total of 234 kidneys were affected by fetal HY, including 60 cases with the left and 30 cases with the right kidney affected, as well as 72 cases with bilateral involvement. According to the post-partum examination, 217 kidneys (92.7%; $n=146$) had physiological HY and 17 kidneys (7.3%; $n=16$) had pathological HY.

SFU and APD grading were performed based on the ultrasound images at 38 gestational weeks. A total of 161 kidneys were scored as SFU grade I, 57 kidneys were SFU grade II, 7 kidneys were SFU grade III and 9 kidneys were SFU grade IV. According to the APD grading system, 112 kidneys were determined as having mild, 104 kidneys as moderate and 18 kidneys as displaying severe HY (Table II).

Table II. Characteristics and grading results of the HY patients.

Parameters	No. of patients (%) or mean \pm SD (range)	No. of kidneys (%)
Gender		
Female	64 (39.5)	91 (38.9)
Male	98 (60.5)	143 (61.1)
Affected side		
Left	60 (37.0)	60 (25.6)
Right	30 (18.5)	30 (12.8)
Bilateral	72 (44.4)	144 (61.5)
Maternal age (years)	29.8 \pm 5.2 (20-41)	
Post-partum outcome		
Physiological HY	146 (90.1)	217 (92.7)
Pathological HY	16 (9.9)	17 (7.3)
SFU grade		
I	111 (68.5)	161 (68.8)
II	36 (22.2)	57 (2.4)
III	7 (4.3)	7 (3.0)
IV	8 (4.9)	9 (3.8)
APD grade		
Mild	72 (44.4)	112 (47.9)
Moderate	73 (45.1)	104 (44.4)
Severe	17 (10.5)	18 (7.7)

HY, hydronephrosis; SFU, Society for Fetal Urology; APD, anterior-posterior diameter; SD, standard deviation.

Association of SFU and APD grades with the clinicopathological characteristics of the patients. To examine the association of clinical characteristics with SFU and APD grades, the Chi-squared test was first adopted, indicating that the patients' gender, affected side or maternal age were not significantly associated with the SFU or APD grade (all $P > 0.05$; Table III). By contrast, the SFU and APD grade were associated with the post-partum outcome (all $P < 0.001$).

SFU and APD grades are independently associated with the post-partum outcome of fetal HY. Logistic regression analysis was then performed to assess the influence of clinicopathological features, and the SFU and APD grading results of the patients on post-partum outcome of fetal HY (Table IV). The univariate analysis revealed that an SFU grade of III/IV and severe HY according to the APD were significantly associated with pathological HY, which indicated that the pathological HY cases were more frequently SFU grade III/IV ($P < 0.001$) and had a larger APD ($P < 0.001$). The multivariate analysis then suggested that the SFU grade (OR=177.840, 95% CI=16.628-1902.081, $P < 0.001$) and APD grade (OR=28.209, 95% CI=4.230-196.218, $P = 0.001$) were independently associated with the occurrence of pathological HY.

Diagnostic accuracy of SFU and APD grading systems to distinguish pathological from physiological HY. Considering the close association of the SFU and APD grading systems

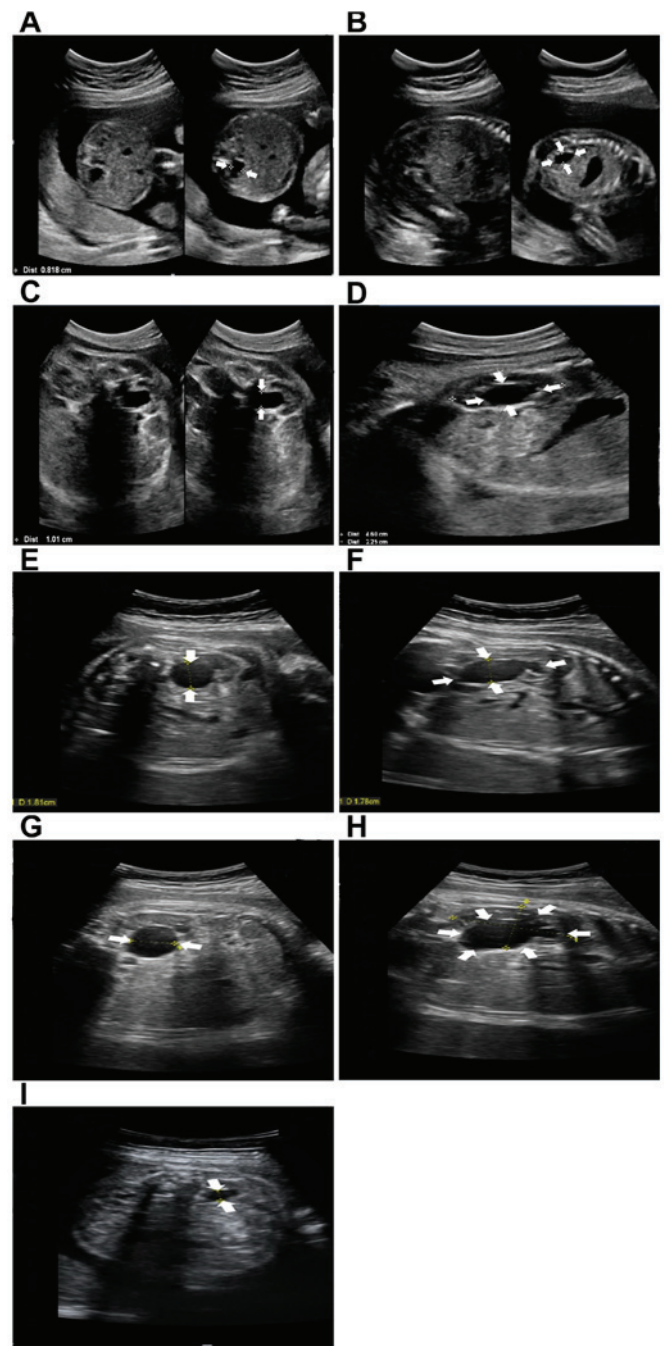


Figure 1. Ultrasound images of subjects with hydronephrosis with different SFU and APD grades. (A) Cross section of kidney with SFU grade I. (B) Vertical section of kidney with SFU grade I. (C) Cross section of kidney with SFU grade II. (D) Vertical section of kidney with SFU grade II. (E) Cross section of kidney with SFU grade III. (F) Vertical section of kidney with SFU grade III. (G) Cross section of kidney with SFU grade IV. (H) Vertical section of kidney with SFU grade IV. (I) Standard measuring section of APD. White arrows indicate the dilatation of the renal pelvis. SFU, Society for Fetal Urology; APD, anterior-posterior diameter.

with the post-partum outcome of fetal HY, their diagnostic value was further evaluated with regard to their ability to distinguish patients with pathological HY from those with physiological HY. The sensitivity and specificity of the SFU grading system was 70.6 and 98.2%, respectively, and the Youden index (YI) was 0.688 for the discrimination of patients with pathological HY from the cases of

Table III. Association of SFU and APD grades with clinical characteristics of the HY patients.

Features	Affected kidneys (n=234)	SFU grade		P-value	APD grade		P-value
		I/II (n=218)	III/IV (n=16)		Mild/moderate (n=216)	Severe (n=18)	
Gender				0.238			0.314
Female	91	87	4		86	5	
Male	143	131	12		130	13	
Affected side				0.290			0.269
Left	132	125	7		125	8	
Right	102	93	9		91	10	
Maternal age (years)				0.120			0.111
≤30	145	138	7		137	8	
>30	89	80	9		79	10	
Post-partum outcome				<0.001			<0.001
Physiological HY	217	213	4		211	6	
Pathological HY	17	5	12		5	12	

Data in this table represents number of kidneys. P-values in the table were obtained using the Chi-square test. HY, hydronephrosis; SFU, Society for Fetal Urology; APD, anterior-posterior diameter.

Table IV. Univariate and multivariate logistic regression analysis of the association of clinicopathological features with pathological fetal HY.

Parameters	Univariate analysis			Multivariate analysis		
	OR	95% CI	P-value	OR	95% CI	P-value
Gender (male vs. female)	1.181	0.421-3.311	0.752	0.183	0.024-1.404	0.102
Affected side (left vs. right)	0.899	0.330-2.450	0.835	1.783	0.284-11.195	0.537
Maternal age (>30 vs. ≤30 years)	2.459	0.914-6.815	0.074	2.307	0.392-13.567	0.355
SFU grade (III/IV vs. I/II)	127.800	30.351-538.134	<0.001	177.840	16.628-1902.081	<0.001
APD grade (severe vs. mild/moderate)	64.472	17.859-232.746	<0.001	28.209	4.230-196.218	0.001

HY, hydronephrosis; SFU, Society for Fetal Urology; APD, anterior-posterior diameter; OR, odds ratio.

physiological HY. The sensitivity and specificity of the APD grading system was 70.6 and 97.2%, respectively, with a YI of 0.678 (Table V). In addition, the ROC curves for these two systems were constructed, and the area under the curve (AUC) was 0.958 for the SFU grade and 0.915 for the APD grade (Fig. 2). These results indicated that the SFU and APD grading systems have a relatively high diagnostic accuracy. Furthermore, we the diagnostic performance of the combined SFU and APD systems was evaluated, resulting in an AUC of 0.986, a sensitivity of 82.4%, a specificity of 98.6% and a YI of 0.810, suggesting that the combination of the SFU and APD grading systems has a higher diagnostic value compared with that of these two systems alone regarding the discrimination of cases of pathological HY from those of physiological HY.

Influence of SFU and APD grades on HY regression. The influence of the SFU and APD grades on fetal HY regression

was then assessed. The 234 kidneys affected by HY included 204 kidneys with spontaneously resolved HY (87.2%) and 30 with persistent HY (12.8%). As presented in Table VI, univariate logistic regression analysis indicated that an SFU grade of I/II and mild to moderate HY according to APD grading are associated with HY regression (all $P<0.001$), suggesting that those cases with resolution of HY more frequently had low SFU and APD grades. Furthermore, multivariate logistic regression analysis revealed that the SFU grade (OR=24.843, 95% CI=5.471-112.804, $P<0.001$) and APD grade (OR=21.301, 95% CI=5.398-84.047, $P<0.001$) were independently associated with the occurrence of HY regression.

Association of SFU and APD grades with the rate of surgery. To facilitate optimal management of HY patients, further analysis focused on the association of SFU and APD grades with post-partum surgery. Among the 16 patients with pathological HY, 12 cases received surgery. As presented in Fig. 3,

Table V. Diagnostic accuracy of SFU and APD grading systems to distinguish pathological and physiological HY.

Parameters	Physiological HY	Pathological HY	Sensitivity	Specificity	YI
SFU grade			70.6%	98.2%	0.688
I-II	213	5			
III-IV	4	12			
APD grade			70.6%	97.2%	0.678
Mild-moderate	211	5			
Severe	6	12			
SFU grade + APD grade			82.4%	98.6%	0.810
I-II + Mild-moderate	214	3			
III-IV + Severe	3	14			

HY, hydronephrosis; SFU, society for Fetal Urology; APD, anterior-posterior diameter; YI, youden index.

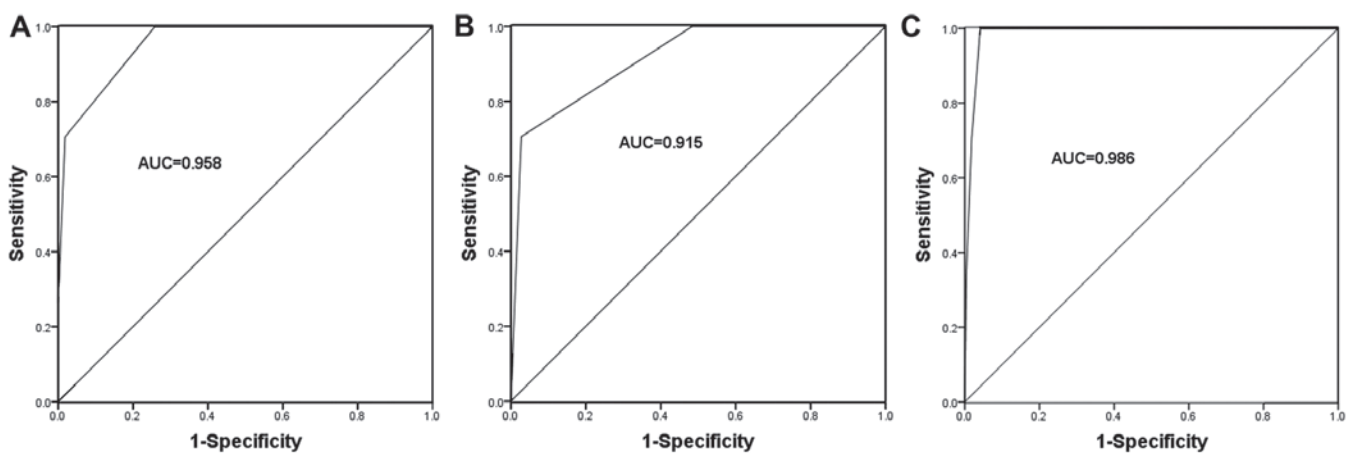


Figure 2. ROC curves for fetal hydronephrosis patients based on SFU and APD grading systems. (A) The SFU grade had high diagnostic accuracy with an AUC of 0.958. (B) The APD grade had a high diagnostic accuracy with an AUC of 0.915. (C) Combination of SFU and APD grading system had an enhanced diagnostic accuracy with an AUC of 0.986. SFU, Society for Fetal Urology; APD, anterior-posterior diameter; AUC, area under the ROC curve; ROC, receiver operating characteristic.

those patients with a high SFU or APD grade had a higher surgery rate compared with those with a low SFU (log-rank $P=0.007$) or APD grade (log-rank $P=0.008$). Furthermore, univariate logistic regression analysis suggested that an SFU grade III/IV and severe HY according to APD grading were associated with a high surgery rate (all $P<0.001$). Multivariate logistic regression analysis further confirmed that the SFU (OR=55.973, 95% CI=2.202-1422.788, $P=0.015$) and APD grades (OR=31.365, 95% CI=1.306-753.495, $P=0.034$) were independent indicators for the occurrence of surgery (Table VII).

Characteristics of the patients diagnosed with pathological HY. The characteristics of the patients with pathological HY are summarized in Table VIII. The patients who received post-partum surgery had a good prognosis, as their HY was resolved following the surgery. However, the prognosis of the patients without surgery was unclear due to no available related follow-up data. The etiological data regarding pathological HY indicated that stenosis at the ureteropelvic junction was the leading cause of pathological fetal HY.

Discussion

Fetal HY refers to the dilatation and separation of the fetal renal pelvis system caused by the obstruction of urine excretion from the kidney (16). It is generally considered that HY is a temporary clinical manifestation of fetal urinary system dysfunction (17). In the majority of cases, fetal HY spontaneously resolves with the increase of gestational weeks or after birth, and is then defined as physiological HY, while persistent or aggravated HY are defined as pathological HY. Woodward and Frank (18) indicated that reversible HY, which regresses during fetal growth and development, accounted for ~65% of all fetal HY cases. A total of 162 patients were included in the present study, with 234 kidneys diagnosed with fetal HY. A total of 16 patients with 17 kidneys were determined to have pathological fetal HY, accounting for 9.9% of all HY patients, and the HY in the remaining cases regressed after birth. Previous studies revealed that pathological HY is mainly caused by structural abnormalities of the renal pelvis system and urine reflux (6,19). The present study indicated that 9 patients, accounting for 56.3% of all pathological HY

Table VI. Univariate and multivariate logistic regression analysis of the influence of clinicopathological features on HY regression.

Parameters	Univariate analysis			Multivariate analysis		
	OR	95% CI	P-value	OR	95% CI	P-value
Gender (male vs. female)	0.948	0.433-2.074	0.894	0.877	0.318-2.422	0.800
Affected side (left vs. right)	1.153	0.535-2.488	0.716	1.085	0.389-3.024	0.876
Maternal age (>30 vs. ≤30 years)	2.810	1.281-6.162	0.010	2.585	0.913-7.315	0.074
SFU grade (III/IV vs. I/II)	51.235	13.289-197.531	<0.001	24.843	5.471-112.804	<0.001
APD grade (severe vs. mild/moderate)	30.435	9.694-95.559	<0.001	21.301	5.398-84.047	<0.001

HY, hydronephrosis; SFU, Society for Fetal Urology; APD, anterior-posterior diameter; OR, odds ratio.

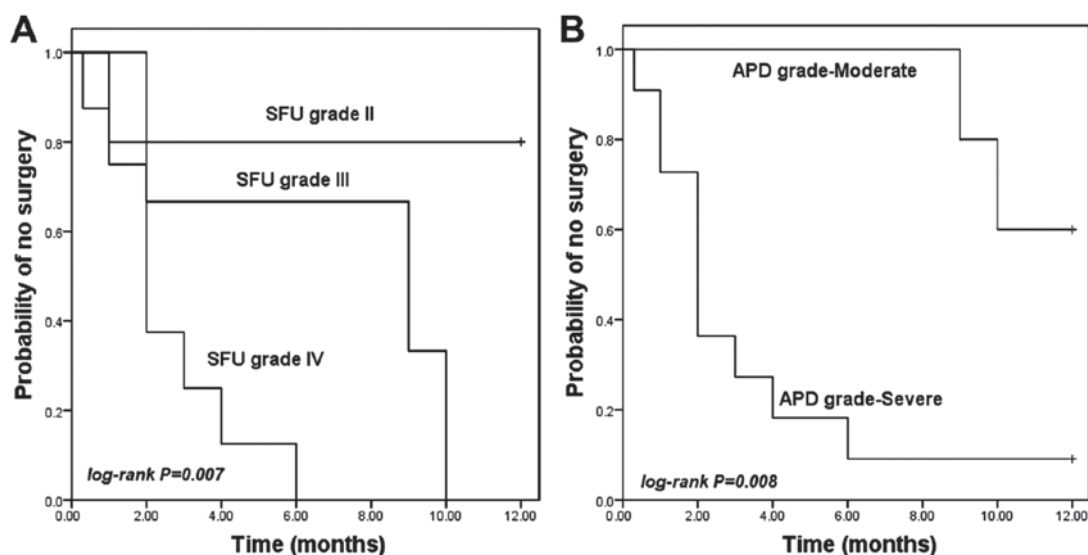


Figure 3. Association of SFU or APD grades with the post-partum surgery rate evaluated using the Kaplan-Meier method. (A) Patients with higher SFU grades had a higher surgery rate compared with those with lower SFU grades (log-rank $P=0.007$ for all three curves). (B) Severe hydronephrosis ($n=12$) according to the APD grade was associated with a high rate of surgery (log-rank $P=0.008$). SFU, Society for Fetal Urology; APD, anterior-posterior diameter.

cases, had stenosis at the ureteropelvic junction, which was the leading cause of pathological HY in this cohort.

Prenatal ultrasound is a widely used method to monitor fetal HY. The SFU and APD grading systems are the two most frequently used standardized systems for the evaluation of HY based on ultrasound images (20). The qualitative assessment of HY via the SFU grading system is based on the degree of pelvicaliectasis and cortical thinning. However, the determination of certain non-quantitative features is limited by inter-observer variability (21). The APD grading system is used to determine the degree of pelvicaliectasis, which mainly relies on the greatest diameter of the renal pelvis measured in the ultrasound images (22). To further facilitate the diagnosis and appropriate management of fetal HY, the present study sought to investigate the predictive value of SFU and APD grades for the post-partum outcome, and explore their association with spontaneous regression of HY and requirement for surgery.

The present study first assessed the association of the SFU and APD grades with the occurrence of pathological HY. The results indicated that the kidneys with pathological HY usually had a high SFU and APD grade, and the grades according to

these two systems were identified as two independent indicators for the presence of pathological HY. Furthermore, the present study assessed whether these two systems may be used to distinguish cases of pathological HY from those with physiological HY. Thus, the YI was calculated and a ROC analysis was performed, revealing that the SFU and APD grading systems had a high diagnostic accuracy for pathological HY. Of note, combination of the SFU and APD grading systems increased the diagnostic accuracy as compared with that of each grading system alone. These results suggested that the combined method provides a reliable predictive tool for the outcome of fetal HY.

Although the incidence of detected fetal HY has increased in recent decades, the condition spontaneously resolves in most cases after birth (23). The present study performed a 12-month post-partum follow-up, during which HY was identified to be resolved in 204 kidneys, accounting for 87.2% of all HY cases. The association of SFU and APD grades with the occurrence of HY regression was further assessed by univariate and multivariate linear regression analyses using the data at 38 gestational weeks. Most of the resolved HY cases had low SFU or APD grades, and the SFU and APD grading systems were

Table VII. Univariate and multivariate logistic regression analysis of the influence of clinicopathological features on the requirement of surgery.

Parameters	Univariate analysis			Multivariate analysis		
	OR	95% CI	P-value	OR	95% CI	P-value
Gender (male vs. female)	1.019	0.323-3.218	0.974	0.833	0.067-10.338	0.887
Affected side (left vs. right)	1.116	0.363-3.429	0.848	1.828	0.138-24.212	0.647
Maternal age (>30 vs. ≤30 years)	2.765	0.875-8.737	0.083	2.265	0.212-24.239	0.499
SFU grade (III/IV vs. I/II)	651.000	67.453-6282.911	<0.001	55.973	2.202-1422.788	0.015
APD grade (severe vs. mild/moderate)	430.000	47.866-3862.866	<0.001	31.365	1.306-753.495	0.034

SFU, Society for Fetal Urology; APD, anterior-posterior diameter; OR, odds ratio.

Table VIII. Characteristics of the patients diagnosed with pathological hydronephrosis.

SFU grade	APD grade	Etiology	Surgery	Prognosis after surgery
IV	Severe	Stenosis at the left ureteropelvic junction	Yes	Favorable
IV	Severe	Obstruction at the left middle ureter	Yes	Favorable
IV	Severe	Stenosis at the right ureteropelvic junction	Yes	Favorable
II	Severe	Stenosis at the left ureteropelvic junction	Yes	Favorable
IV	Severe	Stenosis at the left ureteropelvic junction	Yes	Favorable
IV	Severe	Stenosis at the left ureteropelvic junction	Yes	Favorable
III	Moderate	Stenosis at the end of left ureter	Yes	Favorable
IV	Severe	Stenosis at the left ureteropelvic junction	Yes	Favorable
III	Severe	Stenosis at the left ureteropelvic junction	Yes	Favorable
IV	Severe	Stenosis at the end of left ureter	Yes	Favorable
Left: IV; Right: IV	Left: Severe; Right: Severe	Posterior urethral valve	Yes	Favorable
III	Moderate	Duplication of pelvis and ureter with stenosis at the ureter end and ureterocele	Yes	Favorable
II	Severe	Duplication of pelvis	No	-
II	Moderate	-	No	-
II	Moderate	Stenosis at the right ureteropelvic junction	No	-
II	Moderate	Stenosis at the left ureteropelvic junction	No	-

SFU, Society for Fetal Urology; APD, anterior-posterior diameter; -, no related data.

independently associated with the occurrence of HY regression, which implied that these two grading systems may be used to predict post-partum HY regression.

The predominant treatment for persistent fetal HY is surgery and the prognosis is favorable (24). In spite of the availability of valuable approaches for outcome evaluation of fetal HY, including the SFU and APD grading systems (15), controversy remains regarding the post-partum management on the determination of surgery (25,26). To date, certain parameters have been identified as indicators for the requirement of surgery, including ureteropelvic junction obstruction (27), the renal parenchyma to hydronephrosis area ratio (28) and cortical transit time (29). The present study also assessed the association of the SFU and APD grades with the surgery rate.

The Kaplan-Meier curves indicated that those patients with high SFU or APD grades had a higher surgery rate than those with low SFU or APD grades. The results of the two grading systems were proved to be independent predictors for the performance of surgery, indicating that they may serve as a guide for the decision to perform surgery.

In conclusion, the majority of cases of fetal HY spontaneously resolve after birth, and patients with pathological HY usually have high SFU and APD grades. Stenosis at the ureteropelvic junction was identified as a leading cause of pathological HY. The SFU and APD grades may be used as reliable predictors of the outcome of fetal HY, and may serve as independent indicators for the occurrence of HY regression and post-partum surgery.

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Availability of data and materials

The datasets used and analyzed during the present study are available from the corresponding author on reasonable request.

Authors' contributions

DZ, YZ and PL designed this study, performed the APD and SFU grading, analyzed the data and wrote the manuscript. XS, XC, BY and TL recruited the patients, collected the ultrasound results and analyzed the clinical data of the patients. YC, MY, LL and LM analyzed the association of SFU and APD grades with HY regression and surgery rate. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The protocols of the present study were approved by the Ethics Committee of the Second Affiliated Hospital of Wenzhou Medical University (Wenzhou, China) and written informed consent for the use of ultrasonic data and clinical characteristics was obtained from each participant.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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