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Diagnostic value of diuretic ultrasound in evaluating the need for reoperation in children undergoing pyeloplasty

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Abstract

Background Pyeloplasty currently stands as the standard treatment for UPJO. Our study aimed to assess the diagnostic value of sonographic parameters following Lasix administration in patients who underwent pyeloplasty to predict the recurrence of obstruction and the need for reoperation.

Methods The study included 70 children with UPJO who underwent pyeloplasty. Renal ultrasound was performed on patients three to six months after pyeloplasty. Following the Lasix administration, the changes in ultrasound parameters at the 18th and 30th minute were documented. Within two weeks, patients underwent radioisotope renography. Diuretic ultrasound's diagnostic value in predicting the need for reoperation was assessed through a comparison with radioisotope renography.

Results The average age of the patients was 3.94 ± 3.52 years. Anteroposterior diameter of the renal pelvis (APD) changes at 18 and 30 min, and the average APD after surgery at 18 and 30 min was significantly higher in patients requiring reoperation. The best cutoff point of APD changes in the 18th minute was 9.50 (sensitivity = 91.7%, specificity = 82.8%). The best cutoff point of APD after surgery in the 18th minute was 25.90 (sensitivity = 91.7%, specificity = 81.0%). The best cutoff points of the resistive index (RI) in the 18th and 30th minutes were reported as 0.70 (sensitivity = 41.7%, specificity = 50.0%) and 0.71 (sensitivity = 41.7%, specificity = 37.9%), respectively.

Conclusions The assessment of ultrasound findings following pyeloplasty has revealed that changes in APD can serve as a reliable means for assessing the efficacy of the operation.

Keywords Pyeloplasty, Ultrasound, Ureteropelvic junction obstruction

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1 Background

Hydronephrosis is a medical condition characterized by the dilation of the renal pelvis and calyces that occur because of urine retention or reflux. Prenatal hydronephrosis is found in approximately 1–5% of all pregnancies [1]. Ureteropelvic junction obstruction(UPJO) occurs in every 1:750–1500 live births and is known as the third most common cause of antenatal hydronephrosis, following transient and physiological hydronephrosis [2].

The reduction in urine flow from the renal pelvis to the ureter by UPJO leads to the dilation of the renal pelvis and calyces, subsequently causing hydronephrosis. UPJO

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is a multifactorial condition, with pathologic factors such as the hypoperistaltic ureteral segment, fetal folds of the upper ureter, or intrinsic strictures causing most cases of UPJO in children [3–5]. Ultrasound is a safe, noninvasive, and inexpensive tool for postnatal evaluation of children with antenatal hydronephrosis, posing no radiation exposure risk [6].

Pyeloplasty, as a standard procedure for surgical treatment of UPJO, has a success rate of 95–100% [7, 8]. Laparoscopic or retroperitoneoscopic procedures have been proposed as an alternative to the standard open procedure, with encouraging outcomes. All pyeloplasty approaches have advantages and disadvantages, and no definitive evidence exists to determine the best approach [9]. Following up the child after pyeloplasty is recommended to identify recurrent obstruction or loss of kidney function. Reoperation is needed for up to 5% of children after pyeloplasty [2]. The aim of pyeloplasty is to conserve renal function. After the operation, the success of pyeloplasty is evaluated with renal ultrasounds and radioisotope renography. There has yet to be a consensus regarding the follow-up plan. Some surgeons opt for an early ultrasound in the third month after surgery and diuretic renography between the third and sixth month [10]. Other researchers have asserted that follow-up should last up to two years, including when the first signs of recurrence (infection and pain) are most likely to occur [11]. The most common method to assess obstruction after surgery is radioisotope renography. However, ultrasound has recently been proposed as a feasible option and has gradually gained popularity among physicians [10, 12, 13].

The aim of this study was to determine the diagnostic value of ultrasound parameters following the administration of Lasix in patients who underwent pyeloplasty. Ultrasound results were compared to DMSA renography to assess the ability of ultrasound to predict obstruction recurrence and reoperation necessity.

2 Methods

This research was conducted from 2021 through 2022 in the pediatric ultrasound department of Akbar and Dr. Sheikh Mashhad hospitals. The current study includes children between 3 months and 12 years of age who were diagnosed with severe hydronephrosis in radioisotope renography and underwent pyeloplasty for UPJO. The study excluded patients with anatomical abnormalities such as horseshoe kidney, duplex kidney, ectopia, and single kidney, as well as those with contraindications to Lasix intake.

Following three to six months of pyeloplasty, all patients underwent renal ultrasound. An experienced pediatric radiologist, using the same device, performed an ultrasound on all patients with an empty bladder.

Initially, an ultrasound was conducted to determine the APD of the renal pelvis, the resistive index of intraparenchymal arteries, and the minimum and maximum thickness of the kidney parenchyma. A blinded expert radiologist did all renal ultrasounds. The APD diameter for all patients was measured as the maximal diameter of the intrarenal pelvis in the mid renal transverse plane in supine position [14, 15]. Then, Lasix was administered to all patients at a dose of 1 mg/kg. Ultrasound was then conducted after 18 and 30 min, and the same parameters were assessed. The ultrasound parameters changes following the Lasix administration were recorded. Following the ultrasound, all patients underwent radioisotope renography within a maximum of two weeks. The aim was to assess obstruction and recurrence of hydronephrosis (surgical failure). Patients who showed obstruction in the renography required reoperation. The diagnostic value of ultrasound to predict the need for reoperation and recurrence of obstruction was determined by comparing the ultrasound results and changes following the administration of Lasix with radioisotope renography. We used 18 min post diuretic timing because Lasix maximum effect occurs approximately 18 min following intravenous injection and we used 30 min post diuretic timing because we wanted to have two measurement intervals to increase the analysis accuracy [16, 17].

After completing the checklist forms, the results were described as tables, figures, and central and dispersion indexes.

To calculate the sample size, the findings of Kiblawi et al.'s study were used [18]. Since the specificity of 89% provides a higher number compared to the sensitivity of 100%, we used the specificity parameter as the basis for calculating the sample size. We calculate the sample size as 66 people, considering the type 1 error of 0.05 and including 10% attrition. The normality of the data distribution was checked using the Kolmogorov–Smirnov test. The t-test and Mann–Whitney U test were conducted to identify the relationships among quantitative variables for data with normal and non-normal distributions, respectively. The chi-square and Fisher exact tests were used to determine the relationship among qualitative variables. Correlations were examined through the Pearson test for normally distributed data and the Spearman test for data with a non-normal distribution. Sensitivity, specificity, positive and negative predictive value, and accuracy were calculated based on standard formulas. The statistical analysis was conducted using SPSS version 10 (SPSS Inc., Chicago, IL, USA), and a P value < 0.05 was considered indicating statistical significance.

This study was approved by the medical ethics committee of the Mashhad University of Medical Sciences (Ethics code: IR.MUMS.MEDICAL.REC.1400.837). Informed consentwas obtained from all participants' parents to enter the study and they could withdraw from itwhenever they did not want to continue the study. Patient data were entered anonymously to remain confidential.

3 Results

This study was conducted on 70 patients. The average age of the patients was 3.94 ± 3.52 years and 58 (82.9%) were girls, and 12 (17.1%) were boys. The left kidney was affected in 41 cases (58.6%) while the right kidney was affected in 29 cases (49.4%), and none of the UPJO cases were bilateral. According to the results of the DMSA renography, the patients were divided into two groups: 12 patients requiring reoperation and 58 patients not requiring reoperation.

The results of the ultrasound parameters examined in two categories of patients who required reoperation and those who did not are presented in Table 1.

The results show APD changes in 18 and 30 min after Lasix administration are significantly higher in patients requiring reoperation compared to the other group ($P < 0.001$ and 0.003, respectively). Additionally, the average post-surgery APD before Lasix administration and post-surgery APD at 18 and 30 min was significantly higher in the group requiring reoperation ($P = 0.004$, $P < 0.001$, $P < 0.001$, respectively). No significant difference was observed in the other parameters in the two groups.

Figure 1 shows the ROC curve of parameters related to the APD index.

Based on the analysis of APD changes at the 18th minute, the best cutoff point was 9.50, with a sensitivity of 91.7% and a specificity of 82.8%. In the analysis of the APD index after surgery in the 18th minute, the best cutoff point was 25.90, with a sensitivity of 91.7% and a specificity of 81.0%.

The analysis of other parameters relevant to APD is documented in Table 2.

Additional information concerning cutoff points, sensitivity, and specificity of parameters related to APD can be found in Table 2.

Figure 2 shows the ROC curve of parameters related to the resistive index.

In the analysis of RI parameters in the 18th and 30th minutes, the best cutoff points were reported as 0.70 (sensitivity 41.7% and specificity 50.0%) and 0.71 (sensitivity 41.7% and specificity 37.9%), respectively.

Other cutoff points, sensitivity, and specificity of parameters related to RI are reported in Table 3

Figure 3 shows the ROC curve of parameters related to parenchymal thickness.

The cutoff points, sensitivity, and specificity of parameters related to parenchymal thickness are displayed in Table 4. The results show that for the post-surgery parenchymal thickness index, both at the 18th and 30th minutes, the best cutoff point was 5.25, with a sensitivity of 41.7% and a specificity of 15.5%.

4 Discussion

In the last decade, the management of UPJO has become progressively observational despite the need for precise predictors of outcomes. Although the resolution of hydronephrosis and healthy kidneys is possible in many

Table 1 Results of ultrasound parameters in two groups requiring and not requiring reoperation based on the renography

Parameter	The need for reoperation based on the DMSA renography		*P* value*
	Yes	No	
APD changes in the 18th minute	11.56 ± 2.09	7.14 ± 3.78	0.001 <
APD changes in the 30th minute	12.30 ± 3.01	8.84 ± 4.65	0.003
RI in the 18th minute	0.68 ± 0.05	0.70 ± 0.46	0.266
RI in the 30th minute	0.70 ± 0.04	0.72 ± 0.04	0.174
RI changes in the 18th minute	0.05 ± 0.03	0.06 ± 0.03	0.350
RI changes in the 30th minute	0.00 ± 0.36	−0.04 ± 0.88	0.472
Parenchymal thickness after surgery in the 18th minute	4.87 ± 1.28	7.69 ± 2.58	0.001 <
Parenchymal thickness after surgery in the 30th minute	5.00 ± 1.10	7.66 ± 2.58	0.001 <
APD after surgery before Lasix administration	23.67 ± 10.40	12.77 ± 7.09	0.004
APD after surgery in the 18th minute	34.90 ± 7.23	19.91 ± 8.07	0.001 <
APD after surgery in the 30th minute	35.64 ± 6.90	21.62 ± 8.89	0.001 <
Parenchymal thickness difference in the 18th minute	0.12 ± 0.22	0.02 ± 0.85	0.428
Parenchymal thickness difference in the 30th minute	0.00 ± 0.36	0.04 ± 0.88	0.765

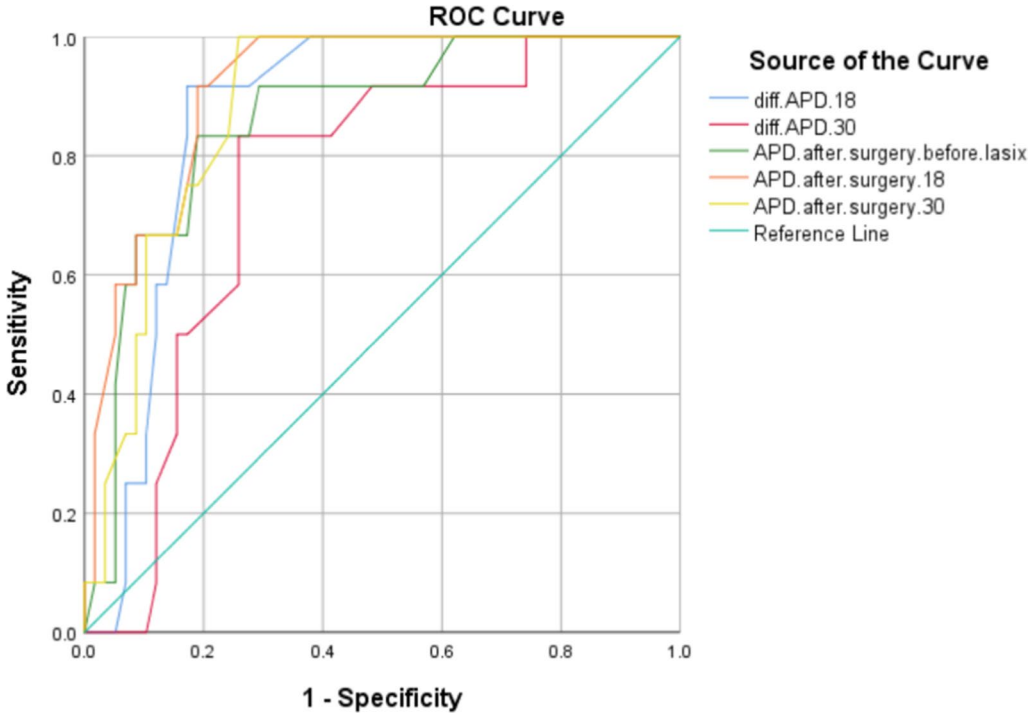

Fig. 1 ROC curve of parameters related to the APD index

Table 2 Cutoff points, sensitivity, and specificity of parameters related to APD

Parameter	Cutoff point	Sensitivity	Specificity	Area under curve	95% Confidence interval	
					minimum	maximum
APD changes in the 18th minute	9.50	91.7	82.8	0.866	0.781	0.950
APD changes in the 30th minute	10.55	83.3	74.1	0.751	0.621	0.882
APD after surgery and before Lasix administration	17.90	83.3	81.0	0.891	0.755	0.968
APD after surgery in the 18th minute	25.90	91.7	81.0	0.913	0.845	0.982
APD after surgery in the 30th minute	29.55	75.0	82.8	0.885	0.807	0.963

children, it is apparent that some are at risk of compromised renal functional development [19–21]. Due to our current knowledge, pyeloplasty is a surgical method that will maintain kidney function in patients; however, there is no approved method or protocol to indicate the procedure's success accurately [10]. The present study investigated the diagnostic value of the diuretic ultrasound for needing reoperation in infants undergoing pyeloplasty. The present study revealed that the diuretic ultrasound evaluation presents more eligible individuals for the reoperation pyeloplasty in comparison with the renal DMSA scan. We observed the best APD (18th minute after the surgery) sensitivity as 91.70% and specificity as 81.00%, while in the 30th minute after surgery, it was 75.00% and 82.80%, respectively. Moreover, APD changes at the 18th and 30th minutes after surgery revealed 91.70% and 83.30% sensitivity and 82.80% and 74.10% specificity, respectively.

According to previous studies, UPJO is known as a prevalent cause of unilateral hydronephrosis in infants and children; hence, pyeloplasty is the standard therapeutic approach, and its success will be indicated by clinical and imaging criteria [22]. Based on the findings of the study and by determining the cutoff and sensitivity and specificity for the variables, this study showed that some of these variables can help differentiate between memorial hydronephrosis after pyeloplasty and hydronephrosis that indicates the need for reoperation. Despite the high success rate of pyeloplasty, developing strong parameters for accurate follow-up of infants undergoing

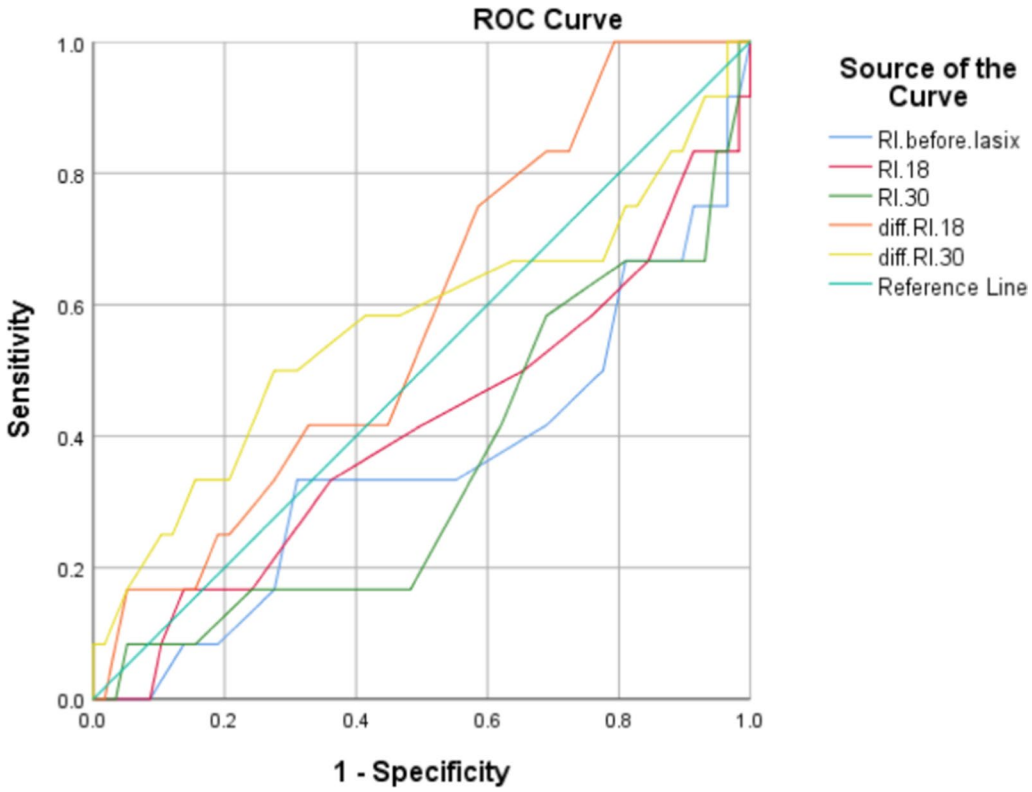

Fig. 2 ROC curve of parameters related to resistive index

Table 3 Cutoff points, sensitivity, and specificity of parameters related to resistive index

Parameter	Cutoff point	Sensitivity	Specificity	Area under curve	95% Confidence interval	
					Minimum	Maximum
RI before surgery	0.63	50.0	22.4	0.358	0.171	0.545
RI in the 18th minute	0.70	41.7	50.0	0.410	0.218	0.602
RI in the 30th minute	0.71	41.7	37.9	0.351	0.172	0.529
RI changes in the 18th minute	0.040	58.3	48.3	0.583	0.419	0.746
RI changes in the 30th minute	0.065	58.3	58.6	0.569	0.362	0.776

the procedure is still necessary. Based on the side effects associated with the DMSA scan, ultrasound approaches are predicted to become a prevalent feature in pyeloplasty follow-up protocols [13]. Several studies have indicated the APD changes before and after the surgery as a valuable follow-up marker. While Rickard et al. revealed over 40% reduces in APD as a valuable marker [13], Kiblawi et al. determined the 100% sensitivity and 89% specificity for APD changes in ultrasound investigations. Studies have found a significant increase in APD and its changes at the 18th and 30th minutes in cases that require reoperation based on the DMSA [18]. Although their study showed greater sensitivity and specificity, even indicating that APD reduction in ultrasound after pyeloplasty eliminates the need for reoperation, our findings did not yield the same high values they reported. These differences could be because of the variability in the APD calculation method and the studied population.

Similarly, Mohajerzadeh et al. [23] compared the ultrasound and DMSA scan outcomes as the follow-up instrument in infants and children who underwent pyeloplasty surgery. Despite our study, they evaluated the pelvic-cortex ratio and the percentage of pelvic improvement in APD six months after the surgery. However, they observed both sensitivity and specificity as 100% in the studied population; these revealed that APD evaluation

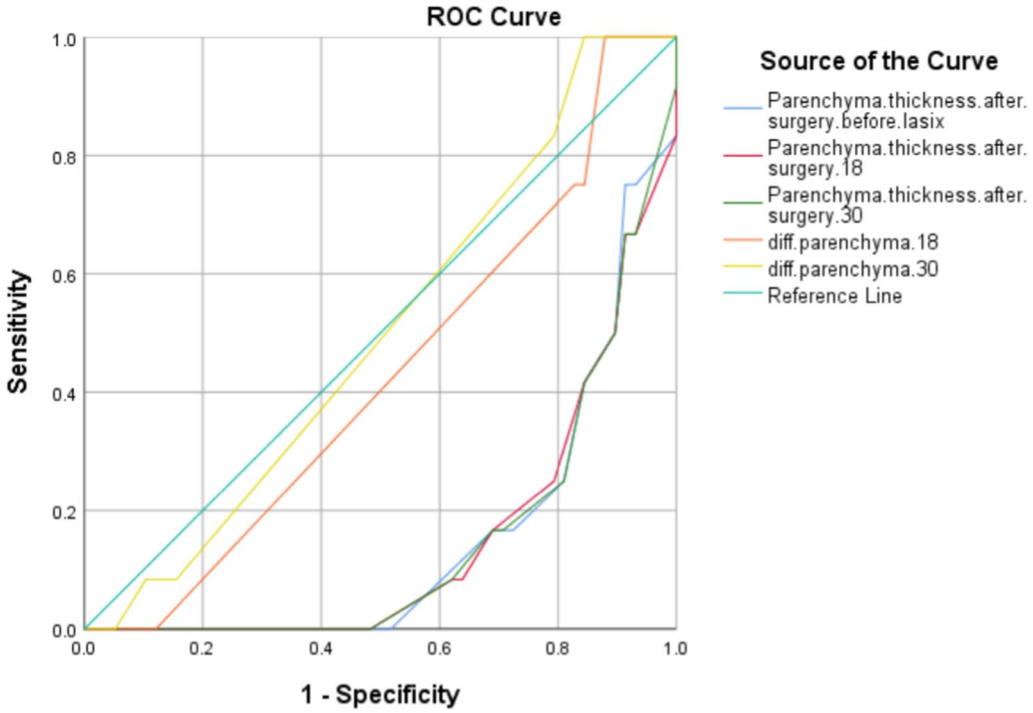

Fig. 3 ROC curve of parameters related to Parenchymal thickness

Table 4 Cutoff points, sensitivity, and specificity of parameters related to the Parenchymal thickness index

Parameter	Cutoff point	Sensitivity	Specificity	Area under curve	95% Confidence interval	
					Minimum	Maximum
Parenchymal thickness after surgery before Lasix administration	5.25	41.7	15.5	0.152	0.054	0.249
Parenchymal thickness after surgery in the 18th minute	5.25	41.7	15.5	0.149	0.051	0.248
Parenchymal thickness after surgery in the 30th minute	5.25	41.7	15.5	0.150	0.052	0.248
The difference in parenchymal thickness in the 18th minute	− 0.125	75.0	17.2	0.429	0.266	0.592
The difference in parenchymal thickness in the 30th minute	− 0.250	83.3	20.7	0.501	0.339	0.664

in 3 and 6 months after the surgery could indicate higher accuracy values, while our reports showed 91.7% sensitivity and 82.8% specificity at the optimal level. On the other hand, Wickramasekara et al. [24] reported a low sensitivity and specificity of the APD reduction to predict the necessity of the pyeloplasty re-surgery. They have observed that a 25% reduction in the APD revealed 87% of sensitivity and 75% of specificity for the necessity of the pyeloplasty reoperation. Additionally, pelvic-cortex ratio and cortex thickness before and after the surgery were not determined as significant factors for the reoperation; however, the parenchymal thickness in the 18th and 30th minutes after surgery has been reported to be significantly lower in patients who need reoperation.

Moreover, Maria et al. reported that a 15% APD decrease could be significantly associated with pyeloplasty success; hence, a DMSA scan will be necessary if the ultrasound parameters do not improve 6 months after surgery [25]. However, Kiblawi et al. stated that any improvement in APD makes the DMSA scan unnecessary, and the DMSA scan should be used if the APD increase after the pyeloplasty surgery [18]. The findings and controversial reports on the diagnostic value of ultrasound parameters and the necessity of reoperation in infants undergoing pyeloplasty show the need to promote current knowledge. Ultrasound is a low-cost and noninvasive method compared to the standard method of evaluating the success of pyeloplasty. The results of

the present study can be used to better understand and manage the complication of UPJO, its treatment, and follow-up. Our study evaluated the diagnostic value of ultrasound in infants and children undergoing pyeloplasty to determine the need for reoperation along with others, which can be used in designing guidelines for management and follow-up after pyeloplasty surgery using ultrasound. Given that ultrasound is an operator-dependent investigation, to reduce ultrasound interobserver variations we recommend that variables be measured by pediatric radiology experts.

Although the present study can be known as a novel study that determined the role of different parameters of the ultrasound, especially APD, in pyeloplasty reopration, it was limited in some aspects, including the retrospective design of the study, limited evaluated parameters, and the few studied population. Future studies should be conducted in the form of cohort and prospective studies, considering a larger sample size and multiple follow-ups with longer intervals. It is also recommended to evaluate different indicators, such as clinical manifestations, their progress, and the reduction percentage, to design appropriate guidelines.

5 Conclusions

The present study was designed and conducted to investigate the diagnostic value of diuretic ultrasound in infants and children undergoing pyeloplasty to determine the need for reoperation. Evaluation of the ultrasound findings after pyeloplasty, compared with renal DMSA scan to check successful operation in patients after pyeloplasty, shows that the changes in APD after surgery in 3- to 6-month follow-up can verify the operation's success. Considering multiple DMSA scans' potentially harmful side effects, performing ultrasound scans at regular intervals and reviewing their parameters would be advantageous in decision-making and patient management. However, further studies are required to determine more aspects of ultrasound efficacy in these terms.

Abbreviations

ADP Anteroposterior diameter of the renal pelvis
UPJO Ureteropelvic junction obstruction

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Not applicable.

Author contributions

MMR, RA, AA, and HM conducted the main idea of the study. MMR and RA contributed to supervision. EH, AP, and NK contributed to data gathering. HM contributed to data analysis. EH, AP, NK contributed to drafting of the manuscript. All authors reviewed and accepted the manuscript.

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Availability of data and materials

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Declarations

Ethics approval and consent to participate

This study was approved by the medical ethics committee of Mashhad University of Medical Sciences (Ethics code: IR.MUMS.MEDICAL.REC.1400.837). Informed consent was obtained from all patients to enter the study and they could withdraw from it whenever they did not want to continue the study. Patient data were entered anonymously to remain confidential.

Consent for publication

Not applicable.

Competing interests

The authors have no competing interests to declare.

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