Resolution of hydronephrosis after pyeloplasty in children

Sanni Värelä a, Erik Omling a,b, Anna Börjesson a,b, Martin Salö a,b,*

Summary

Background
There is still a lack of knowledge regarding the natural course of resolution of hydronephrosis after pyeloplasty, and no consensus exists on how resolution of hydronephrosis is defined or when resolution is expected to occur.

Objective
To determine when resolution of hydronephrosis occurs following pyeloplasty, by type of obstruction and by surgical approach.

Methods
This retrospective study included 125 children age <15 years treated with pyeloplasty and followed for two years with repeated ultrasound and MAG3 scan. Children with single kidneys, bilateral disease, and without hydronephrosis were excluded. Children with reinterventions were excluded in the evaluation of hydronephrosis but not in terms of success rate. Outcomes time to resolution of hydronephrosis (Anterior-Posterior diameter (APD) <10 mm or >50% reduction of APD) and 2-year success rate. Exposure was surgical approach and type of obstruction (intrinsic/extrinsic). Survival analysis was performed, adjusting for age, gender, year, laterality, preoperative renal function on MAG3, calyces dilatation and APD in the multivariable analysis.

Results
At 12 months and 24 months follow-up, 90% and 93% had reached resolution, respectively. All children with persistent dilatation had improved drainage and stable or improved function on MAG3. There was no difference in time to resolution of hydronephrosis between open versus robotic-assisted laparoscopic surgery (adjusted HR 0.90, [0.54–1.52], p = 0.70), nor between different types of obstruction (aHR 0.84 [0.53–1.34], p = 0.47). Eight children had re-intervention, all identified within 3 months after primary surgery, and four had a postoperative drop on MAG3, giving a total success rate of 91% (121/135).

Discussion
The vast majority of cases resolve and do so within 12 months from surgery. Since the improvement of hydronephrosis seems small between the first and second year after surgery, the value of follow-up beyond 12 months could be questioned. Based on the present study and previous literature we would recommend that children with persisting dilatation should continue their follow-up with ultrasound beyond 12 months. Children with complete resolution of their hydronephrosis at 12 months do not likely benefit from further follow-up. The same follow-up protocol should be applied, regardless of whether the obstruction is intrinsic or extrinsic in nature, or the surgery is performed with open or robotic-assisted approach. Overall, the definition of resolution of hydronephrosis varies in the literature and have impact on the results and may compromise comparisons.

Conclusion
Surgical approach or type of obstruction does not seem to affect time to resolution of hydronephrosis after pyeloplasty in children. Follow-up with ultrasound beyond 12 months does not seem to benefit children with complete resolution.
Introduction

Ureteropelvic junction obstruction (UPJO) occurs in 1:750–1500 live births, and is considered the third most common cause of antenatal hydronephrosis after transient and physiologic hydronephrosis [1–3]. The standard treatment with dismembered Anderson-Hynes pyeloplasty has high success rates of 90–95% [4,5]. It is recommended to monitor the child after the pyeloplasty to identify recurrent obstruction and preventable loss of renal function. Up to 5% of children need a re-operation after pyeloplasty [6].

There is still a lack of knowledge regarding the natural course of resolution of hydronephrosis after pyeloplasty, and no consensus on how resolution of hydronephrosis is defined or when resolution is expected to occur [7,8]. Postoperative dilatation may resolve early or persist for long time [8]. This affects postoperative management and may lead to unnecessary examinations [7,10]. Consequently, follow-up routines vary considerably in terms of method, intervals and duration between different centers [9]. US is widely used but with varying frequency and timing, whereas MAG3 is less utilized during follow-up, or not used at all [8].

Few predictive factors for resolution of hydronephrosis following pyeloplasty have been identified and the uncertain prognosis may be distressing to parents and clinicians [7]. Hence, better evidence on how hydronephrosis resolves after pyeloplasty in children is needed. The aims of this study were to investigate the natural course of hydronephrosis after pyeloplasty in children and to evaluate if type of obstruction or type of surgical approach have an impact on the resolution.

Methods

This study was approved by the regional ethics committee (DNR no. 2010/49) and by the hospitals local ethical committee (KVB no. 119–19).

Study design

This was a retrospective study of data collected from a prospectively collected digital database of children who underwent pyeloplasty at a pediatric surgical and urological tertiary center between January 2002 and September 2019. The department provides paediatric urology to a population of about 2.0 million inhabitants in southern Sweden.

Inclusion and exclusion criteria

All patients younger than 15 years of age who underwent pyeloplasty for UPJO were included. Patients with preoperative stent or nephrostomy were also included and the imaging prior to decompression was used as the baseline study. Patients with single kidney, or with bilateral disease requiring surgery, or with preoperative APD <10 mm on regular US, or with missing pre- or postoperative APD measures, were excluded. Children with re-operations were excluded in the analysis of resolution of hydronephrosis but included in the evaluation of the overall success rate of the whole cohort.

Pyeloplasty: indication and follow-up

Indication for pyeloplasty were: UPJO with a progressive differential renal function (DRF) impairment on Tc99m mercaptoacetyltriglycerine scan (MAG3) (>10 percentage points function loss during active follow-up, or DRF <40% on the affected kidney) or symptomatic UPJO (pain or recurrent upper urinary tract infections). Thus, isolated increasing dilatation on US was not an indication for surgery. Pyeloplasty was performed according to Anderson-Hynes [11]. Open pyeloplasty through a lumbotomy or flank incision were standard approach, and Robotic-assisted laparoscopic pyeloplasty (RALP) was considered in children >10 kg. A double J stent was placed perioperatively and extracted approximately one month later. The follow-up programme on all children after pyeloplasty included clinical assessment and double J stent removal after 4 weeks, US scans at 1 (prior to stent removal), 3, 6, 12, and 24 months, and MAG3 scans at 3 and 12 months postoperatively. Ultrasounds are performed by a paediatric radiologist, and always before the MAG3 scan at 3 and 12 months. No specific instructions are given except that parents are informed that the child should be normally hydrated and if possible not urinate just before the examination.

Primary and secondary outcome

The primary outcome was time to resolution of hydronephrosis. APD measures were collected from the US report, or when missing, by re-examination of saved US recordings. Hydronephrosis was defined as APD of 10 mm or more, and resolution was defined as an APD <10 mm, or a decrease in APD to less than 50% of the preoperative APD. Preoperative APD measure was collected from the latest US examination prior to surgery. Postoperative APD measures were collected from scheduled US examinations according to the follow-up protocol. Incidental US examinations were excluded. Secondary outcome was overall success rate, defined as stable or improved renal function on MAG3 scan and reduction of hydronephrosis, with no recurrent infections or pain during long-term follow-up. Renal function <40% (MAG3) on affected kidney was considered abnormal, and a persistent decrease of 5% or more during follow-up was equally considered abnormal. To evaluate the overall long-term success rate, we also measured the clinical follow-up at the pediatrics department in our evaluation, besides the above-mentioned radiological follow-up.

Exposure and independent variables

Main exposure was type of obstruction (extrinsic or intrinsic) and type of surgical approach (RALP, flank incision or lumbotomy). Extrinsic obstruction was defined by the presence of any crossing vessel at the
UPJ, while intrinsic obstruction was those with no crossing vessel or other apparent explanation to the obstruction. Independent variables were sex, age at the time of surgery, year, laterality, prenatally detected hydronephrosis, preoperative dilated calyces, and renal impairment (DRF <40% of total renal function).

Statistics

IBM SPSS Statistics for Mac, Version 25 (Armonk, NY: IBM Corp.) was used for statistical analyses. Continuous data was not normally distributed and therefor presented as median (IQR; interquartile range), and categorical data as absolute numbers and percentages, n (%). Comparison between exposures were performed with Chi-square test for categorical data and with Kruskal–Wallis test for continuous data (3 groups). Resolution of hydronephrosis between exposures were compared with Kaplan Meier curves and differences assessed with log rank rest. Independent variables were adjusted for with multivariable Cox regression analysis and presented as Hazard ratio (HR) with 95% confidence intervals (95% CI). A p-value <0.05 was considered significant.

Results

A total of 175 children underwent pyeloplasty between January 2002 and September 2019. Of these, 50 patients (29%) were excluded as a result of missing data, post-operative intervention, single kidney, bilateral hydronephrosis, or presenting without hydronephrosis, leaving 125 patients for further analysis (Fig. 1). Among the included children, the median age was 3.8 (IQR 1.3 to 10.1) years and 59% were male. Most common type of obstruction was intrinsic (70%), and flank incision (50%) was the most common surgical approach followed by RALP (36%). The median APD was 30 (IQR 23 to 40) mm and the median DRF was 41 (IQR 30 to 48) %. US follow-up were completed at 1, 3, 6, 12 and 24 months by 94%, 88%, 87%, 88%, and 85%, respectively.

Children that had RALP were older and had larger kidney size than children undergoing open surgery (flank incision or lumbotomy). Children who had flank incision had lower preoperative DRF compared to the other two groups, and children undergoing lumbotomy had a higher rate of intrinsic obstruction compared to children with RALP and flank incision (Table 1a). In comparison to children with extrinsic obstruction, children with intrinsic obstruction were younger, had higher rate of antenatal hydronephrosis, and underwent more often lumbotomy and less often RALP (Table 1b).

The median APD decreased during the postoperative follow-up period from 30 mm (preoperative) to 10 mm by 6 months, and <10 mm by 24 months (Fig. 2). The hydronephrosis was resolved within 12 months for 90% (113/125) of the treated, whereas 7% (9/125) remained non-resolved beyond 24 months (Fig. 3). Among the 12 children that did

| Table 1a | Overview of patient characteristics of three different surgical approaches for pyeloplasty in 125 children with ureteropelvic junction obstruction. |
|-----------|-------------------------------------------------------------------------------------------------|
| Flank incision (N = 63) | Lumботomy (N = 17) | RALP (N = 45) | p-value |
| Gender (M) | 35 (56%) | 8 (47%) | 31 (69%) | 0.208a |
| Age at surgery, years | 1.8 (0.8–7.4) | 1.7 (1.3–2.5) | 9.7 (5.5–12.1) | <0.001b |
| Laterality (R) | 28 (44%) | 6 (35%) | 13 (29%) | 0.252a |
| Antenatal hydronephrosis | 39 (62%) | 30 (22.5–41.5) | 30 (20–39) | 0.375b |
| Preoperative APD, mm | 30 (24–40) | 10 (59%) | 28 (62%) | 0.965b |
| Preoperative DRF MAG3 scan, % | 35 (29–44) | 42 (38–52) | 46 (30.5–50) | 0.008b |
| Preoperative dilated calyces | 38 (60%) | 10 (59%) | 28 (62%) | 0.965b |
| Kidney size, mm | 85 (75–110) | 90 (86–97.5) | 110 (100–125) | <0.001b |
| Type of obstruction (intrinsic) | 45 (71%) | 16 (94%) | 26 (58%) | 0.023 |

Values presented as the absolute number and percentage of patients, n (%), and median (IQR; interquartile range); M: male; R: right. APD: anteroposterior diameter, MAG3: Tc99m mercaptoacetyltriglycine, DRF: differential renal function, RALP: robotic-assisted laparoscopic pyeloplasty.

a Chi-square test. 
b Kruskal–Wallis test.
not have resolution at 12 months, all had stable or improved renal function as well as improved drainage on the postoperative MAG3 at 3 and 12 months.

In the univariate analysis, there was no difference in resolution of hydronephrosis between those with extrinsic and intrinsic obstruction ($p = 0.56$) (Supplementary Fig. 1a), nor when adjusting for confounders (adjusted HR 0.84 [0.53–1.34], $p = 0.47$). There was no difference in time to resolution of hydronephrosis by surgical approach ($p = 0.51$) (Supplementary Fig. 1b). Neither was there any difference in the adjusted analysis when comparing open surgery to RALP (aHR 0.90, [0.54–1.52], $p = 0.70$), nor when comparing flank incision with RALP (aHR 0.75, [0.42–1.31], $p = 0.31$) or flank incision with lumbotomy (aHR 0.55 [0.26–1.16], $p = 0.12$).

Children with increasingly larger APD did not seem slower to resolve compared to children with less dilatation (log rank test, $p = 0.72$) (Fig. 4). Further, 79% reached resolution if the definition was normalization of hydronephrosis (APD < 10 mm) versus 87% with a definition of reduction in APD with C21 50% ($p = 0.09$), and there was no difference in time to resolution when comparing these two definitions (chi-square test, $p = 0.37$) (Supplementary Fig. 2).

The overall clinical long-term follow-up for the whole cohort was median 71 (IQR 36 – 120) months. No children had infections or recurrent pain suggestive of re-obstruction. In 27 (22%) children, there was a sequential decrease in APD on every US at 1, 3, 6, and 12 months. Only

### Table 1b Overview of patient characteristics of different types of obstructions in 125 children who underwent pyeloplasty for ureteropelvic junction obstruction.

|                          | Intrinsic (N = 87) | Extrinsic (N = 38) | p-value |
|--------------------------|-------------------|-------------------|---------|
| Gender (M)               | 55 (63%)          | 19 (50%)          | 0.151$^a$ |
| Age at surgery, years    | 2.7 (1.2–6.8)     | 9.0 (5.2–12.4)    | <0.0001$^b$ |
| Laterality (R)           | 34 (39%)          | 13 (34%)          | 0.987$^a$ |
| Antenatal hydronephrosis | 56 (64%)          | 10 (26%)          | <0.001$^a$ |
| Preoperative APD, mm     | 30 (22–39)        | 30 (24–40)        | 0.582$^a$ |
| Preoperative DRF MAG3 scan, % | 40 (31–47)      | 41 (24.5–48)      | 0.516$^a$ |
| Preoperative dilated calyces | 53 (61%)       | 23 (61%)          | 0.898$^a$ |
| Kidney size, mm          | 90 (80–110)       | 110 (92.5–120)    | 0.016$^a$ |

**Surgical approach**

|                          | Intrinsic (N = 87) | Extrinsic (N = 38) | p-value |
|--------------------------|-------------------|-------------------|---------|
| Flank incision           | 45 (52%)          | 18 (47%)          | 0.023$^a$ |
| Lumbotomy                | 16 (18%)          | 1 (3%)            |         |
| RALP                     | 26 (30%)          | 19 (50%)          |         |

Values presented as the absolute number and percentage of patients, n (%), and median (IQR; interquartile range); M: male; R: right; APD: anteroposterior diameter, MAG3: Tc99m mercaptoacetyltriglycine, DRF: differential renal function, RALP: robotic-assisted laparoscopic pyeloplasty.

$^a$ Chi-square test.

$^b$ Mann–Whitney U-test.
8 (6%) had an increase in APD between 3 and 6 months, of which all had improved drainage on MAG3 at 3 months, and again decreased in APD at US at 12 months. The median DRF changed from preoperative 41 (IQR30 – 48) % to median 42 (IQR33 - 48) % at 3 months, and median 43 (IQR 32 – 48) % at 12 months. The drainage measured with MAG3 was improved in all children. In 39 (31%) there was a postoperative improvement of DRF of >5%. There were 4 (3%) children with a postoperative drop on MAG3 of whom all had improved drainage and resolution of hydronephrosis.

There were eight children excluded from primary analysis due to failure of the primary pyeloplasty. Seven (88%) were boys, and six (75%) had internal obstruction. There was no difference in grade of hydronephrosis, preoperative DRF, or in the rate of dilated calyces between children with failed pyeloplasty compared to the rest of the group (data not shown). Of the eight re-operations, four had had symptoms in the intermediate postoperative period, of which three had leakage from the anastomosis and one of these stent dysfunction, and the fourth child a severe urosepsis. Of the remaining four patients, three developed symptoms (two had pyelonephritis and one flank pain) after stent removal at 1 month. The last child had no obvious postoperative symptoms but increasing hydronephrosis on ultrasound and no good drainage on MAG3 at 3 months. Hence, all eight were identified within three months from surgery. Thus, the total number of failed pyeloplasties were 12 (8 re-interventions and four with postoperative drop in DRF), giving a total success rate of 91% (121/133). Children excluded from the primary analysis (n = 42, presenting with bilateral disease, single kidney, missing data or no hydronephrosis) were all successful, rendering an overall success rate of 93% (163/175).

Discussion

This study of 125 children who underwent active postoperative follow-up after pyeloplasty confirms high success rate, in terms of normalization of renal pelvis diameter within 24 months, and indicates that most cases resolve within 12 months from surgery. When adjusting for confounders, no difference was found in the resolution of hydronephrosis between different types of obstruction or different surgical approach.

These results indicate that resolution of hydronephrosis in children may take time after pyeloplasty, however it should be expected in the majority of cases within 24 months postoperatively, regardless of the type of surgical approach or cause of obstruction at the UPJ. Thus, the same follow-up plan applies regardless of type of obstruction or type of surgical approach. One could have speculated that the degree of preoperative chronic dilatation affected the rate and timing of resolution. Treatment at young age may suggest a more severe UPJO, and a higher degree of intrinsic obstruction and chronic dilatation. However, we did not find evidence for this; children with larger dilatation were not slower to resolve. Further, there was no significant difference in resolution rate or time to resolution using different definition of resolution. This may however partly be explained by a rather small cohort. The success rate in the present study was 91% (and 93% with all children that were eligible for inclusion) which seems in par with previously reported numbers [4,5]. The four children with a postoperative drop on MAG3 did not have any symptoms, resolved their hydronephrosis and had good drainage. These children were according to our study’s definition counted as a failure, in accordance with previous
studies [12,13], which may seem a bit arbitrary and lacks clinical significance, but is in line with the indication for the pyeloplasty in terms of preventing further loss in DRF. The reason for their drop in DRF is hard to explain, we don’t believe it is caused by inaccuracy in the MAG3 scan since the drop in these patients was substantial. We also don’t believe it was missed postoperative infections since an infection resulting in a drop in DRF would probably be evident for parents and doctors. Purely hypothetically the drop in DRF could actually be a preoperative event happening between the last MAG3 and the pyeloplasty. Despite these four (3%) patients, we believe that renal function and drainage correlates rather well with the overall degree of hydronephrosis.

There is no established risk factor for delayed resolution of hydronephrosis following pyeloplasty. Carpenter et al. [7] retrospectively studied complete resolution of hydronephrosis in children and found neither surgical approach nor presence of crossing vessel to significantly impact complete resolution [7]. Minnilo et al. reported that 85% had improved hydronephrosis at follow-up after RALP [14]. Braga et al. [15] investigated risk factors for recurrent UPJ after open pyeloplasty and reported dorsal lumbotomy to grade hydronephrosis, or on the APD measured in millimeter or as relative improvement in percent, have impact on the results and may compromise comparisons. Carpenter et al. [7] used APD = 0 mm as the definition of complete resolution and concluded that complete resolution following pyeloplasty is uncommon. On the contrary, Rickard et al. [17] used APD \leq 15 mm to define resolution. The definition used in this study was either APD \leq 10 mm, or a reduction to less than 50% of the preoperative APD. This definition allowed for detection of relative improvements, regardless of the preoperative APD.

Optimal follow-up of children after pyeloplasty have been discussed in the literature [8,18]. The purpose of previous conducted studies has been to identify potential risk factors in order to reduce unnecessary investigations with US scans and MAG3 scans. Rickard et al. [17] suggested that 40% improvement of APD on the first US scan after pyeloplasty strongly predict successful pyeloplasty. Another study shows similar results and suggests 38% improvement as a cut-off value to select the patients with higher risk of recurrent obstruction [19]. Our results suggest that the vast majority of cases that resolve, do so within 12 months from surgery, whereas hydronephrosis persisting beyond 12 months after surgery is less likely to resolve. Since the improvement of hydronephrosis is very small between the first and second year after surgery, the value of follow-up beyond 12 months could be questioned since most failures seem to happen within the first year as seen in the present and in other larger cohorts [7,20,21]. However, there are also studies indicating longer time before failure as in the study by Davis et al. [22], and in the study by Jacobsson et al. [23] in which many were also asymptomatic. Based on the present study and previous literature we would recommend that children with persistent dilatation should continue their follow-up with ultrasound beyond 12 months, and if increasing dilatation a new MAG3 scan should be performed. Children with complete resolution of their hydronephrosis at 12 months do not likely benefit from further follow-up. Further, in the present study, only 8% had an increase in APD between 3 and 6 months, all with good drainage and no drop in DRF. This may also indicate that the US at 6 months may be unnecessary as long as the MAG3 at 3 months is good. The present study may however be too small to recommend removing the US at 6 months also.

In summary, our study gives support to the same follow-up protocol after any pediatric pyeloplasty, regardless of whether the obstruction is intrinsic or extrinsic in nature, or the surgery is performed with open or robot-assisted approach. This study also shows that the follow up US scan at 24 months add limited value for children with complete resolution of hydronephrosis. Skipping the 24-month postoperative control would lead to less unnecessary examinations and result in a more cost-effective healthcare. Children with persisting dilatation at 12 months need further follow-up since late obstructions can occur and some may be asymptomatic. Further, the results may improve preoperative and postoperative counselling for children and their families. There is a small risk of persisting dilatation postoperatively and it is important to provide this information to the parents. Our long-term results suggest that if DRF and drainage is good, there is little risk that the child needs a re-intervention despite persisting dilatation.

Limitations

Our results should be interpreted with the knowledge of its retrospective design, resulting in a risk of less accuracy regarding the collected data. There was also missing data from ultrasound measurements during the two-year follow-up that could introduce a possible bias in the interpretation of the time to resolution of hydronephrosis. Further, it is possible that some degree of tapering was performed in the early years of the study (≤2005) which could affect the postoperative evaluation of APD. Such time-dependant trends in techniques were adjusted for by the inclusion of year of surgery in the multivariable analysis. The number of patients in the present cohort might be too few to reach enough power in the regression analysis. However, small differences possibly found in larger studies may be clinically irrelevant. It should also be noted that the use of a more restricted definition might have shown other results, as less patients would have reached resolution. At last, the standardized follow-up for all patients in this study is a strength, yet the hydronephrosis may in fact have resolved at any given time between two examinations. Even more
frequent US scans may have narrowed the exact time to resolution.

**Conclusion**

High resolution rate of hydronephrosis is achieved within 24 months from pyeloplasty in children with ureteropelvic junction obstruction. Children with complete resolution at 12 months probably don’t benefit from further follow-up while children with persisting dilatation should be followed further. Renal function and drainage correlates rather well with the overall degree of hydronephrosis. There is neither any difference in the natural course of hydronephrosis between different types of surgical approach, nor any difference between the various types of obstructions. Thus, the same follow-up plan applies after paediatric pyeloplasty regardless of type of surgical approach or type of obstruction.

**Funding**

None.

**Conflict of interest**

None.

**References**

[1] Caiulo VA, Caiulo S, Gargasole C, Chiriaco G, Latini G, Cataldi L, et al. Ultrasound mass screening for congenital anomalies of the kidney and urinary tract. Pediatr Nephrol 2012;27(6):949–53.

[2] Hashim H, Woodhouse CRJ. Ureteropelvic junction obstruction. Eur Urol Suppl 2012;11(2):25–32.

[3] Nguyen HT, Herndon CD, Cooper C, Gatti J, Kirsch A, Kokorowski P, et al. The Society for Fetal Urology consensus statement on the evaluation and management of antenatal hydronephrosis. J Pediatr Urol 2010;6(3):212–31.

[4] Autorino R, Eden C, El-Ghoneimi A, Guazzoni G, Buffi N, Peters CA, et al. Robot-assisted and laparoscopic repair of ureteropelvic junction obstruction: a systematic review and meta-analysis. Eur Urol 2014;65(2):430–52.

[5] O’Reilly PH, Brooman PJ, Mak S, Jones M, Pickup C, Atkinson C, et al. The long-term results of Anderson-Hynes pyeloplasty. BJU Int 2001;87(4):287–9.

[6] Asensio M, Gander R, Royo GF, Lloret J. Failed pyeloplasty in children: is robot-assisted laparoscopic reparative repair feasible? J Pediatr Urol 2015 Apr;11(2):69.e1–6.

[7] Braga LH, Pace K, DeMaria J, Lorenzo AJ. Systematic review and meta-analysis of robotic-assisted versus conventional laparoscopic pyeloplasty for patients with ureteropelvic junction obstruction: effect on operative time, length of hospital stay, postoperative complications, and success rate. Eur Urol 2009 Nov;56(5):848–57.

[8] Minnullo BJ, Cruz JA, Sayao RH, Passerotti CC, Houck CS, Meier PM, et al. Long-term experience and outcomes ofrobotic assisted laparoscopic pyeloplasty in children and young adults. J Urol 2011;185(4):1455–60.

[9] Braga LH, Lorenzo AJ, Bagli DJ, Keays M, Farhat WA, Khoury AE, et al. Risk factors for recurrent ureteropelvic junction obstruction after open pyeloplasty in a large pediatric cohort. J Urol 2008;180(4 Suppl):1684–7. discussion 7-8.

[10] Barbosa JA, Kowal A, Onal B, Gouveia E, Walters M, Newcomer J, et al. Comparative evaluation of the resolution of hydronephrosis in children who underwent open and robotic-assisted laparoscopic pyeloplasty. J Pediatr Urol 2013;9(2):199–205.

[11] Rickard M, Braga LH, Oliveria JP, Romao R, Demaria J, Lorenzo AJ. Percent improvement in renal pelvis antero-posterior diameter (PI-APD): prospective validation and further exploration of cut-off values that predict success after pediatric pyeloplasty supporting safe monitoring with ultrasound alone. J Pediatr Urol 2016;12(4):228.e1–6.

[12] Abadir N, Schmidt M, Laube GF, Weitz M. Imaging in children with unilateral ureteropelvic junction obstruction: time to reduce investigations? Eur J Pediatr 2017;176(9):1173–9.

[13] Romao RL, Farhat WA, Pippi Salle JL, Braga LH, Figueiroa V, Bagli DJ, et al. Early postoperative ultrasound after open pyeloplasty in children with prenatal hydronephrosis helps identify low risk of recurrent obstruction. J Urol 2012;188(6):2347–53.

[14] Dy GW, His RS, Holt SK, Lendvay TS, Gore LJ, Harper JD. National trends in secondary procedures following pediatric pyeloplasty. J Urol 2016 Apr;195(4 Pt 2):1209–14.

[15] Ceyhan E, Ileri F, Ceylan T, Aydin AM, Dogan HS, Tekgul S. Predictors of recurrence and complications in pediatric pyeloplasty. Urology 2019;126:87–91.

[16] Davis TD, Burns AS, Corbett ST, Peters CA. Reoperative robotic pyeloplasty in children. J Pediatr Urol 2016 Dec;12(6):394.e1–7.

[17] Jacobson DL, Shannon R, Johnson EK, Gong EM, Liu DB, Flink CC, et al. Robot-assisted laparoscopic reparative repair for failed pyeloplasty in children: an updated series. J Urol 2019 May;201(5):1005–11.

**Appendix A. Supplementary data**

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpuro.2020.10.031.