Systematic Review

Utility of Ureteric Jets as an Adjuvant Diagnostic Modality in Children with Ureteropelvic Junction Obstruction: A Systematic Review and Meta-analysis

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Abstract

Background: Ureteropelvic junction obstruction (UPJO) is a common cause of pediatric hydronephrosis, yet only one-third of affected children require surgery. Differentiating obstructive from non-obstructive cases remains challenging with current imaging methods. This systematic review and meta-analysis evaluated the role of ureteric jets, assessed via color Doppler ultrasonography (USG), as an adjuvant diagnostic modality to complement gray-scale USG in children with UPJO.

Materials and Methods: A systematic search of PubMed, Embase, Scopus, and Web of Science databases was conducted to identify studies reporting on ureteric jet frequency (UJF) in UPJO. Standardized mean difference (SMD) with 95% confidence intervals (CI) was calculated for the pooled data, while the I^2 statistic assessed heterogeneity. Methodological quality was evaluated using the Newcastle–Ottawa scale.

Results: Five studies (111 patients) met inclusion criteria. Ureteric jets were absent in 67.3% of UPJO cases, with diagnostic accuracy reaching 94%. Meta-analysis revealed a significant reduction in UJF in obstructed kidneys (SMD = −2.01, 95% CI: −3.09 to −0.94, $P = 0.0002$), though heterogeneity was substantial ($I^2 = 80\%$, $P = 0.006$). The methodological quality of the included studies was good in four studies and poor in one study.

Conclusions: The current systematic review demonstrated the absence of ureteric jets and a significant reduction in the UJF in the obstructed kidneys. However, due to heterogeneity among the included studies, further studies are needed to standardize the protocols before any definite conclusions are drawn.

Keywords: *Color Doppler ultrasound, hydronephrosis, ureteric jet frequency, ureteric jets, ureteropelvic junction obstruction*

Submitted: 08-Mar-2025.
Revised: 16-Apr-2025.
Accepted: 22-Apr-2025.
Published: 02-Jun-2025.

Introduction

Ureteropelvic junction obstruction (UPJO) is a functionally significant impairment of urine flow from the renal pelvis to the ureter. Diagnosis requires a combination of radiological studies to identify patients at risk of progressive kidney damage or complications, making them candidates for operative intervention. UPJO accounts for 11% of antenatal hydronephrosis, which affects 1%–2% of pregnancies, with an incidence of 1:750–1500 live births.[1]

Gray scale B-mode ultrasonography (USG) is a primary imaging modality for establishing the anatomical diagnosis of hydronephrosis in children and adults.[2,3] However, it lacks the ability to differentiate between obstructive and nonobstructive

Access this article online

Quick Response Code:

Website: www.jiaps.com

DOI: 10.4103/jiaps.jiaps_72_25

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How to cite this article: Prasad G, Agarwal K, Gulia A, Pakkasjärvi N, Ranjan A, Jana M, *et al.* Utility of ureteric jets as an adjuvant diagnostic modality in children with ureteropelvic junction obstruction: A systematic review and meta-analysis. J Indian Assoc Pediatr Surg 2025;30:569-75.

causes of hydronephrosis, limiting its utility in guiding management decisions.[4] Current diagnostic protocols rely on a combinatorial approach, integrating ultrasound with functional assessments such as diuretic renography to evaluate the severity and significance of obstruction. However, diuretic renography is invasive, time-consuming, involves use of radionuclide and exposure to ionizing radiation, often poorly tolerated by infants, and yields equivocal results in approximately 15% of cases,[5,6] raising concerns about its reliability, especially during repeated follow-ups. Moreover, because obstruction may need to reach a critical threshold before manifesting on renography, there is a need for more readily accessible, noninvasive methods that can aid in early functional assessment.

The assessment of ureteric jets, which represent urine flow from the ureters into the bladder, using color Doppler sonography offers valuable insight into the presence of obstruction without exposure to ionizing radiation or contrast media. Recently, it has been explored as a potential complementary noninvasive diagnostic tool to assess the functional aspect of the hydronephrotic kidney.[2,3]

This systematic review and meta-analysis aims to summarize and evaluate the current literature on the utility of ureteric jets, assessed via color Doppler USG, as an adjuvant diagnostic modality in children with unilateral UPJO. By virtue of this, we intend to determine whether the addition of ureteric jet assessment in the routine set of investigations can enhance clinical decision-making in children with UPJO.

Materials and Methods

Search strategy

A systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines.[7] A preliminary search was independently conducted by two authors (GP and KA) in the PubMed database to confirm nonavailability of any systematic reviews on this topic. Subsequently, a systematic search strategy was employed by the authors (GP and KA) to search for relevant studies published between January 1990 to August 2024 in four electronic databases including PubMed, Web of Science, Scopus, and EMBASE. The search terms were: "Uretero-pelvic junction obstruction OR Pelvi-ureteric junction obstruction OR PUJO OR UPJO OR Obstructive hydronephrosis" AND "Ureteric jets OR Ureteral jets." Duplicate records were identified and removed. The remaining references were independently screened by two authors (GP and KA) based on predefined eligibility criteria. The detailed electronic search strategy is provided in the Supplementary Table 1.

Eligibility criteria

Studies were included if they met the following PICO criteria:

- Population (P): Patients under 18 years of age diagnosed with unilateral UPJO (based on USG KUB and diuretic renography findings)
- Intervention (I): Ureteric jet assessment on the obstructed side by using color Doppler USG
- Comparison (C): Comparison was made with the contralateral nonobstructed side
- Outcomes (O): Studies focusing on either of the following outcomes were eligible for inclusion:
  - The absence of ureteric jets on the obstructed side (over a pre-determined time interval stated in the included study)
  - Ureteric jet frequency (UJF) – defined by the number of jets at a particular ureteric orifice per minute.

All study designs including prospective and retrospective cohort studies, cross-sectional studies, and randomized control trials were eligible for inclusion. Studies were excluded if they were case reports, opinion articles, review articles, letters to the editor, correspondences, studies involving animal subjects, or published in languages other than English.

Data extraction

Two authors performed the data extraction using Microsoft Excel spreadsheets. Baseline characteristics of each study, including the first author's name, year of publication, country of origin, study design, the number of study subjects, age distribution, and protocol/radionuclide used in renal scintigraphy were extracted. Information pertaining to the primary and the secondary outcomes were noted. Furthermore, any additional information deemed useful by the authors was collected for potential inclusion as nonpooled data.

Quality assessment

Two authors (AG and SA) independently evaluated the included studies for methodological quality, with any disagreements resolved by consensus or through discussion with a third author (MJ). The quality of the included studies was assessed using the Newcastle–Ottawa Scale (NOS).[7] The NOS evaluates study quality across three domains: Selection of participants, comparability of groups, and ascertainment of outcomes. Studies were assigned scores ranging from 0 to 9, with higher scores indicating higher quality.

Statistical analysis and assessment of bias

Categorical variables were expressed as percentages, whereas continuous variables were reported as mean ± standard deviation or median with range. The

pooled standardized mean difference (SMD) with 95% confidence interval (CI) was calculated for the data on UJF from the included studies. A random effects model was followed, and the inverse variance method was used for pooling the data. The I^2 statistics were used to calculate heterogeneity. $P \leq 0.05$ was considered as statistically significant. The meta-analysis was performed using Review Manager, Version 5.4.1 (Cochrane Collaboration, London, UK).

Results

Study selection

A total of 100 studies were identified through database searches. After removing 26 duplicates, 74 articles remained for screening. Based on the predefined exclusion criteria, 55 studies were excluded, leaving 19 articles for full-text review. Among these, four were review articles,[4,8-10] three were conference abstracts,[11-13] one was published in non-English language,[14] and one study included only adult patients with obstruction due to ureteric stones.[15] Additionally, five articles lacking information on ureteric jets were also excluded.[16-20] Therefore, five studies met the eligibility criteria and were included in the systematic review[2,3,21-23] [Figure 1]. Of these, three studies each provided data on the absence of ureteric jets[3,21,22] and data on UJF between cases and controls.[2,22,23]

Study characteristics

The five studies included in the systematic review had 111 cases of unilateral UPJO. Of these five studies, only 3 were included in the meta-analysis. The age of the patients from the included studies ranged from 1 day to 17 years. The baseline characteristics of the included studies have been summarized in Table 1.

In all included studies, the diagnosis of UPJO was confirmed using renal scintigraphy study: Defined as an obstructive curve and $t½$ >20 min. However, the protocol used (according to the time of administration of furosemide, as per the standard guidelines suggested by the Society for Fetal Urology and the Council of Pediatric Nuclear Medicine: F-0, F+20 or F-15) and the radionuclide varied among the included studies [Table 1].

The method of assessing ureteric jets using color Doppler USG was consistent across all included studies.

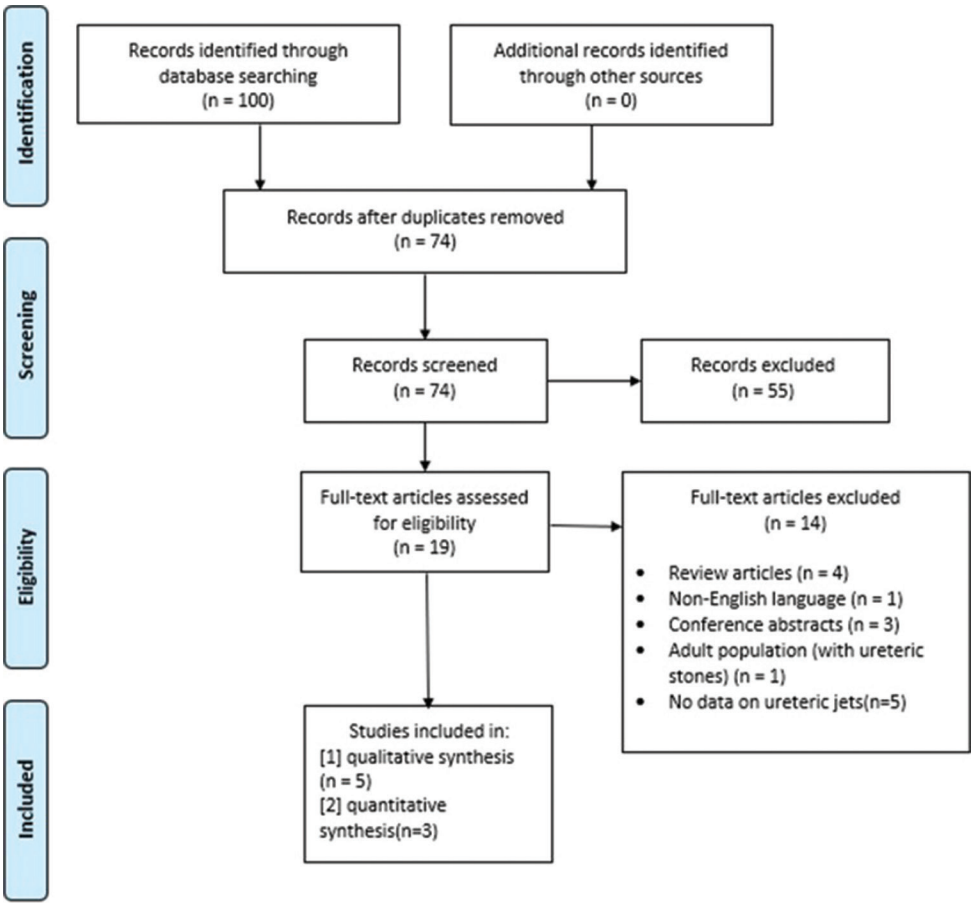

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of study selection. A PRISMA flow diagram illustrating the study selection process for the systematic review and meta-analysis. The diagram outlines the number of records identified through database searches, screened, excluded at various stages, and ultimately included in the final analysis

Assessments were performed with patients in the supine position, using the transverse plane to visualize both ureteric orifices simultaneously. The probes used were of similar frequencies in four of the included studies, ranging from 2.5 to 5 MHz.[2,3,22,23] In all studies, patients were adequately hydrated to ensure a moderately full bladder at the time of assessment, although the specific instructions for hydration (e.g., amount of water intake or breastfeeding) slightly varied among them.

Methodological quality assessment

All the cross-sectional studies were assessed for methodological quality using the NOS. The results from these evaluations demonstrated that the total scores ranged from 5 to 9. Four included studies were of good quality. The recently published prospective study[23] had the highest score and the study by de Bessa *et al*., 2018[3] had the lowest score [Table 2]. The strengths of the included studies were their representative study populations, clear inclusion criteria, and use of the contralateral kidney as a control.

Main outcomes

a. Absence of ureteric Jets: The systematic review identified data on the absence of ureteric jets in unilateral UPJO as follows: Strehlau *et al*.[21] reported absence in 85% of cases with unilateral obstructive uropathy, while Kuzmic *et al*.[22] and de Bessa Junior *et al*.[3] documented absence in 71.4% and 74% of cases, respectively. No corresponding data were available in two studies.[2,23] These results were based on a single color Doppler USG examination of ureteric jets. No study employed serial assessments

b. UJF: A meta-analysis was conducted using comparative data on UJF from three included studies.[2,22,23] Pooling the data yielded 82 subjects in each patient group. The pooled estimate [Figure 2] in the obstructed versus nonobstructed renal units

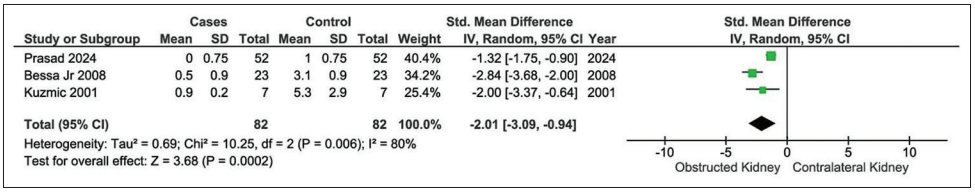

Figure 2: Forest plots comparison of ureteric jet frequency among cases (obstructed kidney unit) versus controls (non-obstructed kidney unit). A forest plot illustrating the standardized mean difference (SMD) in ureteric jet frequency (UJF) between UPJO-affected and nonobstructed renal units across the included studies. The pooled analysis demonstrates a significant reduction in UJF in the obstructed group (SMD = −2.01, 95% confidence interval: −3.09 to −0.94, $P = 0.0002$). The random effects model was used due to substantial heterogeneity ($I^2 = 80\%$)

Table 1: Characteristics of the included studies

Author, Year	Country	Cases (*n*)	Controls* (*n*)	Age (years)	Protocol/radionuclide used in RDS	Ureteric jet assessment$ (min)
Strehlau *et al*., 1997[21]	Germany	10	10	0.4 (1 day - 11.8)	F+20/MAG-3	10
Kuzmic *et al*., 2001[22]	Croatia	7	7#	10.5±4.4	Not mentioned/DTPA	5
Bessa Junior *et al*., 2008[2]	Brazil	23	23	4 (3 months–14)	F+20/DTPA	5
Bessa Junior *et al*., 2018[3]	Brazil	19	-	6.5 (2–17)	F+20/DTPA	5
Prasad *et al*., 2024[23]	India	52	52	35 (1–168)**	F0/LLEC	5

*Contralateral nonobstructed renal unit, **Months, #The study mentions children with no urological anomaly as the controls but data pertaining to the contralateral normal renal moiety has been used as controls for this review, $Duration over which ureteric jets were counted at each orifice. *n*: Number of participants, RDS: Renal dynamic scan, MAG-3: Mercaptoacetyltriglycine, DTPA: Diethylenetriamine pentaacetate, LLEC: L, L, ethylenedicysteine

Table 2: Methodological quality assessment of included studies using the Newcastle–Ottawa Scale

Study	Selection				Comparability - Item 5	Outcome		Total score	Quality#
	Item 1	Item 2	Item 3	Item 4		Item 6	Item 7		
Stehlau, 1997[21]	*		*	*	**	**		7/9	Good
Kuzmic, 2001[22]	*		*	*	**	**	*	8/9	Good
Bessa Junior, 2008[2]	*		*	*	**	**	*	8/9	Good
Bessa Junior, 2018[3]	*			*		**	*	5/9	Poor
Prasad, 2024[23]	*	*	*	*	**	**	*	9/9	Good

#Good quality: 3 or 4 stars in selection domain AND 1 or 2 stars in the comparability domain AND 2 or 3 stars in the exposure domain. Fair quality: 2 stars in selection domain AND 1 or 2 stars in comparability domain AND 2 or 3 stars in outcome/exposure domain. Poor quality: 0 or 1 star(s) in selection domain OR 0 stars in the comparability domain OR 0 or 1 star(s) in the exposure domain

showed a significantly low UJF (SMD = −2.01, 95% CI: −3.09 to −0.94, P = 0.0002). For this outcome, the heterogeneity among the included studies was substantial and significant (I^2 = 80%, P = 0.006).

Other outcomes

Two studies assessed the diagnostic accuracy of ureteric jet assessment. Using renal dynamic scan (RDS) and the Whitaker test as reference standards, Strehlau *et al*. reported a 94% accuracy in diagnosing UPJO in the absence of ureteric jets or a reduction in UJF to <10% of the contralateral kidney.[21] Similarly, de Bessa *et al*. demonstrated an accuracy of 88.6%, noting that in 61% of the cases, RDS could have been avoided, particularly in mild or severe hydronephrosis cases, thus, highlighting the need to reduce invasive diagnostics in these children.[3]

A recent prospective study also evaluated changes in the UJF and relative jet frequency, defined as the proportional reduction in ureteric jet activity when comparing the affected ureter to its contralateral counterpart, at baseline and 6 months postpyeloplasty. Both parameters significantly increased from the preoperative to the postoperative period (P < 0.0001). The ROC curve for UJF indicated a threshold of <1.25, with 75% sensitivity and 64.81% specificity for detecting obstruction.[23] This study also incorporated diuretic administration (Lasix) during ureteric jet assessment and reported a significant reduction in UJF on the obstructed side compared to the contralateral normal moiety, both pre- and postpyeloplasty (P < 0.0001).

Discussion

UPJO is a prevalent cause of obstructive uropathy in children, with an incidence ranging from 1:750 to 1:1500 live births.[1] Despite its high prevalence, only one-third of children with UPJO require surgical intervention,[24] making it critical to identify those at risk for progressive renal damage. This identification often necessitates multiple imaging studies, which, while instrumental, come with inherent limitations. Traditional imaging modalities, such as USG and diuretic renography, remain cornerstones in diagnosis but are not without drawbacks. Diuretic renography, in particular, is invasive, utilizes ionizing radiation, and involves the use of contrast agents or scintigraphy, all of which may limit its applicability, especially in the pediatric population. In addition, diuretic renography yields equivocal results in up to 15% of cases,[5,6] further complicating the diagnostic process.

These limitations underscore the need for less invasive, more reliable alternatives to conventional imaging techniques. Advances in ultrasound technology have given rise to color Doppler ultrasonography (CDUS), a promising modality for the evaluation of UJs. UJs are the urine flow from the ureters into the bladder and are visualized via the difference in specific gravity between the urine in the ureter and the bladder. With CDUS, the visualization rate of UJs has increased dramatically from 50% with traditional gray-scale USG to 90%–100% with color Doppler imaging.[9,25] This noninvasive modality offers the advantage of distinguishing obstructive from nonobstructive causes of UPJO without the need for ionizing radiation or contrast media.

In this systematic review, the absence of ureteric jets was identified in 67.3% of UPJO cases across two studies,[3,22] with the meta-analysis demonstrating a significant reduction in UJF on the obstructed side (SMD of −2.01, 95% CI: −3.09 to −0.94, P = 0.0002).[2,22,23] This indicates that obstructed kidneys exhibit a markedly reduced or almost absent UJF, reflecting impaired urinary flow due to obstruction at the ureteropelvic junction. The statistical significance (P < 0.001) confirms the robustness of this finding, suggesting that UJF could serve as a reliable functional marker for detecting obstruction. Strehlau *et al*. also noted a significantly less number of ureteric jets in a large proportion of patients when only UPJO was considered among obstructive uropathies.[21] These findings underscore the diagnostic potential of color Doppler USG in distinguishing obstructive from nonobstructive cases of UPJO.

The diagnostic accuracy of ureteric jets, as reported by Kuzmic *et al*. and de Bessa *et al*., further supports this finding.[3,22] Both studies demonstrated that the absence or reduction of ureteric jets on the affected side has a diagnostic accuracy approaching 90%, suggesting that UJF may serve as a reliable parameter alongside traditional markers like hydronephrosis grade and anteroposterior Diameter of the renal pelvis. Importantly, de Bessa *et al*. suggested that UJF could potentially reduce the need for more invasive diagnostics such as diuretic renography in certain cases,[3] highlighting the clinical potential of ureteric jet assessment as a noninvasive, effective tool in the management of UPJO. However, further large-scale studies are needed to confirm these findings and define the full scope of UJF's clinical utility. Furthermore, despite its known limitations, RDS remains the most objective and widely accepted criterion for diagnosing UPJO and assessing the need for surgical intervention, whereas ureteric jet assessment may serve as a useful adjunct, particularly in equivocal or borderline cases.

In the reviewed studies, the earliest assessment of ureteric jets using color Doppler USG was reported at 1 day of life (in the study by Strehlau *et al*.).[21]

However, for neonates with antenatally detected unilateral hydronephrosis, it is advisable to perform this evaluation after 48 h of birth, once the initial postnatal phase of physiological oliguria has resolved.

Our study has several strengths, including its comprehensive methodology, adherence to the PRISMA 2020 guidelines, and rigorous evaluation of both pooled and nonpooled data. Nonetheless, there are several limitations that must be considered. The relatively small number of included studies, variations in protocols and methodologies, and the significant heterogeneity between them limit the generalizability of the findings. Furthermore, one of the included studies was of poor methodological quality. Furthermore, the absence of long-term follow-up data in most studies restricts our ability to draw definitive conclusions regarding the role of UJs in predicting long-term renal outcomes.

In addition, the accuracy of UJ assessment is heavily dependent on the skill and expertise of the operator performing the Doppler ultrasound. Inadequate technique, such as failure to align the probe correctly or overlooking the importance of bladder fullness, can lead to missed or inconsistent visualization of jets. While experienced operators can optimize imaging and interpretation, inexperience introduces confounding factors that may lead to diagnostic inaccuracies. While age or body size does not inherently influence the generation of ureteric jets, patient-related issues include the need for adequate hydration to ensure visible jets, which can be challenging in young children who are uncooperative or restless.[21] Moreover, obesity and frequent voiding can obscure jet visualization due to technical challenges or insufficient bladder filling.[25] Addressing these issues through training, standardization, and quality control is essential for the reliable use of ureteric jets in clinical practice.

In light of these challenges, a multimodal diagnostic approach is recommended for the evaluation of UPJO. Combining advanced imaging modalities such as CDUS with conventional USG offers a more comprehensive and reliable method for differentiating UPJO from nonobstructive dilatation. Future research on ureteric jets in pediatric UPJO should address several gaps. Larger, more diverse patient cohorts, especially neonates and infants, are needed to validate findings and enhance generalizability. Standardized protocols for ureteric jet assessment, including patient preparation and scanning techniques, as well as repeat ureteric jet assessments in cases with equivocal findings will help reduce variability and improve diagnostic confidence. Moreover, the role of ureteric jets in the follow-up of both surgical and non-surgical cases requires further investigation.

Conclusions

This systematic review and meta-analysis highlight the potential of ureteric jet assessment via color Doppler USG as a valuable supportive diagnostic tool in the evaluation of pediatric UPJO. The pooled analysis revealed the absence of ureteric jets and a significant reduction in UJF in obstructed kidneys, highlighting its potential role in identifying functional obstruction. However, the substantial heterogeneity among the included studies, driven by variations in protocols and methodologies, underscores the need for further high-quality, standardized research. Future studies must focus on refining the protocols and enhancing the diagnostic accuracy to establish ureteric jet assessment as a reliable, noninvasive adjunct in the comprehensive management of pediatric UPJO.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Supplementary Table 1: Details of the search strategy

Database	Search string	Number of studies
PubMed	((((((Ureteropelvic junction obstruction) OR (Pelviureteric junction obstruction)) OR (PUJO)) OR (UPJO)) OR (Obstructive hydronephrosis))) AND ((Ureteric jets) OR (Ureteral jets))	20
Embase	ALL (“Ureteropelvic junction obstruction” OR “Pelviureteric junction obstruction” OR “PUJO” OR “UPJO” OR “Obstructive hydronephrosis”) AND (“Ureteric jets” OR “Ureteral jets”)	11
Web of Science	Query 1: (Ureteropelvic junction obstruction OR Pelviureteric junction obstruction OR PUJO OR UPJO) AND Query 2: (Ureteric jets OR Ureteral jets)	22
Scopus	ALL (“Ureteropelvic junction obstruction” OR “Pelviureteric junction obstruction” OR “PUJO” OR “UPJO” OR “Obstructive hydronephrosis”) AND (“Ureteric jets” OR “Ureteral jets”)	57
Total		100
Duplications		26
Final articles screened		74
Full text reviewed		19
Final included in systematic review		5