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REVIEW

# Surgical management of obstructing ureteral stones during pregnancy: A systematic review of different techniques

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**Summary** ***Introduction: Renal colic is the most common non-obstetric cause of abdominal pain during pregnancy and is associated with a higher risk of complications in these women. When invasive treatment is required, options are temporary drainage with ureteral stent (JJ) or percutaneous nephrostomy (PCN), or immediate definitive treatment with ureteroscopy (URS). Our goal was to review the safety and efficacy of these procedures in treating urolithiasis during pregnancy.***

***Methods: Adhering to the PRISMA checklist guidelines, we searched PubMed, Embase, and Scopus databases for articles on the efficacy and complications of the three procedures in pregnant women. The quality of evidence and risk of bias were evaluated using the Critical Appraisal Skills Programme and the Institute of Health Economics tools.***

***Results: We included 45 articles, totaling 3424 interventions in pregnant women - 2188 URS, 719 JJ, and 517 PCN. URS was the most assessed procedure, with stone-free rates comparable to the non-pregnant patients. The most frequent complications were lower urinary symptoms and infections independently of the intervention. Obstetric complications for all interventions included 167 cases of preterm labor, resulting in 24 premature births. No statistically significant differences in post-operative complications were reported between the procedures in the few comparative studies.***

***Conclusions: Despite the absence of high-quality studies, current evidence suggests that URS, JJ, and PCN are all safe and effective during pregnancy. As most patients submitted to temporary drainage require a second procedure post-delivery, primary URS appears more efficient. Therefore, it is the preferred option unless there are indications for temporary drainage.***

KEY WORDS: *Urolithiasis; Pregnancy; Ureteroscopy; Ureteral stent; Percutaneous nephrostomy.*

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## INTRODUCTION

Pregnancy induces anatomic, metabolic, and chemical changes in the urinary tract that would predispose pregnant women to stone formation: both uterine extrinsic compression and progesterone's relaxing effect on ureteral smooth muscle cause physiologic hydronephrosis in 90% of pregnant women, especially on the right side, exacerbated by an increase in the glomerular filtration rate, which leads to higher urinary calcium and uric acid concentrations. However, urolithiasis prevalence is similar in pregnant and non-pregnant women, mostly due to the simultaneous increase in inhibitory factors (such as citrate, magnesium, and glycoproteins) (1). One large cohort study demonstrated an incidence of 0.2% of symptomatic urolithiasis in pregnancy (2).

Nevertheless, renal colic is the most common non-obstetric cause of abdominal pain and subsequent hospitalization during pregnancy, especially in the second and third trimesters (1), and it is associated with a higher risk of complications, such as premature rupture of membranes, spontaneous abortion, preterm labor, and preterm birth (2).

Most cases of symptomatic urolithiasis are non-complicated and can be managed conservatively with vigilance, hydration, and analgesia. This is successful in 70-80% of cases with spontaneous stone passage (2, 3). Invasive treatment should be considered within a multidisciplinary discussion in cases of persistent pain or vomiting, signs of infection, decline in renal function, obstructive stones in solitary kidney, bilateral obstruction, or obstetric complications (4). The different available procedures are temporary drainage with a *percutaneous nephrostomy* (PCN) or a *double-J* stent insertion (JJ), or definite treatment with *ureteroscopy* (URS) (4).

If fever or other signs of infection are present, ureteroscopy is contraindicated and urgent temporary drainage is required. Temporary drainage is also usually preferred in cases of large stone burden, complex anatomy, bilateral stone disease, obstetric complications, or presentation in the first trimester or near full term. Ureteral stenting or percutaneous nephrostomy placement are usually fast procedures, require minimal anesthesia, and can be radiation-free, but they require a second definitive intervention postpartum to treat the stone, often need multiple catheter exchanges during pregnancy, and are poorly tolerated (4). Consequently, definitive treatment with ureteroscopy started becoming the first-line procedure, when possible.

Our main objective with this systematic review is to evaluate the safety and efficacy of ureteroscopy, double-J stent insertion, and percutaneous nephrostomy in the treatment of renal colic during pregnancy.

## Methods

We elaborated the present review according to the *Preferred Reporting Items for Systematic Reviews and Meta-analyses* (PRISMA) 2020 checklist (5).

### *Search strategy*

The primary search was conducted using the PubMed, EMBASE, and Scopus databases, for articles published before November 2021. Our query was "(pregnancy OR pregnant) AND (renal colic OR urolithiasis) AND (nephrostomy) AND (ureteral stent OR JJ) AND (ureteroscopy) AND (drainage OR urinary diversion OR urinary catheterization)". Additionally, we used the "snowball" method, tracking references and citations of found articles to identify additional relevant studies. The search results were organized using EndNote with identification and removal of duplicates. Two independent researchers (CLT and MJO) screened the titles and abstracts of the search results against the inclusion criteria. Subsequently, the same two researchers analyzed full-text reports for eligibility. Any disagreement was solved through discussion and consensus. A third reviewer (JPT) resolved any disagreement during report selection and did the final review.

### *Eligibility criteria*

Our PICOS definition was: Participants: Pregnant women with urolithiasis; Intervention: Ureteroscopy (or double-J stent insertion or percutaneous nephrostomy placement when no ureteroscopy was performed); Comparators: Double-J stent insertion or percutaneous nephrostomy placement or conservative treatment; Outcomes: Procedure efficacy or intervention success, perioperative and postoperative complications, and obstetric complications; Study design: This systematic review included randomized controlled trials, cohort studies (prospective or retrospective), case-control studies, and case series.

The articles were considered when they fulfilled the following inclusion criteria: pregnant women; treatment, including ureteroscopy, ureteral stent insertion, and/or nephrostomy; English language.

The exclusion criteria were: non-pregnant; other types of treatment; other languages; grey literature; full text not available; reviews and case reports; animal studies.

### *Data extraction and management*

The following data was collected from each study: author's names; country and year of publication; study duration, design, and objective; sample characteristics (sample number, mean age, mean gestational age or trimester); inclusion and exclusion criteria; type of treatment; intervention success; perioperative, postoperative, and obstetric complications; imaging considerations; relevant conclusion and limitations.

### *Critical appraisal of included studies*

The quality assessment and risk of bias were carried out by

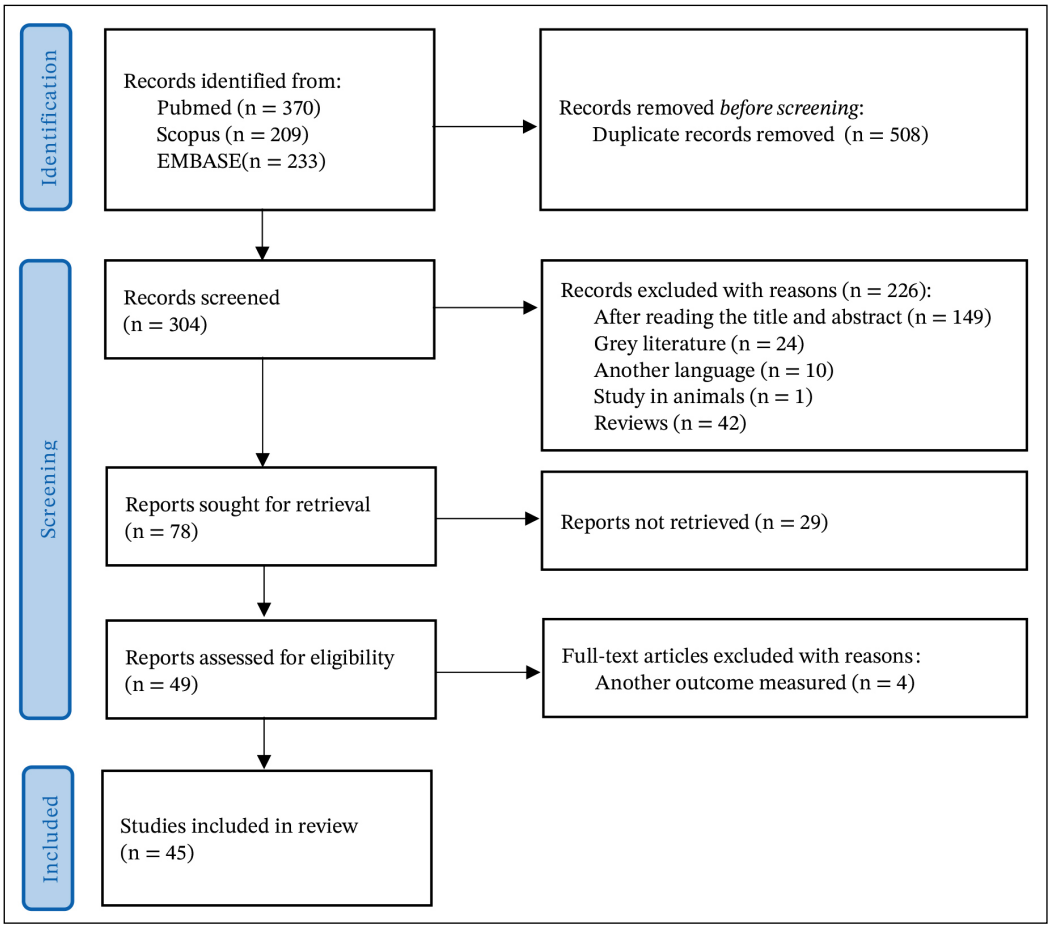


***Figure 1.*** *PRISMA methodology flowchart for article selection.*

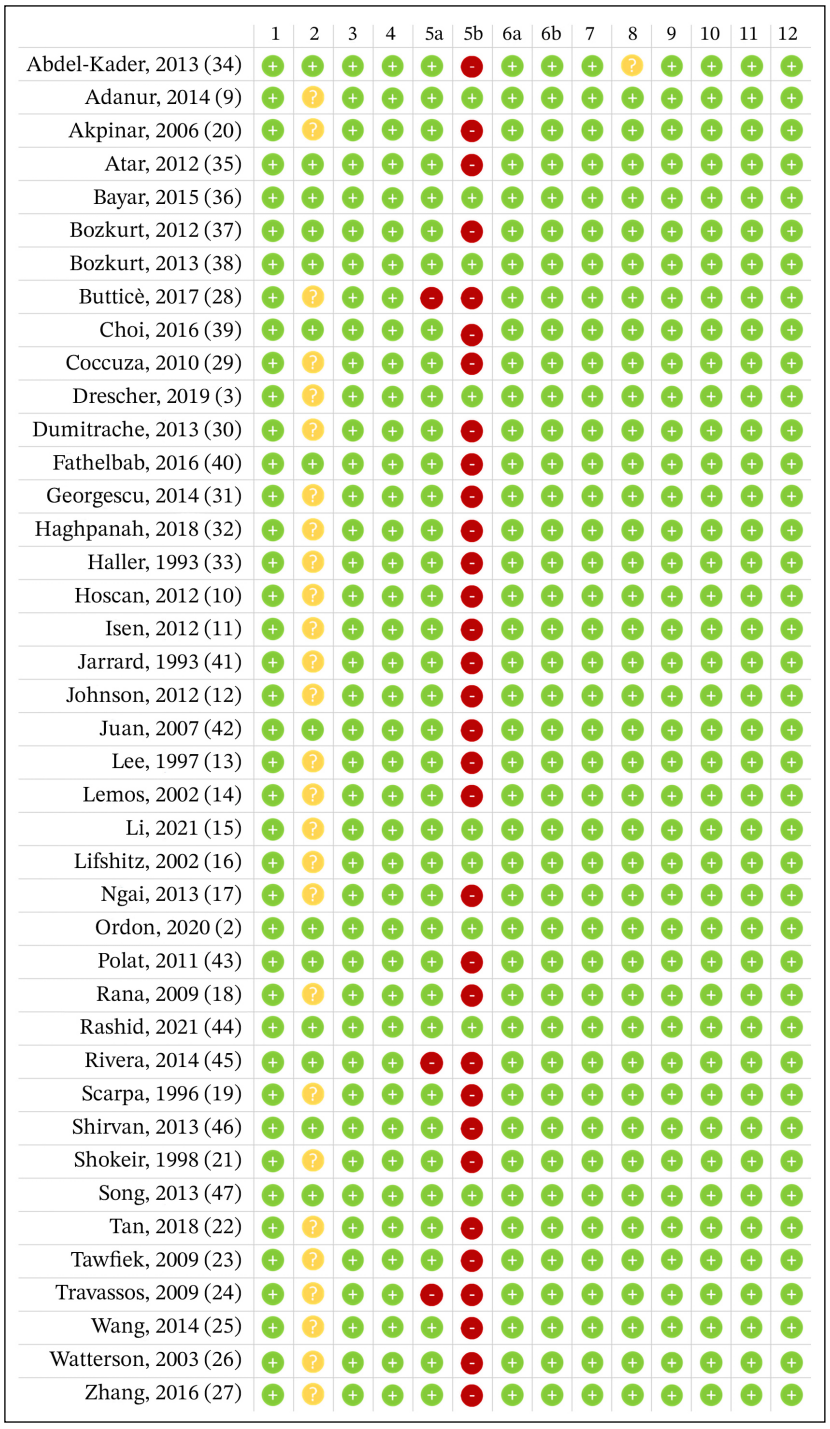


***Figure 2.***
*Critical appraisal skills programme checklist for cohort studies.*

*1) Did the study address a clearly focused issue? 2) Was the cohort recruited in an acceptable way? 3) Was the exposure accurately measured to minimize bias? 4) Was the outcome accurately measured to minimize bias? 5a) Have the authors identified all-important confounding factors? 5b) Have they taken account of the confounding factors in the design and/or analysis? 6a) Was the follow-up of subjects complete enough? 6b) Was the follow-up of subjects long enough? 7) What are the results of this study? 8) How precise are the results? 9) Do you believe the results? 10) Can the results be applied to the local population? 11) Do the results of this study fit with other available evidence? 12) What are the implications of this study for practice?*
*Green circles (+) represent low risk of bias, red circles (-) represent high risk of bias; yellow circles (?) indicate unclear risk of bias.*

two independent reviewers using the *Critical Appraisal Skills Programme* (CASP) checklist (6) for cohort studies and the Institute of Health Economics checklist (7) for case series studies. Any disagreement was solved by discussion and consensus or by the involvement of the third reviewer.

## Evidence synthesis

### *Study selection*

The flowchart in Figure 1 describes in detail the implemented search method.

### *Critical appraisal*

The quality assessment of the studies included in this review is presented in Figure 2 and Figure 3.
Within the cohort studies, the most failed criteria were related to the recruitment of the cohort in an acceptable way, since some articles did not mention the exclusion criteria (3, 8-33) and to the identification and the consideration of confounding factors in the design. Within the case series, all articles failed to meet the follow-

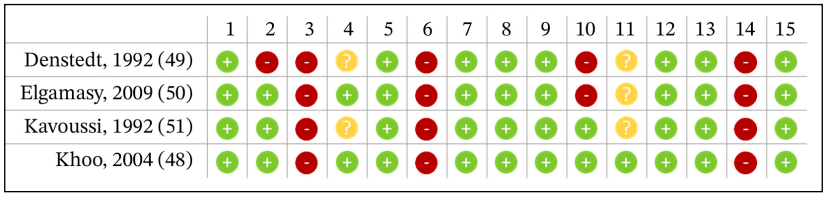


***Figure 3.***
*Institute of health economics quality appraisal checklist for case series studies.*

*1) Was the hypothesis/aim/objective of the study clearly stated? 2) Was the study conducted prospectively? 3) Were the cases collected in more than one center? 4) Were patients recruited consecutively? 5) Were the characteristics of the patients included in the study described? 6) Were the eligibility criteria for entry the study clearly stated? 7) Did patients enter the study at a similar point in the disease? 8) Was the intervention of interest clearly described? 9) Were additional interventions (co-intervention) clearly described? 10) Were relevant outcome measures established a priori? 11) Were outcomes assessors blinded to the intervention that patients received? 12) Were the relevant outcomes measured using appropriate objective/subjective methods? 13) Were the relevant outcome measures made before and after the intervention? 14) Were the statistical tests used to assess the relevant outcomes appropriate? 15) Was follow-up long enough for important events and outcomes to occur?*
*Green circles (+) represent low risk of bias, red circles (-) represent high risk of bias; yellow circles (?) indicate unclear risk of bias.*

ing criteria: cases collected in more than one center, presentation of eligibility criteria for entering the study since none of them presented exclusion criteria, and use of statistical tests to assess the relevant outcomes.

### *Characterization of the studies*

A summary of the main characteristics and conclusions of each article included in our systematic review is presented in Table 1.

***Table 1.*** *Summary of included studies.*

| Article | Country | Study design and methods | Pregnant patients who underwent intervention, n | Mean gestational age (weeks) or trimester | URS, n | JJ, n | PCN, n | Procedure efficacy | Perioperative complications | Postoperative complications | Obstetric outcomes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Abdel-kader et al. (2013) [34] | Egypt | Retrospective cohort study | 23 | 25 | 17 | 6 | 0 | URS stone-free rate: 100%<br>All JJ stents needed postpartum definitive treatment | - | - | All patients delivered at term without adverse fetal outcomes |
| Adanur et al. (2014) [9] | Turkey | Retrospective cohort study | 9 | 24.8 | 9 | 0 | 0 | Stone-free rate: 100% | - | UTI (n=1) | Pre-term uterine contractions (n=1).<br>All patients delivered at term without adverse fetal outcomes |
| Akpinar et al. (2006) [20] | Turkey | Retrospective cohort study | 7 | 1st T: 14.3%<br>2nd T: 71.4%<br>3rd T: 14.3% | 7 | 0 | 0 | Not specified | - | Intense pain (n=2) | All patients delivered at term without adverse fetal outcomes |
| Atar et al. (2012) [35] | Turkey | Prospective cohort study | 17 | 24 | 17 | 0 | 0 | Not specified | Ureteral perforation (n=1); ureteral mucosal injury (n=2) | Dysuria and pain (n=5); UTI (n=1) | All patients delivered at term without adverse fetal outcomes |
| Bayar et al. (2015) [36] | Turkey | Retrospective cohort study | 70 | 23.4 | 41 | 29 | 0 | URS stone-free rate: 87%<br>Higher need of postpartum additional interventions in the JJ group. | Ureteral lesions (n=4)<br>URS: stone could not be reached (n=2), stone migration (n=3), ureteral laceration (n=3), partial perforation (n=1) | URS: Acute pyelonephritis (n=5), urosepsis (n=1)<br>JJ: Acute pyelonephritis (n=1), lower urinary tract symptoms (n=17), lumbar pain (n=13)<br>No statistically significant differences in complication frequency or severity between groups. | URS: pre-term delivery (n=15)<br>JJ: premature contractions (n=2), pre.term delivery (n=7), in-utero fetal death (n=1, complicated twin pregnancy).<br>No statistically significant differences. |
| Bozkurt et al. (2012) [37] | Turkey | Retrospective cohort study | 27 | 24 | 27 | 0 | 0 | Not specified | Ureteric laceration (n=2) | Dysuria and pelvic pain (n=2), UTI (n=4), urosepsis (n=1) | All patients delivered at term without adverse fetal outcomes |
| Bozkurt et al. (2013) [38] | Turkey | Retrospective cohort study | 41 | 23.2 | 41 (+62 in non pregnant patients) | 0 | 0 | No statistically significant differences in stone-free rate. | Ureteric laceration (pregnant n=3; non-pregnant n=10)<br>Ureteric perforation (pregnant n=1; non-pregnant n=3)<br>No statistically significant differences | UTI (pregnant n=4, non-pregnant n=5), dysuria (pregnant n=6, non-pregnant n=16), urosepsis (pregnant n=1, non-pregnant n=1)<br>No statistically significant differences | All patients delivered at term without adverse fetal outcomes |
| Butticè et al. (2017) [28] | Italy | Retrospective cohort study | 133 | 2nd T: 26.1 weeks<br>3rd T: 31.8 weeks | 133 | 0 | 0 | Not specified | Stone migration (n=10) | - | URS: pre-term labor (8.7%) |

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| Choi et al. (2016) [39] | Korea | Retrospective cohort study | 14 | 1st T: 10.2%<br>2nd T: 74.4%<br>3rd T: 20.4% | 0 | 13 | 1 | All procedures were effective | - | - | All patients delivered at term without adverse fetal outcomes |
| Cocuzza et al. (2010) [29] | Brazil | Retrospective cohort study | 8 | 29.2 | 7 | 1 | 0 | Stone-free rate: 100% | - | Dysuria (n=1) | All patients delivered at term without adverse fetal outcomes |
| Denstedt et al. (1992) [49] | Canada | Case series | 13 | 2nd: 41.4%<br>3rd: 58.6% | 3 | 8 | 2 | Not specified | - | JJ: Bladder irritability (n=8) | Pre-term labor after PCN (n=1); all other patients delivered at term without adverse fetal outcomes |
| Drescher et al. (2019) [3] | USA | Retrospective cohort study | 1115 | 1st T: 5%<br>2nd T: 30%<br>3rd T: 65% | 803 | | 312 | Not specified | - | UTIs: URS and/or JJ (n=70 / 8.7%), PCN (n=61 / 19.6%) | Pre-term labor (URS and/or JJ n=90 / 11.2%, PCN n=61 / 19.5%) |
| Dumitrache et al. (2013) [30] | Romania | Retrospective cohort study | 23 | 25.3 | 11 | 10 | 2 | Not specified | - | - | All patients delivered at term without adverse fetal outcomes |
| Elgamasy et al. (2009) [50] | Egypt | Case series | 15 | 25.9 | 0 | 15 | 0 | Not specified | - | Distal stent migration (n=1) | Pre-term labor (n=1)<br>All patients delivered at term without adverse fetal outcomes |
| Fathelbab et al. (2016) [40] | Egypt | Prospective cohort study | 41 | 1st T: 9.8%<br>2nd T: 56.1%<br>3rd T: 34.1% | 41 | 0 | 0 | Stone-free rate: 89.7% | Stone migration (n=3) | Dysuria and urgency (n=12), hematuria (n=5) | All patients delivered at term without adverse fetal outcomes |
| Georgescu et al. (2014) [31] | Romania | Retrospective cohort study | 54 | 1st T: 11.1%<br>2nd T: 59.3%<br>3rd T: 29.6% | 44 | 9 | 1 | Semirigid URS successful in 87.5%, improving to 93.75% with flexible URS. | Ureteric edema, minor laceration or bleeding (n=5); stone migration (n=2), stone not reached (n=2) | UTI (n=4), renal colic (n=2), prolonged hematuria (n=1), bladder irritability (n=4) | Uterine contractions (n=1); All patients delivered at term without adverse fetal outcomes |
| Haghpanah et al. (2018) [32] | Iran | Prospective cohort study | 23 | 1st T: 69.5% | 0 | 11 | 12 | Not specified | - | JJ: UTI (n=1), stent-related symptoms (n=4)<br>PCN: UTI (n=2)<br>No statistically significant differences | All patients delivered at term without adverse fetal outcomes |
| Haller et al. (1993) [33] | Croatia | Retrospective cohort study | 4 | >20 weeks: 90% | 0 | 3 | 1 | 1 PCN placement after failure of JJ insertion.<br>1 nephrectomy due to chronic pyelonephritis in an excluded kidney. | - | - | All patients delivered at term without adverse fetal outcomes |
| Hoscan et al. (2012) [10] | Turkey | Retrospective cohort study | 34 | 26 | 29 | 5 | 0 | Stone-free rate: 85.3% | Ureteric edema, minor ureteric laceration or bleeding (n=5); stone migration (n=3), stone not reached (n=2) | UTI (n=3); Bladder irritability (n=3) | Uterine contractions (n=1); all patients delivered at term without adverse fetal outcomes |
| Isen et al. (2012) [11] | Turkey | Retrospective cohort study | 12 | 23.8 | 8 | 3 | 1 | JJ was tried initially in 6 patients but was only successful in 50%. | - | - | All patients delivered at term without adverse fetal outcomes |

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| Jarrard et al. (1993) [41] | USA | Retrospective cohort study | 5 | 17.8 | 0 | 5 | 0 | 2 JJ exchanges after 10-12 weeks | - | Bladder irritability (n=2); UTI (n=1) | All patients delivered at term without adverse fetal outcomes |
| Johnson et al. (2012) [12] | USA | Retrospective cohort study | 39 | 24.7 | 39 | 0 | 0 | Stone-free rate: 86% | - | - | Pre-term labor (n=2), pre-term delivery (n=1) Obstetric complications 4.3% |
| Juan et al. (2007) [42] | Taiwan | Retrospective cohort study | 8 | 1st T: 11.1% 2nd T: 33.3% 3rd T: 55.5% | 3 | 4 | 1 | Failure of JJ insertion in 3 patients, then treated with URS. | - | - | All patients delivered at term without adverse fetal outcomes |
| Kavoussi et al. (1992) [51] | USA | Case series | 6 | 26.8 | 0 | 0 | 6 | Not specified | - | Fever and persistent pain (n=1) – submitted to a percutaneous nephrolithotomy; tube obstruction (n=4), asymptomatic bacteriuria (n=6) | All patients delivered at term without adverse fetal outcomes |
| Khoo et al. (2004) [48] | United Kingdom | Case series | 4 | Not specified | 0 | 0 | 4 | Not specified | - | Urosepsis (n=1), tube obstruction (n=1) | Pre-term delivery (n=1), all other patients delivered at term without adverse fetal outcomes |
| Lee et al. (1997) [13] | Korea | Retrospective cohort study | 4 | 1st T: 18.8% 2nd T: 62.5% 3rd T: 81.3% | 1 | 3 | 0 | Not specified | - | Incrustation (n=1) | All patients delivered at term without adverse fetal outcomes |
| Lemos et al. (2002) [14] | Brazil | Retrospective cohort study | 18 | 18 | 14 | 4 | 0 | All procedures were effective | - | - | All patients delivered at term without adverse fetal outcomes |
| Li et al. (2021) [15] | China | Retrospective cohort study | 101 | 26 | 101 | 0 | 0 | 26 patients without improvement in pain complaints | - | SIRS (n=11) | Regular contractions in the post-operative period (12h) (n=46) All patients delivered at term without adverse fetal outcomes |
| Lifshitz et al. (2002) [16] | Israel | Retrospective cohort study | 10 | 1st T: 10% 2nd T: 60% 3rd T: 30% | 7 | 3 | 0 | Not specified | - | - | All patients delivered at term without adverse fetal outcomes |
| Ngai et al. (2013) [17] | China | Prospective cohort study | 30 | 1st T: 17% 2nd T: 50% 3rd T: 33% | 0 | 30 | 0 | 100% successful insertion 67% with pain improvement 10% without symptom improvement 23% with symptom worsening | - | Distal stent migration needing surgery (n=3); stent incrustation (n=3, 10%); hematuria and lower urinary tract symptoms (n=5) | Not specified |
| Ordon et al. (2020) [2] | Canada | Population based matched retrospective cohort study | 755 | 1st T: 15.9% 2nd T: 48.5% 3rd T: 35.6% | 379 | 473 | 152 | Not specified | - | - | Pregnancies with a nephrostomy tube or stent had the largest magnitude of risk for an adverse birth outcome. |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| Polat et al. (2011) [43] | Turkey | Retrospective cohort study | 11 | 30 | 11 | 0 | 0 | Stone-free rate: 73% | - | - | No adverse fetal outcomes |
| Rana et al. (2009) [18] | Pakistan | Retrospective cohort study | 19 | 20 | 19 | 0 | 0 | Stone-free rate: 79% | Stone migration (n=3) | JJ incrustation (n=2) | No adverse fetal outcomes |
| Rashid et al. (2021) [44] | Iraq | Prospective cohort study | 26 | 28.38 | 26 | 0 | 0 | Flexible URS stone-free rate: 100%<br>Semirigid URS stone-free rate: 72.7%<br>URS with stone extraction - stone-free rate: 100% | Minor ureteric lesions only in semirigid URS and URS with stone extraction | Flexible URS: hematuria (n=5), stent-related symptoms (n=9), fever (n=3)<br>Semirigid URS: hematuria (n=7), stent-related symptoms (n=10), fever (n=3)<br>URS with stone extraction: hematuria (n=4), stent-related symptoms (n=3) | All patients delivered at term without adverse fetal outcomes |
| Rivera et al. (2014) [45] | USA | Retrospective cohort study | 26 | JJ: 36.5<br>URS: 37.8 | 11 | 15 | 0 | 6 patients needed multiple JJ stent exchanges | - | URS: 0 complications<br>JJ: multiple hospitalizations for pain management (n=1) | JJ: Induction of labor due to inability to tolerate the JJ stent (n=7) |
| Scarpa et al. (1996) [19] | Italy | Retrospective cohort study | 15 | Not specified | 15 | 0 | 0 | Not specified | - | - | All patients delivered at term without adverse fetal outcomes |
| Shirvan et al. (2013) [46] | Iran | Prospective cohort study | 44 | 24 | 44 | 0 | 0 | Stone-free rate: 91% | Stone migration (n=4) | - | All patients delivered at term without adverse fetal outcomes |
| Shokeir et al. (1998) [21] | Saudi Arabia | Retrospective cohort study | 10 | 24 | 10 | 0 | 0 | Not specified | - | UTI (n=2); dysuria (n=1) | All patients delivered at term without adverse fetal outcomes |
| Song et al. (2013) [47] | China | Retrospective cohort study | 54 | 26.5 | 21 | 17 | 16 | 18/21 successful URS (85.7%), 16/16 PCN successfully placed, 12/17 JJ successfully placed. | URS – stone migration (n=3) | URS: Bladder irritability (n=1), hematuria (n=2)<br>PCN: local cutaneous infection (n=2), pain and hematuria (n=1), tube obstruction (n=4)<br>JJ: incrustation (n=4), pain and bladder irritability (n=6), stent migration (n=1) | Pre-term labor (n=1) |
| Tan et al. (2018) [22] | China | Retrospective cohort study | 53 | JJ: 27.5<br>URS: 25.9 | 23 | 30 | 0 | Successful URS: 86.9%<br>Successful JJ insertion: 83.3% | URS: stone migration (n=1) | URS: Bladder irritability (n=1), hematuria (n=1)<br>JJ: Bladder irritability (n=2), JJ distal migration (n=1), incrustation (n=1) | All patients delivered at term without adverse fetal outcomes |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| Tawfiek (2009) [23] | Egypt | Prospective cohort study | 26 | 1st T: 11.5%<br>2nd T: 57.7%<br>3rd T: 30.8% | 26 | 0 | 0 | Successful URS in all patients | - | Dysuria/urgency (n=2), hematuria (n=2), UTI (n=1) | All patients delivered at term without adverse fetal outcomes |
| Travassos et al. (2009) [24] | Brazil | Retrospective cohort study | 10 | 19 | 9 | 1 | 0 | Not specified | - | - | All patients delivered at term without adverse fetal outcomes |
| Wang et al. (2014) [25] | China | Retrospective cohort study | 87 | 29 | 64 | 19 | 4 | 52/64 successful URS, 4/4 PCN successfully placed, 17/19 JJ successfully placed. | URS: ureteric laceration (n=1), bleeding (n=5), stone migration (n=9), unreachable stone (n=3) | JJ: stent replacement (n=4), UTI (n=4), bladder irritation (n=12), hematuria (n=7) | URS: premature uterine contractions with threatened abortion (n=1)<br>All patients delivered at term without adverse fetal outcomes |
| Watterson (2003) [26] | Canada | Retrospective cohort study | 14 | 22 | 10 | 2 | 2 | URS stone-free rate: 89%<br>Successful removal of 2/2 incrusted JJ stents | - | - | All patients delivered at term without adverse fetal outcomes |
| Zhang et al. (2016) [27] | China | Retrospective cohort study | 117 | Not specified | 117 | 0 | 0 | - | Stone migration (n=13) | Urosepsis (n=1), lower urinary tract symptoms (n=21), fever (n=5), hematuria (n=116), leukocyturia (n=37), positive urine culture (n=13) | Unconfirmed abortion suspicion (n=12)<br>All patients delivered at term without adverse fetal outcomes |

*JJ: Ureteral double-J stent; PCN: Percutaneous nephrostomy; URS: Ureteroscopy; USA: United States of America; UTI: Urinary Tract Infection.*

Regarding the study design, we included 41 cohort studies (2, 3, 9-47) and 4 cases series (48-51). Five (11.1%) of the cohort studies analyzed had a prospective design (17, 32, 35, 40, 44). There were no randomized controlled trials.
A total of 3424 interventions in pregnant patients were evaluated. The studies reported a mean age varying from 22 to 30, with a total age range between 16 and 42. The second trimester was the most common timing of presentation and treatment of renal colic. Gestational age range varied from 8 to 38 weeks (8, 10,11, 15, 18, 19, 21, 24, 25, 27, 31, 34, 36, 38, 43, 44, 50, 51), and 24 studies reported treatment in the three trimesters (2, 3, 9, 11-13, 16, 17, 20, 22, 23, 25-27, 31, 32, 36, 40-42, 44, 46, 47, 51).

## Results of included studies

### *Type of treatment*

Ureteroscopy was performed in all studies when there were indications for interventional treatment and no indications for temporary drainage (fever, large stone burden, complex anatomy, bilateral stone disease, obstetric complications, presentation in the first trimester or near full-term) were present.
A total of 2188 ureteroscopies were performed. Most studies included only semirigid ureteroscopies, but flexible ureteroscopy was also used in 9 studies (12, 16, 20, 26, 27, 29, 31, 44, 45).
Stone management was either with lithotripsy (pneumatic or laser) (10, 11, 18, 20, 22, 25, 27, 28, 36, 42-44, 47,52), with stone extraction with baskets or forceps (16, 24, 45, 49) or using both approaches in different patients (9, 14, 15, 19, 21, 23, 29, 31, 34, 35, 37, 38, 40, 46). Five studies, with a total of 1233 ureteroscopies, did not specify the stone management technique used during the procedure (2, 3, 12, 13, 30).
Seventeen studies reported double-J stenting at the end of the procedure when needed (9, 11, 19-23, 25, 27-29, 31, 35, 37, 38, 40, 47).
Temporary drainage was reported in every study when the indications mentioned before were present, fever being the most common trigger. A total of 719 double-J stents were inserted and 517 percutaneous nephrostomy tubes were placed.

### *Perioperative complications*

Sixteen articles reported perioperative complications (2, 10, 15, 18, 22, 25, 27, 28, 31, 35-38, 40, 44, 47).
Concerning ureteroscopies, *Bozkurt et al.* found no statistically significant differences between pregnant and non-pregnant women (38). The other articles reported the complications without comparing groups. Most studies reported minor ureteral injuries including edema, small lacerations or perforations, or bleeding, in a total of 33 events (10, 25, 31, 35-37, 44). Only *Rashid et al.* used the Satava Classification (52) and reported 5 intraoperative G1 ureteral injuries in semirigid ureteroscopy (44). Stone migration during ureteroscopy happened 64 times (18, 22, 25, 27, 28, 30, 31, 36, 40, 46, 47) and the stone could not be reached in 9 cases (10, 25, 31, 36).
Specific perioperative complications for JJ and PCN were not reported. Among 19 articles with 138 double-J stent insertions (2, 3, 11, 13, 14, 16, 17, 24, 26, 29, 30, 32-34, 39, 42, 45, 49, 50), and 11 articles with 344 PCN (3, 11, 26, 30-33, 39, 48, 49, 51), no perioperative complications were reported.
Perioperative complications were not specified at all in 2 articles (2, 15).

***Postoperative complications***

Postoperative complications were compared between the different procedures in 4 studies (3, 32, 36, 47). *Song et al.* reported that the double-J stent group had the highest rate of complications (52.9%) compared to the ureteroscopy and percutaneous nephrostomy groups but without a statistically significant difference (47). One retrospective cohort revealed no significant difference in complications between primary ureteroscopy and ureteral stent placement; while moderate or severe *lower urinary tract symptoms* (LUTS) were significantly lower in the ureteroscopy group, flank pain was not (36). No difference between ureteral stent and percutaneous nephrostomy complications was also noted in a prospective study (32). Regarding *urinary tract infections* (UTIs), *Drescher et al.* presented an infection rate of 8.7% in patients treated with ureteroscopy and/or ureteral stent placement and 19.6% in patients who received percutaneous nephrostomies (3).

In a retrospective cohort, ureteroscopy complications were compared between 41 pregnant patients with 62 non-pregnant women who also underwent surgery, revealing no higher complication rate in the pregnant population (38).

Concerning complications related to each procedure type, in patients submitted to URS, 97 UTIs were reported in 12 articles (3, 9, 10, 21-23, 25, 31, 35, 36, 38), and urosepsis was diagnosed 13 times (15, 36, 37). Irritative lower urinary tract symptoms such as dysuria, pain, bladder irritability, and urgency were observed 45 times in 6 studies (29, 31, 35, 38, 40, 49). Colicky pain was reported in 5 patients (20, 31, 45), and hematuria was observed 10 times (23, 31, 40, 47). Eleven studies did not observe any ureteroscopy postoperative complications (11, 12, 14, 16, 19, 24, 26, 30, 34, 42, 46).

The most frequently reported postoperative complication associated with ureteral stents was bladder irritability. This complication was observed 28 times (8, 10, 22, 25, 47, 49), and *Rivera et al.* reported one case of multiple hospitalizations for pain control (45). Other complications related to ureteral stents were stent encrustation or migration, documented 16 times (17, 22, 25, 47, 50, 53). *Rivera et al.* reported that 6 patients required multiple stent exchanges (45). 7 urinary tract infections were reported in 3 studies (22, 25, 32) and LUTS and hematuria were observed 13 times (17, 25, 29). No postoperative complications associated with ureteral stent insertion were reported in 10 studies (11, 14, 16, 24, 26, 30, 33, 34, 39, 42).

In reference to PCN complications, 10 nephrostomy tube obstructions were described,47,48,51 some requiring tube exchanges. There were 2 cases of localized skin infections (47), 61 cases of UTI,3 and 1 case of sepsis after PCN placement (48). Persistent pain was reported in 2 articles (47, 51). No complications were observed after PCN on 6 articles (11, 26, 30, 33, 39, 42).

***Obstetric complications***

All studies followed the pregnancies until term. Obstetric outcomes were evaluated and managed by obstetricians.

Twenty-three articles did not mention any adverse obstetric outcome (8, 10, 11, 14, 16, 18, 20, 23, 24, 26, 29-34, 37-40, 42, 44, 51) and all patients from these studies delivered at term without adverse fetal outcomes. Furthermore, *Shirvan et al.* followed the children up to the age of 5 with no evidence of mental or physical development alterations (46).

The most frequent obstetric complications reported were preterm uterine contractions and preterm labor. Premature uterine contractions were reported 52 times in 6 studies: 50/288 (17.4%) ureteroscopies and 2/62 (3.2%) double-J insertion (9, 10, 15, 25, 31, 36). One retrospective study focused specifically on this topic, and while reporting the largest frequency of uterine contractions during the first 12 hours after ureteroscopy (45.54%), there were no severe maternal or fetal complications or premature deliveries. The authors propose some measures to reduce the odds of uterine contractions: shorten the surgical time, use phloroglucinol after the procedure, treat pain and infection, and monitor the multiparas more closely, as they seem to have a higher risk of contractions (15).

The selected articles reported a total of 167 cases of preterm labor and 24 premature deliveries (3, 12, 28, 36, 47-50). A population-based retrospective cohort observed that when compared to conservative management, ureteral stent/ureteroscopy patients had higher rates (n = 90, 11.2%) of preterm labor while percutaneous nephrostomy patients had the highest rate (n = 61, 19-5%). Urologic intervention with ureteral stent and/or ureteroscopy, and PCN each independently increased the risk of preterm delivery (3). *Ordon et al.* further concluded that stone disease during pregnancy significantly increased the risk of an adverse birth outcome. The risk was higher if the stones required intervention, compared with conservative treatment, and temporary drainage (nephrostomy tubes or stents) had the largest magnitude of risk for an adverse birth outcome (2). Another cohort study documented 7 cases of induction of labor before term due to stent intolerability, concluding that patients who were treated with temporary stents were significantly more likely to be induced before spontaneous labor when compared with ureteroscopy patients (45). Contradicting this evidence, *Bayar et al.* compared the number of preterm births between ureteroscopy (n = 15, 36%) and double-J stent insertion (n = 7, 24%), reporting no significant differences between them (36).

There was only one case of in-utero fetal mortality one week after a double-j stent was placed but it was not due to urological reasons (36).

Obstetric outcomes were not mentioned in 2 articles (17, 43).

***Procedure efficacy***

Stone-free rate of URS was between 73% and 100% (9, 10, 12, 18, 23, 26, 29, 31, 34, 36, 40, 43, 44, 46). One study that compared URS stone-free rates between pregnant and non-pregnant women showed no statistically significant differences (38). However successful, a study with 101 ureteroscopies performed reported that 26 patients showed incomplete pain relief immediately after URS, but improved with painkillers in the following 12h (15). Only 3 studies reported unsuccessful ureteroscopies, mainly due to ureteral stenosis or stone migration, in 13-19% of the cases (22, 25, 47).

Most temporary drainage procedures were successful. There were no reported failures in nephrostomy tube placement. In regard to ureteral stents, placement failure

occurred at varying rates (12-75%), requiring drainage with PCN or ureteroscopy (11, 25, 33, 42, 47). In one study with 30 double-J stents successfully placed, 67% of the patients had a clinical improvement in pain relief immediately and soon after surgery, but 10% reported no difference and 23% had a worsening of symptoms, with either an increased analgesic requirement or the development of new symptoms related to stent placement (17).
Procedure efficacy was not mentioned in 17 studies (2, 3, 13, 16, 19-21, 24, 27, 28, 30, 32, 35, 37, 48, 50, 51).

***Radiation exposure***
Pre-operative imaging was mainly acquired with ultrasound. MRI was used in selected cases with questionable ultrasound (12, 14, 25, 34, 47). Plain x-ray, intravenous urography and computed tomography was rarely used (12, 16, 18, 26, 33, 41, 51). Most surgical procedures were performed under direct vision and ultrasound guidance; intra-operative fluoroscopy was reported in 8 studies (12, 14, 16, 26, 29, 45, 48, 49). Radiation doses were inconsistently reported.

## Discussion

Ureteroscopy was the most reported procedure, totaling 2188 interventions. Temporary drainage procedures amounted to 1236 interventions. Procedures were not specified by trimester, but most were performed in the second and third trimesters. URS was performed in all trimesters, and 2 studies used flexible ureteroscopes only in the third trimester (27, 31). *Song et al.* suggested that double-J stents should be preferentially placed in third trimester pregnant patients, due to the frequent need for replacement after 4-6 weeks (47). *Densted et al.* recommended PCN placement before 22 weeks of gestation, and JJ subsequently (49). Conversely, there are descriptions of JJ placement in the first trimester without adverse outcomes (17, 32, 36, 41).
Most procedures did not cause any type of perioperative or postoperative complications.
When perioperative complications occurred, they were minor, like minimal ureteral injuries during ureteroscopy. A total of 106 perioperative complications were documented out of 2188 ureteroscopies performed (overall rate of 4.84%); the most common were stone migration, ureteral injury, and bleeding. The only comparative study between ureteroscopy in pregnant and non-pregnant women did not report significant differences (38). It is noteworthy that only one article used the Satava Classification for ureteral injury (44). This classification enables the classification of ureteral injuries and could be an important tool for standardizing such complications. Standardization is important when comparing the results of different studies, which would have been of value to this review. Specific perioperative complications for JJ and PCN were not reported.
Postoperative complications were also mostly minor. There were few comparative studies: two did not report statistically significant differences in postoperative complications between procedures (32, 47), but *Bayar et al.* described a lower rate of moderate or severe LUTS in URS (with double-J stent insertion when needed) than in those treated only with JJ insertion (36), and one study revealed a higher rate of UTI with nephrostomies (3).
Studies have described that the most common postoperative complications after ureteroscopy are fever, UTI, and bleeding, after double-J stent insertion are stent-related discomfort, infection, and encrustation and after percutaneous nephrostomy are sepsis, local bleeding, and tube obstruction (53). The same conclusions could be assessed by this review.
The overall documented complication rate for URS was 7.7%. The most frequent complications were lower urinary symptoms and urinary infections, with 13 cases of urosepsis (0.5%). According to a worldwide multicenter study that analyzed peri and postoperative complications associated with ureteroscopy, the most common perioperative complications were bleeding, perforation, and failed access and it happened in 4.2% of cases (53). This study represented a non-pregnant population, so the evidence presented in our systematic review shows a marginally higher rate of complications in pregnant patients.
Ureteral stenting complications were bladder irritability in most patients, encrustation, and stent migration, in a total of 8.2% complications. PCN had the highest rate of complications (14.8%), and they were fever, bacteriuria, tube obstruction, and hematuria.
Regarding obstetric complications, premature contractions were mostly reported for ureteroscopies. The rate of reported preterm labor was 4.8%, with 0.7% premature births considering all procedures. A comparative study showed no statistically significant differences in preterm labors between URS and JJ patients (36), while another reported a higher rate of preterm induction of labor in JJ patients due to catheter intolerability (45). Two studies reported that percutaneous nephrostomy had the highest rate of adverse birth outcomes (2, 3).
In terms of procedure efficacy, the mentioned stone-free rate varied from 73% to 100%, with no differences between pregnant and no pregnant women (38). Ureteral dilation in pregnancy helps the insertion of the ureteroscopes, enhancing the success of this procedure (47). Besides primary URS decision, URS was also the procedure of choice when temporary drainage failed.
Radiation exposure is a concern during pregnancy. Consequently, ultrasound was the most used pre-operative and intra-operative imaging modality. However, fluoroscopy was still used in some studies (12, 14, 16, 26, 29, 45, 48, 49) with descriptions of low dose settings, protection equipment and pulsed imaging to reduce exposure.
The validity of this systematic review depends largely on the quality of the available evidence.
We included predominantly retrospective case series and cohort studies, typically conducted in single-center settings without a comparative design, which results in an absence of high-quality study designs. The lack of explicitly defined exclusion criteria in several studies raises the possibility of selection bias. Additionally, samples were chosen by convenience, which compromises the external validity of the results.
Noteworthy limitations within this review encompass heterogeneity in both sample characteristics and outcome measurement. Variability in sample sizes across studies introduces a notable source of potential bias, influencing the generalizability of conclusions. Furthermore, the absence of standardization in outcome measurement, with divergent approaches to measuring the same outcome

across studies, hinders the comparability and correlation of reported results.
In conclusion, there is a lack of well-designed high-quality studies on the effect of stone surgical treatments in the pregnant population. Future studies should consider the inclusion of larger sample sizes, multiple centers, and randomized patient assignment to ensure homogeneous sample characteristics. Despite these limitations, this systematic review summarizes the available evidence on a challenging topic, hence its value.

## Conclusions

Invasive treatment may be required for the treatment of urolithiasis during pregnancy, so it is important to assess which procedures are suitable for this population. Based on the findings of this systematic review, ureteroscopy, double-J stent insertion, and percutaneous nephrostomy are safe and effective treatment options in this setting, with minor complications and no severe adverse obstetric or fetal outcomes. Since all three procedures are considered safe, primary ureteroscopy should be considered as the first-line procedure whenever feasible, minimizing the need for subsequent interventions, as opposed to temporary drainage. However, individual patient assessment in a multidisciplinary discussion is crucial to identify cases where temporary drainage remains the appropriate treatment approach. In these cases, the trimester of presentation might influence the option used, as early placement of double-J stents might warrant their exchange during pregnancy.

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