Clinical Investigation / Araştırma

DOI: 10.4274/tjod.galenos.2026.32784

Turk J Obstet Gynecol 2026;23(1):40-46

Role of postoperative renal ultrasound in identifying ureteral injury despite normal intraoperative jet flow

Normal intraoperatif jet akımına rağmen üreter yaralanmasının saptanmasında postoperatif renal ultrasonun rolü

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Abstract

Objective: This study evaluated the diagnostic utility of early postoperative renal ultrasound in detecting ureteral injury in patients who had undergone total laparoscopic hysterectomy (TLH) for benign indications, despite documented normal intraoperative ureteral jet flow on cystoscopy.

Materials and Methods: In this retrospective cohort study at a high-volume tertiary center, data from 3,170 patients who underwent TLH between January 2022 and October 2025 were analyzed. Inclusion required normal bilateral ureteral jet flow on routine intraoperative cystoscopy, a renal ultrasound within the first 24 postoperative hours, and at least 30 days of clinical follow-up. The primary outcome was the diagnostic yield of postoperative ultrasound for identifying ureteral injuries not apparent during surgery. Injuries were confirmed by advanced imaging or surgical exploration.

Results: The overall ureteral injury rate was 0.79% (n=25). Of these injuries, eight were diagnosed intraoperatively, while seventeen occurred despite documented normal bilateral ureteral jet flow during the procedure. Among the latter group, renal ultrasonography performed on postoperative day 1 detected 14 injuries, representing 56% of all injuries. Three injuries (12%) presented later, around postoperative day 10, and were not identified on initial imaging. Early postoperative ultrasonography demonstrated good sensitivity and a high negative predictive value as a screening tool. Comparison with preoperative baseline imaging enhanced diagnostic performance in identifying new-onset obstruction, particularly newly developed pelviectasis.

Conclusion: Normal intraoperative ureteral jet flow does not preclude ureteral injury, particularly those with delayed presentation, such as thermal damage. Early postoperative renal ultrasonography is a valuable non-invasive screening tool that identifies a significant proportion of injuries missed by cystoscopy alone. Comparative evaluation of routine postoperative ultrasonography with preoperative imaging may provide a meaningful contribution to the early diagnosis of ureteral injury following TLH.

Keywords: Ureteral injury, renal ultrasound, laparoscopic hysterectomy

Öz

Amaç: Bu çalışma, benign endikasyonlarla total laparoskopik histerektomi (TLH) uygulanan ve intraoperatif sistoskopide normal üreteral jet akımı izlenen hastalarda, erken postoperatif dönemde yapılan renal ultrasonografinin üreter yaralanmasını saptamadaki tanısal değerini değerlendirmeyi amaçlamıştır.

Gereç ve Yöntemler: Yüksek hacimli üçüncü basamak bir merkezde yürütülen bu retrospektif kohort çalışmasında, Ocak 2022-Ekim 2025 tarihleri arasında TLH uygulanan 3.170 hastanın verileri incelendi. Çalışmaya dahil edilme kriterleri; intraoperatif sistoskopide bilateral normal üreteral

PRECIS: In patients with normal intraoperative ureteral jet flow after total laparoscopic hysterectomy, early postoperative renal ultrasonography may contribute to the detection of some ureteral injuries and can be considered an adjunctive screening tool.

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Received/Geliş Tarihi: 05.12.2025 **Accepted/Kabul Tarihi:** 05.02.2026 **Epub:** 17.02.2026 **Publication Date/Yayınlanma Tarihi:** 05.03.2026

Cite this article as: Kantarcı S, Karabulut A, Dağlı U, Özer PT, Yıldırım F, İleri A, et al. Role of postoperative renal ultrasound in identifying ureteral injury despite normal intraoperative jet flow. Turk J Obstet Gynecol. 2026;23(1):40-46

jet akımının doğrulanması, ilk 24 saat içinde renal ultrasonografi yapılması ve en az 30 günlük klinik takip bulunmasıydı. Birincil sonuç ölçütü, intraoperatif dönemde fark edilmeyen üreter yaralanmalarının postoperatif ultrason ile tanımlanma oranıydı. Yaralanmalar ileri görüntüleme yöntemleri veya cerrahi eksplorasyon ile doğrulandı.

Bulgular: Genel üreter yaralanması insidansı %0,79 (n=25) olup tüm yaralanmalar normal intraoperatif jet akımına rağmen meydana geldi. Postoperatif 1. gün renal ultrasonografi, yaralanmaların %56'sını (n=14) saptadı. Üç yaralanma (%12) postoperatif 10. gün civarında semptomatik hale geldi ve ilk görüntülemede görülmedi. Ultrason performans analizi, erken tarama için yüksek duyarlılık ve negatif prediktif değer gösterdi. Tanısal doğruluk, ultrason bulgularının preoperatif görüntüleme ile karşılaştırılarak yeni başlangıçlı obstrüktif hidronefroz şeklinde yorumlandığı durumlarda en yüksek seviyeye ulaştı; bu yaklaşım mükemmel özgüllük ve pozitif prediktif değer sağladı.

Sonuç: Normal intraoperatif üreteral jet akımı, özellikle gecikmiş termal hasar gibi durumlarda üreter yaralanmasını dışlamamaktadır. Erken postoperatif renal ultrasonografi, sistoskopinin saptayamadığı yaralanmaların önemli bir bölümünü ortaya koyan değerli ve non-invaziv bir tarama aracıdır. Rutin postoperatif ultrasonografinin, preoperatif görüntüleme ile karşılaştırmalı olarak değerlendirilmesi, TLH sonrası üreter hasarının erken tanısına anlamlı katkı sağlayabilir.

Anahtar Kelimeler: Üreter yaralanması, renal ultrason, laparoskopik histerektomi

Introduction

Ureteral injury remains one of the most significant yet relatively uncommon complications of gynecologic surgery. Despite advances in minimally invasive techniques, large contemporary studies report postoperative ureteral injury rates of approximately 0.4-0.8% for benign hysterectomy[1]. The anatomical complexity of the pelvic course of the ureter, the distortion of pelvic structures due to conditions like endometriosis or benign pelvic pathologies, and the widespread use of energy-based surgical instruments are the main factors that increase the risk of ureteral injury during hysterectomy[2]. Iatrogenic ureteral injury can occur in many different settings. Colorectal and abdominal vascular surgeries are known to place the ureters at risk of injury. Most iatrogenic ureteral injuries (52-82%) occur during gynecological procedures[3]. These observations emphasise the need for reliable strategies for early detection in routine surgical practice.

Multiple mechanisms contribute to ureteral injury during laparoscopic hysterectomy. In addition to direct trauma such as suturing, clamping, or devascularization, delayed thermal injury caused by lateral heat spread from energy devices poses a substantial risk. The extent of thermal spread varies with device type, energy settings, applied tissue tension, and duration of activation, and may lead to delayed obstruction, ischemia, or fistula formation, even when intraoperative findings appear normal[4,5]. Because thermal injuries may be clinically silent at the time of surgery, intraoperative detection remains challenging.

Intraoperative cystoscopy has been widely advocated as a means to identify occult injuries by assessing bilateral ureteral jet flow. While the visualization of normal jet flow is reassuring, evidence shows that it does not completely exclude the possibility of ureteral injury, particularly those caused by delayed thermal or ischemic mechanisms[6]. Although proponents of universal cystoscopy highlight its low risk, low cost, and increased detection rates, others favor selective use based on the low overall prevalence of injury and additional operative time required, leaving the debate unresolved[7].

Furthermore, meticulous evaluation of preoperative findings, such as renal pelvic ectasia, minimal hydronephrosis, or borderline pelvicalyceal dilation, is crucial. Accurate documentation of these baseline conditions allows clinicians to differentiate preexisting abnormalities from newly developed postoperative changes. This distinction prevents misinterpretation of mild preoperative dilation as postoperative ureteral injury, improves diagnostic accuracy, and provides medicolegal protection by demonstrating thorough perioperative assessment.

This study aims to evaluate the effectiveness of early postoperative renal ultrasonography in identifying ureteral injuries that occur despite normal intraoperative ureteral jet flow, and to determine whether routine early ultrasonographic screening can enhance early detection and improve clinical outcomes in this setting.

Materials and Methods

This retrospective cohort study, conducted at a high-volume tertiary referral center, evaluated data from 3,170 patients who underwent total laparoscopic hysterectomy (TLH) for benign gynecologic indications between January 2022 and October 2025. Institutional review board approval was obtained prior to study initiation (University of Health Sciences Türkiye, İzmir Tepecik Education and Research Hospital Non-Interventional Ethics Committee, decision no: 2025/10-13, date: 03.11.2025).

The primary analytic cohort was constructed by excluding the eight patients in whom ureteral injury was diagnosed intraoperatively from 25 patients with identified ureteral injuries, and by including only those in whom intraoperative cystoscopy demonstrated normal bilateral ureteral jet flow. Eligibility criteria required postoperative renal ultrasonography to be performed within the first 24 hours and at least 30 days of postoperative clinical follow-up. Preoperative urinary symptoms or ultrasonographic

abnormalities were not considered exclusion criteria, in order to better reflect real-world surgical practice.

All procedures were performed by an experienced minimally invasive gynecologic surgery team using a standardized TLH technique. Routine intraoperative cystoscopy was performed at the end of each operation, and bilateral ureteral jet flow was visually assessed and documented. Recognizing that normal jet flow does not exclude ureteral injury—particularly injuries related to thermal or ischemic mechanisms—all patients underwent postoperative gynecologic ultrasonographic evaluation, during which the renal pelvis and calyces were routinely examined; however, no separate or standardized renal ultrasonography protocol was applied. This targeted ultrasonographic assessment was used as an early screening tool to detect renal pelvic dilatation, new-onset pelvicalyceal enlargement (pelviectasis), or perirenal fluid collections. Patients with suspicious findings were referred for a urology consultation and further imaging, including contrast-enhanced computed tomography urography or retrograde pyelography. Ureteral injury was confirmed based on radiologic findings or direct intraoperative visualization.

Demographic characteristics (body mass index, parity, comorbidities) and perioperative variables (surgical indication, operative time, estimated blood loss, surgeon experience, and length of hospital stay) were recorded. Intraoperative cystoscopic observations, jet symmetry, and any deviations or complications were documented. Postoperative ultrasonographic assessments included hydronephrosis grade, pelvicalyceal system dilation, loss of jet flow, and perirenal fluid collections. For patients in whom ureteral injury was confirmed, the type of injury (suture or clip entrapment, kinking, laceration, thermal/ischemic damage) and the management approach [Double-J (DJ) stenting, ureterolysis, ureteroneocystostomy (UNC), reoperation, percutaneous nephrostomy, or conservative follow-up] were systematically recorded. A predefined subgroup analysis was performed in patients with normal bilateral intraoperative jet flow who were diagnosed with ureteral injury within 30 days postoperatively. Confirmation of injury required evidence of obstruction or contrast extravasation on computed tomography urography or retrograde pyelography; direct visualization of thermal or mechanical trauma during reoperation; or the need for therapeutic interventions such as DJ stenting or reconstructive ureteral surgery. Exclusion criteria included gynecologic malignancy; prior major urologic surgery (such as UNC, nephrectomy, renal transplantation, or extensive pelvic ureteral reconstruction); chronic kidney disease stage ≥3; concurrent intraoperative urologic or colorectal procedures; or incomplete cystoscopy, postoperative imaging, or follow-up records.

The primary outcome of the study was the diagnostic rate of postoperative renal ultrasonography in identifying ureteral injuries among patients with normal intraoperative jet flow. Secondary outcomes included the overall incidence of ureteral injury, timing of diagnosis, proportion of asymptomatic cases, frequency of delayed injury despite preserved jet flow, management strategies, early postoperative complications, and length of hospital stay.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY, USA). Normally distributed continuous variables were expressed as mean ± standard deviation, while non-normally distributed variables were reported as median (minimum-maximum). Categorical variables were presented as numbers and percentages. Group comparisons were performed using the Student's t-test or the Mann-Whitney U test, as appropriate. For comparisons involving more than two groups, one-way ANOVA or Kruskal-Wallis tests were applied, followed by post-hoc procedures when significant differences were observed. Categorical variables were analyzed using the chi-square test or Fisher's exact test when indicated. A two-sided p-value of <0.05 was considered statistically significant.

Results

Among the 3,170 adult patients evaluated, approximately 5% (n=158) had incidental ultrasonographic findings documented on preoperative imaging that were unrelated to ureteral trauma and did not cause obstruction. On postoperative ultrasonographic assessments, these findings were interpreted not as newly developed pathology but as consistent with preoperative baseline imaging. The most common incidental findings included simple cortical renal cysts, mild non-obstructive pelviectasis, small asymptomatic renal calculi, and subtle increases in renal parenchymal echogenicity.

During the study period, a total of 3,170 TLH were performed, and 25 ureteral injuries were identified, corresponding to an overall incidence of 0.79%. Among these injuries, 8 were diagnosed intraoperatively, whereas the remaining 17 were identified postoperatively despite documented normal bilateral intraoperative ureteral jet flow. Of these injuries, 14 cases (56%) were diagnosed on postoperative day 1, 8 cases (32%) were detected intraoperatively, and 3 cases (12%) represented delayed presentations. Early postoperative ureteroscopy revealed suture-related obstruction, stricture, or kinking in 8 patients, all were successfully treated with DJ stenting followed by elective removal at 3 months; in 3 patients, complete ureteral defects requiring early UNC were observed; and in 3 patients, severe edema or complex injury was initially managed with percutaneous nephrostomy and subsequently treated with delayed UNC at 3 months. Intraoperative injuries included five primary ureteral repairs with DJ stenting, one UNC, and two cases with undocumented repair details. Three late-presenting injuries occurred despite

normal day 1 ultrasonography and manifested around postoperative day 10 with fever, flank pain, or vaginal urinary leakage. Imaging demonstrated subcapsular urine collections, and all injuries were ultimately attributed to thermal injury with delayed tissue necrosis. Treatment information for these delayed cases was not fully documented. Notably, postoperative day 1 renal ultrasonography enabled detection of 14 injuries that occurred despite preserved intraoperative jet flow, highlighting its value as a complementary early screening tool (Figure 1).

Postoperative day 1 renal ultrasonography demonstrated a high negative predictive value (NPV) for ruling out ureteral injury in patients with normal intraoperative ureteral jet flow. Among the 3,162 patients evaluated (after excluding 8 cases diagnosed intraoperatively), hydronephrosis detected on day-1 ultrasound correctly identified 14 ureteral injuries. In 158 cases, ultrasonographic findings represented incidental, non-obstructive findings unrelated to ureteral trauma, while 2,987 patients without hydronephrosis showed no evidence of injury during the follow-up period. Three injuries were not detected on day 1 imaging and subsequently presented as delayed thermal injuries approximately postoperative day 10. Based on these findings, day-1 renal ultrasound yielded a sensitivity of 82.4%, a specificity of 95.0%, a positive predictive value (PPV) of 8.1%, and a NPV of 99.9%, confirming its value as an early screening tool despite preserved intraoperative jet flow (Table 1).

When all hydronephrosis findings were considered (Scenario A), diagnostic performance mirrored these results; however, restricting the analysis to new-onset obstructive hydronephrosis confirmed by comparison with preoperative ultrasonography (Scenario B) markedly improved accuracy. All 14 ureteral injuries exhibited new-onset obstruction with no false-positive cases, resulting in 100% specificity and 100% PPV, while the NPV remained high at 99.9%. Collectively, these findings indicate that although any hydronephrosis on day 1 ultrasound provides excellent sensitivity and NPV, new-onset obstructive hydronephrosis offers the highest diagnostic accuracy and clearly distinguishes true ureteral injuries from incidental or preexisting renal findings (Table 2).

Discussion

Although rare, ureteral injuries remain a clinically significant concern following benign gynecologic hysterectomy because diagnostic delays can lead to serious complications such as

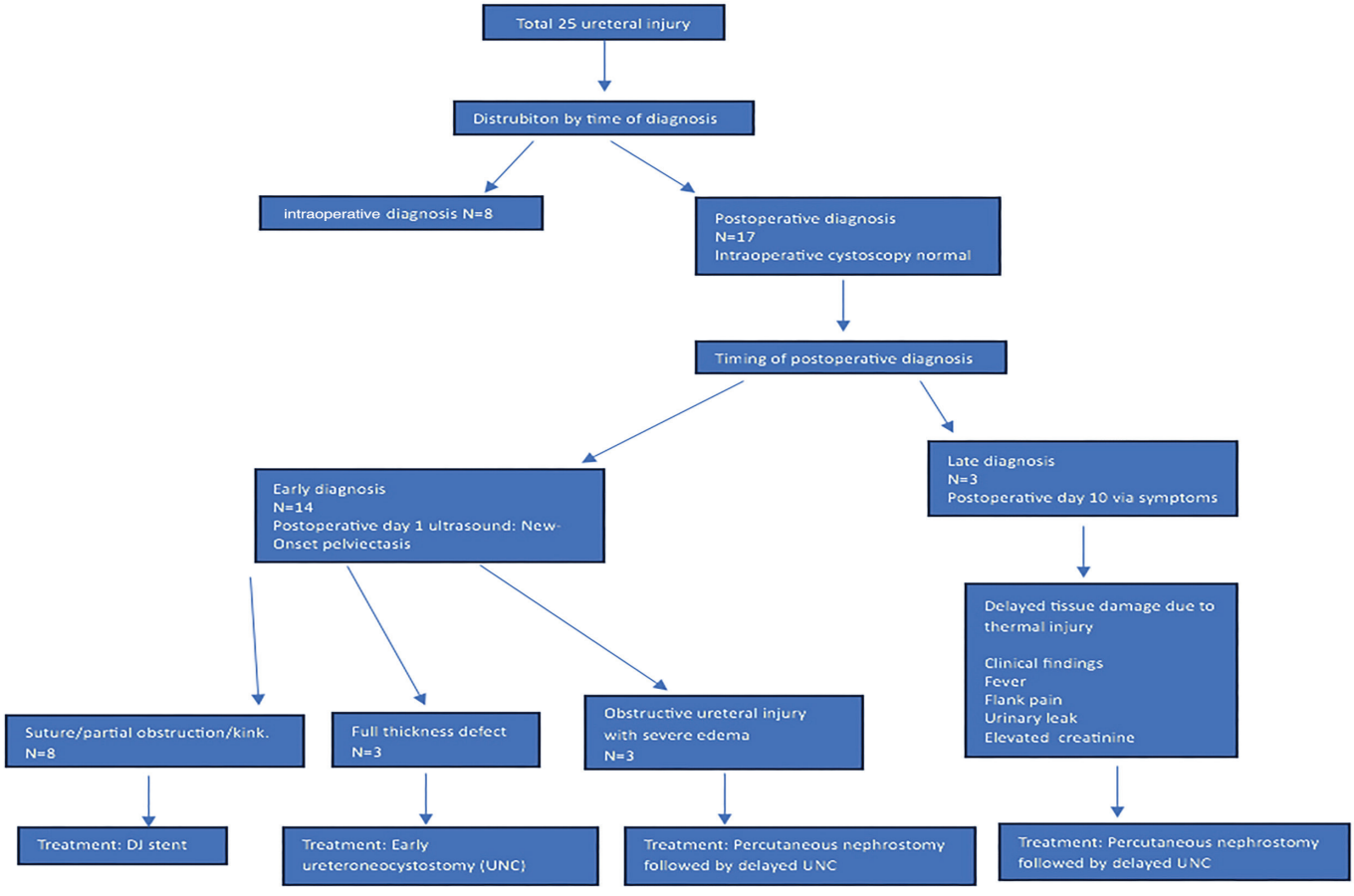

Figure 1. Management algorithm for iatrogenic ureteral injuries

Table 1. Day-1 renal ultrasound for early detection of ureteral injury

Day-1 renal ultrasound	Ureteral injury (+)	Ureteral injury (–)
Hydronephrosis (+)	14 (true positives)	158 (incidental findings)
Hydronephrosis (–)	3 (missed delayed thermal injuries)	2987 (true negatives)

Note: Eight patients diagnosed intraoperatively were excluded from the total cohort (n=3,170), as they did not require further postoperative screening for injury detection

Table 2. Renal ultrasound performance metrics in early ureteral injury detection

Day-1 renal ultrasound	Ureteral injury (+)	Ureteral injury (–)	Sensitivity	Specificity	PPV	NPV
A. All hydronephrosis findings (reflecting common clinical practice)	14	158	82.4%	95.0%	8.1%	99.9%
B. Only new-onset obstructive hydronephrosis (compared with preoperative USG)	14	0	82.4%	100%	100%	99.9%

PPV: Positive predictive value, NPV: Negative predictive value, USG: Ultrasonography

obstructive nephropathy, urinoma, infection, sepsis, and permanent loss of renal function[8,9]. Although intraoperative cystoscopy and jet flow evaluation are useful for detecting mechanical injuries, studies have shown that normal jet flow can be preserved in a significant proportion of delayed thermal or ischemic injuries, particularly those associated with energy devices[10]. Therefore, intraoperative evaluation alone cannot completely rule out an injury, and additional imaging strategies in the early postoperative period may provide diagnostic value. Our study aims to demonstrate the contribution of renal ultrasonography, performed within the first 24 hours postoperatively, to the early diagnosis of ureteral injuries in patients with normal intraoperative jet flow and to evaluate the impact of early screening on clinical outcomes. The non-invasive, widely accessible, and low-cost nature of ultrasonography renders its feasibility as a systematic screening tool in the early period clinically important. Early postoperative ultrasonographic evaluation enhances patient safety following benign total TLH, even when intraoperative jet-flow findings are within normal limits. Accordingly, it is hypothesized that early ultrasonography offers significant diagnostic value in detecting postoperative complications, thereby justifying its routine use regardless of intraoperative assessments.

Intraoperative cystoscopy with ureteral jet evaluation remains a valuable tool for identifying mechanical ureteral injuries; however, its limitations become apparent in the context of energy device-related thermal damage, where preserved ureteral perfusion can yield normal jet flow despite underlying injury[11]. Our findings confirm that normal ureteral jet flow during cystoscopy does not definitively exclude ureteral compromise. While complete transections are often recognized intraoperatively, partial injuries such as thermal damage, kinking, or ischemic lesions may not disrupt jet flow because of partial lumen patency, thereby delaying diagnosis[12]. The absence of jet flow is a significant indicator of injury; however, its presence does not entirely exclude injury[13]. The pathophysiology of energy-induced thermal injury involves progressive tissue necrosis, often with preservation of initial mucosal integrity and ureteral perfusion. This preservation explains why jet flow may appear normal initially, with clinical manifestations emerging 7-14 days postoperatively as necrosis develops[14]. The three delayed-presentation cases in our cohort, which became symptomatic around postoperative days 7-10, are consistent with this mechanism. This finding is consistent with the literature documenting postoperative ureteral injuries despite normal intraoperative cystoscopy, highlighting the limitation of relying solely on intraoperative cystoscopy to detect such injuries[15]. We recommend supplementing postoperative day 1 renal ultrasonography with a repeat study at the first follow-up visit, around postoperative day 10. This two-step imaging approach is critical for detecting late-presenting thermal and ischemic ureteral lesions.

During benign gynecologic surgery, unilateral ureteral injuries often do not cause a significant elevation in serum creatinine because renal functional reserve and contralateral compensatory hyperfiltration produce a biochemical masking effect[16]. In our series, most radiologically confirmed cases of ureteral obstruction did not show a meaningful rise in serum creatinine, which likely reflects rapid contralateral renal compensation; therefore, a normal creatinine level does not exclude ureteral injury. Research demonstrates that while the affected kidney's glomerular filtration rate (GFR) decreases

rapidly, the contralateral kidney increases its GFR by 25-35%, maintaining overall renal function within normal limits[17]. This compensatory mechanism can preserve normal serum creatinine levels even in complete unilateral obstruction, particularly in patients with normal baseline renal function. Given the low diagnostic sensitivity of serum creatinine for detecting unilateral ureteral injury, reliance on biochemical parameters alone is insufficient[18]. Consequently, renal ultrasonography emerges as an essential diagnostic tool that reliably detects obstructive changes and prevents diagnostic delays. The timing of ureteral injury management is one of the most critical determinants of postoperative outcomes, as early recognition significantly reduces the risk of obstructive nephropathy, urinoma, infection, sepsis, and permanent loss of renal function[19]. When identified early, injuries can often be successfully managed with minimally invasive interventions such as endoscopic stenting, primary repair, or early UNC, whereas delayed diagnosis markedly decreases the likelihood of successful treatment. Contemporary guidelines from the American Urological Association and the European Association of Urology emphasize that injuries recognized intraoperatively or within the first 24-72 hours should undergo prompt intervention, as this approach yields substantially better outcomes compared with delayed repair[20]. In this context, early postoperative imaging, integrated into routine evaluation, facilitates timely diagnosis, particularly of injuries that may not be apparent intraoperatively. Therefore, in high-risk procedures such as laparoscopic hysterectomy, early identification of ureteral injury remains essential for preserving renal function and preventing long-term morbidity.

Early ureteral repair consistently demonstrates higher success rates and lower complication rates compared with delayed intervention; historical reconstructive urology series have reported success rates of 89-95% when repair is performed within the first 72 hours[21]. In contrast, injuries diagnosed more than seven days postoperatively are associated with reduced success rates (50-65%) due to inflammation, fibrosis, urinoma formation, and tissue necrosis, all of which complicate reconstruction[21]. More recent studies highlight that energy-related thermal injuries, common in minimally invasive gynecologic surgery, may remain clinically silent in the early postoperative period, and that delayed diagnosis increases the technical complexity and morbidity of surgical repair[22]. Consequently, the literature consistently supports early imaging-based detection and timely repair as the strongest predictors of renal functional preservation, lower reoperation rates, and improved patient outcomes.

The key strengths of this study include the use of data derived from a high-volume, minimally invasive gynecologic surgery center, enhancing the representativeness of the study population. The large case volume supports the robustness of the observed clinical patterns and improves the generalizability of the findings. In addition, the integrated use of preoperative ultrasonography, routine intraoperative cystoscopy, and postoperative renal ultrasonography within the same clinical setting facilitates early recognition and timely management of ureteral injuries.

Study Limitations

Despite the clinical relevance and methodological strengths of the present study, several important limitations should be carefully considered when interpreting the findings. The retrospective study design is inherently associated with risks of selection bias and incomplete or inconsistent clinical documentation. In addition, a formal cost-effectiveness analysis of the proposed diagnostic strategy was not conducted, limiting the ability to draw definitive conclusions about its economic impact. Furthermore, although the overall study cohort was relatively large, the limited number of ureteral injury cases necessitates cautious interpretation of diagnostic performance metrics, particularly PPV and NPVs. Importantly, the PPV observed in this study should not be regarded as a definitive diagnostic outcome, but rather as a hypothesis-generating observation that provides clinically meaningful insight and informs future research directions. Accordingly, the present findings warrant validation in larger, prospective, and well-controlled studies.

Conclusion

The findings of this study indicate that the presence of normal intraoperative ureteral jet flow does not reliably exclude ureteral injury. Renal ultrasonography, when integrated into the routine postoperative clinical assessment performed at our center, allows identification of newly developed pelviectasis and thereby facilitates early recognition of ureteral obstruction. When considered not as an additional screening test but as a natural extension of the standard postoperative evaluation, this approach may reduce morbidity associated with delayed diagnosis. Accordingly, postoperative renal ultrasonography, particularly when interpreted relative to preoperative baseline imaging, appears to be a practical adjunct for the early detection of ureteral injury.

Ethics

Ethics Committee Approval: Institutional review board approval was obtained prior to study initiation (University of Health Sciences Türkiye, İzmir Tepecik Education and Research Hospital Non-Interventional Ethics Committee, decision no: 2025/10-13, date: 03.11.2025).

Informed Consent: Retrospective cohort study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: S.K., Concept: S.K., A.K., A.B., Design: S.K., A.K., U.D., A.H.İ., Data Collection or Processing: U.D., P.T.Ö., F.Y., Analysis or Interpretation: S.K.,

F.Y., Literature Search: S.K., A.İ., A.B., A.H.İ., Writing: S.K., A.İ., A.H.İ.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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