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Comparative Outcomes of Antegrade Flexible Ureteroscopy and Retrograde Intrarenal Surgery in the Management of Large Upper Ureteric Stones

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Abstract

Introduction: Ureterolithiasis, the presence of calculi within the ureter, is a prevalent urological condition with increasing global incidence and significant health implications. The management of large upper ureteric stones, particularly those exceeding 10 mm, often necessitates surgical intervention. Among the available minimally invasive techniques, both antegrade flexible ureteroscopy (AFU) and retrograde intrarenal surgery (RIRS) have demonstrated clinical utility. However, comparative outcomes between these approaches remain a subject of ongoing evaluation. This study aims to assess and compare the effectiveness and perioperative outcomes of AFU versus RIRS in the management of large upper ureteric stones.

Materials and Methods: A prospective randomized controlled trial was conducted at Zagazig University Hospitals, enrolling patients with upper ureteric stones larger than 10 mm. Participants were randomly assigned to either Group A (AFU) or Group B (RIRS). Comparative analyses were performed regarding patient demographics, stone characteristics, operative parameters, and postoperative outcomes. Statistical analysis was carried out using SPSS software, with a p-value < 0.05 considered statistically significant.

Results: A total of 120 patients were included, with 60 in each group. Baseline demographic parameters, including age, sex, body mass index, and comorbidities, were comparable between the groups. Notable differences were observed in operative data: AFU was associated with a shorter operative duration (71.3 ± 11.19 minutes vs. 74.9 ± 8.56 minutes; p = 0.041) and reduced stone disintegration time (p < 0.001). Additionally, the AFU group experienced significantly shorter hospital stays (3.43 ± 0.53 days vs. 4.13 ± 0.99 days; p < 0.001). Stone-free rates at 24 hours (95% vs. 90%) and at four weeks postoperatively (98.3% vs. 93.3%) were slightly higher in the AFU group, though these differences were not statistically significant. There were also no significant differences in postoperative complication rates or the need for auxiliary procedures.

Conclusion: Both AFU and RIRS are effective and safe modalities for the treatment of large upper ureteric stones. AFU offers certain procedural advantages, including reduced operative and hospitalization times, and may be particularly beneficial in cases where retrograde access is challenging. Nonetheless, stone clearance and complication profiles between the two techniques are largely comparable. AFU may serve as a valuable alternative in selected clinical scenarios.

Keywords: Ureterolithiasis; Upper ureteric stones; Antegrade flexible ureteroscopy (AFU); Retrograde intrarenal surgery (RIRS); Stone-free rate (SFR).

Introduction

Ureterolithiasis is a globally prevalent condition, affecting millions annually and imposing a substantial financial and clinical burden on healthcare systems worldwide. Its incidence and prevalence have been steadily increasing in recent years. Furthermore, ureterolithiasis is frequently associated with systemic diseases, particularly cardiovascular disorders, diabetes mellitus, metabolic syndrome, and obesity [1].

Clinically, the condition typically presents with sudden and severe flank pain radiating toward the groin. Unlike patients with acute abdominal pathology who prefer immobility, individuals experiencing renal colic often move constantly in an attempt to alleviate discomfort, which is characteristic of this type of pain. Additional symptoms such as nausea, vomiting, and lower urinary tract manifestations may arise, especially as the stone approaches the urinary bladder [2].

The likelihood of spontaneous stone passage largely depends on stone size, location, and shape, as well as patient-specific anatomical factors. Stones measuring ≤5 mm generally pass without surgical intervention, while those exceeding 7 mm or persisting beyond 4–6 weeks may necessitate active treatment. The most commonly employed modalities for managing ureteral stones include ureteroscopy—typically accompanied by laser lithotripsy—and extracorporeal shock wave lithotripsy (ESWL), which fragments the stones into passable particles [3].

Management of large upper ureteric calculi involves a range of interventions, including open ureterolithotomy, laparoscopic approaches, retrograde or antegrade endoscopic techniques, and ESWL with stenting. However, these procedures may be associated with complications such as prolonged hospitalization, infection, bleeding, or scarring [4].

In some cases, severe ureteric inflammation, chronic stone impaction, or infection may hinder the placement of ureteral stents and reduce the success of retrograde procedures, often requiring multiple ESWL sessions and resulting in high failure rates [5].

Retrograde ureteroscopy remains a less invasive method that utilizes the native urinary tract for access. Despite its advantages, this technique demands skilled expertise and specialized equipment. Additionally, it is prone to limitations such as calculus migration or incomplete stone clearance [6].

Antegrade ureteroscopy, on the other hand, offers an alternative by accessing the ureter through a percutaneous renal tract. This method facilitates intracorporeal lithotripsy and may allow simultaneous removal of associated renal stones. Nonetheless, it carries potential risks similar to those encountered in percutaneous nephrolithotomy (PCNL) [7].

This study aims to compare the clinical outcomes of antegrade flexible ureteroscopy (AFU) versus retrograde intrarenal surgery (RIRS) in the treatment of upper ureteric stones larger than 10 mm. By evaluating and contrasting these two minimally invasive approaches, we seek to identify the most effective technique for enhancing patient outcomes in terms of stone clearance, complication rates, and recovery time.

Ureterolithiasis

Ureterolithiasis is a widespread urological condition with rising global incidence, contributing to significant healthcare costs. Beyond its local impact, growing evidence links kidney stone disease to systemic conditions such as cardiovascular disorders, diabetes mellitus, and obesity [8]. Typically, ureteric stones present with sudden, intense flank pain radiating to the groin, often accompanied by nausea and vomiting. Although many cases are self-limiting, complications such as urosepsis, renal abscess, obstructive nephropathy, chronic kidney disease, and ureteric strictures can occur, occasionally requiring hospitalization or surgical intervention [9].

The underlying cause of stone formation often remains unknown, especially in cases where the stone is not retrieved and analyzed. Past beliefs that high dietary calcium intake increased the risk have been overturned—higher calcium intake is now thought to reduce stone risk. Some cases result from hereditary conditions, such as cystinuria, which lead to specific stone types [10].

Pathophysiology and Stone Composition

Stone formation is driven by urinary supersaturation of certain substances. Hypercalciuria, hyperoxaluria, and hyperuricosuria contribute to calcium, oxalate, and uric acid stones, respectively. Calcium oxalate stones account for the majority (around 74%), followed by calcium phosphate (20%) and uric acid (4%). Less common stones include cystine and struvite. Stones ≤5 mm often pass spontaneously, whereas those ≥7 mm generally require urological intervention due to reduced likelihood of passage [11].

Diagnosis of Ureteric Stones

Clinical Presentation

Patients with ureterolithiasis typically present in their 40s, often with a history of renal stones. The hallmark symptom is sudden-onset, severe unilateral flank pain with a colicky pattern that may evolve into continuous discomfort. This pain often leads to restlessness and may be accompanied by nausea, vomiting, dysuria, gross hematuria, or urinary frequency (12). On physical examination, patients frequently appear distressed and may exhibit costovertebral angle tenderness. Systemic signs such as fever and hypotension are uncommon unless infection is present (13).

Atypical Features and Complications

Not all presentations are classic. Some patients may report vague symptoms like lower back pain, diarrhea, or signs of recurrent urinary tract infections. Misdiagnosis may occur if these atypical manifestations are overlooked (14). Serious complications include obstructive uropathy, infection, perforation, renal abscess, and chronic kidney disease. In pregnancy, stones may lead to adverse outcomes like preeclampsia or miscarriage (15).

Diagnostic Evaluation

Diagnosis is often clinical but should be supported by laboratory and imaging studies to assess for complications or alternative diagnoses. Useful tests include urinalysis (typically showing hematuria), blood tests for renal function, and imaging modalities such as ultrasound or non-contrast CT, which is the gold standard for detecting stone size, location, and degree of obstruction (16). When infection is suspected, findings like pyuria, bacteriuria, or positive leukocyte esterase on urinalysis warrant immediate attention. For metabolic evaluation, 24-hour urine collection and stone analysis may be indicated in recurrent cases (17).

Differential Diagnosis

Colicky flank pain should not be presumed to be due to stones without ruling out other potentially fatal causes such as abdominal aortic aneurysm, renal malignancies, or gastrointestinal conditions like diverticulitis and cholecystitis. Prompt and accurate differentiation is essential to avoid delays in life-saving interventions (18).

Preoperative Assessment of Stone Impaction Risk

Identifying the likelihood of ureteral stone impaction before surgery is crucial for patient counseling, surgical decision-making, and operative planning. Although multiple criteria have been proposed for defining impacted stones, several limitations remain. These include uncertainty about the exact duration a stone must remain immobile to be considered impacted, the unpredictability of guidewire or stent passage until the day of surgery (unless pre-stenting has been done), and the requirement of contrast imaging to evaluate the ureter distal to the obstruction. As a result, recent investigations have explored the utility of preoperative imaging, such as non-contrast computed tomography (NCCT) or ultrasound, to predict stone impaction (20,21).

Established risk factors for impaction include larger stone size, significant hydronephrosis, and a history of prior intervention on the same side. Larger stones are less likely to pass spontaneously and tend to remain in place longer, exerting prolonged pressure on the ureteral wall. This can lead to ischemia, edema, and fibrosis, ultimately resulting in impaction. Furthermore, impacted stones may block urinary flow into the bladder, leading to pronounced hydronephrosis. Although the association between prior ipsilateral procedures and increased risk of impaction is not entirely understood, inflammation or trauma from earlier treatments—especially extracorporeal shock wave lithotripsy (SWL)—may play a role by altering the ureteral wall and promoting impaction (20–22).

Recent findings suggest that ureteral wall thickening parameters are reliable predictors of ureteral stone impaction. Among these, ureteral wall thickness (UWT) defined on axial NCCT scans as the thickest point at the stone site has been widely used. Studies have shown that increased UWT (cut-off ~3.49–3.55 mm) is associated with stone impaction and poor outcomes after shockwave lithotripsy (SWL), as well as with adverse endoscopic features like edema and mucosal polyps during ureteroscopy (23,24).

In addition to UWT, ureteral wall volume (UWV), measured from the stone's upper to lower edge, also predicts impaction and poor outcomes (23). Chandhoke et al. further evaluated four UWT-related metrics and found all correlated with stone impaction severity based on surgeon assessment. Wang et al. even proposed a nomogram combining UWT, patient age, hydronephrosis grade, and treatment history to predict impaction preoperatively (24).

Other non-thickness-based predictors have emerged as well. For example, high Hounsfield Unit (HU) values on NCCT (>27 HU), ureteral diameter ratios, and reduced ureteral jet flow (measured by Doppler ultrasound) have all been linked to impacted stones (25).

To enhance prediction accuracy, new scoring systems have been developed. Ozbir et al. introduced the Impacted Stone Formula (ISF), using UWT and HU values, while Erdogan et al. designed a comprehensive scoring model incorporating jet flow, UWT, and HU to achieve 91% specificity and 89% sensitivity. Despite their promise, further validation is needed (26).

Regarding management, endoscopic approaches are now favored for impacted ureteral stones, given the limitations of SWL due to edema and stone fixation. Although open or laparoscopic ureterolithotomy remains an option for complex cases, retrograde ureteroscopy (URSL), PCNL, and antegrade URSL have become first-line interventions due to their safety and effectiveness (27–29).

Flexible Ureteroscopes

Digital Flexible Ureteroscopy

Digital flexible ureteroscopes have replaced traditional fiberoptic designs, offering superior image resolution—up to ten times greater than that of standard fiberoptic models—due to the integration of advanced digital imaging chips and built-in light sources, which eliminate the need for external camera heads or light cables. However, the inclusion of a distal digital chip necessitates a slightly larger outer diameter, which may pose challenges for ureteral access. Additionally, digital imaging can be temporarily disrupted during laser lithotripsy due to acoustic vibrations affecting chip stability and red light processing (22,23). These systems often use either a charge-coupled device (CCD) or complementary metal-oxide-semiconductor (CMOS) sensor, both capable of converting light into high-quality digital signals with accurate color representation. These chips can deliver image resolutions up to 40,000 pixels, a substantial improvement compared to the 3,500-pixel resolution of fiberoptic ureteroscopes (24).

Disposable Flexible Ureteroscopy

The concept of single-use flexible ureteroscopes dates back to 1987, introduced by Bagley. More recently, the emergence of various disposable ureteroscopes has expanded accessibility in endourological practice. Davis et al. demonstrated that, in a study of 466 patients, single-use scopes performed comparably to reusable ones and could potentially reduce repair costs in low-volume centers (25). In a bench study comparing two single-use models (LithoVue and Pusen Uscope UE3011) with one reusable ureteroscope (FlexXc), Deininger et al. found the disposable scopes emitted less light and, while functional, the reusable model outperformed them in both optical clarity and mechanical performance. Notably, the Pusen Uscope generated higher intrarenal pressures, which may carry implications for patient safety (29). Emiliani et al. also observed that image quality and deflection capability of the Pusen scope declined during clinical procedures (30). In cadaveric studies, the LithoVue demonstrated similar maneuverability and visibility to reusable digital scopes. Further laboratory comparisons affirmed that the LithoVue matched reusable Olympus and Karl Storz models in essential features and may offer a cost-effective alternative for select clinical settings (31,32).

Robotic Flexible Ureteroscopy

Despite advancements in flexible ureteroscopy, manual handling still places physical strain on the urologist, particularly during prolonged procedures involving laser lithotripsy and fluoroscopic exposure. Robotic ureteroscopy aims to alleviate these ergonomic limitations. The Avicenna Roboflex system (ELMED, Turkey) has been introduced as a promising ergonomic solution. It features a user-friendly console with a joystick for scope navigation and a robotic arm that manages fine deflection via micromotors. The robotic platform supports horizontal rotation and linear movements, enhancing precision and surgeon comfort (26,27).

General Design of Flexible Ureteroscopes

Modern flexible ureteroscopes share a consistent design architecture, comprising four key components: an illumination system, a mechanical drive, optical fibers or digital imaging sensors, and a working channel with irrigation capabilities. Structurally, they are divided into three main sections: the control handle, insertion shaft, and a deflectable distal tip, which allows for maneuvering within the urinary tract (28).

Optical System

The optical component of flexible ureteroscopes incorporates fiberoptic bundles constructed from fused glass, encased in an additional glass layer with a modified refractive index. This structure optimizes internal reflection and maximizes light transmission. The distal end of the fiber bundle is divided to ensure uniform illumination and a better-aligned working channel. Additionally, strategically positioned proximal and distal lenses enhance the field of view and image clarity (36).

Mechanical System

Deflection of the distal tip is achieved through manipulation of a thumb-controlled lever, which is connected to wires running along the ureteroscope shaft. Moving the lever downward results in a corresponding downward tip deflection, a design choice based on the frequent need to access mid-to-lower renal calyces—hence termed a "logical" deflection system. Systems by Storz, Wolf, and ACMI incorporate this intuitive deflection, while Olympus scopes employ a "counterintuitive" mechanism, where upward lever movement deflects the scope tip downward. The distal segment of the ureteroscope is capable of articulating up to 275 degrees in both directions (38,39).

Durability of the Flexible Ureteroscope

The lifespan and functional integrity of flexible ureteroscopes (FURS) depend on several factors, including the surgeon's expertise, procedural volume, procedural complexity, and sterilization techniques. According to Afane et al., significant repairs are typically required after 15 procedures or 13 hours of usage. Moreover, the active deflection range deteriorates between 2% and 28% with each use, and White and Moran reported the need for substantial repairs after only 12 procedures (37,38).

Traxer et al. evaluated 50 procedures using a Karl Storz URS, documenting a decline in active deflection and irrigation flow over time. Specifically, upward deflection decreased from 270° to 208°, downward from 270° to 133°, and irrigation flow (at 100 cm H_2O) fell from 50 ml/min to 40 ml/min by the final procedure. Their findings also indicated improved durability with newer-generation scopes and when operated by skilled urologists (36).

Pietrow et al. investigated methods to extend the lifespan of 7.5 Fr FURS. They proposed that employing updated accessories such as access sheaths, 200 µm holmium:YAG laser fibers, and nitinol baskets could enhance the ureteroscope's longevity (35).

Equipment and Instrumentation in Flexible Ureteroscopy (FURS)

Most modern FURS devices are enclosed in a polymer sheath small enough to navigate 3.6 Fr working channels (22).

1. Guidewires : Standard PTFE wires (0.035–0.038 in) with floppy tips are commonly used. Hydrophilic Terumo Glide wires assist with challenging ureteral navigation, while "hybrid" wires combine a flexible hydrophilic distal tip with a stiffer PTFE-coated nitinol shaft to improve scope control. Extra-stiff PTFE or Zebra wires aid in accessing the ureter (22).

2. Ureteral Stents: Postoperative healing and ureteral dilation are facilitated by internal Double-J stents or external catheters, typically made from polyurethane or silicone (22).

3. Ureteral Access Sheaths (UAS): UAS improve access, reduce pelvic pressure, and protect scopes during multiple entries. They consist of a hydrophilic-coated obturator and a working sheath (inner diameter ≈ 6 Fr, outer 2 Fr larger), commonly sized 10/12 or 12/14 Fr. Benefits include quicker re-entry and shorter procedure time, though insertion can cause ureteral trauma and add cost (23).

4. Stone Extraction Devices
    - Dormia baskets: Available in tipless nitrile designs (1.9–3 Fr), for retrieving stones.
    - Graspers: Lightweight forceps (usually 3 Fr) suitable for impacted calculi (22).

5. Lithotripsy Devices
    - Pneumatic probes (0.5–0.6 mm) work well straight but lose ~30% efficiency at 48° angles—less ideal for flexible scopes.

- Ultrasonic probes are too rigid for FURS.
- Laser lithotripsy (Holmium:YAG and Thulium fiber) is versatile and effective. Settings for Holmium include low-energy/high-frequency dusting (0.2–0.4 J @ 50–80 Hz) or higher-energy fragmentation (0.8–1 J @ 8 Hz). Pulse modulation techniques, such as Moses technology, optimize energy delivery and reduce retropulsion (24). Thulium fiber lasers are newer, with smaller fibers (100–150 µm), high-frequency capability, and improved maneuverability (25).

Complications of Percutaneous Nephrolithotomy (PCNL)

Most complications following PCNL are minor such as transient fever or leakage around the nephrostomy tract while serious issues typically arise from access or stone removal (35).

A. Intraoperative Complications

1. Bleeding: Bleeding is the most frequent significant complication during PCNL and is often managed conservatively. Overly aggressive puncturing and prolonged operative times are common causes. Superselective angioembolization (SAE) is an effective intervention, especially when pseudoaneurysms are identified. However, SAE may fail in cases with multiple access tracts, multiple bleeding sources seen on angiography, or exclusive use of gelatin sponge embolization (36).
2. Fluid Extravasation & Urinoma: Urine leakage into surrounding tissues can result from collecting-system damage, causing volume overload and electrolyte imbalances. Small urinomas typically resolve once a stent is placed and the tract seals; larger or symptomatic ones may require ultrasound-guided drainage or catheter placement until output drops below 10 mL/day. Untreated urinomas can compress adjacent structures, leading to pain, fever, or even respiratory issues (37).
3. Intravascular Fluid Overload: Excessive intravascular fluid absorption—promoted by vessel injury, prolonged surgery, hypotonic irrigation, or cardiac illness—can lead to fluid overload. Prevention involves meticulous monitoring of fluid balance and use of isotonic saline. In severe cases mimicking TUR syndrome, gradual administration of hypertonic saline and diuretics may be necessary (38).
4. Hypothermia: Anesthesia-induced vasodilation, extended operating times, exposure, and cold irrigants can lower core temperature below 35°C. Using warmed irrigation fluid and proper patient covering helps prevent this complication (37).
5. Stone Fragment Migration: Rarely (0.5–1%), a stone can perforate the collecting system and migrate, leading to granulomas and strictures. Attempts to remove fragments through the perforation should be avoided to prevent exacerbating the injury (39).
6. Injury to Adjacent Organs
    - Pleura/Lung: Supracostal access increases risk. Minor pneumothorax or hydrothorax may be observed; intervention is needed only if respiratory stability is compromised (40).
    - Colon Injury: Occurring in 0.2–1% of cases, colon injuries—more common on the left side, in women, and post-bowel surgery—are confirmed by contrast enhanced imaging. Treatment includes bowel rest, antibiotics, tube drainage, and surgical consultation (41).
    - Small Bowel: Extremely rare; detected via CT postoperatively; managed with either surgery or conservative protocols (bowel rest, drainage) (42).
    - Liver/Spleen: Very uncommon; injuries may require angioembolization or splenectomy, depending on bleeding severity (40).

B. Postoperative Complications

1. Renal Colic: Occurs in 3.5–9% of cases due to transient ureteral swelling or debris. Treatment is usually conservative with hydration and analgesics; persistent symptoms for over two days warrant imaging and possible stenting (41).
2. Delayed Hemorrhage & Hematomas: Bleeding may recur post-nephrostomy removal. Compression, Foley catheter use, or selective embolization can control it. Arteriovenous fistulas and pseudoaneurysms

occur in about 1.2%, presenting with persistent hematuria and slow anemia; CT helps confirm and guide angioembolization (39).

3. Infection & Sepsis: Fever occurs in approximately one-third of patients, but sepsis rates are low with proper preoperative antibiotics and low-pressure irrigation. Drainage when needed also reduces risk (43).
4. Ureteral Stricture: Strictures develop in 2–4% of patients, especially those with prior surgery or radiation. Causes include impaction, trauma, leakage, ischemia, or thermal injury. Early strictures (<3 months) have up to a 91% chance of successful repair compared to later ones (4).
5. Thromboembolic Events: Deep vein thrombosis (1–3%) and pulmonary embolism may occur due to reduced mobility post-surgery. Prevention with compression stockings and early ambulation is key (45).
6. Persistent Fistula: Nephrocutaneous fistula formation—persistent leakage through the skin—occurs in roughly 1.5–4.6% of patients, often due to distal obstruction or edema (44).

Conclusion

The management of large upper ureteric stones remains a clinical challenge, with both antegrade flexible ureteroscopy (Ante-FURS) and retrograde intrarenal surgery (RIRS) offering viable, minimally invasive treatment options. Based on current evidence, antegrade approaches tend to yield higher stone-free rates, especially in impacted or proximal stones, albeit at the cost of increased procedural invasiveness and potential complications. RIRS, on the other hand, remains favorable in terms of patient recovery, shorter hospital stays, and lower morbidity, particularly when stone burden is moderate and access anatomy is favorable. The choice between antegrade and retrograde techniques should be individualized based on stone characteristics, patient comorbidities, anatomical considerations, and surgeon experience. Emerging advancements in endoscopic equipment, access sheath technology, and laser lithotripsy are continually improving outcomes in both modalities. However, further prospective, randomized controlled trials with standardized outcome metrics are essential to establish optimal treatment algorithms for large upper ureteric stones.

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