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Technical Reports

Robot-Assisted Mini-Endoscopic Combined Intrarenal Surgery for Complex and Multiple Calculi: What Are the Real Advantages?

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Abstract

Background: To determine the stone-free rates (SFR) with robot-assisted mini-endoscopic combined intrarenal surgery (mini-ECIRS) and evaluate the impact of intraoperative assessment of stone-free status compared to postoperative non-contrast computed tomography (NCCT) scan findings.
Methods: A total of 42 consecutive patients (44 renal units) diagnosed with complex/multiple renal stones were enrolled and reviewed in a retrospective manner. While retrograde access with the flexible scope was performed by using Avicenna Roboflex, mini-percutaneous nephrolithotomy was performed through a 16.5F sheath. Demographic, clinical characteristics of the cases along with perioperative complications were recorded, analyzed, and compared to the reported data in the literature.
Results: Forty-two renal units (95.5%) were endoscopically confirmed to be stone-free at the end of the procedure, of which all were confirmed to be stone-free in postoperative NCCT examination. Complications were observed in 3 of the 42 (7.1%) patients, which were classified as Clavien grade I. The mean operation and fluoroscopy time were 103.7 ± 20.6 minutes and 71 ± 13.7 seconds, respectively.
Conclusion: Our results demonstrate that robot-assisted mini-ECIRS could reveal high SFR in complex and multiple stones. In addition, endoscopic flexible ureteroscopic evaluation of the collecting system at the end of the procedure could let the surgeon predict stone-free status more reliably and successfully.

Keywords: Avicenna Roboflex, mini-ECIRS, robotic endourology, urolithiasis

Introduction

Percutaneous nephrolithotomy (PCNL) is accepted as the standard treatment for renal stones larger than 2 cm.[1] Although this approach is associated with reasonably high stone-free rates (SFR) and shorter operative time, multiple accesses may be required in as many as 20%–58% of the procedures performed. On the contrary, the use of the 24F–30F sheath during standard PCNL procedure could make it extremely difficult to remove the stone burden through a single tract in complex renal stones (stones extending to several calyces and/or stones located in several calyces).

To accomplish this task and remove all stones from different parts of the collecting system, multiple tracts may be required and studies have demonstrated well that PCNL performed through several tracts could certainly increase the extent of the renal parenchymal injury, which may be associated with severe complications such as bleeding, requiring transfusion (11.2%–17.5%), extravasation (7.2%), and fever (21.0%–32.1%).[2–4]

Due to the facts mentioned above, the clinical introduction of the ''miniaturization'' concept (mini PCNL from 16F to 20F sheath) has let the endourologists began to prefer relatively smaller-sized access sheaths and instruments in an

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attempt to avoid the possible complications noted particularly during the management of large and/or complex stones.[5] Results of several studies on this aspect have demonstrated the advantages of the mini PCNL procedure in limiting the large bore tract-related complications, with acceptable and comparable SFR's.[6,7]

Moreover, accumulated data so far have demonstrated that simultaneously combined mini-PCNL and flexible ureteroscopic (fURS) lithotripsy (mini-endoscopic combined intrarenal surgery [ECIRS]) may reveal significantly higher complete stone clearance in a single-session procedure when compared to mini-PCNL alone. This approach will certainly require fewer accesses, limit the invasiveness of the procedure, and reduce postoperative pain, without any other additional procedure-related complications.[8,9]

The goal of every endoscopic procedure is to achieve a complete stone clearance in one session. Since residual fragments can lead to symptoms, regrowth, and the need for auxiliary procedures, various treatment techniques and equipment are available to remove all stone particles after disintegration both in PCNL and fURS.[10,11] On the contrary, there is still no standardized definition of the ''stone-free status'' in the current literature and a wide variety of definitions are being used in published studies.

Similarly, no consensus has been reached so far concerning the size of the fragment (to consider it as clinically insignificant), the period for final evaluation after the last session, and the type of imaging modality to be used for this definition. In the light of all these facts, it seems to be highly important to achieve a completely residual fragment-free status at the end of the operation. Regarding this issue, a stone-free status confirmed endoscopically just after the procedure gains more importance as the most reliable way of clarification.

In this present study, we aimed to evaluate the clinical efficacy and advantages of the ''Robot-Assisted Mini-ECIRS'' procedure (simultaneous mini-PCNL combined with robot-assisted retrograde fURS lithotripsy) in the management of large, complex, and multiple stones in terms of SFR and procedure-related complications.

Materials and Methods

Patients

Medical records of 42 patients (44 renal units) undergoing the ''Robot-Assisted Mini-ECIRS'' procedure for the management of complex renal stones between April 2019 and February 2020 were analyzed in a retrospective manner. In addition to a complete physical examination, preoperative evaluation included laboratory tests (urinalysis, urine culture with sensitivity testing, and blood chemistry) and radiological examination with noncontrast spiral computed tomography (NCCT).

In cases with identified urinary tract infection, an appropriate antibiotic regimen based on the urine culture test results was applied before surgery. Precise location and size of stones (number of calyces involved by staghorn stone and/or stones located in several calyces) and the stone(s) located in kidneys with abnormal anatomy were assessed on NCCT examination. While the stone size was determined by the longest diameter of the stone measured, in cases with multiple stones, the sum of the largest diameters of all stones was recorded as the final stone size.

This study was approved by our local Institutional Review Board (IRB).

Surgical technique

All procedures were performed under general anesthesia and following the insertion of the guidewire during cystoscopy, an appropriate sized ureteral access sheath (10.7F/12.7F, Cook Medical) was placed into the ureter over the guidewire, and fURS (Flex-XC, Karl Storz, Tuttlingen, Germany) was docked to the Avicenna Roboflex System (ELMED, Ankara, Turkey).

Percutaneous access was generally performed through the inferior or middle calyx, and tract dilation was done with the help of a telescopic dilator under fluoroscopic control; 16.5F access sheath and 12F mini-nephroscope (Karl Storz, Tuttlingen, Germany) were used during the mini-ECIRS procedure. Two hundred μm (with furs) and 550 μm (with mini-nephroscope) holmium laser probes were used for stone disintegration with two different laser devices and stones were repositioned in the collecting system by using a 1.9F tipless nitinol basket (Cook Medical) if needed.

Stone fragments were extracted with grasping forceps, nitinol basket, and/or by way of bilateral active irrigation from up and below. Two surgeons worked simultaneously during the procedure and while the surgeon sitting at the console of the robot-assisted fURS system (reasonable away from the patient) controlled the endoscope tip, laser fiber, and irrigation pump rate; the mini-PCNL procedure was performed by the second surgeon at the patient side (Figs. 1 and 2). Following the completion of the procedure, the whole collecting system was checked carefully via robot-assisted fURS under better vision concerning the presence of any residual fragment. Although a 6F Double-J ureteral stent was inserted in all patients, a nephrostomy tube was also placed in selected cases when needed at the end of the procedure.

Perioperative evaluation and follow-up

The primary outcome was to evaluate the efficacy and safety of robot-assisted mini-ECIRS in terms of stone-free rates (SFR) and complication rates (CRs) according to the Clavien–Dindo grading. The secondary outcome

FIG. 1. Roboflex Avicenna for flexible ureteroscopy, console with seat, adjustable armrest, and a monitor for digital ureteroscopy.

FIG. 2. Touchscreen functions for laser activation, fine-tuning of movements, and irrigation. Robotic arm with digital flexible ureteroscope fixed in the platform.

was to assess operative time, length of hospital stay, hemoglobin drop, and transfusion rates. The majority of the patients were discharged following 36–48 hours after surgery. Final SFR was assessed 4 weeks postsurgery by the NCCT to evaluate patients after removal of the Double-J stent. The stone-free status was defined as the complete absence of any single residual fragment in the collecting system.

Results

A total of 42 patients, (2 presenting with bilateral kidney stones) were included in the study program. Patient characteristics and stone-related parameters are summarized in Table 1. The mean age of the cases was 42.3 ± 12.8 years and 24 (57.1%) of the patients were males. Thirty-four out of 44 (77.3%) renal units treated were found to have stones filling at least 2 or more calices, in addition to the main stone burden. While the mean body mass index value was 26.2 ± 4.7, the mean American Society of Anesthesiology score was noted to be 1.5 ± 0.6. The average stone size was 28.4 ± 4.6 mm. Kidney/urinary tract anomaly was detected in 6 patients, including horseshoe kidney anomaly in 1, the complete duplicated system in 2, and the incomplete duplicated system in 3 cases. Patient demographics, stone characteristics, and operative parameters are being demonstrated in Table 1.

Evaluation of our results revealed that, while stones were successfully removed through a single tract in 38 of the 44 renal units treated, a second tract was needed in 4 patients to render the patients completely stone free. On the contrary, related to the assessment of stone-free status, in 42 renal units (95.5%), endoscopic confirmation was possible at the end of the procedure. The stone-free status of the treated kidneys was further evaluated and confirmed via NCCT scan after the procedure. The mean operation and fluoroscopy time were 103.7 ± 20.6 minutes and 71 ± 13.7 seconds, respectively. None of the treated cases required blood transfusion after robotic mini-ECIRS.

Last but not the least, concerning the complications observed, although 3 of the 42 (7.1%) patients were found to reveal Clavien grade 1 complications (fever in 2 patients, hematuria in 1 patient), Clavien grade ≥2 complications were not observed in any of the case treated (Table 2).

Table 1. Patient, Operation, and Stone Data

Variable	n = *42 patients, 44 renal units [*n (%) *or mean ± SD]*
Gender	
Male	24 (57.1)
Female	18 (42.9)
Age (years)	42.3 ± 12.8
BMI (kg/m^2)	26.2 ± 4.7
ASA score	
1	23 (54.8)
2	16 (38.1)
3	3 (7.1)
Stone size (mm)	28.4 ± 4.6
Stone number	
Single	10 (22.7)
Multiple	34 (77.3)
Stone location	
Right	
Lower calyx	19 (20.4)
Middle calyx	15 (16.1)
Upper calyx	11 (11.8)
Proximal ureter	3 (3.2)
Left	
Lower calyx	14 (15.1)
Middle calyx	17 (18.3)
Upper calyx	9 (9.7)
Proximal ureter	5 (5.4)
Stone opacity	
No	5 (27.3)
Yes	39 (72.7)
Kidney or urinary tract anomaly	6 (13.6)
Calyx diverticulum	1 (2.3)
Hydronephrosis	
No or mild	15 (34.1)
Moderate or severe	29 (65.9)
Percutaneous access tracts	
Single	40
Two	4
SFR	42/44 (95.6)
Fluoroscopy time (seconds)	71 ± 13.7
Operation time (minutes)	103.7 ± 20.6
Hemoglobin drop (g/dL)	0.9 ± 0.4
Hospital stay (hours)	42.9 ± 5.8

ASA, American Society of Anesthesiology; BMI, body mass index; SD, standard deviation; SFR, stone-free rates.

Discussion

The main aim of all available endoscopic procedures for renal calculi is to render the cases completely stone-free by removing all stone fragments to reduce the risk of stone-related events during the follow-up period. All available stone removal procedures (PCNL, URS, retrograde intrarenal surgery [RIRS]) may result in successful outcomes in experienced hands if stone and patient-related factors are chosen well, particularly in a guidelines-based manner.

Table 2. Intraoperative and Postoperative Complications According to the Modified Clavien–Dindo Classification

Clavien grade	n *(%)*
I	
Fever (>38.5)	2 (4.8)
Hematuria	1 (2.4)
II	
Required blood transfusion	0 (0)
Urosepsis	0 (0)
≥III	0 (0)

However, each modality has its advantages and disadvantages where they are effective, particularly in single, noncomplex stones with reasonably higher SFR. However, efficacy, but more importantly safety concerns, begins to arise particularly in cases with complex (large, branched) and multiple stones when they are applied in a ''single modality'' manner. SFR tend to come down and complication risks (bleeding, infection, perforation, obstruction, etc.) increase in long-lasting as well as complex procedures.

Studies have demonstrated that application of PCNL in large-complex stones by establishing multiple tracts may cause severe bleeding and perforation and also application of RIRS for a long period in large and complex stones may cause severe postoperative infective problems.[12–14] Taking this fact into account, combined procedures instead of a single-mode approach gained more importance in recent years to compensate for the disadvantages of each procedure and increase the rate of final stone-free status.

ECIRS has been reported to be highly effective, with higher SFR obtained in one session, less radiation exposure, decreased need for multiple tracts, and decreased need for additional procedures when compared with the standard PCNL approach in the management of large, complex stones.[15] However, despite its evident successful outcomes, the most important limitation of the standard ECIRS approach (performed with large-sized PCNL tracts and instruments) is the increased risk of intraoperative bleeding, which could significantly affect the quality of vision during same session fURS.

To accomplish this task and lower the extent of invasiveness, as a valuable alternative, mini-PCNL technique through smaller sized tracts began to be preferred for the percutaneous part of the ECIRS procedure to diminish the risk of intraoperative bleeding and provide a better vision for furs when compared to standard ECIRS. in addition, recently published studies have demonstrated that, compared to standard ECIRS, mini-ECIRS could provide high SFR with limited perioperative complications resulting in reduced postoperative pain.[16]

Regarding this issue, in their original, Zhao et al. compared ECIRS in the galdakao-modified supine valdivia position with Mini-PCNL for complex kidney stones, and by using miniaturized instruments (18F percutaneous tract as the maximum size), they were able to achieve a complete stone-free status of 88.1% after a single session in cases undergoing ECIRS procedure compared to the 66.7% of the cases managed with mini-PCNL. In addition, CRs were reported to be lower in the ECIRS group (7.5% versus 16%).[14] The importance of performing antegrade or retrograde flexible nephroscopy for the detection of residual fragments after the PCNL procedure has been well studied by Gökce et al.[17]

The authors reported that by performing an antegrade and retrograde flexible nephroscopy at the end of the PCNL procedure, they were able to detect residual fragments in 35 of 137 (25.5%) patients who were treated with retrograde flexible nephroscopy or second PCNL access. With this approach, they managed to increase the complete stone clearance rate to 90.5% (124 patients). They also stated that the retrograde approach may be more useful than the antegrade fURS to reach and observe the whole collecting system. Moreover, as a possible and important disadvantage, they concluded that the use of flexible equipment through the metallic sheat could increase the damage risk of flexible scops during the anterior approach.

Reports of contemporary mini-ECIRS series were reviewed for SFR, operative time, length of hospital stay, and hemoglobin drop. Table 3 highlights the data obtained and the other parameters in different series.[8,12–14] In our study, we found that SFR was higher, hemoglobin drop was less, and hospital stay was shorter compared to the recently published series. Slightly longer operation time than the values reported for classical mini-ECIRS series noted in our trial could be based on the additional 6 minutes of preparation and docking time for the Roboflex system.

Performance of the endoscopic stone removal procedures under a better vision is the single most important parameter to remove the stone(s) successfully and limit the risk of residual fragments, which may be left in the collecting system at the end of the procedure. Moreover, a better vision is essential in the careful evaluation of all parts of the collecting system and real-time endoscopic confirmation of stone-free status after PCNL with fURS procedure.

Related to this issue, we believe that the robot-assisted mini-ECIRS can provide higher SFR compared with the classical mini-ECIRS approach. An integrated adjustable irrigation pump allows continuous irrigation not only for the effective extraction of small stone fragments but also for a better vision to check the whole collecting system could be helpful in the perfect assessment of the collecting system at the end of the procedure. The use of a robotic system during the mini-ECIRS procedure may provide a suitable and safe platform for the surgeon with significant improvement of ergonomics out of the radiation zone. Suboptimal ergonomics may be one of the reasons for the imperfect performance of fURS resulting in insufficient stone clearance, especially for large stones requiring long-lasting procedures.

Evaluation of our results revealed that the robot-assisted mini-ECIRS procedure provides a high SFR with low CRs. Only 4 patients required a second entry, and none required blood transfusion due to the lack of severe hemoglobin reduction. Although 6 of the patients had kidney anomalies, high SFR in a single session showed that the robot-assisted mini-ECIRS procedure would provide high success in complex kidney stones.

In the light of our findings and published limited data, we may emphasize that the advantages of fURS-assisted mini-PCNL procedure could be stated as follows; it provides a high SFR without increasing CRs, reduces the need for additional

Table 3. Outcomes in Contemporary Mini-Endoscopic Combined Intrarenal Surgery Series

Study	*Type of study*	*No of patients*	*Position*	*Ureteroscope*	*Access*	*Stone size*	*Operation time (minutes)*	*No of tracts*	*SFR (%)*	*Hg drop*	*Double-J stent or nephrostomy*	*Hospitalization (days)*
Wen et al.[8]	RCT	67	PRONE-GMSV	URF-V Olympus	20F	Staghorn	105	1	88	77 mL	Both Double-J stent and nephrostomy	9.8
Yamashita et al.[13]	RS	75	PRONE SPLİT LEG	URF-P5/V Olympus	16.5F–19.5F	4.17 cm^2	124	1	69	1.3 g/dL	Both Double-J stent and nephrostomy	9
Leng et al.[12]	NRCS	87	OBLİQUE LİTHOTOMİC	URF-P5/V Olympus	16F–18F	Staghorn	87.5	1	79.5	1.6 g/dL	Both Double-J stent and nephrostomy	9.6
Zhao et al.[14]	RS	67	GMSV	US (7.5F)	16F–18F	640 mm^2	79.8	US	88	4.1 g/dL	Both Double-J stent and nephrostomy	3

GMSV, galdakao-modified supine valdivia; Hg, hemoglobin; NRCS, nonrandomized comparative study; RCT, randomized controlled trial; RS, retrospective study; SFR, stone-free rates; US, unspecified.

procedures, and reduces complications related to bleeding. Last but not least, precise assessment of stone-free status just after the procedure with the help of good evaluation of entire collecting system is the other important advantage of this approach.

It is well known that as a possible ''headache'' after endoscopic procedures, residual fragments and/or inaccessible fragments may occasionally be noted following PCNL procedures and such fragments could pose certain problems in the follow-up period both for the patients and endourologists. To overcome this problem during the PCNL procedures, either the number of tracts (along with the increasing invasiveness and risk of bleeding) or forced torquing of the nephroscope (during a single tract procedure) to reach other dependent calyces for stone removal will inevitably be required. This maneuver may well increase the risk of calyceal neck tear and subsequent bleeding.

However, as demonstrated in our study, effective application of fURS during and after PCNL will let us get the chance to reach all inaccessible calyces bearing stones to be removed. This will limit the extent of invasiveness and decrease the risk of severe complications such as bleeding and perforation.

On the contrary, use of fURS will enable the application of the so-called pass the ball technique during the PCNL procedure, which will let the endourologist capture the stones in the other (inaccessible) calyceal positions and give a nephroscope to remove them practically. This maneuver will limit the use of flexible scope by small movements in the kidney and prolong its life as well as not passing from the ureter in and out will limit the risk of ureteral injury.

Another more important advantage of this approach is ''endoscopy-assisted confirmation of stone-free status'' just after the procedure. Following the removal of the main burden of the stone(s) with PCNL, the remaining stones could be accessed and disintegrated by fURS without any difficulty. All relevant calyces could be accessed and stone-free status could be checked after the PCNL procedure. The stone-free status will be confirmed, and additional radiological evaluations, particularly with computed tomography, will be diminished and it will also limit the radiation exposure of the patients. Performing the mini-PCNL procedure through small-sized single access will give the chance of a ''tubeless PCNL'' approach, which can be finished without placing a nephrostomy tube after the procedure. This will certainly increase the life quality of the treated patient.

Conclusion

Our results and reported data so far indicate that residual fragments remaining after mini-ECIRS may have a significant impact on the patient's quality of life during the postoperative clinical course. During the mini-ECIRS procedure, the main aim needs to be to obtain a complete stone clearance by confirming well the absence of any residual fragment endoscopically at the end of the procedure. Mini-ECIRS performed with the Avicenna Roboflex system can enable the endourologist to extract all possible stone particles completely based on the advantages mentioned above.

Authors' Contributions

M.A.I.: Protocol/project development, data collection or management, data analysis, and article writing/editing. Z.T.:

Data collection or management and data analysis. K.S.: Protocol/project development, and article writing/editing. All authors read and approved the final version of the article.

Ethical Approval

All procedures performed in studies involving human participants were by the ethical standards of the Institutional and/or National Research Committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Data Availability

All datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Disclosure Statement

The authors have no potential or financial conflicts of interests to declare.

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