Original Article

Does tilt-retrograde intrarenal surgery enhance stone clearance and offer better surgical ergonomics in patients with renal calculi? A prospective randomized control study

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Abstract

Introduction: Retrograde intrarenal surgery (RIRS) is the standard treatment for renal calculi. Direct visualization and fragmentation are its major advantages. The variable stone clearance rates and the ergonomic challenges faced by urologists are a few limitations. Table tilt enhances stone clearance and improves surgical ergonomics by facilitating better access to stones and reducing procedural strain.

Subjects and Methods: In this prospective study, patients with intrarenal calculi were randomized into standard lithotomy RIRS (S-RIRS) and table-tilted RIRS (T-RIRS) groups. Specified table tilts were suggested for each of the stone locations. The outcomes with regard to stone clearance, operative and lasing time, and ergonomics were studied.

Results: About 100 patients were studied, with 50 in each group. The overall operating time and lasing time in the T-RIRS group were less than that in the S-RIRS group ($P < 0.001$). The complication rates were the same in both groups. Most surgeons felt that the surgical ergonomics was better in the T-RIRS group ($P < 0.001$). When stone-free status was analyzed, seven patients in the S-RIRS group and one in the T-RIRS group had residual stones. The mean Borg category-ratio 10 (CR-10) scores in the S-RIRS and T-RIRS groups were 4.18 and 2.20, respectively ($P < 0.001$).

Conclusions: This is the first study to document the distinct advantages of T-RIRS and its benefits on surgical ergonomics. T-RIRS resulted in significantly shorter operative and lasing times, particularly for stones in lower calyces. Surgical ergonomics, assessed by the Borg CR-10 scale, were significantly better in the T-RIRS group. T-RIRS should become a standard of care for patients undergoing RIRS.

Keywords: BORG category-ratio 10, laser, lithotripsy, retrograde intrarenal surgery, T-retrograde intrarenal surgery

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INTRODUCTION

The advent of retrograde intrarenal surgery (RIRS) has caused a paradigm shift in the management of intrarenal calculi. Increased usage of laser and its enhanced fragmentation, powdering, and dusting capabilities have

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greatly revolutionized the treatment of renal stones.[1,2] Extracorporeal shock wave lithotripsy, which was once popular among urologists, has largely become obsolete these days, due to its inherent limitations and also due to the selective advantage of stone fragmentation under direct vision.[3] However, RIRS also has its innate drawbacks. The relatively high cost of the procedure and achieving optimal stone clearance rates have always remained a challenge both for the patient and the treating urologist.[4,5] Reaching the lower calyceal stones and negotiating the acute infundibulopelvic angle have a long learning curve, that, in the past, has caused considerable damage to the flexible ureteroscopes and laser fibers, restricting their usage.[6] Similarly, fragmenting the stones in the upper calyx has its inherent limitations. Reaching up to the tall upper calyx may sometimes be difficult as the directions of the calyx could differ randomly. Inadequate fragmentation and steinstrasse of the fragmented stones are a few other limitations and complications of RIRS. However, with growing expertise and usage of innovative gadgets, various authors have shown excellent results for stones as large as 3.5 cm.[7]

While stones located in the upper and mid calyces are relatively easier to approach, stones in the lower calyx have always been a daunting task for urologists. The critical bend of the lower calyceal infundibulum, the acute infundibulo pelvic angle, narrow width, and longer length of the infundibulum pose considerable challenges to the urologist. Laser fiber perforating the tip of the flexible ureteroscope and causing damage to the scope is also not so uncommon.[8] Keeping the elbow and wrist flexed and upright for a longer duration might cause ergonomic challenges such as pain and stiffness of the elbow, wrist, and thumb of the operating surgeon.[9,10] Various innovations and modifications were suggested to circumvent these difficulties, especially while approaching the lower calyceal stones. Basketing and displacing the stone to the upper calyx or renal pelvis can obviate the need for an acute bend of the ureteroscope, thereby increasing its longevity.[11,12] Tilting the table onto one side can considerably improve the ergonomics of the surgeon. A craniocaudal tilt can enhance gravity-assisted stone clearance and also reduce the total operative time. Such maneuvers are simple and do not incur additional expenditure. Moreover, they offer additional comfort to the operating surgeon and enhance the ease of the procedure. Transverse tilt (T-tilt) (sideways) and craniocaudal tilt (CC-tilt) are a few positional modifications that could increase the rate of fragmented stone clearance.[13]

RIRS keeps evolving. Newer gadgets get added to the armamentarium, making this technique much more user-friendly. The advent of newer technologies such as flexible and navigable suction ureteral access sheaths (FANS), suction ureteral access sheaths (SUAS), and flexible vacuum-assisted ureteral access sheaths have revolutionized the treatment of renal calculi. These innovations also carry with them an extra expenditure. On the other hand, T-RIRS is a maneuver that carries no additional expenditure, can readily be done in the operating room and can be adjusted according to the comfort and ergonomics of the treating physician. In our study, we have suggested specific types of table tilts for each of the stone locations that could enhance stone accessibility, increase the rate of fragmentation/dusting, and ultimately augment the rate of stone clearance. The purpose of this study is to evaluate whether the tilted position is helpful in stone fragmentation and clearance and also to evaluate if it augments the surgical ergonomics of the treating urologist.

SUBJECTS AND METHODS

A prospective, randomized controlled study was carried out on 100 patients with intrarenal calculi from a tertiary care super specialty teaching institution. The study period was from October 2023 to March 2024. All procedures were done by experienced urologists with at least 10 years of experience after basic urology training and performing RIRS for more than 5 years. Two new Flexible (Karl–Storz Flex X^2) reusable ureterorenoscopes (one for each group) with a sheath circumference of 7.5 Fr and full dual 270° deflection and single lever control were used for the study. The study was conducted after ethical clearance.

Patients were randomized into two groups: Standard retrograde intrarenal surgery (S-RIRS) group comprised of patients who had RIRS done in a standard lithotomy position with no tilt. The T-RIRS group had RIRS done in the tilted position. The two groups were randomized by a simple randomization technique, with the odd and even numbers placed in S-RIRS and T-RIRS groups, respectively. Informed consent was taken from both groups. All patients in both groups were prestented 2 weeks before the main procedure only to maintain uniformity. However, primary RIRS is the usual standard of practice in other patients with accommodative ureters.

Demographic details including patients' age, sex, comorbidities, and spinal deformities were noted. Details of stone such as location, number, volume, and hardness were noted. The volume of the stone was calculated using the ellipsoid formula $\pi \times$ Length $\times$ Breath $\times$ Width $\times$ 0.167.[14] Radiographic details included the length and width of the infundibulum, pelvicalyceal angle (angle between the vertical line drawn across the middle of the renal pelvis and the line drawn through the long axis of the infundibulum of the calyx harboring the stone), degree of malrotation (if any) and presence or absence of hydronephrosis. Intraoperative details such as operative time, lasing time, type of stone fragmentation, and size of laser fiber used were noted. Postoperative details such as the presence or absence of residual fragments, stone-free rate, and complications if any were also recorded. All patients had a double J stenting done after the procedure and stents were removed after 2–3 weeks. Soon after the procedure, the Borg category-ratio 10 (CR-10) questionnaire handout was given to the urologist and his survey on surgical ergonomics for each of the patients was individually recorded soon after the surgery was completed. Follow-up assessments included a plain X-ray kidney, ureter, and bladder and an ultrasound abdomen. Stone-free rates at 1-month follow-up were defined as any residual stones <4 mm in size.

Figure 1 illustrates the method of randomization and the summary of patients included in our study. Patients with solitary stones in any of the calyces or renal pelvis were included in our study. Those with untreated urinary tract infections, pregnant women, patients with coagulopathy or on anticoagulants, larger stones more than 1.5 cm in size, severe kyphoscoliosis, stones with pelvic-ureteric junction obstruction, and secondary calculi were excluded from the study, although many of them underwent RIRS. Patients not willing for prestenting, or with multiple calculi were excluded from the study.

Patients from the S-RIRS group underwent RIRS in standard lithotomy position. For those in the T-RIRS group, positioning was done according to stone location, as mentioned in Table 1.

Table 1 illustrates stone locations and their corresponding table tilt. For the right renal calculi, the right side of the table was tilted upward (right up) and for the left renal calculi, the left side of the table was tilted up (left up). Cranio caudal tilt, CC+, and CC − indicated head-end elevation and head-end depression, respectively.

Figure 2 gives a schematic illustration of the types of tilt adopted for various stone locations. The table tiltings were done as per the stone locations mentioned in Table 1.

Figure 3 depicts the real-time positions recorded, whereas RIRS was in progress. The six positions [Figure 3a-f] correspond to the schematic illustrations mentioned above.

An initial trial study was conducted on 15 patients undergoing RIRS. Patients were positioned in lithotomy with varying degrees of T-tilt (10°, 20°, and 30°) and CC-tilt (+ or −). Various factors such as surgeon's ergonomics, anesthesiologist's comfort, and ease of access to stone were looked into, to decide on the optimal degree of table tilt for the main study. The 20° craniocaudal tilt was finally considered the optimal table tilt for the present study.

Surgical technique

All patients had stones fragmented using a 100W Holmium Laser System. Two flexible ureteroscopes were used, one for each group. The energy and frequency of lasing were initially set at 1J and 10 Hz, respectively, but it was very difficult to fix the same setting for the entire procedure, as the operating surgeons changed the settings in between according to the stone size, relative hardness, and their convenience. The S-RIRS group was positioned in a standard lithotomy position and the T-RIRS patients were positioned as per Table 1 specifications. The degree of tilt was measured using the measuring application software "Measure" on iPhone. Figure 4 illustrates the details of the software used in measuring the degrees of table tilt. The standard degree of right/left tilt or craniocaudal was 20°.

Statistical analysis

The quantitative variables were represented as mean ± standard deviation/median (interquartile range).

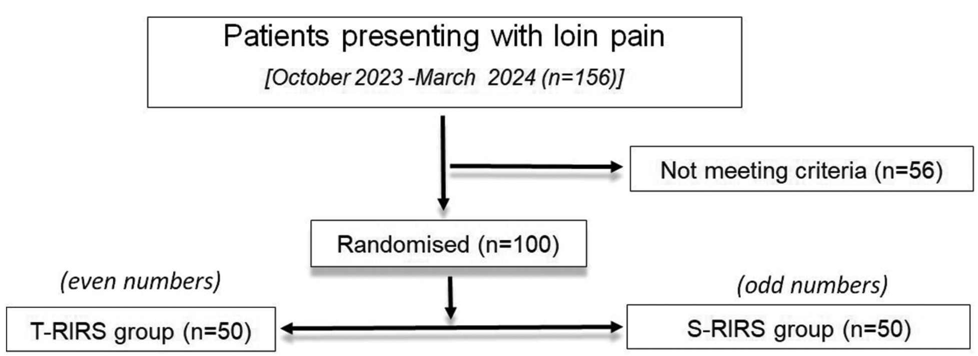

Figure 1: Randomization and summary of patients in the study. S-RIRS: Standard retrograde intrarenal surgery, T-RIRS: Tilt-retrograde intrarenal surgery

Qualitative variables were presented as numbers with percentages. The normality of the distribution of variables was assessed using Shapiro–Wilk test. The Student *t*-test was performed to compare continuous variables for normally distributed data. The nonparametric Mann–Whitney *U*-test was used to compare the continuous variables that had a skewed distribution. For the qualitative variables, the Chi-square test/Fisher's exact test was used to analyze the association. Two way ANOVA was used to find the changes in the quantitative measurement according to the levels of two categorical variables. Statistical analysis was performed using the SPSS software version 23.0 (SPSS Inc., Chicago, IL, USA). Statistical tests were two tailed and a $P < 0.05$ was considered statistically significant.

Table 1: Stone location and corresponding table tilts

Stone location	T-tilt	cc-tilt
Right kidney		
Upper calyx	Right up	CC+
Middle calyx	Right up	CC+
Lower calyx	Right up	CC−
Renal pelvis	Right up	CC+
Left kidney		
Upper calyx	Left up	CC+
Middle calyx	Left up	CC+
Lower calyx	Left up	CC−
Renal pelvis	Left up	CC+

T-tilt: Transverse tilt, cc-tilt: Craniocaudal tilt

RESULTS

A total of 100 patients with renal calculi were included in our study, with 50 patients in each of the groups.

Table 2 illustrates the demographic details. Both groups had a similar age and body mass index distribution. T-RIRS had more men than women, but there was no statistical difference between the two in the demographic profile, comorbidities, or congenital anomalies. The stones were also equally distributed among all calyces. There was no significant difference in the stone volume and density between the two groups.

Table 3 demonstrates the intraoperative details. The T-RIRS group had a significantly shorter overall operating time than the standard patients irrespective of the calyceal locations. The operating time for renal pelvic stones did not vary much between the two groups. The total lasing time was significantly shorter in T-RIRS, especially for the upper and lower calyceal stones and renal pelvic calculi. In

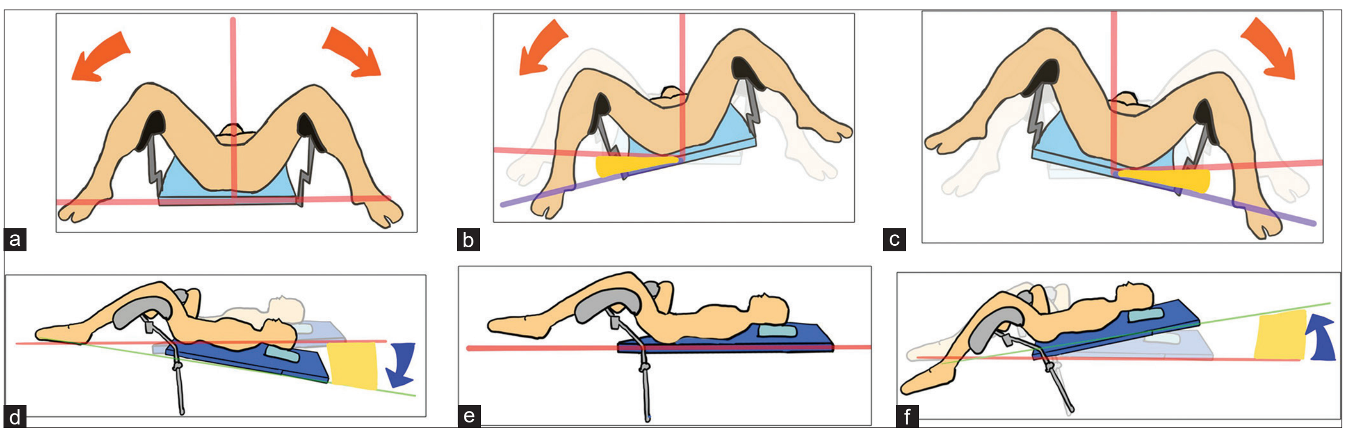

Figure 2: Schematic illustration of various positionings. (a) Standard lithotomy, (b) right transverse tilt (T-tilt) lithotomy, (c) left T-tilt lithotomy, (d) Cranio-caudal tilt (cc-Tilt) (−), (e) neutral lithotomy, (f) cc-Tilt (+)

Figure 3: Schematic and real-time positionings of patients. (a) Standard lithotomy, (b) right transverse tilt (T-tilt) lithotomy, (c) left T-tilt lithotomy, (d) Cranio-caudal tilt (cc-Tilt) (−), (e) neutral lithotomy, (f) cc-Tilt (+)

the S-RIRS group, the lower calyceal stones took almost twice the duration of lasing time than the stones in other locations. However, in T-RIRS, lasing time was almost fairly constant for all calyceal locations. Most stones in T-RIRS were treated by dusting, whereas most in S-RIRS were fragmented. The difference between the two groups was significant.

Table 2: Patient demographic and stone details

Characteristics	S-RIRS (*n*=50), *n* (%)	T-RIRS (*n*=50), *n* (%)	*P*
Age	45.48±4.122	45.26±5.134	0.814
Sex (male and female)			
Male	25 (50)	34 (68)	0.104
Female	25 (50)	16 (32)	
BMI	25.02±1.868	25.12±1.848	0.788
Comorbidities			
DM	10 (20)	13 (26)	0.5248
HT	9 (18)	13 (26)	0.6399
DM and HT	6 (12)	2 (4)	0.3099
None	25 (50)	22 (44)	0.7248
Laterality			
Right	19 (38)	26 (52)	0.159
Left	31 (62)	24 (48)	
Congenital anomalies (*n*)			
Ectopic kidney	0	1 (2)	0.3197
Malrotated kidney	1 (2)	1 (2)	1.000
Horseshoe kidney	1 (2)	2 (4)	0.5694
Kyphoscoliosis	1 (2)	1 (2)	1.000
Total (*n*)	3 (6)	6 (12)	0.295
Stone characteristics			
Location (*n*=50)			
Upper calyx	15 (30)	13 (26)	0.7743
Middle calyx	12 (24)	12 (24)	1.0000
Lower calyx	15 (30)	12 (24)	0.6623
Renal pelvis	8 (16)	13 (26)	0.4171
Other stone characteristics			
Volume (mm^3)	498.27±209.84	500.42±276.70	0.965
Density (HU)	1146.38±132.32	1126.22±144.14	0.468

HT: Hypertension, DM: Diabetes mellitus, S-RIRS: Standard retrograde intrarenal surgery, BMI: Body mass index, T-RIRS: Tilt retrograde intrarenal surgery

Table 4 illustrates that there is no significant difference in radiological findings between the two groups. The infundibular length and width, the extent of pelvicalyceal dilatation, and the infundibulopelvic angle were almost similar between the two groups.

Table 5 summarizes the residual stones in our study. About eight patients in S-RIRS and one patient in T-RIRS had residual fragments. Nearly 90% of residual stones (8 out of 9) were located in the lower calyx. Patients in the T-RIRS group had better stone clearance than those in the other group. Both groups had only mild complications and

Table 3: Intraoperative details

Characteristics	S-RIRS (*n*=50)	T-RIRS (*n*=50)	*P*
Operative time (min)			
Upper calyx	30.86±1.26	29.93±1.01	0.043
Middle calyx	42.46±1.59	30.00±0.62	<0.001
Lower calyx	54.62±2.97	31.06±0.57	<0.001
Renal pelvis	28.1±1.54	28.4±1.82	0.704
Overall (*n*=50)	37.93±11.29	29.82±1.46	<0.001
Lasing time (min)			
Upper calyx	9.61±0.77	8.13±1.06	0.0002
Middle calyx	9.13±1.04	8.6±0.78	0.178
Lower calyx	16.88±0.55	8.92±0.62	<0.001
Renal pelvis	5.6±0.70	5.9±0.66	<0.001
Overall (*n*=50)	11.03±4.16	7.86±1.42	<0.001
Type of stone fragmentation			
Dusting	10	44	0.0002
Fragmentation	40	6	0.0001

S-RIRS: Standard retrograde intrarenal surgery, T-RIRS: Tilt retrograde intrarenal surgery

Table 4: Radiological characteristics

Characteristics	S-RIRS (*n*=50)	T-RIRS (*n*=50)	*P*
Hydronephrosis, *n* (%)	3 (6)	4 (8)	0.695
Infundibular length (cm)	3 (2–4)	3 (2–4)	0.932
Infundibular width (mm)	4 (3–5.25)	5 (3–6)	0.318

S-RIRS: Standard retrograde intrarenal surgery, T-RIRS: Tilt retrograde intrarenal surgery

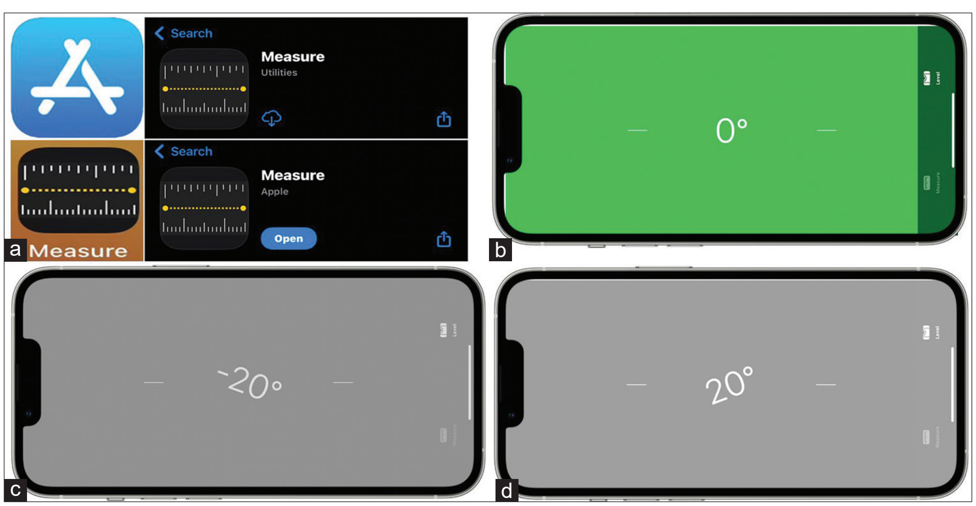

Figure 4: Device and application used. (a) The "measure" application on the iPhone was used, (b) Calibration is done to 0°, (c and d) table tilts were measured by placing the phone on the table

the overall complication rates did not differ much between the two groups.

The physical exertion by the treating urologist in getting the stone cleared was subsequently assessed by a standardized questionnaire. Table 6 illustrates the Borg CR-10 scores for both groups across all stone locations. From the table, we could infer that the overall urologist comfort was much better in the T-RIRS group and was statistically significant. However, the ergonomics were the same in both groups while treating stones in the middle calyx and renal pelvic calculi.

Table 7 compares the surgical outcomes of the two groups, with particular reference to the stones in lower calyx. When lower calyceal stones were pitted against the stones in all other calyces (combined), it was observed that the lower calyceal stones took a significantly longer time to fragment than the other location stones, especially in the S-RIRS group. On the other hand, T-RIRS took a significantly shorter time to fragment the lower calyceal stones ($P < 0.001$). The lasing time was shorter, improved ergonomics was perceived and better stone free rates were observed in the T-RIRS patients than the standard group ($P < 0.001$).

A two-way ANOVA test was carried out to study the effects of stone location with regard to various treatment outcomes. Stones in the lower calyx were pitted against stones in all other locations put together. It was observed that the lower calyceal stones in both groups took a longer time to be fragmented than the stones in other locations. When the mean operative time for the lower calyceal stones alone was studied, it was evident that the overall operative time was shorter in the tilt RIRS group ($P < 0.001$).

The lasing time was considerably higher for the lower pole stones in the S-RIRS group. However, in the T-RIRS patients, the lasing time was almost the same, irrespective of the stone location. Most surgeons felt that the lower calyceal stones were physically more challenging in the S-RIRS group. In the S-RIRS group, we observed that the physical exertion score was more than thrice that they had with stones in other calyces. On the other hand, in the T-RIRS group, the overall CR-10 score was minimal and was almost the same, irrespective of the location.

Stone-free status was poor in the lower calyceal stones of S-RIRS patients, whereas the tilt RIRS group demonstrated a good stone-free status in all calyces.

Table 5: Postoperative complications

Characteristics	S-RIRS (*n*=50), *n* (%)	T-RIRS (*n*=50), *n* (%)	*P*
Complications, if any (Clavien Dindo classification)			
Grade I	22 (44)	22 (44)	1.000
Grade II	28 (46)	28 (46)	1.000
Grade III–V	0	0	0
Residual fragments			
Upper calyx	0	0	NA
Middle calyx	1 (2)	0	1.000
Lower calyx	7 (14)	1 (2)	0.020
Renal pelvis	0	0	NA
Total (n=50)	8 (16)	1 (2)	0.014

NA: Not available, S-RIRS: Standard retrograde intrarenal surgery, T-RIRS: Tilt retrograde intrarenal surgery

Table 6: Ergonomics in retrograde intrarenal surgery

Characteristics	S-RIRS (*n*=50)	T-RIRS (*n*=50)	*P*
BORG CR score - mean (IQR)			
Upper calyx	2 (2–3)	1 (1–2.50)	0.010
Middle calyx	2.50 (2–3.75)	3 (2–4)	0.671
Lower calyx	8 (8–9)	2 (2–3)	<0.001
Renal pelvis	2 (1–3.75)	2 (0.5–3.5)	0.697
Total (*n*=50)	4.18±2.70	2.20±1.10	<0.001

IQR: Interquartile range, BORG CR10: Borg Category ratio, S-RIRS: Standard retrograde intrarenal surgery, T-RIRS: Tilt retrograde intrarenal surgery

Table 7: Comparison of surgical outcomes for stones in lower calyx versus all other locations (upper and middle calyces and renal pelvis)

Location of stone	Details		
	S-RIRS (*n*=50)	T-RIRS (*n*=50)	*P*
Operative time (min)			
Lower calyx (*n*=27)	54.62±2.97	30.45±2.30	<0.001
Other locations (*n*=73)	30.78±2.16	29.43±2.67	0.003
P	<0.001	0.082	
Lasing time (min)			
Lower calyx	16.88±0.55	8.52±0.69	<0.001
Other locations	8.53±0.90	7.99±1.45	0.028
P	<0.001	0.072	
Ergonomics (BORG CR10 score)			
Lower calyx	8.07±0.74	2.42±0.51	<0.001
Other locations	2.51±0.88	2.13±1.23	0.070
P	<0.001	0.2389	
Stone-free status			
Lower calyx (*n*=15+12=27)	8/15	11/12	0.0433
Other locations (*n*=35+38=73)	34/35	38/38	0.479
P	<0.001	0.24	

BORG CR10: Borg category ratio, S-RIRS: Standard retrograde intrarenal surgery, T-RIRS: Tilt retrograde intrarenal surgery

Figure 5 illustrates the patient positioning for RIRS for the right lower polar calculus. The instruments used in the tilt position (right UP and CC+) are depicted.

DISCUSSION

The primary aim of RIRS is to render the patient stone free. The secondary aim is to achieve that stone-free status

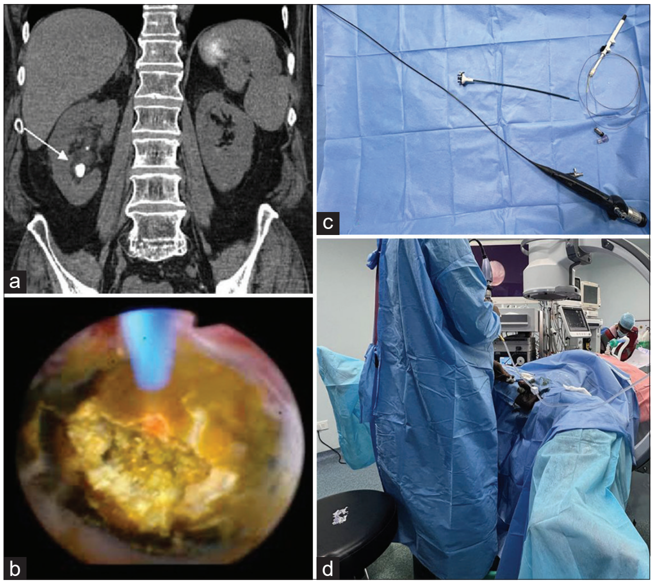

Figure 5: Real-time tilt-retrograde intrarenal surgery (T-RIRS) in progress. (a) Computed tomography showing the lower polar stone, (b) Stone fragmentation in progress, (c) flexible ureteroretinoscope FLEX-X2S used in our study, (d) real-time patient positioning for T-RIRS

without any complications, or causing discomfort to the treating physician. Various studies have shown good results after RIRS. Stone-free status of 50%–94.2% after RIRS has been reported.[15] Such wide ranges may be due to multiple factors. The use of various energy sources and laser settings, variations in the sizes of stones fragmented and usage of different dimensions for clinically significant residual fragments have all been attributed to this wide range of stone-free status.[16] Various authors have defined clinically significant residual stones as 2,3, and 4 mm in size.[17-19] In our study, a stone size of 4 mm at the end of 3 months was considered for defining stone-free status.

The stone location between the two groups is almost similar. The stone burden in both groups was almost the same. Similarly, the stone density did not differ much between the two groups. The radiological findings such as infundibular length and diameter and infundibulopelvic angle were similar between the two groups. This implies that the statistical analysis is unbiased between the two groups about the rate of fragmentation, mean operating time, and residual fragments. Table 3 indicates that the overall mean operative time was lesser in the tilt RIRS group than the standard lithotomy, irrespective of the location in the calyces. It may be that gravity-assisted drainage enhances the rate of stone clearance and also makes the stone fragments easily accessible for fragmentation. Moving the stone to a favorable calyx would also enhance fragmentation and clearance. Schuster *et al*., in their study on 78 patients with lower calyceal stones, observed that stone displacement into a favorable calyx makes it easier to access and fragment, thereby enhancing stone clearance.[20] Another review by Inoue *et al*. indicated that the dusting technique is becoming increasingly popular in the Western world because of the difficulty in fragmentation and basketing.[21] It was also observed that more stones were dusted and powdered in the T-RIRS than in the standard group. El-Nahas reported a shorter overall operating time with the dusting group and a greater stone-free status with the fragmentation group.[22] Humphreys *et al*., in their study on 159 patients divided into dusting and fragmentation groups, observed that the short-term stone-free status was higher in the fragmentation group than in the dusting group. However, the multivariate analysis did not show any significant difference between the two modalities of stone clearances.[23]

Most of the patients in both groups had mild complications such as fever, pain, and mild hematuria. The complication rates between the two groups were almost similar and minimal. The overall complication rates after RIRS were 26.1%.[24] Zhang *et al*. observed that the infection-related complications after RIRS were around 7.1%.[25,26] In their study, the mean operating time and the stone size were independent risk factors for complications after RIRS. A systematic review by Grosso *et al*. observed that the overall complications after RIRS were 11.5%, whereas that after percutaneous nephrolithotomy (PCNL) was only 8.5%.[27]

Residual fragments following RIRS pose a real challenge to the treating urologists. The actual success of a stone surgery is reflected by the number of residual stones present after the procedure. The PCNL, although more invasive than RIRS, is preferred by most urologists even today, given the ability to clear the stone completely and rapidly. Residual stones gather more importance, as these fragments cause infection, and obstruction and form a nidus for new stone formation in the future. Various scoring systems preoperatively predict the postoperative stone-free rates.[6,28] Although each study claimed success for their scoring systems, the subsequent meta-analysis did not show any significant superiority of one over the other.[2] Wang *et al*., in their study on 147 patients, observed that the application of the RIRS scoring system accurately predicted the stone-free status after surgery.[29] In our study, we observed that 90% of residual fragments occurred in lower calyceal stones. Furthermore, the residual stone rate in the tilted group was significantly lesser than the standard group.

The location of the stone plays a significant role in the overall operative time, lasing time, stone-free status, and ergonomics of the treating urologist. Sorokin *et al*. observed that the lower calyceal stones took a longer time to be fragmented.[30] In our study too, the overall operative time was longer in the lower pole stones. We also observed that the T-RIRS group had a significantly shortened mean operative time than the standard ones. Similarly, the lasing time was also significantly prolonged in the lower calyx, but in the tilt RIRS group, the lasing time was drastically reduced.

With RIRS establishing itself as the standard of care, further studies focused on maximizing the outcomes of the procedure. As most urologists prefer to stand while performing RIRS, and as the wrist of the surgeon is held almost at chest level and the neck obliquely tilted toward the monitor, a prolonged procedure could cause a considerable ergonomic hazard for the treating physician. Rolling the thumb and the wrist while treating lower calyceal stones also caused considerable occupational hazards. Accessing the lower calyceal stone, negotiating the long narrow infundibulae, and getting the laser fibre across the acutely bent ureteroscope have many a time resulted in inadequate fragmentation, defective stone clearance, or damage to ureteroscopes.

Ergonomics is one area that is given lesser attention by urologists performing RIRS. As most urologists do the procedure in a standing posture, surgeons performing RIRS must have robust physical health, resilient mental stability, strong shoulders, powerful legs, and flexible wrists. Borg developed the Borg CR10 scoring system, a CR scale ranging from 1 to 10. It is a general intensity scale with special anchors to measure exertion and pain. The Borg rating of perceived exertion CR (Borg CR-10) scale was calculated based on the treating urologists' experiences with different table tilts.[31] A score of at least 4 on the Borg CR10 scale seemed to indicate high muscular loading was occurring and a score of 10 represented an extreme intensity of activity.

Gabrielson *et al*. observed that poor ergonomics can have deleterious effects on the physical and psychological well-being of the urologists.[32] In our study, the Borg CR score questionnaire survey on the urologists helped us to assess if any of the positional tilts were ergonomically favorable in getting the stones fragmented and cleared. Although most urologists recorded a higher Borg score while treating lower calyceal stones, the tilted group showed a lower score while treating the stones in the lower calyx. To date, no other study has objectively documented the ergonomic challenges while performing RIRS. All urologists in our study observed that in the tilt RIRS group, it was easier to access the stones with less bending of the tip of the scope. Although we are not able to objectively document this finding, considering the lesser flexion of the thumb while bending the tip of the scope, lesser rotation of the wrist observed, and the experience of the surgeons, we could at the most assume that the degree of manipulation of the scope may be a lot lesser in the Tilt RIRS than the standard group. However, an objective documentation of this data would add more value to our study.

The end goal of RIRS should be to enhance and optimize the stone clearance rates while ergonomically not compromising the physical status of the treating urologist. The T-RIRS group had a higher stone clearance rate and also had better surgical ergonomics for the treating physician.

Limitations

However, there are a few limitations that we observed in our study.

1. Only solitary stones were studied, which could be a major drawback as many patients present with multiple calculi
2. Many young urologists are performing RIRS these days. As our study is done by surgeons with 10 years of endourology and 5 years of RIRS experience, such high stone clearance rates cannot be extrapolated to the results of young aspiring urologists performing RIRS
3. All RIRS were done in prestented patients, especially for the ease of study and for uniformity. However, the real-time scenario may be different
4. The CR-10 questionnaire survey was conducted on urologists in the age group of late thirties. An ergonomic survey on surgeons performing RIRS, who are aged 45 years and above, would be more relevant and informative.

CONCLUSIONS

RIRS has now been established as the standard of care for the treatment of renal calculi. Ours is the first-ever study to objectively document the advantages of T-RIRS and simultaneously evaluate its benefits on surgical ergonomics. T-RIRS is a safe, surgeon-friendly and cost-effective procedure that can be readily modified according to the comforts and needs of the treating urologist. T-RIRS significantly enhances stone accessibility, reduces overall operative time, augments stone clearance, and offers better surgical ergonomics to the treating surgeon. T-RIRS should be now considered the standard of care in patients undergoing RIRS for renal calculi.

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Conflicts of interest

There are no conflicts of interest.

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