Wideband Doppler Ultrasound-guided Mini-endoscopic Combined Intrarenal Surgery as an Effective and Safe Procedure for Management of Large Renal Stones: A Preliminary Report

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OBJECTIVE To evaluate the efficacy and safety of wideband Doppler ultrasound-guided mini-endoscopic combined intrarenal surgery (mini-ECIRS) for large renal stones.

MATERIALS AND METHODS This study included 41 patients with large renal stones (>30 mm) treated by mini-ECIRS using a retrograde flexible ureteroscope and miniature nephroscope by wideband Doppler ultrasound guidance in the modified Valdivia position from January 2013 to September 2015. Surgical parameters, including the stone-free rate, operative time, complications (especially hemorrhagic complications), and hemoglobin drop were recorded and analyzed. Univariate analysis was performed to identify risk factors for a hemoglobin drop of ≥1 g/dL.

RESULTS The mean stone size, including staghorn calculi in 41.4% of cases, was 45.5 ± 14.7 mm. Percutaneous access into the calices using wideband Doppler ultrasound was successful in all cases. The mean total operative time was 158.4 ± 51.3 minutes. The mean mini-ECIRS time (from first percutaneous puncture to end of procedure) was 106.2 ± 36.0 minutes. The initial stone-free rate was 73.2% (n = 30). The final stone-free rate after auxiliary treatment was 97.5% (n = 40). The mean hemoglobin drop was 0.54 ± 0.65 g/dL. Three (7.3%) postoperative modified Clavien grade II complications occurred. Univariate analysis revealed no significant risk factors for a hemoglobin drop of ≥1 g/dL.

CONCLUSION Wideband Doppler ultrasound-guided renal puncture is safe and feasible. Wideband Doppler ultrasound-guided mini-ECIRS is a beneficial, versatile, and safe treatment option for management of large renal stones of >30 mm. UROLOGY 95: 60–66, 2016.

Percutaneous nephrolithotomy (PCNL) was first introduced as a minimally invasive modality in 1976. It has since remained the gold standard treatment for large renal stones of >20 mm.[1,2] However, despite the high stone-free rate (SFR), investigators have reported a high incidence of complications (20.5%-83.0%).[3,4] Bleeding is the most troublesome of these complications and can occur due to mispuncture of major vessels (such as interlobar arteries), tract creation, renal mucosa laceration due to stone manipulation, and postoperative pseudoaneurysm formation.[5] In several reports, the perioperative hemoglobin drop after standard PCNL using a ≥ 24F tract was 1.66 to 2.33 g/dL.[6-8] However, the risk of bleeding in some novel techniques, such as minimally invasive PCNL (mini-PCNL), ultramini-PCNL, and micro-PCNL, which are characterized by a reduced tract sheath size, is lower than that in standard PCNL.[9,10] In contrast, the decreased size of the scope and tract sheath increases the operative times for management of large renal stones, resulting in systemic absorption of irrigation fluid due to elevated intrapelvic pressure in the prone position.[10,11] The combination of retrograde intrarenal surgery (RIRS) and mini-PCNL, termed minimally invasive endoscopic combined intrarenal surgery (mini-ECIRS), recently showed better outcomes than mini-PCNL alone for large renal stones of >30 mm.[12]

To decrease the risk of intraoperative and postoperative renal hemorrhage, the most important process during PCNL is the establishment of ideal caliceal access for tract creation. Generally, percutaneous caliceal puncture aims

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for the fornix of the target calyx because this area contains fewer blood vessels. However, hemorrhage may occur, albeit rarely, despite puncture into the fornix of the target calyx. Recognition of the blood vessel paths within the renal parenchyma is usually impossible even with fluoroscopic or B-mode ultrasound guidance. Lu et al[5] reported that the use of color Doppler ultrasound guidance for puncture of the target calyx allowed for real-time detection and avoidance of renal blood vessels and decreased the incidence of hemorrhagic complications. However, compared with the real vessel size, color Doppler and power Doppler ultrasound cause the blood vessels to appear thicker and more protruding (blooming appearance). Therefore, more sensitive puncture of the target calyx for avoidance of renal blood vessels such as interlobar arteries is difficult.[5,13] Wideband Doppler ultrasound suppresses the blooming appearance and displays a clearer picture of how the blood vessels run throughout the tissue in real time than do color Doppler and power Doppler.

In this study, we selected the renal puncture line using wideband Doppler ultrasound and performed mini-ECIRS for large renal stones (>30 mm). We evaluated the efficacy and safety of this technique.

MATERIALS AND METHODS

Preoperative Evaluation and Settings

We retrospectively analyzed 41 patients in our prospective database who underwent mini-ECIRS using wideband Doppler ultrasound for management of renal stones (>30 mm) from January 2013 to September 2015 at the Department of Urology and Stone Center, Kansai Medical University Takii Hospital, Osaka, Japan. Our institutional review board approved this study. All patients provided written informed consent.

All patients were evaluated preoperatively by obtaining a medical history and performing a clinical examination, routine laboratory tests, including measurement of the hemoglobin concentration and estimated glomerular filtration rate (eGFR), and performance of imaging examinations, such as plain X-rays of the kidney, ureters, and bladder (KUB); computed tomography; abdominal ultrasonography; and intravenous urography. The stone size and location were reviewed on the imaging series. The size of simple stones was measured by the long axis of the stone, and the size of multiple renal stones was measured by adding the length of the longest axis of each stone. We routinely administered an antibiotic (flomoxef sodium 1 g) 30 minutes before surgery in patients with a negative urine culture, and we usually administered an appropriate antibiotic based on the result of the positive urine culture starting the day before surgery. Patients who were taking an anticoagulation agent withdrew the agent for an appropriate duration before surgery.

Percutaneous caliceal puncture during the procedure was performed using wideband Doppler ultrasound (Aplio 300 TOSHIBA Ultrasound System, Japan, or α7 Aloka Ultrasound System, Japan). Wideband Doppler ultrasound provides a blood flow image with high resolving power and improved spatial resolution and time resolution. Wideband Doppler ultrasound suppresses the blooming appearance and displays a clearer image of the path of the blood vessels in real time than do conventional color Doppler and power Doppler. Therefore, this method can be used to accurately visualize peripheral vascular flow (Fig. 1A-C).

Operative Technique

All procedures were performed under general anesthesia in the modified Valdivia position (semi-supine combined lithotomy position), allowing for simultaneous antegrade and retrograde access. The procedure was performed by 2 surgeons; 1 performed antegrade mini-PCNL and the other performed RIRS. Mini-PCNL in all procedures was performed by a single surgeon. First, using a retrograde approach, a semi-rigid ureteroscope was inserted into the ureter of the diseased side with a 0.035-mm guidewire, and the lower and middle ureters were observed to confirm the presence of stones and predict a usable size of ureteral access sheath (UAS). If no stones were found in the ureter, a UAS of size 9.5/11.5F (Flexor; Cook Medical, Bloomington, IN) or 11/13F (Navigator HD; Boston Scientific, Marlborough, MA) was placed near the ureteropelvic junction under fluoroscopic guidance. A flexible

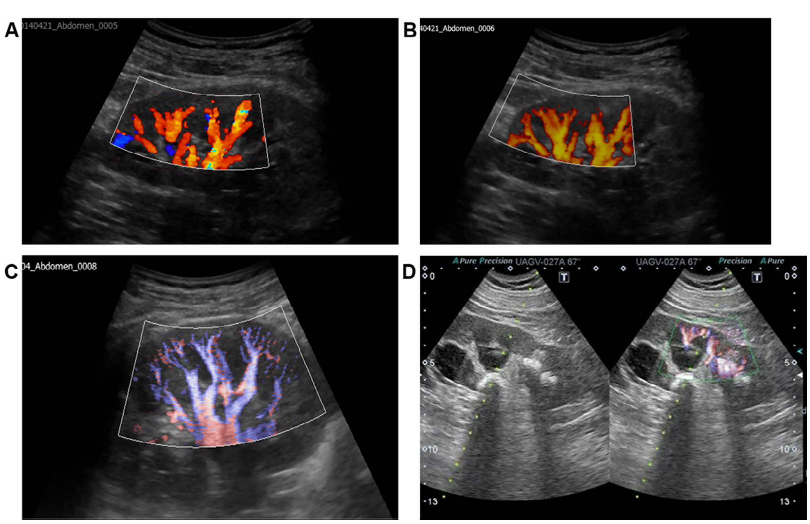

Figure 1. Doppler ultrasound images in same ultrasound system. **(A)** Color Doppler mode; **(B)** power Doppler mode; **(C)** wideband Doppler mode; **(D)** twin-view image of B-mode and wideband Doppler modes during puncture. Percutaneous puncture was performed in real time to detect and avoid renal blood vessels. (Color version available online.)

ureteroscope (URF-P6; Olympus, Tokyo, Japan, or FLEX-X^2; Karl Storz, Tuttlingen, Germany) was inserted through the UAS to confirm the stones in the pelvis and the target calyx for antegrade puncture. If the UAS could not be inserted near the ureteropelvic junction because of large ureteral stones, RIRS was initially performed to treat the ureteral stones using a holmium laser. Second, using an antegrade approach, the target calyx was confirmed using B-mode ultrasound, and the path of the blood vessels in the same renal parenchyma was confirmed in real time using wideband Doppler ultrasound. When puncturing the target calyx, the ultrasound screen was converted to a twin-view image (Fig. 1D). The target calyx was punctured in 2 steps. An 18-gauge coaxial needle was first used to puncture the renal capsule, and a 22-gauge coaxial needle was then inserted into the outer cylinder of the 18-gauge coaxial needle and used to puncture the renal parenchyma until the target calyx was reached. This technique provides the 22-gauge coaxial puncture needle with a stable axis, which allows for finer puncture of the target calyx. After successful puncture, an 18F or 19.5F mini-PCNL tract (Karl Storz) was created under fluoroscopic guidance. A 12F miniature nephroscope (LithoClast; Boston Scientific Japan, Tokyo, Japan) and a holmium laser were then used to disintegrate the renal stones. The fragments were actively flushed out of the collecting system by irrigation fluid, or extracted using nitinol baskets. Renal stones that could not be reached by percutaneous procedures were disintegrated using flexible ureteroscopy and laser lithotripsy. The almost-disintegrated fragments were passed to the percutaneous tract with flexible ureteroscopy and removed through the percutaneous tract sheath. At the conclusion of the procedure, an indwelling 6F ureteral stent was placed in the urinary tract, and a 14F or 16F nephrostomy tube was inserted. If no residual fragments were seen on the image, the nephrostomy tube was clamped the next day and removed 2 to 3 days after surgery. The ureteral stent was removed 1 to 2 weeks later.

Postoperative Evaluation and Analysis

The day after surgery, all patients were evaluated by routine laboratory tests including determination of the hemoglobin concentration and eGFR and performance of urinalysis, ultrasonography, and KUB X-rays. A stone-free status was defined as <4-mm residual fragments on KUB X-rays and ultrasonography at 1 day and 1 month postoperatively. If ≥5-mm residual fragments were present on KUB X-rays and ultrasonography 1 day postoperatively, auxiliary treatment was performed 1 week postoperatively. We prospectively recorded the perioperative data and intraoperative and postoperative complications. In this study, we defined a hemoglobin drop of ≥1 g/dL as severe bleeding. Univariate analysis was performed to identify risk factors for a hemoglobin drop of ≥1 g/dL. Postoperative complications were graded according to the modified Clavien classification system. SPSS version 21 (IBM Corp., Armonk, NY) was used to analyze the collected data. The mean ± standard deviation was calculated, and Pearson's chi-square test and the Mann-Whitney *U* test were performed as appropriate. Statistical significance was defined as a *P* value of <.05.

RESULTS

The patient and stone demographics are summarized in Table 1. The mean patient age was 59.1 ± 11.8 years. The mean stone size was 45.5 ± 14.7 mm, including 26.8% (n = 11) partial staghorn calculi and 14.6% (n = 6) complete staghorn calculi. All 41 patients underwent successful percutaneous access of the target calyx in the modified Valdivia position under ultrasound guidance. The treatment outcomes are summarized in Table 2. The distance between the skin and renal capsule, measured ultrasonographically during percutaneous puncture, was 51.9 ± 21.7 mm. The mean number of attempts until successful puncture of the target calyx was 1.8, and most successful punctures were of the middle calyx (75.6%). All procedures were successfully performed using a single tract with an 18F (73.1%) or 19.5F (26.9%) tract sheath size and combined RIRS. The initial SFR was 73.2% (n = 30). Auxiliary treatments were performed in 10 cases of residual stones, including 9 second ECIRS procedures for treatment of 4 complete staghorn calculi, 4 partial staghorn calculi, and 1 non-staghorn calculus, and ureteroscopy for 1 non-staghorn calculus. As a result, the final SFR was 97.5% (n = 40). The total operative time (from cystoscopy to the end of the procedure) was 158.4 ± 51 minutes. The total

Table 1. Patient and stone demographics

	Wideband Mini-ECIRS (n = 41)
Sex (male or female)	28/13
Age (years)	59.1 ± 11.8
BMI (kg/m^2)	25.1 ± 4.3
ECOG performance status	
0	32 (78.0)
1	4 (9.7)
2	3 (7.3)
3	2 (5.0)
4	0 (0.0)
Hemoglobin (g/dL)	13.6 ± 2.0
eGFR (ml/min/1.73 m^2)	69.5 ± 20.5
Positive preoperative urine cultures	21 (51.2)
History of renal operations	
Shockwave lithotomy	6 (14.6)
Retrograde intrarenal surgery	9 (21.9)
Percutaneous nephrolithotomy	2 (4.8)
Open surgery	2 (4.8)
Preoperative interventions	
Stent	7 (17.1)
Nephrostomy	0 (0.0)
History of anticoagulation	
Antiplatelet agent	5 (12.1)
Anticoagulant agent	0 (0.0)
Stone location	
U1	0 (0.0)
R2	29 (70.7)
R3	12 (29.2)
Stone shape	
Non-staghorn	24 (58.5)
Staghorn	17 (41.4)
Complete staghorn	6 (14.6)
Partial staghorn	11 (26.8)
Stone size (mm)	45.5 ± 14.7
Stone CT value (HU)	1106.8 ± 322.1

BMI, body mass index; CT, computed tomography; ECIRS, endoscopic combined intrarenal surgery; ECOG, Eastern Cooperative Oncology Group; eGFR, estimated glomerular filtration rate; HU, Hounsfield unit.
Data are presented as mean ± standard deviation or n (%).

Table 2. Treatment outcomes

	Wideband Mini-ECIRS (n = 41)
Number of attempts until successful puncture of target calix is achieved	1.8 ± 1.3
Skin to renal capsule distance using ultrasound (mm)	51.9 ± 21.7
Number of calices punctured	
Upper calix	2 (4.8)
Middle calix	31 (75.6)
Lower calix	8 (19.5)
Type of ureteral access sheath	
Sheathless	2 (4.8)
9.5/11.5F	23 (56.1)
11/13F	16 (39.1)
Number of tracts	
Single	41 (100.0)
Multiple	0 (0.0)
Tract size	
18F	30 (73.1)
19.5F	11 (26.9)
Total operative time (min)	158.4 ± 51.3
Total mini-ECIRS time (min)	106.2 ± 36.0
Fluoroscopy time (s)	336.4 ± 169.7
Stone-free rate	
Initial (1 day postoperatively)	30 (73.2)
Final (1 month postoperatively)	40 (97.5)
Auxiliary treatments	
Second ECIRS	9 (21.9)
Retrograde intrarenal surgery	1 (2.4)
Shockwave lithotomy	0 (0.0)
Comparison of preoperative and postoperative data	
Hb drop (g/dL)	0.54 ± 0.65
With use of 18F tract (g/dL)	0.63 ± 0.66
With use of 19.5F tract (g/dL)	0.39 ± 0.70
eGFR drop (mL/min/1.73 m^2)	2.0 ± 9.8
Complications	
Fever of ≥38.5°C	3 (7.3)
Adjacent organ injury	0 (0.0)
Pelvic extravasation	0 (0.0)
Perirenal urinoma	0 (0.0)
Transfusion	0 (0.0)
Significant bleeding (Hb drop of ≥2 g/dL)	0 (0.0)
Hb drop of ≥1 g/dL	10 (24.4)
Clavien grade classification	
I	0 (0.0)
II	3 (7.3)
IIIa	0 (0.0)
IIIb	0 (0.0)
IV	0 (0.0)
V	0 (0.0)
Hospitalization (days)	12.8 ± 7.3

Hb, hemoglobin; other abbreviations as in Table 1.
Data are presented as mean ± standard deviation or n (%).

mini-ECIRS time (from insertion of the puncture needle to the end of the procedure) was 106.2 ± 36.0 minutes.

The mean hemoglobin drop was 0.54 ± 0.65 g/dL. The maximum hemoglobin drop was 2.0 g/dL. The mean hemoglobin drop with use of an 18F and 19.5F sheath size was 0.63 ± 0.66 g/dL and 0.39 ± 0.70 g/dL, respectively, with no significant difference (P = .443). No patient required a blood transfusion. The mean eGFR drop was 2.0 ± 9.8 mL/min/1.73 m^2. Postoperative fever (>38.5°C) occurred in 3 patients (7.3%, Clavien grade II). No major complications such as adjacent organ injury, pelvic extravasation, or perirenal urinoma occurred.

Univariate analysis revealed no significant risk factors for a postoperative hemoglobin drop of ≥1 g/dL (Table 3).

COMMENT

In the present study, wideband Doppler ultrasound-guided mini-ECIRS was a useful and safe procedure for the management of large renal stones. Although standard PCNL usually uses a 24F to 30F percutaneous tract sheath, some investigators recently reported that a larger tract sheath size is associated with a higher bleeding risk.[14] Kukreja et al[6] reported that the mean hemoglobin drop associated with the use of a <22F and >26F tract sheath was 1.1 ± 0.7 g/dL and 1.66 ± 1.1 g/dL, respectively (P = .002). Yamaguchi et al[15] reported that the incidence of blood transfusion associated with the use of an <18F, 24-26F, 27-30F, and 32-34F tract sheath was 1.1%, 4.8%, 5.9%, and 12.1%, respectively (P < .0001). Therefore, mini-PCNL, which uses a smaller tract sheath, was introduced to decrease the bleeding risk. Mini-PCNL is performed using a 16F to 20F tract sheath and a 12F miniature nephroscope. Sabnis et al,[16] who performed mini-PCNL through an 18F to 19.5F percutaneous tract sheath for 32 patients with renal stones with a mean size of 15.2 mm, found that the mean hemoglobin drop was 1.43 ± 1.01 g/dL. Shah et al,[10] who performed ultramini-PCNL using a 13F tract sheath for treating renal stones with a mean size of 26.6 ± 4.7 mm, found that the mean hemoglobin drop was 1.2 ± 0.3 g/dL. Furthermore, Armagan et al[17] performed micro-PCNL using an 8F tract sheath for treating renal stones with a mean size of 17.9 ± 5.0 mm and found that the mean hemoglobin drop was 1.1 ± 0.8 g/dL. The advantages of a smaller tract sheath are less bleeding and fewer hemorrhage complications. However, a smaller tract sheath, nephroscope, and working channel increase the operative time and may limit the indication for the procedure with respect to stone size. A smaller tract sheath may also cause postoperative fever because of high renal pelvic pressure and possible absorption of microorganisms from the fragmented calculi.[10,18] We performed wideband Doppler ultrasound-guided mini-ECIRS in the modified Valdivia position to overcome these disadvantages, diminish the bleeding risk, ensure a high SFR, and decrease the risk of postoperative urinary infection.

Percutaneous caliceal puncture during PCNL generally aims for the fornix of the target calyx. However, bleeding may occur despite puncture of this fornix. Therefore, most investigators have suggested that the best entry into the desired calyx would be through Brodel's line. It is difficult to distinguish this avascular plane using fluoroscopy or B-mode ultrasonography.[7] In several studies, the hemoglobin drop during PCNL by fluoroscopy and

Table 3. Factors associated with postoperative Hb decrease of ≥1 g/dL

	Hb Decrease of <1 g/dL (n = 31)	Hb Decrease of ≥1 g/dL (n = 10)	Univariate Analysis (*P* Value)
Age (years)	58.5 ± 15.1	55.9 ± 14.6	.393
Sex			.894
Male	21	7	
Female	10	3	
BMI (kg/m^2)	25.3 ± 4.6	24.5 ± 3.3	.482
History of anticoagulation			.386
Yes	3	2	
None	28	8	
Skin to renal capsule distance using ultrasound (mm)	50.9 ± 24.5	55.2 ± 8.7	.081
Mini-ECIRS time (min)	102.5 ± 34.0	117.0 ± 40.1	.622
Punctured calix			.71
Middle calix	23	8	
Other calix	8	2	
Tract size			.575
18F	22	8	
19.5F	9	2	

Abbreviations as in Tables 1 and 2.
Data are presented as mean ± standard deviation or n.

ultrasonography guidance was reportedly 1.10 to 2.16 g/dL and 1.20 to 2.33 g/dL, respectively.[6,8,19] These hemoglobin drops occurred because more bleeding is associated with a larger tract sheath size. In 1989, McNamara[20] first reported the performance of percutaneous procedures using color Doppler ultrasound mode. Doppler ultrasonography has a power Doppler mode that displays the magnitude of vascular flow and a color Doppler mode that displays the running of vascular flow. These Doppler modes can show the vascular flow in real time. Using these Doppler modes for puncture of the target calyx might result in easy detection and avoidance of renal blood vessels such as interlobar arteries and veins and arcuate arteries and veins. Tzeng et al,[7] who performed PCNL through a 30F tract sheath using B-mode or power Doppler ultrasound guidance, found that the hemoglobin drops associated with each method were 2.33 ± 0.46 g/dL and 1.47 ± 0.61 g/dL, respectively. Thus, Doppler ultrasonography is a beneficial method with which to decrease hemorrhagic complications. However, color and power Doppler ultrasound have some weaknesses. First, the blood vessels shown by these Doppler modes are thicker than the actual size because of the blooming appearance. Therefore, it is difficult for some physicians to identify an accurate puncture line in the renal parenchyma that will avoid major vessels. Second, when performing the puncture under color or power Doppler in real time, the tip of the puncture needle exhibits halation and the puncture needle cannot be seen on the ultrasound screen. To overcome these weak points, we punctured the target calyx by combining wideband Doppler and B-mode ultrasound on a twin-view image. Wideband Doppler ultrasound suppresses the blooming appearance and clearly displays peripheral blood vessels. Furthermore, the twin-view image, which shows wideband Doppler ultrasound on 1 screen and B-mode on the other screen, can avoid halation of the tip of the puncture needle. We also performed a 2-step puncture to reduce the blur of the tip of the puncture needle, ensuring a delicate puncture. Consequently, the mean hemoglobin drop in the present study was 0.54 ± 0.65 g/dL, which is lower than in other reports (Table S1). This method may be 1 option that allows safe puncture of the target calyx because of the ability to capture an accurate and objective view of the blood vessel path. However, if there is a large distance between the skin and renal capsule on ultrasonography, the path of the blood vessels within the renal parenchyma can be difficult to discern because the ultrasonic waves cannot penetrate deeply enough. In the present study, although the hemoglobin drop tended to increase (≥1 g/dL) when the distance between the skin and renal capsule was >55.2 mm, likely because the ultrasonic waves could not reach the renal parenchyma, that distance was not significant.

Although a fluoroscopy- or ultrasound-guided approach for percutaneous renal access is the usual method, precise percutaneous renal access remains challenging. Several approaches were recently reported to allow easy and safe puncture of the renal collecting system. These methods include 3-dimensional CT guidance, marker-based navigation systems, real-time electromagnetic tracking systems, and electronically instrumented needles.[21-24] There is now high expectation for the efficacy of these methods.

Generally, the first treatment option for large renal stones may be standard PCNL, which is superior to mini-PCNL. However, Knoll et al[25] reported similar SFRs of 96% and 92% between mini-PCNL and standard PCNL, respectively, for the management of 20-mm renal stones. Pan et al,[26] who performed mini-PCNL for the management of 20- to 30-mm renal stones, reported a high SFR of 96.6%. Recently, Shah et al[10] also found an SFR of 81.8% using ultramini-PCNL for patients with 20- to 30-mm renal stones. Even if PCNL is performed using a small tract sheath for large renal stones (20-30 mm), the SFR is higher. However, mini-PCNL alone for the management of large renal stones (>30 mm) has a poor SFR of 38.9%.[9] Therefore, although the general indications for mini-PCNL in adults may include renal stones of <20 or 30 mm in size, the definite indications for mini-PCNL have not been clearly defined.[11] However, Hamamoto et al[12,27] found that when mini-ECIRS was combined with RIRS and mini-PCNL for 30- to 40-mm and >40-mm renal stones, including staghorn stones, better outcomes were obtained, with a high SFR of 71.4%. The simultaneous approach involving both RIRS and PCNL improves the efficiency of disintegration and removal of renal stones and increases the SFR. In the present study, mini-ECIRS was performed for management of large renal stones of 45.5 mm, and a high SFR of 73.2% was achieved.

We performed mini-ECIRS with the patients in the modified Valdivia position. This position has some advantages, including a comfortable simultaneous approach for both RIRS and PCNL, elimination of cardiovascular and respiratory problems, easy flushing out of small fragments by the flow of the irrigation fluid, a comfortable sitting position for surgeons during PCNL, and maintenance of lower renal pelvis pressure because of the horizontal tract sheath, which reduces the risk of fluid absorption.[7,28,29] In the present study, although the operative time for the management of large renal stones was relatively long at 158.4 minutes, the incidence of postoperative fever was low at 7.3%. However, disadvantages of this modified Valdivia position include constant collapse of the pyelocaliceal system and difficulty maintaining the operative field. Additionally, the performance of lower-pole puncture is more difficult in this position than in the prone position because of renal hypermobility to the ventral side.

Few reports have described the use of wideband Doppler in clinical practice. In gastroenterological medicine, wideband Doppler ultrasound has been used for the quantitative evaluation of bowel wall vascularity in patients with Crohn's disease and the vascularity of liver tumors, such as hemangiomas or focal nodular hyperplasia.[30,31] To our knowledge, this is the first report of mini-ECIRS using wideband Doppler ultrasound in the urological field. However, a limitation of the study is that it was an experimental case series. Therefore, a prospective randomized control study involving a large number of cases, such as comparison among B-mode and wideband Doppler, fluoroscopy, and wideband Doppler, is required. Another limitation is that in some cases, the ultrasonic waves could not penetrate the full distance between the skin and renal capsule; in these cases, wideband Doppler was not available. Future studies should investigate in which cases wideband Doppler is available and effective.

CONCLUSION

Wideband Doppler ultrasound-guided renal puncture is safe and feasible. Wideband Doppler ultrasound-guided mini-ECIRS is efficient, safe, and versatile for management of large renal stones of >30 mm.

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APPENDIX

Supplementary Data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.urology.2016.05.038.