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CASE REPORT

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Manual manipulation and ex vivo flexible ureteroscopic lithotripsy to salvage deceased donor kidneys with renal stones: a case series

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Abstract

Background Nephrolithiasis is generally considered a relative contraindication for kidney donation. This study aimed to evaluate the feasibility and effectiveness of a surgical technique designed to salvage deceased donor kidneys with renal stones. The technique involves manual manipulation of the recovered kidney combined with flexible ureteroscopic lithotripsy (MM-FURSL) to clear the stones prior to transplantation.

Case presentation A total of nine kidneys were recovered from six deceased donors. The recipients (66.7% female; mean age 43.9 ± 12.2 years) had been on dialysis for an average of 2.6 years before undergoing renal transplantation with MM-FURSL. Donor kidneys contained 1 to 4 stones each, with a mean maximum stone diameter of 15.1 ± 10.6 mm and an average CT density of 942.0 ± 106.6 HU. The mean warm and cold ischemia times were 5 min and 480 ± 108.2 min, respectively. The average total operative duration was 57.0 ± 63.4 min. The first patient to undergo MM-FURSL had the longest operative and cold ischemia times due to the use of a reusable flexible ureteroscope, which was damaged during the procedure. She was the only patient to experience acute tubular necrosis (ATN), but her creatinine levels normalized within three weeks. No other complications were observed during a mean follow-up period of 11.7 ± 8.2 months.

Conclusion MM-FURSL is an effective method for removing renal stones in donor kidneys. Short-term outcomes were favorable, suggesting that this technique could be a viable approach to expand the donor pool by salvaging kidneys with nephrolithiasis. However, prolonged cold ischemia time may increase the risk of ATN and should be minimized.

Keywords Donor kidney, Renal stone, Transplantation, Flexible ureteroscopic lithotripsy

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Background

China has established an ethical organ donation and transplantation system in accordance with World Health Organization principles, permitting only deceased donors and living-related renal transplants [1]. This framework has led to a notable increase in deceased donor kidney donations over the past few years [2]. Concurrently, the rising prevalence of renal stones suggests that the number of donor kidneys affected by nephrolithiasis may also rise, potentially complicating post-transplant recovery due to risks such as ureteral obstruction [3]. As a result, kidneys from donors with urolithiasis are often classified as marginal and may be disqualified from donation, thereby limiting the available pool of potential donors and deceased donor kidneys. There are also notable differences between American and international guidelines regarding the acceptance of donor kidneys with a history of renal stones [4].

To address the shortage of available kidneys affected by renal stones, ex vivo ureteroscopy techniques have been reported, primarily in case studies or small cohorts [5–7]. However, these methods have yet to achieve broad expert consensus, likely due to the limited evidence from studies with small sample sizes.

In this case series, we describe the manual manipulation of donor kidneys with renal stones as a method to effectively facilitate ex vivo flexible ureteroscopic lithotripsy (MM-FURSL), aiming to achieve stone clearance prior to transplantation.

Case presentation

Characteristics of kidney donors and recipients

The characteristics of individual kidney donors and their recipients are summarized in Tables 1 and 2, respectively. Nine deceased donor kidneys (five right kidneys) were obtained from six patients. Five donors died of cerebrovascular accidents, and one succumbed to head trauma. The mean age of the donors was 42.8 ± 8.9 years, while the mean age of the recipients was 43.9 ± 12.2 years. No donor had reported obstructive renal stone. Preoperative computed tomography (CT) assessment was performed in all deceased donors. The mean maximum diameter of donor renal calculi was 15.1 ± 10.6 mm and the mean CT value was 942 ± 106.6 HU. The underlying causes of renal failure among the recipients included glomerulosclerosis, lupus nephritis, IgA nephropathy, crescentic glomerulonephritis, and, in four cases, unknown etiologies. All recipients required regular permanent dialysis.

The first and fifth retrieved donor kidneys each contained four renal stones, distributed across at least two renal calyces. Both stones were relatively large, with the first measuring 27 mm and the fifth measuring 37 mm. The largest stone from the first donor kidney had a mean CT value of 1115 HU, the highest among all detected

Table 1 Donor demographics and stone characteristics of the recovered 9 donor kidneys

Donor kidney	#1	#2	#3	#4	#5	#6	#7	#8	#9
Gender	Female	Male	Male		Male	Male		Male	
Age	52	34	55		41	41		34	
Cause of death	Cerebrovascular accident							Head trauma	
Creatinine, μmol/L	120	86	115		69	114		56	
Kidney location	Right	Left	Left	Right	Right	Left	Right	Left	Right
Stone characteristics									
Number	4	2	1	1	4	2	1	2	1
Renal calyx	Middle, Inferior	Middle	Inferior	Inferior	Superior, middle, Inferior	Middle	Inferior	Middle, inferior	Middle
Max. Diameter, mm	27	8	14	13	37	5	11	16	5
Mean CT value, HU	1115	1056	1018	998	880	892	813	862	844

stones. Additionally, one of the stones in the fifth donor kidney was a staghorn stone.

Procedural details

Recovered donor kidneys were immediately submerged in a sterile ice bath, followed by routine perfusion and trimming procedures. The operation required a team comprising one chief surgeon and two assistants: one to hold and manipulate the kidney, and the other to continuously expose the ureteral opening for the chief surgeon. The procedure is illustrated in Fig. 1.

A zebra guidewire was introduced into the ureteral stump, and either a 12/14 Fr conventional ureteral access sheath (UAS; 35 cm) or a 14 Fr peel-away sheath (PAS; 17 cm) used in percutaneous nephrolithotomy (PCNL) was inserted, with the outlet positioned just distal to the renal pelvis. After removing the inner guidewire, a digital flexible ureteroscope (FURS; Karl Storz, Germany) or a disposable FURS (Innovex Medical Devices Co., Shanghai, China) was introduced. Continuous flushing was maintained by suspending a cold saline bag 60 cm above the operating table.

Holmium laser lithotripsy (using a 200 μm fiber at 0.6 W and 50 Hz) was performed to fragment the stones. Following fragmentation of the renal stones in the target calyx, MM was applied by adjusting the kidney so that the target calyx was elevated. The kidney was carefully tilted and shaken to allow stone fragments to tumble into the renal pelvis and pass through the catheter at the ureteral stump. Fragments larger than 2 mm or those lodged along the mucosal lining were removed with a stone basket (Cook Medical, Bloomington, IN, USA). The lithotripsy, manual manipulation, and stone basket retrieval were repeated as necessary until only a few small fragments (< 1 mm in diameter) remained visible.

Once stone clearance was achieved, the donor kidney was transplanted into the recipient's right iliac fossa. The donor kidney's renal artery and vein were anastomosed end-to-side to the recipient's external iliac artery and vein, respectively. The distal end of the ureter was then anastomosed to the recipient's bladder. The procedure concluded with the placement of a 5 Fr ureteral stent.

Treatment outcomes

Postoperative immunosuppressive and anti-rejection therapy included FK506, mycophenolate, and prednisone. Procedure details and outcomes are summarized in Table 2. The mean duration for retrograde intrarenal surgery (RIRS), including flexible ureteroscopic lithotripsy and manual manipulation for stone removal, prior transplantation was 57 ± 63.4 min (range, 5–180 min). Eight patients (88.9%) made uneventful postoperative recoveries, all of which used disposable flexible ureteroscopes. A radiographic review was conducted for all patients one month after the operation. Doppler ultrasound of the transplanted kidney vessels showed excellent patency, and CT confirmed the absence of residual stones in all kidneys.

The first recipient to undergo transplantation with MM-FURSL was a 38-year-old female with glomerulosclerosis. The preoperative CT scan of the right donor kidney prior retrieval and post-transplantation CT scan of the recipient are shown in Fig. 2(A) and (B), respectively. This case involved the longest cold ischemia time among the deceased donor kidneys, lasting 11 h. A faulty reusable FURS was used that damaged intraoperatively, which inadvertently prolonged the total RIRS time to 180 min. On the third postoperative day, the patient developed oliguria due to acute tubular necrosis (ATN). She was managed conservatively, and her urine output gradually returned to normal within three weeks.

Discussion and conclusion

This case series demonstrates the early results of a novel technique for ex vivo stone management in donor kidneys with nephrolithiasis. MM-FURSL was feasible for the ex vivo removal of stones > 15 mm, including a staghorn stone. All transplants were performed successfully with only one case of postoperative ATN that resolved spontaneously. The two prolonged MM-FURSL was due to the presence of four stones distributed in separate renal calyces, having a stone with larger size and higher mean stone density, which were significant risk factors for longer operative times in stone removal procedures [8].

Ex vivo stone management options include ureteroscopy, pyelotomy, and lithotripsy [9, 10]. Previous cases have managed stones ranging from 1 to 8 mm in diameter, even including staghorn stones [11]. FURS was favored for several reasons: (1) its wide deflection angle (> 270°) allows effective management of lower pole stones, particularly useful for stones in the lower calyx up to 27 mm in size; (2) it has a relatively short learning curve [12]; (3) Disposable FURS reduces the risk of damage from repeated insertion and withdrawal during fragmentation, providing similar efficacy to reusable FURS [13]. The first case involved a faulty reusable FURS that damaged intraoperative, which inadvertently led to prolonged RIRS time.

The use of an introducer sheath creates a passage that facilitates fragment removal. In our study, four cases used conventional UAS, while the remaining used a shorter PAS from a PCNL kit. Due to the rigidity and longer length of conventional UAS, reaching the proximal kidney can be challenging, which may reduce retrieval efficiency. Tip-flexible (TF) UAS can overcome this limitation by reaching the target calyx and removing stones through its suction system [14–17]. However,

Table 2 Recipient demographics and transplant procedure details and outcomes

Gender	Female	Male	Female	Female	Female	Female	Female	Male	Male
Age, years	38	49	46	42	39	24	38	50	69
Etiology of renal failure	Glomerulosclerosis	Unknown	Lupus nephritis	IgA nephropathy	Unknown	Crescentic glomerulonephritis	Unknown	IgA nephropathy	Un-known
Dialysis duration, years	1	1	8	0.8	2	3	4	1	2.5
Procedural details									
Donor kidney received	#1	#2	#3	#4	#5	#6	#7	#8	#9
Date of transplant (year-month)	2022-4	2022-9	2023-1	2023-1	2023-7	2023-9	2023-9	2024-4	2024-4
Warm ischemia time*, min	5	5	5	5	5	5	5	5	5
Cold ischemia time, min	660	360	480	540	540	300	420	480	540
Total RIRS time, min	180	18	42	48	150	5	20	40	10
Type of flexible ureteroscope used	Reusable	Disposable	Disposable	Disposable	Rigid and disposable	Disposable	Disposable	Disposable	Dispos-able
Sheath									
Type	Ureteral access sheath				Peel-Away sheath				
Size, Fr	35	35	35	35	17	17	17	17	17
Length, cm	12/14	12/14	12/14	12/14	14	14	14	14	14
Postoperative complication	Acute tubular necrosis	None							
Postoperative creatinine, μmol/L	290	120	160	174	131	105	102	76	93
Follow-up, months	25	20	16	16	10	8	8	1	1
Residual stone	None detected on computed tomography.				One 3 mm stone	None detected on computed tomography.			

*Warm ischemia time is defined as the interval between the cessation of blood supply and the initiation of cold perfusion. RIRS, retrograde intrarenal surgery

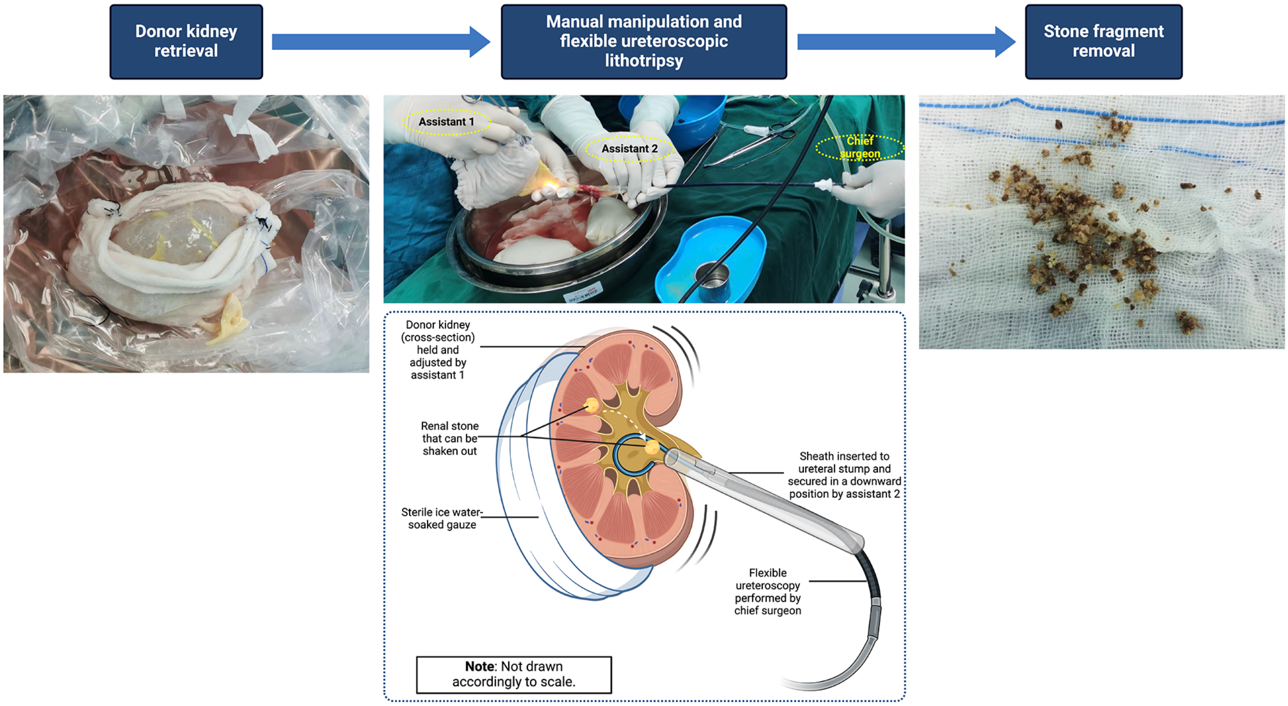

Fig. 1 Illustration of the manual manipulation and ex vivo flexible ureteroscopy procedure performed on the recovered donor kidney. The kidney is wrapped in gauze soaked with sterile ice water to maintain a cool temperature. One assistant holds, adjusts, and gently shakes the kidney to allow the renal stone fragments to tumble out. Another assistant ensures that the sheath is securely fixed to the ureteral stump with the outlet facing downward to facilitate stone removal. The remaining procedure is carried out by the chief surgeon and progresses to transplantation once no residual stones are detected

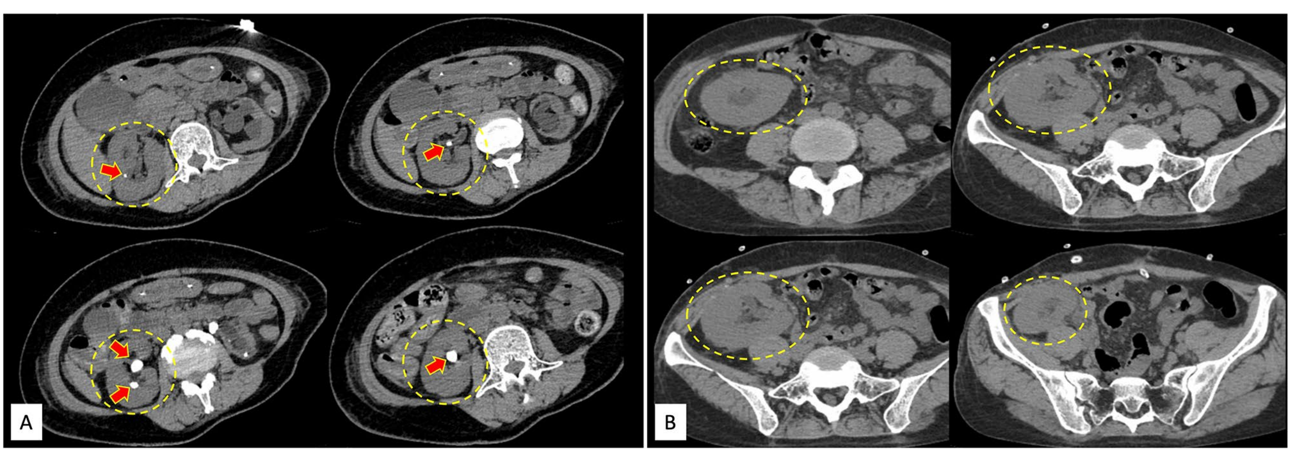

Fig. 2 (**A**) Preoperative computed tomography of the deceased donor in the axial plane at multiple levels, showing the right kidney (dashed yellow circle) with four renal stones of varying sizes (red arrow). The largest stone (27 mm) is located at the renal pelvic orifice. The left kidney shows significant hydronephrosis and is discarded. (**B**) Postoperative computed tomography scan of the recipient who received the right kidney from the deceased donor described above. No renal stones were detected in the transplanted right kidney (dashed yellow circle)

the shortest commercially available TF-UAS is 34 cm. In contrast, the shorter length of PAS (17 cm) enabled more efficient stone fragment expulsion via gravity, reducing operative time while achieving a similar clearance rate. PAS is preferred in selected cases to avoid mucosal damage from suction in TF-UAS. Both methods help minimize the need for stone basket retrieval. In the future, a tip-flexible PAS could potentially combine vacuum-assisted suction and a shorter tunnel outlet for improved retrieval efficiency.

ATN is a leading cause of delayed graft function, often manifesting as oliguria or anuria lasting over a week post-transplantation [18]. Cold ischemia time is a critical factor in ATN development [19, 20]. In our study, the sole recipient who developed ATN had the longest cold ischemia time and operative duration. Although shorter cold ischemia time may reduce ATN incidence, other factors like prolonged operative time, postoperative hypotension, and inadequate renal perfusion may have contributed in this case [21].

Ex vivo stone removal from donor kidneys offers several advantages, including enhanced visibility and access for precise stone clearance, potentially reducing the risk of postoperative complications such as urinary obstruction, infection, and graft dysfunction [22]. This approach simplifies postoperative management for recipients, who may avoid additional procedures and imaging requirements, and also lowers the risk of sepsis, as bacteria-laden stones are removed before immunosuppression begins. However, ex vivo removal can increase both operative time and cold ischemia duration, potentially raising the risk of ischemia-related complications like ATN such as the patient in this case [23]. Handling the kidney outside the body for stone removal also risks mechanical damage to the graft, and certain large or embedded stones may still be challenging to completely clear. In contrast, performing stone removal after transplantation minimizes cold and warm ischemia times, potentially preserving graft viability, and allows for the possibility that small stones may pass spontaneously due to increased urine flow post-transplant. Additionally, avoiding pre-transplant manipulation of the kidney reduces the risk of direct trauma to the graft.

Nonetheless, Yin et al. concluded that the ex vivo surgical removal of small asymptomatic stones (< 4 mm) might outperform conservative management [24]. The incidence of stone events and the cumulative incidence of urinary infections among recipients in the conservatively-managed group was significantly higher. Ex vivo asymptomatic stone removal was associated with a lower risk of urinary infections. Therefore, leaving stones in situ until post-transplantation can introduce risks, including potential urinary obstruction, infection, and the need for secondary interventions, all of which can complicate recovery. Post-transplant ureteroscopy for stone removal is also limited by reduced access and visualization and may lead to elevated intrarenal pressure, which could compromise graft function or increase the risk of infection. Therefore, while ex vivo stone removal appears favorable for comprehensive clearance and reduced postoperative risk, careful consideration of ischemia-related complications remains crucial.

Maintaining long-term graft survival remains a challenge, as the incidence of post-transplant acute renal injury is reported to be around 20.4% [25]. In our study, no recipients experienced acute renal injury during one year of follow-up, suggesting that ex vivo MM-FURSL could be a safe and viable technique for salvaging kidneys with nephrolithiasis. Based on the authors' experiences, it is recommended to pulverize stones to fragments < 3 mm to allow passage through the introducer sheath. Lithotripsy, flushing, and MM can be repeated in cycles to facilitate fragment expulsion. However, attempting to expel too many fragments at once may obstruct the UAS and increase intrarenal pressure, raising the risk of infection and renal impairment [26, 27].

Due to the shortage of donor kidneys and advances in post-transplant stone management, attitudes are shifting towards accepting donor kidneys with prior stones [28, 29]. In 2007, donor kidneys meeting specific criteria – unilateral, asymptomatic, ≤ 2 stones, and ≤ 1.5 cm in diameter—were considered suitable for transplantation [12]. While the short-term outcomes of MM-FURSL were favorable, further long-term follow-up is needed to validate its safety and efficacy, considering limitations such as the retrospective design and small sample size, which may introduce bias.

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Author contributions
LX, JYP, and YXF were responsible for the transplantation procedures conducted in this study. LX, KJSK wrote the main manuscript text. LX, ZQL, and YXF were responsible for the overall project. JYP took the intraoperative pictures. LX and KJSK organized patient data and tables. All authors reviewed the manuscript.

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Data availability
The datasets used and/or analyzed during the study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This research was approved by the institutional ethics committee of the University of Hong Kong – Shenzhen Hospital and the Third People's Hospital of Shenzhen (Reference: 2023-036-02). Clinical trial number not applicable.

Consent for publication
Written informed consent was obtained from the patient for publication of clinical information, including diagnosis, biochemical data, procedural details, and any accompanying images as a case report.

Competing interests
The authors declare no competing interests.

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