



Efficacy and safety of modified tract dilation technique using simultaneous pulling of proximal and distal ends of a guidewire for percutaneous nephrolithotomy in modified supine position

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Purpose: Recently, the needs for supine percutaneous nephrolithotomy (PCNL) have become more increased because of an easy approach for endoscopic combined intrarenal surgery. However, making a nephrostomy tract during supine PCNL is more difficult than prone position due to movable kidney. To overcome this limitation, we used a modified nephrostomy tract dilation (MTD) technique using guidewire traction.

Materials and Methods: From January 2014 to June 2019, a total of 259 patients underwent PCNL in the modified supine position. Among them, the MTD technique was performed in 171 patients. For the MTD technique, two hydrophilic guidewires were passed from the nephrostomy tract and brought out through the urethra, then both proximal and distal ends were contralaterally pulled with tension for the easy placement of a fascia-cutting needle and a balloon catheter. We analyzed the efficacy of this technique in comparison with the conventional method.

Results: Intraoperative radiation exposure time (RET) (68.87 vs. 212.11 s) and hospital stay (5.90 vs. 6.74 days) were significantly shorter, while the success rate (77.2% vs. 63.6%) was significantly higher in the MTD group. Multivariate analysis showed that only the maximal stone diameter (odds ratio [OR], 1.928; 95% confidence interval [CI], 1.314–2.828; $p=0.001$) and MTD technique (OR, 0.017; 95% CI, 0.007–0.040; $p<0.001$) were independent factors for predicting short RET (<120 s).

Conclusions: This study demonstrated that MTD technique can be effectively and safely performed in modified supine position PCNL, and it can be helpful in reducing RET and enhancing success rates.

Keywords: Kidney calculi; Nephrolithotomy, percutaneous; Nephrostomy

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INTRODUCTION

Percutaneous nephrolithotomy (PCNL) is still the standard treatment for large volumes or complex renal stones since it was first introduced by Fernström and Johansson in 1976 [1,2]. To date, with the qualitative improvement of endoscopy instruments, PCNL has come to show several advantages compared to other options including high success, low morbidity and early convalescence [3]. Recently, it is also being performed in a supine or modified supine position due to several advantages, such as reducing risk of cardiopulmonary complications and allowing the possibility of performing a simultaneous retrograde procedure. However, it is more difficult to make a nephrostomy tract in the supine position due to a more movable kidney.

PCNL is still related to higher radiation exposure compared to other urological procedures regardless of whether the approach is in a prone or supine position [4,5]. Most of radiation exposures from PCNL occur during nephrostomy tract dilation and, if the nephrostomy tract dilation is not performed with proper stability, radiation exposure time (RET) can increase. Therefore, it is important to have a proper renal puncture technique and a stable tract dilation technique during PCNL in the supine position [6]. In order to prevent kidney hypermobility during tract dilation and to perform an easier and more stable tract dilation in the modified supine position, the guidewire was entered into urinary bladder which passed through the ureter from nephrostomy tract, and was eventually pulled out through urethra using cystoscopy, then we performed tract dilation by traction on both ends of the guidewire. Herein, we evaluated the efficacy of the modified tract dilation technique in PCNL in the modified supine position, and analyzed safety of this new technique in comparison to the conventional method.

MATERIALS AND METHODS

1. Ethics statement

This study was approved by the Institutional Review Board of Kyungpook National University Hospital, Daegu, Republic of Korea (approval number: KNUH 2019-04-019). The study was carried out in agreement with the applicable laws and regulations, good clinical practices, and ethical principles as described in the Declaration of Helsinki. The board exempted informed consent because it was a retrospective study.

2. Study population and surgical procedure

From January 2014 to June 2019, a total of 280 patients



Fig. 1. Galdakao modified supine Valdivia (GMSV) position.

underwent PCNL in the modified supine position. Unless there were specific patients' conditions, such as spastic paraplegia, or hip joints' ankylosis, this procedure was applied to all patients. We excluded the patients who underwent any combined rigid and flexible ureteroscopic lithotripsy. A total of 259 patients who underwent PCNL in the modified supine position were included in this retrospective study. Among these patients, the first 88 (34.0%) consecutive patients underwent conventional tract dilation, while the modified nephrostomy tract dilation technique was performed in latter 171 (66.0%) consecutive patients.

Percutaneous nephrostomy (PCN) was placed the day before operation under sonography guidance by radiologist. As a pre-operative PCN catheter, 8.5Fr pig-tail catheter or 5Fr KMP (Kumpe Access) catheter was used according to the radiologists' preference. All the PCNLs were performed using the Galdakao modified supine Valdivia (GMSV) [7] position (Fig. 1). A single surgeon performed all cases of PCNL. For the conventional technique, two hydrophilic guidewires including working and safety guidewires were placed in an antegrade direction into the ureter or renal pelvis through the PCN. For the placement of the second guidewire, we used 8/10 dilator/sheath set (Boston Scientific, Boston, MA, USA) or dual lumen ureteral catheter (Boston Scientific). Roadrunner hydrophilic guidewires (Cook Medical, Bloomington, IN, USA) were used as hydrophilic guidewires. Working guidewire was used for the tract dilation and Amplatz sheath insertion, and safety guidewire was placed to prepare the case of Amplatz sheath loss during the stone retrieval and to insert nephrostomy tube after completing surgery. A nephrostomy tract was made using a 30Fr nephrostomy balloon catheter. An Amplatz sheath was placed overriding the nephrostomy balloon catheter, and an ureteropelvic junction (UPJ) occlusion balloon catheter

was placed using a cystoscope under fluoroscopy-guidance. In the modified tract dilation technique, the distal ends of two hydrophilic guidewires were advanced into the bladder and extracted through the urethra using a cystoscope and foreign body forceps, then both the proximal and distal ends of the guidewires were contralaterally pulled with tension for the easy placement of a fascia-cutting needle and nephrostomy balloon catheter (Figs. 2, 3). When the guidewire did not pass through the ureter in cases of staghorn stone, impacted stone or anatomical variances, flexible ureteroscope was retrogradely introduced. After relocating the stones or navigating the calyx, distal tip of guidewire was grabbed and retrieved using a stone basket. The Amplatz sheath was placed in the same manner, and the UPJ occlusion catheter was placed in a retrograde direction overriding the working guidewire, which was used for tract dilation. For both groups, a 24Fr rigid nephroscope (Olympus, Tokyo, Japan) was introduced, and lithotripsy was performed using pneumatic and ultrasonic lithotripters (Swiss LithoClast Master; EMS, Nyon, Switzerland). After completing the surgery, 18Fr nephrostomy tube was placed.



Fig. 2. Modified tract dilation technique.

3. Definition

All patients underwent evaluation of renal stones by computed tomography (CT) scan within two weeks prior to surgery. Maximal stone size was determined by measurement of the greatest diameter on any view of the CT scan. In cases of multiple renal stones, the sum of the greatest diameter of each stone was calculated as maximal stone size. Partial staghorn stones were defined as renal pelvic stones extending into two calyces, and complete staghorn stones were defined as renal pelvic calculi extending into all major calyces, occupying at least 80% of the collecting system [8,9]. Portable C-arm fluoroscopy (GE OEC 990 Elite; GE Healthcare, Waukesha, WI, USA) was used in standard mode (32 impulses/second; 98 kV and 3.8 mA) during PCNL. Calculating RET was programed in the portable C-arm and a radiologic technician recorded the RET. Success was defined as the absence of any residual stone fragment or the presence of residual stones less than 0.3 cm on CT scan at postoperative one month without any related symptoms [10]. The hospital stay was recorded from one day before surgery to the day of discharge. Patients and stone characteristics, number and site of punctures, perioperative surgical outcomes and postoperative complications were compared. Receiver operating characteristic curve analysis of success rate was used to identify the optimal RET cutoff point as 120 seconds (sensitivity: 65.6%, specificity: 78.9%). Dividing RET by 120 seconds is similar to the results of previous studies [4,11].

4. Statistical analysis

We used Student's t-test for continuous variables and the chi-square test or Fisher's exact test for non-continuous variables. Multivariate logistic regression model was used for predicting RET <120 seconds. Statistical analyses were performed using SPSS for Windows, version 23 (IBM Corp,

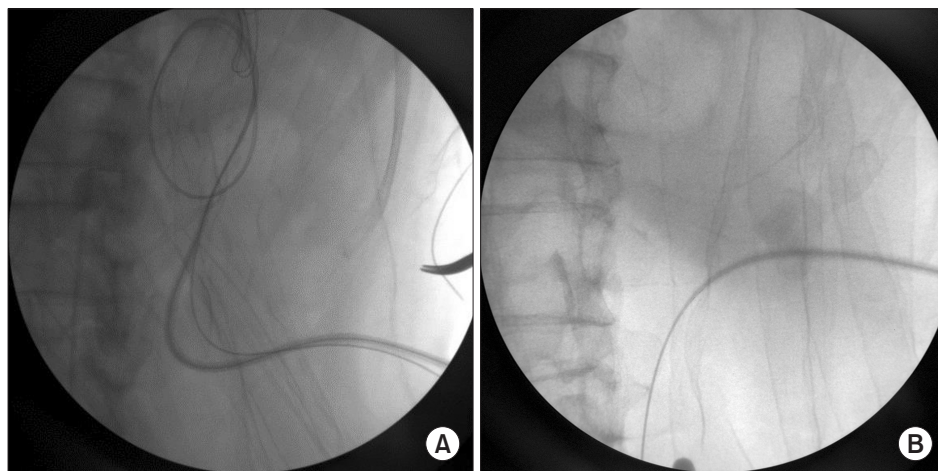


Fig. 3. (A) Conventional tract dilation and (B) modified tract dilation with guidewire traction.

Table 1. Basic characteristics of patients who underwent PCNL in the modified supine positions

Variable	Total (n=259)	Modified tract dilation (n=171)	Conventional method (n=88)	p-value
Age (y)	56.93±13.73	57.28±13.10	56.24±14.92	0.564
Sex				0.816
Male	179 (69.1)	119 (69.6)	60 (68.2)	
Female	80 (30.9)	52 (30.4)	28 (31.8)	
Body mass index (kg/m ²)	25.15±3.78	25.72±3.88	24.04±3.33	0.001
Laterality				0.012
Left	157 (60.6)	113 (66.1)	44 (50.0)	
Right	102 (39.4)	58 (33.9)	44 (50.0)	
Stone location				0.031
Lower pole	66 (25.5)	52 (30.4)	14 (15.9)	
Upper pole	15 (5.8)	11 (6.4)	4 (4.5)	
Renal pelvis	88 (34.0)	59 (34.5)	29 (33.0)	
Multiple location	44 (17.0)	21 (12.3)	23 (26.1)	
Partial staghorn	23 (8.9)	14 (8.2)	9 (10.2)	
Complete staghorn	23 (8.9)	14 (8.2)	9 (10.2)	
Stone number				0.085
Single	89 (34.4)	65 (38.0)	24 (27.3)	
Multiple	170 (65.6)	106 (62.0)	64 (72.7)	
Maximal stone size (cm)	2.55±0.95	2.49±0.94	2.67±0.97	0.153
Number of punctures				0.127 ^a
1	250 (96.5)	164 (95.9)	86 (97.7)	
2	8 (3.1)	7 (4.1)	1 (1.1)	
3	1 (0.4)	0 (0.0)	1 (1.1)	
Site of punctures				0.257 ^a
Lower calyx	233 (90.0)	155 (90.6)	78 (88.6)	
Middle calyx	6 (2.3)	4 (2.3)	2 (2.3)	
Upper calyx	11 (4.2)	5 (2.9)	6 (6.8)	
Lower and middle calyx	3 (1.2)	2 (1.2)	1 (1.1)	
Lower and upper calyx	4 (1.5)	4 (2.3)	0 (0.0)	
Middle and upper calyx	1 (0.4)	1 (0.6)	0 (0.0)	
All three calyces	1 (0.4)	0 (0.0)	1 (1.1)	

Values are presented as mean±standard deviation or number (%).

PCNL, percutaneous nephrolithotomy.

^a:Fisher’s exact test.

Armonk, NY, USA), and statistical significance was established with p<0.05.

RESULTS

Basic characteristics of patients are shown in Table 1. Mean age was 56.93±13.73 years. Males accounted for 69.1% (179/259). Mean body mass index was 25.15±3.78 kg/m². Left sided renal stones comprised 60.6% (157/259). Stone locations were counted at 66 cases (25.5%) in the lower pole, 88 (34.0%) in the renal pelvis. Multiple stones comprised 65.6% (170/259). The mean maximal stone diameter was 2.55±0.95 cm. 250 cases (96.5%) underwent operation using only a single puncture tract and 233 cases (90.0%) underwent a lower calyceal puncture. The number and site of punctures did not statistically differ between the modified tract dilation and conventional groups.

Mean operative time was not significantly different between the two groups. However, the mean nephrostomy tube indwelling time, mean hospital stay, and mean RET were significantly shorter in modified tract dilation group (Table 2). Success rates was significantly higher in the modified tract dilation group (77.2% vs. 63.6%, p=0.021). Meanwhile, the mean hemoglobin drops were not statistically different between the two groups (Table 2).

Table 3 shows postoperative complications according

Table 2. Comparison of surgical outcomes between modified tract dilation and conventional method groups

Variable	Modified tract dilation (n=171)	Conventional method (n=88)	p-value
Operative time (min)	80.55±38.23	87.38±36.84	0.170
Nephrostomy tube indwelling time (d)	3.88±2.78	4.83±2.46	0.007
Success rate	132 (77.2)	56 (63.6)	0.021
Hospital stay (d)	5.90±2.61	6.74±2.56	0.014
Radiation exposure time (s)	68.87±43.70	212.11±77.48	<0.001
Hemoglobin drop (g/dL)	1.82±1.26	2.25±2.02	0.076

Values are presented as mean±standard deviation or number (%).

Table 3. Postoperative complications according to Clavien–Dindo classification

Grade	Complication	Modified tract dilation (n=171)	Conventional method (n=88)	p-value
Grade II	Febrile UTI	14 (8.2)	10 (11.4)	0.404
	Transfusion	11 (6.4)	6 (6.8)	0.906
Grade IIIa	Angioembolization	3 (1.8)	3 (3.4)	0.402
≥Grade IIIb		0 (0.0)	0 (0.0)	-

Values are presented as number (%).

UTI, urinary tract infection; -, not available.

to Clavien–Dindo classification. Overall, the postoperative complications observed in this study were febrile urinary tract infection (UTI), blood transfusion and angioembolization due to pseudoaneurysm or persistent bleeding. Of 259 patients, 6 (2.3%) patients underwent angioembolization, 17 (6.6%) patients received blood transfusion and 24 (9.3%) patients showed febrile UTI. However, the occurrence rate of postoperative complications was not significantly different between the two groups.

The results of univariate and multivariate analysis for predicting short RET (<120 s) are shown in Table 4. We divided the patients into group of RET<120 seconds (n=157) and RET≥120 seconds (n=102). Multivariate analysis showed that only the maximal stone diameter (odds ratio [OR], 1.928; 95% confidence interval [CI], 1.314–2.828; p=0.001) and modified tract dilation technique (OR, 0.017; 95% CI, 0.007–0.040; p<0.001) were independent factors for predicting short RET (<120 s).

DISCUSSION

Initially, PCNL was performed in the supine-oblique position, however, the prone position has become the formal and conventional procedure after that [7]. The prone position PCNL has several advantages, such that the surgeon can create a large space for renal access and instrument manipulation, leading to a lower risk of visceral organ injury. However, the prone position PCNL has disadvantages, including patient discomfort associated with the position,

increased radiation exposure dose on the hands of surgeon, and the need for several ancillary staff to achieve the prone position. Furthermore, it can lead to significant problems during anesthesia, including circulation, hemodynamics, and ventilation difficulties, especially in patients with cardiopulmonary disease or severe obesity [12,13]. To overcome these disadvantages, increased attention had been paid to the supine PCNL in the recent years.

Numerous types of the modified positions have been introduced over the decades as effective and safe methods for patient positioning for PCNL. These new positioning techniques are as follows; the reverse lithotomy position [14], the prone split-leg position [15], the lateral decubitus position [16], the supine position [17], and the GMSV position [12]. Although there are currently no RCTs comparing and analyzing the surgical outcomes of modified positions, many urologic centers have been performing PCNL in the GMSV position since it was first introduced in 2007.

The GMSV position enables the urologists to perform complex renal stone management with percutaneous tract formation and simultaneous retrograde ureteroscopic procedures. In other words, great advantages for the GMSV position are the higher feasibility of stone manipulation along the whole urinary tract, as well as the ability to use combined or subsequent ante or retrograde access to the urinary tract with both rigid and flexible ureteroscope [12]. Moreover, repositioning of the patient is unnecessary, thus shortening the total operative time [7]. It has a lower rate of perioperative cardiopulmonary complications and peripheral nerve in-

Table 4. Univariate and multivariate analysis for predicting short RET (<120 s)

Variable	RET<120 s (n=157)	RET≥120 s (n=102)	p-value		OR (95% CI)
			Univariate	Multivariate	
Age (y)	57.91±13.21	55.41±14.43	0.153	-	
Sex			0.490	-	
Male	106 (67.5)	73 (71.6)			
Female	51 (32.5)	29 (28.4)			
Body mass index (kg/m ²)	25.49±3.62	24.63±3.98	0.075	-	
Laterality			0.005	0.208	
Left	106 (67.5)	51 (50.0)			1.00 (Ref.)
Right	51 (32.5)	51 (50.0)			1.671 (0.751–3.722)
Stone characteristic			0.015	0.246	2.243 (0.572–8.792)
Non staghorn	137 (87.3)	77 (75.5)			
Staghorn	20 (12.7)	25 (24.5)			
Stone number			0.059	-	
Single	61 (38.9)	28 (27.5)			
Multiple	96 (61.1)	74 (72.5)			
Maximal stone size (cm)	2.39±0.89	2.80±0.99	0.001	0.001	1.928 (1.314–2.828)
Number of punctures			0.706 ^a	-	
1	151 (96.2)	99 (97.1)			
≥2	6 (3.8)	3 (2.9)			
Puncture site			0.243	-	
Lower only	144 (91.7)	89 (87.3)			
Non lower	13 (8.3)	13 (12.7)			
Apply of modified technique			<0.001	<0.001	0.017 (0.007–0.040)
No	10 (6.4)	78 (76.5)			
Yes	147 (93.6)	24 (23.5)			

Values are presented as mean±standard deviation or number (%).

RET, radiation exposure time; OR, odds ratio; CI, confidence interval; -, not available.

^a:Fisher’s exact test.

juries [18]. It has a better chance of spontaneous drainage of stone fragments through Amplatz sheath during PCNL [19]. It can reduce the radiation exposure to the surgeon’s hands because the hands of the operators are usually out of the irradiation field in supine position PCNL [20]. The one step procedure is possible not only for complex renal and ureteral stones but also other urologic conditions, including ureteral stricture or ureterointestinal stenosis in neobladders [12].

The disadvantages of the GMSV position are as follows [12]: 1) Manipulation of the nephroscope is more difficult because the space within the renal pelvis can collapse with the continuous drainage of irrigation fluid by gravity, leading to a narrow cavity. 2) Tract dilation is more complicated because of the anteromedial movement of the kidney during the maneuvers. 3) Punctures of anterior or superior calyx are more sophisticated. The successful renal puncture is the most important procedure during PCNL [21]. Due to the absence of supporting structure on anterior body wall, kidney displacement is inevitable during supine PCNL [22]. Kidney displacement can increase the time of fluoroscopy and tract

dilation [17,23]. Therefore, securing the proper access to collecting system is the top priority in supine PCNL. However, the limitations of puncture site selection due to the difficulty of kidney puncture in supine position PCNL can be overcome by preoperative PCN puncture in collaboration with radiologist.

Ultrasound as a guiding modality for renal puncture has several of advantages such as lack of ionizing radiation, shorter procedure time, fewer punctures and reducing cost [24-27]. Using real-time ultrasound with transducer, puncture of renal calyx was performed with an angiographic needle attached to the probe. After puncturing into renal collecting system and confirming of urine coming out through needle, the hydrophilic guidewire was inserted, and PCN catheter was placed subsequently. Before the renal puncture for PCNL, a surgeon and radiologist always discussed and determined the puncture site after making consensus based on preoperative CT scan. Therefore, there were no re-puncture events due to inappropriate renal access during PCNL.

Preoperative PCN can be performed in the prone posi-

tion, and we can take the advantage of using the same puncture site as with the prone position PCNL, thus overcoming the disadvantages of supine position PCNL. In addition, after tilting the patient laterally during supine PCNL, sufficient space for surgery can be obtained. When it comes to hypermobility of kidney, we used our center's own technique. After patient is placed with GMSV position, a main operator passes the hydrophilic guidewire from the renal pelvis to the bladder, then an assistant surgeon introduces the cystoscope and extracts the distal tip of the guidewire using foreign body forceps. If the distal tip of the guidewire fails to reach the bladder, a semi-rigid or flexible ureteroscope could be introduced to extract the distal tip of the guidewire using a stone basket from the ureter or renal pelvis. Since the guidewire is successfully extracted from urethra, the proximal and distal ends of guidewire tips are pulled in opposite directions with careful tension. It can fix the kidney during the tract dilation maneuver and also help introduce instruments for tract dilation, such as the fascia-cutting needle and nephrostomy balloon catheter. Moreover, it was reported that technique of one shot renal dilation using nephrostomy balloon were safer and more effective than metal telescopic dilation or serial Amplatz dilation for nephrostomy tract dilation, resulting in a shorter tract dilatation fluoroscopy time and less hemoglobin drop [28-30]. Therefore, the nephrostomy tract can be made faster, safer, and more easily than the conventional method. There can be a concern related to the UPJ or collecting system injury due to excessive force with guidewire traction. However, no cases of guidewire-related UPJ or collecting system injury were observed during nephroscopic procedure. This may be attributed to the usage of hydrophilic guidewires instead of stiff type guidewires and gentle traction of a guidewire during procedures.

In our results, mean RET was 68.87 ± 43.70 seconds in the modified tract dilation group and 212.11 ± 77.48 seconds in the conventional group, with the difference being statically significant. It is presumed that RET was increased in the conventional method group due to the hypermobility of the kidney. RET can be increased because many attempts are required not only during guidewire passage but also during the introduction and positioning of fascia-cutting needle and nephrostomy balloon catheter. In addition, if there is severe fibrosis in the subcutaneous tissue, kidney parenchyma or capsule, insertion of the instruments may not be smooth. The guidewire may even be pulled out, which may require another puncture, resulting in a longer RET. However, in the modified tract dilation technique with the cystoscope or ureteroscope-assisted method, the guidewire can be safely

moved with less radiation, while the kidney is fixed by traction on both sides, thus minimizing RET. The UPJ occlusion catheter can also be inserted directly through the guidewire, which is inserted through urethra, further reducing RET.

Other than a shorter RET, we demonstrated that our modified tract dilation technique can shorten the nephrostomy tube indwelling time, hospital stay as well as enhance the success rate. Although difference in success rate between the two groups in this study may not be due to the difference in the tract dilation technique, rather it may be influenced by accumulated surgeon's experience and more favorable stone locations. As we described in the materials and methods section, the conventional group included the first 88 consecutive patients and modified tract dilation group included the latter 171 patients. In addition, significantly more cases of multi-calyceal stones were included in conventional group. Nevertheless, these favorable outcomes of modified tract dilation group were thought to be related to reduced bleeding from the access tract, and less postoperative pain from the muscle or Gerota's fascia. Accurate tract formation leads to less bleeding, and a clearer surgical view, thus enhancing better surgical outcomes. Similarly, it results in a shorter nephrostomy tube indwelling time and hospital stay. Fewer trials of introducing instruments for tract dilation can reduce postoperative pain on the surgical site, while less bleeding can reduce nephrostomy tube indwelling time, leading to an earlier discharge than the conventional method group.

The limitations of the current study include a single-center study design, relatively small cohort size, heterogeneous groups of the patients, and the retrospective nature of the data collection. Furthermore, stone analysis was not performed in all of the patients and the analysis of recurrence rate was not included. Finally, a comparison of different lithotripsy endoscopic instruments, which can affect the success rate, was not performed in this study. In near future, further large-scale population-based prospective studies involving multiple institutions, taking into account all the factors concerning stone management should be performed.

CONCLUSIONS

We demonstrated that modified nephrostomy tract dilation technique can be effectively and safely performed in modified supine position PCNL. This technique can be more helpful to reduce RET, to enhance the success rate, and to reduce hospital stay for patients.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

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AUTHORS' CONTRIBUTIONS

Research conception and design: Bum Soo Kim. Data acquisition: Heon Ha. Statistical analysis: Dong Jin Park. Data analysis and interpretation: So Young Chun. Drafting of the manuscript: Jae-Wook Chung. Critical revision of the manuscript: Tae Gyun Kwon. Obtaining funding: Bum Soo Kim. Administrative, technical, or material support: Yun-Sok Ha and Jun Nyung Lee. Supervision: Yun-Sok Ha and Jun Nyung Lee. Approval of the final manuscript: Bum Soo Kim.

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