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Feasibility and Safety of Transradial Access for Renal Artery Embolization: A Single Center Prospective Study

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Objective: The objective of this study is to evaluate the feasibility and safety of renal artery embolization (RAE) via transradial access (TRA) in patients with renal angiomyolipoma (AML) or renal hemorrhage.

Materials and Methods: Data were collected for this prospective single-center study from 50 patients (51 ± 12 years; male:female, 11:39) who underwent RAE for renal AML (n = 46) or renal hemorrhage (n = 4) between November 2020 and January 2024. Patients with a Barbeau D waveform or a radial artery diameter of <1.5 mm were excluded. Technical success in patients with renal AML and renal hemorrhage was defined as achieving selective catheterization of the culprit artery with embolization, leading to flow stasis and the absence of bleeding evidence, respectively. Clinical success was indicated by a reduction in AML size on follow-up CT scans and the absence of bleeding signs without necessitating additional RAE. The EuroQol 5-Dimension 5-level (EQ-5D-5L) questionnaire was utilized to assess health-related quality of life (HRQoL).

Results: In one patient with AML, embolization could not be performed following selective catheterization and angiography due to the lack of visible tumor vascularity, resulting in a technical success rate of 98% (49/50). The clinical success rate was 96% (48/50 patients). No instances of TRA failure, conversion to transfemoral access (TFA), or hemostasis failure were noted. During the follow-up period, no major adverse events associated with the RAE occurred. Two patients exhibited asymptomatic radial artery occlusion, and one patient displayed asymptomatic partial thrombosis of the renal artery at the first follow-up visit. The EQ-5D-5L scores were 0.90 (95% confidence interval [CI]: 0.86–0.95) within 24 hours post-procedure and 0.89 (95% CI: 0.85–0.92) at the first follow-up (P = 0.332).

Conclusion: TRA is a feasible and safe approach for performing RAE in patients with renal AML or hemorrhage. RAE performed using TRA demonstrated high HRQoL outcomes and may serve as a viable alternative to TFA for performing RAE.

Keywords: Transradial approach; Transarterial embolization; Angiomyolipoma; Renal hemorrhage; Quality of life

INTRODUCTION

Transcatheter renal artery embolization (RAE) is a minimally invasive and effective procedure for managing renal hemorrhage and mitigating bleeding risks in patients with angiomyolipoma (AML), and is now considered the treatment of choice [1,2]. Advances in endovascular techniques and interventional devices have enabled superselective embolization, allowing for controlled occlusion of renal artery branches while minimizing the risk of irreversible renal function loss [3,4].

The most commonly used access for RAE is the transfemoral access (TFA). However, transradial access (TRA) has been gaining popularity as a coronary intervention [5-7], and recent studies have increasingly published data on the safety and feasibility of TRA as an alternative to TFA in noncoronary interventions [8-10]. Furthermore, evidence suggests that TRA may offer advantages over TFA, such as improved patient preference, reduced rates of adverse events and morbidity, shorter hospital stays, and enhanced quality of life [11,12]. This study was conducted to evaluate the feasibility and

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safety of RAE using TRA in patients with renal AML or hemorrhage.

MATERIALS AND METHODS

Study Design and Patient Enrollment

This study was designed as a prospective pilot study to evaluate the feasibility and safety of TRA for RAE. As an exploratory study—not a hypothesis-driven clinical trial—a formal power calculation was not conducted. This single-center study enrolled adult patients (aged >18 years) referred for RAE due to renal AML or renal hemorrhage. The study protocol was approved by the Institutional Review Board of Asan Medical Center (IRB No. 2017-1433), and all patients provided written informed consent after receiving a detailed explanation of the procedures and potential complications.

Prior to radial artery puncture, radial artery ultrasonography and the Barbeau test were performed. The minimum radial artery diameter required for study inclusion was set at 1.5 mm, given that the outer diameter for the 4 Fr sheath was 1.6 mm [13]. Patients exhibiting a Barbeau type D waveform were excluded due to the risk of hand ischemia associated with TRA [11]. The primary inclusion and exclusion criteria are outlined in Table 1.

Technique for RAE via TRA

In all cases, the patients were placed in the supine position with their left arm abducted to 75°–90°and directed toward the operator's right side (Fig. 1) [11,14]. The left radial artery was accessed under ultrasound guidance using a 21-gauge needle after local administration of a 2% lidocaine solution. A hydrophilic-coated introducer sheath (4-F or 5-F Prelude short sheath introducers; Merit Medical, South Jordan, UT, USA) was inserted, followed by administration of a cocktail solution containing 3000 units of heparin, 200 μg of nitroglycerin, and 2.5 mg of verapamil to prevent radial artery spasm and thrombosis. A 4-F or 5-F angled catheter (Performa Transradial Angiographic Catheter, 125 cm; Merit Medical) and a 0.035-inch hydrophilic guidewire (Terumo, Tokyo, Japan) were utilized for catheterization of the main renal artery, followed by digital subtraction arteriography. The culprit renal artery branches for superselective catheterization were accessed coaxially using a 1.9-Fr 150-cm microcatheter (Progreat Lambda; Terumo) and a 0.014-inch microwire (True Form; Merit Medical), followed by embolization using polyvinyl alcohol (PVA) particles (Contour; Boston Scientific, Galway, Ireland), N-butyl cyanoacrylate (NBCA, Histoacryl; Braun, Sempach, Switzerland), or microcoils (Concerto Helix; Medtronic, Minneapolis, MN, USA) until arterial flow stasis was confirmed (Fig. 2). After the procedure, the introducer sheath was removed, and an inflatable pressure compression device (TR-band; Terumo) was applied over the puncture site to achieve hemostasis. All procedures were performed by two experienced interventional radiologists (each possessing >10 years of experience).

Definitions and Data Assessment

Technical success was defined as achieving selective

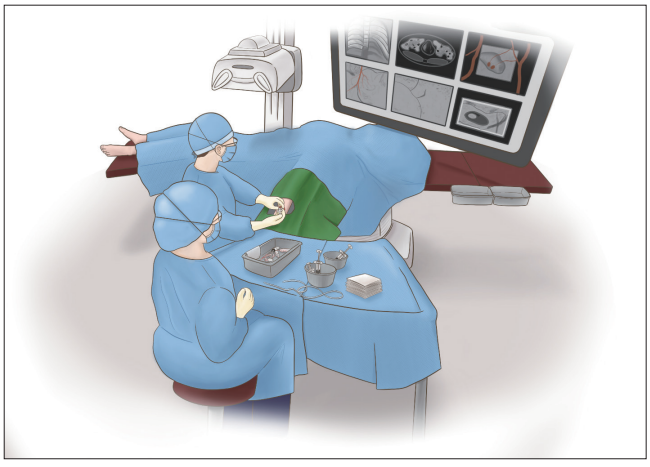

Fig. 1. Illustration of patient posture, table arrangement, and physician's position during the transradial access procedure.

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
• Patients aged 18 years or older	• Barbeau test indicating type D
• Diagnosis of renal AML requiring embolization	• Radial artery diameter of 1.5 mm or less
• Diagnosis of renal hemorrhage requiring embolization	• Significant azotemia or renal insufficiency contraindicating the procedure
	• Left-hand contractures or conditions preventing safe radial access
	• History of prior renal artery embolization
	• Known allergies to materials or medications used during the procedure

AML = angiomyolipoma

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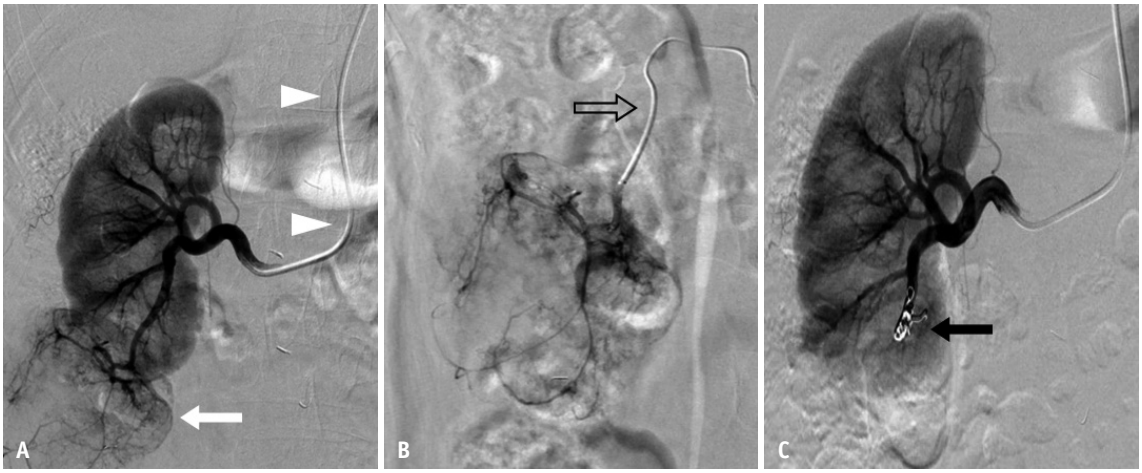

Fig. 2. Digital subtraction angiography image of a 70-year-old female patient with a single AML in the right kidney, showing prophylactic embolization. **A:** Right renal artery angiography using a 5-Fr catheter (arrowheads) shows feeding arteries to the AML (arrow). **B:** Superselective angiography of the main feeding artery to the AML using a 1.9-Fr microcatheter (arrow) shows the internal hypervascularity of the AML. **C:** Right renal angiography after embolization with polyvinyl alcohol and microcoils (arrow) shows devascularization of the previously noted tumor staining. AML = angiomyolipoma

catheterization of the culprit artery with embolization that resulted in flow stasis for patients with renal AML; for patients with renal hemorrhage, this success was defined by the absence of bleeding evidence following selective catheterization and embolization. Clinical success was indicated by a reduction in AML size on follow-up CT scans for patients with renal AML (determined by comparing the largest diameter on respective axial scans pre- and post-procedure) and the absence of bleeding signs for patients with renal hemorrhage without the need for additional RAE. Superselective embolization was characterized by the embolization performed after the catheterization of an arterial branch beyond the second-order level.

Adverse events were classified according to the Society of Interventional Radiology (SIR) clinical practice guidelines [15]. Major adverse events encompassed significant escalations in care, including hospital admissions or extensions of existing hospital stays beyond 24 hours, atypical hospital admissions relative to the procedure, transfer from a regular or telemetry floor to the intensive care unit, or necessitating complex interventions requiring general anesthesia in previously non-intubated patients. Life-threatening or disabling events along with patient mortality were likewise classified as major adverse events. All other adverse events were considered minor. Post-embolization syndrome was defined as fever and/or nausea and/or pain (with a pain score exceeding 6 on a visual analog scale) occurring within 48 hours after RAE. Procedural radiation dose data were collected in the form of cumulative air kerma expressed in milliGray (mGy) and fluoroscopy time in minutes. All patients underwent color Doppler ultrasound of the access site during the first postoperative follow-up visit (mean ± standard deviation, 18 ± 7 days) to evaluate post-procedural adverse events, and clinical assessments were performed for procedure-related adverse events up to the second follow-up visit (Fig. 3).

Quality of Life Assessment

Assessment of health-related quality of life (HRQoL), a crucial consideration in evaluating patient preferences for access strategies, was conducted using the EuroQol 5-Dimension 5-level (EQ-5D-5L) questionnaire, a validated generic instrument. The EQ-5D-5L profile utilized in this study was an authorized version from the EuroQol Group. It encompasses five dimensions (mobility, self-care, usual activities, pain/discomfort, and anxiety/depression), with each dimension representing five levels of severity (no problems, slight problems, moderate problems, severe problems, and extreme problems) [16,17]. The EQ-5D-5L questionnaire was administered within 24 hours of the procedure and at the first follow-up. The Korean value set developed by the EuroQol Group and a Korean research team was applied to calculate the utility index [18]. The resulting index score ranges from -0.171 to 1, where 1 signifies perfect health, 0 represents a health state equivalent to being deceased, and negative values indicate health states worse than being deceased. The Wilcoxon signed-rank test was employed to compare the EQ-5D-5L index scores within

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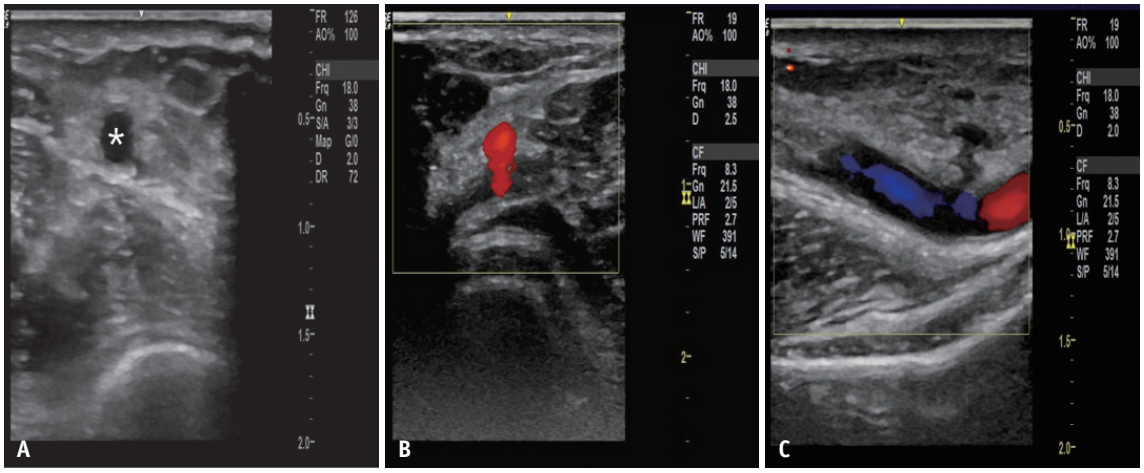

Fig. 3. Ultrasound images of a 70-year-old female patient at 1-month follow up after renal artery embolization via transradial access. **A:** Transverse plane image shows a patent left radial artery (asterisk). **B, C:** Transverse and longitudinal planes of color Doppler imaging demonstrating the blood flow signal in the left radial artery.

24 hours after the procedure and at the first follow-up visit.

Handling of Missing Data

Missing data were to be addressed according to a predefined statistical analysis plan to minimize bias and maintain data integrity. Continuous variables with missing values were to be managed through multiple imputations by chained equations, while a complete-case analysis was planned for categorical variables. Should the proportion of missing data for any key variable exceed 10%, a sensitivity analysis was to be conducted to examine the potential impact of missing data on study outcomes.

RESULTS

Study Sample and Baseline Characteristics

Between November 2020 and January 2024, 53 patients were screened for enrollment. Subsequently, three patients were excluded: one with left-hand contracture, one with azotemia, and one with a history of RAE. The study cohort comprised 50 patients (11 male patients and 39 female patients; mean age, 51 ± 12 years). Of the 50 patients undergoing RAE, 46 (92%) had renal AML, and four (8%) had renal hemorrhage including pseudoaneurysms and arteriovenous fistulas. Upon physical examination, 25 patients (50%) exhibited Barbeau grade A, 21 patients (42%) showed Barbeau grade B, and data were unavailable for four patients (8%). No patients presented with Barbeau grades C or D. The mean radial artery diameter, assessed via pre-procedural ultrasonography, measured 2.4 ± 0.5 mm (range, 1.6–3.5 mm; data were not available for four patients).

Procedural Outcomes

All procedures were conducted by two experienced interventional radiologists, each possessing over seven years of experience, adhering to the SIR Quality Improvement Standards for percutaneous transcatheter embolization [5]. No occurrences of TRA failure, conversion to TFA, or hemostasis failure were observed. The technical and clinical success rates for RAE were determined to be 98% (49/50) and 96% (48/50), respectively. Superselective embolization of the culprit branch of the renal artery was successfully achieved in all procedures. Nevertheless, embolization could not be performed in one patient with AML due to an absence of tumor vascularity observed on renal angiography. Furthermore, one patient who underwent superselective embolization for renal AML demonstrated an increase in tumor size on follow-up CT performed six months post-procedure. The mean radiation exposure, quantified as cumulative air kerma, was recorded at 294 ± 229 mGy (median [interquartile range, IQR], 222 [125–398]), while the mean fluoroscopy time registered at 12 ± 8 minutes (median [IQR], 9 [8–13]). Detailed patient and procedural characteristics are presented in Tables 2 and 3, respectively.

Safety and Adverse Events

Patent hemostasis was realized 30 minutes following pneumatic compression using the TR band. No patients experienced major adverse events during the postoperative follow-up period. Post-embolization syndrome was

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Table 2. Baseline characteristics of the 50 patients enrolled in the study

Characteristic	Value
Age, yrs	51 ± 12
Sex	
Male	11 (22)
Female	39 (78)
Etiology	
AML	46 (92)
PSA	3 (6)
AVF	1 (2)
Baseline Barbeau type	
A	25 (50)
B	21 (42)
C	0
D	0
Unmeasured	4 (8)
RA diameter, mm*	2.4 ± 0.5

Data are presented as mean ± standard deviation or n (%).
*There are 4 missing data points, and the values were calculated excluding them.
AML = angiomyolipoma, PSA = pseudoaneurysm, AVF = arteriovenous fistula, RA = radial artery

Table 3. Procedural parameters of the study

Parameters	Value
Superselection	50 (100)
Air kerma, mGy*	294 ± 229
Total fluoroscopy time, mins*	12 ± 8
Hospital stays, days*	3 ± 2
Complications	24 (48)
Major	0 (0)
Minor	
PES	21 (42)
Asymptomatic RAO	2 (4)
RA partial thrombosis	1 (2)

Data are presented as mean ± standard deviation or as number of patients with % in parentheses, unless otherwise stated.
PES = postembolization syndrome, RAO = radial artery occlusion, RA = radial artery

encountered in 21 (42%) patients, categorized as a minor adverse event. Two patients (4%) were found to exhibit asymptomatic radial artery occlusion (RAO) at the first follow-up visit; however, they maintained patent blood flow to the distal wrist and hand via collateral pathways from the ulnar artery. Additionally, there was one case (2%) of partial thrombosis of the radial artery (involving less than 50% of the diameter) while maintaining blood flow.

Health-Related Quality of Life

The calculated EQ-5D-5L index scores, derived from individual health profiles utilizing the Korean value set (range -0.066 to 1), were recorded at 0.90 (95% confidence interval [CI]: 0.86–0.95) within 24 hours post-procedure and 0.89 (95% CI: 0.85–0.92) at the first follow-up. No significant difference was noted between the two time points (P = 0.301). The EQ-5D-5L data from the patients is summarized for both time points in Supplementary Figure 1.

DISCUSSION

The results of this prospective feasibility study underscore the role of TRA in RAE. Notably, no major adverse events associated with the procedure were reported. Twenty-one patients (42%) experienced post-embolization syndrome, all of which were successfully managed with conservative treatment. The study documented high technical and clinical success rates. Importantly, the absence of conversions to TFA reinforces the reliability of TRA for RAE procedures. A prevalent challenge in adopting TRA involves the operator-learning curve. Tso et al. [19] established that high success rates with TRA can be achieved after performing between 25 and 50 cases. In the present study, despite operators possessing substantial experience in interventional radiology, their prior inclination was toward TFA over TRA, impacting the frequency with which TRA was utilized. Nonetheless, there were no recorded cases of radial artery puncture failure or difficulties advancing the guidewire and catheter into the renal artery; this suggests that proficiency in basic ultrasound-guided puncture techniques may sufficiently mitigate challenges linked with TRA.

In addition to a lack of familiarity with TRA, interventional radiologists may exhibit reluctance to adopt this technique due to concerns surrounding the placement of a large-bore vascular sheath in the radial artery, which might elevate the perceived risk of RAO, in conjunction with the limited availability of devices specifically designed for radial access [20,21]. However, in the case of RAE, a 5-F system or smaller is conventionally utilized, thereby alleviating concerns related to vascular sheath size [22]. The observed RAO rate of 4% (2/50) aligns with previously reported incidences following TRA, which range from 1% to 6% [5,8,23,24].

Previous studies suggest that RAO is predominantly asymptomatic due to ulnar-palmar collateral blood supply to the hand, thus emphasizing the benign nature of this complication [5,9,25]. Patients in this study were classified as Barbeau A and B, confirming stable ulnar collateral circulation. Notably, there were no symptoms associated

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with the RAO or other adverse events at the TRA site. The use of a cocktail solution consisting of heparin, verapamil, and nitroglycerin likely played a significant role in mitigating the incidence of RAO by preventing radial artery spasm and thrombosis [24]. This pharmacological strategy corresponds with the positive outcomes observed in our study, supporting the efficacy of the cocktail solution in improving the procedural safety and success of TRA. Despite the administration of heparin, there were no occurrences of rebleeding or complications in achieving hemostasis.

Li et al. [26] reported reference radiation dose levels for a comprehensive list of fluoroscopy-guided interventional procedures. In their study, the median cumulative air kerma for RAE performed via TFA was reported at 1145 mGy, and the median fluoroscopy time was documented at 16 minutes—both exceeding the values obtained in our study (222 mGy and 12 minutes). Cao et al. [8] reported marginally lower, radiation doses and shorter fluoroscopy times for RAE performed via TRA as compared to TFA, although these differences were not statistically significant. These results may be explained by anatomic variations that facilitate a more stable and efficient selection process when performing RAE via TRA, given the downward angulation of the renal arteries from the aorta, thereby minimizing technical challenges and fluoroscopy time, resulting in lower radiation exposure during renal artery interventions with the cranio-caudal approach, thereby offering substantial procedural benefits for TRA over TFA [27,28].

The left radial artery was utilized for access in all patients due to several advantages. The left subclavian artery typically exhibits less tortuosity than the right, and the proximity of the left radial artery to the renal arteries eliminates the necessity of crossing the aortic arch [29,30]. Commonly perceived drawbacks of the left radial approach include increased procedural time and discomfort for the operator; however, studies have indicated that left TRA does not elevate contrast exposure for patients and could potentially reduce radiation exposure for operators [30-32].

HRQoL was evaluated utilizing the EQ-5D-5L questionnaire, with utility index scores calculated via the Korean value set, revealing a range from -0.066 to 1 [18]. In this study, EQ-5D-5L index scores were found to be 0.90 within 24 hours following the procedure and 0.89 at first follow-up, with no statistically significant discrepancy observed between the two time points (P = 0.301). This indicates consistently high levels of HRQoL across the assessment periods, suggesting that TRA does not lead to significant short-term changes in HRQoL, implying that patients maintained stable QoL levels in the early follow-up period after the procedure. The high absolute HRQoL scores associated with TRA imply a potential positive impact on patient quality of life.

Several limitations were identified in this study. First, although the research demonstrated TRA's safety and feasibility for RAE, it did not include a direct comparison with TFA. Future randomized controlled trials comparing TRA and TFA are essential to substantiate the potential benefits of TRA. Second, we planned to handle missing data through multiple imputations using chained equations. Within this study, four patients exhibited missing data, primarily concerning demographic information unrelated to primary outcomes; hence, no additional statistical processing was implemented. Missing parameters specifically related to radial artery measurements and Barbeau test results were not recorded despite these patients meeting the study's inclusion criteria. Third, the single-center nature of this study and its relatively small sample size may limit the generalizability of the findings. Moreover, the follow-up duration was relatively short, focusing predominantly on immediate and short-term outcomes post-procedure. Lastly, RAE is often associated with pain, which could serve as a confounding variable when assessing procedural convenience regarding pain, thus complicating accurate evaluation. Future studies explicitly examining pain related to TRA are warranted.

In conclusion, this study demonstrated that TRA is a safe and effective alternative for RAE in patients with AML or renal hemorrhage. The use of TRA was associated with favorable HRQoL outcomes, as evidenced by consistently high EQ-5D-5L scores.

Supplement

The Supplement is available with this article at https://doi.org/10.3348/kjr.2024.1324.

Availability of Data and Material

The datasets generated or analyzed during the study are available from the corresponding author on reasonable request.

Conflicts of Interest

Jin Hyoung Kim, an Editorial Board Member of the *Korean Journal of Radiology*, was not involved in the editorial evaluation or decision to publish this article. The remaining author has declared no conflicts of interest.

Author Contributions

Conceptualization: Ji Hoon Shin. Data curation: Jihoon Kim, Hee Ho Chu, Ji Hoon Shin, Kyung-Hyun Jung. Formal analysis: Jihoon Kim, Ji Hoon Shin. Funding acquisition: Ji Hoon Shin. Investigation: Jihoon Kim, Hee Ho Chu, Ji Hoon Shin, Kyung-Hyun Jung. Methodology: Ji Hoon Shin. Project administration: Ji Hoon Shin. Resources: Hee Ho Chu, Ji Hoon Shin. Software: Jihoon Kim. Supervision: Ji Hoon Shin. Validation: Ji Hoon Shin. Visualization: Jihoon Kim, Hee Ho Chu. Writing—original draft: Jihoon Kim. Writing—review & editing: Jihoon Kim, Ji Hoon Shin, Jin Hyoung Kim.

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