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Endoscopic Surgery for Deeply Located Intracranial Cysts: Risk Factors for Re-Operation and Symptom Improvement

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Purpose: We investigated the results of endoscopic fenestration for deeply located intracranial cysts (DLICs), risk factors for re-operation, and symptom improvement.

Materials and Methods: We included 51 patients with DLICs who underwent endoscopic fenestration between November 2006 and October 2022. The median age was 5±20 years (6 days–67 years), and 36 (70.6%) patients were aged <20 years. The male-to-female ratio was 1.3:1. The ventriculoscope was used to fenestrate the cysts, which had diameters under 4.5 mm. The volume of DLICs was measured separately on serial magnetic resonance imaging, and the patients were followed up for 32±40 months.

Results: The mean preoperative volume of DLICs was 63.5±87.4 cm^3, which decreased to 23.7±56.2 cm^3 postoperatively, with a 45.4%±32.1% decrease rate in 32 months. All DLICs were approached appropriately, avoiding the eloquent areas. Overall, 39 (76.5%) patients showed symptom improvement after a single operation, which was preserved without recurrence, whereas 12 (23.5%) underwent a second operation [shunting (17.6%) or repeating the endoscopic fenestration (5.9%)] owing to symptom aggravation and recurrent cysts. Patients aged <12 months showed 7.4 times more re-operation rate (p=0.046) and 7.4 times less symptom improvement (p=0.038) compared to those with older age. Females showed 6.5 times more re-operation rate (p=0.037) and 7.1 times less symptom improvement (p=0.027) than males. No patients experienced complications such as cerebrospinal fluid leakage, postoperative hemorrhage, or infection.

Conclusion: Endoscopic surgery is feasible for the treatment of DLICs. Female sex and age <12 months are risk factors for re-operation and less symptom improvement.

Key Words: Endoscopy, central nervous system, cysts, risk factors

INTRODUCTION

Congenital intracranial cysts, originating from aberrations in the lining membranes, are benign developmental cysts.[1,2] Owing to improvements in neuroimaging techniques, more patients with these cysts are being observed. These cysts are categorized according to their location and pathology, with Sylvian fissure arachnoid cysts (SFACs) being the most common type.[3,4]

SFACs have the largest number of arachnoid cysts, comprising 47%–66% of all cases in pediatric patients.[5-7] However, the optimal surgical technique for treating symptomatic SFACs remains controversial, and there is an ongoing debate on whether to fenestrate (microsurgery or endoscopy) or to perform a shunting of the cyst.[8-10]

Except for SFACs, the remaining arachnoid cysts can be classified as suprasellar, ventricular, posterior fossa (quadrigeminal and retrocerebellar), and interhemispheric arachnoid cysts,

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which should be approached through the brain cortex. Other intracranial cysts, such as porencephalic, neuroglial, subependymal, and choroidal fissure cysts, are also located in the deep portion of the brain.

With the development of surgical instruments, endoscopic surgery continues to demonstrate its value in treating deeply located intracranial cysts (DLICs).[11,12] Therefore, in this study, we aimed to focus on analyzing the results of endoscopic surgery for these heterogeneous intracranial cysts.

MATERIAL AND METHODS

Surgical method

Over the past 17 years, endoscopy techniques have changed along with instrumental developments. We commonly use a rigid ventriculoscope with a diameter <4.5 mm, which is used alternately at 6° and 30° scopes, as needed. Recently, we begun using a rigid ventriculoscope (little LOTTA System, Karl storz, Tuttlingen, Germany). Surgery was performed with the assistance of electromagnetic stealth station surgical navigation system (Medtronic, Louisville, CO, USA) to increase the accuracy of the entry and fenestration points.

When planning the entry point, we first considered avoiding eloquent areas, such as the Broca's, Wernicke's, and motor areas. The deeper the operation targets, the more adjacent the brain cortex damage occurs owing to motional limitations. The entrance area requires more angular movement to tear the deeply located membranes. Therefore, the entry point should be as far away from the eloquent area as possible. For the same reason, the penetration length of the brain parenchyma should be minimized in a small and developing pediatric brains.

The surgical method was unified based on the cyst's location.[13]

To treat suprasellar cysts, a burr hole was made 1 cm in front of the coronal suture and 2–3 cm lateral to the midline. This burr hole was positioned just in front of the one used for endoscopic third ventriculostomy, which facilitated viewing of the aqueduct of sylvius. The suprasellar cyst was opened at both its rostral and caudal points. Passing the ventriculoscope through the opening ensured communication between the cyst and the ventricular system.

Burr holes used for approaching quadrigeminal cysts were the same as those used for suprasellar cysts. A lateral ventricle-incising cyst was opened. The deep venous system, including the internal cerebral vein, the vein of Rosenthal, and the straight sinus, was checked while advancing into the cyst through the opening. In addition to ventriculo-cystostomy, a third ventriculostomy was performed simultaneously, as a long-standing quadrigeminal cyst could have caused aqueductal stenosis.

To treat posterior fossa cysts, burr holes were made 1 cm laterally from the midline and below the transverse sinus in the paramedian area. We performed a cystocisternostomy between the cyst and either the quadrigeminal cistern or the cisterna magna. We preferred fenestration into the cisterna magna since it has a wider CSF space and a less significant vein compared to the quadrigeminal cistern.

Compared with microsurgery, difficulty in bleeding control is a disadvantage of endoscopic surgery. To prevent intraventricular hemorrhage, we coagulated the target site widely and weakly using a monopolar instrument before puncturing the membrane. This is also intended to prevent the opening points from being sealed again. The windows were made using endoscopic forceps or a monopolar tip without electrical power, and as many windows as possible were made (Fig. 1).

When an insufficient volume decrease or unsolved mass effects were found, we considered a second operation, such as shunt insertion or repeating the endoscopic surgery. Although there were no exact criteria, shunting was mostly selected (n=9 vs. n=3).

Image analysis

Postoperative volume changes were verified using magnetic resonance imaging (MRI). The first and second postoperative MRI were conducted within a month and a year, respectively. Depending on the symptom improvement or remaining DLIC volume, a third MRI was conducted 1–2 years later to re-evaluate the cysts. Volume changes between values observed on preoperative and last follow-up MRI scans were compared. They were calculated using the ABC/2 method in the PACS system (GE Healthcare, Chicago, IL, USA): A=maximum length (mm), B=width perpendicular to A on the same MRI slice, and C=number of slices multiplied by the slice thickness.[14] In the comparison of preoperative and postoperative DLIC volumes, a reference point of 50% was used.[4,15] The presence of hydrocephalus was determined by radiology reports interpreted by radiologists in a retrospective study.

Statistical methods

Data are presented as mean±standard deviation for continuous variables and number (percentage) for categorical variables. Multiple logistic regression was used to calculate the odds ratio (OR) with a 95% confidence interval for volume change, necessity for a second operation, and symptom improvement. Data on age, sex, hydrocephalus, and cyst location were considered independent variables in the multiple logistic regression analysis. Two-sided p-value <0.05 were considered statistically significant. All statistical analyses were performed using the R software (version 4.1.1; R Foundation for Statistical Computing, Vienna, Austria). The management of retrospective data was approved by the Institutional Review Board of Yongin Severance Hospital (2023-0526-002).

RESULTS

Of the 51 included patients, the male-to-female ratio was 1.3:1.

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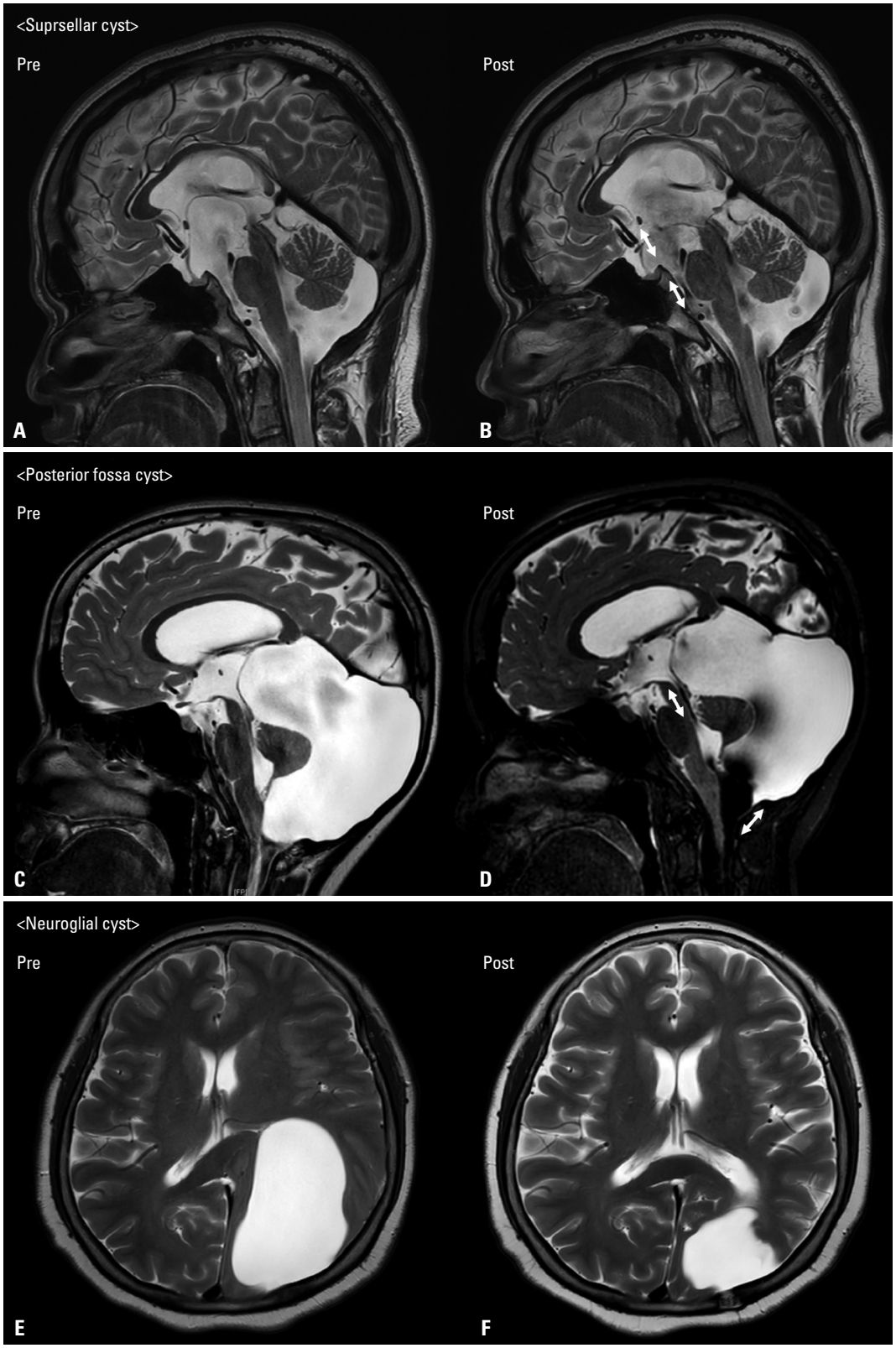

Fig. 1. Endoscopic fenestration for suprasellar arachnoid cyst (A and B), posterior fossa cyst (C and D) and neuroglial cyst (E and F) (white arrows: signal voids through opening).

Table 1. Patient Characteristics (n=51)

	Value
Age, yr (range)	5±20 (6 days–67 years)
<12 months	10 (19.6)
≥12 months	41 (80.4)
Sex	
Male	29 (56.9)
Female	22 (43.1)
Sign and symptoms	
Hydrocephalus	26 (51.0)
Headache	10 (32.3)
Macrocephaly	6 (19.4)
Delayed development and memory impairment	5 (16.1)
Visual disturbance	3 (9.7)
Dizziness	2 (6.5)
Weakness	2 (6.5)
Seizure	1 (3.2)
Incidental finding	1 (3.2)
Location	
Suprasellar	21 (41.2)
Lateral ventricle	14 (27.5)
Quadrigeminal cistern & posterior fossa	9 (17.6)
Third ventricle	4 (7.8)
Interhemispheric	3 (5.9)
Intracranial cyst	
Arachnoid cyst	44 (86.3)
Pathological diagnosis	23 (45.1)
Diagnosis in MRI	21 (41.2)
Neuroglial cyst	2 (13.7)
Undiagnosed cyst	5 (9.8)

Data are presented as mean±standard deviation or n (%).

Table 2. Success Rate of Endoscopic Surgery of DLICs (n=51)

	Value
Preoperative cyst volume, cm^3	63.5±87.4
Postoperative cyst volume, cm^3	23.7±56.2
Post/pre cyst volume ratio (post/pre*100)	
<50%	35 (68.6)
>50%	16 (31.4)
Second operation (redo endoscopic surgery or shunt)	
Yes	12 (23.5)
No	39 (76.5)
Symptom	
Complete	10 (19.6)
Improved	29 (56.9)
No change	4 (7.8)
Aggravated	6 (11.8)

DLICs, deeply located intracranial cysts.
Data are presented as mean±standard deviation or n (%).

The median patient age was 5±20 years (6 days–67 years), and 36 patients (70.6%) were aged <20 years. The mean follow-up period was 32±40 months. DLICs were located in the suprasellar (n=21, 41.2%), lateral ventricle (n=14, 27.5%), quadrigeminal cistern (n=9, 17.6%), third ventricle (n=4, 7.8%), and interhemisphere (n=3, 5.9%). Clinical symptoms and signs in the patients were hydrocephalus (n=26, 51.0%), headache (n=10, 32.3%), macrocephaly (n=6, 19.4%), delayed development or memory impairment (n=5, 16.1%), visual disturbance (n=3, 9.7%), dizziness (n=2, 6.5%), weakness (n=2, 6.5%), seizure (n=1, 3.2%), and incidental finding (n=1, 3.2%).

Among the DLICs, 23 (45.1%) were pathologically diagnosed arachnoid cysts. Although 21 (41.2%) were not pathologically diagnosed, they were regarded as arachnoid cysts owing to their single round shape, an intensified cyst component with cerebrospinal fluid (CSF), and locations such as suprasellar, quadrigeminal, and posterior fossa. Two (13.7%) were diagnosed with neuroglial cysts. The remaining 5 cysts (9.8%) located in the intraventricular area were considered choroid plexus cysts or porencephalic cysts.

Of the patients, 12 (23.5%) were diagnosed using pre- and postnatal neurosonography and observed first. Among them, 10 (19.6%) underwent surgery at age <12 months, when symptom aggravation was observed along with increased cyst volume. Patients aged <12 months were mostly diagnosed through neurosonography, and the improvement of symptoms was assessed by changes in head circumference after surgery and follow-up neurosonography or follow-up MRI. In other patients, arachnoid cysts were diagnosed based on presenting symptoms, and postoperative outcomes were assessed by the degree of symptom improvement and follow-up MRI.

The mean pre- and post-operative DLIC volumes were 63.5±87.4 cm^3 and 23.7±56.2 cm^3, respectively. Based on the ABC/2 method, 35 (68.6%) showed a <50% volume-decreasing ratio. Among the patients, 39 (76.5%) experienced a volume decrease after the first endoscopic fenestration, whereas the remaining 12 (23.5%) underwent second surgery, such as repeat endoscopic surgery (n=3, 5.9%) or shunt insertion (n=9, 17.6%). One patient (2.0%) showed increased cyst volume even after a repeated fenestration. No patients showed enhancing portions or malignant changes during the follow-up period (Table 1).

Regarding the surgery results, 39 (76.5%) showed symptom improvement or completion. Four patients showed no symptom changes (7.8%), and 6 underwent symptom aggravation (11.8%) (Table 2). Multiple logistic regression analysis revealed that patients aged ≥12 months showed significantly lower reoperation rate (OR=0.060, p=0.029) and higher symptom improvement (OR=12.424, p=0.047) compared to those with younger age. Furthermore, female patients showed higher reoperation rate (OR=7.373, p=0.049) and less symptom improvement (OR=0.115, p=0.040) compared to male patients. The third ventricle arachnoid cysts showed significantly lower volume changes and symptom improvement; however, there were only three patients with this type of cyst (Table 3).

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Table 3. Multiple Logistic Regression for Volume Change, Necessity of Second Operation and Symptom Improvement

	Postoperative volume change (<50%)		Second operation (redo fenestration or shunt)		Symptom (complete or improved)	
	Odds ratio (95% CI)	*p* value	Odds ratio (95% CI)	*p* value	Odds ratio (95% CI)	*p* value
Age						
<12 months	1.000 (ref)		1.000 (ref)		1.000 (ref)	
≥12 months	0.327 (0.033–2.118)	0.275	0.060 (0.003–0.609)	0.029*	12.424 (1.225–208.312)	0.047*
Sex						
Male	1.000 (ref)		1.000 (ref)		1.000 (ref)	
Female	3.368 (0.705–24.978)	0.163	7.373 (1.193–75.956)	0.049*	0.115 (0.010–0.739)	0.040*
Hydrocephalus						
No	1.000 (ref)		1.000 (ref)		1.000 (ref)	
Yes	3.773 (0.510–79.047)	0.258	2.834 (0.252–37.191)	0.392	1.280 (0.129–17.633)	0.837
Location						
Suprasellar	1.000 (ref)		1.000 (ref)		1.000 (ref)	
Lateral ventricle	1.379 (0.216–8.373)	0.723	6.000 (0.416–297.172)	0.258	0.235 (0.007–2.798)	0.307
Quadrigeminal cistern & posterior fossa	0.321 (0.009–11.209)	0.494	28.323 (0.862–2882.943)	0.091	0.088 (0.001–4.538)	0.219
Third ventricle	0.014 (0.000–0.203)	0.007*	12.415 (0.644–608.918)	0.130	0.027 (0.001–0.468)	0.027*
Interhemispheric	0.132 (0.002–5.642)	0.269	1.611 (0.019–136.939)	0.824	0.288 (0.003–20.692)	0.556

CI, confidence interval.
*$p<0.05$.

DISCUSSION

The key findings of our study were as follows: 1) 50 patients (98.0%) underwent a decrease in DLIC volume, and 68.6% showed significant volume changes >50%; 2) endoscopic fenestration showed a 76.5% success rate, given symptom improvement and no need for a second operation; 3) age <12 months and female sex were significant risk factors for endoscopic fenestration of DLICs; and 4) none of the patients experienced postoperative infections or hemorrhagic complications.

Avoiding the eloquent areas and creating multiple fenestration points with adjacent cisterns are important factors when creating a corridor for DLICs. These considerations can be efficiently achieved with one-portal endoscopic surgery. Reducing brain damage is important, even in pediatric patients with small and developing brains.

Microsurgery tends to have longer cystocisternostomy permeability than endoscopic surgery for treating SFAC.[8] Through a relatively large bone flap and enlarged sylvian space, a microscope can remove sufficient arachnoid cyst membranes and make more CSF flows between cysts and cisterns. However, compared with endoscopy, microscopes offer limited operational views and manipulation areas, which are disadvantageous for DLICs. On the other hand, when cystoperitoneal shunting procedures are performed, there are many possible complications, such as postoperative infection or obstruction.[16] Therefore, endoscopic fenestration should be the first choice for treating DLICs.[17-19]

In pathologically heterogeneous groups, many portions were occupied with arachnoid cysts even when SFAC, which showed half or slightly higher incidence within the total arachnoid cyst patients, was excluded.[5-7] This corresponded with the results of our study, in which arachnoid cysts were diagnosed pathologically in 23 (45.1%), and 21 (41.2%) were additionally diagnosed with arachnoid cysts using MRI. Confirming the pathology was not mandatory since these congenital cyst groups were benign and MRI had already proved no enhancing portion. Moreover, retaining sufficient membrane tissue using a one-portal endoscope is usually difficult. At our institute, no patient had been misdiagnosed with malignant tumors for 17 years. An unreasonable biopsy can cause unexpected and unsolvable bleeding. In contrast, ensuring sufficient CSF flow is of utmost concern. Due to this common concern, we classified these homogeneous cysts into the same group, namely DLICs.

Many studies have reported a significant tendency for SFACs to occur in males.[20-23] Genetic mechanisms have also been suggested; however, the reason why males develop more middle fossa cysts remain stills unknown. On the contrary, Helland, et al.[23] reported that cerebellopontine angle (CPA) cysts have a significant female preponderance and no sexual differences in arachnoid cysts, excluding temporal fossa and CPA cysts. This implies that male preponderance is a factor limited to SFACs, and that other arachnoid cysts can be separated from SFACs. Among DILCs, the proportion of females was relatively higher than that of SFACs (43.1%). Moreover, females showed higher surgical failure and re-operation rates, as well as less symptom improvement. This suggests that female sex can be a risk factor for both the incidence and surgical results of DLICs. Progesterone receptors were identified with an enzyme immunoassay in cytosols from human arachnoid cysts.[24] Following dam-

age to the brain, estrogens can promote neurogenesis and neural recovery by attenuating neural outgrowth and glial activity.[25] Further research is necessary; these female hormones have the potential to reform cysts and affect CSF fluid dynamics.

It remains unclear whether infants have a higher risk of treatment failure after neuroendoscopic procedures for the treatment of intracranial cysts. Sutural expansion rather than CSF flow via the fenestration site, the plasticity of the developing brain, immaturity of the subarachnoid CSF dynamics, and deficiency of the absorptive capacity of the subarachnoid space for hemorrhage or meningitis could be the reasons for endoscopic fenestration failure in infants aged <1 year.[26-32] From the same point of view, failure rate of endoscopic 3rd ventriculostomy is known to be related with young age.[33,34] El-Ghandour[18] reported that a prerequisite for treating intracranial cysts in infants aged <12 months is the presence of an area of contiguity within the subarachnoid cisterns and/or ventricular system.

In the present study, we first observed 12 DLICs (23.5%) detected using pre-and post-neurosonography. Despite a close follow-up using neurosonography, only two patients with DLICs (16.7%) could endure observation over 12 months. Endoscopic surgery at the age of 12 months showed a significantly high re-operation rate and lower symptom improvement rate. Unfortunately, shunt insertion is also disadvantageous for treating young patients due to the high infection rate.[35-39] Therefore, endoscopic fenestration should be delayed as much as possible for up to 12 months with close imaging follow-up. Nevertheless, if early surgery is required, creating large windows at multiple points is essential to prevent plasticity.

In conclusion, endoscopic surgery is feasible for the treatment of DLICs. We observed that 76.5% of patients experienced symptom improvement, and 98.0% showed volume decrease with a single endoscopic surgery. Female sex and age <12 months were significant risk factors for re-operation and symptom improvement. Further research is needed due to the small number of patients in this study.

AUTHOR CONTRIBUTIONS

Conceptualization: Dong-Seok Kim. Data curation: Kyu Won Shim. Formal analysis: Eun Kyung Park. Funding acquisition: Dong-Seok Kim. Investigation: all authors. Methodology: Jun Kyu Hwang. Project administration: Ju-Seong Kim. Resources: Eun Kyung Park. Software: Kyu Won Shim. Supervision: Dong-Seok Kim. Validation: Kyu Won Shim. Visualization: Jun Kyu Hwang. Writing—original draft: Jun Kyu Hwang and Ju-Seong Kim. Writing—review & editing: all authors. Approval of final manuscript: all authors.

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