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Meningiomas of the Cerebellopontine Angle: Tips and Pearls for Safe Surgical Resection

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ABSTRACT

AIM: To present our series of cerebellopontine angle (CPA) meningiomas, and to provide some innovative surgical steps for safe removal of these tumors.

MATERIAL and METHODS: The clinical, radiological, and surgical characteristics of 32 patients with meningioma in the CPA were retrospectively analyzed. A statistical analysis was performed to determine the factors that affect the incidence of complication.

RESULTS: The mean age was 49.5 yr, and 87.5% of patients were men had World Health Organization (WHO) grade I meningioma, while the remaining patients had WHO grade II tumors. The mean tumor volume was 33.98 mL, and gross total resection was performed on 65.6% of the patients. Preoperative tumor size/extension and extent of resection were related with the development of complications.

CONCLUSION: CPA meningiomas are challenging tumors to remove safely. Important risk factors for the development of postoperative complications include tumor size and extent of resection.

KEYWORDS: Meningioma, Cerebellopontine angle, Surgery, Complication

INTRODUCTION

Posterior fossa meningiomas account for 8%–23% of all intracranial meningiomas (9,13,19). These tumors are typically benign and slow-growing. Therefore, clinical symptoms sometimes do not appear until the tumors reach giant dimensions; thus, tumors in the cerebellopontine angle (CPA) may result in irreversible neurological deficits and even sudden death if not treated. The CPA is hardly reachable and is a complex zone in terms of surgery because of its anatomical location and structure. Although surgical resection includes many challenges, the main treatment strategy for meningiomas is gross total resection (GTR) without damaging neurovascular structures. As surgeons' knowledge and experience on skull base surgery has increased, various approaches, such as the retrosigmoid (RS) and translabyrinthine (TL) approaches, have been described and used for CPA meningiomas for many years. The TL approach is particularly preferred for patients with small tumors that are associated with hearing loss, as it allows for direct access to the tumor with less cerebellar retraction (20). However, this approach is insufficient for large tumors or tumors that do not affect hearing function. The RS approach, which is frequently preferred for such tumors, stands out because of the surgeons' experience and the reduced risk of hearing loss compared with the TL approach. However, this approach may prevent total resection and cannot provide sufficient visibility for large tumors. In addition, the RS approach involves greater cerebellar retraction and provides an insufficient area for surgical manipulation. Therefore, this technique limits total tumor resection and may lead to neurovascular complications during surgery. Moreover, the severity of cerebrospinal fluid (CSF) leakage and infections that may result from this surgery are not to be underestimated.

In this study, we aimed to minimize the risk of complications and achieve complete tumor resection as much as possible by

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introducing the tips and pearls of surgery. We emphasized the main steps of surgical resection and pointed out the factors that affect the risk of complication.

MATERIAL and METHODS

Study Design

Two neurosurgery clinics at tertiary hospitals collaborated to conduct this study (22.12.2020/11-27). The same surgical technique was performed in 32 cases of CPA meningioma, and the results were evaluated. The surgeries were performed between 2013 and 2020. Neurological examinations, hearing tests, magnetic resonance imaging (MRI), and computed tomography were performed for all the patients before and after surgery. The study excluded patients who had previously undergone surgery, radiotherapy, or chemotherapy were excluded from the study. The diagnosis of meningioma was confirmed by postoperative histopathological examinations in all patients. Ethics board approval was obtained from the institutional ethics committee, and consent for the use of imaging scans was obtained from all the patients. Cranial MRI was performed within the first 48 hours after the surgery to determine the extent of resection and postoperative changes. The patients were followed-up 1, 3, and 6 months after discharge. Prior to the sixth month, follow-up was considered short-term, and that after the sixth month was considered long-term.

Surgical Technique

Patient Positioning

While under general anesthesia, the patients were fastened using a head holder in a slanted position with the head turned 10–15° toward the ground in flexion. An arterial line and a central venous catheter were placed in all patients. Dexamethasone was started 48 hr before surgery, and prophylactic antibiotics were administered 30 minutes before surgery. Soft pads were placed at sites neural injury might occur. The patients were supported from the front and rear parts of the operation table and fixed to the table to ensure that the surgical site could be viewed from a wide range of angles.

Skin Incision and Muscle Dissection

After skin cleaning, an approximately 12-cm skin incision was performed up to C1–C2 in the inferior region and to the transverse sinus projection in the superior region, approximately 2 cm lateral to the mastoid eminence. The skin incision was extended by subcutaneous dissection of the suboccipital galea and periosteum. Although the galeal and subperiosteal layers were peeled off, the posterior borders of the sternocleidomastoid and trapezius muscles were carefully dissected. Emissary vein bleeding during the subperiosteal dissection was stopped with bipolar coagulation and bone wax. The subperiosteal dissection was continued until the foramen magnum and surface of the C1 side appeared.

Craniectomy

The standard RS craniectomy was performed using a high-speed drill. Mannitol administration was started before the craniectomy. Afterward, the craniectomy site was extended to the foramen magnum to protect the occipital condyle in the inferior region to extend the tumor resection up to the caudal end and centerline posteriorly. A hole was made with a high-speed drill superiorly to expose the transverse sinus. Mastoid air cells were drilled down to the lateral level. The surface of the sagittal sinus became as thin as eggshells and thus was removed using a Kerrison Rongeur. The sigmoid sinus was completely exposed. The sigmoid sinus is adjacent to the bone structure—especially in old people—and causes minimal bleeding. Thus, to stop the bleeding and repair the injured part, a surgical absorbable haemostat was used. The mastoid bone was completely closed with bone wax, and the risks of otorrhea and otorrhagia were prevented (Figure 1A).

The Dural Opening and Tumor Exposure

A star-shaped incision was made to allow access to the sinuses through the dura mater. The parts that bled during the opening were sutured. The four parts of the dura that were formed by the incision were opened and hung. The arachnoid of the cisterna magna was incised, and CSF leakage was prevented. To increase exposure and prevent undesired injuries, the cerebellum was elevated to, cotton pads were placed over its surface. The arachnoid was opened up to the jugular foramen, and CSF drainage was ensured. The damage that can result from surgical dissection and hemorrhage was prevented by leaving the brain stem and arachnoid membrane intact.

Tumor Removal

To minimize bleeding during resection and to shorten the operation duration, the feeding vessels of the tumor were eliminated by rapidly cauterizing the tumor from the part adhered to the dura using bipolar coagulation. After complete separation of the tumor from the dura, it was excised from the surface with an ultrasonic aspirator. After removal, the tumor was covered with cotton pads, and the adhered parts were separated by sharp dissection using scissors. After a tumor reduction, neural structures were checked with a neurostimulator, and the tumor was excised with sharp dissections without harming the structures. The tumor parts remaining on the dura were excised with partial dura excision and cauterization. Large tumors generally result in displacement of cranial nerves (CNs). Therefore, the operation must be performed within the narrow distance between the CNs. The disconnection of the tumor from the CNs is ensured by sharp dissection after the tumor debulking. The tumor is not moved toward the brain stem during the dissection of extremely large tumors or with those compressing the brain stem. Tumor tissues adjacent to the CNs are excised by mobilizing lateromedially.

Closing the Incision

Once the tumor was removed, at the closure stage, a synthetic dura graft was used to cover the surface of the cerebellum, and the surgery was completed after the bleeding was under control. The dura was closed with primary suturing if possible (Figure 1B) and a three-layer dural closure was performed using a synthetic dura graft when necessary (Figure 1C). A titanium

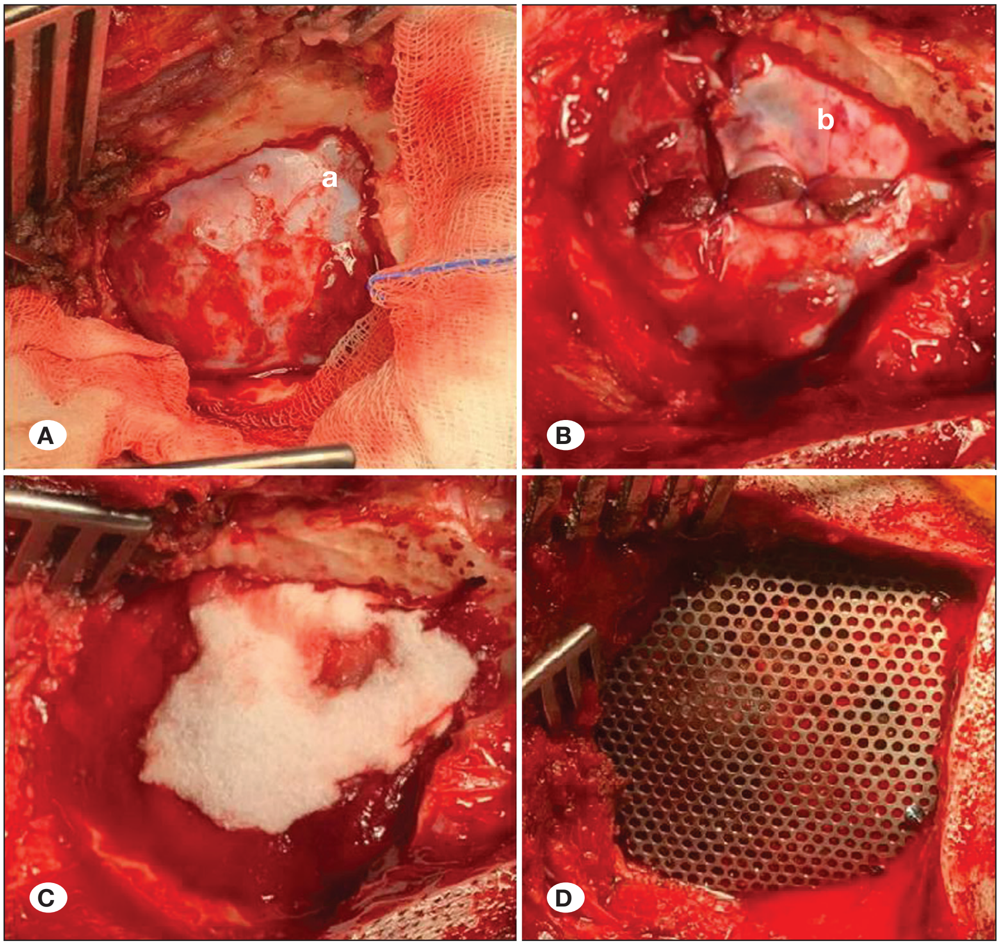

Figure 1: A) Dura was exposed after craniectomy. **B)** Synthetic dura graft was used to cover the surface of the cerebellum, and the dural edges were approached as much as possible. **C)** Three-layer dural closure was performed using a synthetic dura graft to cover the dural surface. **D)** Craniectomy area was closed using titanium mesh and mini-screws.

mesh was inserted over the craniectomy area and secured with mini-screws (Figure 1D). Afterward, the surgical region was classically closed in a way that would be convenient for the muscles, fascia, subcutaneous zone, and skin layers.

Statistical Analysis

SPSS v. 26.0 (IBM Corporation, Armonk, NY, USA) was used for the statistical analyses. The conformity of the univariate data to a normal distribution was assessed with the Shapiro–Wilk or Shapiro–Francia tests, and variance homogeneity was assessed with the Levene test. To compare two independent groups for quantitative data, independent-samples *t*-tests were performed with bootstrapping, and the Mann–Whitney *U* test was performed using the results of Monte Carlo analysis. For the comparisons of categorical variables, Pearson's chi-squared tests and Fisher's exact tests were performed. The column ratios were compared and expressed according to the corrected *p* values obtained using the Benjamini–Hochberg procedure. Odds ratios with 95% confidence intervals were calculated to compare the frequency of risk factors occurring and not occurring. Sensitivity and specificity ratios were examined and expressed with the receiver-operating curve analysis of the relationship between the real classification and the classification based on the cut-off values for the groups that were calculated according to the variables. Quantitative variables are presented as mean ± standard deviation and median (range) in the tables, and categorical variables as number (%). The variables were examined at a 95% confidence interval level, and those with p values < 0.05 were considered significant.

RESULTS

Patient Demographics

A total of 32 patients underwent surgery for CPA meningioma. The mean age of the patients at the time of admission was 49.50 ± 12.70 yr (range, 25–77 yr). The mean follow-up period was 43 months (range, 11–92 months). Of the patients who underwent surgery, 87.5% were women. Based on histopathological examinations, none of the patients had World Health Organization (WHO) grade III meningioma, 87.5% had WHO grade I meningioma, and the remainder had WHO grade II meningioma. The mean preoperative tumor volume was 33.98 ± 26.01 mL (range, 5.4–120.1 mL), and 65.6% of the patients underwent GTR (Figure 2). The full summary of the cases is presented in Table I.

Clinical Presentation

In previous studies, a wide range of clinical symptoms have been observed for CPA meningiomas, from CN deficits to

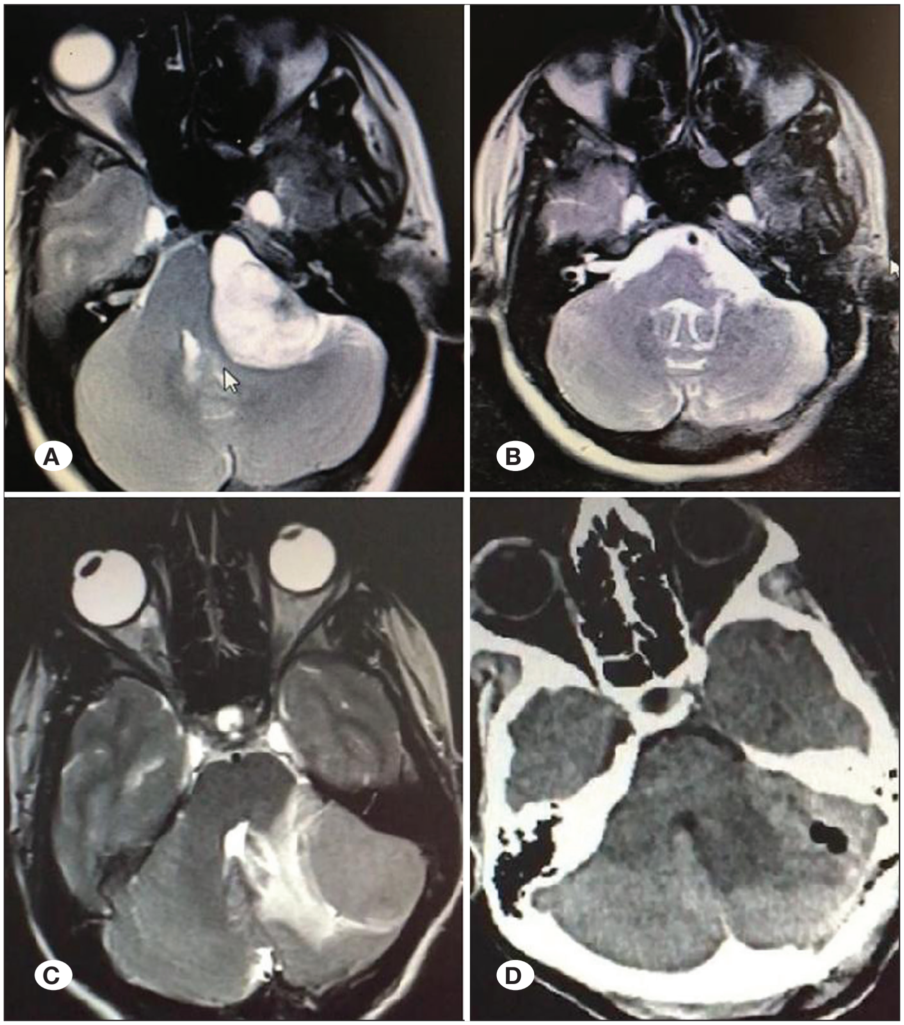

Figure 2: A) Preoperative T2-W axial MRI scan showing a large meningioma in the cerebellopontine angle (CPA) with brain stem compression. **B)** Postoperative T2-W axial MRI scan confirming the gross total resection (GTR). **C)** Preoperative T2-W axial MRI scan showing a large meningioma in the CPA with brain stem compression. **D)** Postoperative computed tomography scan confirming the GTR.

acute cerebellar ataxia. In the current study, the most common symptom was headache, followed by hearing loss, ataxia, and tinnitus. The symptoms at presentation are summarized in Table II. Although the tumor extended to the jugular foramen in 12 cases in our study, no abnormal findings were found for the lower CNs. When we evaluated internal auditory canal (IAC) invasion clinically, 16 of the 32 patients had IAC invasion, while 17 had hearing problems.

Relationship between CPA Meningioma Resection and Hearing Loss

Complete relief was not achieved in postoperative period in any of the 17 patients with preoperative hearing problems. After the surgery, nine patients had hearing levels that remained unchanged, three had partial recovery, three had worsened hearing loss, and two had complete hearing loss. The hearing level decreased in 2 of the 15 patients who had no prior hearing problems, resulting in deafness in one of the patients.

Cranial Nerve Complications

Early complications occurred in 10 of the 32 patients. While two patients died from hematoma, CN deficits developed in the remaining eight patients. A ventriculoperitoneal shunt device was inserted in three of the eight patients because of hydrocephalus. A total of 19 CNs were affected in the eight patients with CN deficits. While complete healing was achieved in four of the eight patients in the long-term follow-up, the CN deficits became permanent in the other four patients. Four patients had a CN VIII deficit, two had a CN X deficit, and one had a CN VII deficit.

Factors Affecting the Incidence of Complications

Various factors, such as tumor size/extension and extent of resection, were found to affect the incidence of complications. The cut-off value tumor volume was >28.56 mL for short-term ($p<0.001$) complications and >32.64 mL for long-term ($p<0.001$) complications. In addition, the incidence of CN deficits was higher in patients with tumor volumes > 32.64 mL (Table III). Total excision was achieved in 17 of the 20 patients without jugular extension and in four of the 12 patients with jugular extension. Thus, the total resection rate is lower in the presence of jugular extension.

We found that IAC invasion did not hinder the total removal of the tumors and that the development of postoperative complications was not related to the CN deficits.

Table I: Summary of All Cases

	Mean ± SD	Median (minimum/ maximum)
Age	49.50 ± 12.70	48.5 (25/77)
Volume, ml	33.98 ± 26.01	31.4 (5.4/120.1)
	n	**%**
Sex		
Female	28	87,5
Male	4	12.5
Side		
Right	10	31.2
Left	22	68.8
IAC invasion		
No	16	50.0
Yes	16	50.0
Jugular extension		
No	20	62.5
Yes	12	37.5
Resection		
GTR	21	65.6
STR	11	34.4
Pathology		
Grade I	28	87.5
Grade II	4	12.5
Complication in the short term period		
No	22	68.8
Yes	10	31.2
Complication in the long term period		
No	26	81.2
Yes	6	18.8
Complication in the short term*		
CN	10	28.5
CSF leakage	1	2.9
Hematoma	2	5.7
V-P shunt	3	8.6
V	2	5.7
VI	3	8.6
VII	3	8.6
VIII	4	11.4
IX	2	5.7
X	5	14.3
Complication in the long term*		
CN	6	40.0
EX	2	13.3
VII	1	6.7
VIII	4	26.7
X	2	13.3

***SD:** Standard deviation, **CN:** Number of complications *Calculated using the number of complications, **V-P shunt:** ventriculoperitoneal shunt, **CSF:** Cerebrospinal fluid, **CN:** Cranial nerve, **EX:** Exitus.*

Table II: Clinical Presentations

Symptom	Number of Patients (%)
Headache	20 (62.0)
Hearing loss	17 (53.0)
Ataxia	8 (25.0)
Tinnitus	4 (12.0)
Dyplopia	3 (9.0)
Facial numbness/pain	3 (9.0)
Hemifacial spasm	2 (6.0)

Table III: Relationship Between Tumor Volume and Complications

Volume (ml)	Short-term complication	Long-term complication
Cutoff	>28.56 ml	>32.64 ml
Sensitivity	100	83.3
Specificity	63.6	73.1
AUC ± SE	0.855 (0.066)	0.853 (0.085)
p value	**<0.001**	**<0.001**

***ROC:** Receiver-operating characteristic (Honley&McNell-Youden index J), **AUC:** Area under the ROC curve, **SE:** Standard error.*

Other Complications

The patients experience early-stage wound site infection, and one patient experienced pulmonary complications. Although hydrocephalus occurred in three patients, CSF leakage occurred in only one patient. The worst hydrocephaly was observed in the patient with CSF leakage, which was resolved with a shunt operation.

DISCUSSION

Surgical management of CPA tumors is challenging, and the best surgical technique has been controversial for a long time owing to the complex anatomical structure of this region. The total resection rate ranged from 27% to 55% before microsurgery era, with high mortality rates (1,5,9,13,18,19,23). Many studies support the total resection of CPA meningiomas, and the GTR rates reported as 27%–86% (1,5,8,16,18,23). This was also observed in the present study, and GTR was achieved in 21 cases (65%), and the mortality rate was 6.2%. Tumors that reach large dimensions make GTR difficult due to adherence to vital structures and sometimes impossible. Performing a GTR of these tumors causes serious complications. In the current series, GTR was less frequently achieved for patients with jugular extension. This indicates that the probability of GTR is low if the tumor extends toward the lower CNs. However, the accuracy of this finding must be investigated in further studies.

Many studies showed that the larger the tumor size, the lower the total resection rate (1,3,17). However, the tumor regrows at different time points if not totally removed. The risks of mortality and morbidity with repeated surgeries are higher. Therefore, some authors suggested safe subtotal resection (STR) and follow-up by radiotherapy (22). The surgical approach in this study was to first ensure total resection of the tumor. However, STR has been performed to prevent irreversible complications for tumors surrounding and adhering to neurovascular structures, and those that are difficult to separate from the vital structures.

In terms of clinical findings, hearing problems were the most frequent complaint. We observed that all of the patients who presented with hearing loss had IAC invasion, and one patient presented with hearing loss despite the absence of IAC invasion. In this study, 50% of the patients had IAC invasion. Hearing worsened in approximately 20% of patients. This was better than some literature data (4). When the results were evaluated in terms of hearing loss, surgical resection of CPA meningiomas with or without IAC invasion generally had good results.

Although the incidence rate of CN VII deficits differs across studies, it ranges from 4% to 25% on average (2,11). In agreement with previous results, it was 9.3% in the current study. Although the incidence rate of newly developing lower CN deficits is 62% based on a study by Sanna et al. (19), it ranges from 17% to 33%, according to Kane et al. (11). In the current study, the incidence rate of newly developing lower CN deficits was 6.2%. This was achieved by careful microsurgical dissection and appropriate tumor removal with lower CN neighborhood.

Surgical manipulation may be difficult and lead to parenchymal injury from cerebellar retraction and neurovascular injuries due to the limited field of view and mass impact, especially for large CPA meningiomas. Limited craniectomy prevents directly opening the cistern magna and CSF leakage (10,12,21). In this way, sufficient relaxation of the cerebellum cannot be achieved, and complications may be inevitable (7,8,15,17). The tumors are traditionally resected with the RS approach (9,16,18). This approach remains insufficient for resecting large tumors because it provides limited exposure (6,9,16,17,18). Therefore, the extended RS approach (ERA) has been applied in all surgical procedures. The ERA was previously argued by some authors to provide benefits in terms of complete resection of the bone on the sigmoid sinus, lateral extension and thus extension of the surgical area, and easier access to deep vascular structures (1,6,7,8,14). In addition, in a cadaver study by Ceylan et al. (6), the exposure is increased by 50%. Surgical manipulation over large tumors also increased in this study, and easier manipulation was possible in the surgical area owing to the wider exposure. Resection could be easily performed because the intervention could be performed to the tumor from every angle while peeling off the tumor from the CNs. Moreover, easier bleeding control was ensured by wider exposure compared with the standard RS approach.

One of the most worrisome complications of this approach is CSF leakage. Because of the need for reoperation depending on the severity of the CSF leakage, the development of infection, and increased risks of mortality and morbidity depending on the cause, many surgeons shun these types of surgeries. In the literature, the incidence of CSF leakage ranges from 6% to 10% for CPA tumors. In short-term and long-term periods, no CSF leak occurred with this technique. Only subcutaneous CSF collection was observed in one patient, which was resolved after shunting. However, larger series are needed to better understand the efficacy of this technique especially in patients with CPA meningioma.

CONCLUSION

ERA decreases the complication rate while also increasing the total tumor resection rate. Tumor size and extent of resection are important risk factors for the development of postoperative complications. Surgery for CPA meningiomas should not just be evaluated by removal of the tumor and the occurrence or non-occurrence of complications, but should also be assessed overall from opening to closure.

AUTHORSHIP CONTRIBUTION

Study conception and design: IG, CY
Data collection: AD
Analysis and interpretation of results: IG, AD
Draft manuscript preparation: IG, CY
Critical revision of the article: AD
Other (study supervision, fundings, materials, etc...): AD, CY
All authors (IG, CY, AD) reviewed the results and approved the final version of the manuscript.

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