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ORIGINAL ARTICLE

Clinical Outcomes of Combined Transcranial and Endoscopic Transnasal Approaches in the Management of Cranionasal Communicating Tumors.

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Abstract

BACKGROUND: Cranionasal communicating tumors often originate from the extra-axial intracranial tissue, nasal cavity, and sinuses, and mostly invade the anterior skull base, leading to communication between the cranial and nasal cavities. Cranionasal communicating tumors are clinically rare and thus have been rarely reported in the literature.

OBJECTIVE: To investigate the clinical outcomes of combined transcranial and endoscopic transnasal approaches in the surgical management of cranionasal communicating tumors.

METHODS: We retrospectively analyzed patients with cranionasal communicating tumors treated at the Department of Neurosurgery, Jinhua Hospital, affiliated with Zhejiang University, from July 2017 to March 2020. All patients were surgically treated using combined transcranial and endoscopic transnasal approaches or the cranionasal dual approach, and skull base reconstruction was performed simultaneously. The postoperative gross tumor resection rate, perioperative complications, and postoperative efficacy were evaluated.

RESULTS: Eleven patients with 14–37 months of follow-up were included. Eight patients underwent total resection, two patients underwent subtotal resection, and one patient was treated with partial resection. Postoperative pathological diagnoses revealed four olfactory neuroblastomas, three atypical meningiomas, two recurrent papilloma malignancies, one recurrent invasive pituitary tumor, and one recurrent invasive pituitary adenocarcinoma. Among the 11 patients, severe cerebral edema was observed postoperatively in one patient, and decompression craniectomy was performed. Intracranial infection was observed in two patients, including one with transient cerebrospinal fluid leakage, which was cured after symptomatic treatment. Moreover, postoperative ocular dysmotility and worse olfactory sensation were observed in one and two patients, respectively. The mean follow-up time of the 11 patients was (24.4 ± 5.7) months. The one-year survival rate of the patients was 100%; 10 patients (90.9%) had a favorable outcome (Glasgow Outcome Scale score of 4–5), and only one patient (9.1%) had a Glasgow Outcome Scale score of 3. Furthermore, during the last follow-up, tumor recurrence occurred in two patients (18.2%).

CONCLUSION: Surgical treatment of cranionasal communicating tumors using the cranionasal dual approach and simultaneous skull base reconstruction improves the gross tumor resection rate with fewer postoperative complications and good short-term efficacy.

INTRODUCTION

Cranionasal communicating tumors are clinically rare and thus have been rarely reported in the literature. Cranionasal communicating tumors often originate from the intra-axial intracranial tissue, nasal cavity, and sinuses, and mostly invade the anterior skull base, leading to communication between the cranial and nasal cavities (He *et al.* 2021). In principle, surgical treatment is the first choice for tumors, which should be excised as much as possible to prevent recurrence. However, because of the trans-regional lesions of the skull base and the complicated surrounding anatomical relationships adjacent to important structures, such as the eye, cranial, and nasal neurovascular structures, the treatment of these tumors is a great challenge for neurosurgeons (Casselman 2005, Jimbo *et al.* 2010). Moreover, the pathological types of tumors vary, and invasive tumor growth leads to the invasion and destruction of the basicranial dura mater and skull base, which easily leads to postoperative complications such as cerebrospinal fluid rhinorrhea, intracranial infection, and neurological dysfunction (Patel *et al.* 2012).

Traditionally, the transcranial approach has been combined with the transfacial approach, also called the craniofacial approach, to treat sinonasal skull base tumors. This approach allows access to tumors communicating with the nasal cavity (Liu *et al.* 2003). However, the transfacial approach often involves invasive techniques, including extensive facial incisions, lateral rhinotomies, and/or facial osteotomies, which result in unsatisfactory cosmetic results (Eloy *et al.* 2009). In the past decades, the endoscopic endonasal approach (EEA) has gained increasing popularity owing to continuous advances in intraoperative image guidance, endoscopic instrumentation, and surgical techniques (Komotar *et al.* 2013). Compared to the craniofacial approach, transnasal endoscopic resection of anterior ventral skull base tumors has been reported to be associated with decreased hospital stay, decreased estimated blood loss, and faster recovery (Wood *et al.* 2012). However, a pure EEA has limitations when treating cranionasal communicating tumors with significant intracranial extension (Liu *et al.* 2016). Therefore, a dual cranionasal approach combining transcranial and endoscopic transnasal approaches remains useful for the treatment of sinonasal and ventral skull base malignancies (Liu *et al.* 2017). However, few studies have been performed on the clinical efficacy of this approach for treating cranionasal communicating tumors.

METHODS

Patient Population and Radiological Features

Between July 2017 and March 2020, 11 patients with cranionasal communicating tumors were included in the study. Inclusion criteria for this study included the following: 1. The tumor invaded into the skull and nasal cavity. 2. A single surgical approach (transcranial approach or transnasal approach) does not allow complete exposure of the tumor, resulting in incomplete tumor resection.

Seven patients were male and four patients were female, and their mean age was 51.2 ± 9.4 years (range, 38–72 years). The main clinical manifestations were headache (five patients, 45.4%), nasal congestion (four patients, 36.3%), hyposmia (three patients, 27.3%), nausea and vomiting (two patients, 18.2%), and ocular dysmotility (two patients, 18.2%). Four patients (36.4%) had a history of tumor reoperation for recurrence. Examination using cranial computed tomography angiography (CTA) and cranial enhanced magnetic resonance imaging (MRI) confirmed that all the tumors invaded the cranial and nasal cavities, and there were bony defects in the skull base (ethmoid plate, sphenoid sinus, or frontal sinus). Clinical information including previous surgical intervention and presenting symptoms of patients included in this study is summarized in Table 1.

This study reports a case series of patients with cranionasal communicating tumors that underwent combined transcranial and endoscopic transnasal resection in the Department of Neurosurgery, Jinhua hospital affiliated with Zhejiang University from July 2017 to March 2020. This study aimed to review the surgical management of cranionasal communicating tumors using combined transcranial and endoscopic transnasal approaches and investigate the prognosis and clinical outcomes following implementation of this strategy.

Surgical Approach and Surgical Technique

After general endotracheal anesthesia and appropriate venous and arterial access were obtained, all patients were placed in the supine position. The head was then elevated 10° to 15° to facilitate venous drainage and was also rotated 10° to 15° toward the contralateral side. The surgical incision was designed based on the location and size of the lesion, including the surrounding tissues and structures involved in the tumor. All patients underwent a combined transcranial and endoscopic transnasal approach (cranionasal dual approach), and skull base reconstruction was performed simultaneously.

Transcranial approach: A pterion or coronal scalp flap incision was made according to the range of intracranial lesions and bony defects of the skull base. Particular attention was paid to protect the pedicle frontal periosteal graft and supraorbital artery during

Tab. 1. Clinical information including previous surgical intervention and presenting symptoms of patients included in this study

Pt	Age/Sex	Previous surgical intervention	Presenting symptoms
1	61/M	No	Nasal congestion
2	45/M	No	Headache, hyposmia
3	72/F	No	Nasal congestion, nausea and vomiting, ocular dysmotility
4	51/M	No	Nausea and vomiting
5	52/F	Yes	Headache, hyposmia
6	47/M	No	Nasal congestion
7	43/M	No	Nasal congestion
8	51/M	Yes	Headache, hyposmia
9	57F	No	Headache, ocular dysmotility
10	46/M	No	Nasal congestion
11	38/F	No	Headache

surgery. Tumors that invaded the dura mater, bony defects of the skull base, and nasal cavity could be clearly observed, and the tumor and invaded brain tissue, dura mater, and surrounding bone were carefully resected. Transnasal approach: Endoscopic endonasal surgery was performed using a STORZ endoscope and a dynamic system (Karl STORZ, Germany; 0° and 30° lenses). Epinephrine was routinely used to contract the nasal mucosa, and the middle or superior turbinate on the affected side was resected based on the extent of tumor invasion. If the nasal mass is large, the tumor volume should first be reduced before fully exposing the skull base. The CTA neuronavigation system (Medtronic S7) was used to guide the removal of the skull base bone (including the ethmoid sinus, anterior wall of the sphenoid sinus, sellar floor, and tuberculum sellar), and the base dura mater was then fully exposed. Skull base reconstruction: After successful tumor removal, skull base reconstruction and dural repair were prioritized. A multi-layer repair, or "sandwich repair", technique was performed simultaneously. The first layer was the dural layer, which could be repaired using the temporalis muscle fascia or artificial dura mater; the suture should be as tight as possible. If the defect was too small or unsuturable, the artificial dura mater was placed beneath the dura mater, and the defect area was completely covered. The second layer was free autogenous tissue, a rotating pedicled temporalis flap, or surrounding fat placed extradurally between the first and third layers. The third layer is the skull base, which is covered with a pedicled septal mucosa flap or pedicle frontal periosteal graft. After reconstruction, biological

Tab. 2. Clinical information including follow up, gross tumor resection, tumor recurrence, GOS score, pathological diagnosis and complications of patients included in this study

Pt	Last follow up (months)	Gross tumor resection	Tumor recurrence	Last GOS score	Pathological diagnosis	Complications
1	26	Total removal	No	5	Recurrent papilloma malignancy	No
2	18	Total removal	No	5	Olfactory neuroblastoma	Severe cerebral edema
3	14	Partial resection	No	3	Recurrent papilloma malignancy	Ocular dysmotility
4	26	Total removal	No	5	Atypical meningioma	No
5	37	Subtotal resection	Yes	4	Recurrent invasive pituitary adenocarcinoma	Intracranial infection and worse olfactory sensation
6	24	Total removal	No	5	Olfactory neuroblastoma	No
7	28	Total removal	No	5	Atypical meningioma	No
8	23	Subtotal resection	Yes	4	Recurrent invasive pituitary tumor	Intracranial infection and worse olfactory sensation
9	24	Total removal	No	5	Atypical meningioma	No
10	23	Total removal	No	5	Olfactory neuroblastoma	No
11	25	Total removal	No	5	Olfactory neuroblastoma	No

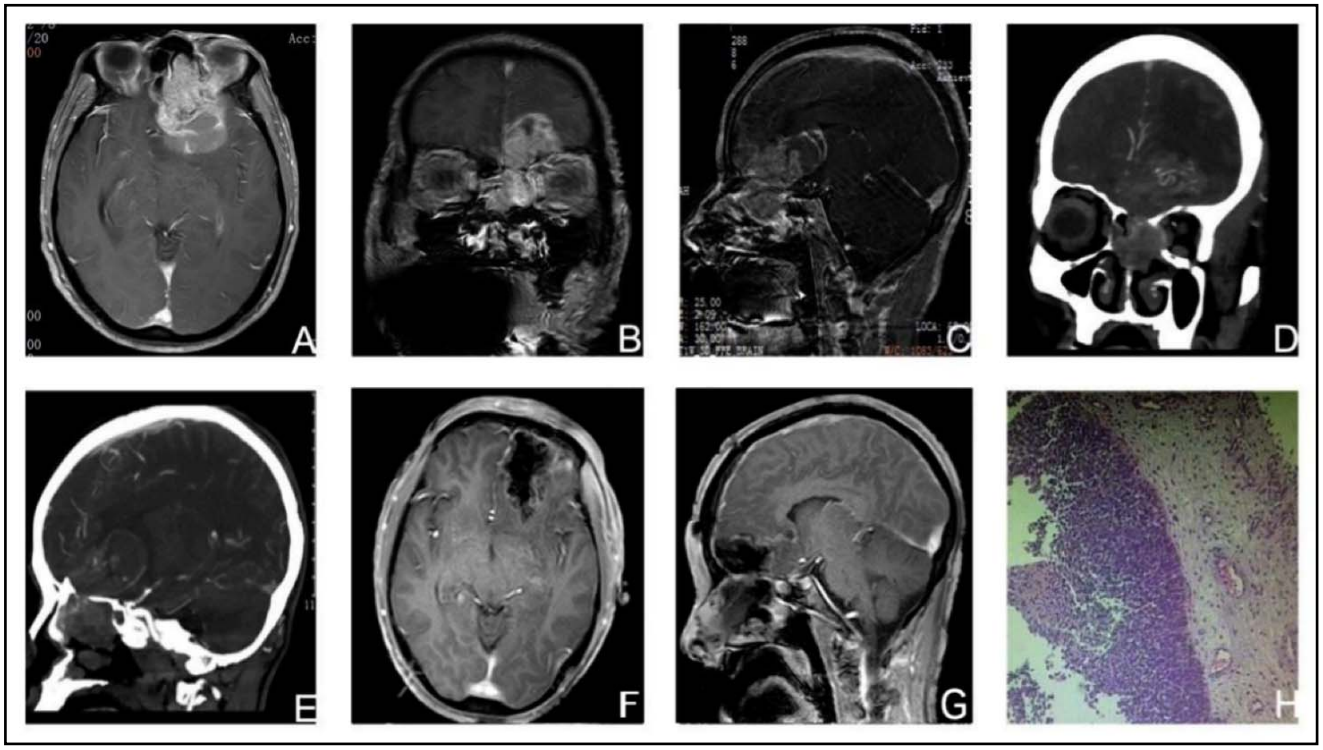

Fig. 1. A 61-year-old male patient with cranionasal communicating tumor. Preoperative cranial enhanced MRI showed a tumor on the left frontal lobe with intracranial hematoma, and there was a soft tissue shadow in the left nasal cavity: **(A)** axial, **(B)** coronal, **(C)** sagittal. Preoperative CTA showed the tumor invaded the left frontal and nasal cavity, and there was a bony defect in anterior skull base: **(D)** coronal, **(E)** sagittal. Postoperative cranial MRI (three months after surgery) showed a total tumor resection of intracranial and nasal tumors: **(F)** axial, **(G)** sagittal. Postoperative pathological diagnosis revealed non-keratinized carcinoma (poorly differentiated), and the papilloma malignancy was from the nasal cavity: **(H)** hematoxylin-eosin staining, 10×.

protein glue was used for fixation, and iodoform gauze strips and Merocel material were inserted into the nasal cavity for support, which were removed after 7–14 days.

Clinical Outcome Evaluation and Follow-Up

Postoperative complications, such as rebleeding, cerebrospinal fluid rhinorrhea, intracranial infection, and neurological dysfunction, were recorded. Postoperative cranial-enhanced MRI was used to evaluate the gross tumor resection rate. Total removal was defined as no obvious tumor observed on MRI, subtotal resection as residual tumor less than 10%, and partial resection as less than 50%. Cranial enhanced MRI was repeated 3, 6, and 12 months postoperatively. The tumor recurrence rate, patient survival rate, and Glasgow Outcome Scale score (GOS) were used to evaluate clinical efficacy. Clinical information including follow up, gross tumor resection, tumor recurrence, GOS score, pathological diagnosis and complications of patients included in this study is summarized in Table 2.

Illustrative Cases

Case One

A 61-year-old male patient presented with nasal congestion for one month and dizziness for five days; no obvious positive signs were found during physical examination. Enhanced cranial MRI revealed a lesion in the left frontal lobe with an intracranial hematoma and a soft tissue shadow in the left nasal cavity (Figure 1). The cranionasal communicating tumor was resected using a dual cranionasal approach. The postoperative pathological diagnosis revealed a non-keratinized carcinoma (poorly differentiated) and papilloma malignancy originating from the nasal cavity. Nasal congestion was completely relieved postoperatively, and no cerebrospinal fluid leakage or intracranial infection was observed. Postoperative cranial enhanced MRI revealed total tumor resection, and no obvious tumor recurrence was observed at the 26-month follow-up.

Case Two

A 45-year-old male patient presented with a 2-month history of headache and hyposmia. Preoperative cranial enhanced MRI showed a cranionasal communicating tumor in the right nasal cavity and frontal base (Figure 2). A cranionasal dual approach was used for treatment. Postoperative CT showed satisfactory results of tumor excision on the first day after surgery. There was edema but no bleeding in the surgical area. The patient presented with a decline in consciousness and right pupil dilation on the fifth postoperative day. Cranial CT showed severe cerebral edema and a displaced midline structure, which indicated cerebral herniation; decompression craniectomy was subsequently performed. The patient recovered well after symptomatic treatment, and

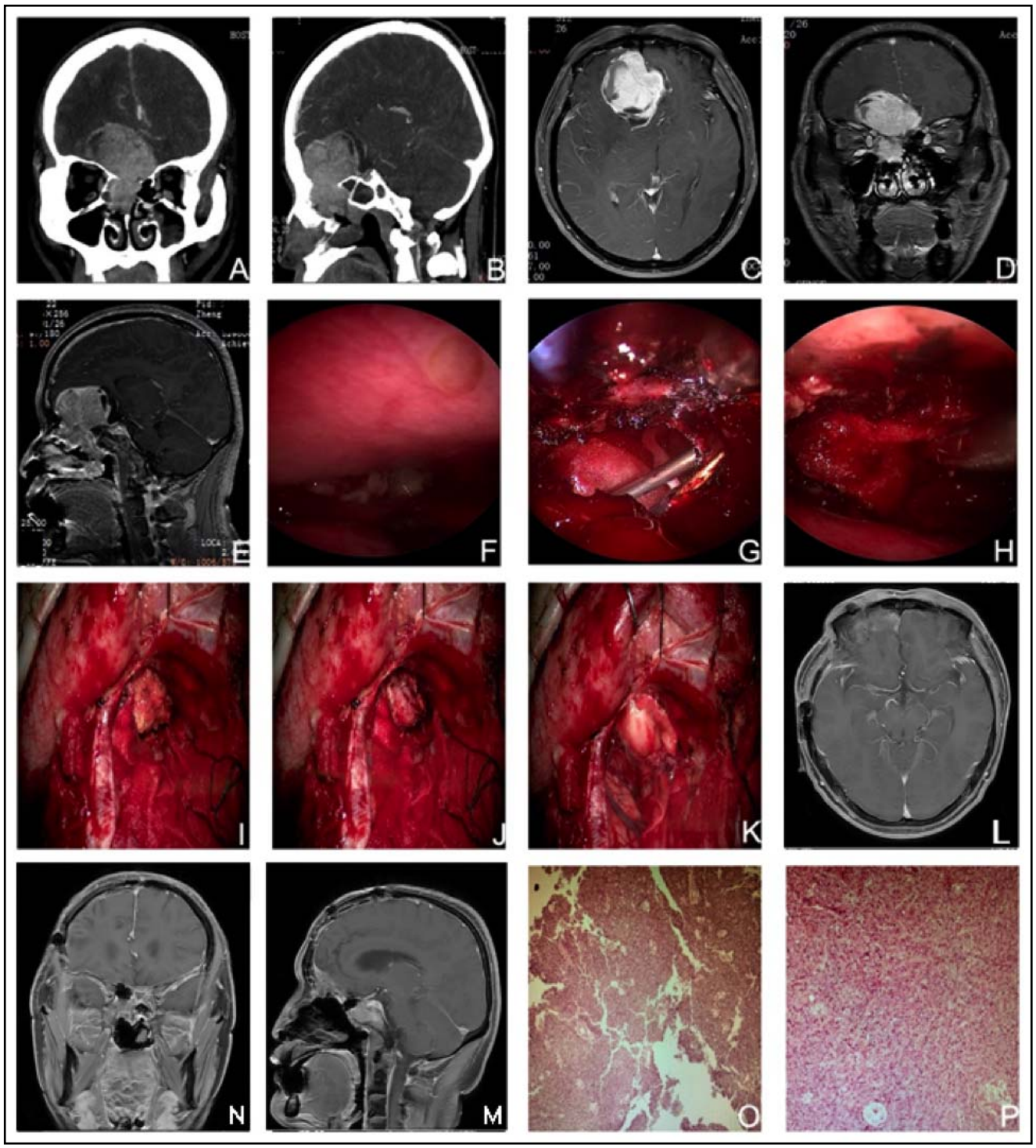

Fig. 2. A 45-year-old male patient with cranionasal communicating tumor. Preoperative cranial CTA showed a mass in frontal base and nasal cavity with bony defect of frontal base: **(A)** coronal, **(B)** sagittal. Preoperative cranial enhanced MRI showed that the tumor had invaded the bilateral frontal base (mainly on the right side). The tumor had invaded the anterior skull base and protruded into the nasal cavity. In addition, the tumor was significantly enhanced and locally uneven with surrounding edema **(C)** axial, **(D)** coronal, **(E)** sagittal. Cranionasal dual approach was performed, and the "sandwich repair" technique was used to reconstruct the skull base simultaneously. **(F)** Clear view of the tumor from EEA approach, and the tumor originating from the anterior skull base. **(G)** The "junction moment" in the dual approach, and the local enlarged resection of invaded dura matter and bone of the skull base. **(H)** The third layer reconstruction with pedicled mucosa flap; hemostatic gauze was used to promote an inflammatory response. **(I)** The second layer reconstruction with autogenous fat. **(J)** and **(K)** The first layer reconstruction with the temporalis muscle fascia and artificial dura matter was placed beneath the dura matter. Postoperative cranial enhanced MRI showed satisfactory tumor resection 18 months after surgery: **(L)** axial, **(N)** coronal, **(M)** sagittal. Postoperative pathological diagnosis revealed olfactory neuroblastoma (grade III): **(O)** hematoxylin-eosin staining, 10×; **(P)** immunohistochemical results.

the postoperative pathological diagnosis revealed olfactory neuroblastoma (grade III). Postoperative cranial enhanced MRI showed satisfactory tumor resection, and no obvious tumor recurrence was observed at the 18-month follow-up.

RESULTS

Eleven patients with 14–37 months of follow-up were included in this study. Among the 11 patients, eight (72.7%) underwent total resection, two (18.2%) underwent subtotal resection, and one (9.1%) underwent partial resection. Postoperative pathological diagnoses revealed four olfactory neuroblastomas, three atypical meningiomas, two recurrent papilloma malignancies, one recurrent invasive pituitary tumor, and one recurrent invasive pituitary adenocarcinoma. Regarding postoperative complications, one patient with olfactory neuroblastoma presented with a decline in consciousness, pupil dilation on the affected side, and low flap tension on the fifth postoperative day. Cranial computed tomography (CT) revealed severe cerebral edema and a displaced midline structure, and decompression craniectomy was performed. The patient recovered well after the symptomatic treatment. Moreover, intracranial infection was observed in two patients, including one with transient cerebrospinal fluid leakage, which was cured after lumbar cistern drainage and antibiotic therapy. Ocular dysmotility was observed in one patient postoperatively, and the patient did not fully recover at discharge. Moreover, two patients had worse olfactory sensations after surgery. The mean follow-up time of the 11 patients was (24.4 ± 5.7) months, and no complications such as cerebrospinal fluid leakage and infection occurred during the follow up. The one-year survival rate of the patients was 100%; 10 patients (90.9%) had a favorable outcome (GOS of 4–5), and only one patient (9.1%) had a GOS of 3. Furthermore, during the last follow-up, tumor recurrence occurred in two patients (18.2%).

DISCUSSION

Cranionasal communicating tumors are rare and are highly difficult and risky for neurosurgeons to operate on. Normally, they are located deep and the width of bony defects in the skull base are always less than the maximum diameter of the intracranial or intranasal tumors, so it is difficult to expose the other side of the cranionasal communicating tumor using a single surgical approach (Ganly *et al.* 2005a; 2005b; Bao *et al.* 2006). In addition, they usually invade the peripheral neurovascular and/or brain tissue; therefore, the treatment strategy of complete tumor excision after volume reduction is not effective for these tumors (Abu-Ghanem & Fliss 2013). Thus, appropriate surgical strategies and approaches are crucial for improving tumor resection rates and preserving neurological function. In the past, the combined transbasal and transfacial approaches have been considered as the traditional "gold standard" for treating these kind of tumors, but this strategy is reported to have many surgical complications, high mortality, and poor quality of life postoperatively (Batra *et al.* 2005, Abuzayed *et al.* 2011). In this study, 11 cases of cranionasal communicating tumors were successfully treated using a cranionasal dual approach with a good gross tumor resection rate, few postoperative complications, and good short-term efficacy.

Surgical resection of cranionasal communicating tumors has poor efficacy due to their anatomical complexity, difficulty to completely resect, and likely recurrence after surgery (Eloy *et al.* 2013). Therefore, an increase in intraoperative exposure and improvement in the surgical resection rate are closely related to the therapeutic effect. With the cranionasal dual approach, the advantages of the EEA were fully utilized to observe the blind area of the transcranial approach (Liu *et al.* 2017). By surgically removing part of the skull base bone, the sphenoid, ethmoid, and frontal sinuses can be fully exposed, and the cavernous sinus and pterygopalatine fossa can be exposed laterally. Satisfactory exposure helps to achieve better resection of residual tumors. Using the cranionasal dual approach, tumors can be observed from multiple angles, and the surgical field is sufficiently broadened. Moreover, the offending vessels and surrounding cranial nerves are clearly exposed. In olfactory neuroblastoma cases, supplementation of the extracranial tumors (anterior ethmoid artery or sphenopalatine artery) was accurately controlled by resecting the middle turbinate (medial wall of the maxilla) from the EEA, thus effectively relieving surgical trauma and reducing intraoperative bleeding. We believe that, apart from the exposure of the extracranial part, the transcranial approach is also very important. Different craniotomy approaches, such as the pterion, orbitozygomatic, and coronal approaches, can be adopted to better expose the lesion based on its anatomical location, tumor category, demarcation, size, and other characteristics, in addition to the goal of the surgery and anticipated pathology (He *et al.* 2021). In addition to the preoperative consideration of complete tumor resection, skull base reconstruction should also be carefully designed preoperatively. In particular, when the septal mucosa is seriously invaded and the pedicled septal mucosa flap is insufficient for reconstruction, repair by means of the periosteal flap becomes more important. In this study, eight patients underwent total resection, two patients were treated with subtotal resection, and one patient underwent partial resection; the total resection rate was 72.7%, which was consistent with previous reports (62.9% to 100%) (Ganly *et al.* 2005a, Ganly *et al.* 2005b, Bao *et al.* 2006). During the last follow-up, two patients had tumor recurrence; the recurrence rate was 18.2%, and ten patients (90.9%) had a favorable outcome (GOS of 4–5), and the clinical

outcome was similar to that reported in a recent study (Ngo *et al.* 2022).

Cerebrospinal fluid rhinorrhea is a common postoperative complication of the cranionasal dual approach, and is sometimes complicated by intracranial infections in severe cases (Batra *et al.* 2005). Reliable skull base reconstruction is one of the key factors to avoid these complications, and the "sandwich repair" technique we usually perform can repair multiple layers and reconstruct the skull base simultaneously, and it can be done more easily and reliably with the help of the dual approach compared with any single approach: (1) the transcranial approach was usually adopted for the planum sphenoidale, while the EEA approach could extend the repair range from the sella turcica to the lateral skull base; (2) during the whole repair process (including dura matter suturing, artificial dura matter or fat filling and pedicle periosteal graft flipping), the dura mater defect could be closely observed with the help of a nasal endoscope to confirm that no dura mater defect remained; (3) for lesions which extensively involved the frontal sinus, the crypt could be fully exposed with the transcranial approach, while the EEA approach could expand the residual cavity to the nasal canal opening, subsequently reducing postoperative complications such as sinusitis, subcutaneous abscess and skin ulceration (Eloy *et al.* 2013). In this study, only one patient (9.1%) had postoperative transient cerebrospinal fluid leakage, which was resolved using lumbar cistern drainage and antibiotic therapy, and the incidence of postoperative cerebrospinal fluid leakage was lower than that using a single transcranial approach. We suggest that reliable repair of cerebrospinal fluid leakage is one of the most effective measures to prevent intracranial infection, and that the period of intra operative communication between the cranial and nasal cavities should be shortened as much as possible (Castelnuovo *et al.* 2006). If the condition permits, it is better to start repairing the dura mater first using the transcranial approach. After the intracranial tumor is resected, remove the invaded paranasal sinus mucosa and irrigate the surgical field with povidone-iodine and subsequently normal saline; the surgical team should replace gloves regularly. Moreover, bony repair is necessary when the size of the anterior skull base bone defect is > 3 cm; a large defect could result in downward drift of the anterior skull base, subsequently leading to meningocele and cerebrospinal fluid leakage (Attia *et al.* 2013). Anatomical skull base reconstruction can significantly reduce cerebrospinal fluid leakage and intracranial infection, and a small titanium mesh or internal skull plate can be used for skull base support in patients with large defects (Belli *et al.* 2009). In this study, bony repair was not performed because of small defects in the skull base.

Our study has some limitations. The sample size was small, and thus lacked compelling quality. This was a retrospective case series, and further high-quality randomized controlled trials with larger sample sizes and longer follow-up durations are required.

CONCLUSION

Using the cranionasal dual approach, there is a better gross tumor resection rate with fewer postoperative complications and good short-term efficacy for the surgical treatment of cranionasal communicating tumors.

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