Craniofacial Resection for Tumors of the Nasal Cavity and Paranasal Sinuses

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Background and purpose: Craniofacial resection provides multidirectional approaches to remove nasal and paranasal tumors that involve the skull base. The purpose of this study was to determine the survival and local control rate in patients undergoing craniofacial resection for tumors of the nasal cavity, paranasal sinuses, and adjacent areas.

Methods: The medical records of 30 consecutive patients who had undergone craniofacial resection for tumors of the nasal cavity, paranasal sinuses, and adjacent areas were reviewed. The extent of disease, treatment results, complications, and prognoses were analyzed.

Results: Lesions were malignant in 28 patients and benign in two. Sixteen of the patients had dural or intradural involvement. There was no surgical mortality, and the rate of surgical morbidity was 7%. The 2-year survival of the 28 patients with malignancies was 46% and the mean follow-up time was 35 months. Local control was achieved in 53% of patients. Nine of 16 patients with dural or intradural invasion had a mean survival time of 17 months. There was no significant difference in the frequency of local control between previously treated and untreated patients. Patients who had a clear margin showed significantly better local control than those with an involved or questionable margin.

Conclusions: Tumors of the nasal cavity and paranasal sinus that involve the skull base can be effectively treated using craniofacial resection, with a reasonable survival and low complication rate.

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Key words:
craniofacial resection
nasal cavity
paranasal sinus
survival
complication

Neoplasia of the superior vault of the nasal cavity and paranasal sinuses can transcend the cribriform plate and ethmoid roof to involve the central nervous system and, therefore, provide a formidable challenge to head and neck surgeons [1, 2]. Based on anatomic and oncologic considerations, a combined craniofacial approach, which offers access both from the superior and anteroinferior directions, can provide a more rational resection [1, 2].

The craniofacial resection of sinonasal tumors was first reported by Smith et al [3], and was subsequently developed most notably by Ketcham et al [4]. Shah and Galicich [1] and Schramm et al [2] have further developed the operation. Thus, craniofacial resection is recognized as a standard approach for tumors involving the anterior cranial base [1, 2]. The purpose of this study was to determine the overall survival in patients undergoing craniofacial resection for tumors arising from the nasal cavity, paranasal sinuses, and adjacent areas.

Subjects and Methods

Patients who underwent anterior craniofacial resection for nasal cavity and paranasal sinus tumors between July 1993 and July 1999 in the Lin-Kou Medical Center, Chang Gung Memorial Hospital, Chang Gung University, a tertiary referral center and teaching hospital, were included in this study. Magnetic resonance (MR) imaging was used to evaluate the local

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tumor extension. Computed tomography (CT) was used only in cases of primary osseous lesions or to evaluate the involvement of the skull base bone. All patients were regularly followed up in clinics.

The survival and local control rate were evaluated using the Kaplan-Meier product limit method. The cut-off point of this study was December 1999. The follow-up time ranged from 2 to 65 months (mean, 35 mo).

Craniofacial resection

Surgery started with a bi-coronal incision, and the scalp, including the pericranium, was raised. After initial bifrontal or frontolateral craniotomy, the orbital bar was skeletonized and an orbito-fronto-ethmoidal osteotomy was performed [5]. This piece of bone was separately removed. A subfrontal dissection was then carried out. If there was frontal lobe invasion, the involved dura was resected, the frontal lobe tumor was removed, and the dura was repaired with the pericranium. Watertight closure is crucial at this point.

The frontal lobe was then gently retracted to expose the planum sphenoidale, orbital roof, cribriform plate, and ethmoid roof. An osteotomy was performed over the skull base according to the area of tumor extension. Then, a lateral rhinotomy incision was made and a facial bone disassembly approach was used to explore the naso-paranasal tumor. The nasolacrimal apparatus was skeletonized and preserved if feasible. The lower transected end of the nasolacrimal duct was usually marsupialized.

Removal of tumors *en bloc* was attempted; however, this was not always possible. After tumor removal, specimens from suspicious margins were sent for frozen section. Every effort was made to obtain a negative margin. If there was gross residual tumor or questionable margin, a hemoclip was left *in situ* to guide postoperative radiotherapy.

In the reconstructive phase, a galeopericranial flap based on the supraorbital arteries was raised and transposed to interpose between the dura and the underlying nasoparanasal cavity, thus separating the intracranial space from the upper aerodigestive tract. The facial bone graft was reimplanted and secured with microplates, and the facial incision was then closed in layers. The frontal sinus was always cranialized and the craniotomy was repositioned with a hemovac left *in situ*.

Results

Thirty patients (22 men, 8 women) were included in this study; their ages ranged from 10 to 92 years. The spectrum of pathology in these patients was extremely broad (Table 1). Lesions were malignant in 28 cases and benign in two cases. The most common tumor in the 28 malignancies was olfactory neuroblastoma, followed by recurrent nasopharyngeal carcinoma. The pathology, treatment modality, prognosis, and complications in the 28 patients with malignant tumors are summarized in Table 2. Seventeen patients had not previously been treated, and 13 patients had initially been treated but had had a recurrence. One patient with olfactory neuroblastoma initially presenting with neck metastasis underwent neck dissections along with craniofacial resection.

There was no surgical mortality in this series. Surgical morbidity occurred in two patients, including temporary cerebrospinal fluid (CSF) rhinorrhea and meningitis in one patient, and CSF rhinorrhea, blindness, and massive bleeding in the other patient (Table 2). The two patients with CSF leakage had gross residual cancer over the optic chiasma area, which made watertight dural closure almost impossible. One of these patients had meningitis. The other case, complicated by blindness and massive bleeding, was an osteogenic sarcoma of the sphenoid sinus—the patient had preoperative right eye blindness and left eye sense only. The optic chiasma and nerve were severely encased by the tumor. The initial plan was to decompress the optic nerve and chiasma; however, massive bleeding from the left ophthalmic artery occurred during the attempt to dissect the optic nerve and ophthalmic artery. The patient was blind after the operation.

Temporary epiphora was noted immediately after surgery, but usually resolved shortly after the nasal packing was removed. Partial necrosis of the translocated facial bone graft was observed in four patients, but it

Table 1. Pathology among patients undergoing anterior craniofacial resection

Malignant		Benign	
Olfactory neuroblastoma	7	Aggressive polyposis	1
Recurrent nasopharyngeal carcinoma	4	Mucocele	1
Malignant fibrous histiocytoma	4		
Adenocystic carcinoma	3		
Squamous cell carcinoma	3		
Osteogenic sarcoma	2		
Adenocarcinoma	1		
Undifferentiated carcinoma	1		
Malignant mixed tumor	1		
Malignant melanoma	1		
Chordoma	1		
Total	28	Total	2

Table 2. Clinical data of 28 patients with malignant tumors

Pathology	Treatment	Complication	F/U, months	Prognosis
ONB	S + RT		3	NER
NPC	S + RT		4	NER
Adenocarcinoma	S + RT		4	Alive with local disease
SCC	S	Meningitis, CSF leak	4	NER
MFH	S		2	Death (local failure)
MFH	S		5	Alive with local disease
Undifferentiated carcinoma	S + RT		6	NER
Chordoma	S		6	Death (local failure)
ONB	S + RT		19	NER
NPC	S		10	Death (local failure)
NPC	S		22	Alive with axilla node metastasis
ONB	S + RT		6	Death (local failure)
Malignant melanoma	S + RT	ORN	13	Death (liver metastasis)
ONB	S + RT		27	NER
Malignant mixed tumor	S + RT	ORN	26	NER
Osteogenic sarcoma	S + RT		8	Death (local failure)
ONB	S + RT	ORN	45	NER
ONB	S + RT		56	NER
Adenocystic carcinoma	S + RT		51	NER
SCC	S + RT		61	NER
ONB	S + RT		65	NER
Osteogenic sarcoma	S	CSF leak, blindness, bleeding	3	Death (local failure)
Adenocystic carcinoma	S + RT		24	Death (liver metastasis)
Adenocystic carcinoma	S + RT	ORN	39	Alive with lung metastasis
MFH	S		6	Death (local failure)
MFH	S		12	Death (local failure)
NPC	S		6	Death (local failure)
SCC	S + RT		10	Death (local failure)

F/U = follow up; ONB = olfactory neuroblastoma; S = surgery; RT = radiation therapy; NER = no evidence of recurrence; NPC = nasopharyngeal carcinoma; SCC = squamous cell carcinoma; CSF = cerebrospinal fluid; MFH = malignant fibrous histiocytoma; ORN = osteoradionecrosis.

occurred only in patients undergoing postoperative radiotherapy. Among the 28 patients with malignancy, 14 had a clear margin and 12 of these achieved locoregional control; eight had a questionable margin, of whom only four achieved local control; and six had an involved margin—these six died of local disease soon after surgery. The local control rate in patients with a clear resection margin was significantly better than that in patients with tumor involvement or a questionable margin ($p = 0.006$, Fisher's exact test).

The 2-year survival rate of the 28 patients with malignancies was 46%, with a mean follow-up period of 35 months (Fig. 1). The local control rate was 53% (Fig. 2). There was no significant difference in local control rate between previously treated (3/12) and untreated (9/16) patients ($p = 0.136$, Fisher's exact test). Sixteen patients had dural involvement or intradural invasion, seven of whom survived with a mean survival time of 17 months.

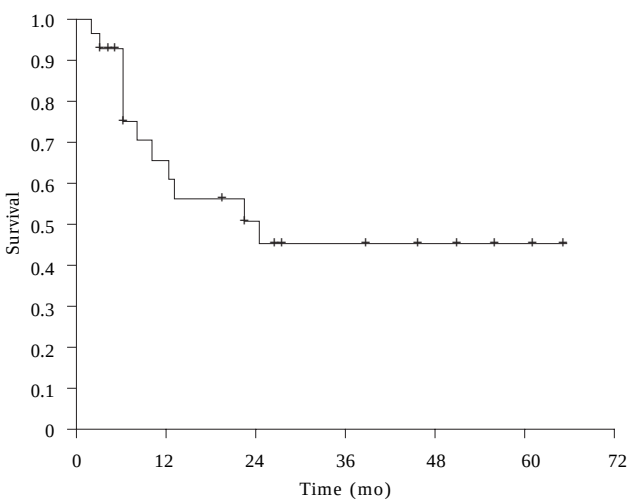

Fig. 1. *Survival among 28 patients with malignant tumors.*

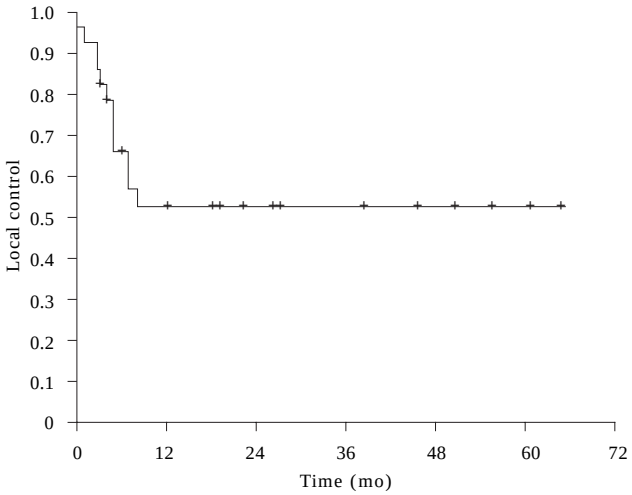

Fig. 2. *Local control among 28 patients with malignant tumors.*

Discussion

Patients with tumors arising from the superior vault of the nasal cavity and paranasal sinuses had a poor prognosis before the development of craniofacial resection. One explanation is that most patients manifest nonspecific symptoms of long-standing duration, which might mimic chronic sinusitis and were treated as such. Another explanation is that, before the development of skull base surgery, the cribriform plate, fovea ethmoidalis, and planum sphenoidale area were relatively inaccessible. However, after the introduction of craniofacial resection by Smith et al in 1954 [3], and its further development by Ketcham et al [4], Shah and Galicich [1], and Schramm et al [2], craniofacial resection became a standard approach for resection of tumors of the anterior cranial base. Craniofacial resection not only allows excellent access to this difficult area, but also provides the opportunity for oncologically complete *en bloc* resection. The ability of craniofacial resection to control tumors in this difficult area is evident.

Although craniofacial resection is now widely used in major medical centers around the world, the technical aspects of this technique are still being improved, for example, through modifications in craniotomy technique. In contrast to the small frontal fenestration used by Ketcham et al [6] and Cheesman et al [7], a wider frontal craniotomy was used in this series.

The craniotomy should also be tailored to the extent of the tumor. For tumors confined to the central nasal cavity or uppermost ethmoid sinuses, a low frontal craniotomy is sufficient. However, tumors extending laterally to the orbit, the supra-orbital ridge, or even to the lateral orbital wall should be removed along with the frontal or frontolateral craniotomy [8]. A separative orbito-fronto-ethmoidal osteotomy can further minimize the need for frontal lobe retraction [3]. A wider craniotomy not only allows wider surgical exposure, but also helps transposition and anchorage of the galeopericranial flap during the reconstructive phase. Dura resection and repair are also much more easily accomplished in a wider craniotomy. The complete cranialization of the frontal sinuses in this series also prevented mucocele formation.

A facial translocation approach, with temporary removal of the facial skeleton and reinsertion at the end of the procedure, further facilitates tumor exposure and aids complete resection [8]. The postoperative functional results and cosmesis are also satisfactory. However, the temporarily removed and laterally reimplanted facial bone graft sometimes becomes necrotic, especially in patients who have had radiotherapy. To minimize necrosis of the transplanted bone flap, we advocate that, for patients who have undergone or will undergo radiotherapy, the translocated bone flap should be attached to the cheek soft tissue, thus remaining vascularized to prevent osteoradionecrosis caused by radiotherapy [9]. Long-term epiphora was not observed in our series, since we usually skeletonized the lacrimal apparatus and marsupialized its transected lower end, rather than only transecting and stenting it.

Dural closure is almost inevitable in anterior craniofacial resection. Watertight closure is crucial to prevent CSF leakage and ascending infection. The pericranium or superficial temporal fasciae were our repair material. The repaired dura is further reinforced by a transposed pedicled galeopericranial flap, which has been the workhorse of anterior cranial base reconstruction [4]. The flap is used to completely separate the intracranium from the underlying upper aerodigestive tract and prevent ascending infection. We had only two patients with temporary CSF leakage; both had intracranial involvement and required extensive dural resection. The dural repair was extremely difficult, especially over the anterior edge of the optic chiasma where residual tumor was evident and the chiasma was decompressed. The CSF leak stopped after conservative management with lumbar shunting, but one patient soon died of local disease.

No bony reconstruction for the ethmoid roof was needed in this series, and none of the patients developed a meningocele. However, a large bony defect of the orbital roof should be reconstructed with bony material, or pulsation of the ophthalmus will interfere with vision.

Currently, MR imaging with its superb ability to evaluate soft tissue invasion has become the imaging technique of choice for skull base tumors. MR imaging is more

informative than CT in differentiating retained tenacious secretions within the paranasal sinuses from tumors. This differentiation enables the surgeon to further clarify the extent of any needed resection. The use of MR imaging for preoperative evaluation of certain critical areas, such as the cavernous sinus, internal carotid artery, frontal lobe, and/or optic chiasma and tract, are crucial to determining the resectability of the tumor. In this series, immediate postoperative pneumocephalus was common and not harmful as long as it was not a tension pneumocephalus. However, blowing of the nose was completely prohibited during the immediate postoperative phase.

In this series, the local control rate for new patients (9/16) was better than that for previously treated patients (3/12); however, this difference was not statistically significant. Cantu et al reported that, in patients with previous surgical failure, multifocal recurrence due to tumor seeding from the previous surgery is likely and can complicate surgery [10]. Shah et al [11] and Ketcham et al [12] also reported that there was no difference in survival between previously treated and untreated patients.

The skull base, with its complex anatomy, is one of the most difficult regions to fully access surgical margins. In this series, only a narrow margin could be achieved. *En bloc* resection could not be accomplished in most cases and piecemeal resection was, thus, performed. Tumor involving the surgical resection margin was encountered in six patients, and all of these patients died of local disease soon after the operation (mean postoperative survival, 6 mo). Patients who had a clear margin had substantially better local control than those with tumor involvement in the margin or a questionable margin. Therefore, achieving a clear margin is an extremely important prognostic factor in skull base surgery.

There is no doubt that survival is closely related to the histopathologic characteristics of the tumor. Cantu et al reported that olfactory neuroblastoma and adenocarcinoma had a better prognosis, while melanoma and epidermoid carcinoma had a poor prognosis [10]. Shah et al reported that patients with olfactory neuroblastoma, squamous cell carcinoma, and adenocystic carcinoma had the best prognoses [11]. In the present series, the small number of patients in each histopathologic category precluded a formal statistical analysis. However, the operative findings and pathologic correlations suggest that the sarcoma group is the most difficult to control by skull base surgery, because of the difficulty of evaluating the disease extension and the inability to access the surgical margin in these tumors. Appropriate patient selection criteria are important to ensure optimal treatment.

Sisson et al postulated that frontal lobe invasion, posterior extension of the tumor beyond the planum sphenoidale, and/or pharyngobasilar fasciae involvement were contraindications to surgical resection of paranasal malignancies [13]. Shah et al considered internal carotid artery, optic chiasma, or temporal lobe involvement contraindications to anterior craniofacial resection [11]. We postulate that direct involvement of the internal carotid artery, cavernous sinus, or optic chiasma are absolute contraindications for high-grade malignancies. Dural or transdural involvement of the frontal lobe is no longer a strong contraindication to surgery, especially in favorable pathologies such as olfactory neuroblastoma. Van Tuyl and Gussack reported a 22% survival rate among patients demonstrating dural involvement [14]. Shah et al [10], Kraus et al [15], and Bilsky et al [16] pointed out that dural invasion was a particularly bad prognostic indicator. In our series, seven of 16 patients with dural or intradural involvement survived, with a mean postoperative survival time of 17 months. However, these patients all had less aggressive tumor types, including three with olfactory neuroblastoma, two with nasopharyngeal carcinoma, one with squamous cell carcinoma, and one with sinonasal undifferentiated carcinoma.

Fortunately, the frontal lobes are mainly silent areas and resection of tumors from the frontal lobe leaves patients with minor sequelae. In our series, the survival rate of 46% and the local control rate of 53% with a mean follow-up of 35 months was equal to or slightly lower than those of some major series from other centers [17, 18]. Shah et al reported a 58% disease-specific survival at 5 years [17]. Lund et al reported a 44% 5-year actuarial survival [18]. However, in the present series, there was no surgical mortality and the surgical morbidity was only 7%, which is lower than the 42% reported in studies from Memorial Sloan-Kettering Cancer Center in New York [16] and the 49% from Hospital do Cancer/INCa in Rio de Janeiro [19]. The difference might be the result of the use of the modified surgical techniques described above. Craniofacial resection is a safe procedure and the outcome is predictable.

In conclusion, a series of 30 patients who underwent craniofacial resection for tumors of the nasal cavity, paranasal sinuses, and adjacent areas was reported. The 2-year survival of the 28 patients with malignancies was 46% and the local control rate was 53%. There was no surgical mortality, and the surgical morbidity was only 7%. Patients who had a clear margin showed significantly better local control than those with an involved or questionable margin.

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Craniofacial resection techniques were developed to allow complete monobloc removal of malignant tumours of the ethmoid region. Such a surgical approach may also occasionally be useful in certain non-malignant conditions. Extensive â€˜destructiveâ€™ aspergillosis of the paranasal sinuses has a high mortality once the anterior cranial fossa dura is reached. Craniofacial surgery provides excellent access to excise such large infective â€˜tumoursâ€™. Type. Clinical Records.Â Cheesman, A. D., Lund, V. J. and Howard, D. J. (1986) Craniofacial resection for tumours of the nasal cavity and paranasal sinuses. Journal of Head and Neck Surgery. 8: 429â€“439.CrossRef Google Scholar PubMed. Colman, M. F. (1985) Invasive aspergillus of the head and neck. Laryngoscope. Nasal cavity and subsequent paranasal sinus development begins at the frontonasal prominence with the formation of bilateral oval thickenings of the surface ectoderm, referred to as nasal placodes, that are present by the end of the fourth week.1,2 Subsequently, these recede into flat depressions called nasal pits (the primordia of anterior nares or future nostrils). From the fifth week of gestation, the nasal pits deepen toward the oral cavity, eventually resulting in an open communication between the oral and nasal cavities. An elaborate cascade of growth and fusion then leads to the downward growth of the nasal septum, formation of the definitive secondary palate, and other structures constituting the nasal cavity. Tumors of the nasal cavity and paranasal sinuses present a challenge to treat them. A combination of surgery and radiation therapy can improve treatment outcomes in 49-56% of patients with locally advanced nasal cavity and paranasal sinus cancer. The midface reconstruction poses a formidable challenge to the reconstructive surgeon due to the regionâ€™s complex skeletal and soft-tissue anatomy.Â Craniofacial Resections for Tumors Involving the Base of the Skull. J. Shah, S. Narayan, G. Joseph. The American Journal of Surgery, 154: 1987. Background: Craniofacial resection is the established "gold standard" for surgical treatment of tumors affecting the anterior skull base. Methods: This study analyzed 308 patients (220 males, 88 females) who had undergone craniofacial resection for sinonasal neoplasia with up to 25-year follow-up. Results: An overall actuarial survival of 65% at 5 years and 47% at 10 years was found for the cohort as a whole. For patients with malignant tumors, the 5-year actuarial survival was 59%, falling to 40% at 10 years. For patients with benign pathology, the actuarial survival was 92% at 5 years falling to 82% at 10 years. Statistical analysis again identified brain involvement, type of malignancy, and orbital involvement as the 3 most significant prognostic factors.