Extended transsphenoidal approach for pituitary adenomas invading the anterior cranial base, cavernous sinus, and clivus: a single-center experience with 126 consecutive cases

Clinical article

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Object. The standard transsphenoidal approach has been successfully used to resect most pituitary adenomas. However, as a result of the limited exposure provided by this procedure, complete surgical removal of pituitary adenomas with parasellar or retrosellar extension remains problematic. By additional bone removal of the cranial base, the extended transsphenoidal approach provides better exposure to the parasellar and clival region compared with the standard approach. The authors describe their surgical experience with the extended transsphenoidal approach to remove pituitary adenomas invading the anterior cranial base, cavernous sinus (CS), and clivus.

Methods. Retrospective analysis was performed in 126 patients with pituitary adenomas that were surgically treated via the extended transsphenoidal approach between September 1999 and March 2008. There were 55 male and 71 female patients with a mean age of 43.4 years (range 12–75 years). There were 82 cases of macroadenoma and 44 cases of giant adenoma.

Results. Gross-total resection was achieved in 78 patients (61.9%), subtotal resection in 43 (34.1%), and partial resection in 5 (4%). Postoperative complications included transient cerebrospinal rhinorrhea (7 cases), incomplete cranial nerve palsy (5), panhypopituitarism (5), internal carotid artery injury (2), monocular blindness (2), permanent diabetes insipidus (1), and perforation of the nasal septum (2). No intraoperative or postoperative death was observed.

Conclusions. The extended transsphenoidal approach provides excellent exposure to pituitary adenomas invading the anterior cranial base, CS, and clivus. This approach enhances the degree of tumor resection and keeps postoperative complications relatively low. However, radical resection of tumors that are firm, highly invasive to the CS, or invading multidirectionally remains a big challenge. This procedure not only allows better visualization of the tumor and the neurovascular structures but also provides significant working space under the microscope, which facilitates intraoperative manipulation. Preoperative imaging studies and new techniques such as the neuronavigation system and the endoscope improve the efficacy and safety of tumor resection. (DOI: 10.3171/2009.3.JNS0929)

Key Words • cavernous sinus • clivus • cranial base • extended transsphenoidal approach • pituitary adenoma

*Dr. Zhao and Wei contributed equally to this study.
Pituitary adenoma

approach could be used for total removal of pituitary adenomas extending into the CS. A transmaxilloethmoidal approach was reported to allow pituitary tumors invading the CS to be adequately exposed and removed. In 1997, Mason et al. adopted the transsphenoidal approach to incise sellar diaphragm and resect ectopic ACTH-secreting adenomas originating in the pituitary stalk while fully preserving pituitary function. In 1998, Kato et al. used the transsphenoidal-transcisternal sellar approach to remove supradiaphragmatic tumors. Subsequently, the extended transsphenoidal approaches with PR of maxillary bones, posterior ethmoidectomy, or anterior extracapsular resection were explored. Romano et al. conducted a detailed review of the microanatomical features of the extended transsphenoidal approach. Recently, a retrospective analysis of this approach in 105 patients presented a detailed technical introduction to various extended transsphenoidal approaches. At present, the extended transsphenoidal approach has also been used to resect clival chordomas, craniohypophysealgiomas and hemangioblastomas, meningiomas of the tuberculum sellae, and preoptic epidermoid tumors, and even to clip an anterior communicating artery aneurysm. In addition, the extended endoscopic transsphenoidal approach for the removal of suprasellar tumors has been described. Taken together, the extended transsphenoidal approach can adequately expose tumors extending in various directions and improve the rate of total resection. However, this approach needs further improvement to reduce the incidence of postoperative complications such as neurovascular injury and CSF leakage.

The transsphenoidal approach has been used for pituitary adenomas in the Neurosurgical Center of Pituitary Tumors at the Peking Union Medical College Hospital since 1978. During the past 3 decades, we have operated on > 4000 patients by using this approach. On the basis of our experience with the standard approach, we attempted to resect pituitary adenomas with parasellar and retrostellar extension via the extended transsphenoidal approach in 1999. In the present study, we reviewed our surgical experience in 126 consecutive cases and analyzed the complications, advantages, and possible confounding factors associated with the procedure.

Methods

Patient Data

A total of 126 consecutive patients with pituitary adenoma undergoing extended transsphenoidal microsurgery in Peking Union Medical College Hospital between September 1999 and March 2008 were assigned for the retrospective analysis study. The extended transsphenoidal approach was performed when preoperative MR imaging diagnosis revealed 1 of the following: 1) the pituitary adenomas protruded from the tuberculum sellae for > 1 cm on sagittal images; 2) the tumors extended laterally to the lateral tangent of intra- and supracavernous ICAs on coronal scans; and 3) the tumors invaded the middle and inferior clivus and compressed the preoptic cistern or the brainstorm on sagittal and axial scans.

The PRL-secreting adenomas in this study were treated surgically in patients who had serious side effects or no reaction to dopamine agonist, except for 1 patient who manifested spontaneous cerebrospinal rhinorrhea after receiving bromocriptine therapy.

There were 55 male and 71 female patients with a mean age of 43.4 years (range 12–75 years). Their disease courses ranged from 3 days to 25 years, with an average of 42.3 months. Of the 126 cases, visual dysfunction was found in 104 patients, among whom there were 18 cases of bitemporal hemianopia; headache was found in 55 patients; menstrual disorder, menostasia, or lactopoiesis in 45 patients; acromegaly in 19 patients; gigantism in 3 patients; Cushing syndrome in 2 patients; hyperthryoidism in 1 patient; hyposensitivity in 19 patients; cranial nerve palsy in 8 patients (abducent nerve palsy in 6 and oculomotor nerve palsy in 2 patients); preoperative cerebrospinal rhinorrhea in 1 patient; and incidentally discovered tumors on neuroimaging examination in 10 patients. In addition, of 57 patients who had received previous treatment, 3 were treated with somatostatin and 35 with bromocriptine. In another 19 patients, the tumor recurred following resection via transsphenoidal approach or craniotomy, of whom 9 patients were treated with conventional radiotherapy or GKS.

Imaging Examination

Preoperative MR imaging and CT examinations of the sella turcica were performed in all patients. The largest diameter of the tumors ranged between 15.4 and 65 mm, with an average of 36.3 mm. Of the 126 patients, 82 had macroadenoma (> 40 mm in diameter) and 44 had giant adenoma (≥ 40 mm in diameter). In addition, there were 19 patients with pituitary tumor apoplexy and 11 with cystic degeneration. There were 14 patients whose tumor extended forward to the bottom of the frontal lobe and 111 whose tumor extended laterally to the unilateral or bilateral CS, of whom 3 patients presented with pituitary adenoma extending into the inferior temporal lobe. According to an MR imaging–based classification system proposed by Knosp et al., there were 32 cases of Grade 3 and 79 cases of Grade 4 adenoma. The MR imaging findings also revealed that the tumor extended posteriorly and invaded the clivus in 28 cases and that the lesion broke through the sellar floor and invaded the sphenoidal sinus in 47 patients. In addition, tumor growth in a multidirectional manner was observed in 59 patients.

Endocrinological Classification

Endocrinological types of pituitary adenomas were established according to clinical manifestations, preoperative hormone levels, postoperative pathological findings, and immunohistochemical results. Of the 126 patients, 71 and 55 had a nonfunctional and a hormonally active adenoma, respectively. Among patients with hormonally active adenoma, there were 28 with PRL-secreting adenoma, 17 with GH-secreting adenoma, 7 with PRL/GH–secreting mixed adenoma, 2 with ACTH-secreting adenoma, and 1 with TSH-secreting adenoma.

Surgical Technique

The surgical procedures were similar in all cases. General anesthesia was induced using intratracheal intubation. During the operation, patients were placed supine...
with the head unfixed and ~ 20° higher than the feet, allowing free intraoperative adjustment of the head position. Among the 126 patients, 54 underwent the extended transnasal transseptal transsphenoidal approach and 72 underwent the extended sublabial transseptal transsphenoidal approach. The latter procedure is the preferred choice when the tumors extend in a multidirectional manner or invade the clivus.

In the present study, the dissociation range of the mucosa of nasal septum was larger than that in the standard approach. The transsphenoidal speculum was placed at the juncture between nasal septum cartilage and nasal septum bone to push the nasal septum cartilage laterally and excise the nasal septum bone. Next, the bilateral sphenoidal ostia were identified. Then, the ventral wall of the sphenoidal sinus was resected with an osteotome to remove the inner mucosa of sphenoidal sinus and expose the sellar floor. To avoid possible damage to the ICA and cranial nerves and to make good use of the exposure, the transsphenoidal speculum did not enter the sphenoidal sinus. The sellar floor was removed using an osteotome or a drill, and then a routine puncture was performed before the dural incision was made. Much attention should be paid to avoiding active bleeding of the inferior hypophy­sal artery, which often lays posterolaterally to the dura mater of the sellar floor. Subsequently, standard resection was performed to remove the tumor localized in the suprasellar and intrasellar region, in which the peripheral part of the lesion was first excised, followed by the resec­tion of the central part. During the dural opening and tumor removal, efforts should be made to preserve the integrity of the arachnoid membrane as much as possible.

Guided by fluoroscopy or the neuronavigation system, the direction of the transsphenoidal speculum was adjusted in accordance with the sites of tumor invasion. When the pituitary tumors grew anteriorly and extended into the anterior cranial base, the center of the transsphenoidal speculum was aligned with the direction of the tuberculum sellae. Then part of tuberculum sellae bone was removed using a high-speed drill and microrongeurs. Additionally, the posterior wall of ethmoidal sinus and planum sphenoidale could also be removed, if necessary. Care should be taken to avoid injury to the bilateral optic canals. Next, the dura mater of the cranial base was incised anteriorly to expose and resect the tumor. When tumors extended laterally and encased the CS, the center of the speculum was aligned with the direction of the CS. Then part of ventral wall bone of the CS was removed using microrongeurs, followed by cutting off the fibrous septa in the CS under direct vision and careful removal of the tumor located in the CS. In case of hemorrhage in the CS, pressure can be directly applied to stop bleeding with Surgicel oxidized cellulose (Ethicon, Inc.). When tumors extended posteriorly into the clivus, the center of the transsphenoidal speculum was aimed with the direction of the clivus. Then part of the bone located in front of the tumor was drilled using a high-speed drill, and the tumor was resected. When the tumor invaded the middle and lower clivus, the sublabial transseptal transsphenoidal approach provided better exposure and working space than the transnasal transseptal transsphenoidal approach. Moreover, partial osteotomy of the maxilla can be performed to facilitate the exposure if necessary.

After tumor removal, accurate hemostasis was performed with compression and cautery, and then the tumor cavity was rinsed with saline solution several times to remove residual tumor. Subsequently, reconstruction of the skull base was performed for all patients. If the arachnoid membrane was intact and without CSF leakage, the tumor cavity, intrasellar region, and sphenoidal cavity can be packed with gelatin sponge and instant fibrin sealant (Shanghai Pine & Power Bio-Tech Co.). If the arachnoid membrane was breached and CSF leakage occurred during the course of tumor resection, the tearing of the arachnoid membrane was sealed with autologous fat tissue and otological and cranio­cerebral glue (Guangzhou BaiYun Medical Adhesive Co.). Following a period of observation under direct vision to ensure no recurrence of CSF leakage, the tumor cavity was filled with autologous fat, gelatin sponge, and instant fibrin sealant. Then the dural defect was sealed with Dura Max (Beijing Tian Xin Fu Medical Appliances Co.) and otological and cranio­cerebral glue, and the sphenoidal cavity was filled with gelatin sponge and instant fibrin sealant, in parallel with the performance of lumbar subarachnoid drainage. Finally, bilateral nasal cavities were packed with Vaseline-impregnated gauze.

In the present study, the endoscope (Karl Storz) was used in 18 cases and the VectorVision neuronavigation system (BrainLAB) was used in 17.

Results

Surgical Results and Postoperative Complications

The percentage of tumor resection was based on intraoperative observations and postoperative follow-up MR imaging findings. The following criteria were used: For GTR, the tumor localized in the suprasellar and intrasellar region and its extended parts had been resected with the aid of the operating microscope, the diaphragma sellae extended down into the sellae, and postoperative MR imaging showed no residual tumor (it is emphasized that GTR is not equal to complete tumor removal because removal of all microscopic parts of the lesions is impossible as a result of dural and osseous invasion). For STR, the volume of residual tumor was < 10% (calculated from pre- and postoperative MR imaging data according to the formula height × length × width/2). For PR, the volume of residual tumor was 10–40%. The results demonstrated that GTR was achieved in 78 patients (61.9%), STR in 43 (34.1%), and PR in 5 (4%) (Tables 1–4). The postoperative complications associated with the extended transsphenoidal approach are summarized in Table 5.

Follow-Up Results

The follow-up period ranged from 6 to 108 months, with an average of 43.4 months. A follow-up procedure included neurological examination, endocrinological evaluation, and contrast MR imaging studies of the sellar region as well as a routine clinical interview (1, 3, and 6 months and 1 year after surgery, and reexamination every year.
Pituitary adenoma

TABLE 1: Tumor consistency and resection percentage in 126 patients with pituitary adenoma*

<table>
<thead>
<tr>
<th>Category</th>
<th>Soft</th>
<th>Firm</th>
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<tbody>
<tr>
<td>GTR</td>
<td>64.1% (68)</td>
<td>50% (10)</td>
</tr>
<tr>
<td>STR</td>
<td>32.1% (34)</td>
<td>45% (9)</td>
</tr>
<tr>
<td>PR</td>
<td>3.8% (4)</td>
<td>5% (1)</td>
</tr>
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</table>

* Numbers in parentheses denote the number of patients in each category.

thereafter). The latest follow-up was performed by phone interview in September 2008.

Among the 104 patients with visual function impairment, 97 experienced various degrees of improvement, whereas 3 did not achieve any improvement, 2 had visual deterioration, and 2 progressed to monocular blindness. For the other 22 patients with normal visual function before the operation, no significant changes were observed during the follow-up period. Among patients with cranial nerve palsy before the operation, 7 recovered completely and 1 performed in 15 and 20 cases, respectively. Drug intervention was administered in 15 patients, of whom 13 received bromocriptine and 2 received cabergoline. In addition, 2 patients received GKS because of tumor recurrence at 24 and 30 months after operation. No reoperation was performed in the study. The endocrinological follow-up results in patients with hormonally active adenoma are presented in Table 6.

Illustrative Cases

Case 1

This 51-year-old woman presented with declining vision and vision field defect that had been occurring for > 1 year and dizziness for > 1 month. Endocrine examination suggested the presence of a nonfunctional pituitary adenoma. Preoperative MR imaging studies obtained with Gd enhancement showed that the tumor extended to the anterior cranial base (Fig. 1A). Sagittal CT scanning performed on the day after surgery showed total tumor resection and skull base bone defect (Fig. 1B). A contrast-enhanced MR imaging examination performed 6 months after surgery revealed that the tumor had been removed thoroughly and the position of the optic nerve chiasm had almost recovered to normal (Fig. 1D). Furthermore, visual function also returned to normal 6 months after the operation. During the follow-up period of 5 years, the patient regained a normal life without tumor recurrence.

Case 2

This 21-year-old man presented with declining vision accompanied by 1 year of diplopia and also complained of a decline in sexual desire. The preoperative endocrinological evaluation showed normal results. The preoperative contrast-enhanced MR imaging studies revealed that bilateral CSs had been encased by the tumor (Knosp Grade 4), which was confirmed to be a giant adenoma (Fig. 2 left). The postoperative contrast-enhanced MR imaging studies showed that the tumor had been totally removed (Fig. 2 right). During the follow-up period of 8 years, he experienced no recurrence of pituitary adenoma and a less satisfactory restoration of sexual function.

Case 3

This 51-year-old woman, who had undergone surgical

TABLE 2: Size of tumor and resection percentage in 126 patients with pituitary adenoma*

<table>
<thead>
<tr>
<th>Category</th>
<th>Macroadenoma (&lt;40 mm)</th>
<th>Giant Adenoma (≥40 mm)</th>
</tr>
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<tbody>
<tr>
<td>GTR</td>
<td>62.2% (51)</td>
<td>61.4% (27)</td>
</tr>
<tr>
<td>STR</td>
<td>35.4% (29)</td>
<td>31.8% (14)</td>
</tr>
<tr>
<td>PR</td>
<td>2.4% (2)</td>
<td>6.8% (3)</td>
</tr>
</tbody>
</table>

* Numbers in parentheses denote the number of patients in each category.

TABLE 3: Sites of tumor invasion and resection percentage in 126 patients with pituitary adenoma*

<table>
<thead>
<tr>
<th>Category</th>
<th>Anterior Cranial Base</th>
<th>Unilateral or Bilateral CS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Knosp Grade 3†</td>
<td>Knosp Grade 4‡</td>
</tr>
<tr>
<td>GTR</td>
<td>100% (3)</td>
<td>100% (3)</td>
</tr>
<tr>
<td>STR</td>
<td>0% (0)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>PR</td>
<td>0% (0)</td>
<td>0% (0)</td>
</tr>
</tbody>
</table>

* Numbers in parentheses denote the number of patients in each category.
† Tumor extension lateral to the lateral tangent of the intra- and supracavernous ICA.
‡ Tumor encasing the cavernous segment of the ICA.

The follow-up period of 8 years, he experienced no recurrence of pituitary adenoma and a less satisfactory restoration of sexual function.
removal of a PRL-secreting pituitary adenoma 25 years before, presented with dizziness occurring over the last 6 months. The preoperative PRL level was 6150 mg/ml. The patient was given oral bromocriptine at a dose of 2.5 mg/day and then experienced serious side effects of the gastrointestinal tract. As a result, she refused pharmacological treatment. The preoperative MR imaging studies obtained with Gd enhancement showed that the tumor had extended into the whole clivus (Fig. 3 upper). The postoperative contrast-enhanced MR images showed that the tumor had been totally resected (Fig. 3 lower). The postoperative PRL level decreased to 249.2 mg/ml. The patient received cabergoline until the PRL level returned to normal. During the follow-up period of 2 years, no tumor recurrence was reported.

Case 4

This 61-year-old woman, who experienced left eyesight loss and anosmia 1 year after craniotomy for her 4-year nasal obstruction, was admitted. The endocrinological examination revealed the presence of a nonfunctional pituitary adenoma. The preoperative contrast-enhanced MR images revealed that the tumor extended in a multidirectional manner and invaded bilateral CSs, clivus, and sphenoidal sinus, and reached the nasopharynx, causing nasal obstruction (Fig. 4A and B). The postoperative contrast-enhanced MR images showed that the tumor had been totally removed (Fig. 4C and D). During the follow-up period of 2 years, no tumor recurrence was reported.

Discussion

Basic Concept and Anatomical Considerations of the Extended Transsphenoidal Approach

The extended transsphenoidal approach is a well-established technique for the removal of sellar tumors, which has evolved enormously by continuous incorporation of technological advancement over the years. However, a precise definition of the extended transsphenoidal approach is complicated by the variety of modifications. Based on our surgical experience, we propose that the extended transsphenoidal approach differs from the standard approach in the wider range of bone resection of the sellar floor; extending anteriorly beyond the boundary of tuber culum sellae, laterally over the cavernous segment of the ICA, or posteriorly beyond the dorsum sellae.

The anatomical bases of the extended transsphenoidal approach are well documented. The natural cavities, such as the nasal cavity, the sphenoidal sinus, and the posterior ethmoidal sinus, provide an excellent surgical corridor to the sellar region for the procedure. The compartment encircled by the tuberculum sellae, the posterior ethmoidal artery, and bilateral optic canals provides a safe area for removing the tuberculum sellae and planum sphenoidale. The ICA is the main structure in the CS. In addition to the abducent nerve running alongside the ICA through the CS, the oculomotor nerve, the trochlear nerve, and ophthalmic and maxillary branches of the trigeminal nerve pass through the CS via its exterior wall. Therefore, entering the CS through its floor or interior wall does not injure the neurovascular structures. Moreover, the absence of important neurovascular structures in the midline region of the clivus allows safe removal of the bone in front of the brainstem.

Factors Influencing Tumor Removal

The extent of tumor removal is subject to the nature

<table>
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<tr>
<th>TABLE 4: Endocrinological types and resection percentage in 126 patients with pituitary adenoma*</th>
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<tr>
<td>Category</td>
</tr>
<tr>
<td>GTR</td>
</tr>
<tr>
<td>STR</td>
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<tr>
<td>PR</td>
</tr>
</tbody>
</table>

* Numbers in parentheses denote the number of patients in each category.

<table>
<thead>
<tr>
<th>TABLE 5: Complications related to the extended transsphenoidal approach in 126 patients with pituitary adenomas</th>
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<tbody>
<tr>
<td>Complication</td>
</tr>
<tr>
<td>CSF leakage</td>
</tr>
<tr>
<td>partial abducent nerve palsy</td>
</tr>
<tr>
<td>partial oculomotor nerve palsy</td>
</tr>
<tr>
<td>rupture of ICA</td>
</tr>
<tr>
<td>monocular blindness</td>
</tr>
<tr>
<td>panhypopituitarism</td>
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<tr>
<td>permanent diabetes insipidus</td>
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<tr>
<td>perforation of nasal septum</td>
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<tr>
<th>TABLE 6: Endocrinological follow-up results in 55 patients with hormone-secreting pituitary adenomas*</th>
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<tr>
<td>Adenoma Type</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>GTR</td>
</tr>
<tr>
<td>GH</td>
</tr>
<tr>
<td>PRL/GH mixed</td>
</tr>
<tr>
<td>ACTH</td>
</tr>
</tbody>
</table>

* RT = radiotherapy.
† Three patients still had high levels of GH.
of the pituitary adenomas and the areas they have invaded. As shown in Table 1, the rate of total removal of a firm tumor (50%) is significantly lower than that of a soft tumor (64.1%). Tumors invading the anterior cranial base or the clivus can be excised thoroughly, whereas tumors invading the CS and encasing the cavernous segment of the ICA or extending in a multidirectional manner are difficult to resect totally. There are no significant differences in the rate of GTR between macroadenoma, giant adenoma, and other endocrine tumors. Therefore, we tend to believe that GTR of pituitary adenomas that are firm, highly invasive to the CS, or invading multidirectionally may be hard to achieve, whereas the size and endocrinological type of the tumors have no marked effects on the degree of tumor removal. It should be noted that the surgical skills and experience of surgeons matter a great deal as to the efficacy and safety of surgical procedures when using the extended transsphenoidal approach. Neurosurgeons need to be well acquainted with the spatial structure and anatomical variations of the sella turcica. Additionally, surgeons are also expected to be familiar with such procedures as dissection and resection of tumors and hemostasis manipulation, which are of enormous significance for tumor resection and avoidance of damage to neurovascular structures. All operations in our present work were performed by experienced neurosurgeons who had conducted > 1000 pituitary surgeries, as well as having performed an average of > 150 resections via the transsphenoidal approach annually.

Role of Postoperative Adjuvant Radiotherapy

Overall, the recurrence rate for gross totally removed
pituitary adenomas is quite low. Moreover, radiotherapy has some well-known side effects such as irreversible damage to pituitary function or optic nerves, as well as radiation-induced tumors. Therefore, postoperative adjuvant radiotherapy for pituitary adenomas should be chosen prudently. We propose the following postoperative actions: 1) follow-up and observation in patients with hormonally active adenomas whose postoperative follow-up MR imaging showed no residual tumor and whose abnormally high hormone levels became normal, and in patients with nonfunctional adenomas whose postoperative follow-up MR imaging showed no residual tumor but who had high postoperative hormone levels; and 3) stereotactic radiosurgery (GKS) in patients with hormonally active adenomas whose postoperative follow-up MR imaging showed apparent residual tumor, and in patients with nonfunctional adenomas whose postoperative follow-up MR imaging showed tumor recurrence or residual regrowth.

Postoperative Complications

The common complications of the transsphenoidal approach include diabetes insipidus, cerebrospinal rhinorrhea, and so forth. Transient diabetes insipidus may spontaneously recover. The incidence of cerebrospinal rhinorrhea after conventional transsphenoidal surgery is estimated to be 1.5–4.9%. However, the most common postoperative complication associated with the extended transsphenoidal approach is cerebrospinal rhinorrhea, with a reported morbidity rate of 6–20%. In the present study, we demonstrated that the incidence of cerebrospinal rhinorrhea was 5.6%. To prevent this complication, reconstruction of the dura mater and cranial base defect during the operation has been proposed. In another study, a subdural double-layer patch graft was used to repair the dural defects caused by the extended transsphenoidal approach, achieving an effective prevention of cerebrospinal rhinorrhea. Nevertheless, patients with cerebrospinal rhinorrhea in the present study were cured by conservative therapy without any reconstruction of the cranial base or dural repair. Our results indicate that preserving the integrity of the arachnoid membrane and precisely closing the tear in the arachnoid membrane as well as filling the dead space with autologous fat tissue may be the key factors in prevention of cerebrospinal rhinorrhea.

Cranial nerve palsy is another common complication of the extended transsphenoidal approach. In Couldwell and coworker’s report, this disorder occurs exclusively in patients with tumors invading the CS (4%), presenting with partial palsy of abducent or oculomotor nerves, and these patients completely recovered within 6 months. The most dangerous complication associated with the extended transsphenoidal approach is the intraoperative rupture of the ICA, whose incidence varies between 0 and 3.8%. In the present study, intraoperative rupture of the ICA occurred in 2 patients (1.6%), who experienced varying degrees of improvement after having received gauze packing for hemostasis, decompressive craniectomy, and interventional therapy. We therefore suggest that attempts should be made to acquire information about the compensation status of anterior and posterior circulation before the operation, and the Matas test could be a simple but useful method. In case of intraoperative rupture of the ICA, more postoperative attention should be addressed to the patient, and a digital subtraction angiography examination should be performed as soon as possible if they manifest symptoms of cerebral ischemia. Postoperative nasal complications associated with the standard transsphenoidal approach are < 3%. In our series, there were 2 cases of perforation of the nasal septum (1.6%). Other complications, such as postoperative nasal hemorrhage, didn’t occur. It is therefore reasonable to infer that nasal complications associated with the extended transsphenoidal approach and resulting from relatively wide dis...
Pituitary adenoma

sociation of nasal mucosa and large, wide, bone resection would not be more serious than the standard procedure.

Advantages of the Approach

Youssef et al. pointed out that the indications for the transcranial approach to remove pituitary adenoma should include dumbbell-shaped tumors caused by a narrow waist at the diaphragma sellae, but this surgical avenue is not applicable to the safe removal of pituitary tumors invading the CS. After a thorough review of transcranial and transsphenoidal approaches to treat pituitary adenoma, stipulated that the extended transsphenoidal approach is a minimally invasive method to reach the suprasellar regions, the CS, and the clivus. Based on the specific anatomical characteristics of the sella turcica and the cranial base as well as our previous experience, the extended transsphenoidal approach exhibits the following advantages in removing pituitary adenomas invading the anterior cranial base, CS, and clivus. First, the tumor can be exposed adequately without brain retraction and olfactory nerve impairment. Second, the removal of tumors from under the optic nerve allows the operating field to be unaffected by the position of the optic chiasm. Third, pituitary adenomas usually lie outside of the arachnoid membrane, and because the extended transsphenoidal approach is also performed outside of this membrane, damage to the nerves and blood vessels underneath it is minimal. Fourth, the tumors and bilateral anatomical structures can be sufficiently exposed during operation. As a result, it will be easier to identify the spatial layouts of tumors and the neurovascular structures. Moreover, this approach provides significant working space under the operating microscope. Therefore, this procedure allows for various delicate surgical manipulations including dissection, curettage, and hemostasis under direct vision, which avoid possible damage to nerves and blood vessels. Fifth, the tumors with suprasellar extension and normal size of the sella turcica can be exposed and removed by additional bone resection in the anterior cranial base. Sixth, this surgery allows for the approach to the CS via its inferior and medial walls, where there are no important anatomical structures. Seventh, in the event of intraoperative rupture of the ICA, the hemorrhagic spots can be instantly localized, leading to a reduction in the risk of intraoperative bleeding. Last but not least, the procedure is optimal for the removal of tumors invading the middle and inferior clivus.

Considerations of Efficacy and Safety of the Procedure

Preoperative imaging studies are the first step toward a safe operation. Preoperative imaging data, particularly MR imaging with T1-weighted studies, can clearly show the degree of pneumatization of the sphenoidal sinus and posterior ethmoidal sinus, the localization of septa in the sphenoidal sinus, the shape of the sellar floor, the size of the tumors, and the direction of tumor invasion, as well as the localization of bilateral optic canals and intracavernous ICAs. Therefore, preoperative imaging data can help

Fig. 4. Contrast-enhanced MR images demonstrating a nonfunctional giant adenoma. A and B: Preoperative sagittal and coronal images showing the tumor invading in a multidirectional manner into areas such as bilateral CSs, clivus, sphenoidal sinus, and nasopharynx, causing nasal obstruction. C and D: Postoperative sagittal and coronal images showing GTR.
to establish accurate topographical relationships between the sellar anatomical structure and the spatial arrangement of tumors. In addition, it can measure directly the diameter of sphenoidal sinus as well as the distance of bilateral optic canals and ICAs. Taken together, it can be used to tailor the individual surgical strategy and to improve the efficacy and safety of tumor resection.

To date, various modern technologies have been widely applied to the extended transsphenoidal approach. For example, the neuronavigation system can accurately locate the critical neurovascular structures surrounding the sella turcica, and the endoscope can provide better visualization and stronger magnification than conventional microscopes. In 2005, we started using these techniques during the extended transsphenoidal approach. The neuronavigation system provided a “real-time” location of important anatomical structures, such as the cavernous segment of the ICA, the brainstem, the optic canal, the tuberculum sellae, the dorsum sellae, the clivus, and so on. The endoscope offered a subtle and clear visualization and shed light on the obscure structures surrounding the sella turcica and residual tumor. The practice of extended transsphenoidal approach does not rule out the use of the endoscope. Aided by endoscopy, neurosurgeons can better identify the fine structure of important neurovasculature. Incorporation of the endoscope in the extended transsphenoidal approach can also be used for examining the extent of tumor resection or ensuring thorough removal of the tumors. These advantages result in minimizing the chance of inaccurate orientation, precisely resecting the bone of the cranial base, and accurately assessing the extent of tumor removal. Furthermore, intraoperative MR imaging has offered surgeons an immediate, intraoperative method for quality control and allowed them to judge the extent of tumor removal. Undoubtedly, these new techniques facilitate tumor resection and greatly reduce the complications associated with the extended transsphenoidal approach.

Conclusions

The extended transsphenoidal approach has proven to be highly effective, and postoperative complications are relatively low, due to the ability to fully expose tumors invading the anterior cranial base, CS, and clivus. Nevertheless, it should be noted that total removal of pituitary tumors that are firm, highly invasive to the CS, or multiderivational in extension remains a big challenge. According to follow-up endocrinological evaluation and MR imaging studies obtained with a contrast agent, postoperative adjuvant radiotherapy for pituitary adenomas should be chosen prudently. The extended transsphenoidal approach not only allows better visualization of the tumor and the neurovascular structures, but also provides significant working space under the operating microscope, which facilitates intraoperative manipulation. Preoperative imaging studies and new techniques, such as the neuronavigation system and the endoscope, improve the efficacy and safety of tumor resection. Based on 126 consecutive cases, our study may provide valuable experience to neurosurgeons who remove lesions extending beyond the limit of the sella turcica with the aid of the operating microscope. We hope that our surgical results, such as complications and the percentage of tumor resection, will become a baseline with which other techniques, for example the pure endoscopy technique, can be compared.

Disclosure

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