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Research Article

Craniopharyngioma Removal via Supraorbital Keyhole Approach

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Abstract

Objectives : For anterior surgical approaches to the suprasellar lesions, a relative larger craniotomy was always required in order to facilitate illuminating deeply several years ago. The improvement of surgical techniques, as well as the development of diagnostic imaging and the introduction of neuroendoscope, allows us to manage various intracranial lesions through a small keyhole. Although the supraorbital keyhole approach has nowadays gained ground in the surgeries of aneurysms and pituitary adenomas at suprasellar region, there are few descriptions of craniopharyngioma removal via such approach.

Methods : 17 patients with craniopharyngiomas were experienced 18 surgeries to remove the lesions via the keyhole approaches, including 17 supraorbital and 1 pterional keyhole approaches. The head MRI, ophthalmological and endocrinological assessments were conducted pre- and postoperatively to evaluate the therapeutic effects.

Results : Total resection of craniopharyngioma in 12 surgeries and subtotal resection in 6 surgeries were achieved. Obstructive hydrocephalus in 5 cases was resolved in one session after the removal of lesions. Visual acuity and visual field improved in 7 cases after operations, aggravated in 3 cases however, and 2 of them alleviated after the hyperbaric oxygen therapy. 8 patients experienced postoperative electrolyte disorder and diabetes insipidus temporarily, and 1 patient suffered from disturbance of consciousness for two days after the resection of lesion.

Conclusion : The supraorbital keyhole approach offers surgical possibilities with effective resection of lesion and less approach-related morbidity compared with the conventional craniotomy approaches in the surgery of craniopharyngiomas. It is most beneficial to remove lesions infiltrated into the third ventricle on account of recanalization of the obstructive cerebrospinal fluid pathway.

Keywords : Supraorbital keyhole approach; Craniopharyngioma; Microsurgery; Minimally invasive neurosurgery

Introduction

Many different approaches to suprasellar lesions have been described during the past decades [1-5], including the pterional approach, the transcallosal approach, and the subfrontal approach as well. One kind of disadvantage for all these approaches are the relative extensive brain exposure and retraction that result in the increase of approach-related morbidity, but is not in relation to the lesions themselves. Therefore, the ultimate goal of neurosurgery ought to be the smallest approach-associated injury with the optimal surgical results [6,7].

The development of medical imaging over the past decades has not only brought out the more accurate diagnoses, but allowed us to study the elaborate intracranial anatomy individually [8-12]. Understanding almost all anatomical details about the vicinity of lesions in advance, we can constitute the appropriate surgical strategies that are propitious to the lesions and anatomical structures of individual patient. All these improvements play an important role in the development of the keyhole neurosurgery [13].

As the most common congenital benign neoplasm at suprasellar region, craniopharyngioma is deep-seated and surrounded by nerves and vessels, which gives rise to the dramatic difficulty of surgical resection totally. By means of the combination of “keyhole effect” and skull base surgical skills, keyhole approaches have been widely used in the surgery of aneurysms of anterior Willis circle as well as giant pituitary adenomas at suprasellar region [14-16]. In spite of the differences of hardness and content between craniopharyngioma and pituitary adenoma, we attempt to remove craniopharyngioma via the supraorbital keyhole approach due to their similar location and vicinity.

Patients and Methods

From September 2007 to August 2012, 17 patients with craniopharyngiomas were experienced 18 surgeries via the keyhole approaches by senior authors in our department. All these clinical files and surgical procedures were studied retrospectively (Table 1). Patients’ age ranged from 16 to 74 years old with a mean age of 48.71 years old. There were 7 males and 10 females. The prominent

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Table 1: Patient Characteristics.

Patient	Age, y/Sex	Presentation	Prior Therapy	Lesion				Hydrocephalus
				Maximum Diameter, mm	Infiltration	Characteristics	Location of Pituitary Stalk	
1	32/M	Headache, Vision Loss	None	37	None	Cystic Partially	Posterior	Obstructive
2	53/F	Headache, Dizziness	None	30	Third Ventricle	Parenchymal	Posterior	Obstructive
3	48/F	Headache, Vision Loss	None	49	Third Ventricle	Cystic Partially	Posterior	None
4	53/M	Headache	γ-knife	15	Third Ventricle	Cystic Partially	Posterior	Obstructive
5	54/M	Hemianopsia, Diplopia	Medication	20	None	Cystic	Posterior	None
6	38/F	Amenorrhea, Polydipsia	None	10	None	Cystic Partially	Posterior	None
		Vision Loss, Headache	Surgery	20	Third Ventricle	Cystic	Posterior	None
7	59/F	Polyuria	None	12	Sella Turcica	Cystic Partially	Anterior	None
8	46/M	Hemianopsia, Vision Loss	None	11	None	Cystic Partially	Posterior	None
9	58/F	Headache	None	22	None	Cystic	Posterior	None
10	28/F	Headache, Vomiting	None	49	Third Ventricle Sella Turcica	Parenchymal	Posterior	Obstructive
11	72/F	None	None	12	None	Parenchymal	Posterior	None
12	51/F	Polyuria, Vision Loss, Headache	None	20	Third Ventricle	Cystic	Wrapped	None
13	38/M	Fatigue, Sexual Dysfunction, Vision Loss	None	39	Third Ventricle	Cystic Partially	Posterior	None
14	56/F	Vision Loss	Medication	29	None	Cystic Partially	Posterior	None
15	62/M	Headache, Vision Loss	Medication	15	None	Cystic	Posterior	None
16	16/F	None	None	18	None	Cystic Partially	Posterior	None
17	64/M	Vision Loss, Dizziness	None	54	Third Ventricle	Cystic Partially	Anterior	Obstructive

symptoms were headache (in 9 cases) and/or dysfunction of visual acuity and visual field (in 10 cases). 3 of them had polydipsia and polyuria concurrently. Amenorrhea occurred in 1 female and sexual disturbance in 1 male respectively. Lesions in 2 patients were found by the health examination occasionally. The postoperative γ-knife procedure was carried on in 1 patient, and another patient received surgery again due to the recurrence of lesion.

The preoperative head magnetic resonance imaging (MRI) for all patients revealed the focal location in suprasellar region predominantly, with infiltration into the sella turcica in 2 patients and into the third ventricle in 8 patients. 13 craniopharyngiomas were parenchymal or cystic partially, and another 5 lesions were cystic. The peak diameter of lesions arranged from 10 to 54mm with an average diameter of 24.58mm. 5 cases were found obstructive hydrocephalus in MRI.

Attempts were made for all cases to undergo total resection of craniopharyngiomas. Under the circumstance that lesions strongly adhered to the adjacent structures such as the internal carotid artery (ICA), the optic nerve and chiasm, the pituitary stalk, etc., we performed subtotal excision of lesions followed by the γ-knife radiotherapy in order to prevent the structures mentioned above from injuring. Comprehensive ophthalmological and endocrinological evaluations were conducted for all patients pre- and postoperatively. The ophthalmological assessment consisted of visual acuity and visual field testing, and the endocrinological assessment consisted of pre- and postoperative studies including the morning cortisol, the thyroid function testing, the prolactin, the adrenocorticotropic hormone, the growth hormone, the follicle-stimulating hormone and the luteinizing hormone. The latter one was also performed next day and repeated about one week postoperatively before discharging. The extent of resection was determined by the comparison of pre- and postoperative (in three days after operation) T1-weighted contrast-enhanced MRI.

Follow-ups were performed through the outpatient clinic visiting and telephone correspondence routinely after discharging from our hospital. The contrasted-enhanced MRI was reexamined as well as the serum morning cortisol and the thyroid function testing in the period of three months and six months after surgeries, besides the general conditions of patients. Other hormone levels, as well as visual acuity and visual field testing, would also be reviewed when abnormalities of the ophthalmological and the endocrinological assessment occurred before discharging and during follow-ups.

Surgical Techniques

Individual surgical strategies were defined according to the location, characteristic and vicinity of lesions. 17 surgeries were conducted via the supraorbital keyhole approach, and the pterional keyhole approach was used once. All patients were placed in the pin fixation of Mayfield head holder to allow for neuronavigation.

Supraorbital Keyhole Approach

Positioning

Patient lied in the supine position with the head rotating 20 to 40° to contralateral side (depending on the location of lesion), retroflexing 10 to 50° (allowing the frontal lobe to fall away from orbital roof by gravity), lateroflexing 5 to 15° to contralateral side (offering a comfortable position for surgeons) (Figure 1).

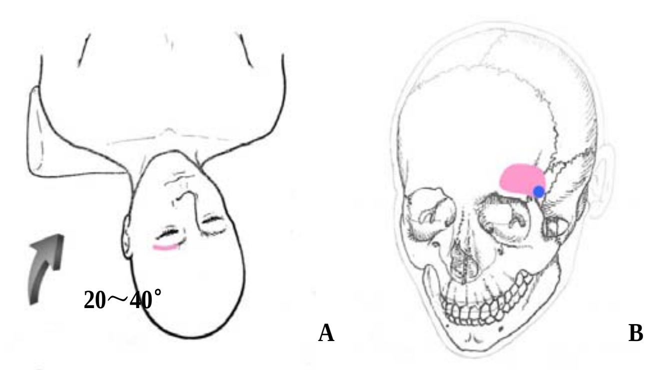

Figure 1: The skin incision and craniotomy of the supraorbital keyhole approach. (A) Patient in the supine position with degree of the head rotation and retroflex ion according to the location of lesion. The skin incision in the eyebrow is labeled by pink curve. (B) The typical craniotomy is presented by pink in color with blue dot as the burr hole.

Skin Incision

The skin incision was in the eyebrow with length of approximate 4cm, starting laterally from the supraorbital nerve and finishing at the terminal segment of the eyebrow. The superficial temporal artery and branches of the facial nerve did not cross the surgical field. Shaving eyebrow was not necessary. The fascia of temporal muscle was incised at the temporal line for 2 to 3cm. The frontal fascia was cut from the temporal line in a semicircular fashion over the frontal bone with its base along the orbital rim. The temporal muscle was dissected bluntly and retracted posteriorly for 1 to 2cm.

Craniotomy

One burr hole was made in the temporal fossa with a high-speed drill, and was behind the superior temporal line of the frontal bone. The bone flap was created by a high-speed milling cutter with length of 2.0 to 2.5cm and width of 1.5 to 2.0cm usually. Special attention should be given to the frontal sinus in preoperative MRI, opening of which should be prevented. Otherwise, the gelatin sponge and the bone wax, as well as the artificial dura and the medical glue if necessary, should be used for sealing the opened frontal sinus appropriately. The internal lamina of orbital rim was drilled off to obtain better visualization of the surgical field, which facilitated the introduction of micro instruments. Since such approach was small, special care should be taken to the small bony extensions of the frontal skull base, which might become the major obstacles in a keyhole approach. These extensions should be drilled off extradurally. Then the dura was opened as a flap with its base to the orbital roof.

Lesion Exposure

The brain pressure could be reduced by continuous aspiration of the cerebrospinal fluid (CSF) followed with gradual lifting of the frontal base by a brain spatula. Then the carotid cistern, the optic chiasm cistern and others were able to be exposed and opened, so that a large mount of CSF could be removed to facilitate further retraction of the frontal lobe in order to gain adequate surgical space intracranially.

Closure

The bone flap was reset and fastened with the skull lock after running or single sutures of dura. Then the subcutaneous structures were sutured intermittently, and the skin was running sutured intracutaneously. The surgical wound was compressed by fingers for several minutes in order to avoid subcutaneous hematoma as well as the adhesive bandage if necessary.

Pterional Keyhole Approach

Positioning

Patient lied in the supine position with the head rotating 45 to 60° to contralateral side, retroflexing 10 to 50°, lateroflexing 5 to 15° to contralateral side (Figure 2). The shoulder of affected side was cushioned if necessary.

Skin Incision

The skin incision was along the hair line with length of about 4cm by setting the position, which was 2cm apart from the keyhole laterally, as a central point (Figure 3). Combining with the scalp, the fascia of the temporal muscle was dissected. The temporal muscle was incised along the sphenoidal crest.

Craniotomy

A bone flap with 2.0 to 2.5cm in diameter was milled by considering the pterion as a central point after one burr hole was made nearby the middle of skin incision. The sideward of the sphenoidal crest should be removed at least 1/3 by a high-speed drill. Then the dura was opened as a flap with its base to the sphenoid crest. Concerning into the bone window, the exposure of 2/3 brain was the frontal lobe, as well as the 1/3 brain was the temporal lobe.

Lesion Exposure

The brain pressure could be reduced by aspiration of CSF after the opening of the sylvian fissure. The frontal base was lifted gradually

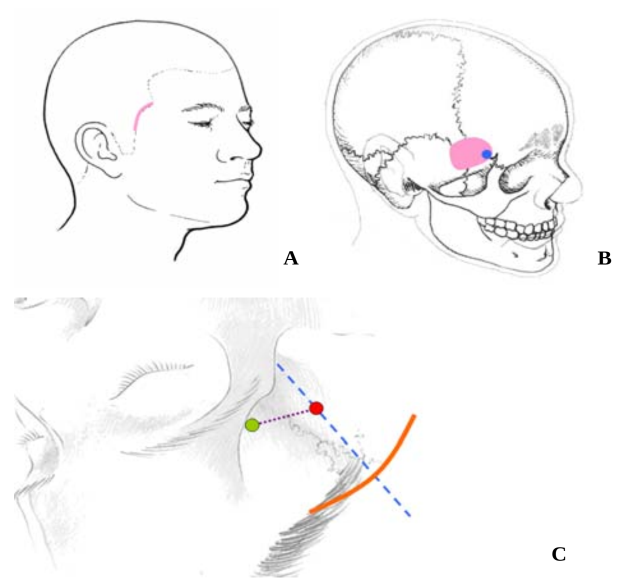

Figure 2: The skin incision and craniotomy of the pterional keyhole approach. (A) The skin incision along the hair line is labeled by pink curve. (B) The typical craniotomy is presented by pink in color with blue dot as the burr hole. (C) A central point (red dot) is 2cm (purple line) apart from the keyhole (green dot) laterally, based on which the sphenoidal crest (blue line) can be confirmed and the skin incision (orange line) can be designed.

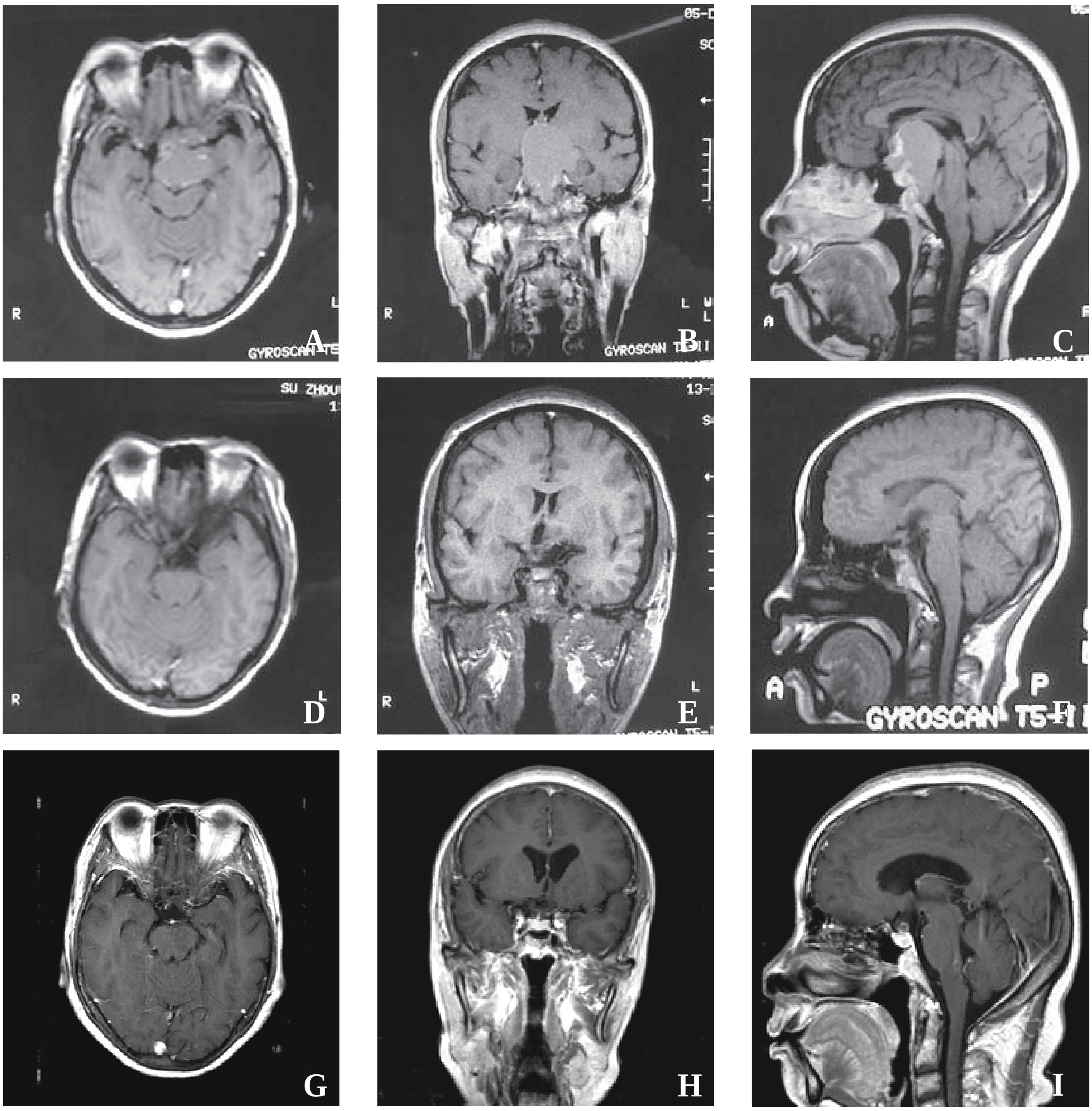

Figure 3: Illustrative case: 48-year-old woman. (A) (B) (C) Preoperative MRI demonstrated partial parenchymal craniopharyngioma with infiltration into the third ventricle and the prepotine cistern. (D) (E) (F) Postoperative MRI revealed total resection of craniopharyngioma.
(G) (H) (I) MRI of 3 years follow-up after surgery showed no recurrent of craniopharyngioma.

along the sphenoidal crest to the anterior clinoid process in order to expose the deep structures.

Closure

The wound closure was mainly similar to that of the supraorbital keyhole approach with running or single sutures of dura, fixation of the bone flap with the skull lock, muscular and subcutaneous sutures, and single sutures of the skin.

Resection of Craniopharyngioma

Adequate surgical space was able to be gained by the removal of CSF after the opening of the carotid cistern, the optic chiasm cistern and the sylvian fissure. There were several anatomical intervals at suprasellar region, which were very important for the surgery of craniopharyngioma, such as the prechiasmatic cistern triangle, the optico-carotia triangle, the carotido-tentorial triangle, the chiasmatic-terminal lamina triangle, and the interspace superior to the bifurcation of ICA. Lesions were capable of excising piecemeal by taking full advantage of these intervals. During the surgery, the cystic portion of lesions was punctured and aspirated firstly for the sake of decompression if necessary. For patients with the complication of hydrocephalus, the obstruction in the CSF pathway could be resolved by removal of lesion in the third ventricle in one session without the procedure of ventricular peritoneal shunt. The endoscope was introduced into surgical field to confirm the total removal of lesions and the intactness of pituitary stalk. No intracranial drainage was used externally after surgery.

Results

In our 17 patients, 1 patient was operated twice due to the recurrence of craniopharyngioma three months after subtotal resection, so that a total of 18 microsurgeries were conducted (Table 2). One of them was operated via the pterional keyhole approach; other 17 surgeries were operated via the supraorbital keyhole approach. The endoscope was introduced into surgical field for inspection in 10 surgeries. Total resection of lesions in 12 surgeries (66.67%) and subtotal resection in 6 surgeries (33.33%) were achieved. The pituitary stalk was injured in 1 case and fractured in another case. 8 patients presented as electrolyte disorder and diabetes insipidus after surgery. 10 cases presented as dysfunction of the thyroid hormones including 2 of them accompanied with dysfunction of the serum cortisol, as well as 1 case with dysfunction of the serum cortisol only. In 5 patients with obstructive hydrocephalus, the shape of the ventricles recovered tomographically after the removal of lesions. Visual acuity and visual field improved in 7 patients, who suffered from dysfunction of visual acuity and visual field preoperatively, but aggravated in 3 patients, and 2 of them alleviated significantly after the hyperbaric oxygen therapy. Postoperative disturbance of consciousness occurred for two days in one patient, who was in a clear state in mind before surgery (Table 3). The adjunctive γ-knife radiotherapies were carried out in 4 patients with subtotal resection of lesions after discharge from our department, as well as one patient who received second surgery due to the recurrence of lesion. With the exception of 2 patients, whose pituitary stalks were fractured or injured, being in need of long-term hormone replacement therapy, the hormone levels of residual patients recovered by short-term complement of the "prednisone" and "Levothyroxine Sodium".

Illustrative Case

This 48 years old woman received a MRI examination because of paroxysmal headache persisted for two years accompanied with aggravated loss of vision acuity for 10 months. Preoperative ophthalmological assessment revealed poor visual acuity of left side and temporal hemianopsia of right side. The lesion at suprasellar region was detected, with infiltration into the prepotine cistern. Partial parenchymal craniopharyngioma was diagnosed according to MRI. The lesion, which was about 49mm×35mm×34mm in volume, resulted in the defect ophthalmological assessment mentioned above due to the compression of bilateral optic nerves. A 2.0cm×1.5cm craniotomy was made following a left-sided eyebrow incision. Intraoperatively, the tumor was removed piecemeal through the prechiasmatic cistern triangle, the optico-carotia triangle, the carotido-tentorial triangle, the chiasmatic-terminal lamina triangle, and the interspace superior to the bifurcation of ICA respectively. The endoscope was introduced into the surgical field for inspection, which confirmed the intactness of pituitary stalk and the total removal of lesion, as well as the portion located at the prepotine cistern. After surgery, diabetes insipidus did not occur and visual acuity alleviated significantly. Postoperative MRI revealed the total resection of lesion. Temporary medication was recommended based on the postoperative endocrinological assessment of decreased thyroid function, which recovered three months later. MRI demonstrated total resection of lesion two days after surgery, as well as no recurrence three years after operation.

Discussion

Feasibility of Craniopharyngioma Removal via Keyhole Approach

Table 2 : Surgical Outcomes.

Patient	Keyhole Approach	Extent of Resection	Pituitary Stalk	Hydrocephalus	Complications	Adjunctive Therapy
1	Supraorbital	Subtotal	Intact	Resolved	Transient Diabetes Insipidus, Subdural Hydrops	γ-knife
2	Supraorbital	Total	Intact	Resolved	Transient Diabetes Insipidus	None
3	Supraorbital	Total	Intact	None	None	None
4	Supraorbital	Subtotal	Fractured	Resolved	Transient Diabetes Insipidus	γ-knife
5	Pterional	Total	Intact	None	CSF Leakage	None
6	Supraorbital	Subtotal	Intact	None	None	None
	Supraorbital	Subtotal	Intact	None	Transient Diabetes Insipidus	γ-knife
7	Supraorbital	Total	Intact	None	Transient Disturbance of Consciousness	None
8	Supraorbital	Total	Intact	None	Transient Diabetes Insipidus	None
9	Supraorbital	Total	Intact	None	None	None
10	Supraorbital	Subtotal	Intact	Resolved	Transient Diabetes Insipidus	γ-knife
11	Supraorbital	Total	Intact	None	None	None
12	Supraorbital	Total	Injured	None	Transient Diabetes Insipidus	None
13	Supraorbital	Subtotal	Intact	None	Transient Diabetes Insipidus	γ-knife
14	Supraorbital	Total	Intact	None	None	None
15	Supraorbital	Total	Intact	None	None	None
16	Supraorbital	Total	Intact	None	None	None
17	Supraorbital	Total	Intact	Resolved	None	None

Table 3 : Ophthalmological and Endocrinological Outcomes.

Patient	Ophthalmological Assessment			Endocrinological Assessment			MR		Further Therapy
	Preoperative	Postoperative	Follow-up	Preoperative	Postoperative	Follow-up	Postoperative	Follow-up	
1	Vision Loss, Hemianopsia	Improved	Improved	Normal	Normal	Normal	Subtotal	Stable	γ-knife
2	Normal	Normal	Normal	Normal	Low TSH	Recovered	Total	Stable	None
3	Vision Loss, Hemianopsia	Improved	Improved	Normal	Low fT3	Recovered	Total	Stable	None
4	Normal	Normal	Normal	Normal	Low TSH, Cortisol	Recovered	Subtotal	Stable	γ-knife Long-term Medication
5	Vision Loss	Improved	Improved	Low TSH	No Change	Recovered	Total	Stable	None
6	Normal	Normal	Normal	Normal	Low fT3	Recovered	Subtotal	Recurrent	None
	Normal	Normal	Normal	Normal	Low fT3	Recovered	Subtotal	Stable	γ-knife
7	Normal	Normal	Normal	High PRL	Improved	Recovered	Total	Stable	None
8	Hemianopsia	Improved	Improved	Normal	Low fT3	Recovered	Total	Stable	None
9	Normal	Normal	Normal	Normal	Normal	Normal	Total	Stable	None
10	Vision Loss, Hemianopsia	Aggrevated	Improved	Normal	Low fT3, Cortisol	Recovered	Subtotal	Stable	γ-knife Hyperbaric Oxygen
11	Normal	Normal	Normal	Normal	Low fT3	Recovered	Total	Stable	None
12	Vision Loss, Hemianopsia	Improved	Improved	Normal	Low fT3	Recovered	Total	Stable	Long-term Medication
13	Vision Loss, Hemianopsia	Aggrevated	Improved	Normal	Low fT3	Recovered	Subtotal	Stable	γ-knife Hyperbaric Oxygen
14	Hemianopsia	Improved	Improved	Normal	Low Cortisol	Recovered	Total	Stable	None
15	Vision Loss, Hemianopsia	Improved	Improved	Normal	Normal	Normal	Total	Stable	None
16	Hemianopsia	Aggravated	No change	Low fT3	Improved	Recovered	Total	Stable	None
17	Vision Loss	Improved	Improved	Normal	Normal	Normal	Total	Stable	None

Due to the introduction of surgical microscope in the 1960s, the illumination of deep surgical fields and the magnification of anatomical and pathological structures were improved [17]. This led to a completely new, less invasive, surgical technique. Based on such technique, special attention to the size of craniotomy was given by Perneczky [18], which facilitated the development of keyhole microneurosurgery.

The keyhole approach offers several advantages compared to the standard craniotomies [19,20]. First of all, there is only minimal brain exposure to the air and the accidental surgical trauma, and the brain retraction is minimalized or absent, which significantly decreases the approach-related surgical morbidity and shortens the hospitalization. The nerve and vascular supply to the temporal and frontal muscles are preserved with an excellent cosmetic result. The surgical procedure is markedly facilitated compared to the standard techniques. The duration of craniotomy and closure was shorten significantly to about 30 minutes respectively.

The keyhole concept is defined as the principle: the intracranial optical field widens with increasing distance from the keyhole [21-23]. Therefore, lesions at or close to the surface of brain require an approach that is at least as large as the lesion itself, but lesions at the base of brain can be visualized through a relative small keyhole. The suprasellar region is deeply seated in the base of brain that is in conformity with the above principle. In addition, the piecemeal resection fashion has to be complied with for resection of relative huge lesions even via the standard approaches due to the limitation of vicinal nervous and vascular structures [24,25]. Consequently, the bone window with diameter of about 2cm can adequately meet the requirements of such surgeries and will not prolong the surgical duration [26].

Approach Selection of Keyhole Surgeries

Individual approaches of keyhole surgeries shall be determined according to the focal characteristics of localization, texture, size and infiltration mode. Many approaches have been described as follows [27-29]: the supraorbital keyhole approach, the orbit-supraorbital keyhole approach, the interhemispheric keyhole approach, the pterional keyhole approach, the subtemporal keyhole approach, the interhemispheric transcallosal keyhole approach, the transcallosal-transforaminal keyhole approach, etc. In despite of these different approaches, the conventional four anatomical intervals in the suprasellar region, including the prechiasmatic cistern triangle, the optico-carotia triangle, the carotido-tentorial triangle and the chiasmatic-terminal lamina triangle, are available primarily to remove lesions. Special attention shall be paid to the interspace superior to the bifurcation of ICA, because it is crucial for removing lesions at the suprasellar region posteriorly. In this study, 1 patient had a residual craniopharyngioma due to the difficult arrival of visual projection in ignorance of the space described above when treated in another hospital, and the tumor was excised totally by our surgery via this interval.

The infiltration into the third ventricle up- and backwardly occurs in craniopharyngiomas generally [30] and appeared in 8 cases of 18 patients in this study. The fore-and-aft projection of visual angle of the supraorbital keyhole approach is in favor of taking full advantage of the chiasmatic-terminal lamina triangle to open the lamina terminalis and remove the lesions in the third ventricle. In comparison of the supraorbital keyhole approach, the visual angle of the pterional keyhole approach projected laterally, which is not beneficial if lesions seat deeply in the third ventricle [31,32]. Therefore, 1 patient in this study experienced surgery laterally via the pterional keyhole approach to prevent the pituitary stalk from injuring on account of preoperative MRI, which revealed the pituitary stalk was in front of the lesion and the infiltration into the third ventricle was excluded.

Cosmetic Effect of Supraorbital Keyhole Approach

The skin incision of the supraorbital keyhole approach has designed as the location above eyebrows, in frontal wrinkles, inside and outside eyebrows, etc [33,34]. Although the incision we used is hidden in the eyebrow laterally with relative slight cosmetic effect, it is still exposed on the outside surface in comparison to the pterional keyhole approach, whose incision is hidden in the hair line. Unfavorable appearance would be acquired if the incision is healed undesirably or the scar is obvious. Therefore, the supraorbital keyhole approach is not designed for patients with sparse eyebrows or scar constitution in our department.

The early practice we did for the fixation of bone flap was making knots with threads by drilling small holes on the edge of bone window. But unstable fixation of bone flap and sinking of skin due to the wide bone seam occurred in several patients. Subsequently, the skull lock made from titanium alloys was introduced to fix the bone flap, which facilitated the stable fixation of bone flap and the ideal covering of bone seam. The metallic suture was also adopted for running suture intracutaneously to alleviate tissue reaction and lessen incisional scar.

Hypodermal effusion will be induced by small amount of CSF and blood leakage due to the loose tissues around orbit. So the skin incision shall be compressed for several minutes to prevent hypodermal hematoma after suturing, and then be dressed with elastic bandage appropriately if necessarily in an early stage.

Techniques of Craniopharyngioma Removal

Dissecting lesions along the layer, which is a proliferative glia between the craniopharyngioma and the vicinal structure, is beneficial to the resection of focus without injury to normal tissues [35]. Attribute to the lack of parenchymal lesion that can severely adhere to the vicinity, cystic craniopharyngiomas are usually able to be removed entirely. Moreover, puncture and aspiration of cyst firstly is good for obtaining adequate surgical space. Total removal as possible of lesions in the first surgery is recommended due to the high recurrence rate after partial resection [36]. Furthermore, for the adhesion of lesion and vicinity, reoperation for recurrent craniopharyngiomas is relative difficult and dangerous [37,38]. The factors, such as the severe adhesion of lesion and hypothalamus, the inadequate exposure of lesions, the huge calcification, the vascular structures wrapped by focus seriously, usually result in infeasibility of total removal of craniopharyngiomas [39]. Giant craniopharyngiomas are often full of every interval at the suprasellar region, and the surgical space is relatively small at the beginning of resection. The introduction of the cavitron ultrasonic aspiration (CUSA) is in great favor of piecemeal resection of lesions to expand maneuvering room gradually. Craniopharyngiomas could be smashed and aspirated by CUSA due to the majority lesions are medium in texture even if calcified partially. The intensity of CUSA shall be adjusted if needed. For instance, the intensity ought to be reduced when removing lesions nearby the pituitary stalk and the vascular structures. In addition, manual aspirator is recommended as possible to avoid the injuries to normal tissues by the suction of CUSA. Some calcified tissues which are very hard in texture can also be removed by a bayonet rongeur.

The pituitary stalk may be adhered to or wrapped by craniopharyngioma as well as many vascular structures. The feeders of craniopharyngiomas are always arisen from the circle of Willis. The intrasellar lesion is fed by the branches of cavernous segments of the bilateral ICA laterally, the suprasellar focus is fed by the branches of the anterior communicating artery (ACoA) and the anterior cerebral arteries (ACA) superiorly, and the bilateral tumors are fed by the branches of the posterior communicating arteries (PCoA). Generally, these vascular structures are only compressed and pushed by craniopharyngiomas with a relative clear border, but severe adhesion may also occur sometimes. Therefore, over-pulling shall be avoided when excising the walls of lesions in order to prevent the adverse outcome caused by the injuries of deep seated vascular structures.

Subtotal resection of craniopharyngiomas for 5 patients in 6 surgeries was conducted in this study due to the severe adhesion of lesions and pituitary stalks. 2 surgeries with partial excision of lesions were carried out on the same patient because of the recurrence of lesions three months after first subtotal resection. These 5 patients were recommended for γ-knife radiotherapy after the latest surgeries in a short term.

Protection of Pituitary Stalk

The surgical treatment of pituitary adenomas only remove lesions within the capsule without severe invasion to the vicinity, and craniopharyngiomas, however, shall remove the capsule to avoid recurrence. Therefore, the surgery of craniopharyngiomas is harder than of pituitary adenomas due to the protection of important vicinity such as the pituitary stalk [40]. Because the manipulation to craniopharyngiomas, including retracting and dissecting, is liable to disturb the normal function of hypothalamus and pituitary gland inevitably, determination of pituitary stalk in an early stage during surgery is in favor of preventing from injuring consequently.

Special attention shall be paid to the pituitary stalk, which is located at the rear of lesions usually with bright redness in color that is different from tumorous tissues obviously, when removing the posterior wall of lesions [41]. The pituitary stalk is often flat due to the compression from craniopharyngiomas, which results in the confusion with the capsule of lesion sometimes. Although there were variations of location in front of lesions (1/17 in this study) or wrapped by lesions (2/17 in this study), the pituitary stalk were intact generally.

Management of Complicated Hydrocephalus

The obstructive hydrocephalus occurred usually in cases with infiltration of lesions into the third ventricle, which accounted for 27.78% (5/18) in this study. For all patients with hydrocephalus, the complication disappeared after the surgical removal of lesions in the third ventricle without any external-ventricular drainage or ventricular peritoneal shunt pre- or postoperatively. Therefore, removing the obstruction of craniopharyngiomas infiltrated into the third ventricle is the basis of resolving hydrocephalus, instead of the drainage of ventricles.

Neuroendoscope

The main disadvantage of a microsurgical keyhole approach is the probable poor illumination of a deep surgical field. Proper handling of surgical microscope by changing the visual angle continuously is able to deal with this problem in most cases. But sometimes certain structures may cause shadows and illumination did not suffice for further procedure. Especially lesions and pituitary stalks, which are behind the optic nerves and chiasm, are not capable of visualization by surgical microscope directly. In these cases, intraoperative usage of endoscope without moving away microscope can shed light into the depth [42]. The endoscope can be introduced under the direct visual control of microscope, and also allows surgeons to look around the corner during surgery without additional retraction of the structures by angled lens scopes [43]. The surgical field of the supraorbital keyhole window is extended by endoscope to the regions such as the interpeuncular cisterns [44]. Therefore, the endoscope helps to minimize the trauma to tissues retracted for inspection, and it has acted as a watchdog during keyhole surgeries to prevent structures from unexpected injury routinely in our department.

Limitations of keyhole approaches

In accordance with the concept of keyhole surgeries [45], we are obliged to study individual case in detail before surgery in order to position accurately and avoid injury unnecessarily. The surgeons shall be equipped with expert techniques of microneurosurgery and clinical experiences, and take full advantage of the "keyhole" effect to magnify the deep surgical field by adjust the surgical microscope and operation table, introducing endoscope if necessary as well. In addition, appropriate instruments and facilities are also the prerequisite of keyhole microneurosurgery such as the surgical microscope, the head holder, the self-retaining retractor, the high speed drilling and milling cutter. It is difficult for surgeons to focus on the tip of instruments directly via the keyhole approach because of the parallelism between the visual projection and the long axis of instruments. So special minimally invasive instruments, such as bayonet shaped microelevator, scissors and aspirator, are essential.

Conclusion

A supraorbital keyhole approach for the surgery of craniopharyngioma at suprasellar region is feasible anatomically. In comparison with the conventional craniotomical approaches, this approach provides effective tumor resection and less approach-related morbidity. For lesions infiltrated into the third ventricle, the recanalization of cerebraospinal fluid pathway is the key point of disposing of the obstructive hydrocephalus.

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