Paranasal sinus CT and 3 kinds of nasal endoscopic sphenoid sinus surgical approaches
Retrospective analysis of 128 cases
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1. Introduction
In human, sphenoid sinus locates at the geometric center of the head. Its posteroinferior margin lies adjacent to the hypophysis cerebri, while the great peripheral vessels and vital nerves form the cavernous sinus segment of internal carotid and II, III, IV, V, and VI cranial nerves, respectively. Its location is deep and covert comparing to frontal sinus, maxillary sinus, and ethmoidal cellules. Therefore, missed diagnosis and misdiagnosis of early lesions are highly probable. The space for surgical operation is relatively confined and limited. Severe complications may arise following any unconscious inconsiderateness during the surgery.\textsuperscript{1,2} The morphological changes of unhealthy sphenoid sinus exhibited in computed tomography (CT) images, and outcomes after receiving either one of the 3 surgical approaches for sphenoid sinus, such as nasal-cavity-olfactory cleft path, Messerklinger path, and Wigand path, were retrospectively analyzed.

2. Material and methods

2.1. Clinical information
Inclusion criteria:
(1) Clinical manifestations and CT findings mainly describing sphenoid sinus lesions;
(2) All subjects having integrated follow-up data.

Exclusion criteria: Patients with underlying conditions of the coagulation system, severe hypertension, and those in asthma attack period, were excluded from this study. The clinical data of the 128 patients (60 males and 68 females, ranged from 14–78 years old with an average of 45) with sphenoid sinus lesion who
were hospitalized in department of otolaryngology under head and neck surgery section of Hangzhou Red Cross Hospital from January 2015 to June 2018 were randomly collected; the course of disease progression in the patients selected ranged from 3 months to 30 years. Among these patients, 20 of them presented with apparent clinical symptoms, while the other 108 patients exhibited major clinical symptoms, such as nasal obstruction, running nose, hyposmia, dizziness, headache, crying bloody tears, or blurred vision, etc. The diversities of sphenoid sinus lesions in all 128 subjects were generated by combining pre-operative superfine electronic nasal endoscopic (with the diameter of 2.7 mm) examinations, CT examinations, intraoperative explorations, and postoperative pathological confirmations, which covers 39 cases with chronic inflammation of mucosa for sphenoid sinus (30.64%), 27 patients with cyst of mucus and mucosa of sphenoid sinus (21.09%), 22 patients with hemorrhagic necrosis polypus (17.19%), 5 patients with inverted papilloma (3.91%) and 35 patients with fungoid sphenoiditis (27.34%).

2.2. Method

2.2.1. CT examination. All 128 patients underwent a CT examination of the paranasal sinus before surgery. Philips Brilliance 64-layer spiral CT scanner was used for spiral scanning of sections of the paranasal sinus, with scanning parameters set as below: matrix of 512 × 512, collimation of 64 × 0.625, 0.75 seconds as the slew time of bulb tube, screw pitch of 0.64 mm, a voltage of 120 kV, and current of 300 mA. The images were reconstructed by bone algorithm, with the layer thickness as 0.17 mm, interlamellar spacing as 0.67 mm, image bone window as width 2000 HU and window level 200 HU.

2.2.2. Surgical procedures. Nasal endoscopic sphenoidostomy was performed using 3 kinds of surgical approaches. The surgeons had more than ten years of experience in endoscopic surgery. STORZ nasal endoscope, Sony display system, and Medtronic 3000 dynamic system were applied during the surgery. Endotracheal intubation and general anesthesia were used for all 3 surgical approaches, along with cotton stick amid nasal cavity astringent for complete restraining of the nasal cavity. Depending on the need for drainage and ventilation, 0° and 45° endoscopes were used for nasal septum formation in patients with deviated nasal septum. The fenestration of the sphenoid sinus was performed using different approaches, following the fenestration of the adjacent paranasal sinus lesion. After the surgery was completed, the surgical cavity was filled with absorbable hemostatic material. The processing and cleaning steps of the nasal cavity were carried out according to the standard procedures of nasosinusitis surgery. After discharge, the nasal cavity was re-examined and cleaned every 1 to 2 weeks, until sphenoid sinus was entirely epithelialized. All these patients have been followed-up for more than 12 months.

2.2.2.1. A group: Nasal-cavity-olfactory cleft pathway (superior turbinate-natural opening of the sphenoid sinus-sphenoid sinus). Middle and superior turbinate were removed (or excised) during nasal endoscopy, and the natural opening of sphenoid sinus was observed inside the sphenoidethmoidal recess. The sphenoidal sinus lesion was cleaned using a universal sphenoid rongeur to enlarge the natural opening. Among all 128 patients, this approach was applied to 64 patients to open the sphenoid sinus.

2.2.2.2. B group: Messerklinger approach (anterior ethmoidal cells-posterior ethmoidal cells-sphenoid sinus-ethmoidal cells plate-sphenoid sinus). Processus uncinatus was excised by nasal endoscopy before ethmoidal bulb fenestration. After the basal plate of middle turbinate being exposed, separations of ethmoidal cells were incised stepwise towards the posterior ethmoidal cells. The sphenoid sinus-ethmoidal cells plate (anterior wall of sphenoid sinus) was opened slightly on the inferior side to reach the sphenoid sinus. When encountered with sphenoid sinus-ethmoidal cellular plate that was thicker, it would be opened by means of grinding using a nasal diamond drill. This approach was applied to 54 patients in the group.

2.2.2.3. C group: Wigand pathway (excision or removal of middle turbinate-posterior ethmoidal cells-anterior wall of the sphenoid sinus-sphenoid sinus). The rear surface of middle turbinate was excised in sphenoidal shape to expose posterior ethmoidal cells, and to access sphenoid sinus from the anterior wall of sphenoid sinus. This approach was applied to 10 patients.

2.2.3. Therapeutic effects evaluation. The evaluation was carried out following the standards formulated by department of otolaryngology, head and neck surgery of the Chinese Medical Association. Complete control: Complete disappearance of clinical symptoms, smooth fenestration of sphenoid sinus, and the mucosa inside sphenoid sinus was smooth with no abnormal secretions. Partial control: Either partially relieved or completely disappeared clinical symptoms, visible scar proliferation at the fenestration site of sphenoid sinus, either detectable smooth mucosa or edema inside the sphenoid sinus, and small amount secretion inside the sphenoid sinus. No control: Unimproved clinical symptoms, adhered surgical cavity detected under endoscope, either narrow or closed fenestration site at sphenoid sinus; polypus recurrence or tumors occurrence, and evident purulent secretion.

2.2.4. Surgical performance and outcome assessment. Intraoperative bleeding amount and the duration of operation were analyzed for all 128 cases. Days of hospitalization are calculated by reviewing the medical records.

3. Results

The conditions of 128 patients with sphenoid sinus lesion represented by CT data varied markedly. Gas and liquid inside sphenoid sinus could be detected in those with acute or chronic inflammation, as well as mucosa of sphenoid sinus wall that was in incrasation (Figs. 1 and 2). Ground-glass high density shadow and punctate calcification (Figs. 3 and 4) could be detected in fungoid sphenoiditis. Paranasal sinus CT representation of inverted papilloma was manifested as partial hyperostosis and intra-sinus high-density shadow (Fig. 5). Spherical or hemispheric high-density shadow could be noticed in sphenoid sinus mucus and mucosa cyst, with equivalent density (Fig. 6). Hemorrhagic necrosis polypus and sphenoid sinus polypus were manifested as partially irregular density shadow. Individual sphenoid sinus polypus in ptosis forms postnasri hug polypus. The 128 patients with sphenoid sinus were divided into concha type (2/128, 1.56%), before-saddle type (11/128, 8.59%), and saddle type (115/128, 89.84%), according to the extent of gasification of the sphenoid sinus with the vertical line of tuberculum sellae being the boundary. Saddle type was further classified into semi-sellar type (47/115, 40.87%), full-sellar type
(48/115, 41.74%), and sellar-occipital (20/115, 17.39%) type (Table 1). Onodi cells and symmetric development of the sphenoid sinus were observed. There were 24 patients with Onodi cells (18.75%), 12 patients with the septum of sphenoid sinus in the center (9.38%), 13 patients with sphenoid sinus of more than 2 rooms (10.16%), and 39 patients with internal crest or separation of sphenoid sinus (30.47%) (Table 2). Before surgery, natural opening of sphenoid sinus, thickness and width of sphenoid sinus-ethmoidal cellular plate between sphenoid sinus and posterior ethmoidal cellules, as well as the development of superior turbinate and uppermost nasal concha were identified through paranasal sinus CT examining.

No serious complications were observed in the selected 128 patients during and after the surgery. Four weeks after surgery, clinical symptoms of these patients relieved at various degrees. During the follow-up for over 12 months, health conditions were well controlled in 123 patients. Endoscopic examination showed that the fenestration of sphenoid sinus was unobstructed and the mucosa in sinus was smooth, with no purulent secretions (Figs. 7 and 8). Narrowing or blocking of the fenestration membrane could be detected by nasal endoscope in 1 patient undergoing nasal cavity-olfactory cleft approach and one patient undergoing Messerklinger approach. Additionally, the fenestrations of sphenoidal sinus in 14 cases were smooth but exhibited with repeated edema of mucous membrane in sinus. No statistically significant difference was observed in terms of curative effects among all three groups (Table 3).
No significant differences were observed in terms of intraoperative bleeding amount, surgical duration, and the number of days of hospitalization among nasal-cavity-olfactory cleft pathway, Messerklinger pathway, and Wigand pathway procedures (Table 4).

4. Discussion

4.1. Morphological changes in sphenoid sinus

The anatomy of human sinonasal varies widely among each individual patient, making it challenging for surgeons to operate in sinuses. The advent of endoscopic sinus surgery raised a resurgence of interest in in-depth anatomy of internal nose and paranasal sinuses. CT scans obtained in this study showed that the extent of gasification differed in different sphenoid sinuses and the proportions of concha type together with before-saddle type accounted for about 10% while that of semi-saddle type, whole-saddle type, and pillow-saddle type made up about 90% of

Figure 2. Bilateral group sinusitis. We used the Messerklinger approach to open the front walls of the bilateral sphenoid sinus near the arrow, and found empyema sphenoidal.

Figure 3. Bilateral sphenoid sinus was asymmetric with local calcification in the high-density shadow of the right sphenoid sinus. Fungal mass was confirmed during the operation, and the postoperative pathology report indicated Aspergillus infection. The development of the posterior ethmoid was good; the olfactory cleft area was narrow and limited. We used the Wigand approach to open the sphenoid sinus, which was conducive to the operation and postoperative cleaning.

Figure 4. Pansinusitis, bilateral sphenoid sinus were asymmetrical, CT scan diagnosed the glass-like change (↙) at the right sphenoid sinus. We used the Messerklinger approach, and mucin was found during the operation. Postoperative pathology proved it to be fungal sinusitis.
all categories. The poorer sphenoid sinus gasification exhibited among the first 2 types, the smaller was the sphenoid sinus cavity, the thicker was the bone surrounding sphenoid sinus, and the more difficult would be in approaching it. The gasification status of the last three types of sphenoid sinus was good with pituitary fossa being either partially or completely surrounded by sphenoid sinus. Additionally, there was only a thin bone between the stem of brain and posterior wall of the sphenoid sinus, which potentially indicates a higher likelihood of intracranial complications. In this study, the thorough analysis of preoperative CT led to zero case of cerebrospinal fluid leakage or accidental injury in any vital intracranial tissues in either of the three surgical approaches.

Figure 5. Calcification changes (→) in the right posterior ethmoid shadow, oblitative inflammation (✓) of the sphenoid sinus, bony crest (\) in the sphenoid sinus, we used the Messerklinger approach. During the operation, a gray and white tumor was found, the tumor foundation was located in the anterior wall (↓) of sphenoid sinus, and was resected completely; the postoperative pathology showed inverted papilloma.

This study also identified that plurilocular sphenoid sinus accounted for 10.16% of all investigated cases. A careful preoperative understanding of the sinus CT would assist in locating the lesions of sphenoid sinus during surgery.

4.2. Options of surgical approaches

The length of hospitalization is positively correlated with the number of surgical complications, such as postoperative bleeding, postoperative fever, headache, etc. In this retrospective study, no significant difference was observed with regard to the days of hospitalization among the three groups. The selection of surgical approach was decided based on preoperative paranasal
sinus CT, wherein if hyperosteogenesis was observed in the anterior wall of sphenoid sinus, the surgeon would choose nasal-olfactory cleft approach. Natural opening of sphenoid sinus surrounded by thin and weak bone makes it obligatory to proceed with this surgical approach.\[11\]

In this study, the occurrence rate of Onodi chamber was 18.75%. For those cases whose sinus CT indicated the presence of Onodi chamber, the sphenoethmoidalis plate was opened cautiously to gain entry into the sphenoid sinus.\[12\] To avoid intracranial injury while entering the posterior wall of posterior ethmoid, which might be mistaken as the anterior wall of sphenoid sinus, special attention must be paid to the presence of Onodi chamber while applying Messerklinger and Wigand approaches.

It should be noted that in those cases undertook the Messerklinger approach, polyps could be detected on the superior turbinate and sphenoid sinus mouth, which were then removed through the olfactory cleft to avoid the omission of lesions.

4.3. Comparison of advantages and disadvantages of the three surgical approaches

In this study, distinct differences among nasal-olfactory cleft, Messerklinger, and Wigand approaches were highlighted. For nasal-olfactory cleft approach, the natural ori

Figure 6. Bilateral sphenoid sinus was asymmetrical, the left sphenoid sinus was filled with cystic soft tissue (*), and the density was uniform. We used the cavity-olfactory cleft approach (⇓) to resected cyst (*) completely.

Table 1

Variation of sphenoid sinus morphology of 128 patients.

| Type               | Percentage |
|--------------------|------------|
| concha type        | 41.74%     |
| before-saddle type | 17.39%     |
| semi-sellar type   | 4.08%      |
| full- sellar type  | 8.59%      |
| sellar-occipital type | 1.56%        |

As ethmoid sinus was opened using the last 2 surgical approaches, the window of the sphenoid sinus was completely exposed, thereby facilitating convenient postoperative observation and cleaning of the surgical cavity. The obstruction of both ethmoid sinus and middle and inferior turbinate made it difficult for direct observation during postoperative follow-up, and increased the challenge in cleaning. Being the keys to surgical treatment of inflammatory lesions of sphenoid sinus, adequate ventilation and drainage are the major requirements, which have been fulfilled by all three surgical approaches according to available data.\[14\] When choosing the surgical approaches for sphenoid sinus tumors removal, such as inverted papilloma,
Table 2
Variation of sphenoid sinus morphology of 128 patients.

|                      | Percentage |
|----------------------|------------|
| Onodi gas room       | 35.00%     |
| more than 2 rooms    | 30.00%     |
| internal crest       | 20.00%     |
| central septum       | 15.00%     |

Figure 7. The different postoperative shapes of sphenoid sinus openings: Panel a (distant view), and Panel b (close view) represent the right Messerklinger approach. Panel c illustrates left cavity-olfactory cleft approach, and Panel d is the left Wigand approach.
complete exposure of the tumor must be considered, and substantial safe surgical margin should be guaranteed to minimize recurrence.

Table 3
Comparison of the outcomes of 3 groups 12 months after the surgery.

| Surgical path | Controlled completely | Controlled partially | Not controlled | Total |
|---------------|----------------------|---------------------|----------------|-------|
| A group       | 56 (87.5%)           | 7 (10.9%)           | 1 (1.6%)       | 64    |
| B group       | 47 (87.0%)           | 6 (11.1%)           | 1 (1.9%)       | 54    |
| C group       | 9 (90.0%)            | 1 (10.0%)           | 0 (0.0%)       | 10    |

$H_0 = 0.076$, $\gamma = 3-1 = 2$, $x^2$ boundary value table can be referred. $95 < P < .975$, so there is no statistical significance among the 3 groups.

5. Conclusion

This study has limitations. One is that it was a retrospective and a single-center study. In addition, the limited sample size, as well as the experience and habits of different surgeons might contribute to the bias in the study.

To summarize, morphologies of each patient’s sphenoid sinus changes and varies greatly. The findings of this study implicated that there were no significant differences in efficacy, efficiency, and safety of these 3 surgical approaches. The selection of a certain surgical approach was determined by multiple factors, such as the characteristics of the lesion, the scope of the lesion, and morphological changes in the sphenoid sinus. This study illustrated that the fenestrations of sphenoid sinus often contract to different degrees after surgery, after being applied with either one of the three surgical approaches. The authors demonstrated
that the opening should not be too small and some sphenoid sinus surgeries may require partial removal of the middle turbinate or upper turbinate. More theoretical and clinical studies are needed to confirm the impact on olfaction.

Author contributions

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