Original Article

Clinical Characteristics and Endoscopic Endonasal Removal of Foreign Bodies within Sinuses, Orbit, and Skull Base

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Abstract

Background: Foreign bodies within the sinuses, orbit, and skull base (FBSOS) are rare; hence, diagnosis and management guidelines are lacking. Endoscopic sinus surgery (ESS) removal is preferred because of the less invasiveness and minimal morbidity. This study was designed to summarize clinical experience with ESS management of FBSOS.
Methods: We retrospectively reviewed clinical manifestations, imaging findings, treatment, and outcomes in consecutive patients with ESS removal of FBSOS between 2004 and 2015 at a tertiary academic medical center. The Chi-square test was performed to compare the infection rate between wooden and nonwooden FBSOS.
Results: There were 23 male and five female patients, with median age of 11 years. FBSOS were located within the sinuses (86%), orbit (75%), and skull base/intracranial region (46%). Wooden FBSOS had a significantly higher risk of infection (78%) compared with nonwooden FBSOS (5%, $P < 0.05$). Contrast-enhanced computed tomography (CT) plus three-dimensional reconstruction was sensitive in all cases. Twenty-seven (96%) FBSOS were removed by ESS alone, while 1 (4%) FBSOS was removed using the combined ESS and lateral cervical approach. Four of the nine intracranial penetrating FBSOS patients had intraoperative cerebrospinal fluid (CSF) leak and received endoscopic CSF leak repair. Twelve (43%) patients suffered complications (meningitis, diplopia, and vision loss).
Conclusions: ESS is a minimally invasive, safe, and promising surgical approach for FBSOS removal. Contrast-enhanced CT is effective in preoperative diagnosis and intraoperative guidance. Wooden FBSOS had higher risk of infection, thus antibiotics are recommended.

Key words: Foreign Body; Orbit; Paranasal Sinuses; Skull Base

Introduction

Foreign bodies within the sinuses, orbit, and skull base region (FBSOS) are rarely reported in literature, and most of them are caused by trauma.[1,2] This region is adjacent to vital blood vessels and nerves, making FBSOS life-threatening.[3] Endoscopic sinus surgery (ESS) provides good illumination and direct visualization, and is thus the most accurate technique for removing FBSOS.[3,4] However, ESS requires strong familiarity with the anatomy of the sphenoethmoidal region and surrounding skull base structures because of the presence of critical structures such as the internal carotid artery (ICA), optic nerves, and ethmoidal artery.[5,6] In addition, ESS is still prone to visual and intracranial complications, potential for incomplete foreign body removal, or even an inability to locate the FBSOS. Thus, an accurate preoperative assessment and a comprehensive management strategy are critical for cases involving ESS removal of FBSOS.

This study retrospectively reviewed cases of FBSOS treated through ESS in our hospital between 2004 and 2015, with the aim of improving diagnosis and management of FBSOS cases in clinical practice.

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Methods

Ethical approval

We retrospectively reviewed the medical records of patients diagnosed with FBSOS at the Department of Otolaryngology in the First Affiliated Hospital of Sun Yat-sen University from January 2004 to January 2015. As a retrospective study and data analysis was performed anonymously, this study was exempt from the ethical approval. Informed written consent for use of photograph was obtained from patients or parents in this study.

Patients

Each patient underwent a sinonasal-skull base contrast-enhanced computed tomography (CT) scan to locate FBSOS, and three-dimensional (3D) reconstruction was used to demonstrate the spatial relationship between FBSOS and vital structures, especially the ICA. Cases involving the orbit were examined by an ophthalmologist, who conducted a detailed preoperative eye examination. Cases involving the intracranial region were examined by a neurosurgeon, and the Glasgow Coma Scale (GCS) score was calculated to fully assess the intracranial condition. Detailed records of the cause, type, and position of the foreign bodies, surgical treatment, and postoperative complications were evaluated. Follow-up assessment was performed for at least 6 months.

Statistical analysis

All statistical analyses were performed using SPSS software version 16.0 (SPSS Inc., Chicago, IL, USA). Results were presented as number (percentage) for categorical variables. The Chi-squared test was used to compare statistical differences between the rates; A $P < 0.05$ was considered statistically significant.

Results

Epidemiological data

There were 28 FBSOS patients who underwent ESS removal in this period. Among these cases, 27 FBSOS were removed by ESS alone, while one FBSOS was removed using the combined ESS and lateral cervical approach. The patients' demographic data were illustrated in Table 1.

Table 1: Demographic data of patients with FBSOS removed by endoscopic sinus surgery (n = 28)

Parameters	Values
Age (years), Median (range)	11 (2–68)
≤14 years, *n* (%)	16 (57)
>14 years, *n* (%)	12 (43)
Gender, *n* (%)	
Male	23 (82)
Female	5 (18)
Time interval between injury and surgery	
Average (range)	78 h (6 h to 2 months)

FBSOS: Foreign body within the sinuses, orbit, and skull base.

Table 2: Clinical characteristics of patients with FBSOS removed by endoscopic sinus surgery

Characteristics	*n*/*N* (%)
FBSOS location	
Sinus involved	24/28 (86)
Orbit involved	21/28 (75)
Skull base/intracranial involved	13/28 (46)
GCS in the ED	
15	11/13 (85)
13–14	1/13 (8)
9–12	1/13 (8)
Type of FBSOS	
Wooden material	9/28 (32)
Bullets	11/28 (39)
Other metallic material	5/28 (18)
Plastic material	2/28 (7)
Glass	1/28 (4)
Main clinical symptoms in the ED	
Vision loss	7/28 (25)
Diplopia	1/28 (4)
Epistaxis	22/28 (79)
Fever	8/28 (29)

FBSOS: Foreign body within the sinuses, orbit, and skull base; GCS: Glasgow Coma Scale; ED: Emergency department.

Clinical overview of the cases

Clinical characteristics including location, type of foreign body, and main symptoms at presentation of FBSOS were illustrated in Table 2. The most important clinical data, including trajectory of the FBSOS and pre-, intra-, and post-operative abnormal findings, were summarized in Table 3.

Contrast-enhanced CT combined with 3D reconstruction was sensitive in 100% of cases, demonstrating the location and spatial relationship of the FBSOS to adjacent vital blood vessels, thereby providing guidance for the surgery. Among the 21 cases of foreign bodies involving the orbit, 43% (9/21) involved the orbital apex and 57% (12/21) were within the intraorbital region. Among the 13 cases of foreign bodies involving the cranial base region, four were located in the skull base and nine had penetrated the intracranial fossa. Four patients with intracranial foreign bodies suffered intraoperative cerebrospinal fluid (CSF) leak after foreign body removal, as the dura and partial brain tissue had been penetrated.

Eight patients presented with preoperative systemic symptoms (fever), seven of whom had wooden foreign body-induced injuries. Wooden foreign bodies carried a significantly higher risk of infection (7/9) compared with nonwooden foreign bodies (1/19, $\chi^2 = 15.74$, $P < 0.05$).

Twelve patients suffered postoperative orbital and cranial symptoms, including three cases of meningitis, two cases of diplopia, and seven cases of vision loss. All the three cases of meningitis were cured before discharge. Two cases of vision loss developed improved vision during the follow-up period.

Table 3: Summary of data from patients who underwent endoscopic sinus surgery removal of FBSOS

Case number	Trajectory of FBSOS	Type of FBSOS	Preoperative orbital and cranial symptoms	Intraoperative abnormal conditions	Postoperative orbital and cranial symptoms	Follow-up period (months)
1	Right ethmoidal sinus - orbit	Bullet	None	None	None	8
2	Right ethmoidal sinus, sphenoid sinus - orbital apex - cavernous sinus	Bullet	None	None	None	12
3	Right ethmoidal sinus - orbit - skull base	Steel bar	None	None	None	10
4	Right ethmoidal sinus - anterior skull base - frontal lobe	Chopstick	GCS of 14	CSF leak	Meningitis	15
5	Multiple sinuses - orbit	Explosion fragment	Vision loss	None	Vision loss	19
6	Right orbit - intracranial region	Wooden strip	None	None	Meningitis	12
7	Right ethmoidal sinus - orbital apex	Bullet	None	None	None	14
8	Left intraorbital region - ethmoidal sinus - skull base	Glass	Vision loss	CSF leak	Vision loss	9
9	Right ethmoidal sinus - orbital apex	Bullet	None	None	None	17
10	Right ethmoidal sinus - intraorbital region	Chopstick	None	None	None	6
11	Left intraorbital region	Bullet	None	None	None	27
12	Left ethmoidal sinus - orbit	Tree branch	Vision loss	None	Vision loss	31
13	Right maxillary sinus - infraorbital region	Wooded stick	None	None	Diplopia	46
14	Left ethmoidal sinus - intraorbital region - intracranial region	Metal strip	None	None	Meningitis	15
15	Right sphenoid sinus	Plastic stick	Vision loss	None	Vision loss	64
16	Left sphenoid sinus - orbital apex - cavernous sinus	Bullet	None	None	None	57
17	Right ethmoidal sinus - intraorbital region - intracranial region	Bullet	Diplopia	None	Diplopia	71
18	Right ethmoidal sinus - orbital apex - intraorbital region	Bullet	None	None	None	62
19	Left sphenoid sinus - skull base	Bullet	None	None	None	82
20	Left ethmoidal sinus - orbital apex - skull base	Chopstick	None	None	None	74
21	Right sphenoid sinus - cavernous sinus - intracranial region	Bullet	None	None	None	95
22	Right orbital apex	Bullet	None	None	None	96
23	Right intraorbital region - orbital apex	Iron bar	Vision loss	None	Vision loss	100
24	Right ethmoidal sinus - sphenoid sinus	Bamboo chip	Vision loss	None	Vision loss	102
25	Left ethmoidal sinus - sphenoid sinus	Chopstick	None	None	None	107
26	Left ethmoidal sinus - orbital apex	Pencil	Vision loss	None	Vision loss	68
27	Right medial canthus - ethmoidal sphenoid sinuses - pituitary fossa	Plastic chopstick	None	CSF leak	None	7
28	Left nostril - sphenoidal planum - right thalamus	Ballpoint pen	GCS of 12	CSF leak	None	6

FBSOS: Foreign body within the sinuses, orbit, and skull base; GCS: Glasgow Coma Scale; CSF: Cerebrospinal fluid.

Representative cases

Case 1

A 2-year-old boy was admitted to our department with a metal strip piercing his nasal cavity for 14 h. Physical examination revealed a metal strip in his left nasal cavity, and his body temperature was 37.8°C on admission. He was neurologically intact, with a negative meningeal irritation sign. GCS score was 15. A CT scan revealed that the foreign body had penetrated the left ethmoidal sinus through the medial wall of the orbit and reached the anterior skull base, with about 8 mm penetrating into the intracranial region [Figure 1a-1c]. The foreign body was removed by ESS. Intraoperative endoscopic examination found an approximately 4 mm × 4 mm osseous defect in the skull base without CSF leakage. Postoperative CT revealed a regional bone fracture and swelling of the left medial rectus [Figure 1d-1f]. Effective and sufficient antibiotics were administered as the patient developed acute bacterial meningitis postoperatively. The patient's body temperature and the results of CSF testing had returned to normal after 2 weeks. There was no further complication or CSF rhinorrhea after 15 months of follow-up.

Case 2

A 44-year-old man was admitted to our department with a ballpoint pen pierced into his nasal cavity for 6 h. Physical

examination revealed that the end of the pen was embedded in his left nasal vestibule [Figure 2a]. He was drowsy on admission, with a GCS score of 12 (E3, V4, M5). CT scan revealed that the FBSOS had penetrated through the left nasal cavity to the sphenoidal planum and reached the right thalamus, with an intracranial penetration of 5 cm as well as pneumocephalus [Figure 2b and 2c]. Multiple plane and 3D reconstruction of the CT images showed that the foreign body was adjacent to the anterior and middle cerebral arteries. There was no vital blood vessel injury indicated on the images [Figure 2d-2f]. The surgical plan was made by the otolaryngologist, neurosurgeon, and anesthetist for ESS removal of the FBSOS from the nasal cavity; preparation included blood transfusion, craniotomy, and bilateral ligation of the ICA. During surgery, the foreign body was completely removed backward along the direction of penetration. Under endoscopic view, pink-colored CSF leakage had overflowed from the bone defect of the sphenoidal planum (about 1.2 cm × 1.2 cm). No active intracranial hemorrhage was observed. A second ESS for CSF leak repair was performed the next day after delayed intracranial hemorrhage and residual FBSOS were excluded by CT scan. Sufficient antibiotics were administered to prevent intracranial infection. There was no complication or CSF rhinorrhea after 6 months of follow-up.

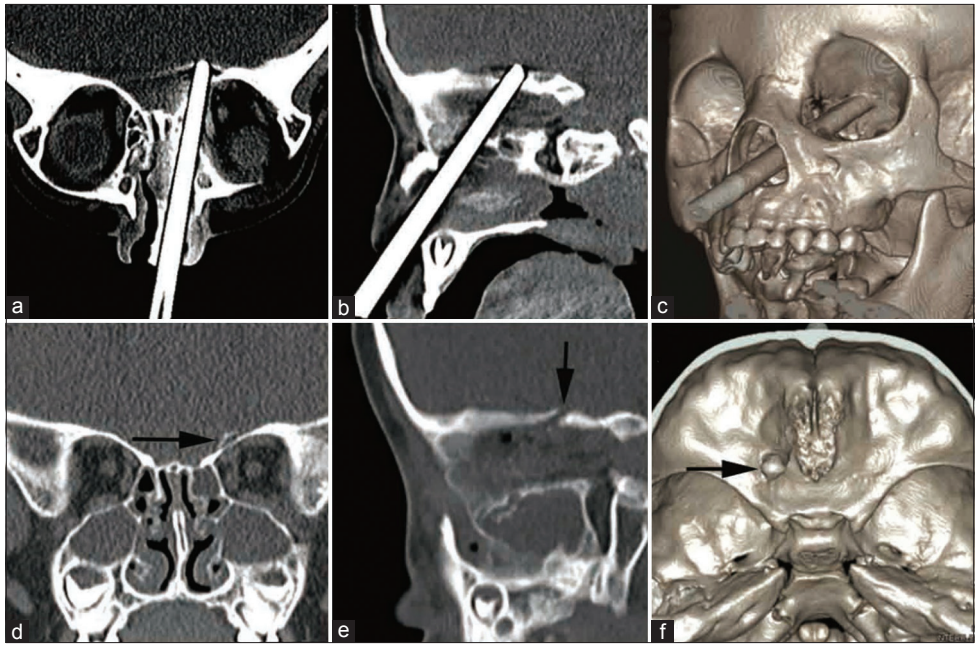

Figure 1: Penetration of a metallic foreign body into the left ethmoidal sinus to the medial wall of the orbit to the anterior cranial fossa. Preoperative computed tomography images showing the foreign body (a-c). Postoperative computed tomography images showing the bone defect of skull base (arrow) (d-f).

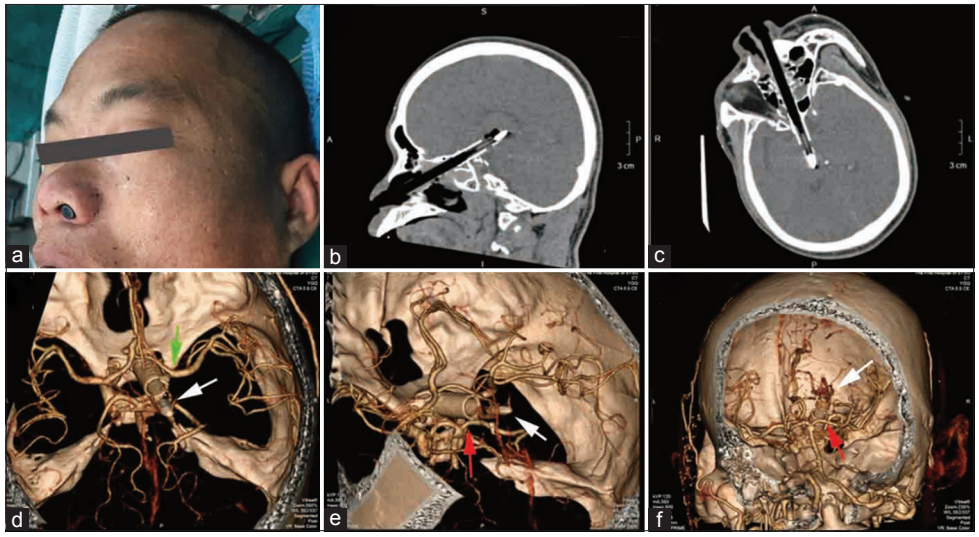

Figure 2: Penetration of a ballpoint pen into the left nasal cavity to the sphenoidal planum and reaching the right thalamus (a). The end of the embedded pen (b and c). Multiple plane reconstruction of the computed tomography images showing the route of the penetrated pen (d-f). Three dimentional reconstruction of CT images showing the foreign body (white arrow) and intracranial arteries. White arrow: Foreign body; Green arrow: Anterior cerebral arteries; Red arrow: Posterior communicating artery.

Case 3

An 18-year-old man was admitted to our department with a steel bar penetrating his right orbit for 14 h. Physical examination found a steel bar and sticky secretions next to his right medial canthus. Visual disturbance and diplopia were not noted. CT scan showed that the FBSOS had penetrated through the right orbit to the maxillary sinus to the right lateral pterygoid muscle and parapharyngeal space to the right nape, with the far end reaching the right transverse process of the atlas [Figure 3a-3d]. Our multidisciplinary team (MDT) including the Departments of Otolaryngology, Ophthalmology, Vascular Surgery, and Interventional Radiology conducted a joint consultation and reached a consensus for an external cervical approach combined with an endoscopic approach for removal of the hook-shaped foreign body. During surgery, a curved incision was made below the right mastoidale, and the muscles were carefully dissected; the far end of the metallic foreign body was then located and carefully pulled out along the direction of penetration. A 17-cm steel wire was eventually removed. No bleeding was detected in the nasal cavity under endoscopic vision. No diplopia or vision loss was detected after 10-month follow-up.

Discussion

To date, there is no standard guideline for diagnosis and management of FBSOS, as retained FBSOS is an uncommon condition. Clinical assessments are extrapolated from other scenarios, because prospective study is not feasible on rare cases. In this series, males were affected more often than females (male: female ratio of 4.6:1). Children under the age of 14 years accounted for 57% of patients, indicating that adolescent boys represented the main study population; this is similar to previous reports of intraorbital foreign bodies.[7,8] Sinonasal foreign bodies are more commonly found in the maxillary sinus and frontal sinus in literature,[1,9] while in our series, ethmoidal sinus was most frequently involved. This discrepancy may be due to small sample size.

Transnasal or transorbital penetrating injury by foreign bodies may be overlooked.[10,11] The patients may not realize that the foreign bodies have penetrated their heads because of the high velocity of the objects, and the residue of the foreign bodies may be inconspicuous [Figure 4]. Therefore, caution should be applied if any foreign body-associated trauma, even only minor injury, is found adjacent to the orbit. A history of rough removal of a foreign body and persistent inflammation in certain local region necessitates further examination to verify whether a residue of the foreign body remains.

CT scanning is indicated in patients to locate the FBSOS and their relationship with the surrounding structures. Magnetic resonance imaging is a potential alternative diagnostic method in radio-opaque foreign body, such as bamboo sticks.[3,12] Digital subtraction angiography (DSA) can be used to identify potential vascular injury and trauma-related pseudoaneurysm of the ICA and vertebrobasilar artery.[13] However, DSA is not routinely used for diagnosis unless there is suspicion of vascular injury.[14] In the current study, contrast-enhanced CT combined with 3D reconstruction was effective in demonstrating the spatial relationship between FBSOS and the surrounding vessels, which played an important role in preoperative assessment and served as intraoperative guidance for surgeons.

The surgical approach for FBSOS removal should be determined by the size and location of the object. ESS removal is preferred because of the less invasiveness and minimal morbidity. Intraoperative navigation technique may

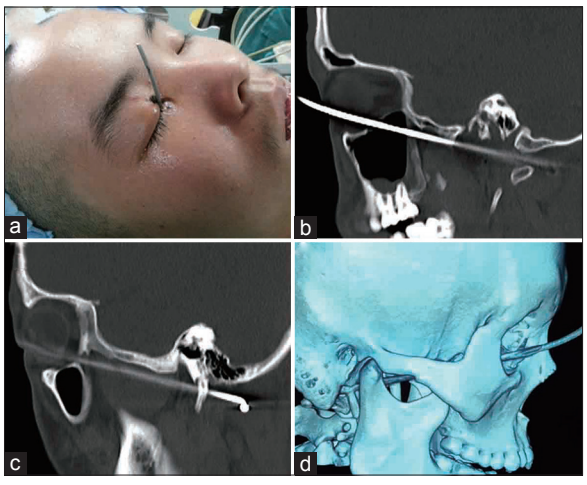

Figure 3: Penetration of a steel bar into the right medial canthus to the maxillary sinus to the right lateral pterygoid muscle and parapharyngeal space. (a) The penetrated steel bar. Multiple plane (b and c) and three-dimentional (d) reconstruction of the computed tomography images showing the route of the foreign body. The hook-shaped far end had reached the transverse process of the atlas.

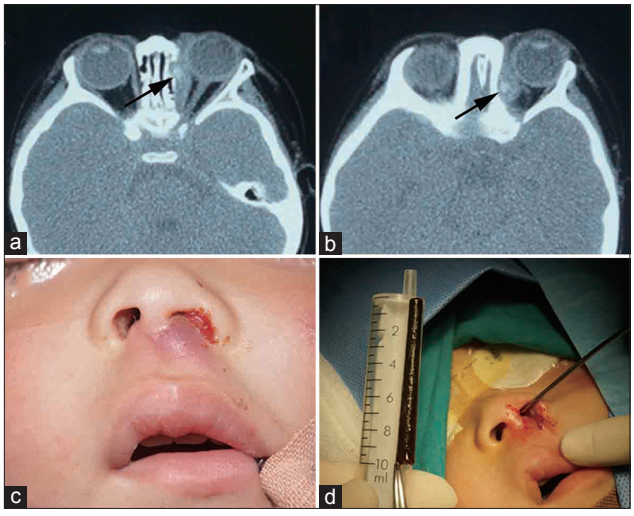

Figure 4: Residue of a bamboo chopstick remained in the left nasal cavity to the intraorbital region. (a and b) Horizontal computed tomography imaging revealing an intermediate density shadow (arrow) in the left nasal cavity-ethmoidal-intraorbital region, which had compressed the left medial rectus. (c and d) The left nasal vestibule was swollen and a granulation-like lump was found, which had blocked the left anterior naris. The length of the removed foreign body was approximately 5 cm.

provide further guidance to locate the foreign body, such as the small-sized ones hiding in the orbital fat. Rather than arbitrarily retracting the foreign body, once it is located, full evaluation of the accurate spatial relationship between the foreign body and surrounding vital structures (such as pulsation observation) is necessary before meticulous removal. Nevertheless, single endoscopic removal is less feasible for objects that enter this region by an angled

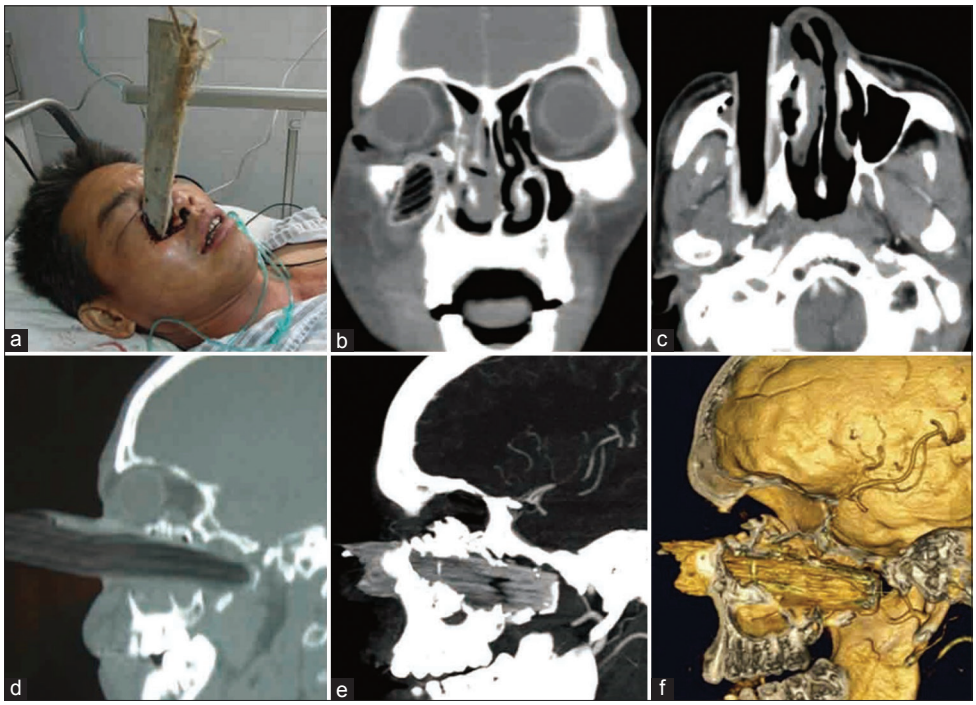

Figure 5: Penetration of a wooden block into the right cheek. (a) The penetrated foreign body in the right cheek. (b) Computed tomography demonstrating the foreign body having penetrated through the maxillary sinus, damaging the inferior orbital wall, and extending into the infratemporal fossa, embedded between the pterygoid process and the lateral pterygoid muscles (c and d). (e and f) Contrast-enhanced computed tomography combined with three-dimensional reconstruction demonstrating the position of the far end of the foreign body and the right internal carotid artery.

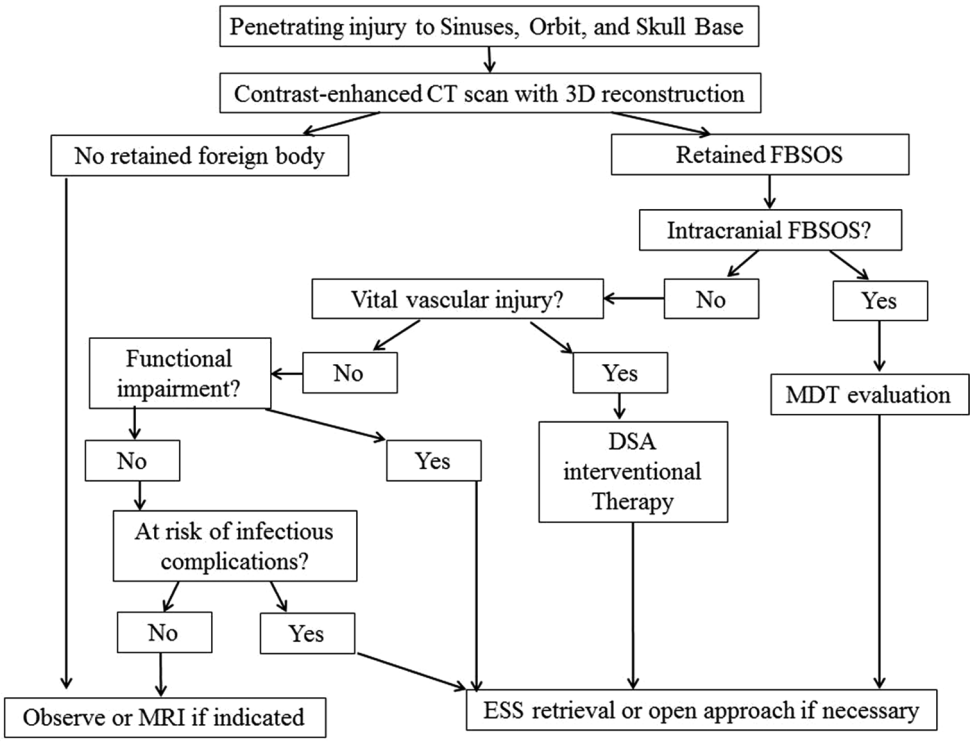

Figure 6: Proposed algorithm for management of retained FBSOS. FBSOS: Foreign body within the sinuses, orbit, and skull base; DSA: Digital subtraction angiography; 3D: Three-dimensional; MDT: Multidisciplinary team.

transcutaneous route or have a hook-shaped far end, as in case 3. In these cases, MDT consultation is necessary to determine a better approach such as a combined endoscopic and open approach for FBSOS removal.

Clinical assessment of a CSF leak should be performed preoperatively as well as intraoperatively. Our findings in this study suggest that a sole skull base bone defect caused by a foreign body without CSF leak may not need to be repaired during surgery. Immediate endoscopic reconstruction of the skull base is warranted in cases of CSF leak without residual intracranial foreign body and intracranial hemorrhage.

Penetrating intracranial injury may cause immediate complications such as subarachnoid hemorrhage, brain damage, CSF leaks, and pneumocephalus; it can also cause delayed but severe complications such as meningitis or brain abscess.[6] Preoperative assessment should be made together with neurosurgeons. Patients' GCS score is commonly used to evaluate surgical indications for penetrating intracranial FBSOS. Early surgery is strongly recommended in patients with GCS score ≥8, indicating relatively intact neurological function.[15-18] If a decline in GCS is noted, the surgical risk should be assessed by an MDT including an otolaryngologist, neurosurgeon, ophthalmologist, anesthetist, and radiologist. There are two cases with little declined GCS in this study. Fortunately, the patients did not develop any severe complication after removal of the FBSOS.

A foreign body in the sinuses is a potential source of infection.[1] As this region is adjacent to the optic nerves, cavernous sinus, the ICA, and other critical structures in the skull base, sphenoid sinusitis caused by a foreign body may lead to serious consequences.[19,20] Therefore, any sphenoidal sinus foreign body should be completely removed. In our series, wooden foreign bodies [Figure 5 and Supplementary Video 1] caused infection significantly more often than nonwooden foreign bodies. The high risk of infection due to wooden foreign bodies may be attributed to the organic porous nature of wood, which is a strong growth medium for microorganisms.[11] Hence, great attention should be paid to wooden intracranial penetrating foreign body, as it is more likely to lead to severe intracranial infection. We recommend initiation of antibiotic therapy on admission if the FBSOS is wooden. If there have been signs of infection, such as fever or increased white blood cell, sufficient and effective empirical antibiotics should be administered as soon as possible.

Based on our study, we recommend an algorithm to guide management of FBSOS [Figure 6]. Sufficient preparation and detailed strategy are warranted preoperatively. Postoperative cranial CT scanning is recommended to assess for delayed intracranial hemorrhage in penetrating intracranial FBSOS. Patients' consciousness should also be closely monitored.

This is a retrospective analysis that contains several limitations. The study population only included a small number of patients. Our proposed algorithm lacks of statistical power due to limited sample size. However, prospective controlled study is not feasible as FBSOS is an uncommon and unique entity. Future prospective studies would be helpful for statistical validation of this algorithm. Despite the limitations, we believe that this study identifies a population of patients with FBSOS which is in dire need of improvements in treatment paradigms and highlights an important treatment experience of ESS removal of FBSOS.

In conclusion, contrast-enhanced CT combined with 3D angiography reconstruction can reveal the accurate location and spatial relationship between the FBSOS and adjacent vital blood vessels, thereby providing guidance for surgery. Wooden foreign bodies may carry a higher risk of infection, so sufficient antibiotic treatment is necessary to prevent infection. ESS is a minimally invasive, safe, and promising surgical approach for FBSOS removal. For any FBSOS beyond the reach of endoscopic exposure, a combined endoscopic and open approach could be alternative.

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Conflicts of interest

There are no conflicts of interest.

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