Management and Surveillance of Frontal Sinus Violation following Craniotomy

Alexander Farag¹ Marc R. Rosen² Natalie Ziegler³ Ryan A. Rimmer⁴ James J. Evans²
Christopher J. Farrell² Gurston G. Nyquist²

¹ Department of Otolaryngology, The Ohio State University, Columbus, Ohio, United States

² Department of Otolaryngology and Neurological Surgery, Thomas Jefferson University, Philadelphia, Pennsylvania, United States

³ Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia, Pennsylvania, United States

⁴ Department of Otolaryngology, Thomas Jefferson University, Philadelphia, Pennsylvania, United States

Address for correspondence Gurston G. Nyquist, MD, Department of Otolaryngology and Neurological Surgery, Thomas Jefferson University, 925 Chestnut St., 6th floor Philadelphia, PA 19107, United States (e-mail: gurston.nyquist@jefferson.edu).

J Neurol Surg B 2020;81:1–7.

Abstract

Objectives In the setting of craniotomy, complications after traversing the frontal sinus can lead to mucocoele formation and frontal sinusitis. We review the etiology of frontal sinus violation, timeline to mucocoele development, intraoperative management of the violated sinus, and treatment of frontal mucocoeles.

Design Case series in conjunction with a literature review.

Participants A total of 35 patients were included in this meta-analysis. Nine of these patients were treated at a tertiary academic medical center between 2005 and 2014. The remaining patients were identified through a literature review for which 2,763 articles were identified, of which 4 articles met inclusion criteria.

Main Outcomes Measures Etiology of frontal violation, timeline to mucocoele development, and method of management.

Results The overall interval from initial frontal sinus violation until mucocoele identification was 14.5 years, with a range of 3 months to 36 years. The most common cause of mucocoele formation was obstruction of the frontal recess with incomplete removal of the frontal sinus mucosa. The majority of patients were successfully managed with an endoscopic endonasal approach.

Conclusions Violation of the frontal sinus during craniotomy can result in mucocoele formation as an early or late sequela. Image guidance may help avoid unnecessary frontal sinus violation. Mucocoeles may develop decades after the initial frontal sinus violation, and long-term follow-up with imaging is recommended. While the endoscopic endonasal approach is usually the preferred method to treat these lesions, it may be necessary to perform obliteration or cranialization in unique situations.

Keywords

- frontal sinusitis
- craniotomy
- mucocoele
- frontal sinus mucocoele
- craniotomy complications

Introduction

Mucocoeles are benign, mucus-filled lesions covered with pseudostratified columnar epithelium. Sinonasal mucocoeles usually originate secondary to blockage of the sinus drainage

pathway, typically in the setting of chronic inflammation, infection, trauma, or prior surgery.¹ The frontal sinus may be violated during craniotomy with intracranial entrapment of sinus mucosa or obstruction of frontal sinus outflow due to

received

August 12, 2018

accepted

November 14, 2018

published online

January 21, 2019

© 2020 Georg Thieme Verlag KG
Stuttgart · New York

DOI <https://doi.org/10.1055/s-0038-1676826>.
ISSN 2193-6331.

scar formation. Signs and symptoms of a frontoethmoidal mucocele include pain, swelling, aesthetic deformity, and erosion of the surrounding bone.² Advanced disease can be associated with diplopia, ptosis, vision loss, meningitis, or brain abscess. While there is no universally accepted method for the management of frontal sinus mucocèles, standard practices include endoscopic marsupialization, frontal sinus obliteration, and cranialization.^{3,4}

This study analyzes nine patients managed at our institution with a history of frontal sinus violation after craniotomy and subsequent development of mucocèles. In addition, we performed a meta-analysis through a PubMed search using the search terms “frontal sinus mucocele,” “frontal craniotomy complication,” and “frontal sinusitis.” Based on this data, we make recommendations on how to avoid frontal sinusitis in the setting of craniotomy and manage this condition.

Materials and Methods

Patients in the case series all presented to the Thomas Jefferson University Hospital between 2005 and 2014 with a mucocele after a frontal sinus violation through a craniotomy initially performed at another institution. Surgical management was performed by our skull base team consisting of a neurosurgeon and otolaryngologist.

In addition, we performed a meta-analysis through a PubMed search using the search terms “frontal sinus mucocele,” “frontal craniotomy complication,” and “frontal sinusitis,” which yielded 2,763 articles. Of these articles, four manuscripts, consisting of 26 patients, met our inclusion criteria of examining frontal sinus mucocele formation after craniotomy (►Fig. 1).

Results

Retrospective analysis revealed nine patients at our institution with a history of frontal sinus violation and subsequent mucocele formation. The average time from the initial frontal sinus violation to presentation was 14.5 years (range: 3 months to 36 years), with most patients presenting with headache symptoms. All of the mucocèles were successfully addressed through an endoscopic endonasal approach, except in one patient who developed lateral orbital and frontal bone osteomyelitis and subdural empyema that required craniotomy for debridement and frontal sinus repair (►Fig. 2). This patient had previously undergone an “eyebrow” approach craniotomy with a violation of the anterior and posterior lateral walls of the frontal sinus with titanium reconstruction of the anterior wall.

Review of the literature yielded four articles, with a combined total of 26 patients who met the inclusion criteria of our meta-analysis. Indications for the initial craniotomy were skull base tumors, aneurysm, craniofacial deformity, and arteriovenous malformation. Patients with chronic rhinosinusitis or those who initially underwent surgery for frontal sinusitis were excluded. The average time from craniotomy to mucocele presentation for these four articles was 13.9 years (range: 0.3–35 years). Yoshioka⁵ reported on six patients, with an average time from craniotomy to presentation of 20.7 years. Meetze et al⁶ reported

Fig. 1 Flow diagram of the literature review.

their finding of delayed frontal sinus mucocele formation in six patients, with an interval of 14.8 years. Chandra et al⁷ reviewed a series of patients who underwent a frontal sinus obliteration after craniotomy, developing mucocèles 10.5 years later. Schramm and Maroon⁸ also reported six cases of mucocele formation after craniotomy at an average interval of 5.6 years.

The overall average time interval between frontal sinus violation and frontal sinus mucocele presentation for this meta-analysis was 14.5 years, with a range of 3 months to 36 years (►Tables 1 and 2).

Discussion

Frontal sinus mucocèles arise from a variety of etiologies, with frontal sinus traumatic fracture or sinus violation during craniotomy representing two precipitating factors. The incidence of inadvertent frontal sinus violation during a craniotomy and optimal means of managing such violations remains uncertain. Careful long-term follow-up is necessary, as complications are typically significantly delayed.

Fig. 2 (A) Computed tomography (CT) demonstrating violation of the anterior and posterior walls of the frontal sinus with lateral sinusitis. (B) Obstruction of the right frontal recess. (C) Delayed magnetic resonance imaging (MRI) demonstrating worsening frontal sinusitis with leptomeningeal enhancement. (D) Subdural restricted diffusion indicative of empyema.

Mucocele formation can occur in the early postoperative period or decades later as our results demonstrate a range of 3 months to 36 years (mean: 14.5 years). The best way to prevent frontal sinus mucocele formation is to avoid entering the frontal sinus when performing a craniotomy. In the age of image guidance, the surgeon can better delineate the anatomical boundaries of the frontal sinus and avoid this structure when possible. However, when the frontal sinus is disrupted, either purposefully or inadvertently, outflow obstruction of the frontal sinus must be avoided unless the entirety of the frontal sinus mucosa has been exenterated. Yoshioka⁵ identified that each of his revision procedures for delayed mucocele formation occurred when the frontal recess had been “plugged” at the time of initial surgery with incomplete removal of the frontal sinus mucosa. He recommended management with complete cranialization of the frontal sinus and mucosal exenteration followed by frontal sinus recess obliteration. Failure to fully obliterate the frontal sinus recesses allows for direct communication between the sinus and intracranial cavity potentially, leading to postoperative pneumocephalus and infection (► Fig. 3).

In the setting of limited frontal sinus bony violation without significant mucosal disruption, extensive cranialization and exenteration of the mucosa is likely not necessary as the drainage pathway for the mucous secretion from the frontal sinus remains undisturbed. When the mucosa has been disrupted, careful reconstruction of the frontal sinus cavity will generally prevent long-term intracranial mucocele formation as long as the frontal outflow tract remains undisturbed. A vascularized pericranial graft represents the ideal reconstruction

material for a cranialized frontal sinus, although this material is not always available or viable at the time of closure. Reconstruction with hydroxyapatite or bone cement should be avoided as these materials have been associated with high rates of infection when employed in the region of the sinuses. Furthermore, the patient may require an endoscopic procedure to reestablish a functional frontal outflow tract, and these materials are difficult to remove. After significant frontal sinus violation, we prefer cranialization as opposed to obliteration in most situations. In the case of obliteration, we find that complete removal of sinus mucosa is difficult, and retained mucosa may lead to mucocele formation. Moreover, surveillance and treatment of an obliterated frontal sinus are challenging.

There are a variety of options for the management of frontal sinus mucoceles. Most contemporary surgeons consider marsupialization through an endoscopic endonasal approach to be the procedure of choice as it has the least morbidity (► Fig. 4).⁴ In Courson et al's meta-analysis of patients with frontal sinus mucoceles, patients were successfully treated with an endoscopic endonasal approach with equal efficacy and decreased morbidity as compared with open craniotomy. Our experience echoes the results of Meetze et al, as we were also able to effectively treat nearly all patients through an endoscopic approach. The endoscopic endonasal approach may be precluded if the mucocele is too far lateral above the orbit or if the frontal sinus has been obliterated by material that cannot be easily removed through the nose. Additionally, an endoscopic approach is contraindicated if there is neurologic tissue obstructing instrumentation of the frontal sinus or in the setting of brain abscess or epidural/subdural empyema.

Table 1 Meta-analysis of cases reviewed from the Jefferson experience, as well as Yoshioka, Chandra et al, Schramm and Maroon, and Meetze et al

	Case	Indication for craniotomy	Treatment of frontal sinus violation following craniotomy	Age, Sex	Years from craniotomy	Presenting symptoms	Recurrence	Follow-up period (months)	Management of frontal sinus pathology
Jefferson experience	1	Crouzon's syndrome	None	58, F	36	Eye swelling, headache	No	22	Endoscopic marsupialization
	2	Osteoma	None	72, F	20	Forehead swelling, nasal discharge	No	8	Endoscopic marsupialization
	3	Brain abscess	Cranialization	48, M	20	Postnasal drip, headache	No	6	Endoscopic marsupialization
	4	Unknown	None	55, M	11	Eye and eyelid swelling	Yes	5	Endoscopic marsupialization
	5	Mucopyocele	Cranialization	71, F	6	Headache and facial pain	Yes	73	Endoscopic marsupialization
	6	Optic nerve tumor	None	71, F	3	Periorbital pain, vertigo	Yes	21	Endoscopic marsupialization
	7	Meningioma	Cranialization	38, M	7	Periorbital cellulitis, frontal sinusitis	No	24	Endoscopic marsupialization
	8	Frontal sinus fracture	Cranialization	36, M	3	Headache and frontal sinusitis	No		Endoscopic marsupialization
	9	Frontal sinus fracture	None	53, M	30	Proptosis and progressive loss of vision	No	1	Endoscopic marsupialization
Yoshioka, 2014	10	Brain tumor	Cranialization with methyl methacrylate	47, F	12	Forehead swelling and mucopyocele	No	60	Cranialization with staged cranioplasty with hydroxyapatite
	11	Brain tumor	Unknown	48, M	21	Purulent discharge from a forehead fistula	No	48	Cranialization with staged cranioplasty with hydroxyapatite
	12	Brain tumor	Obliteration with methyl methacrylate	58, F	20	Purulent discharge from a forehead fistula	No	40	Cranialization with staged cranioplasty with hydroxyapatite
	13	Subarachnoid hemorrhage	Unknown	77, M	25	Purulent discharge from a forehead fistula	No	17	Cranialization with staged cranioplasty with hydroxyapatite
	14	Subarachnoid hemorrhage	Unknown	66, F	20	Purulent discharge from a forehead fistula	No	14	Cranialization with staged cranioplasty with hydroxyapatite
	15	Subarachnoid hemorrhage	Unknown	61, M	26	Purulent discharge from a forehead fistula	No	12	Cranialization with staged cranioplasty with hydroxyapatite
	16	Frontal sinus fracture	Obliteration with methyl methacrylate	43, M	25	Purulent discharge from a forehead fistula	No	50	Cranialization with staged cranioplasty with hydroxyapatite
	17	Frontal sinus fracture	Obliteration with methyl methacrylate	71, M	35	Purulent discharge from a forehead fistula	No	43	Cranialization with staged cranioplasty with hydroxyapatite
	18	Mucocele	Fat obliteration	75, M	10	–	Yes	31	Endoscopic marsupialization
Chandra et al, 2004	19	Sarcoid	Fat obliteration	34, M	7	–	No	10	Endoscopic marsupialization
	20	Aneurysm	Fat obliteration	47, M	20	–	Yes	23	Endoscopic marsupialization
	21	Arteriovenous malformation	Fat obliteration	65, F	19	–	No	7	Endoscopic marsupialization

Table 1 (Continued)

	Case	Indication for craniotomy	Treatment of frontal sinus violation following craniotomy	Age, Sex	Years from craniotomy	Presenting symptoms	Recurrence	Follow-up period (months)	Management of frontal sinus pathology
Schramm and Maroon, 1979	22	Osteoma	Fat obliteration	43, F	17	–	No	5	Endoscopic marsupialization
	23	Frontal sinus fracture	Fat obliteration with bone cement	61, M	0.4	Frontal mucocoele and proptosis	No	21	Endoscopic marsupialization
	24	Frontal sinus fracture	Fat obliteration	39, M	0.3	Persistent headaches and sinus infections	No	8	Endoscopic marsupialization
	25	Aneurysm	None	42, M	2	Headaches, frontal swelling, and cellulitis with mucopyocele	No	–	Fat obliteration
	26	Pituitary tumor	None	47, M	3	Headache and mucopyocele	Yes	–	Fat obliteration
	27	Aneurysm	None	44, M	4	Frontal swelling and pain	Yes	36	Fat obliteration
	28	Frontal sinus fracture	None	48, M	2	Cellulitis of orbit and frontal mucopyocele	No	24	Fat obliteration
	29	Aneurysm	None	26, M	3	Frontal swelling with mucopyocele	Yes	24	Incision and drainage with washout
	30	Frontal sinus fracture	None	42, M	20	Orbitofrontal mucocoele and osteomyelitis with headaches and pain	No	24	staged cranioplasty with frontal exenteration
	Case	Indications for craniotomy	Management of frontal sinus following craniotomy ^a	Average Age	Average time from craniotomy	Presenting symptoms	Recurrence	Average time for follow up (months)	Management of frontal sinus pathology
Meetze et al, 2004	31	Brain tumor	Unknown	31.3	14.8	Headaches, frontal edema, and cellulitis	No	27	Endoscopic marsupialization with possible combined trephine
	32	Brain tumor	Unknown						
	33	Arteriovenous malformation	Cranialization						
	34	Aneurysm	Fat obliteration						
	35	Craniofacial deformity	Bone obliteration						

^aItems in this column do not correspond precisely with the respective indications for craniotomy in the previous column. This information was not evident in the source article. Abbreviations: F, female; M, male.

Table 2 Summary of ►Table 1

Indications for Craniotomy		Total number of patients	Management of frontal sinus following Craniotomy		Total number of males	Total number of females	Average age (years)	Average time from frontal violation until complication (years)	Average time for follow-up (months)
Frontal sinus fracture	8	35	None	11	23	12	42.1	14.5	24.4
Aneurysm	5								
Brain tumor	5		Fat obliteration	8					
Subarachnoid hemorrhage	3		Unknown	6					
Arteriovenous malformation	2		Cranialization	5					
Craniofacial deformity	2		Obliteration with methyl methacrylate	3					
Mucopyocele	2								
Osteoma	2		Cranialization with methyl methacrylate	1					
Brain abscess	1								
Optic nerve tumor	1								
Meningioma	1		Bone obliteration	1					
Pituitary tumor	1								
Sarcoid	1								
Unknown	1

Fig. 3 (A) Postoperative computed tomography (CT) demonstrating incomplete frontal recess obliteration with persistent aeration of the frontal sinus. (B) CT showing resultant tension pneumocephalus.

Mucocele may develop decades after the initial frontal sinus violation. Our meta-analysis identified that the average time to presentation was 14.5 years, with a range of 3 months to 36 years. It would be reasonable to perform imaging, either a computed tomography (CT) or magnetic resonance imaging (MRI) scan, in the first few years, which may be obtained as part of routine surveillance for the initial intracranial lesion. Delayed

imaging at 5 to 15 years with a CT or MRI would seem prudent to identify late mucocele formation. The proposed method of surveillance parallels the recommendations for surveillance of frontal sinus fracture repair.^{9–11} Furthermore, follow-up with an otolaryngologist to perform nasal endoscopy and review imaging may help prevent complications from mucocele formation, such as orbital and intracranial infections.

Fig. 4 Right frontal sinus mucocele treated through an endoscopic endonasal approach. (A) Coronal computed tomography (CT) sinus. (B) T1 postcontrast coronal magnetic resonance imaging (MRI) of the brain. (C) Axial CT of the sinus.

Conclusion

Violation of the frontal sinus, through either craniotomy or fracture, can result in a mucocele as an early or late sequela. Image guidance may help avoid unnecessary frontal sinus violation during a craniotomy. Mucoceles may develop decades after the initial frontal sinus violation, and long-term follow-up with imaging and an otolaryngologist is recommended to care for these patients. While the endoscopic endonasal approach is usually the preferred method to treat these lesions, it may be necessary to perform obliteration or cranialization in unique situations.

Conflict of Interest

None.

References

- 1 Park CM, Stoffella E, Gile J, Roberts J, Herford AS. Osteoplasty flap technique for repair of latent (30-year) post-traumatic frontal sinus mucocele: case report and review of the literature. *J Oral Maxillofac Surg* 2012;70(09):2092–2096
- 2 Busaba NY, Salman SD. Ethmoid mucocele as a late complication of endoscopic ethmoidectomy. *Otolaryngol Head Neck Surg* 2003; 128(04):517–522
- 3 Galiè M, Mandrioli S, Tieghi R, Clauser L. Giant mucocele of the frontal sinus. *J Craniofac Surg* 2005;16(05):933–935
- 4 Courson AM, Stankiewicz JA, Lal D. Contemporary management of frontal sinus mucoceles: a meta-analysis. *Laryngoscope* 2014;124(02):378–386
- 5 Yoshioka N. Modified cranialization and secondary cranioplasty for frontal sinus infection after craniotomy: technical note. *Neurol Med Chir (Tokyo)* 2014;54(09):768–773
- 6 Meetze K, Palmer JN, Schlosser RJ. Frontal sinus complications after frontal craniotomy. *Laryngoscope* 2004;114(05):945–948
- 7 Chandra RK, Kennedy DW, Palmer JN. Endoscopic management of failed frontal sinus obliteration. *Am J Rhinol* 2004;18(05):279–284
- 8 Schramm VL Jr, Maroon JC. Sinus complications of frontal craniotomy. *Laryngoscope* 1979;89(9 Pt 1):1436–1445
- 9 Weber R, Draf W, Keerl R, et al. Osteoplastic frontal sinus surgery with fat obliteration: technique and long-term results using magnetic resonance imaging in 82 operations. *Laryngoscope* 2000;110(06):1037–1044
- 10 Guy WM, Brissett AE. Contemporary management of traumatic fractures of the frontal sinus. *Otolaryngol Clin North Am* 2013;46(05):733–748
- 11 Horowitz G, Amit M, Ben-Ari O, et al. Cranialization of the frontal sinus for secondary mucocele prevention following open surgery for benign frontal lesions. *PLoS One* 2013;8(12):e83820