The Laryngoscope

Reconstruction of the Obliterated Eustachian Tube: A Pilot Case Series

Joonas Toivonen, MD; Dennis Poe, MD, PhD

Objective: To investigate the safety and early efficacy of a procedure for reconstruction of the obliterated Eustachian tube (ET).

Study Design: Retrospective case series.

Methods: Patients with total obliteration of the cartilaginous ET, with intractable mucoid effusion causing repeated occlusion of tympanostomy tubes were included. Patients underwent endoscopic transnasal/transoral reconstruction of the obliterated ET using transtympanic illuminated guidewire guidance. A temporary stent (angiocatheter filled with bonewax) was placed to maintain patency while healing. In four cases an additional steroid-eluting propel stent was placed in the ET orifice. Main outcome measures were otomicroscopy results, absence of middle ear effusion, and nasopharyngoscopy showing patency of the ET orifice.

Results: Nine ETs (seven patients), ages 17–68 years (mean 37.9) underwent ET reconstruction. Follow-up ranged from 4 to 56 months (mean 30.9 months). 89% of operated ears had no effusion at last follow-up. Two patients (three Eustachian tubes) underwent successful reoperation. There were no complications directly related to the procedure. Etiologies of obliteration included scarring after sinus surgery, obstruction after maxillo-mandibular advancement surgery (two patients), bullous pemphigus, gunshot trauma, and previous patulous obliteration (two patients).

Conclusions: Complete occlusion of the cartilaginous ET can be associated with intractable mucoid effusion; endoscopic examination should be considered in such cases. In this pilot study, ET reconstruction was found to be a safe and possibly effective procedure in patients with total obliteration of the ET from various etiologies. Larger studies with long term follow up are indicated.

Key Words: Eustachian tube, obstruction, obstructive dysfunction, reconstruction.

Level of Evidence: 4

***Laryngoscope*, 00:1–6, 2022**

INTRODUCTION

Total obliteration of the Eustachian tube (ET) prevents its functions of pressure equalization and clearance of secretions, leading to chronic middle ear problems.[1] Potential causes for total obliteration of the ET include trauma, surgery, and diseases affecting the nasopharyngeal orifice or cartilaginous portion of the ET.[2–4]

Scarring from an adjacent procedure such as adenoidectomy can affect the ET orifice.[5] Aural symptoms, such as tinnitus, fullness, and otalgia, have been reported after orthognathic surgery typically lasting for 6–8 weeks possibly due to surgical edema. However, scarring or altered anatomy may cause longer lasting or even permanent changes in function.[6–8] Nasopharyngeal tumors and other extrinsic masses can cause obstruction and malignant neoplasms are significantly more likely to cause middle ear effusion, which is usually serous rather than mucoid.[4] Radiation therapy and surgical treatments adjacent to the ET may have a high incidence of otitis media with effusion (OME) post-treatment.[9,10] Granulomatous diseases such as sarcoidosis or Granulomatosis with Polyangiitis (GPA, aka. Wegener's disease) have also been reported to have local variants that affect the nasopharynx causing crusting, edema, and scarring in the ET region.[11]

Total intrinsic obliteration of the ET results in chronic middle ear effusions that are often thick and mucoid with symptoms of aural fullness, hearing deficiency, and frequent occlusion or extrusion of tympanostomy tubes.[12,13] Obstructive ET dysfunction (OETD) most commonly does not result in complete occlusion of the lumen of the ET. Rather, there is usually inflammatory pathology that causes insufficient opening of the functional valve and treatments targeted to the cause can be effective in restoring the function of the valve.[14] In the case of total anatomical blockage of the nasopharyngeal orifice or cartilaginous portion, function cannot be restored by medical or balloon dilation treatment. Chronic OETD has been shown to have a significant burden on patients' lives and with total obliteration the symptoms are potentially even more difficult due

From the Department of Otolaryngology and Communication Enhancement (J.T., D.P.), Boston Children's Hospital and Harvard Medical School, Boston, Massachusetts, USA; Department of Otorhinolaryngology—Head and Neck Surgery (J.T.), Turku University Hospital and University of Turku, Turku, Finland.

Additional supporting information may be found in the online version of this article.

Editor's Note: This Manuscript was accepted for publication on August 24, 2022

The authors have no funding, financial relationships.

Send correspondence to Joonas Toivonen, Turku University Hospital, Department of Otorhinolaryngology—Head and Neck Surgery, Savitehtaankatu 5, PL 52, Turku 20521, Finland.

Email: joonas.toivonen@utu.fi

DOI: 10.1002/lary.30399

to persistence of the condition and the challenges of thick mucoid effusion.[15,16]

One case report described a procedure to reconstruct a totally obliterated ET in which an illuminated guidewire was inserted transtympanic through the ET to guide reopening from the nasopharynx.[12]

The purpose of this study is to introduce a procedure for the treatment of total obstruction of the ET with the results of a pilot case series. In addition, the causes and clinical presentation of complete obliteration are presented to raise awareness of this less common cause of chronic OETD.

MATERIALS AND METHODS

This retrospective case series was performed at a tertiary medical center and was approved by the institutional review board.

Patients diagnosed with total obliteration of the nasopharyngeal orifice or cartilaginous portion of the ET and having intractable mucoid effusion that could not be adequately managed with tympanostomy tubes, due to frequent repeated obstruction of the tubes, were considered for candidacy for the surgery. All patients who underwent reconstruction to restore a functional lumen to the ET were included. All patients previously had tympanostomy tubes for intractable effusions, but viscous mucoid effusions repeatedly reaccumulated due to occlusion of the lumen, early extrusion of the tubes or both. Follow-up evaluations included reporting of symptoms of ET dysfunction, otomicroscopy, flexible fiberoptic or rigid nasopharyngoscopy, and tympanometry if the tympanic membrane (TM) was intact. Primary outcome was presence or absence of mucoid middle ear effusion. Additional outcome measures for success were absence of retraction of the TM on otomicroscopy, tympanometry if there was no TM perforation, and visible patency of the lumen of the cartilaginous ET as far as could be seen on endoscopy from the nasopharyngeal orifice.

Description of the Surgical Procedure

All candidates underwent a thorough ear, head, and neck examination in the office, including otomicroscopy and flexible fiberoptic nasopharyngoscopy with video monitoring. Complete obliteration of the ET lumen across the entire nasopharyngeal orifice was observed in all patients. A preoperative computed tomography (CT) scan was performed for all patients to ensure absence of any dehiscence of the internal carotid artery within the bony portion of the ET. In addition, intact anatomy of the bony portion was also a criteria for candidacy for the surgeon.

ET reconstruction was performed under general anesthesia using a combined transtympanic and endoscopic transnasal/transoral approach. The patient was placed in the supine position and an oral endotracheal tube was taped midline to the lower lip. Oxymetazoline nasal spray was administered for decongestion.

Under the operating microscope a myringotomy was made radially-oriented directly anteriorly over the location of the orifice of the bony ET. No myringotomy was made if there were a pre-existing favorably located anterior perforation in the TM. An illuminated sinuplasty guide wire (0.9 mm dia, Luma, Acclarent, Irvine, CA, USA, off-label use) was introduced through either the anterior myringotomy or through the existing perforation into the middle ear. The guidewire is flexible and has a "J" tip that was rotated anteriorly to seek the lumen of the orifice of the bony portion of the ET. By following the semilunar canal through the protympanum, the variable air cells in the protympanum were avoided, allowing for smooth passage into the orifice of the bony ET. The guidewire was gently advanced down the full length of the bony ET into the cartilaginous ET until meeting resistance at the site of the obstruction within the cartilaginous portion. The ear speculum was removed, leaving the guidewire, which was positioned to exit the ear canal meatus through the intertragal notch to avoid bending tension that could enlarge the myringotomy. The guidewire was secured to the face with tegaderm (3 M, St Paul, MN, USA).

Attention was then directed to the nose and mouth. A 0° 4 mm rigid endoscope (Karl Storz, El Segundo, CA, USA) was used for initial inspection and a 45° scope was used for the remainder of the operation. A navigation system was utilized to assist in the cases of suspected alteration of anatomy or expectation that the obstruction could be proximal within the cartilaginous ET and therefore in close proximity to the extratemporal internal carotid artery. A Crow-Davis tonsil mouth-gag was placed to hold the mouth open. A red flexible catheter was placed through the contralateral nostril to retract the palate. The 45° endoscope was positioned through the ipsilateral nasal cavity to view the orifice of the ET and secured in place with an endoscope holder (Karl Storz, El Segundo, CA, USA). The majority of the procedure was performed transorally, passing angled instruments, including dedicated endoscopic nasopharyngeal instruments (Karl Storz, El Segundo, CA, USA—discontinued, but similar instruments available from Spiggle & Theis), beyond the palate. The ET orifice was inspected to see if the light from the guidewire was visible through the obstruction (Fig. 1A). The light could be best seen by turning down the light from the endoscope to standby for a reduced output or completely off. A faint red glow could be seen through the tissues if the obstruction were sufficiently limited in thickness. Once in sight, the light served as a guide to indicate the exact location of the ET lumen.

Lidocaine with epinephrine was infiltrated into the orifice of the ET. Endoscopic scissors were used to cut down in the direction of the illuminated guidewire if seen. In the event that the light was not seen, dissection proceeded using what available landmarks remained such as remnants of the torus tubarius and its underlying medial cartilaginous lamina, the roof of the ET (basi-sphenoid), medial pterygoid plate, or tensor veli palatine (TVP) muscle. If there were severe distortion of anatomy, the navigation system was used to assure an appropriate trajectory toward the isthmus of the bony ET until the guidewire light came into view. Hemostasis was assured with monopolar cautery (Karl Storz, El Segundo, CA, USA). The sharp scissors dissection progressed toward the isthmus, periodically turning down the endoscope light until identification of the red glow from the guidewire was seen. Cut-down was done onto the guidewire to expose it within the lumen and the lumen was then widely opened with the scissors (Fig. 1B). The dissection continued through the obstruction until reaching uncompromised mucosal-lined ET lumen. Once reaching the ET lumen, mucus was usually encountered as reassurance of reaching the lumen.

A stent using a 14 gauge angiocatheter that would be placed into the newly formed ET was prepared before beginning the procedure. The stent was occluded to prevent it from becoming filled with secretions and risking infection over time. Bone wax was melted in metal cup floating in a water bath incubator, heated to 80°C. The bone wax was aspirated through the full length of the 14-gauge angiocatheter and it was allowed to cool. It was then cut to appropriate length. The full length of the adult ET is between 31 and 38 mm.[1] For the stent to span the full length of the ET from the orifice of the bony ET to protrude into the nasopharynx and allow it to be sutured to the anterior pillar of the nasopharyngeal orifice, the angiocatheter was trimmed to

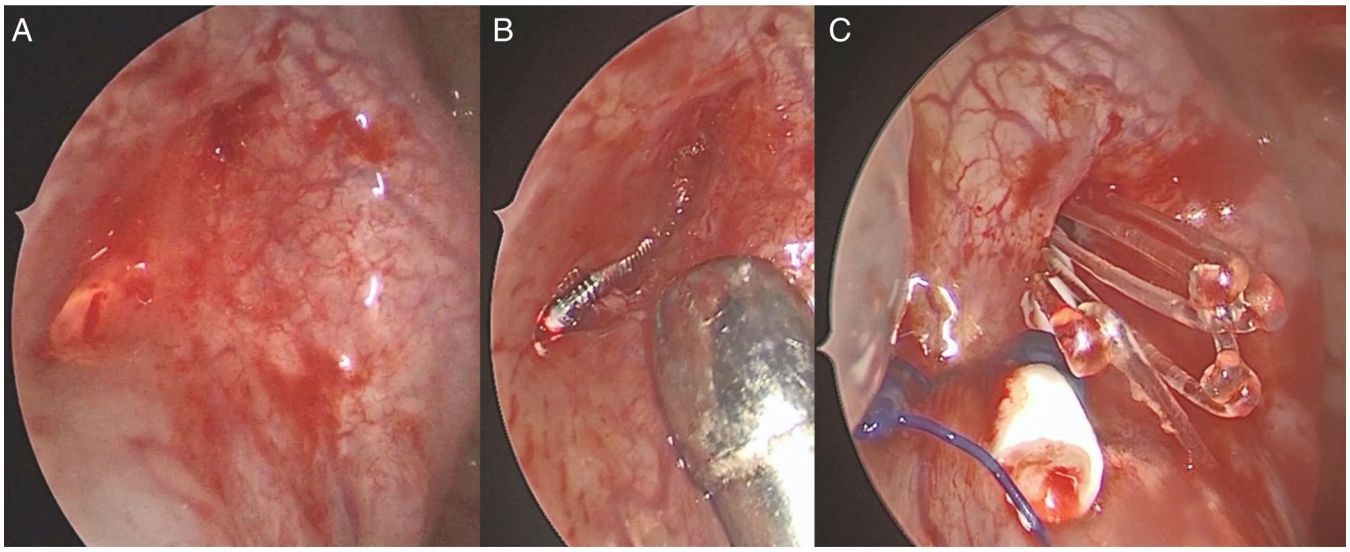

Fig. 1. Endoscopic images of Patient 5, right ET. (A) Illuminated guidewire visible through obliterated ET orifice. (B) Cutdown onto guidewire, exposing lumen widely. (C) Angiocatheter stent inserted full length of ET, sutured to anterior pillar. Steroid-eluting sinus stent inserted alongside angiocatheter into cartilaginous portion of ET only. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

between 40 and 44 mm in length as indicated. A 4–0 nylon suture was passed through the nasopharyngeal cut end of the catheter and the tapered tip would face the middle ear. The catheter with the suture was loaded into an ET insertion tool (Karl Storz, El Segundo, CA, USA). The insertion tool was passed transorally and delivered up to the opening of the newly established lumen, resting initially alongside the guidewire, which was still in place. The guidewire was then withdrawn entirely out of the ET and out of the ear. The catheter was slowly and carefully inserted through the entire remaining length of the ET, feeling resistance as it passed through the isthmus. The catheter came to rest just inside the anterior pillar. Inspection of the ear with a 0° endoscope was done to be sure that the catheter was not visible through the myringotomy within the middle ear. If so, it was further withdrawn into the nasopharynx. The catheter was secured to the anterior pillar with a single suture using endoscopic instruments and previously described techniques (Karl Storz, El Segundo, CA, USA).[17]

A Propel mini steroid-eluting stent (Intersect ENT, Menlo Park, CA, USA, off-label use) was additionally placed into the ET lumen alongside the angiocatheter stent at the end of the procedure in later cases to improve the chances for preservation of a lumen (Fig. 1C).

An adhesive Steri-Strip (3 M, St. Paul, MN, USA) patch cut into appropriate size was placed on the newly formed myringotomy at the end of the procedure.

It was intended to leave the angiocatheter stent in place for a minimum of 6 months and with optional removal after 12 months, or longer if not causing symptoms.

RESULTS

Seven patients (9 ETs) underwent reconstruction of total obliteration of the ET between 2011 and 2019. Two patients underwent bilateral reconstruction. Two patients (3 ETs) needed reoperation. An additional steroid-eluting propel stent was placed in three procedures alongside the catheter to aid in preserving a lumen. Demographics, interventions, and outcomes are presented in Table I. A total of 12 ET reconstruction procedures (9 primary and 3 revisions) were performed on 7 patients, 3 (43%) female and 4 (57%) male. Mean age at surgery was 37.9 years (range 17–68 years). Mean duration of follow-up was 30.9 months (range 4–56 months). All procedures were performed by the senior author. There were no complications directly related to the procedure. Two patients (3 ETs) developed scarring and recurrence of complete occlusion of their ET orifices and revision surgery was done in these cases. From the primary procedures, 5/7 were successful in eliminating further mucoid middle ear effusions. One patient later underwent tympanoplasty to repair a chronic TM perforation. Four patients had either a small perforation or a tube in their TM at the last visit, but no accumulation of mucoid effusion. For the two patients undergoing reoperation, successful recanalization of the ET was achieved. Both resolved their mucoid ME effusions; one had an intact TM on the only operated side and the second with bilateral reconstruction had a perforation on one and a tube on the other side at the latest follow-up visit. (Table I; Description of cases, Data S1).

DISCUSSION

This case series of ET reconstruction describes a procedure to correct total obliteration of the ET with ≥2 year follow up except for one patient. We also report a variety of etiologies for obstruction found in this series. Re-establishment of a lumen was achieved in all cases and there were no complications directly related to the procedure.

OETD is a common problem in the adult population with a prevalence of 4.5%,[16,18] but the prevalence of complete obliteration of the ET is unknown and is likely underdiagnosed. It will not respond to medical or dilation

TABLE I.
Patient Characteristics, Reconstruction Information and Findings at Last Visit.

Patient no.	Age	Gender	Side	Reconstruction indication	Propel -implant used	Revision surgery	Otoscopy at last visit	Effusion at last visit	Endoscopy of ET lumen	Valsalva ability	Patulous ET post-op (duration)	Duration of follow-up
1	28	Male	Right	Previously obliterated due to patulous	No	No	Tube	Serous	Patent	Present	Present (4 weeks after stent removal)	4 months
1	28	Male	Left	Previously obliterated due to patulous	No	No	Tube	No	Patent	Present	Present (intermittent)	4 months
2	41	Male	Left	Injuries due to gunshot to the head	No	No	Asymptomatic TM perforation	No	Patent	Present	Absent	2 years 1 month
3	35	Female	Right	Scarring due to bullous pemphigus	No	Yes	20% TM perforation	No	Obstructed	NA	Absent	4 years 5 months
3	35	Female	Left	Scarring due to bullous pemphigus	No	Yes	Tube	No	Obstructed	NA	Absent	4 years 5 months
4	65	Female	Left	Total obstruction after cauterization for patulous	No	No	Small asymptomatic TM perforation	No	Stented	Present	Absent	4 years 6 months
5	17	Female	Right	Scarring after LeFort I and mandibular osteotomies to correct underbite	Yes	Yes	Intact TM, aerated ME	No	Patent	Present	Present (intermittent)	2 years 9 months
6	47	Male	Right	Scarring after MMA surgery for OSA	Yes	No	Pinhole after tympanoplasty, aerated ME	No	Patent	Present	Absent	2 years 1 month
7	68	Male	Left	Scarring after sinus procedures	Yes	No	Pinhole TM perforation	No	Patent	Present	Absent	1 year 4 months

ME, middle ear; MMA, maxillomandibular advancement; OSA, obstructive sleep apnea; TM, tympanic membrane.

TABLE II.
Patients with a Diagnosis of Eustachian Tube Dysfunction (ETD) or Eustachian Tube (ET) Obliteration in the Clinic of Author DP from 2004 to 2019.

$n = 1852$ patients	n	%
OETD without obliteration		
Adults (≥18)	911	98.8
Pediatric (<18)	918	98.7
ET obliteration		
Adults (≥18)	11	1.2
Pediatric (<18)	12	1.3

treatment. The prevalence within the senior author's subspecialty clinic for ET disorders was examined from 1/2004–12/2019. OETD was diagnosed in 1829 patients of which complete ET obliteration was found in 23 patients (1.2%) (Table II).

Obliteration of the cartilaginous ET can only be recognized by an endoscopic examination of the lumen of the ET. Obliteration should be considered with intractable mucoid effusions or when OETD is persistent in association with granulomatous diseases, trauma, and surgical procedures such as sinus surgery, turbinectomy, adenoidectomy, and maxillary advancement.[19]

After the opening of total obliteration, the mucosal raw surfaces may readily scar back together. A stent is necessary to maintain a lumen through the healing process. Ho et al have reported stenting of the ET to significantly decrease the rate of OME after nasopharyngectomy.[9] It is theoretically optimal to use the largest diameter stent that can be accommodated in the lumen of the ET and the isthmus will typically accommodate no larger than a 14 gauge angiocatheter (2.1 mm OD).

An additional way to reduce the risk of re-scarring could be the use of steroid eluting stents, as was done for three patients in our study, which has been shown to be effective after sinus surgery.[20] One patient in our series developed re-obliteration after stent removal 9 months postoperativley. A steroid-eluting stent was placed in addition to the angiocatheter stent in the ET lumen during the revision procedure. A second steroid releasing stent was also placed at 19 months post-op during removal of the angiocatheter stent. The ET lumen has thus stayed open. The role of a steroid-eluting stent remains to be determined for routine cases, but placement at the time of angiocatheter-stent removal might be expected to aid in preventing restenosis. It was a tight fit placing both angiocatheter-stent and propel such that the propel was inserted alongside the angiocatheter as best as possible. If the propel were to be inserted first, it would collapse and prevent insertion of the angiocatheter through the lumen of the propel.

Ward et al reported a case of ET obliteration after surgery for patulous ET dysfunction. The autophony resolved but the patient suffered from constant mucoid middle ear effusion, tympanostomy tube clogging, ear pain, and pressure limiting daily function even more than the original patulous dysfunction.[12] The symptoms, especially the intractable middle ear effusions, were similar with our patients. In addition, in our cohort, two of the patients had earlier undergone obliteration for patulous dysfunction, but the viscous mucoid effusions prompted them to seek reversal of the obliteration.

The etiology of the blockage of the nasopharyngeal orifice of the ET can be heterogenous. Systemic inflammatory diseases may cause obliteration as has been reported with sarcoidosis, and GPA[11] and we presented one case of bullous pemphigus. Management of the underlying condition, assuring it to be in remission, is important before undertaking surgical intervention. Unfortunately, our patient unexpectedly relapsed shortly after the procedure, developing restenosis of the ET. Even by the time a revision procedure was deemed safe, the tissue around the ET orifice was so fragile that it would not hold a suture to keep a stent in place. The stents extruded and scarring recurred.

Excessive scarring can cause complications after surgery. Either accidental or overly aggressive resection in the immediate vicinity of the ET orifice can result in scarring and even in total blockage of the ET.[5,21] One patient in our cohort had repeated surgeries for complicated sinus disease. Considering the volume of sino-nasal and adenoid surgery, the rate of such complications is very low, but nevertheless should be considered should a patient develop persistent symptoms of OETD after

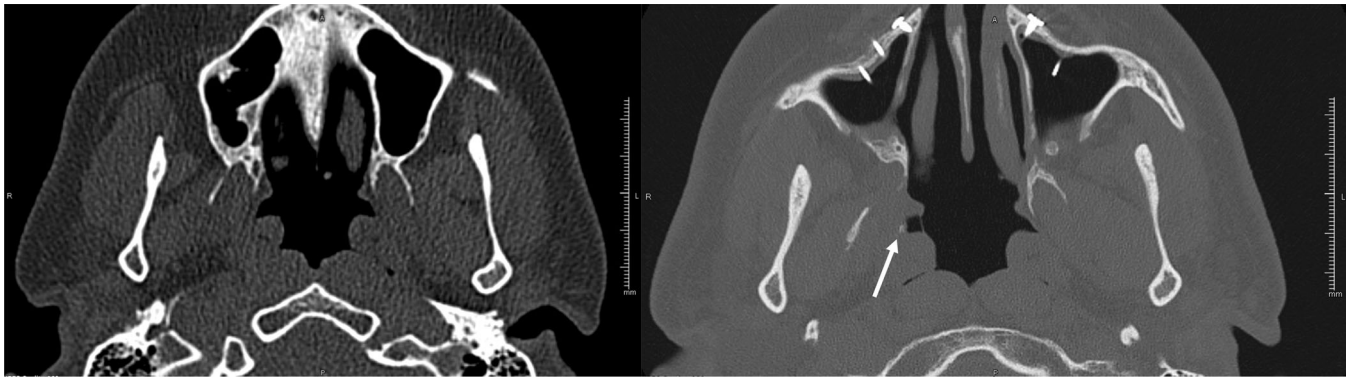

Fig. 2. Axial CT images of Patient 6 before MMA surgery (left) and after (right) showing bone fragments and obstruction in the right ET orifice.

surgery. (Luong et al.,[20] Safety and Effectiveness of a Bioabsorbable Steroid-Releasing Implant for the Paranasal Sinus Ostia: A Randomized Clinical Trial).

Two patients in our cohort had undergone maxillomandibular advancement (MMA) surgery prior to developing total blockage of the ET, which has not been previously reported as a complication of such surgery. Studies evaluating the effects on the ear and hearing after orthognathic surgery have reported changes in hearing and middle ear function.[7,8,22] Jedrzejewski et al.[6] hypothesized in a review that early changes in auditory function may be a result of surgical edema, but persistent problems would likely be due to compromised ET function. Both scarring or changes in muscular tension and orientation may lead to dysfunction. Yaghmaei et al.[7] reported on auditory changes after orthognathic surgery on 54 patients. At the last follow-up 8 weeks postoperatively, 26% of subjects had abnormal ET function when performing the Toynbee maneuver and measuring middle ear pressure with a tympanogram. With Patient 6 in our cohort who had MMA surgery, postoperative CT showed bone fragments in the region of the ET that were likely related to injury that caused scarring and persistent obstruction of the lumen (Fig. 2). We hypothesize that maxillary advancement surgery may place the ET at risk when the maxillary plates are fractured by a rocking motion for the final mobilization. These bony plates have the potential to lacerate the adjacent ET. Persistent OETD following such surgery should be evaluated for the possibility of obliteration of the lumen of the ET.

All but one of the patients (1/9 ETs) had intractable mucoid effusions. Further investigation is needed to determine if complete intrinsic obstruction of the lumen of the ET may predispose to effusions with a high proteinaceous content. Serous effusions are typically seen with extrinsic obstruction, such as with neoplasms and masses. Complete obstruction of the ET may be considered in cases of intractable viscous mucoid effusion. Given this possible consequence, complete obliteration for the treatment of patulous ET should be considered only as a last resort.

Limitations of our study include a small cohort due to the rarity of the condition and the novelty of the procedure. During the timespan of the performed procedures the technique has evolved with experience from earlier procedures. There were variations in duration of the stent postoperatively, suturing the stent or not and the use of a steroid-eluting stent at either the primary procedure or at the time the stent was removed. In addition, the heterogeneity of the etiologies of the ET obstruction makes comparison difficult. However, there was consistency that all cases had technical success in re-establishing the lumen and all cases resolved their troublesome mucoid effusions.

CONCLUSION

Reconstruction of the ET was demonstrated to be safe and possibly effective in patients with total obliteration. Studies with larger cohorts and long-term follow-up are needed to determine whether ET reconstruction will be ultimately effective to restore full function and prevent recurrence.

CONFLICT OF INTEREST

Dennis Poe is a consultant for Acclarent.

BIBLIOGRAPHY

1. Bluestone CD, Bluestone MB. *Eustachian Tube: Structure, Function, Role in Otitis Media*. BC Decker; 2005:xiii:219.
2. Mills R, Hathorn I. Aetiology and pathology of otitis media with effusion in adult life. *J Laryngol Otol*. 2016;130(5):418-424. https://doi.org/10.1017/S0022215116000943.
3. Young YH. Irradiated ears in nasopharyngeal carcinoma survivors: a review. *Laryngoscope*. 2019;129(3):637-642. https://doi.org/10.1002/lary.27303.
4. Tsunoda A, Suzuki M, Kishimoto S, Anzai T, Matsumoto F, Ikeda K, Terasaki O Otitis media with effusion caused by a parapharyngeal tumor showing normal nasopharyngeal findings. *Ear Nose Throat J* 2019 100: 145561319881513. doi:https://doi.org/10.1177/0145561319881513, 543–545.
5. Abdel-Aziz M, El-Tahan AR, El-Fouly M, Kamel A, Abdel-Wahid A. Treatment of post-adenotonsillectomy velopharyngeal stenosis with bivalved uvular flaps. *Int J Pediatr Otorhinolaryngol*. 2019;126:109600. https://doi.org/10.1016/j.ijporl.2019.109600.
6. Jędrzejewski M, Smektała T, Sporniak-Tutak K, Olszewski R. Preoperative, intraoperative, and postoperative complications in orthognathic surgery: a systematic review. *Clin Oral Investig*. 2015;19(5):969-977. https://doi.org/10.1007/s00784-015-1452-1.
7. Yaghmaei M, Ghoujeghi A, Sadeghinejad A, Aberoumand D, Seifi M, Saffarshahroudi A. Auditory changes in patients undergoing orthognathic surgery. *Int J Oral Maxillofac Surg*. 2009;38(11):1148-1153. https://doi.org/10.1016/j.ijom.2009.06.002.
8. Wong LL, Samman N, Whitehill TL. Are hearing and middle ear statuses at risk in Chinese patients undergoing orthognathic surgery? *Clin Otolaryngol Allied Sci*. 2002;27(6):480-484. https://doi.org/10.1046/j.1365-2273.2002.00616.x.
9. Ho AC, Chan JY, Ng RW, Ho WK, Wei WI. Stenting of the Eustachian tube to prevent otitis media with effusion after maxillary swing approach nasopharyngectomy. *Laryngoscope*. 2014;124(1):139-144. https://doi.org/10.1002/lary.24320.
10. Hsin CH, Chen TH, Liang KL, Tseng HC, Liu WS. Postirradiation otitis media with effusion in nasopharyngeal carcinoma patients treated by intensity-modulated radiotherapy. *Laryngoscope*. 2013;123(9):2148-2153. https://doi.org/10.1002/lary.23215.
11. Braun JJ, Gentine A, Pauli G. Sinonasal sarcoidosis: review and report of fifteen cases. *Laryngoscope*. 2004;114(11):1960-1963. https://doi.org/10.1097/01.mlg.0000147928.06390.db.
12. Ward S, Parnes L, Rotenberg B. Endoscopic transnasal Eustachian tube reconstruction via light cable technique: a technical report. *Allergy Rhinol*. 2013;4(3):e176-e178. https://doi.org/10.2500/ar.2013.4.0069.
13. Ward BK, Chao WC, Abiola G, et al. Twelve-month outcomes of Eustachian tube procedures for management of patulous Eustachian tube dysfunction. *Laryngoscope*. 2019;129(1):222-228. https://doi.org/10.1002/lary.27443.
14. Adil E, Poe D. What is the full range of medical and surgical treatments available for patients with Eustachian tube dysfunction? *Curr Opin Otolaryngol Head Neck Surg*. 2014;22(1):8-15. https://doi.org/10.1097/MOO.0000000000000020.
15. Teklu M, Kulich M, Micco AG, et al. Measuring the health utility of chronic Eustachian tube dysfunction. *Laryngoscope*. 2019;130:E39-E44. https://doi.org/10.1002/lary.27934.
16. Vila PM, Thomas T, Liu C, Poe D, Shin JJ. The burden and epidemiology of Eustachian tube dysfunction in adults. *Otolaryngol Head Neck Surg*. 2017;156(2):278-284. https://doi.org/10.1177/0194599816683342.
17. Rotenberg B, Davidson B. Endoscopic transnasal shim technique for treatment of patulous Eustachian tube. *Laryngoscope*. 2014;124(11):2466-2469. https://doi.org/10.1002/lary.24751.
18. Shan A, Ward BK, Goman AM, et al. Prevalence of Eustachian tube dysfunction in adults in the United States. *JAMA Otolaryngol Head Neck Surg*. 2019;145:974-975. https://doi.org/10.1001/jamaoto.2019.1917.
19. Poe DS, Abou-Halawa A, Abdel-Razek O. Analysis of the dysfunctional Eustachian tube by video endoscopy. *Otol Neurotol*. 2001;22(5):590-595.
20. Luong A, Ow RA, Singh A, et al. Safety and effectiveness of a bioabsorbable steroid-releasing implant for the paranasal sinus ostia: a randomized clinical trial. *JAMA Otolaryngol Head Neck Surg*. 2018;144(1):28-35. https://doi.org/10.1001/jamaoto.2017.1859.
21. Wan DC, Kumar A, Head CS, Katchikian H, Bradley JP. Amelioration of acquired nasopharyngeal stenosis, with bilateral Z-pharyngoplasty. *Ann Plast Surg*. 2010;64(6):747-750. https://doi.org/10.1097/SAP.0b013e3181a73009.
22. Bayram B, Deniz K, Aydin E, Uckan S. Is auditory function affected after Le fort I osteotomy? *Int J Oral Maxillofac Surg*. 2012;41(6):709-712. https://doi.org/10.1016/j.ijom.2012.01.011.