Diagnostic approaches to and management options for patulous eustachian tube

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ABSTRACT

الأهداف: مراجعة منهجية وتلخيص جميع الأدلة المتعلقة بتشخيص وعلاج اتساع قناة استاكيوس.

الطرق: تم إجراء الدراسة الحالية وفقًا لبنود المراجعات المنهجية والتحليلات الوصفية (PRISMA). تم إجراء بحث شامل باستخدام قواعد بيانات PubMed و Scopus و Web of Science و Embase و Virtual Health Library و Cochrane Central للدراسات ذات الصلة المنشورة حتى ديسمبر 2019. كما تم إجراء البحث اليدوي للمراجع ذات الصلة.

النتائج: بشكل عام ، تم إدراج 59 مقالة في التحليل. شملت الدراسات العلاجية 1279 مريضا ، مع مدة متابعة تتراوح من بضعة أيام وحتى سنتين. ذكرت ثماني دراسات أن تقطير محلول ملحي عن طريق الأنف هو الخيار الأكثر دراسة. ذكرت دراسات أخرى علاجات جراحية مختلفة تتراوح من أنابيب الأذن إلى الإجراءات التداخلية التي تستهدف فتحة قناة استاكيوس أو الأجزاء التشريحية المحيطة بها. بالإضافة إلى ذلك ، تم ضم 10 دراسات تشمل 367 شخصًا وناقشت طرق التشخيص المختلفة.

الخاتمة: حاليا ، هناك مجموعة واسعة من التدخلات التشخيصية والعلاجية ولكنها على قدر بسيط من الكفاءة السريرية ، كما يوجد نقص في التوجيهات المنهجية ، والعديد من الثغرات في الأبحاث السابقة.

Objectives: To systematically review the literature and to summarize all evidence related to the diagnosis and management of patulous eustachian tube.

Methods: The present study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.

Results: Overall, 59 articles were retrieved and included in the analysis. Studies investigating treatments enrolled 1279 patients collectively, with follow-up duration varying from few days and up to 2 years. Eight studies reported medical treatments with intranasal saline instillation as the most frequently studied option. Other studies reported various surgical treatments varying from simple tympanostomy to invasive procedures targeting the orifice of the ET or the anatomical features surrounding it. In addition, 10 studies including 367 subjects investigated different diagnostic methods.

Conclusion: Currently, there is a wide spectrum of diagnostic and therapeutic interventions with minimal clinical efficacy, a persistent lack of systematic guidelines, and several gaps in previous research endeavours.
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Keywords: patulous eustachian tube, management, diagnosis

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Patulous eustachian tube (PET), a benign, largely idiopathic, condition, was first described in 1867. It has adverse effects that can markedly affect quality of life such as abnormal autophony, breathing, or hearing.[1] Several factors have been reported to be causative, including pregnancy, neurological disorders, weight loss and radiotherapy, and some medications including oral contraceptives and diuretics.[2] In terms of pathophysiology, all stressors that distort normal closure

of the eustachian tube (ET) during the resting state can result in PET. This includes conditions affecting the elasticity, surface tension, and opening pressure of the ET.[2]

According to experts, there is currently a lack of universal consensus regarding symptom scores, tests, and guidelines to diagnose PET. Meanwhile, the diagnostic approach relies primarily on clinical assessment of the presenting symptoms.[3] This non-systematic approach makes the identification of these cases challenging. Symptoms that should raise suspicion include aural fullness, popping, and discomfort or pain, in addition to autophony of breathing or voice. Signs include tympanic membrane retraction and signs of negative middle ear pressure.[3,4] Further studies have been recommended to enhance the diagnostic approach to this condition.

Despite the modest rarity of PET and the hurdles to diagnose, it also represents a challenging condition for patients and clinicians due to limited therapeutic options.[5] Current approaches vary depending on the severity of symptoms and range from informative reassurance to invasive interventions. Some cases may need combined or surgical treatment such as those with no clinical improvement and persistent movement of the tympanic membrane.[6] To date, there have been limited research papers with variable outcome measures and no definite recommendations that outline a precise evidence-based, patient-centered therapeutic guideline.[3,5]

Given the insufficient diagnostic and therapeutic guidelines, we aim to systematically review the literature and to summarize all evidence related to the diagnosis and management of PET.

Methods. This study has followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[7] The study protocol was applied for recording in PROSPERO. Provided the nature of the present study (example, systematic review), requirements for ethics review were waived.

Any primary study that reported or investigated diagnostic approaches or management options for PET were included. There were no restrictions regarding different populations, race, origin, age, ethnicity, language, or publication date. However, letters, editorial comments, theses, book chapters, non-human and experimental studies, and articles with no available full text were excluded. Studies with no extractable data were also excluded.

A computerized systematic search was performed for potentially eligible articles published up to December 2019 using the PubMed, Scopus, ISI Web of Science, Embase, Virtual Health Library (VHL), and Cochrane Central Register of Controlled Trials databases. The search term "patulous eustachian tube" was used to retrieve all relevant articles within the scope of the present study. A manual inspection of the reference section of all competent reports was also considered to recognize any further articles. Search results were retrieved and duplicates were removed using EndNote X7.[4] (EndNote, USA) for Windows (Microsoft Corporation, Redmond, WA, USA). Two independent reviewers screened potentially relevant articles and included all reports that met the research criteria. Initial screening of titles and abstracts was followed by full-text review. Disagreements were resolved by discussion and consensus between reviewers and among senior researchers.

Three authors independently collected the target outcomes from the eligible articles and filled it into blind Excel sheets. Any discrepancy was resolved by discussion to reach consensus. The extraction form was established using a pilot extraction of a few blindly selected studies. Extracted outcomes comprised demographic informations of the enrolled subjects. In addition, different types of therapeutic and diagnostic approaches, and follow-up period were analyzed. Complete, partial, and non-resolution rates were also compared. Descriptive statistics was carried out and the data were presented as numbers and proportions.

Results. The search of the medical literature retrieved 1062 titles (PubMed [n = 204]; VHL [n = 199]; Scopus [n=246], Embase [n=202], ISI Web of Science [n=204], Cochrane Central Register of Controlled Trials [n=7]). After removing 215 duplicates, 847 titles and abstracts were pooled for initial screening (Figure 1). Three reviewers working independently selected 71 articles for full-text screening. After discussion, 25 articles were excluded for irrelevance or improper design, among other reasons (Figure 1). Ultimately, 46 articles were eligible by screening and 13 were identified through the manual search, resulting in 59 articles included for data extraction and analysis.

Of the 59 included studies, 49 investigated treatment options, while 10 described diagnostic approaches.[8-54] The studies investigating treatments collectively enrolled 1279 patients (1442 ears), with follow-up intervals

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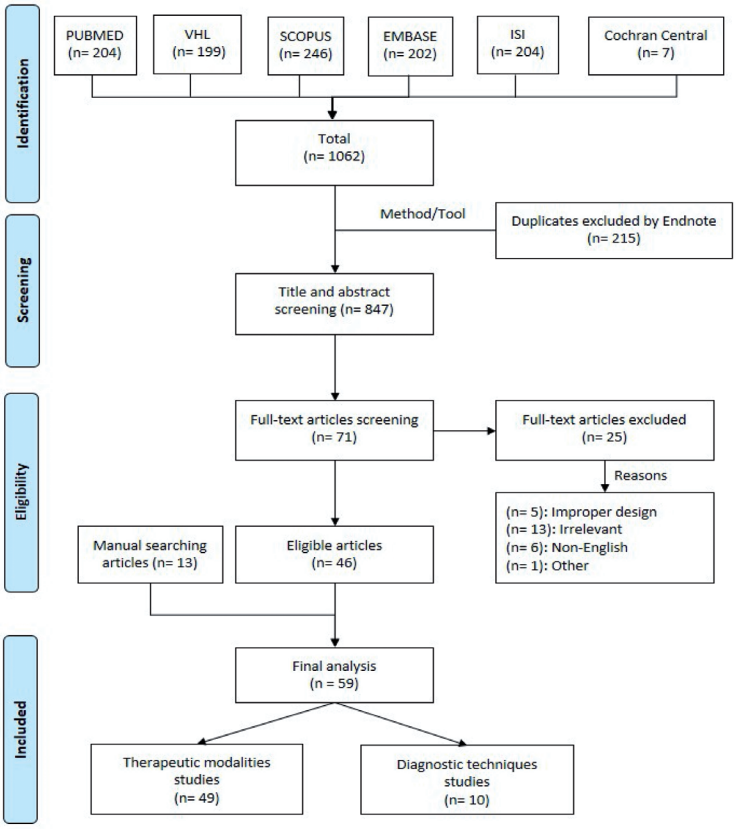

Figure 1 - PRISMA flowchart of studies selection and screening. ISI: Web of Science, VHL: virtual health library

varying from 2 weeks to 2 years. Baseline demographics of the enrolled articles are summarized in Table 1.

Medical treatment approach. Eight articles described several non-surgical, intranasal or intratubal treatments (Table 2). Treatment options included guidance to stop sniffing and nasal saline instillation, irrigation using normal saline, potassium iodide, diluted hydrochloric acid, beta chlorobutanol, benzyl alcohol, atropine, 1:4 salicylic acid powder, boric acid powder. The latter was reported in 3 studies enrolling 40 patients, which led to a 100% resolution of PET symptoms.[48,53,54] Irritation was the only side effect reported. More recent studies favored the use of topical normal saline with high efficacy (65.7% experienced complete resolution in the study by Ikeda[9]) and safety (example, no adverse events were reported with the use of saline drops).

Tympanic membrane mass loading approach. Several techniques were used to increase the mass of the tympanic membrane, which is aimed at decreasing its movement and, therefore, potentially improving PET symptoms. In the review, 10 studies reported different means to load the tympanic membrane, which are summarized in Table 3. These techniques included paper patching, loading with ventilation tubes, cartilage chip insertion, myringoplasty, potassium-titanyl-phosphate (KTP) laser, and loading with blue tack. Complete resolution was more frequently reported with the use of blue tack (78.6%) in a sample size of 11 subjects, and paper patching (65.2-76.2%) in 44 patients (56 ears). The side effects of paper patching were limited to mild to moderate discomfort.

Eustachian tube occlusion approach. Ten studies investigated ET occlusion using several modalities including plugging (example, silicon plug, catheter with bone wax, and orifice suturing), cautery, and injections. The outcomes of these reports are elaborated in Table 4. The largest sample size was reported by Kikuchi et al,[14] in which 252 ears were occluded using Kobayashi plug, with a complete resolution rate (CRR) of 64.7% and several reported side effects including tympanic membrane perforation (17.5%) and plug dropping toward the pharyngeal tube (22.6%). Cauterization was reported in 3 case series including 22 patients. Several

Table 1 - Baseline characters of 49 studies reporting treatment of patulous eustachian tube.

Author/year	Sample size	Age mean (range)	Gender male n (%)	Follow-up period mean (range) months
Alli et al[8]/2019	8 (12 ears)	52.4 (41-73)	3 (37.5)	29 (6-62)
Ikeda et al[9]/2019	28	48	7 (25)	6
Kim et al[10]/2019	23	45 (10-79)	15 (38.5)	3
Janatová et al[11]/2018	1	38	0	6
Jeong et al[12]/2018	11 (14 ears)	40.8	2 (18.2)	16.4
Jolly et al[13]/2018	1	27	0	6 weeks
Kikuchi et al[14]/2017	191 (252 ears)	16-83	84 (43.97)	25.2 (3-168)
Endo et al[15]/2016	31 (44 ears)	51 (14-88)	5 (16.1)	NR
Mackeith & Bottrill[16]/2016	11	38 (20-67)	5 (45.5)	18.3 (3-44)
Oh & Kong[17]/2016	25 (33 ears)	NR	19 (76.0)	25.2 (12-40)
Si et al[18]/2016	12	34 (23-46)	4 (33.3)	6-60
Oh et al[19]/2015	29 (36 ears)	NR	16 (55.1)	19.3(6-37)
Schröder et al[20]/2015	20	18-96	8 (40.0)	6
Boedts[21]/2014	21 (33 ears)	46 (19-72)	3 (14.28)	1-2
Brace et al[22]/2014	Cartilage tympanoplasty (10 [11 ears])	47.8	4 (40.0)	230 (52-882) days
	KTP LM(10 [15 ears])	40.7	5 (50.0)	436 (90-719) days
Oh et al[23]/2014	1	39	1 (100)	12
Rodrigues et al[24]/2014	1	36	0	6
Rotenberg et al[25]/2014	7	21-43	2 (28.6)	6-21
Vaezeafshar et al[26]/2014	14 (23 ears)	53 (14-83)	4 (28.6)	17.5
Rotenberg et al[27]/2013	11 (14 ears)	37.5 (31-66)	3 (27.3)	6
Ikeda et al[28]/2011	414	43.7 (8-85)	187 (45.2)	NR
Kong et al[29]/2011	2	45 and 54	2 (100)	18 and 24
Yanez et al[30]/2011	11	38 (17-54)	9 (81.8)	24
Bartlett et al[31]/2010	14	43.57	5 (35.7)	2 years
Oshima et al[32]/2010	52	50.7 (16-84)	27 (51.92)	2-8 weeks
Wolraich & Zur[33]/2010	1	4	0	18
Olthoff et al[34]/2007	1	45	0	12
Poe[4]/2007	11	NR	5 (45.4)	15.8 (3-30)
Takano et al[35]/2007	10 (15 ears)	31-79	3 (30.0)	13-27
Sato et al[36]/2005	37 (44 ears)	10-79	17 (45.9)	38.9 (6-68)
Doherty & Slattery[37]/2003	2	38 and 47	1 (50.0)	12
Boudewyns & Claes[38]/2001	1	35	1 (100)	5 weeks-4 and half months
DiBartolomeo Henry[39]/1992	10	NR	NR	3
Dyer Jr & McElveen[40]/1991	1	75	1 (100)	2
Chen & Luxford[41]/1990	46 (60 ears)	(24-84)	21 (45.6)	2 weeks
Robinson & Robinsin[42]/1989	13	(24-79)	4 (30.7)	3-36
Morita & Matsunaga[43]/1988	6 (8 ears)	48 (23-66)	5 (83.3)	NR
Virtanen & Palva[44]/1982	13 (16 ears)	45 (20-78)	8 (61.5)	24 (2-60)
Bluestone & Cantekin[45]/1981	4	NR	NR	36
O'Connor &Shea[1]/1981	7	22-59	NR	NR
Crary et al[46]/1979	12	24-72	0	12
Ogawa et al[47]/1976	16 (22 ears)	20-75	7 (43.7)	1 week- 1 year
Bhide et al[48]/1976	1	49	1 (100)	NR
Stroud et al[49]/1974	3	25-75	0	2 weeks- 3 months
Misurya[50]/1974	2	38 and 55	1 (50.0)	4-6
Pulec[51]/1967	26	NR	NR	NR
Thaler & Yanagisawa[52]/1966	4	18-41	1 (25.0)	5-11
Miller[53]/1961	30	20-75	12 (40.0)	NR
Moore & Miller[54]/1951	12	20-76	4 (33.3)	NR

NR: not reported, KTP: potassium-titanyl-phosphate, LM: laser myringoplasty

Table 2 - Outcomes from 8 studies reporting treatment of patulous eustachian tube through medical approach.

Author/year	Study type	Subjects (n)	Treatment	Complete resolution n(%)	Partial resolution n(%)	Adverse events
Ikeda et al[9]/2019	RCS	35 (63 ears)	Instruction to stop sniffing + nasal saline instillation	23 (65.7)		NR
Oshima et al[32]/2010	RCS	52	Nasal saline instillation	24 (46.2)	9 (17.3)	NR
Boudewyn A/2001	Case report	1	Saturated potassium iodide solution (60g potassium iodide in 42g water), 20 drops daily through tympanostomy tubes	0	0	vertigo and SNHL
DiBartolomeo Henry[39]/1992	PCS	10	Diluted hydrochloric acid þ chlorobutanol, benzyl alcohol nasal drops	8 (80)	2 (20)	rhinorrhea and nasal irritation: 2
Morita & Matsunaga[43]/1988	PCS	6 (8 ears)	Intratubal atropine	6 (100)		NR
Bhide et al[48]/1976	Case report	1	1:4 salicylic: boric acid powder through tympanostomy tubes	1 (100)		NR
Miller[53]/1961	RCS	27	Boric and salicylic acid powder insufflated directly into the torus tubarius	27 (100)		Irritation from solution
Moore & Miller[54]/1951	RCS	12	Insufflation of salicylic acid powder and boric acid powder 1:4 proportions	12 (100)		NR

NR: not reported, SNHL: sensorineural hearing loss, RCS: retrospective case series, PCS: prospective case series

Table 3 - Outcomes from 10 studies reporting treatment of patulous eustachian tube through tympanic membrane mass loading approach.

Authot/year	Study type	Subjects (n)	Treatment	Complete resolution n (%)	Partial resolution n (%)	Adverse events
Kim et al[10]/2019	RCS	23	Paper patching over the most mobile quadrants of the tympanic membrane	15 (65.2)	6 (26.1)	NR
Jeong et al[12]/2018	PCS	11 (14 ears)	Tragal cartilage chip insertion via a transcanal approach into ET	4 ears (28.6)	5 ears (35.7)	NR
Si et al[18]/2016	PCS	12	A myringoplasty with ipsilateral full-thickness tragus cartilage		12 (100)	NR
Oh et al[23]/2014	RCS	29 (36 ears)	TCI	22 (62.9)	7 (20.0)	OME: 2 ears unilateral mastoiditis: 1 ear
Brace et al[22]/2014	RCS	10 (15)	Resurface TM with KTP laser	7 (46.7)		NR
		10 (11)	Cartilage tuboplasty	8 (72.7)		
Boedts[21]/2014	RCS	21 (33 ears)	Paper patch on TM	16 (76.2)		Discomfort with drying patch
Ikeda et al[9]/2019	RCS	8 ears	Ventilation tubes	6 (75.0)	2 (25.0)	
Bartlett et al[31]/2010	PCS	14	Mass loading of TM with blue tack	11 (78.6)		dislodged tack: 1
Chen & Luxford[41]/1990	RCS	46 (60 ears)	Ventilation tubes	32 (53.3)		otorrhoea: 2 persistent perforation: 2
Thaler & Yanagisawa[52]/1966	RCS	4	Short, double flanged, polyethylene tube	3 (75.0)	1 (25.0)	AOM: 1

ET: eustachian tube, TM: tympanic membrane, TCI: trans-tympanic catheter insertion, AOM: acute otitis media, OME: otitis media with effusion
NR: not reported, RCS: retrospective case series, PCS: prospective case series, KTP: potassium-titanyl-phosphate

techniques and resolution rates are summarized, with otitis media as the only reported side effect. Various types of injectable elements used for inducing ET occlusion are also summarized in Table 4. Those with the largest sample sizes included autologous cartilage injection (33 ears [CRR 27.3%]), soft-tissue bulking agent (26 ears [CRR, 35%]), calcium hydroxyapatite (23 ears [CRR 57-63%]), absorbable gelatin sponge solution (22 ears [CRR 100%]), and Teflon (26 ears [CRR 73.1%]). Otitis media with effusion, epistaxis, tinnitus, and temporomandibular joint discomfort were reported as adverse events post-injection.

Muscular techniques. Modulating the tone of the tensor veli palatine muscle can change the patency of

Table 4 - Outcomes from 10 studies reporting treatment of patulous eustachian tube through eustachian tube occlusion.

Author/year	Study type	Subjects (n)	Treatment	Complete resolution n (%)	Partial resolution n (%)	Adverse events
Eustachian tube occlusion: plugging						
Ikeda et al[9]/2019	PCS	28	Silicone plug (Kobayashi plug)		23 (82.1)	MEE: 5 TMP: 4 Tinnitus: 1
Kikuchi et al[14]/2017	RCS	191 (252 ears)	Kobayashi plug in ET (prototype plug-new plug)	163 (64.7)	46 (18.3)	TMP: (prototype 22.6%, new 17.5%) MEE: (prototype 20.2%, new 10.2%) Ventilation tube placement: (prototype 14.8%, new 4.4%) dropped to pharyngeal orifice: (prototype 22.6%)
Endo et al[15]/2016	RCS	sniff type (6 ear)	trans-tympanic silicone plug insertion	2 (66.7)	2 ears (33.3)	Symptom recurrence: 2 ears TMP: 3 ears OME: 2 ears
		non-sniff type (27 ear)	trans-tympanic silicone plug insertion	13 ear (74.1)	7 ears (25.9)	Symptom recurrence: 7 ears TMP: 3 ears OME: 2 ears
		sniff type (11 ears)	ventilation tube insertion	3 ears (27.3)	7 ears (63.6)	Deviation from treatment: 1 ear
Rotenberg et al[25]/2014	PCS	7	Endoscopic insertion of a 3.5 cm shim (trimmed irrigation catheter with bone wax) sutured into the eustachian tube in patients who failed ET suture ligation	6 (85.7)	1 (14.3)	NR
Rotenberg et al[27]/2013	PCS	11 (14 ears)	Endoscopic closure of ET (cautery, fat placed in ET, ET orifice sutured, tissue glue injected into the torus orifice) and tympanostomy tube	13 (92.8)		Epistaxis: 1
Ikeda et al[28]/2011	RCS	13 ears	Transtympanic ET plugging with a Kobayashi PEP through a myringotomy	13 ears (100)		MEE: 1
Takano et al[35]/2007	PCS	10 (15 ears)	Endoscopic transnasal/transoral ligation of pharyngeal orifice of ET	2 (13.3)	7 (46.7)	Temporary OME: 1 Infection: 1 Odynophagia: 1 Revision operations: 3
Sato et al[36]/2005	RCS	35 (42 ears)	Transtympanic insertion of silicone plug via a myringotomy	22 (52.4)	8 (19) 11 exchanged for larger plug	Foreign body sensation
Doherty & Slattery[37]/2003	RCS	2	Complete closure of ET at nasopharyngeal orifice (cautery of the internal circumference of the ET orifice, fat graft, further electrocautery) and tympanostomy tubes	2 (100)		NR
Dyer Jr & McElveen[40]/1991	Case report	1	Transcanal insertion of an angio-catheter into the ET via tympanomeatal flap and tympanostomy tube	1 (100)		NR
Bluestone & Cantekin[45]/1981	RCS	4	Transtympanic insertion of IV indwelling catheter through a tympanotomy and tympanostomy tube	4 (100)		NR
Eustachian tube occlusion: cautery						
Yanez C/2011	RCS	11	Unilateral or bilateral curvature inversion tubuloplasty	8 (72.7)	1 (9)	NR

PEP: patulous eustachian tube plug, OME: otitis media with effusion, OM: otitis media, CT: computed tomography, TMP: tympanic membrane perforation, TMJ: tempromandibular joint, CHL: conductive hearing loss, ET: eustachian tube, MEE: middle ear effusion, RCS: retrospective case series PCS: prospective case series

Table 4 - Outcomes from 10 studies reporting treatment of patulous eustachian tube through eustachian tube occlusion (continuation).

Author/rear	Study type	Subjects (n)	Treatment	Complete resolution n (%)	Partial resolution n (%)	Adverse events
Robinson & Robinsin[42]/1989	RCS	5 (6 ears)	Eustachian tube diathermy	4 (66.7)	1 (16.7)	Secretory OM: 2
Eustachian tube occlusion: injection						
O'Connor &Shea[1]/1981	RCS	6	20% silver nitrate cautery	5 (83.3)	1 (16.7)	Serous OM: 1
Alli et al[8]/2019	Case series	8(12 ear)	CT-guided transcutaneous injection using polydimethylsiloxane elastomer (Vox)	7 ears (58)	4 ears (33.3)	MEE: 1 ear, Ear pain: 1 ear Numbness in the distribution of the maxillary nerve: 4 ears Numbness of face on the side of the treated ear: 3 cases Numbness of the tongue: 1 case
Jolly et al[13]/2018	Case report	1	ET obliteration using endovascular coils	1 (100)		Right-sided tinnitus and mild CHL secondary to MEE
Jančatová et al[11]/2018	Case report	1	0.4 + 0.4 ml of calcium hydroxylapatite injection into two locations (the anterior and posterior aspect of the nasopharyngeal orifice of the right Eustachian tube)	1 (100)		NR
Oh et al[23]/2016	RCS	25 (33 ears)	Autologous cartilage injection	9 ears (27.3)	14 ears (42.4)	Temporary OME: 1 ear
Mackeith & Bottrill[16]/2016	RCS	11	Combined transnasal-transoral endoscopic injection of Polydimethylsiloxane elastomer	8 (73)	1	Persistent MEE: 1 Temporary effusions: 2
Schroder et al[20]/ 2015	RCS	20(26 ears)	Endoscopic injection of soft tissue bulking agent into torus tuburius (vox-implants)	7 (35)	6 (30)	Transient epistaxis
Oh et al[23]/2014	Case report	1	Transnasal endoscopic injection of calcium hydroxyapatite to ET orifice	1 (100)		NR
Vaezeafsharet al[26]/2014	RCS	14(23 ears)	Transnasal endoscopic injection of calcium hydroxyapatite to ET orifice	(57-63)		NR
Rodrigues et al[24]/2014	Case report	1	Transcutaneous CT guided silicone elastomer suspension implant	1 (100)		NR
Kong et al[29]/2011	RCS	2	Autologous cartilage injection to anterior/posterior nasopharyngeal ET orifice	2 (100)		NR
Wolraich & Zur[33]/2010	Case report	1	Transoral injection of calcium hydroxylapatite to lateral pharyngeal wall and torus tubarius	1 (100)		NR
Poe[4]/2007	PCS	11(14 ears)	Endoscopic patulous ET reconstruction: Cartilage graft 2 Pts; Alloderm 12 Pts: placed around ET orifice	1 (7)	12 (86)	Temporary OME: 1
Crary et al[46]/1979	PCS	10	Polytef paste injection		9 (90)	NR
Ogawa et al[47]/1976	PCS	16(22 ears)	Infusion of absorbable gelatin sponge solution into ET (1 g gelfoam, þ 10 mL, glycerin þ 10 mL saline þ/ 1 g carbomethylcellulose sodium)	22 (100)		Temporary tinnitus: 2
Pulec[51]/1967	RCS	26	Teflon to anterior ET	19 (73.1)	6 (23.1)	Ear or TMJ discomfort

PEP: patulous eustachian tube plug, OME: otitis media with effusion, OM: otitis media, CT: computed tomography, TMP: tympanic membrane perforation, TMJ: tempromandibular joint, CHL: conductive hearing loss, ET: eustachian tube, MEE: middle ear effusion, RCS: retrospective case series. PCS: prospective case series

the ET and was investigated as a potential therapeutic approach to PET. Appendix 1 summarizes relevant evidence. The most commonly investigated technique was tensor veli palatine transection or transposition with pterygoid hamulotomy, which was reported by Virtanen (44) on 16 ears, with a CRR of 56.2%.

Diagnostic approaches. Ten studies including 367 subjects investigated various diagnostic methods.[55-64] The various diagnostic options summarized in this review (Table 5) include the 678 Hz acoustic immittance probe tone of GSI TympStar Middle Ear Analyzer (Grason-Stadler, Eden Prairie, MN, USA), patient-reported outcome measure (PROM), sonotubometry acoustic click stimulus, nasal-noise masking audiometry (NNMA), computed tomography in the sitting position, and sonotubometry.

Discussion. Patulous eustachian tube is a modestly prevalent condition that impacts the quality of life of affected individuals. The recognition of and approach to this condition is usually challenging due to the highly subjective nature of the disease and various management options that fail to be consistent in terms of clinical efficacy.[3] The present systematic review summarized therapeutic and diagnostic options published in the literature, updated previous work in this field, and included more studies and approaches compared with previous reviews. Although the diagnosis of PET is mainly clinical, several approaches have been proposed to confirm the diagnosis.[3] This is significant because symptoms can be nonspecific or misleading in some instances, especially autophony, which is often incorrectly regarded as a pathognomonic sign of PET, while several other conditions may precipitate it, such as external ear canal occlusion, superior canal dehiscence, and foreign bodies such as hair or wax.[1,65] These approaches are

Table 5 - Summary of 10 studies reporting different applied diagnostic methods of patulous eustachian tube.

Author/Year	Study design	Procedure	Sample size	Outcome
Pyne et al[55]/2018	PCS	The 678 Hz acoustic immittance probe tone of GSI TympStar Middle Ear Analyzer	Healthy:11 (11 ears) PET: 7 (7 ears)	The 678 Hz tone yields a larger response for PET than the 226 Hz tone. For the 226 Hz tone PET patients had a median COT difference 0.19 mL higher than healthy ET patients, and for the 678 Hz tone, PET patients had a median COT* difference of 0.57 mL higher than healthy ET patients
Smith et al[56]/2018	PCS	patient-reported outcome measure (PROM)	Healthy: 33 Obstructive ET: 60 PET: 7 Hearing loss and Menier's: 24	PROM had excellent diagnostic accuracy using only healthy controls as comparator for ETD, but specificity was very poor when controls with other otological disorders were included.
Pyne et al[57]/2017	PCS	sonotubometry acoustic click stimulus	Healthy:11 (19 ears) PET: 5 (6 ears)	Novel click stimulus described is a reliable method to determine ET opening in healthy ears, and distinguish between healthy ET and PET states
Paradis et al[58]/2015	RCS	nasal-noise masking audiometry (NNMA)	Healthy:10 (20 ears) PET: 21 (42 ears)	Definitive and probable PET groups had significantly higher NNMA mean auditory thresholds compared to normal ears at 250 Hz ,1,000 Hz and 6,000 Hz .
Oonk et al[59]/2014	Case report	CT in the sitting position	1	The patulous ET could clearly be visualized from the tympanic to the pharyngeal orifice.
Kikuchi et al[60]/2009	PCS	CT in the sitting position	35	The full length of the ET could be visualized in most patients suffering from patulous ET in the sitting position
Kikuchi et al[61]/2007	PCS	CT in the sitting position	Healthy: 20 (30 ears) PET: 67 (111 ears)	The OTD* was significantly longer in the patulous ET group than in the control group under both resting and Valsalva conditions
Hori et al[62]/2006	PCS	Audiometry with Nasally Presented Masking Noise	Healthy: 10 (20 ears) PET: 18 (27 ears)	This caused elevation of the threshold for the tone presented in the external auditory canal which was significantly greater, particularly in the lower-frequency region, in ears with patulous ET and was decreased to the normal range after obstructive treatment of the PET.
Yoshida et al[63]/2003	Case report	CT in the sitting position with the MPR technique	2	The ET lumen was identified at most of the portion from the pharyngeal orifice to the tympanic orifice in sitting position and recumbent position. At the cartilaginous portion, the air space in the ET lumen was larger in the sitting position than in the recumbent position.
Virtanen etl[64]/1978	PCS	sonotubometry	25 (31 ears)	It is a useful addition for diagnosing the abnormal patency of the Eustachian tube and for following up the results of its treatment

PET: patulous eustachian tube plug, MPR: multiplanar reconstruction, CT: computed tomography, ET: eustachian tube, NNMA: nasal-noise masking audiometry, COT: compliance over time, OTD: open tubal distance

also important for persistent treatment-resistant cases and for research purposes.[66] Thus, having a consistent diagnostic approach is important for clinical studies that investigate various management options, and for synthesizing comparative evidence. Meanwhile, there is still no gold standard for diagnosing PET. The most commonly reported approach is computed tomography in the sitting position with or without the Valsalva maneuver, which is used to detect any anatomical patency and measure open tubal distance.[60,61] It remains; however, costly, and not readily available in all healthcare centers. Sonotubometry, tympanometry, and audiometry, along with other approaches, that may or may not need special equipment, were summarized in this review to emphasize the need for a tailored, case-specific approach that combines clinical assessment with diagnostic tests to detect PET. Given the results and nature of the included studies, this appears to be better than standard tests. More research is, nevertheless, needed to inform and develop future guidelines.

In terms of therapeutic approaches, several medical and surgical interventions were suggested, none of which, however, proved to be consistently effective.[67] Our review highlights the lack of randomized controlled trials and the need for more interventional studies. Non-surgical interventions mainly include the intratympanic or intranasal administration of different agents. Most recent studies have focused on the role of saline instillation for symptom relief in those with PET.[28,32] Intranasal saline was suggested as the initial step in the management plan due to its moderate to high efficacy and clean safety profile.[32] However, confounders such as instructing patients to stop sniffing were reported, especially in those with PET and habitual sniffing, which need to be accounted for in future studies. Similar to previous systematic reviews, we failed to find any evidence supporting the use of nasal estrogen cream to treat PET.[67]

Patients with no clinical improvement and persistent movement of the tympanic membrane may be candidates for combination therapies or surgical treatment.[6] The wide spectrum of surgical interventions mainly targets the tympanic membrane, ET orifice or the surrounding anatomical features, and range from simple to invasive procedures. Again, surgical approaches are limited by the lack of consistency of clinical efficacy, scant descriptions of the details of some procedures, and the primitive evidence that we still have in this area. For example, the outcome of "partial resolution" was not consistently defined among the studies.

Our results highlight several additional challenges that impede a more informed approach to PET. Some of these challenges are specific to the nature of the condition, such as the scarcity of objective outcomes and that symptoms can be self-limited, which is an important confounder in research studies. Other challenges leave room for improvement through further research and interventions. They include small sample sizes, high risk of bias, unmatched confounders, poorly defined follow-up periods, and poorly described intervention(s), in addition to the lack of clinical trials and guidelines for diagnosing and managing PET. The present systematic review was limited by the lack of quantitative meta-analysis and the exclusion of non-English articles due to a lack of native speakers.

In conclusion, the present systematic review is the most recent comprehensive investigation of diagnostic and therapeutic approaches to PET to date. It revealed a highly variable spectrum of choices, with a lack of systematic guidelines and several gaps in current research endeavours. As such, a case-specific, step-wise approach is recommended.

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