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REVIEW ARTICLE

Laser Eustachian Tuboplasty for Eustachian Tube Dysfunction: a case series review

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Abstract The authors reviewed the literature regarding the safety and efficacy of Laser Eustachian Tuboplasty (LETP) in the treatment of Eustachian tube dysfunction (ETD). Medline via Pubmed, OvidSP and Science Direct were consulted, with a supplementary manual review of citations. English language case series constituted a baseline for inclusion. Primary outcome measures were pre- and post-operative tympanometry, otoscopy findings, subjective symptoms and pure tone audiometry, and findings were stratified into short term (≤6 months) and long term (>6 months–5 years). Eight unique case series were identified, detailing LETP procedures in 306 patients (462 Eustachian tubes). LETP demonstrated mixed short-term and positive long-term results across primary outcome measures. There was an overall complication rate of ≈4.4%, and no major adverse events were reported. Poor documentation of pre- and post-operative primary outcome measures and inter-study outcome heterogeneity prevents substantive comment on efficacy. Whilst LETP is safe, its use should remain limited to research in adults. Future trials should be case controlled, and detail pre- and post-operative tympanometry, otoscopy findings, subjective symptoms, and pure tone audiometry. Patients should also be stratified into those suffering from baro-challenge induced ETD, and those suffering from ETD with intractable sequelae, such as Chronic Otitis Media.

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Introduction

The Eustachian tube is a dynamic structure, connecting the middle ear to the nasopharynx. At rest it is closed, protecting the middle ear from transmitted sounds and pathogens from the nasopharynx. When opened, usually during swallowing, it allows middle ear aeration, pressure equalisation and mucous clearance from the middle ear.

The failure of the Eustachian tube to dilate is termed Eustachian tube dysfunction (ETD). It is common, with an estimated incidence of 0.9% [1], and can cause symptoms of hearing loss, otalgia, aural fullness, tinnitus and otic barotrauma. ETD is furthermore implicated in the pathogenesis of common middle ear pathology Otitis Media with Effusion (OME) [2, 3]. Whilst ETD affects over 80% of children [4], tubal maturation into adulthood usually causes ETD and its sequelae to cease. For adults who continue to suffer with ETD, a number of options have been trialled, although established and definitive treatment remains lacking: a randomised controlled trial has demonstrated nasal steroid sprays to be no more effective than placebo [5]. Ventilation tubes extrude, and fail to treat the underlying pathology, with recurrence rates of OME as high as 50% [6, 7]. More recently, Balloon dilatation of the Eustachian tube has demonstrated promising short term outcomes in the treatment of ETD, although it remains a novel treatment option, approved by the National Institute for Health and Clinical Excellence (NICE) in the trial setting only, with evidence limited to case series [8, 9, 26].

Laser Eustachian Tuboplasty (LETP)—the laser ablation of an enlarged mucosal and cartilaginous portion of the Eustachian tube to improve dilatory function—has been attempted at various centres. It is the aim of this paper to review published literature on the efficacy and safety of LETP.

Methods

Search strategy

A complete literature review was performed on 9th September 2016 of Medline via Pubmed, OvidSP, and Science Direct, utilising the terms 'Eustachian' AND 'laser'. Due to the novel nature of LETP, English language case series constituted a baseline for inclusion in this review. Non-clinical studies, systematic reviews and published conference abstracts were excluded. A manual review of citations was additionally performed for further studies.

Outcome measures

A recently published consensus statement on the definition, types, and diagnosis of Eustachian tube dysfunction has explicitly advocated the use of the following four assessments pre- and post-operatively, which form our primary outcome measures [10]:

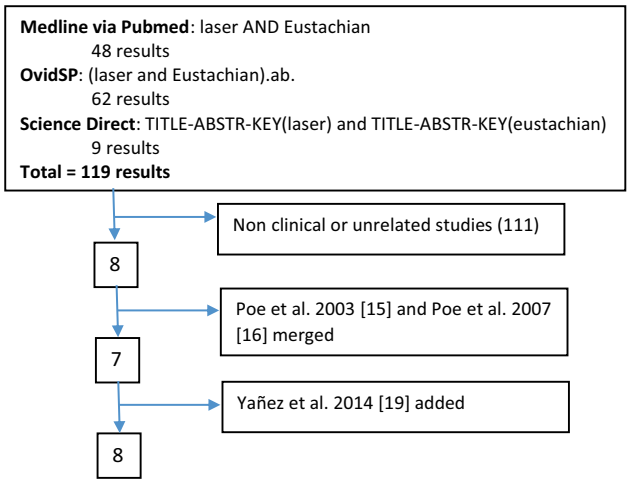
1. *Tympanometry* Normal (type A); abnormal (type B; C; open)
2. *Otoscopy* Normal; abnormal (retracted tympanic membrane, Otitis Media with effusion)
3. *Subjective symptoms of ETD* Improved/not improved/worsened
4. *Pure tone audiometry* Pure tone average (PTA)

Secondary outcome measures were documented as they presented in the literature, and included the ability to perform the Valsalva maneuver (+ve; −ve), nasopharyngoscopic findings, and pressure chamber tests. The nature and rates of complications were described, and where possible, data were synthesised to allow for the estimates of efficacy and safety. Outcomes were stratified into short term (<6 months post operatively) and long term (≥6 months).

Results

Our search strategy yielded 119 results, and 8 unique case series (Table 1) [11–18]. A further case series was found on manual review of citations and included in our results [19]. Two studies were merged as they provided short and long term follow-up data on the same patient group [15, 16]. A total of 306 patients (462–500 ETs) underwent LETP, the doubt in number of ETs arising from one paper that failed to indicate whether unilateral or bilateral LETP was performed [17]. As the authors were not contactable, we have assumed the lower value. Follow-up ranged from 2 months to 5 years.

Table 1 Search strategy



Patient selection

Basic inclusion criteria were patients with symptoms consistent with chronic Eustachian tube dysfunction (Table 2). One study specifically limited inclusion to divers suffering from baro-challenge induced ETD with intact tympanic membranes [13], and in three further studies this made up a significant proportion of cases [11, 12, 17]. Poe et al. and Kujawski et al. conversely limited their study to individuals with intractable Chronic Otitis Media with effusion, refractory to multiple ventilation tubes and maximal medical therapy of intranasal steroids and if applicable antihistamines and proton pump inhibitors [14–16]. Commonly cited exclusion criteria included a clear extrinsic cause for ETD, such as severe allergy or laryngopharyngeal reflux disease, and children (<18 years), although two studies did include paediatric cases [14, 19].

Variations in technique

Laser ablation of mucosa and submucosa of the dorsal margin of the tubal ostium was the most prevalent technique used, the extent of ablation determined in all studies by the degree of hypertrophy visualized by the operator [11–17]. One exception was Yañez et al. [18, 19] who performed a deep, 'cross-hatch' dissection through the cartilage of the posterior cushion. In two series, patients with Chronic Otitis Media and perforation underwent

Table 2 Paper characteristics

Study, location	Number of Eustachian tubes (patients)	Patient selection	Procedure information	Follow-up range Loss to follow up
Caffier et al. [11], Berlin	31 (31)	COM with perforation (16) OME, Baro-challenge induced ETD, atelectasis (15) All cases refractory to conventional therapy	Dorsal margin of torus tubarius ablated interval tympanoplasty in perforation group at 10 weeks LA	2 months–1 year
Jumah et al. [12], Cologne	30 (30)	Baro-challenge induced ETD or recurrent OME. Intact TM	Dorsal margin of torus tubarius ablated LA	2–4 months
Jumah et al. [13], Berlin	9 (9)	Divers with chronic ETD refractory to conservative management	Posterior margin of tubal ostium ablated LA	4 months–4 years
Kujawski et al. [14], Geneva	108 (56)	COM with effusion or atelectasis refractory to ≥5 ventilation tubes	Dorsal margin of torus tubarius ablated GA	24–54 months 8 patients (11 ETs) lost at 3 year follow-up
Poe et al. [15, 16], Boston	13 (13)	COM with effusion refractory to ≥2 ventilation tubes	Posteromedial wall of torus tubarius ablated GA	0–2 years 5 patients lost at 2 year follow-up
Sedlmaier et al. [17], Berlin	Not stated (38)	Baro-challenge induced ETD (19) COM and associated sequelae (19)	Dorsal margin of torus tubarius ablated LA (30) GA (8)	2 months–1 year 18 patients lost at 1 year follow-up
Yañez [18], Mexico City	25 (35)	Persistent symptoms of ETD with abnormal tympanogram OR baro-challenge induced ETD Distributions unspecified	Full-thickness 'cross hatching' of torus tubarius cartilage GA	3–37 months 0 drop out
Yanez et al. [19], Mexico City	198 (120)	COM with effusion refractory to ventilation tubes OR Conductive hearing loss of 5 or more years OR Chronic ETD symptoms Distributions unspecified	Full-thickness 'cross hatching' of torus tubarius cartilage GA	0–5 years

COM Chronic Otitis Media, *OME* Otitis Media with effusion, *VT* ventilation tubes, *LA* local anaesthetic, *GA* general anaesthetic, *TM* tympanic membrane

planned tympanoplasties 8–10 weeks after LETP [11, 17]. In one of the earliest published studies, temporary post-operative tubal packing plus myringotomy for middle ear aeration was performed, but this was not continued in subsequent studies [14]. A range of lasers, including 812–980 nm diode, argon, carbon dioxide and potassium-titanyl-phosphate were used. The procedure has been carried out under both general [14–16, 18, 19] and local anaesthetic [11–13, 17].

Primary outcome measures

Laser Eustachian Tuboplasty demonstrated mixed short-term and positive long-term results across primary outcome measures (Table 3).

Tympanometry

All studies collected pre- and post-operative tympanometry data, although in two papers this was not performed in patients with visible tympanic membrane perforations [11, 17]. 383/427 (92%) of pre-operative tympanogram profiles were abnormal. Of the pre-operatively abnormal tympanograms that were followed up in the short term (<6 months), 9/48 (19%) had resolved [11, 12, 16, 17]. Long-term data were collected in 5 studies at approximately 1 year, demonstrating resolution of 277/362 (77%) previously abnormal profiles [11, 14, 16–19].

Otoscopy

Pre- and post-operative otoscopy findings were documented in four studies [11, 14, 16, 17]. In two studies, this

Table 3 Key findings—primary outcome measures

Study	Pre-operative findings	Post-operative findings			
		<6 months	1 year	2 years	3–5 years
Caffier et al. [11] n = 31	T: 2/15 Type A 13/15 abnormal O: 9/31 normal S: 0/31 normal A: ac 48.2 ± 15.8 (COM + perforation group) ac 34.7 ± 17.6 (Intact TM group)	T: 4/15 Type A S: 31/31 improvement in symptoms (excluding tinnitus)	T: 4/15 normal (Intact TM group) O: 16/16 (Post myringoplasty group) A: ac 29.4 ± 12.1 (Post myringoplasty group) ac 32.7 ± 17.8 (Intact TM group)		
Jumah et al. [12] n = 30	T: 20/30 Type A	T: 24/30 Type A			
Jumah et al. [13] n = 9	T: 9/9 Type A S: 0/9 normal	T: 9/9 normal S: 9/9 improved, 7/9 resume diving			
Kujawski et al. [14] n = 108	T: 0/108 Type A O: 0/108 normal		T: 63/108 normal O: 63/108 normal	T: 53/98 normal O: 53/98 normal	T: 56/92 normal O: 56/92 normal
Poe et al. [15, 16] n = 13	T: 0/13 normal O: 0/13 normal A: ac 36 ± 12.1	T: 1/9 normal O: 0/11 normal A: ac 34.6 ± 14	T: 2/8 normal O: 0/10 normal A: ac 25.5 ± 17.6	T: 2/4 normal O: 0/8 normal	
Sedlmaier et al. [17] n = 38	T: 3/19 Type A O: 14/38 normal	T: 5/19 Type A	O: 11/11 normal (Post myringoplasty group)		
Yañez [18] n = 35	T: 0/35 normal A: ac 30		T: 34/35 improved Type A/B/C unspecified S: 23/25 patients report subjective improvement A: ac 20		
Yañez et al. [19] n = 198	T: 0/198 normal		T: 176/198 improved Type A/B/C unspecified A: ac 20 dB improved Pre-/post-operative thresholds and follow up not specified	T: 184/198	T: 185/198 O: 118/120 S: 96% asymptomatic Poorly documented

T tympanometry, *O* otoscopy, *S* reported symptoms, *A* pure tone audiometry, *ac* average air conduction threshold (dB)

was limited to patients with pre-existing perforation, who underwent myringoplasty following LETP, to assess for recurrence of middle ear pathology [11, 17].

167/190 (87%) pre-operative otoscopy examinations were reported as abnormal. Short-term outcomes were limited to one study which reported 0/11 (0%) normal findings, but noted improvement from OME to retraction in 4/11 (36%) cases [16]. At 1 year 90/145 (62%) previously abnormal cases were reported as normal [11, 14, 16, 17].

Symptoms

Four studies directly addressed subjective symptoms. Caffier et al. utilising a visual analogue score, documented varying degrees of improvement in symptoms of aural fullness, otic-barotrauma, and dulled hearing in 100% cases at 1 year ($n = 31$) [11]. Jumah et al. whose patients were divers suffering from pressure-mediated symptoms reported resolution in 100% of cases at 1 year ($n = 9$), with 7/9 returning to diving (8/9 previously had to stop) [13]. Yañez preliminary study reported symptoms improvement in 96% cases

($n=25$) [18]. In a larger study by the same author ($n=198$) successive resolution in symptoms of ETD were reported at up to 5 years, although these were poorly recorded precluding numerical interpretation [19].

Pure tone audiometry

Three studies provided pre- and post-operative pure tone audiometry data [11, 16, 18]. Poe et al. documented an average post-operative improvement in PTA of 1.4 dB at 6 months and 10.5 dB at 1 year, respectively, in patients with intractable OME [16]. Caffier et al. documented an average PTA improvement at 1 year of 2 dB and 18.8 dB in two distinct patient groups; individuals suffering from ETD symptoms +/− OME, and individuals with perforations secondary to Chronic Otitis Media who subsequently underwent myringoplasty [11]. Yañez reported a 10dB improvement in PTA at approximately 1 year [18], and in a larger study reported an average improvement in pure tone average of 20 dB, but failed to provide pre- and post-operative audiometry data [19].

Secondary outcome measures

Valsalva

Four studies documented Valsalva manoeuvre pre- and post-operatively [11–13, 17]. 82/108 (76%) pre-operative assessments were abnormal. Of the abnormal cases 56/82 (68%) resolved post operatively at up to 6 months. Long term follow up was available in 51 cases at 1 year, which demonstrated normal findings in 71% cases (36/51) [11, 17].

Nasopharyngoscopy

All studies reported a significant post-operative volume reduction of the dorsal circumference of the tubal ostium, with acceptable superficial scarring in all cases. Three studies additionally performed slow-motion video endoscopic analysis of dilatory function, noting, respectively, improved tubal dilation in 25/25 (100%), 74/108 (69%), and 87% of cases at approximately 1 year [14, 18, 19].

Pressure chamber testing

Two studies by the same author reported on the ability of individuals to equilibrate the middle ear under changing ambient pressures [12, 13]. Of the 22 patients unable to equilibrate pre-operatively, 17 (77%) were able to do so post-operatively.

Complications

There was an overall complication rate of ≈4.4% (Table 4). A majority of these complications were peritubal, and in one instance intranasal synechia, which appeared to be of no clinical significance. One potentially serious case of post-operative epistaxis was reported, requiring laser cautery. Two cases of scar granuloma resolved following a course of intranasal steroid spray.

Discussion

McCoul et al. discuss the history of Eustachian tube surgery at length, highlighting the difficulties it has posed in its "occult anatomic position, unclear function, and misunderstood physiology" [20]. Further consideration must be given to the ETs proximity to the internal carotid artery, and the risk of damage to this vital structure [20, 21]. Video endoscopy has shed significant light on the close relationship between middle ear disease and ET function, identifying the cartilaginous portion of the ET as the most frequent site of dysfunction [22–24]. This has led to the development of a range of novel techniques including the use of microdebriders [25], lasers as outlined in this paper, and balloon dilators to improve ET function. Balloon dilatation

Table 4 Complication rates

	Caffier et al. [11] ($n=31$)	Jumah et al. [12] ($n=30$)	Jumah et al. [13] ($n=9$)	Kujawski et al. [14] ($n=108$)	Poe et al. [15, 16] ($n=13$)	Sedlmaier et al. [17] ($n=38$)	Yañez [18] ($n=35$)	Yañez et al. [19] ($n=198$)	Overall % ($n=362$)
Peritubal synechia (%)	3.2			8.3	7.7	2.6			3.3
Intranasal synechia (%)					7.7				0.3
Epistaxis (%)				0.9					0.3
Granuloma formation (%)					15.4				0.5
Overall (%)	3.2	0	0	9.3	30.8	2.6	0	0	4.4

has received sustained attention over the last decade, with pooled data consistently suggesting symptom improvement in 67–100% of cases, and comparable rates for resolution of abnormal outcome measures such has tympanometry profiles and otoscopic findings [8]. Systematic reviews have confirmed the relative safety of the procedure but also recognized the poor quality of studies and the need for controlled trials [9, 26].

Our literature review details the outcomes of 462 procedures on 306 patients, and demonstrates that LETP is safe, and in some cases appears to be an effective treatment for ETD. A number of factors limit our conclusions regarding the procedures efficacy.

In spite of a large number of overall cases, primary outcomes—with the exception of tympanometry—were very poorly reported, with at best four of the eight studies commenting on any one measure, often in non-comparable fashions. This significantly diminished sample sizes.

There was marked heterogeneity between study results. Numerous smaller studies reported only modest post-operative improvements across primary outcomes measures [11, 15–17], and in one case series, there was no resolution (0%) of pathological otoscopic findings in both short and long term [15, 16]. This is in contrast with the two largest studies to date [14, 19] which have reported positive long-term outcomes, for example in the resolution of abnormal tympanogram profiles in 61% cases at 3 years and 93% cases at 5 years, respectively [14, 19]. The largest study in particular was of very poor quality, with inadequate clarification of the pre-operative state of patients middle ears, and incomplete data for all but one primary outcome measure, precluding their inclusion in our pooled analysis [19].

The degree of heterogeneity may partly be attributable to patient selection, which as discussed above, ranged in some studies from individuals with baro-challenge induced Eustachian Tube Dysfunction, to individuals with intractable Chronic Otitis Media who had failed maximal standard therapy. In two studies, selected patients also underwent scheduled tympanoplasties, further confounding post-operative outcomes [11, 17].

In two studies [14, 19], a number of cases were performed on children. Given the significant anatomical and physiological differences in adult and child Eustachian tubes, it is unclear to what degree these results are transferable to adult populations and vice versa [27].

Conclusions

Whilst our study confirms the relative safety of LETP, significant inter-study heterogeneity in primary outcomes precludes substantive comment on efficacy. Evidence remains limited to case series with a high risk of bias. The authors recommend that LETP remain limited to use in research in adults, and that future LETP or Eustachian tube surgery research is:

- Case-controlled
- ETD recruitment consistent with published diagnostic criteria [10]
- Pre- and post-operative outcome measures include tympanometry, otoscopy, symptoms and pure tone audiometry [10].

Future studies will also benefit from clearly stratifying patients into those suffering from isolated or baro-challenge induced ETD and those suffering from ETD plus intractable sequelae such as Chronic Otitis Media.

Compliance with ethical standards

Conflict of interest Benjamin Miller, Mustafa Jaafar and Hassan A. Elhassan declare that they have no conflicts of interest.

Ethical approval This article does not contain any studies with animals performed by any of the authors.

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