Aetiology and management options for secondary referred otalgia: a systematic review and meta-analyses

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Abstract

Objectives of review To review the literature for the evidence base for the aetiology and management of referred otalgia, looking particularly at non-malignant, neuralgic, structural and functional issues.

Type of review Systematic review.

Search strategy A systematic literature search was undertaken from the databases of EMBASE, CINAHL, MEDLINE®, BNI, and Cochrane Library according to predefined inclusion and exclusion criteria.

Evaluation method All relevant titles, abstracts and full text articles were reviewed by three authors who resolved any differences by discussion and consultation with senior author.

Results 44 articles were included in our review. The overall quality of evidence was low, with the vast majority of the studies being case-series with three cohort and four randomised-controlled trials included. The prime causes and management strategies were focussed on temporomandibular joint dysfunction (TMJD), Eagle syndrome and neuralgia. Our meta-analyses found no difference on the management strategies for the interventions found.

Conclusions Referred otalgia is common and treatment should be aimed at the underlying pathology. Potential aetiologies are vast given the extensive sensory innervation of the ear. An understanding of this and a structured approach to patient assessment is important for optimal patient management.

Keywords Adult · Ear · Earache · Otalgia · Pain · Referred

Introduction

Otalgia (pain/discomfort felt in the ear) is a common and indiscriminate presentation with a lifetime prevalence of nearly 100% [1]. It can be divided into primary and secondary otalgia. The former is usually a consequence of otologic disease, which can sometimes be identifiable on otoscopy with or without audiometric findings. It is worth noting that inner ear conditions including hydrops can cause otalgia with normal otoscopy. In secondary or referred otalgia pain originates from pathology around or outside the ear and thus examination and investigations of the ear itself are normal [2]. The ear receives sensory innervation from cranial nerves (CN) V, VII, IX and X and branches of the cervical plexus (C2, C3). Given the extensive anatomical territory covered by these shared neural networks which range from the brain, skull base, spine, aerodigestive tract, deep spaces of the neck, salivary gland, face, paranasal sinuses, orbits,

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skin and viscera [1], referred otalgia can be challenging to diagnose and treat.

Our aim was to review the literature for the evidence base for the aetiology and management of referred otalgia looking particularly at non-malignant, neuralgic, structural and functional issues.

Methods

A systematic review was conducted according to The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Embase, CINAHL, MEDLINE ®, Cochrane Library and BNI databases were searched between 1980 and June 2021 using the medical subject hearings (MeSH) and free-text words as outlined in Appendix 1.

Inclusion criteria were: case series, cohort studies, case-controlled studies, retrospective analyses and randomised controlled trials focussing on aetiology and management of otalgia excluding malignancy in the adult population in the English language. To capture as many articles as possible we did not restrict selection to specific geography or setting (hospital/community-based care). Where otalgia outcomes were reported, we did not discriminate between methods of assessment and relevant articles were included irrespective of follow-up period. While our initial search was conducted between 1980 and 2021, articles prior to 1990 were excluded as we felt many of the management strategies are less applicable in the practice of modern medicine. We had also only included original articles in our systematic review as primary sources of literature on referred otalgia. Reviews were considered as secondary sources and hence excluded; however, given our broad search criteria, we checked to ensure that the original articles cited in the reviews were captured and included if relevant.

Systematic review protocol and data extraction

11,927 articles were retrieved initially. The results were de-duplicated leaving 5137 papers. Titles were screened by author MA and 393 selected. Authors MA and AV proceeded to independently screen the abstracts. Final review of full papers by MA and AM for eligibility identified 44 full text articles for inclusion. Disagreements were resolved by discussion between the authors MA and AM and confirmation with senior author AV.

Mendeley Desktop v1.19.8 2008–2020 was used to organise all titles, abstracts and full text articles and for referencing. Our PRISMA flow diagram for article inclusion is shown in Fig. 1. We were unable to source/access seven papers despite attempting to contact the authors of those studies.

Data/statistical analysis

The total number of treated patients, as well as the number of patients with either improvement or resolution, was extracted from each study. The pooled proportion of treatment outcome (i.e., improvement or resolution) and corresponding 95% confidence interval (CI) were calculated according to random-effects models of DerSimonian and Laird [3] using the logit transformation. Statistical heterogeneity among studies was evaluated using the I^2 and t^2 statistics. Influence analysis was performed when pooled proportions were estimated: pooled proportion was calculated by omitting one study at a time. Publication bias was assessed through a funnel plot.

The results of the meta-analysis were presented graphically using forest plots, plotting the individual paper, pooled proportions and corresponding 95% CI. Analyses were conducted using R 3.6, and statistical significance was claimed for $p < 0.05$ (two sided).

Risk of bias and quality assessment

Risk of bias was assessed using the Brazzelli risk of bias tool represented in Table 1 [4] in Appendix 1. The studies were also ranked according to the University of Oxford OCEBM Levels of Medicine [5]. Any discrepancies were resolved by discussion between authors.

Ethical consideration

Ethical review was not sought due to the review nature of the paper.

Results

44 full text articles were included after meeting all inclusions and exclusion criteria. A summary of the papers can be found in Table 2. We categorised articles according to pathology and whether they focussed on aetiology or management. The level of evidence in Table 2 was based on the University of Oxford OCEBM Levels of Medicine [5].

Temporomandibular joint dysfunction (TMJD)

TMJD is a musculoskeletal disorder characterised by pain or dysfunction of the masticatory apparatus. Studies evaluating the prevalence of otological symptoms in TMJD vary in their evaluation methods and symptoms reported. Nonetheless, it

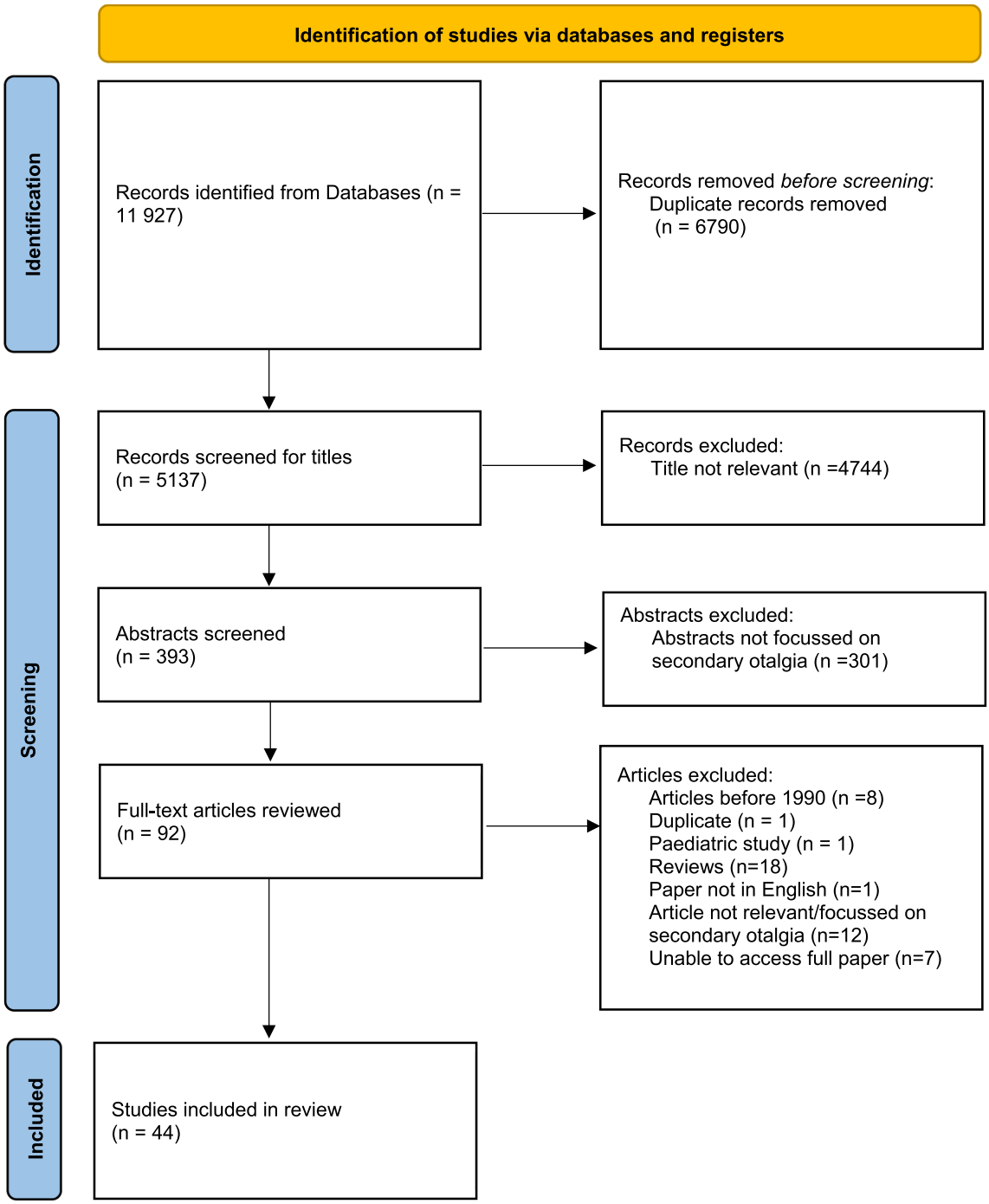

Fig. 1 PRISMA flow diagram of included articles

has been found that TMJD is significantly associated with otalgia [6]. The aetiology remains controversial, although it is presumed to be due to signals crossing between the mandibular branch of the trigeminal nerve that supplies both the TMJ and the ear, via the auriculotemporal branch.

A population study which assessed 91 people with confirmed secondary otalgia found that only 15% did not demonstrate clinical evidence of either TMJD or cervical spine disorder [7]. According to Sumitha and Joseph's study, TMJD accounted for the commonest presumed cause of referred otalgia [8]. In observational studies, reported rates of otalgia experienced by patients suffering from TMJD range from 6% to 82% [9–13]. Both Lam et al. and Kuttila et al. found that aural symptoms were more prevalent in females with TMJD [6, 14]. Patients with aural symptoms appear to demonstrate more clinical signs of TMJD, for

Table 1 Brazzelli risk of bias assessment

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Anwar el al 2019	Y	Y	Y	Y	Y	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Kuttila et al 2001	Y	N	n/a	n/a	Y	Y	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sumitha and Joseph 2015	Y	Y	Y	Y	Y	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Taziki and Behnampour 2012	Y	Y	Y	Y	Y	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cooper and Kleinberg 2007	Y	Y	Y	Y	N	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ferendiuk et al 2014	Y	Y	Y	Y	N	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Lam et al 2001	Y	Y	Y	Y	N	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Macedo et al 2014	Y	Y	Y	Y	Y	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Silveira et al 2007	Y	Y	Y	Y	Y	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Tuz el al 2003	Y	Y	Y	Y	N	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Kuttila et al. 1999	Y	Y	Y	Y	N	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Kuttila et al. 2004	Y	Y	Y	Y	Y	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Murphy and Gay 2011	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	n/a	n/a	N	N
Di Rienzo Buscino et al 2004	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	N	N
Keersmaekers et al 1996	Y	N	N	Y	N	Y	Y	Y	Y	N	N	N	Y	N	N	N	N	N
Kuttila et al 2002	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	N	N
De Felicio et al 2008	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	N	N	Y	N	N
Tozoglu et al 2015	N	N	Y	Y	Y	n/a	Y	Y	Y	N	Y	N	N	N	N	n/a	N	N
Wright 2000	Y	Y	Y	Y	Y	n/a	Y	Y	Y	N	N	N	N	N	N	n/a	N	N
Jaber et al 2008	N	N	N	Y	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N
Lamer 1991	N	N	N	N	N	n/a	Y	Y	Y	N	N	N	N	N	N	n/a	N	N
Kef 2021	Y	N	Y	Y	Y	n/a	Y	Y	Y	Y	Y	N	N	N	N	n/a	N	N
Fitzpatrick et al 2020	N	N	N	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	N	N
Hardin et al 2018	N	N	N	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	N	N
Malik et al 2018	N	N	N	Y	Y	N	Y	Y	Y	N	N	N	N	N	N	Y	N	N
Maru and Patidar 2003	Y	N	Y	N	N	n/a	Y	Y	Y	N	N	N	N	N	N	n/a	N	N

Table 1 (continued)

Sundaram and Punj 2020	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	N	N
Waters et al 2019	N	N	N	N	N	n/a	Y	Y	Y	N	N	N	N	N	N	n/a	N	N
Clifton et al 2020	N	N	N	N	N	n/a	N	Y	Y	N	N	N	N	N	N	n/a	N	N
Fernandes et al 2017	N	Y	Y	N	N	n/a	Y	Y	Y	N	N	N	Y	N	N	n/a	N	N
Holste et al 2017	N	Y	Y	N	N	n/a	Y	Y	Y	N	N	N	Y	N	N	n/a	N	N
Lovely and Janetta 1997	N	Y	Y	N	N	n/a	Y	Y	Y	N	N	N	Y	N	N	n/a	N	N
Peris-Celda et al 2018	N	Y	Y	N	N	n/a	Y	Y	Y	N	N	N	N	N	N	n/a	N	N
Pulec 2002	N	N	Y	N	N	n/a	Y	Y	Y	N	N	N	Y	N	N	n/a	N	N
Robblee 2021	N	N	N	N	N	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Rupa et al 1991	N	N	N	Y	N	n/a	Y	Y	Y	N	N	N	Y	N	N	n/a	N	N
Ulubil et al 2009	N	N	N	N	N	n/a	Y	Y	Y	N	N	N	Y	N	N	n/a	N	N
Reddy et al 2019	N	Y	N	Y	N	n/a	Y	Y	Y	N	N	N	N	N	N	n/a	N	N
Roberts et al 2016	N	Y	N	Y	N	n/a	Y	Y	Y	N	N	N	Y	N	N	n/a	N	N
Teixido 2011	Y	Y	Y	Y	N	n/a	Y	Y	Y	N	N	N	Y	Y	n/a	n/a	N	N
Mohammedi et al 2005	Y	N	N	Y	Y	n/a	Y	Y	Y	N	N	N	Y	Y	n/a	n/a	N	N
Hagr and Bance 2011	Y	N	Y	Y	N	n/a	Y	Y	Y	N	N	N	N	N	N	n/a	N	N
Birnbaum 2015	N	N	N	N	N	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Iikuni et al 2013	N	Y	N	N	N	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

1. Were participants a representative sample selected from a relevant patient population (e.g., randomly selected from those seeking treatment despite age, duration of disease, primary or secondary disease, and severity of disease)?, 2. Were the inclusion/exclusion criteria of participants clearly described?, 3. Were participants entering the study at a similar point in their disease progression (i.e., severity of disease)?, 4. Was selection of patients consecutive?, 5. Was data collection undertaken prospectively?, 6. Were the groups comparable on demographic characteristics and clinical features?, 7. Was the intervention (and comparison) clearly defined?, 8. Was the intervention undertaken by someone experienced at performing the procedure? ("Yes" if the practitioner received training on conducting the procedure before or conducted same kind of procedure before [i.e., no learning curve].), 9. Were the staff, place, and facilities, where the patients were treated appropriate for performing the procedure (e.g., access to back-up facilities in hospital or special clinic)?, 10. Were any of the important outcomes considered (i.e., on clinical effectiveness, cost-effectiveness, or learning curves)?, 11. Were objective (valid and reliable) outcome measures used, including satisfaction scale?, 12. Was the assessment of main outcomes blind?, 13. Was follow-up long enough (≥ 1 year) to detect important effects on outcomes of interest?, 14. Was information provided on nonrespondents, dropouts? ("No" if participants were those whose follow-up records were available [retrospective].), 15. Were the characteristics of withdrawals/dropouts similar to those that completed the study and, therefore, unlikely to cause bias? ("Yes" if no withdrawal/dropout; "No" if dropout rate ≥ 30% or differential dropout), 16. Was length of follow-up similar between comparison groups?, 17. Were the important prognostic factors identified (e.g., age, duration of disease, and disease severity)? ("Yes" if two or more than two factors were identified.), 18. Were the analyses adjusted for confounding factors?

example, pain on palpating the TMJs or masticatory muscles [6, 14, 15]. Cooper and Kleinberg established the front of the ear as a palpation pain site in 49.8% of their study population [12]. It has also been reported that up to 16% of TMJD patients may experience ear symptoms alone (otalgia, tinnitus, vertigo or perceived hearing loss) [6].

The literature assessing the response of otologic symptoms, particularly otalgia, to the treatments provided for TMJD is limited. Most of the studies in our review, which

Table 2 Articles included in systematic review

Category	Topic/Pathology	Authors	Year	Study type	Sample size	Evidence level
A	Otalgia	Anwar et al.	2019	Prospective case series	150	4
A	Otalgia	Kuttila et al.	2001	Prospective cohort study	391	3
A	Otalgia	Sumitha and Joseph	2015	Prospective case series	103	4
A	Otalgia	Taziki and Behnampour	2012	Prospective case series	94	4
A	TMJD	Cooper and Kleinberg	2007	Retrospective case series	4528	4
A	TMJD	Ferendiuk et al.	2014	Retrospective case series	1208	4
A	TMJD	Lam et al.	2001	Retrospective case series	776	4
A	TMJD	Macedo et al.	2014	Cross-sectional study	197	4
A	TMJD	Silveira	2007	Cross-sectional study	211	4
A	TMJD	Tuz et al.	2003	Cross-sectional study	200	4
A	TMJD	Kuttila et al.	1999	Case series	411	4
A	TMJD/CSD	Kuttila et al.	2004	Prospective cohort study	91	3
M	TMJD/CSD	Murphy and Gay	2011	Retrospective case series	4	4
M	TMJD	Di Rienzo Businco et al.	2004	RCT (non-blinded)	36	2
M	TMJD	Keersmaekers	1996	Case–control	400	4
M	TMJD	Kuttila et al.	2002	RCT (double-blind)	36	2
M	TMJD	De Felicio et al.	2008	RCT (non-blinded)	28	2
M	TMJD	Tozoglu et al.	2015	Case series	57	4
M	TMJD	Wright et al.	2000	Case series	15	4
A + M	CSD	Jaber et al.	2008	Retrospective case series	123	4
M	CSD	Lamer	1991	Case series	2	4
M	Bruxism	Kef	2021	Prospective case series	37	4
M	Eagle Syndrome	Fitzpatrick et al.	2020	Retrospective case series	19	4
M	Eagle Syndrome	Hardin et al.	2018	Retrospective cohort study	21	3
M	Eagle Syndrome	Malik et al.	2018	Case series	12	4
M	Eagle Syndrome	Maru and Patidar	2003	Retrospective case series	332	4
M	Eagle Syndrome	Sundaram and Punj	2020	RCT (non-blinded)	51	2
M	Eagle Syndrome	Waters et al.	2019	Retrospective/prospective case series	32	4
A + M	NIN	Clifton et al.	2020	Case series	12	4
M	NIN	Fernandes et al.	2017	Retrospective case series	8	4
M	NIN	Holste et al.	2017	Retrospective case series	15	4
M	NIN	Lovely and Jannetta	1997	Retrospective case series	14	4
M	NIN	Peris-Celda et al.	2018	Retrospective case series	11	4
M	NIN	Pulec	2002	Retrospective case series	64	4
A + M	NIN	Robblee	2021	Case series	2	4
M	Neuralgia/NIN	Rupa et al.	1991	Retrospective case series	31	4
M	Neuralgia	Ulubil et al.	2009	Case series	3	4
M	Neuralgia	Reddy et al.	2019	Case series	8	4
M	Neuralgia	Roberts et al.	2016	Retrospective case series	12	4
M	Migraine	Teixido	2011	Retrospective case series	26	4
A + M	GORD	Mohammedi et al.	2005	Prospective case series	55	4
M	ATOM	Hagr and Bance	2011	Case–control	35	4
A + M	Rheumatic diseases	Birnbaum	2015	Retrospective case-series	3	4
A	Fibromyalgia	Iikuni et al.	2013	Case series	20	4

Articles categorised according to main focus; aetiology and/or management of pathology. Author, year of publication, study type, sample size of patients in article and evidence level detailed

A—aetiology, M—management, TMJD—temporomandibular joint dysfunction, CSD—cervical spine disease, NIN—nervus intermedius neuralgia, RCT—randomised controlled trial

include three randomised controlled trials albeit with relatively small case numbers, used only conservative management strategies; systemic and topical analgesia, appliance devices and myofascial therapy [15–19]. All of these studies showed a good response in resolution or improvement of non-otogenic otalgia following treatment for TMJD. Di Rienzo et al.'s randomised controlled trial (RCT) established that topical and oral diclofenac were equally effective in treating TMJD with topical application, hence avoiding adverse systemic effects [16].

A related condition, TMJ 'closed lock', which may also cause secondary otalgia was managed with a more invasive approach (arthrocentesis) which appeared to be effective in resolving or improving the associated otalgia [20].

Bruxism is often related to TMJD. Kef et al. treated 37 patients with otalgia secondary to bruxism with application of botulinum toxin to the temporal and masseter muscles concluding that it reduces both otalgia and muscle aches. Pain was observed to decrease at 2 weeks. Visual analogue scale scores were significantly lower post treatment at 1, 2 and 4 months but not at 6 months. Loss of effect occurred in 99.30 ± 11.32 days on average [21].

Thus, in general, treatment of TMJD is conservative with patient education, heat massages and splints. Non-steroidal medications are the first line of medical management. Surgical intervention is rarely required and generally reserved for correcting articular or anatomical abnormalities. Some centres have developed multidisciplinary clinics to guide treatment.

Dental pathology

TMJD is sometimes considered a dental cause of otalgia. Of course, other dental causes such as oral mucosal inflammation, pulpitis, apical periodontitis/abscess and 'impacted' third molars may all result in secondary otalgia. Three prospective case series in our review from India, Pakistan and Iran investigated the possible aetiologies of referred otalgia. Dental pathology was implicated as either the commonest [22] or second commonest cause [8, 23] with implication rates of 62.8%, 10% and 31%, respectively. Prompt referral to a dentist should be made in such cases.

Cervical spine disorder (CSD)

Cervical spine pathology, which includes degenerative diseases, has been associated with referred otalgia. The exact mechanism is controversial. Jaber et al. describe involvement of the upper cervical plexus (greater auricular and lesser occipital nerves) [24]. Typically, the pain is described as constant retroauricular or infra-auricular otalgia frequently related to changes in neck position [24].

Kuttila et al. investigated the association of secondary otalgia with CSD, TMJD or both in patients with and without CSD and TMJD. 35% of patients in his cohort with secondary otalgia had clinical signs of CSD, while a further 30% had signs and symptoms of both CSD and TMJD. He also found that most patients (60%) with secondary otalgia and TMJD demonstrated moderate or severe signs of CSD [7]. Cervical spine disorders were implicated in a small proportion of cases (4%) in Anwar et al.'s study in which tonsillar pathology (31%) was the leading cause [23].

Jaber et al. reported that cervical spine degenerative disease is a significant cause of referred otalgia representing 37% of their patient cohort with a statistically significant preponderance in patients over 65. All patients for which they had outcome data following physical therapy had subjective pain relief and thus they advocate conservative medical management [24]. Murphy and Gay chiropractically treated four patients with otalgia, of which three were diagnosed with cervical spine dysfunction, with a combination of chiropractic manual therapy of the ear and exercise. They reported resolution of otalgia in all cases [25]. Lamer, however, reported good outcomes in two patients with cervical spine arthritis and unilateral otalgia following injection of local anaesthetic and corticosteroid into the C1–C2 facet joint [26].

Given an ageing population it is important to consider degenerative cervical spine disease as a cause for referred otalgia, which necessitates appropriate physiotherapy. In the majority of cases, a history of neck pain or restriction of neck movement on examination can be elicited and the diagnosis may be supported by signs of degenerative disease on imaging which is present in most cases [24].

Fibromyalgia

Fibromyalgia is associated with increased sensitivity to pain all over the body. A Japanese study involving 20 patients found that otologic symptoms including otalgia are exacerbated following onset of fibromyalgia. Otalgia was reported in only one ear prior to onset of fibromyalgia, but in 16 post diagnosis based on retrospective recall via a questionnaire [27].

Eustachian tube dysfunction (ETD)

ETD can be a failure of opening (dilatory), a failure of closure (patulous) or baro-challenge induced. There is significant variation in the diagnostic criteria for ETD which was addressed in a consensus statement in 2015 [28]. Both dilatory and patulous dysfunction are associated with otoscopic or tympanometric evidence of ETD and would could be considered a primary cause of otalgia, but symptoms and signs can be intermittent. In baro-challenge-induced ETD,

otoscopy and tympanometry may be normal; however, we did not find any relevant studies that met our search criteria.

Eagle syndrome

Dr Watt Eagle first published on the condition now known as Eagle syndrome in 1937 (Eagle, 1937), which he described as secondary to an elongated styloid process causing irritation of the glossopharyngeal nerve (GPN). We now recognise calcified stylohyoid ligament as causing a similar constellation of symptoms, which includes non-otogenic otalgia.

To aid diagnosis, the tonsillar fossa is palpated for an elongated styloid process, symptomatic benefit is assessed with infiltration of local anaesthetic into the tonsillar fossa and are exacerbated with head turning. CT evidence of an elongated styloid process is confirmatory in addition to the symptoms [29].

Our literature search identified six papers demonstrating the evidence for non-surgical and surgical management of this condition between 2003 and 2020.

Waters et al. highlights that referred otalgia was one of the most common and highly rated symptoms of Eagle syndrome presentation [30]. It has been reported as the primary symptom in 44%, 48% and 67.46% of cases [29, 31, 32]. In one further study 16.6% of patients experienced referred otalgia [33].

Sundaram and Punj conducted a randomised controlled trial comparing ultrasound-guided vs surface anatomical landmarks for glossopharyngeal nerve blocks as the nerve is thought to be the cause of pain in Eagle syndrome. Both techniques proved to be effective but the greater precision using ultrasound-guidance provided a more prolonged period of pain relief [34]. Three patients received medical management with pregabalin in Malik et al.'s series. This appeared beneficial, although only with continuous use in two out of three patients [33].

In the largest series, Maru and Patidar's 332 patients underwent transoral styloidectomy under a local anaesthetic with no recurrence reported at 6 weeks [32]. Four further studies performed styloidectomy via transoral robotic surgery [35], traditional transoral approach [30, 31, 33] or transcervical approach [30, 31, 35] all of which reported largely positive outcomes.

Across all articles, complications were uncommon. Waters et al. described two cases of temporary mild marginal mandibular and hypoglossal nerve weakness with transcervical approach [30]. Hardin et al. reported 24% experiencing first bite syndrome, where patients experience severe facial pain with the first bite of a meal, and 19% reporting numbness, both of which were temporary [31]. The operative approach these patients underwent was not specified.

Medical management includes analagesia, steroid injections, anticonvulsants and antipsychotics [29]. The evidence supporting surgical management of Eagle syndrome is predominantly from limited case series in which preoperative CT imaging has confirmed the diagnosis followed by transoral or transcervical styloidectomy. There has been debate over optimal approach. The former is associated with a shorter intraoperative time and no external scar, but can be limited by poor exposure and lighting, increasing risk of damage to neighbouring neurovascular structures, e.g., carotid artery, vagus nerve. The latter approach facilitates exposure of the entire styloid length potentially enabling total styloidectomy which may prevent persistent symptoms due to remnant styloid bone and is associated with a higher risk of infection, a longer general anaesthesia, a neck scar and a risk of damaging the facial nerve (CNVII) [29, 30]. Transoral robotic surgery confers advantages of superior instrument manoeuvrability and endoscopic visualisation and has been performed in selected number of patients [29].

Meta-analyses performed found no statistical difference between the management strategies quoted within the three papers (Waters, Fitzpatrick, Malik) based on outcome measured by resolution of otalgia and interventional route (transoral vs transcervical). This is likely due to the heterogenicity of the studies and small numbers of patients (Fig. 2a, b).

Neuralgia

Neuralgia typically causes lancinating pain in the distribution of the affected nerve in the absence of neurologic deficit. Neuralgic pain manifesting as otalgia can be attributed to several nerves including the trigeminal, glossopharyngeal, facial and sphenopalatine nerves [1]. Due to the complex sensory innervation of the ear with overlapping contributions from CN V, VII, IX and X preoperative diagnostic tests, e.g., nerve blockade studies may not aid in differentiating neuralgias. Pharyngeal cocainisation may allude to glossopharyngeal neuralgia. MRI is useful to rule out other pathologies and can demonstrate neurovascular compression, although this is not always reliable.

We reviewed nine retrospective case series published between 1991 and 2021. Papers describe isolated geniculate neuralgia (GN) also known as nervus intermedius neuralgia (NIN) [36–38], cases with also likely concomitant trigeminal (TG) and/or glossopharyngeal neuralgia (GPN) [39–42], neuralgia of the sensory auricular branch of the facial nerve [43] and GPN attributed to Jacobson's nerve [44, 45].

Nervus intermedius neuralgia

Robblee et al. described medical management of NIN with amitriptyline, gabapentin and carbamazepine reporting favourable outcomes [46]. Seven case series describe surgical management of NIN in which nerve sectioning, microvascular decompression (MVD) or a combination of both

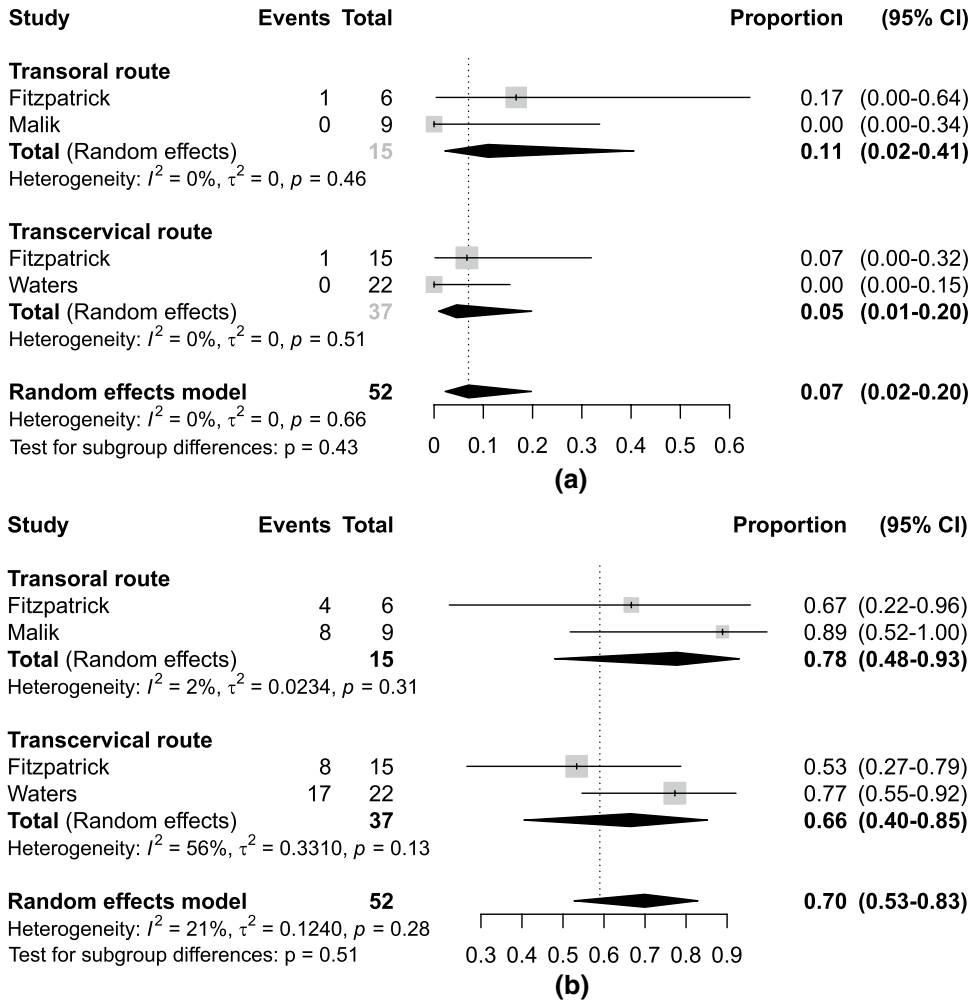

Fig. 2 **a** Forest plot for improvement rate according to type of intervention. Each study prevalence is displayed through as a black square, whose size was inversely proportional to standard error; horizontal bar represents 95% confidence interval. Diamonds represent the summary prevalences. **b** Forest plot for resolution rate according to type of intervention. Each study prevalence is displayed through as a black square, whose size was inversely proportional to standard error; horizontal bar represents 95% confidence interval. Diamonds represent the summary prevalences

were performed on differing nerves (nervus intermedius (NI) ± geniculate ganglion (GG), CN V, CNVII/VIII, CN IX and X).

Fernandes et al. performed MVD only and reported a high success rate in seven out of eight patients [36], while three other series [38, 40, 41] described a further seven patients, all with favourable outcomes following MVD alone for NIN. Of studies which reported outcomes for NI sectioning alone, Peris-Celda et al. and Clifton et al. found that two of four patients and four of five patients, respectively, experienced favourable pain outcomes [38, 40]. The majority of studies described combinations of NI and/or other nerve sectioning and MVD. In the largest series, 64 patients underwent NI + GG sectioning with 63 of 64 having excellent pain relief [37]. NI sectioning and MVD was performed in two studies with pain relief experienced by 14 of 16 patients [38, 41]. Overall results showed a good response to all treatments.

Five studies used the retrosigmoid approach to the NIN [36, 38–41], while Pulec used the middle cranial fossa approach [37]. Rupa et al. performed the middle cranial fossa approach for GG, posterior cranial fossa approach for NI, CN IX and CN X sectioning and a combined posterior-middle fossa approach for GG and exposure of NIN, CNV, CNIX and CNX [42].

With regard to complications, four series [37, 39, 41, 42] reported temporary facial nerve palsy; however, there were no cases of permanent facial nerve palsy. Six patients experienced CSF leak across the series. The only major complication reported is by Clifton, who described one patient with unserviceable hearing loss [38]. Pulec highlighted that all 64 of his patients had an expectant non-lacrimating eye on the involved side; a result of greater petrosal nerve excision [37]. In general, patients were spared deficits in taste and lacrimation unless there was destruction of the geniculate ganglion.

In general, MVD or NI sectioning is considered following failed medical therapy with anticonvulsants or antidepressants. The literature suggests the procedures are effective, though the evidence base is poor. Studies have thus far failed to demonstrate any significant difference between the surgical techniques. We attempted to compare the techniques; however, heterogeneity of surgical procedures with

multiple studies performing sectioning of differing nerves or MVD made interpretation of the results difficult. This may be attributed to concerns of an alternative or confounding neuralgia, although not all series specify this. Indeed, Lovely and Janetta supported the prophylactic MVD of CN V and IX–X in patients who underwent NI sectioning reporting pain relief in 90% of patients [41]. Peris-Celda included MVD or sectioning of CN V or IX–X in most patients who underwent NI sectioning and also report generally favourable outcomes [40]. Rupa et al. were even more aggressive performing multiple nerve sectionings, reporting an overall success rate of 72.2% [42]. The benefit of combination procedures may be attributed to the complex overlapping sensory innervation of the ear. Conversely, Fernandes et al. advocated MVD of CNVII/CNVIII complex alone demonstrating good outcomes [36].

With regard to morbidity it does seem reasonable to infer that sectioning of neural structures is associated with more permanent sequelae. Indeed, Pulec's 64 patients experienced an ipsilateral non-lacrimating eye secondary to geniculate ganglionectomy [37], while most of the complications experienced by patients undergoing MVD in Fernandes et al.'s series were temporary [36].

Neuralgia of the sensory auricular branch of the facial nerve

Ulubil et al. presented a less invasive approach to treat three patients diagnosed with idiopathic recalcitrant otalgia of the sensory auricular branch of CN VII. They sectioned the sensory branch along the posterior wall of the ear canal via a standard mastoidectomy approach. Due to the extracranial nature potential morbidity is reduced compared to intracranial procedures. No patients had any complications and patients remained symptom-free at 1-year follow-up. With no further reports in the literature and given the branch is a disputed structure, validation in larger cohorts is required [43].

Glossopharyngeal neuralgia

Roberts et al. described tympanic plexus neurectomy for intractable otalgia in 12 patients (13 ears) with no associated morbidity. 69.2% of their cases had complete resolution (of which three underwent revision surgery), while 15.4% had partial benefit from the procedure [44]. Reddy et al. performed endoscopic tympanic neurectomy in eight patients with otic neuralgia refractory to medical management, four of which underwent an additional procedure for concurrent pathology (hyperacusis, autophony, imbalance, semi-circular canal dehiscence). According to their results all patients were pain free at 9-month follow-up, although one patient necessitated a repeat procedure [45].

The literature on tympanic neurectomy for neuralgic otalgia is rare albeit 11.3% of patients with glossopharyngeal neuralgia are thought to have isolated otalgia [44]. Reddy et al. propose that otic neuralgia may be a result of post infectious or traumatic insult to the tympanic nerve comparable to the pathophysiology of post-herpetic neuralgia. Recurrence of symptoms has been attributed to regrowth of the nerve and thus Reddy et al. advocate an endoscopic approach due to enhanced visualisation enabling a more accurate and complete neurectomy [45]. Although Roberts et al. largely performed the procedure microscopically an endoscope was used to aid visualisation of Jacobson's nerve for their revision cases [44].

Due to the heterogeneity of the surgical techniques and lack of consistent outcome data confounded by generally small cohort sizes in the included studies, statistical analysis was not possible for neuralgias in this review.

Migraine

Teixido et al. evaluated the response of otalgia, for which no cause had been identified despite a full workup, to migraine treatment. Dihydroergotamine nasal spray was employed as abortive treatment in patients experiencing infrequent long-lasting episodes of otalgia, while prophylactic treatment included tricyclic antidepressants, beta-blockers, calcium channel blockers and sodium channel blockers. He found that 92% responded to migraine therapy. Interestingly, while 65% of patients met International Headache Society criteria, otalgia not headache was the primary complaint [47].

Gastro-oesophageal reflux disease (GORD)

Observational studies of GORD suggest that otalgia may be present in up to 40% of cases of GORD. Mohammedi et al. showed that 83% of 55 patients with confirmed GORD in history and at least one physical sign on flexible nasendoscopy (including, amongst others, pachyderma laryngitis and inflamed arytenoids) had a positive response to 6-month treatment of lifestyle advice and a proton pump inhibitor [48].

Anterolateral tip of mastoid syndrome (ATOM)

A very specific syndrome, named ATOM by the authors, and generally affecting patients following a post aural incision for mastoid surgery was treated using lidocaine injections in 11 patients with benefit to 10 of them. These patients had very specific tenderness at the anterior tip of the mastoid process. All patients had ear surgery in the past at least 3 months before enrolment in the study (to exclude acute post-operative pain). All of the 10 patients who benefitted from lidocaine injections were relatively pain free at 1-month

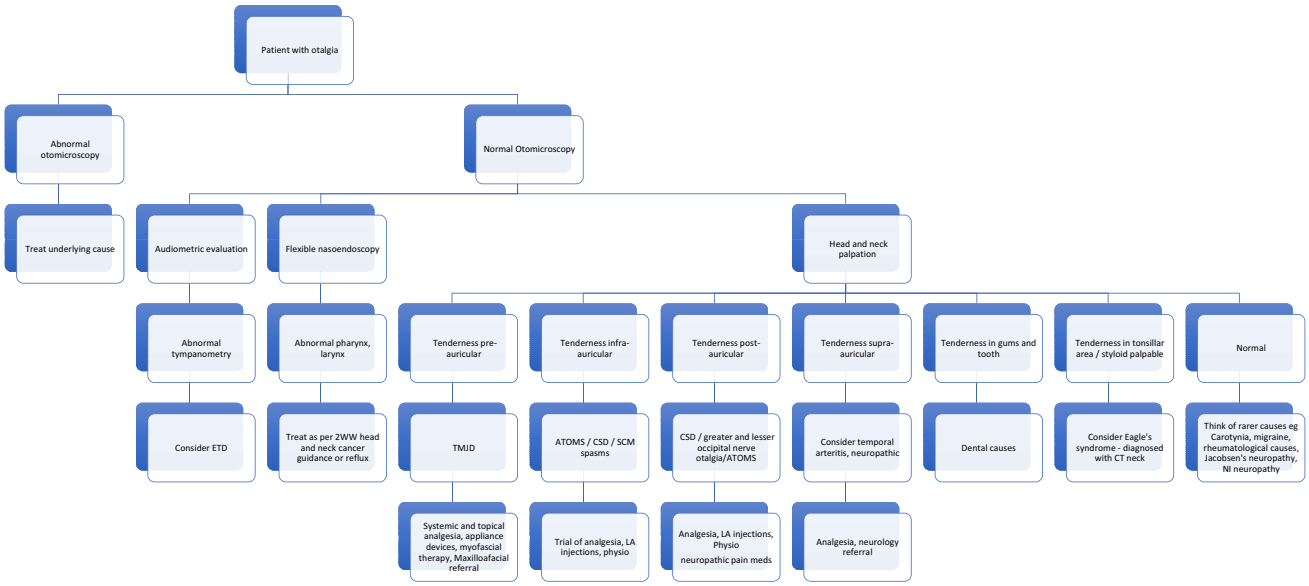

Fig. 3 Algorithm for management of secondary otalgia. *ETD* Eustachian tube dysfunction, *2WW* 2-week wait head and neck cancer referral, *TMJD* Temporomandibular joint dysfunction, *ATOM* anterolateral tip of mastoid syndrome, *CSD* cervical spinal disorders, *SCM* sternocleidomastoid, *LA* local anaesthetic

follow-up and the two who had relapsed at the 10-month follow-up had re-injection. The pathophysiology remains unknown [49].

Rheumatic disease

Otalgia with a normal ear has been recognised as a feature of rheumatoid diseases. One publication has alluded to a novel neurological disorder in three rheumatic disease patients defined by a triad of facial weakness, otalgia with neuropathic features and hemifacial spasm. Intravenous immunoglobulin was successfully used to treat one patient [50].

Other

Interestingly, despite known associations of secondary otalgia with other non-malignant head and neck pathologies, for example, sinonasal and salivary gland disease, our search did not yield original articles meeting the search criteria on many such topics.

Discussion

Quality of evidence and potential bias in review

This systematic review aimed to analyse the available evidence base for the aetiology and management of secondary otalgia focussing on non-malignant causes. TMJD, Eagle syndrome and NIN were the most commonly described conditions. We appreciate that the majority of the conditions described in the review are associated with otalgia without definitive proof of causation and multiple aetiologies may account for the patient's otalgia. Furthermore, many of the diagnoses are based on clinical judgement, which may be subjective. The majority of the included 44 articles were level four case series according to the Oxford Centre for Evidence-based medicine grading. Thus, the overall quality of the studies and evidence for most causes and interventions was judged to be poor. That said, most articles retrieved were on TMJD, and its management was associated with the highest quality of evidence with three randomised controlled trials conducted in Italy, Finland and Brazil. There was one further RCT included in our review on management of Eagle syndrome from India.

The literature focussing on secondary otalgia and other causes, for example, sinonasal disease, migraine, or thoracic conditions appears scarce. This could be attributed to the fact that otalgia may not be the predominant symptom in these pathologies contributing to the diagnostic challenge. Likewise, although several neuralgias have been implicated in secondary otalgia, our search yielded articles predominantly centred on those being described as NIN despite its rarity. Our search indicated that other neuralgias had stronger associations with symptoms other than otalgia, e.g., throat or facial pain and thus were excluded from our review. It is important to note that in many cases the ascribing of neuralgic pain to a particular nerve seems arbitrary in the literature. We acknowledge there were no studies on the surgical management of TMJD in patients with secondary

otalgia perhaps reflecting the more predominant musculoskeletal symptoms and response to conservative approaches.

Summary

Treatment of secondary otalgia is dependent on the diagnosis. Figure 3 outlines a decision-making algorithm guide based on the evidence we have reviewed.

Limitations

Our study was limited by several factors. We recognised that we had chosen to study a fairly niche topic; however, the applications to a general practice or ENT clinic is vast with otalgia being a very frequent presenting complaint. As a result of the myriad aetiology to this presentation, we recognised that the evidence base to each individual cause and its management was likely to be poor and hence incorporated a wide and extensive search result to ensure all grounds were covered. This is also reflected in our meta-analyses, which found no real difference in management strategies due to the heterogeneity, which includes duration of follow-up, and low power of the studies.

Conclusions

Most of the published literature on the aetiology and management of conditions associated with referred otalgia is level 4. The patient presenting with referred otalgia is a diagnostic challenge. The differential diagnosis is vast and thus knowledge of the complex neuroanatomic innervation of the ear is imperative. Systematic and diligent assessment and management is needed to diagnose and treat the underlying pathology. In some instances, a 'trial and error' approach may need to be employed.

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Declarations

Conflict of interest The author declares that they have no conflict of interest.

References

1. Norris CD, Koontz NA (2020) Secondary otalgia: referred pain pathways and pathologies. AJNR Am J Neuroradiol 41(12):2188–2198. https://doi.org/10.3174/ajnr.A6808
2. Earwood JS, Rogers TS, Rathjen NA (2018) Ear pain: diagnosing common and uncommon causes. Am Fam Physician 97(1):20–27. https://auth.elsevier.com/ShibAuth/institutionLogin?entityID=https://idp.eng.nhs.uk/openathens&appReturnURL=https%3A%2F%2Fwww.clinicalkey.com%2Fcontent%2FplayBy%3Fissn%3D0002-838X%26vol%3D97%26issue%3D1%26pgfirst%3D20
3. Normand SL (1999) Meta-analysis: formulating, evaluating, combining, and reporting. Stat Med 18(3):321–359. https://doi.org/10.1002/(sici)1097-0258(19990215)18:3%3c321::aid-sim28%3e3.0.co;2-p
4. Brazzelli M, Cruickshank M, Tassie, McNamee P, Robertson CE (2015) Appendix 4 risk-of-bias checklist: non-randomised comparative studies. Collagenase clostridium histolyticum for the treatment of Dupuytren's Contracture: systematic review and economic evaluation. Health Technol Assess (Rockv)
5. OCEBM Levels of Evidence Working Group (2011) The Oxford 2011 Levels of Evidence. Oxford Cent Evidence-Based Med. http://www.cebm.net/index.aspx?o=5653
6. Lam DK, Lawrence HP, Tenenbaum HC (2001) Aural symptoms in temporomandibular disorder patients attending a craniofacial pain unit. J Orofac Pain 15(2):146–157
7. Kuttila S, Kuttila M, Le Bell Y, Alanen P, Suonpää J (2004) Characteristics of subjects with secondary otalgia. J Orofac Pain 18(3):226–234
8. Sumitha R, Joseph NA (2015) Referred otalgia—a case series. Asian J Pharm Clin Res 8(2):343–345
9. Ferendiuk E, Zajdel K, Pihut M (2014) Incidence of otolaryngological symptoms in patients with temporomandibular joint dysfunctions. Biomed Res Int 2014:824684. https://doi.org/10.1155/2014/824684
10. Macedo J, Doi M, Oltramari-Navarro PV et al (2014) Association between ear fullness, earache, and temporomandibular joint disorders in the elderly. Int Arch Otorhinolaryngol. 18(4):383–386. https://doi.org/10.1055/s-0034-1385844
11. Tuz HH, Onder EM, Kisnisci RS (2003) Prevalence of otologic complaints in patients with temporomandibular disorder. Am J Orthod Dentofacial Orthop 123(6):620–623. https://doi.org/10.1016/s0889-5406(03)00153-7
12. Cooper BC, Kleinberg I (2007) Examination of a large patient population for the presence of symptoms and signs of temporomandibular disorders. Cranio 25(2):114–126. https://doi.org/10.1179/crn.2007.018
13. Silveira AM, Feltrin PP, Zanetti RV, Mautoni MC (2007) Prevalence of patients harboring temporomandibular disorders in an otorhinolaryngology department. Braz J Otorhinolaryngol 73(4):528–532. https://doi.org/10.1016/s1808-8694(15)30105-1
14. Kuttila S, Kuttila M, Le Bell Y, Alanen P, Jouko S (1999) Aural symptoms and signs of temporomandibular disorder in association with treatment need and visits to a physician. Laryngoscope 109(10):1669–1673. https://doi.org/10.1097/00005537-199910000-00022
15. de Felício CM, de Melchior MO, Ferreira CLP, Da Silva MAMR (2008) Otologic symptoms of temporomandibular disorder and effect of orofacial myofunctional therapy. Cranio 26(2):118–125. https://doi.org/10.1179/crn.2008.016
16. Di Rienzo BL, Di Rienzo BA, D'Emilia M, Lauriello M, Coen TG (2004) Topical versus systemic diclofenac in the treatment of temporo-mandibular joint dysfunction symptoms. Acta Otorhinolaryngol Ital 24(5):279–283
17. Wright EF, Syms CA, Bifano SL (2000) Tinnitus, dizziness, and nonotologic otalgia improvement through temporomandibular disorder therapy. Mil Med 165(10):733–736
18. Hodges JM (1990) Managing temporomandibular joint syndrome. Laryngoscope 100(1):60–66. https://doi.org/10.1288/00005537-199001000-00013

19. Kuttila M, Le Bell Y, Savolainen-Niemi E, Kuttila S, Alanen P (2002) Efficiency of occlusal appliance therapy in secondary otalgia and temporomandibular disorders. Acta Odontol Scand 60(4):248–254. https://doi.org/10.1080/000163502760148034
20. Tozoglu S, Bayramoglu Z, Ozkan O (2015) Outcome of otologic symptoms after temporomandibular joint arthrocentesis. J Craniofac Surg 26(4):e344–e347. https://doi.org/10.1097/SCS.0000000000001808
21. Kef K (2021) Application of botulinum toxin in patients with secondary otalgia caused by bruxism. J Pain Res 14:1051–1059. https://doi.org/10.2147/JPR.S292550
22. Taziki MH, Behnampour N (2012) A study of the etiology of referred otalgia. Iran J Otorhinolaryngol 24(69):171–176. https://doi.org/10.22038/ijorl.2011.195
23. Anwar K, Khan S, Shahabi I, Niazi ZB (2019) The frequency of involvement of head & neck sites in referred otalgia—an experience at a tertiary care hospital. Pakistan J Med Sci 35(4):1138–1142. https://doi.org/10.12669/pjms.35.4.236
24. Jaber JJ, Leonetti JP, Lawrason AE, Feustel PJ (2008) Cervical spine causes for referred otalgia. Otolaryngol Head Neck Surg 138(4):479–485. https://doi.org/10.1016/j.otohns.2007.12.043
25. Murphy DR, Gay CW (2011) Manual therapy and ear pain: a report of four cases. J Can Chiropr Assoc 55(1):40–46
26. Lamer TJ (1991) Ear pain due to cervical spine arthritis: treatment with cervical facet injection. Headache 31(10):682–683. https://doi.org/10.1111/j.1526-4610.1991.hed3110682.x
27. Iikuni F, Nomura Y, Goto F, Murakami M, Shigihara S, Ikeda M (2013) Why do patients with fibromyalgia complain of ear-related symptoms? Ear-related symptoms and otological findings in patients with fibromyalgia. Clin Rheumatol 32(10):1437–1441. https://doi.org/10.1007/s10067-013-2287-2
28. Schilder AGM, Bhutta MF, Butler CC et al (2015) Eustachian tube dysfunction: consensus statement on definition, types, clinical presentation and diagnosis. Clin Otolaryngol 40(5):407–411. https://doi.org/10.1111/coa.12475
29. Fitzpatrick TH, Lovin BD, Magister MJ, Waltonen JD, Browne JD, Sullivan CA (2020) Surgical management of Eagle syndrome: a 17-year experience with open and transoral robotic styloidectomy. Am J Otolaryngol 41(2):102324. https://doi.org/10.1016/j.amjoto.2019.102324
30. Waters CM, Ho S, Luginbuhl A, Curry JM, Cognetti DM (2019) Surgical management of stylohyoid pain (Eagle's) syndrome: a 5-year experience. Ann Otol Rhinol Laryngol 128(3):220–226. https://doi.org/10.1177/0003489418816999
31. Hardin FM, Xiao R, Burkey BB (2018) Surgical management of patients with Eagle syndrome. Am J Otolaryngol 39(5):481–484. https://doi.org/10.1016/j.amjoto.2018.05.003
32. Maru YK, Patidar K (2003) Stylalgia and its surgical management by intra oral route-clinical experience of 332 cases. Indian J Otolaryngol Head Neck Surg 55(2):87–90. https://doi.org/10.1007/BF02974610
33. Malik J-N, Monga S, Sharma A-P, Nabi N, Naseeruddin K (2018) Stylalgia revisited: clinical profile and management. Iran J Otorhinolaryngol 30(101):335–340. https://doi.org/10.22038/ijorl.2018.21760.1787
34. Sundaram S, Punj J (2020) Randomized controlled trial comparing landmark and ultrasound-guided glossopharyngeal nerve in eagle syndrome. Pain Med 21(6):1208–1215. https://doi.org/10.1093/pm/pnz370
35. Fitzpatrick TH, Lovin BD, Magister MJ, Waltonen JD, Browne JD, Sullivan CA (2020) Surgical management of Eagle syndrome: a 17-year experience with open and transoral robotic styloidectomy. Am J Otolaryngol Head Neck Med Surg 41(2). https://go.openathens.net/redirector/nhs?url=https%3A%2F%2Fwww.clinicalkey.com%2Fcontent%2FplayBy%2Fdoi%2F%3Fv%3D10.1016%2Fj.amjoto.2019.102324
36. Goulin Lippi Fernandes E, van Doormaal T, de Ru S, Miller K, Han KS (2018) Microvascular decompression of the VII/VIII cranial nerve complex for the treatment of intermediate nerve neuralgia: a retrospective case series. Oper Neurosurg (Hagerstown, Md.) 15(4):378–385. https://doi.org/10.1093/ons/opx271
37. Pulec JL (2002) Geniculate neuralgia: long-term results of surgical treatment. Ear Nose Throat J 81(1):30–33. http://gateway.proquest.com/openurl?ctx_ver=Z39.88-2004&res_id=xri:pqm&req_dat=xri:pqil:pq_clntid=48038&rft_val_fmt=ori/fmt:kev:mtx:journal&genre=article&issn=0145-5613&volume=81&issue=1&spage=30
38. Clifton WE, Grewal S, Lundy L, Cheshire WP, Tubbs RS, Wharen RE (2020) Clinical implications of nervus intermedius variants in patients with geniculate neuralgia: let anatomy be the guide. Clin Anat 33(7):1056–1061. https://doi.org/10.1002/ca.23536
39. Holste KG, Hardaway FA, Raslan AM, Burchiel KJ (2018) Pain-free and pain-controlled survival after sectioning the nervus intermedius in nervus intermedius neuralgia: a single-institution review. J Neurosurg 131(2):352–359. https://doi.org/10.3171/2018.3.JNS172495
40. Peris-Celda M, Oushy S, Perry A et al (2018) Nervus intermedius and the surgical management of geniculate neuralgia. J Neurosurg 131(2):343–351. https://doi.org/10.3171/2018.3.JNS172920
41. Lovely TJ, Jannetta PJ (1997) Surgical management of geniculate neuralgia. Am J Otol 18(4):512–517
42. Rupa V, Saunders RL, Weider DJ (1991) Geniculate neuralgia: the surgical management of primary otalgia. J Neurosurg 75(4):505–511. https://doi.org/10.3171/jns.1991.75.4.0505
43. Ulubil SA, Eshraghi AA, Telischi FF (2009) Sectioning the sensory auricular branch of the facial nerve to treat recalcitrant otalgia. Otol Neurotol 30(4):522–524. https://doi.org/10.1097/MAO.0b013e31819e9084
44. Roberts DS, Yamasaki A, Sedaghat AR, Lee DJ, Reardon E (2016) Tympanic plexus neurectomy for intractable otalgia. Laryngoscope Investig Otolaryngol 1(5):135–139. https://doi.org/10.1002/lio2.31
45. Reddy R, Jufas N, Bance M, Patel N (2019) Endoscopic tympanic neurectomy for otic neuralgia—a case series. Aust J Otolaryngol 2(August):21–21. https://doi.org/10.21037/ajo.2019.07.01
46. Robblee J (2021) A pain in the ear: two case reports of nervus intermedius neuralgia and narrative review. Headache 61(3):414–421. https://doi.org/10.1111/head.14066
47. Teixido M, Seymour P, Kung B, Lazar S, Sabra O (2011) Otalgia associated with migraine. Otol Neurotol 32(2):322–325. https://doi.org/10.1097/MAO.0b013e318200a0c4
48. Mohammadi M, Ghadimi R, Saedi B (2005) Empiric therapy in otolaryngologic manifestations of gastroesophageal reflux disease. Acta Med Iran 43(1):15–18
49. Hagr A, Bance M (2011) An otalgia pain syndrome, the anterolateral tip of the mastoid syndrome (ATOMS): diagnosis and response to treatment. J Otolaryngol Head Neck Surg 40(5):359–366. https://doi.org/10.2310/7070.2011.100282
50. Birnbaum J (2015) Facial weakness, otalgia, and hemifacial spasm: a novel neurological syndrome in a case-series of 3 patients with rheumatic disease. Medicine (Baltimore) 94(40):e1445. https://doi.org/10.1097/MD.0000000000001445