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Systematic Review of Management Strategies for Middle Ear Myoclonus

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Abstract

Objective. Middle ear myoclonus is a rare condition with distinct characteristics at presentation. Diagnosis is based primarily on history, clinical examination, and long-time-based tympanometry. No consensus exists regarding treatment at present. This review was designed to identify relevant studies on current investigation and management.

Data Source. A systematic electronic literature search of MEDLINE, Embase, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane Trials register, and Web of Science was conducted for articles describing middle ear myoclonus through to May 2011. English- and non-English-language articles that focused on investigation and treatment were considered for review.

Review Method. Two authors independently reviewed the articles for study design, treatment, intervention, and outcome. Data from human and experimental studies were considered.

Results. A total of 21 articles were identified for this review. Most studies were found to be case reports or small case series. In general, there was no evidence of a conclusive diagnostic test or treatment for middle ear myoclonus.

Conclusion. There is a need for high-quality prospective controlled trials to determine the most effective management of middle ear myoclonus. The authors describe a treatment algorithm based on the data available and clinical knowledge.

Keywords

middle ear myoclonus, intratympanic myoclonus, stapedial myoclonus, tensor tympani myoclonus, tinnitus

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Myoclonus is a sudden, involuntary jerking of a muscle or group of muscles.[1] Middle ear myoclonus (MEM) is a rare disorder produced by repetitive contractions of the middle ear muscles.[2,3] It is unclear whether the myoclonus is a part of a systemic myoclonic disorder or an isolated middle ear entity. The contractions are normally limited to one side and may result in objective or subjective tinnitus. This tinnitus is described as clicking or buzzing in nature but varies widely between patients.

How MEM produces an auditory sensation is unknown. Tensor tympani contraction is said to produce a clicking sound, whereas stapedius muscle contraction produces a buzzing noise.[4] The tinnitus could be due to the conduction of the muscle contraction noise, which may explain in some cases why it is objective in nature. It could also be due to potential vibration of the tympanic membrane during contraction of the intratympanic muscles, as shown by a saw-toothed pattern on long-time-based tympanometry. It may also be the case that the movement of the ossicular chain in MEM directly sends a pressure wave to the cochlea. Since its first description in the 19th century,[5] MEM remains a clinical enigma with obscure etiology and variable management strategies.

Anatomy and Physiology

The stapedius muscle arises from the wall of a conical cavity, hollowed out of the interior of the pyramidal eminence. The stapedius tendon (ST) arises from the apex of the pyramid and inserts into the posterior surface of the neck of the stapes. It is innervated by the facial nerve. The tensor tympani (TT) arises from the wall of the bony canal lying above the eustachian tube. Parts of the muscle also arise from the cartilaginous portion of the eustachian tube and the greater wing of sphenoid; the muscle enters the processus cochleariformis and passes laterally to insert into the medial aspect of the malleus handle. The mandibular nerve (a motor branch of the trigeminal nerve) supplies the TT. The contraction of stapedius pulls the

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stapes posteriorly with lateral displacement of the posterior tympanic membrane while the contraction of TT pulls the malleus medially and anteriorly with inward movement of the tympanic membrane (TM).

Moderate to loud sound in a conscious human will normally evoke an "acoustic reflex" with contraction of the stapedius muscle; this leads to an increase in the stapes-annular ligament impedance and decreased middle ear sound transmission.[6,7] It is also shown to attenuate frequency stimulus components, improving the intelligibility of speech at high intensities.[8] The stapedius muscle may have nonauditory inputs, as a few patients are able to voluntarily contract the muscle, suggesting cortical projections to the stapedius motor neurons.[9] The TT in humans is associated with a startle reflex, which may be elicited by intense/abrupt sound[10] or other stimuli. The extent to which this is a pure startle or an auditory reflex remains unclear. Contraction of the middle ear muscles may also serve to damp out unwanted resonance at high frequencies, as shown by experimental observations on cats by Simmons.[11] The TT is associated with the tensor veli palatini muscle, which controls tension in the wall of the eustachian tube.[12] The tensor veli palatini muscle and the TT both are supplied by the trigeminal nerve, and both have insertions in the cartilaginous portion of the eustachian tube and are assumed to play an important role in middle ear ventilation. The spontaneous TT contractions when synchronous with tubal muscle activity will cause an increase in pressure, which aids pushing open the eustachian tube isthmus by breaking the mucous membrane surface tension. The TT has also shown to contract in response to stimuli other than external sound, including stimulation of the cornea by a puff of air, touching the skin around the eye or external ear, closing of the eyes, body movements, vocalization, and, in some subjects, by voluntary effort.[10]

In summary, the functions of the contractions of the stapedius and TT that have been proposed are protection from noise-induced cochlear dysfunction and selective attenuation of low-frequency sound components.

This review was designed to gain insight into the diagnosis and treatment of middle ear myoclonus. The efficacy of both surgical and nonsurgical management was evaluated by conducting a systematized and thorough search of the available literature for both human and animal studies. An algorithm of the management based on the available literature is suggested.

Methods

The search strategy used MEDLINE, Embase, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane Trials register, and Web of Science databases to review the English and non-English literature. No filter was applied to the date of publication. The search terms *middle ear myoclonus, intratympanic myoclonus, stapedial myoclonus, tensor tympani myoclonus, transtympanic myoclonus*, and *myoclonus* were used. To ensure comprehensive coverage of an underresearched area, a secondary assessment was performed of the reference lists and citation indexes of identified manuscripts to include further relevant literature. Short listing was performed independently by the 2 lead authors on the basis of relevance, followed by synthesis and a discussion of differences.

Study Selection Criteria

Articles for potential selection were screened using the following inclusion criteria: availability of an English- or non-English-language abstract and focus on symptoms, investigation, and use of adjuvant, pharmacological, or surgical treatment in middle ear myoclonus. Relevant studies describing underlying pathophysiology were also included. General tinnitus review articles and those that described non-MEM pulsatile tinnitus were excluded.

Methodological Quality of Selected Studies

Study design was reviewed for all studies, with summary details provided in **Tables 1** to **3**. As there were no randomized trials in this analysis, the Newcastle-Ottawa (N-O) criteria were employed to assess quality of studies where indicated.[13] This checklist directs assessment of study methods, presentation, data reporting, and external and internal validity. Because of the paucity of literature, no articles were excluded on the basis of quality. Letters, comments, editorials, abstracts, reports from meetings, and case reports were all included.

Results

Literature Search Results

The initial literature search yielded 44 potential candidate citations. Screening of titles and abstracts using the inclusion criteria identified 27 abstracts (**Figure 1**). Seven additional studies were identified through searching related articles, references, and publications by previously identified primary authors, bringing the total to 34 abstracts. Where abstracts alone were unavailable, the full text was reviewed. English full text was available for review for all but 2 articles.[14,15] These were both translated within our institution (see Acknowledgment). After review of all 34 studies, 13 were excluded, yielding a total of 21 articles for inclusion in this review. Among those studies provided in **Table 1**, 1 case was published in 3 different journals[3,16,17] with similar duplication in a further case.[18,19] **Table 2** contains a case series that included 4 patients with MEM from a total of 13 patients with objective tinnitus.[5]

Study Quality

The search revealed mainly case reports or case series; however, 2 human experimental studies and 1 animal study were included. **Table 1** and **Table 2** describe the clinical features, investigations, treatment, and outcome from retrospective case reports and case series, respectively. **Table 3** includes controlled observational studies and an animal study, which were assessed using the N-O criteria.

Human Studies

Tinnitus is the most common presenting symptom in patients with MEM. Most commonly, a clicking or buzzing quality is described, but this varies widely between patients and may be variable for the individual.[2,5,20] The tinnitus also varies widely in reported intensity, frequency (pitch), and frequency of

Table 1. Case Reports with Management

Study	Level[a]	Clinical Features	Investigation	Intervention	Follow-up	Outcome
Liu et al (2011)[21]	4	Unilateral tinnitus + hemifacial spasms	Audiometry; CT + MRI head serology	Topical botulinum	NA	Full resolution for 3 months
Ha (2007)[28]	4	Unilateral objective intrusive tinnitus second to foreign body	Audiometry; MRI brain	Orphenadrine citrate + piracetam	3 weeks	Partial resolution
Howsam et al (2005)[24]	4	Bilateral objective tinnitus. Not incapacitating.	Audiometry; tympanometry	Conservative	12 months	No intervention required as hearing loss mild + discussed bilateral MEM to be a congenital phenomenon
Abdul-Baqi (2004)[29]	4	Unilateral continuous high-frequency objective tinnitus	Audiometry; tympanometry	Orphenadrine citrate	5 weeks	Full resolution
Van der Gaag (2004)[14]	4	Unilateral tinnitus after traumatic facial nerve injury	Audiometry; tympanometry; CT head	ST tenotomy	NA	Full resolution
Cohen and Perez (2003)[27]	4	Bilateral subjective R>L	Audiometry; tympanometry	Bilateral TT tenotomy	2 months	Full resolution
Brosch et al (2003) [15]	4	Bilateral objective tinnitus	Audiometry; tympanometry; MRI head	Hearing aid	12 months	Tolerable tinnitus
Oliveira et al (2003)[25]	4	Bilateral tinnitus	Audiometry; tympanometry; MRI brain; CT temporal bone	ST and TT tenotomy	2 months	Partial resolution due to associated palatal myoclonus
Zipfel et al (2000)[20]	4	Bilateral subjective incapacitating tinnitus in a patient with multiple sclerosis	Audiometry; MRI brain; tympanometry	Bilateral ST + TT tenotomy	NA	Full resolution
Bento et al (1998)[3]	4	Unilateral continuous high-frequency objective tinnitus	Audiometry; CT temporal bone; magnetic resonance angiography; CSF analysis; tympanometry	Muscle relaxant (curare) to aid diagnosis + ST and TT tenotomy	1 year	Full resolution
Rajah (1992)[23]	4	Bilateral tinnitus associated blinking of eye	Audiometry; tympanometry; stapedial reflexes; blood: ESR, FBC; CT head	Carbamazepine	3 months	Partial resolution
Williams (1980)[22]	4	Unilateral tinnitus	Audiometry; tympanometry	ST tenotomy	NA	Full resolution

Abbreviations: CSF, cerebrospinal fluid; CT, computed tomography; ESR, erythrocyte sedimentation rate; FBC, full blood count; L, left; MEM, middle ear myoclonus; MRI, magnetic resonance imaging; NA, not available; R, right; ST, stapedius tendon; TT, tensor tympani.
[a]Levels of evidence, Oxford Centre for Evidence-Based Medicine.[40]

rapid bursts: it may be subjective or objective (eg, perceivable by an external listener).[3,15,18] In patients with previous facial palsy, the resulting synkinesis can cause tinnitus associated with hemifacial spasm and exposure to loud noise or blepharospasm.[3,21] It may also cause alterations in tinnitus.[22] In one case, tinnitus was associated with blinking of an eye with no history of facial nerve palsy.[23] Some patients had associated pain in the ear, hearing loss,[18] and vertigo.[3]

Diagnosis of MEM vs Other Disorders

The diagnosis of MEM is based on a history of pulsatile tinnitus, observation of rhythmic movements of the TM synchronous with the tinnitus, and associated demonstration of impedance changes on tympanometry[18,19] and long-time-based tympanometry. A tympanometric cogwheel or saw-toothed pattern has been described in MEM by various authors[4,18,19,24,25] for both ST and TT myoclonus, making it an unreliable tool for diagnosing specific muscle myoclonus. Diagnosis may be confirmed only at tympanotomy on direct visualization of MEM.

The main differential diagnosis is palatal myoclonus. Other differential diagnoses, such as temporomandibular joint (TMJ) abnormalities, patulous eustachian tube, and vascular abnormalities, should be considered.

Palatal myoclonus is diagnosed in patients with objective pulsatile tinnitus associated with involuntary movement of the

Table 2. Case Series with Management

Study	No.	Level[a]	Clinical Features	Investigation	Treatment	Follow-up	Outcome
Golz et al (2003)[18]	3	4	Bilateral + unilateral objective tinnitus	Audiometry	Bilateral ST + TT tenotomy ×2; unilateral ST tenotomy ×1	1 year	Full resolution
Badia et al (1994)[2]	6	4	Involuntary and rhythmic clicking or buzzing tinnitus, which is invariably unilateral	Audiometry; tympanometry	Unilateral ST + TT tenotomy ×3; benzodiazepine ×1; conservative ×2	1-2 mo	Full resolution for surgical patients; partial control of symptoms for muscle relaxant patients only; conservative therapy not helpful
East and Hazell (1987)[5]	4	4	Bilateral + unilateral objective tinnitus	Audiometry; vestibular function test ×2; ABR ×2; tympanometry	Tinnitus masking	4 mo to 5 y	Full resolution for at least 2 y in 3 cases and for at least 6 mo in 3 cases
Yamamoto et al (1985)[41]	20	4	Unilateral tinnitus and hearing loss after facial nerve injury	Audiometry; tympanometry	No intervention	NA	ST contractions reduce hearing threshold and middle ear compliance due to synkinesis
Marchiando et al (1983)[34]	2	4	Tinnitus	Audiometry	ST tenotomy	NA	Full resolution
Watanabe et al (1974)[4]	8	4	Subjective tinnitus after facial nerve palsy	X-ray of temporal bone; audiometry	ST tenotomy	NA	Full resolution

Abbreviations: ABR, auditory brainstem response; NA, not available; ST, stapedius tendon; TT, tensor tympani.
[a]Levels of evidence, Oxford Centre for Evidence-Based Medicine.[40]

Table 3. Experimental Studies

Study	Subjects	Level[a]	Clinical Features	Investigation	Intervention	Quality[b]	Outcome
Zehlicke et al (2008)[38]	9	2	Controlled experimental study on guinea pigs to determine possible ototoxicity of intratympanic botulinum therapy	Objective audiometry; histological examination of middle ear mucosa	Intratympanic botulinum	7.5/9	No ototoxicity demonstrated at either 1- or 3-wk follow-up
Pau et al (2005)[36]	5	3	Observational study of cadaveric temporal bones to simulate TT myoclonus	Tympanometry; endoscopic visualization	Direct force applied to muscle belly of TT	4/9	TT contraction caused decrease in peak amplitude/increase in high-frequency resonance on tympanometry
Rock (1995)[37]	432	3	Observational study of tensor tympani muscle response to forced eye closure	Tympanometry; pure-tone audiometry	Forced eye-lid closure	5/9	Objective decrease in low-frequency hearing threshold; 25% of subjects displayed retraction of posterior TM; 75% of subjects displayed increased impedance on tympanometry

Abbreviations: TM, tympanic membrane; TT, tensor tympani.
[a]Levels of evidence, Oxford Centre for Evidence-Based Medicine.[40]
[b]Newcastle-Ottawa criteria.[13]

palate and/or suprahyoid muscles confirmed by direct visualization of palatal twitching. Palatal myoclonus has been associated with lesions in the central nervous system in the Guillain-Mollaret triangle identified by magnetic resonance imaging (MRI).[25] Where the TMJ is implicated, patients present with history of pain, joint tenderness, painful clicking, grating of joint on opening or closing of mouth, and, in some cases, crepitus on palpation. The diagnosis is based on history and, in some cases, imaging of the TMJ. The patulous eustachian tube is diagnosed by noting synchronous movement of TM with respiration-associated symptoms of autophony.[26] Vascular anomalies may present as pulse synchronous tinnitus, and compression of neck vessels often alters or suppresses the tinnitus in this group. Head and neck examination

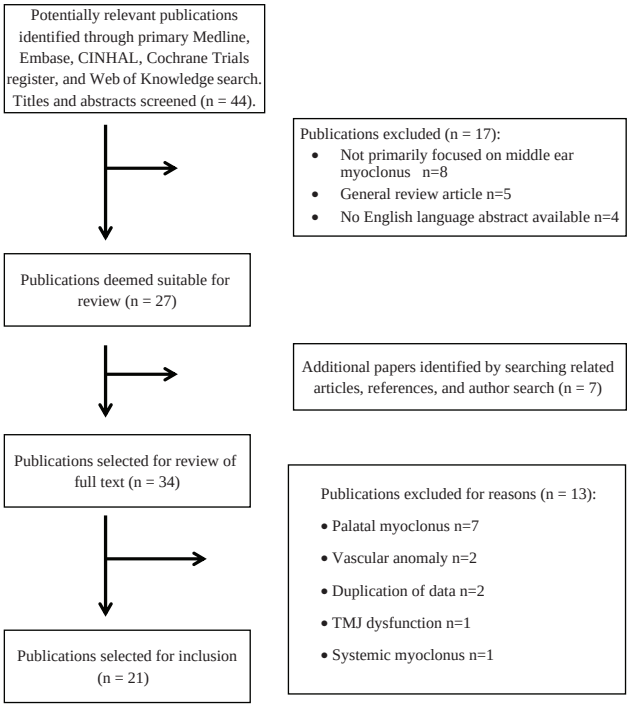

Figure 1. The flow diagram showing the search strategy. CINHAL, Cumulative Index to Nursing and Allied Health Literature; TMJ, temporomandibular joint.

provides a clue to the site and type of anomaly. Radiological imaging is required to confirm the vascular cause.

Diagnosis of Stapedial Myoclonus

Differentiating the diagnosis of stapedial myoclonus from that of tensor tympani myoclonus has been sparsely described in the literature, and at present, there are no definitive or objective methods of separating one from another. Patients with tinnitus and history of previous facial nerve palsy/injury provide an indication to the underlying site of MEM. The stapedius muscle with its common nerve supply with the facial muscles becomes involved due to synkinesis secondary to aberrant facial nerve regeneration. The type of displacement of the TM membrane in this situation has been described: ST contraction can cause movement of the posterior quadrant of the tympanic membrane, although this observation is subject to significant variability. The definitive diagnosis of stapedial myoclonus is by tympanotomy and direct visualization of the stapedius tendon for contractions.

Diagnosis of Tensor Tympani Myoclonus

Similar to stapedial myoclonus, definitive features to suggest TT myoclonus are not described in the literature. Cohen and Perez[27] described a case with twitching sounds emanating from both ears with fine movement of TM (frequency of 30/min) with objective impedance changes, and the diagnosis of TT myoclonus was confirmed only by direct visualization at tympanotomy. Howsam et al[24] described a case with objective pulsatile tinnitus and visible tympanic movement on microscopy. The patient was diagnosed as having tensor tympani myoclonus based on the argument that the myoclonus of the stapedius tendon would not cause visible movement of the tympanic membrane because of the way the incudostapedial joint articulates.

Pharmacological Treatment

Reports of medical treatment have involved the use of pharmacological drugs in 6 patients, which included benzodiazepine,[2] orphenadrine citrate[28,29] (2 patients), carbamazepine,[23] piracetam,[28] and botulinum toxin.[21] The benzodiazepine is an anxiolytic, and the proposed mode of action in MEM is as a muscle relaxant. The benzodiazepine has been shown to ameliorate the MEM but not to inhibit it entirely, but it was ineffective in other studies, causing excessive patient drowsiness.[20,27] Orphenadrine citrate is a skeletal muscle relaxant with anticholinergic effects also used in Parkinson disease as orphenadrine hydrochloride.[30] It is used for its muscle-relaxant properties and has been shown to reduce MEM over 3 weeks of treatment, but mild recurrence of symptoms was seen in this group 2 weeks after ceasing treatment.[29]

Piracetam is a cyclic derivative of γ-aminobutyric acid (GABA) and is used in adjunctive treatment of cortical myoclonus and as a cognitive enhancer.[31] Piracetam was used in only 1 case report along with orphenadrine citrate. No details of the dosage, duration of treatment, and long-term efficacy of its use in MEM are described.

Carbamazepine (used in the treatment of epilepsy, trigeminal neuralgia, and primary hemifacial spasm) has been used in MEM in doses up to 200 mg 3 times daily.[23] It reduces the excitability of nerve and muscle fibers.[32,33] This nonspecific effect might be the reason for success in MEM, although the exact mechanism is unclear. Because of potential complications of bone marrow suppression and abnormal liver and kidney function, patients need monitoring by repeat full blood count, liver function, and electrolyte testing. The tests are performed weekly for 8 weeks and then monthly while the dose of carbamazepine is attenuated.

Most studies reporting pharmacotherapy suggest a reduction in MEM tinnitus and other symptoms, but these effects may be caused by bias in reporting. None of the studies reported use of outcome measures such as a symptom diary or quantitative severity scores to assess the effect of the pharmacological intervention.

Botulinum toxin has been used topically in 1 patient who had a perforation of the tympanic membrane with visible stapedius tendon contractions through the tympanic perforation. Gelfoam soaked in botulinum toxin placed close to the stapedius tendon resolved the tinnitus for 3 months but required further treatment. It is unclear from the case report if the patient also had a simultaneous tensor tympani myoclonus and if the topical botulinum toxin dissipated into the middle ear, causing paralysis of both the muscles.

Sectioning of Middle Ear Muscles

The interpretation of published studies is challenging as it is difficult to ascertain if both stapedial and tensor tympani myoclonus occur simultaneously or sequentially. It may also

be the case that stapedial or tensor tympani myoclonus can be confused with each other. Direct visualization and confirmation of specific muscle myoclonus is needed for appropriate tenotomy. Surgical tenotomy was performed in 23 patients with tenotomy of the stapedius tendon in 13 patients,[4,15,22,34] tenotomy of both ST and TT in 9 patients,[2,3,17,18,20,25] and TT in only 1 patient.[27] Ten of the 13 patients who had ST tenotomy had synkinesis of the facial muscles secondary to facial nerve injury/palsy, and the remaining 3 patients had visible stapedius muscle contractions only at tympanotomy. Nine patients (where no contractions could be seen at tympanotomy) had both TT and ST tenotomy. One patient displayed only visible TT contraction requiring an isolated tenotomy. Symptoms resolved in all patients who had tenotomy of middle ear muscles except in 1 patient who had associated palatal myoclonus. The follow-up period ranged from 1 month to 3 years, with 3 of the 11 case reports providing no postoperative information to infer the longevity of surgical intervention.

Other Treatment Modalities

Supportive interventions such as relaxation therapy,[35] psychotherapy,[27] tinnitus masking,[5] and biofeedback[5] have been used and have shown variable results. Relaxation therapy is a useful aid in patients with stress-related tinnitus. Details of the use of relaxation therapy, psychotherapy, and biofeedback and their outcomes are poorly documented. A tinnitus masking device was used in 4 patients; East and Hazell[5] claimed resolution of symptoms in 3 of 4 patients within 6 weeks of using this technique.

Natural History

The MEM is equally distributed in both males and females. It can occur at any age but most commonly is seen in the third decade (range, 11-77 years). Patients with MEM go through multiple medical assessments over several years before a correct diagnosis is made. In our review, patients had symptoms ranging from a few days to several years (mean 4 years). It is not clear whether MEM will resolve naturally if left untreated. Six of the 56 patients in our review had symptoms for more than 5 years.

Patients who had tenotomy of intratympanic muscles showed full resolution of symptoms in all cases except 1 patient, who had associated palatal myoclonus.[25] The follow-up in most of these patients ranged from several weeks to 1 year, with only 1 patient being followed up for 3 years. Although it is reasonable to assume that if the correct tendon is cut, the symptoms will abate and that this will be permanent, it is possible that the remaining middle ear muscle will become myoclonic. No patients in the pharmacological treatment group had total resolution. This group had a short follow-up of weeks to months, making it difficult to know if the effect of treatment was sustained. One patient, treated with botulinum toxin, had recurrence of symptoms at 4 months.[21]

The sustained use of a masking device showed varying periods of respite. Of the 4 patients having tinnitus masking, 1 recurred in 2 months and the remaining 3 had symptom-free periods of 2, 3, and 5 years.[5] Two patients who received no pharmacological or surgical treatment had tolerable symptoms at 6 months[24] and 1 year, respectively.[15]

Experimental Studies/Animal Studies

Tonic contractions of TT are associated with ear symptoms and changes in middle ear status, including tympanic membrane movement and changes in middle ear impedance. A study of human temporal bones indicated that contraction of the tensor tympani can cause an increase in impedance and shifting of middle ear resonance to higher frequencies.[36] Contractions of TT in human subjects have caused objective tinnitus induced by forced eye closure. Impedance audiometry detected such changes in 75% of ears tested, whereas microscopic examination detected contractions in 25% of ears.[37] Animal experiments on the use of pharmacological agents to reduce the symptoms of MEM have been reported in literature. A recent study on intratympanic use of botulinum toxin to paralyze the middle ear muscles showed no ototoxic effects in guinea pigs when tested by auditory brainstem response (ABR) at 1 and 3 weeks following injection.[38]

Discussion

Our review of 21 articles included 6 case series, 12 case reports, 2 observational studies, and 1 controlled intervention study. The initial intention of this study was to systematically review the subject, but because of the paucity of evidence, only a review of available literature was possible.

The prevalence and incidence of MEM in the population are not known. The only epidemiological study regarding MEM (of whatever etiology) in a defined population was performed in Olmsted County, Minnesota.[39] The average annual incidence of pathological and persistent MEM for 1976 to 1990 was 1.3 cases per 100,000 person-years.

As discussed previously, how middle ear myoclonus produces an auditory sensation remains obscure. The possibilities—which are not mutually exclusive—are as follows. The percept could be due to the conduction of noise associated with the muscle contractions, which may explain in some cases why it is objective in nature. It could also be due to potential vibration of the tympanic membrane during contraction of the intratympanic muscles, as demonstrated by a saw-toothed pattern on long-time-based tympanometry (**Figure 2**). It may also be the case that the movement of the ossicular chain in MEM directly sends a pressure wave to the cochlea.

For an otolaryngologist in an ear, nose, and throat (ENT) outpatient clinic, a simple clear protocol may help in identifying and treating this rare condition of MEM (**Figure 3**). Although it is not a convention for a systematic review to propose a management strategy, the rarity of the condition means it may be of benefit. When considering the diagnosis of MEM, it is important to keep in mind other differentials, as discussed in the Methods section. Less common causes such as vascular, infectious, and demyelinating disorders as well as anxiety, trauma, and neoplastic disease may need to be excluded.[20] The presence of mental status abnormalities, seizures, ataxia, or other movement disorders should alert the otolaryngologist to

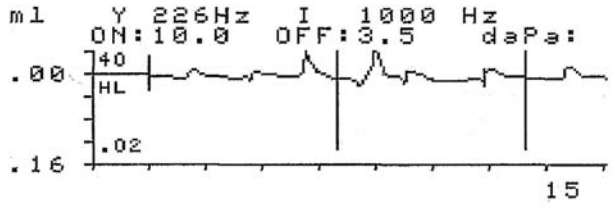

Figure 2. Long-time-based tympanometry (uses recording of tympanic membrane compliance for 15-second epochs, such as in stapedial reflex decay testing, but in the absence of an auditory stimulus).

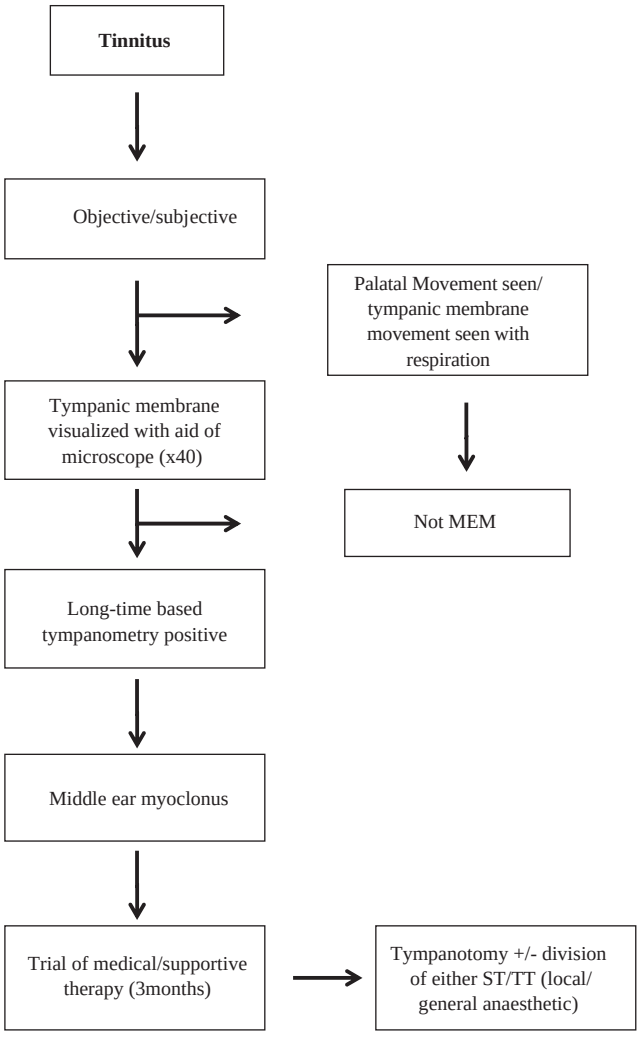

Figure 3. An aid to the diagnosis and treatment of middle ear myoclonus (MEM) based on the available evidence in conjunction with clinical experience. ST, stapedius tendon; TT, tensor tympani.

the presence of a systemic myoclonic syndrome and the need for appropriate referral.

A detailed history and both otolaryngological and neurological examination should be performed. An objective tinnitus should evoke a suspicion of possible MEM, so auscultation of the ear should be done. All patients should be subjected to a microscopic examination of the tympanic membrane so as not to miss the fine movement of the tympanic membrane. A saw-toothed tympanogram on long-time-based tympanometry and/or negative palatal movements on nasoendoscopy narrow the diagnosis to intratympanic myoclonus. Specific muscle myoclonus in the middle ear is confirmed only at tympanotomy. An audiological assessment is useful to aid sound-based treatment (eg, masking device)[5] but is not diagnostic. Imaging of the head and neck may be helpful if one cannot exclude a neurological or vascular cause by clinical examination.

Treatment is tailored to the patients' needs depending on the severity of symptoms, age, and associated medical conditions. Initial management should consist of explanation and reassurance. Supportive therapy may be offered depending on availability and patient preference, but little objective evidence exists to substantiate this intervention. Carbamazepine in doses up to 200 mg 3 times daily has been used, but close monitoring for side effects such as bone marrow suppression and abnormal liver and kidney function should be done. Because of limited evidence on the efficacy of the pharmacological agents, use of these drugs should be the responsibility of the individual clinician. Further studies to determine the efficacy of these interventions are needed.

Most of the published studies recommend exploration of the middle ear under local anesthesia when patients are severely troubled. Local anesthesia has the advantage in that the patient can confirm if the symptom resolves intraoperatively after each individual tenotomy. If no muscular contractions are seen, tenotomy of both the intratympanic muscles should be considered. The theoretical risk of hyperacusis exists (because of the intensity modulation function of acoustic reflexes) but has not been reported in the literature.

Limitations of the Study

None of the studies identified were randomized or controlled. The evidence presented was through retrospective observational use of case series and reports. None of the studies showed objective change in the outcome by assessing the response of intervention both before and after treatment (ie, lack of recording objective sounds/long-time-based tympanometry). The studies included in this article did not describe the rationale for choosing particular treatment such as psychotherapy, biofeedback, and sound therapy, making the comparisons difficult. No studies used symptom diaries or other scores to assess the impact of therapy. Considering all these factors, the overall quality of studies was judged to be poor.

Future Research

Although rare, treatment of MEM needs the robust methodology of large studies to test the evidence and efficacy of use of pharmacological agents and alternative therapies. Use of topical intratympanic botulinum toxin holds promise, as animal models have not shown any ototoxicity; further studies in humans are needed to confirm the long-term safety on vestibulocochlear function.

A number of themes for future research emerge from this review. The first is the need for a reliable indication of which middle ear muscle is undergoing myoclonus, which will allow targeted interventions. The second concerns the understanding of

the ignition of the myoclonus: does some premorbid state manifest with the experience of a precipitating event? The final theme is that of effective nondestructive interventions. Although there is debate as to the function of the stapedial reflex, and the function of the tensor tympani remains obscure, clearly both have some useful function to have been retained in human evolution—in which case surgical ablation may not be necessary. Further work on these themes should be watched with interest.

Conclusion

The articles included in this review provide insufficient evidence of the diagnostic criteria and use of pharmacological agents in the diagnosis and management of MEM. There is weak evidence in favor of surgical resection of the stapedius and tensor tympani tendons in the treatment of MEM.

Implications for Practice

- Middle ear myoclonus is a rare condition with unknown etiology.
- The diagnosis is by typical history and examination with active exclusion of other causes of tinnitus.
- Treatments include supportive therapy, as well as pharmacological and surgical treatments.
- Surgical tenotomy of middle ear muscles is the definitive treatment, but this is based on weak evidence.
- Tenotomy of the intratympanic muscles has yet to show long-term side effects.

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Author Contributions

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