WHAT ARE THE LONG TERM EFFECTS AND STRATIFIERS ON HEARING FROM HAVING TYMPANOSTOMY TUBE INSERTION? A SYSTEMATIC REVIEW

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ABSTRACT Introduction: Middle ear disease is common in childhood and is often associated with hearing loss. Seventy-one percent of all children have at least an episode of otitis media with effusion (OME) by three years. The high incidence of OME in patients with middle ear disease concluded that treatment with tympanostomy tube insertion (TTI) would solve the inevitable hearing loss associated with middle ear disease. Studies reporting an association between hearing loss and TTI are conflicting and warrant a systematic review of the evidence. Methods: A dual review process was used to assess eligible studies drawn from PubMed, Medline via Ovid, Science direct, and reference lists from 2007 to 2018. Five studies were selected. Results: Three studies did not specify a primary outcome measure in terms of the types of hearing loss, i.e. did not specifically measure CHL and reported benefits in hearing with TTI. The other studies reported incidences of CHL with the use of the TTI. Discussion: Shorter tubes tended to reduce long term complications. Tube stay-time was 6-12 months and required to follow up if later than this due to an increase in complications. The number of insertions was positively correlated with children with symptomatic pathology. Tube location is important as medial displacement can occur as well as not checking tube function. Children aged from zero to six years old benefitted the most from TTI as their hearing loss tended to be the greatest at the baseline compared to older children. Conclusions: An extensive systematic review identified five studies examining hearing loss and TTI in young children from 2008 to 2018. There are two main findings from this review. First, two studies reported hearing loss in two studies with TTI. Second, the association between hearing loss and TTI may be influenced by the hearing loss measure, technical aspects of TTI, and demographic and health characteristics. These findings are strengthened by evidence from a large (n= 3128) globally representative sample of young adults. A proportion of children may experience a conductive hearing loss with TTI. We recommend allied health professionals and general practitioners increase their awareness and understanding of the hearing loss experienced during TTI.

KEYWORDS Child; Preschool; Middle Ear; Hearing Loss, Conductive; Tympanostomy tube Insertion; Myringostomy; Grommet Insertion; Otitis Media; Otitis Media with Effusion; Nonsuppurative Otitis Media; Technical aspects; General Practitioners; Otorhinolaryngology.
Introduction

Middle ear disease is common in childhood and is often associated with hearing loss. Seventy-one percent of all children have at least an episode of otitis media by three years (1, 2). There are two types of otitis media. Recurrent acute otitis media is defined as three or more acute infections of the middle ear cleft in a six-month period and otitis media with effusion (OME) when a collection of non-purulent fluid builds up in the middle ear space. This fluid may accumulate in the middle ear due to an upper respiratory infection, cold or a sore throat.

OME is usually self-limited, which means the fluid usually resolves on its own within four to six weeks. However, in some instances, the fluid may persist for a longer period of time and cause a temporary decrease in hearing, or the fluid may become infected (acute otitis media).

When children require surgery for otitis media with effusion, insertion of tympanostomy tubes is the preferred initial procedure, with candidacy dependent primarily on hearing status, associated symptoms, and the child’s developmental risk (3).

The high incidence of OME in patients with middle ear disease led to the conclusion that treatment with ventilation tube insertions (VTIs) or tympanostomy tube insertions (TTIs), or grommets would solve the inevitable hearing loss associated with middle ear disease and prevent the sequence of OME including cholesteatoma formation, retraction pockets, ossicular fixation, and atelectasis (4). In addition, studies have confirmed that early intervention with TTI does provide an appreciable benefit regarding short-term hearing, between six to twelve months (5, 6, and 7). However, this regimen usually requires TTIs to be completed in the first year of life to reduce further complications. These complications include increased risk of otitis media because of immature immune systems and poor Eustachian tube function. In addition, this tube-like connection between the middle ear and back of the nose normally ventilates the middle ear space and equalizes pressure with the external environment (8).

However, currently, prophylactic tympanostomy tubes are being heavily scrutinised due to associated complications such as; perforations, otorrhea, eardrum atrophy, granulation tissue, and tympanosclerosis (which can be as high as 80%). Prophylactic VTs are tubes placed in patients who have not yet met the threshold for tympanostomy tube placement dictated in clinical practice guidelines (4).

Other studies have revealed that children who undergo multiple tympanostomy tube insertions increase their risk of conductive hearing loss in the long term (9).

Children with OME less than three months and those without effusion at the time of evaluation should not receive tubes (in the absence of other developmental concerns) (10, 11).

Many reviews on the use of tympanostomy for OME have been published. However, many of these were narrative (12). Other systematic investigations pertained mainly to otherwise healthy children with normal development (3) or were in symptomatic patients with syndromes such as cleft palate (4). Despite all mentioned complications of tympanostomy, there are no sufficient systematic reviews or meta-analyses that show the exact association, incidence, and prevalence of each complication. Having such studies guides practitioners in deciding each patient’s treatment option by balancing risks and benefits. Thus, this systematic review focuses on conductive hearing loss after tympanostomy in children. The primary aim is to synthesize the available evidence to assess if there is an association between conductive hearing loss and TTI. The secondary aim is to examine whether the study (e.g., design, outcome measures), technical (e.g. tube type, tube stay-time, number of insertions, tube location, prior pathological status, age of or participant (e.g., demographic, health) characteristics may influence the association between hearing loss and TTI.

Methods

Search strategy and selection criteria

The intervention in our review was tympanostomy tube insertion and the incidences of conductive hearing loss. In addition, a systematic review of the literature was conducted using CINAHL, PubMed/MEDLINE and science direct. Details of the electronic search strategy, including the search terms used, are contained in Table 1. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed in this systematic review (13).

Papers were identified for inclusion based on the following criteria:

- Published from 2007-2018.
- Sample ages of the population from 0-17 years.
- Use of TTI as a treatment for OME.
- Reported in English.
- Conducted in any setting, home, school or hospital etc.
- Exclusion criteria included.
- Not reporting post-operative hearing levels.

The selection process used is outlined in Fig. 1. The titles and abstracts of the selected articles were screened for the inclusion criteria, and the full articles were retrieved. Overall, 394 abstracts were reviewed. Three hundred and twenty citations were excluded for various reasons, including seventy-one for duplication (see Fig. 1). This left a sample of 74 papers where the full text was obtained. Thirty of these papers described a study protocol only (did not report results) and were excluded. Twenty-six papers were excluded for the following reasons: Papers looking at transcription marker expression during TTI, drugs that could be used in addition to TTI and that affect TTI, types of bacteria that could contaminate tubes and how to manage TTI other symptoms of acute otitis media, markers of middle ear pathology, and exclusion criteria. Thirteen papers were excluded for reasons pertaining to best clinical practice on TTIs and cost. Five papers were included in the final analysis.

Data extraction and quality assessment

Data extracted from articles included study design, sample size, sample characteristics, mean age at intervention baseline, types

Figure 1 PRISMA flow diagram of the search strategy.
of interventions, duration of intervention, and follow-up information. Two independent reviewers extracted data. Three methods evaluated the quality of each article. The first method is the Preferred Reporting Items for Systemic Reviews and Meta-Analyses (PRISMA) checklist. The checklist consists of seven parts: Title, Abstract, Introduction (rationale and objectives), Methods (Protocol and registration, Eligibility criteria, Information sources, Search, Study selection, data collection process, Data items, Risk of bias in individual studies, Summary measures, Synthesis of results, Risk of bias across studies and Additional analyses), Results (Study selection, Study characteristics, Risk of bias within studies, Results of bias across individual studies, Synthesis of results, Risk of bias across studies and Additional analysis), Discussion (Summary of evidence, Limitations and Conclusion) and funding. The second method is the PRISMA flow chart (Identification, Screening, Eligibility, and Included). The third and last method is the Newcastle Ottowa scale. It is a ‘star system’ where the study is judged on three broad perspectives: the selection of the study groups, the comparability of the groups, and the ascertainment of either the exposure or outcome of interest for case-control or cohort studies, respectively. Best studies are given the highest stars, which are nine stars.

Ref. PRISMA and Newcastle Ottowa scale.

Results

Our quality assessment found different designs in the studies, four studies were on a case series, and one was a randomised controlled trial. Information was also extracted from the papers concerning stratifies associated with TTI, such as tube type, tube stay-time and number of insertions, tube location, prior pathological status, age and their contribution to hearing (Table 2). We, therefore, decided not to exclude any of the studies but to describe the methodological problems in each paper and extract as much information as possible from each paper. Authors are listed in alphabetical order.

Because of the different designs, we could not perform any meta-analysis. As we were evaluating the effect of an intervention with a possible outcome, randomised trials, in which interventions are assigned experimentally to have no important differences between those receiving and not receiving the intervention of interest, would have been appropriate. Randomisation was included for both children and ears in one study for children (TTI versus no TTI), for ears (TTI one ear only) (14). Children randomised three studies, and ears randomised one, i.e. one ear had the tube, and the other ear had no treatment. One study had four comparison groups (15), and one had six (16) (Table 3).

We will report on the five studies separately and as a group. Data and outcomes were extracted directly from the full-text paper in table 4.

**Study characteristics**

The five studies included 3128 individuals (Table2), and two included the bulk of these participants (14, 17). The first study was a systematic review that recruited the participants from the Cochrane ENT disorders register (14). The second study included participants recruited from a clinical database at Boston Children’s hospital, USA (17). The mean age of study participants at baseline ranged from three months to 16 years (Table 4).

One study achieved seven stars using the Newcastle-Ottowa scale (18). In contrast, four studies scored six stars as there was no statement to indicate no history of disease and subjects were lost to equipment breakdown and dropping out (14,15,16,17). Overall, because the star ratings were fairly high, this points out that studies were of mostly moderate quality.

**Hearing characteristics**

Three studies did not specify a primary outcome measure in terms of the types of hearing loss, i.e. did not specifically measure CHL (14, 15, and 18). Two studies reported incidences of CHL and sensorineural deafness using the TTI (16, 17). The other studies reported benefits in overall hearing with the TTI (14, 15, and 18). In one study, follow up showed that TTIs were mainly beneficial in the first six months. At six to nine months of follow up, the mean hearing level in the children treated with TTI measured by tympanometry (n = 271) was 4.2 dB better (95% CI 2.4 to 6.0 dB) than the mean hearing levels of those in the ‘watchful waiting/active monitoring group (n = 252). At 12 months follow up, no differences in mean hearing levels were found primarily due to natural resolution (Table 4) (14). In another study, the hearing thresholds were determined by age-appropriate hearing tests with pure tone audiogram, play audiometry or auditory brainstem evoked response. Hearing pre- and post-TTI insertion showed improvement in all frequencies for all four age groups. The average pre-TTI hearing on the right was 34.4dB +/- 0.9 and 36.1dB +/- 4.3 on the left. The average post-TTI hearing was 23.5dB +/- 10 on the right and 24.6dB +/- 6.8 on the left. The improvement was 32% on both sides, which is statistically significant (p<0.05) (Table 4) (15). In another study, no hearing loss was found in the study participants. However, complications related to the tubes were seen that included myringosclerosis (34.6%), persistent perforation (5.6%), atrophy (23.5%), retraction (16.7%) and medial displacement of tubes (1.2%) (18).

### Table 1 Search strategy.

<table>
<thead>
<tr>
<th>Search details</th>
<th>Medline Citations</th>
<th>PubMed citations</th>
<th>Science direct</th>
<th>Total citations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Conductive hearing loss</td>
<td>5,597</td>
<td>1,322</td>
<td>1,428</td>
<td>8,347</td>
</tr>
<tr>
<td>2 Middle ear hearing loss</td>
<td>19,852</td>
<td>3,761</td>
<td>3,651</td>
<td>27,264</td>
</tr>
<tr>
<td>3 Tympanostomy</td>
<td>1,626</td>
<td>945</td>
<td>423</td>
<td>2,994</td>
</tr>
<tr>
<td>4 Ventilation tube insertion</td>
<td>1,486</td>
<td>1,445</td>
<td>6,012</td>
<td>8,943</td>
</tr>
<tr>
<td>5 Otitis media with effusion</td>
<td>345</td>
<td>1,453</td>
<td>7,349</td>
<td>9,147</td>
</tr>
<tr>
<td>6 #1 and #2</td>
<td>6</td>
<td>870</td>
<td>4,860</td>
<td>5,736</td>
</tr>
<tr>
<td>7 #1 or #2 and #3</td>
<td>418</td>
<td>72</td>
<td>75</td>
<td>565</td>
</tr>
<tr>
<td>8 #1 or #2 and #4 and #5</td>
<td>92</td>
<td>250</td>
<td>52</td>
<td>394</td>
</tr>
</tbody>
</table>
### Table 2: Design, inclusion criteria and the number of patients.

<table>
<thead>
<tr>
<th>Study</th>
<th>Design and Follow up</th>
<th>Intervention</th>
<th>Inclusion criteria</th>
<th>Number recruited</th>
</tr>
</thead>
<tbody>
<tr>
<td>(14)</td>
<td>Randomised controlled trial We included 10 trials (1728 participants). We searched the Cochrane ENT Disorders Group Trials Register, other electronic databases and additional sources for published and unpublished trials (most recent search: 22 March 2010)</td>
<td>TTI</td>
<td>Randomised by ears or children Level was 31 to 33 dB HL. Outcomes include age-specific child tests (e.g., comprehension) or auditory performance tests (e.g. speech in noise) by the clinician. Domains considered most relevant include speech and language, cognition and mental development, behaviour, impact on the family, physical health, reported hearing difficulty, and their overall effect on the quality of life and functioning. OME bilaterally for 90 days or unilaterally for 135 days.</td>
<td>1728</td>
</tr>
<tr>
<td>(15)</td>
<td>Case series- Cohort had its first TTI between January 2006 and December 2008. Design parameters Patient data on demographic profile, presenting complaints, indications, medical history, ear examination, hearing threshold and tympanometry evaluations, and complications of TTI were collected.</td>
<td>TTI</td>
<td>OME that persists longer than 3 months. A telephone survey was performed with questions on whether the parents felt that the hearing loss associated with the OME had adversely impacted school performance prior to TTI and if school performance in such cases has improved after TTI.</td>
<td>105</td>
</tr>
<tr>
<td>(16)</td>
<td>Case series- over three years Medical records of thirty-nine children who were referred for either conductive or mixed hearing loss post-tympanostomy tube placement were reviewed for clinical histories, physical examinations, audiological evaluations, diagnostic studies, consultations, and surgical findings.</td>
<td>TTI</td>
<td>Referral by health service provider to a tertiary paediatric hospital.</td>
<td>39</td>
</tr>
<tr>
<td>(17)</td>
<td>Case series and medical review for 12 months The medical records were reviewed with information abstracted for sex, date of birth, date of TT I insertion, dates and results of preoperative and postoperative audiometric evaluations, tympanometry Results, and medical histories of patients who were found to have hearing losses.</td>
<td>TTI</td>
<td>The i2b2 (Informatics for Integrating Biology and the Bedside) The database at Boston Children’s Hospital, a centralized repository of clinical data, was queried for the Current Procedural Terminology(CPT) code for TT placement (69436) over the year period of June 1, 2010, through June 1, 2011</td>
<td>1175</td>
</tr>
<tr>
<td>(18)</td>
<td>Case series 6-66 months. The medical records of 162 ears of 87 children (52 male and 35 female) were reviewed retrospectively. The children were between 3 to 16 years old (mean age = 8.1 ± 3.1). The patients were followed up 6–66 months (mean 23.3 ± 14.9 months) after tympanostomy tube insertion. We reviewed age, sex, time to tube extrusion and complications.</td>
<td>TTI</td>
<td>OME for at least three months.</td>
<td>87</td>
</tr>
</tbody>
</table>

### Table 3: Problems and dropouts.

<table>
<thead>
<tr>
<th>Study</th>
<th>Problem with study design/ medical issue</th>
<th>Comparison groups</th>
<th>Drop out after randomisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(14)</td>
<td>Different studies yield different results, and in some studies, tests for well-being may not have been used as well as compared in others.</td>
<td>Children and ears were randomised. One group also included a watchful waiting group with no intervention.</td>
<td></td>
</tr>
<tr>
<td>(15)</td>
<td>14 needed a repeat TT and 12 further surgery.</td>
<td>Four comparison groups Below three years old. Three to six years old. Six to twelve years old Twelve to eighteen years old.</td>
<td></td>
</tr>
<tr>
<td>(16)</td>
<td>Incidence is not determined as many from outside institutions</td>
<td>Children randomised</td>
<td></td>
</tr>
<tr>
<td>(17)</td>
<td>Inability to obtain ear specific data. Some tubes were non-functional. Data collected in a clinical setting Operative audiometric evaluations were variable—performance of audiometry, the timing of evaluation, and completeness of testing all varied.</td>
<td>Children randomised</td>
<td>Drop-outs 26(1.1%)</td>
</tr>
<tr>
<td>(18)</td>
<td>Displacement of tubes.</td>
<td>Six comparison groups Unilateral TTI Adenoidectomy with TTI Multiple TTI First tube only Second tube Third tube</td>
<td>No tube (1) (1.1%)</td>
</tr>
</tbody>
</table>

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Table 4 Outcomes including final hearing levels at the end of follow up for each study.

<table>
<thead>
<tr>
<th>Study</th>
<th>Intervention group (number completed)</th>
<th>Age</th>
<th>Gender</th>
<th>Primary effect measure</th>
<th>Hearing after 6 months</th>
<th>Hearing after two years</th>
</tr>
</thead>
<tbody>
<tr>
<td>(14)</td>
<td>1728 TT</td>
<td>5-7 years</td>
<td></td>
<td>12 dB benefit (95% CI 10-14 dB)</td>
<td>4dB benefit in hearing (95% CI 2-6dB)</td>
<td>No difference in hearing levels</td>
</tr>
<tr>
<td>(15)</td>
<td>105 TT</td>
<td>3 months to 15 years</td>
<td>60M 45 F</td>
<td>32% improvement on both sides, 23.5 dB right side and 24.6 dB left side for all age groups</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(16)</td>
<td>39 TT</td>
<td>5.92 years average</td>
<td>39 M</td>
<td>22(56%) had CHL and mixed hearing loss.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(17)</td>
<td>1466 (84.2%) functional TT</td>
<td>1.48-4.94 years</td>
<td>1364 M 910 F</td>
<td>15 (0.66%) CHL</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(18)</td>
<td>87 TT</td>
<td>3-16 years</td>
<td>52 M 35 F</td>
<td>No hearing loss</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Conductive hearing loss
Two studies in this review have reported the conductive hearing loss due to TTI use for OME. One study mentions a 56% incidence of conductive hearing loss or mixed hearing loss. This study also mentions that the actual incidence could not be determined as many patients were from outside institutions, and data regarding TTI were unobtainable (Table 3) (16). In the other study, 15 patients (0.66%) were found to have conductive hearing loss in the absence of middle ear effusion (17). However, this article mentions within this case series of 2274 that there are no patients with permanent postoperative hearing loss after a normal preoperative audiometric evaluation result with no comorbidities or complications (Upper 95% CI 0.13%). In this study, the patients who had CHL had underlying syndromes such as cleft lip and palate (17) (Table 4).

Length of follow up
The follow-up periods used in the studies ranged from everything up to 2010 (14), three years (15 and 16), one year (17), and 5 years (18). Of interest, the longest studies reported no CHL in their analysis and hearing improved in the patients overall (14, 15 and 18) (Table 2).

Placement of tube and age
One study compared hearing levels at different ages of TTI insertion, and it was found that hearing pre and post-TTI showed improvement in all frequencies for all four age groups. In addition, there was a significant 32% improvement for both right and left sides of the ear after TTI in one study (15) (Table 3).

Effectiveness of tympanostomy for hearing loss
Three studies reported that TTI effectively prevents the hearing loss associated with OME (14, 15, and 18). Yaman compared single tubes with multiple tubes and found no evident hearing loss. Browning found that the mean hearing level was 10dB better with TTI after insertion and was 6dB after two years (Table 4).

Age of insertion
The worst hearing was seen in children between zero to three years old, which coincides with when hearing is crucial to speech and language acquisition—nine percent of children between the ages of three and six presented with behavioural issues. Most of the children needing TTI insertion for chronic OME were less than six years old, and these were the ones who benefited the most compared to those children with a much smaller hearing loss at the baseline (15).

Tube stay-time
Yaman reports the follow-up period to be the time from tube insertion to the control end time of six to twelve months(18). Anything longer than this is linked to issues (14).

Location of tube
Myringotomy with tympanostomy tube placement is a surgical procedure in which a small incision is made in the tympanic membrane, and a pressure equalization tube is placed. This allows air exchange through the tympanic membrane and the middle ear space aeration. In one study, two percent of tubes were displaced medially. There was no report if this affected the outcomes as these were reinserted (18).

Discussion
This paper aimed to systematically review TTI interventions in children and the long-term effects on hearing as a result of this treatment and stratified related to the TTI and how they relate to the side effects. The studies sourced were heterogeneous regarding the design type and outcomes assessed.

Hearing level and TTI
An abundance of literature refers to the benefits of hearing using the TTI (14, 15, and 18). This coincides with similar data that also report an improvement in hearing using TTI (19, 20, and 21). Rover compares the hearing levels of the patients after either having a TTI or just having a watchful waiting (WW) period. After six months of follow up in this group, there was a 5.6 dB benefit of hearing in the TTI group compared to the WW group. However, after twelve months, this benefit disappears (20). However, this contrasts with two of our studies that have found CHL with the use of a TTI (16, 17). This is similar to data from other studies that also report a decrease in hearing after TTI. For example, one study reports a 3.3-fold increase in the risk of mean hearing thresholds in the TTI group (22, 23, and 24). However, several patients had underlying conditions such as
cleft palate at the time of TTI, which could have contributed to CHL incidences (25).

In terms of conductive hearing loss, it was not easy to get an exact incidence. The incidence noted in Whittemore 2016 of 0.66% was mostly with symptomatic patients with an underlying disorder such as cleft palate. A greater proportion of boys in the two studies were diagnosed with conductive and mixed hearing loss. In one study, they had a higher rate of the third window effect (17). In the presence of a third window, incoming acoustic energy from the oval window is shunted away, decreasing transmission to the round window. This result reduces sound perception because less acoustic energy is available to the hair cells (26). 56% had mixed and conductive hearing loss (16). The other studies did not report a gender difference in the hearing levels after TTI. Further investigation with a longitudinal study with a larger patient population is needed to confirm these findings.

**Measuring the hearing loss**

In terms of diagnosing the hearing loss in the different studies. A mixture of computed Tomography (CT) testing to investigate the temporal bone provides a superior evaluation of the bony sound conduction pathway was used to diagnose 16 out of 24 patients in one study. Vestibular-evoked myogenic potential (VEMP) testing was used to investigate the presence of a third window for the vestibular function to make a diagnosis in three out of four children in the same study (17). VEMP testing can be measured quickly and easily and is more specific than CT (27). The newborn baby screening was not considered effective, having missed out on patients with congenital abnormality (16). Further investigations could take note of these methods when measuring conductive hearing loss.

**Tube stay time**

One study reported non-functional tubes that contributed to hearing loss (18). When results such as these are observed, serial audiological and otologic evaluations should be performed to ensure the stability of the hearing loss while tubes are in place and functional. An audiological evaluation following TT extraction or removal is imperative in these cases to ensure a return to normal hearing. Tube stay-time was, on average, six to twelve months and required to follow up if later than this due to an increase in complications when tube stay time was up to 36 months (28). Our study saw benefits in hearing with the studies that had longer follow-up times (14, 15 and 18). Identifying hearing loss as early as possible is critical for children’s social and cognitive development. The link between hearing loss and speech/language development and delay is well documented. In one study, it was higher among females even after controlling for a wide range of confounding factors (29). Yaman reports the follow-up period to be the time from tube insertion to the control end time of six to twelve months (18).

**Tube placement and size**

In terms of placement of the tube, Nurliza’s study of 2011 coincides with a similar study in six-year-old students where if the tube was placed earlier or later, there was no difference in the hearing loss, and this was unrelated to the presence or type of tympanic membrane abnormality (21). In another study, it was noted that the type of tube could have an impact where results in one study were generalised to short tubes where there was a reduced incidence of otorrrhea compared to long tubes (30).

Another study noted that children with craniofacial abnormalities tended to have a significantly higher rate of tympanostomy tube insertion and tend to have more prolonged issues with Eustachian tube dysfunction and often require multiple sets of tympanostomy tubes compared to children with no underlying disorders (31).

**Location and no of insertions**

The insertions were positively correlated with children with symptomatic pathology (21). Tube location is important as medial displacement can occur and not check tube function (18).

**Age**

A prior pathological status preceding a pathological condition was associated with increased conductive hearing loss. Children aged from zero to six years old benefitted the most from TTI as their hearing loss tended to be the greatest at the baseline compared to older children. However, age was not such a big factor in hearing loss as all aged children in one study achieved benefits on their hearing loss with TTI (15).

**Strengths**

This review is strengthened due to a large population size with the correct age group. Also, the majority of the studies are in good agreement with each other where the use of TTI is beneficial to the hearing loss associated with OME in the short term.

**Limitations**

A limitation of this review is that only papers written in English were included, possibly resulting in the omission of important studies. Additionally, only three databases were searched, which may have limited the review’s findings. Finally, sample sizes could have been bigger to increase validity and accuracy. Nonetheless, the findings help to elicit the current state of the issue in general.

Children aged from zero to six years old benefitted the most from TTI as their hearing loss tended to be the greatest at the baseline compared to older children. Yet age was not a significant factor in hearing loss as all aged children in one study achieved benefits on their hearing loss with TTI. More studies are needed to look at the effects of age and TTI.

**Conclusions**

An extensive systematic review identified five studies examining hearing loss and TTI in young children from 2008 to 2018. There are two main findings from this review. First, two studies reported hearing loss in two studies with TTI. Second, the association between hearing loss and TTI may be influenced by the type of hearing loss measure, technical aspects of TTI, and demographic and health characteristics. These findings are strengthened by evidence from a large (n= 3128) globally representative sample of young adults. A proportion of children may experience a conductive hearing loss with TTI. We recommend allied health professionals and general practitioners increase their awareness and understanding of the hearing loss experienced during TTI.

TTI is a viable treatment for preventing hearing loss associated with OME for any age. Short tubes, fewer insertions and no prior pathological status were important for long term benefit.
Acknowledgements
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Authors contributions
Study concept and design: SA. Data extraction (abstracts and full articles): RN and NA. Independent review of full articles: RN and NA. Data analysis and interpretation: RN. Quality review RN and SA. Drafting of the manuscript SA. Editing and reviewing the final manuscript: RN, NA and SA. All authors read and approved the final manuscript.

Conflict of interest
The authors report no conflicts of interest.

References


Appendix

Please find table of abbreviations used in this study.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>TT</td>
<td>Tympanostomy tube</td>
</tr>
<tr>
<td>TTI</td>
<td>Tympanostomy tube insertion</td>
</tr>
<tr>
<td>VT</td>
<td>Ventilation tube</td>
</tr>
<tr>
<td>OME</td>
<td>Otitis media with Effusion</td>
</tr>
<tr>
<td>CPT</td>
<td>Current Procedural Terminology</td>
</tr>
<tr>
<td>CHL</td>
<td>Conductive hearing loss</td>
</tr>
</tbody>
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