Tympanometry in Discrimination of Otoscopic Diagnoses in Young Ambulatory Children

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Background: Tympanometry can indicate middle ear effusion in children referred for tympanostomy tube placement. In outpatient setting, objective adjunctive tools are needed to diagnose the otitis media spectrum.

Methods: We enrolled and followed 515 children aged 6–35 months at primary care level. We compared tympanometry with pneumatic otoscopy and evaluated the proportions of type A, C1, C2, Cs and B tympanograms in relation to specific otoscopic diagnoses in 2206 and 1006 examinations at symptomatic and asymptomatic visits, respectively.

Results: At symptomatic visits, different peaked tympanograms were associated with a healthy middle ear as follows: type A in 78%, type C1 in 62%, type C2 in 54% and type Cs in 18% of examinations. In contrast, any peaked tympanogram was related to healthy middle ear in 67% of examinations. Flat (type B) tympanogram was related to otitis media with effusion in 44% and to acute otitis media in 56% of examinations, respectively. At asymptomatic visits, the peaked tympanograms together were associated with a healthy middle ear in 87% of otoscopic examinations. Flat tympanogram indicated otitis media with effusion as well in 87% of examinations.

Conclusions: Tympanometry is not a useful tool in detecting specific otoscopic diagnoses because it cannot distinguish between otitis media with effusion and acute otitis media. However, among outpatients all peaked tympanograms suggest a healthy middle ear and a flat tympanogram is useful in detecting any middle ear effusion. Thus, tympanometry can be used as an adjunctive tool, but accurate diagnosis requires careful pneumatic otoscopy.

Key Words: otitis media, otoscopic diagnosis, primary care, tympanometry

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Otitis media is a common disease in children and the main reason for antimicrobial treatment in primary care. Most episodes of otitis media are diagnosed in primary care units, which is a diagnostic challenge. Diagnosis relies on pneumatic otoscopy, which requires subjective assessment of otoscopic findings. Thus, objective diagnostic tools would be needed, because the accurate diagnosis is the cornerstone of the management of otitis media.

Tympanometry is an adjunctive diagnostic tool providing objective information of the middle ear. Tympanometry has been available for several decades, but previous studies have mostly been conducted in children undergoing tympanostomy tube placement.5,6 Such results cannot be applied to ordinary outpatient populations. Previously, 2 large outpatient studies evaluated tympanometry in detecting middle ear effusion, but in these studies different otoscopic diagnoses were not taken into account.6,7

We collected a large database including young outpatients with the whole range of otoscopic diagnoses from healthy middle ear or minor middle ear effusion to acute otitis media (AOM) with bullae on the tympanic membrane. This allowed us to assess the relationship between tympanograms and otoscopic diagnoses. The aim of this study was to evaluate the usefulness of tympanometry in detecting specific otoscopic diagnoses of otitis media in young children at primary care level.

MATERIALS AND METHODS

We studied 515 young children at both symptomatic and asymptomatic visits. Written informed consent was obtained from a parent of each child before any study procedure was done. The study protocol was approved by the ethical committee of the Hospital District of Southwest Finland. We performed spectral gradient acoustic reflectometry, tympanometry and pneumatic otoscopy. Pneumatic otoscopy served as the diagnostic standard, and we classified the findings into 5 otoscopic diagnoses: healthy middle ear (no pathologic otoscopic findings), air-interface OME (a-OME, visible air-effusion interface and/or air bubble(s)), complete OME (c-OME, the middle ear was completely filled with effusion), air-interface AOM and complete AOM. The diagnosis of AOM required middle ear effusion, acute inflammatory signs in the tympanic membrane and acute symptoms. The full version of the Methods section is presented in this issue of Pediatric Infectious Disease Journal.

Tympanometry

Tympanometry was performed using a MicroTym 2 tympanometer with a printer. The device uses a probe tone of 266 Hz and a sweep range of +200 to −400 daPa, from positive to negative pressure with a speed of 400 ± 40 daPa/s.

Tympanograms were presented according to the original classification by Jerger, as modified by Orchik et al10 and Zielhuis et al.11 Peaked tympanograms were classified to be type A when tympanometric peak pressure was over −100 daPa, type C1 when pressure was between −100 and −200 daPa, type C2 when pressure was lower than −200 daPa and type Cs when the tympanogram was low peaked and wide (peak compliance <0.2 mmho, width over 300 daPa). A flat tympanogram was classified to be type B. If a flat tympanogram was obtained, tympanometry was repeated 3 times whenever possible. In other cases, tympanometry was repeated twice. Only clearly interpretable tympanograms without artifacts were classified. Two study physicians independently interpreted the tympanograms blinded to the otoscopic diagnoses (M.K.L. and A.R.), and when disagreeing, A.R. made the final decision.

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RESULTS

We enrolled 515 patients. Their mean age was 16 months (range 6–35 months), mean number of previous AOM episodes was 2 (range 0–12) and mean age at first AOM episode was 10 months (range 0–29 months). At 2123 visits, all diagnostic examinations were performed in both ears. This led to 4246 tympanometric examinations, of which 3212 (76%) were successful and 1034 (24%) failed, that is, the tympanogram could not be interpreted or no tympanogram was obtained. The study physicians had success rates between 44% and 79%. However, the success rate was not affected by cerumen, otoscopic diagnosis or the child’s symptoms (data not shown). Results of spectral gradient acoustic reflectometry are presented concurrently in this issue of Pediatric Infectious Disease Journal.8

Symptomatic Visits

At symptomatic visits, the number of successful tympanograms was 2206 (Table 1; Fig. 1A). The majority of type A, C1 and C2 tympanograms was associated with healthy middle ears. Type Cs tympanograms did not distinguish between different otoscopic diagnoses; however, Cs consisted only of 5% of all peaked tympanograms. The peaked tympanograms together (ie, A, C1, C2 and Cs) were related to a healthy middle ear and to a-OME in 942/1407 (67%) and 226/1407 (16%) examinations, respectively. Type B tympanogram was not able to indicate the otoscopic diagnosis although it was almost exclusively associated with middle ear effusion (Fig. 1A).

Looking at the results from another perspective, when the middle ear was healthy, the acquired tympanogram was peaked in 942 (96%) of 981 examinations. When the otoscopic diagnosis was a-OME or c-OME, the tympanogram was type B in 113/339 (33%) and 224/303 (74%) examinations, respectively. When the otoscopic diagnosis was air-interface AOM or complete AOM, the tympanogram was type B in 70/138 (51%) and 353/445 (79%) examinations, respectively.

Asymptomatic Visits

At asymptomatic visits, 1006 successful tympanograms were acquired (Table 2; Fig. 1B). Type A and C1 tympanograms were related to a healthy middle ear in 92% and 82% of examinations, respectively. Type C2 and Cs tympanograms were rare at asymptomatic visits. Peaked tympanograms together (ie, A, C1, C2 and Cs) were associated with a healthy middle ear and with a-OME in 713/824 (87%) and 72/824 (9%) examinations, respectively. In contrast, when the tympanogram was type B, 87% of otoscopic examinations were related to middle ear effusion.

From another perspective, when the middle ear was healthy, the tympanogram was peaked in 713 (97%) of 736 examinations.

TABLE 1. Tympanograms in Relation to Otoscopic Diagnoses in 2206 Successful Examinations at Symptomatic Visits

<table>
<thead>
<tr>
<th>Otoscopic Diagnosis, N</th>
<th>Healthy Middle Ear (N = 981)</th>
<th>Air Interface OME (N = 339)</th>
<th>Complete OME (N = 303)</th>
<th>Air Interface AOM (N = 138)</th>
<th>Complete AOM (N = 445)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tympanogram type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (N = 717)</td>
<td>559</td>
<td>58</td>
<td>30</td>
<td>27</td>
<td>43</td>
</tr>
<tr>
<td>C1 (N = 416)</td>
<td>259</td>
<td>83</td>
<td>22</td>
<td>25</td>
<td>27</td>
</tr>
<tr>
<td>C2 (N = 209)</td>
<td>112</td>
<td>61</td>
<td>19</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Cs (N = 65)</td>
<td>12</td>
<td>24</td>
<td>8</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>B (N = 799)</td>
<td>39</td>
<td>113</td>
<td>224</td>
<td>70</td>
<td>353</td>
</tr>
</tbody>
</table>
When the otoscopic diagnosis was a-OME or c-OME, the tympanogram was type B in 61/133 (46%) and 96/135 (71%) examinations.

**DISCUSSION**

This study showed that tympanometry is not useful in detecting specific otoscopic diagnoses of otitis media although it is able to differentiate middle ears with effusion from those without effusion.

To provide new views for the diagnostic information of tympanometry, we analyzed the distribution of tympanograms in 5 otoscopic diagnoses. Most importantly, this allowed us to show that the type B tympanogram is not useful in differentiating AOM from OME even at symptomatic visits. Because both AOM and OME are frequent among symptomatic children, visualization of the tympanic membrane is needed to determine the accurate diagnosis for qualified consideration of treatment options. However, it could be suggested that tympanometry might in some cases replace the pneumatic component of otoscopy. This is based on the finding of several studies, including ours, that the type B tympanogram is useful in detecting middle ear effusion.6,13,14 Smith et al6 developed an algorithm to calculate the probability of middle ear effusion. According to their algorithm, tympanometric width and peak height are stronger predictors of middle ear effusion than traditional division of tympanograms by the tympanometric peak pressure. The algorithm developed by Smith et al is excellent for research purposes. However, from a pragmatic point of view, it might be easier for the clinician to keep in mind that a flat tympanogram indicates middle ear effusion but a flat tympanogram should not be regarded as an indication of antimicrobial treatment even in symptomatic children. We previously showed that children with and without AOM cannot be differentiated from each other according to symptoms.15 Taken together, tympanometry is a useful adjunctive tool in diagnosing AOM and OME, but the cornerstone of accurate diagnosis is based on careful pneumatic otoscopy.

Another clinically important finding was that all peaked tympanograms, namely A, C1, C2 and Cs, were mainly associated with a healthy middle ear. Furthermore, if a peaked tympanogram was associated with OME or AOM, the pneumatic otoscopic examination usually indicated air-effusion interfaces that contribute to less severe diagnoses. Although type Cs tympanograms were related to all otoscopic diagnoses, they were rare in our study as in other outpatient populations.6,14,16 Thus, even at symptomatic visits, interpreting all peaked tympanograms as normal in clinical practice would not cause us to miss any great amount of severe diagnoses. Interestingly, Koivunen et al13 suggested that the amount of middle ear effusion would correspond to the potential hearing loss caused by effusion, and thus the consequences of effusion with air interfaces would be minimal. Therefore, we suggest that all peaked tympanograms could be considered normal when children are asymptomatic and, if accepting a few misdiagnoses, in all children in primary care.

The usefulness of tympanometry as an adjunctive diagnostic tool is emphasized by our findings that the success rate was not affected by cerumen, otoscopic diagnosis or the child’s symptoms. On the other hand, the overall success rate of tympanometric examinations varies between physicians and may be modest at otitis-prone age. According to our results, when middle ear examination is needed, tympanometry provides useful adjunctive information in roughly half of examinations.

The major strength of this study is the large, unselected outpatient population at otitis-prone age. The study population presented with the whole spectrum of otoscopic findings that were categorized as different diagnoses of otitis media. Our criteria for AOM were even stricter than those recommended by the 2004 guideline of the American Academy of Pediatrics.13 As previously suggested, we repeated all tympanograms at least twice.13 Taken together, our results are well applicable to primary care. Our study also has limitations. Tympanometric examination was performed before otoscopy, which may have interfered with the otoscopic diagnoses which were the references for tympanograms. However, we used video otoscopy for objective documentation of the findings, and equally important, we interpreted and classified all tympanograms blinded to the otoscopic diagnoses. Performing tympanometry before otoscopy is the order in clinical practice, which optimizes the co-operation among young children. Furthermore, this order allowed us to study whether cerumen affects the success rate of tympanometry. The optimal reference for tympanometry would have been tympanocentesis which, nevertheless, is not justified without the need of microbiologic diagnosis. The rather large proportion of unsuccessful tympanograms can be seen as a limitation or, on the other hand, as a result due to the young age of our study population and variation between study physicians. These aspects correspond well to clinical practice in primary care. All in all, our study responds to everyday practice at primary care level, and thus, our results are largely applicable.

In conclusion, tympanometry is not useful in diagnosing specific otoscopic diagnoses of otitis media although it can be used as an adjunctive tool. We suggest, by acknowledging a few misdiagnoses, that all peaked tympanograms could be considered as a sign of a healthy middle ear in primary care. Although a flat tympanogram indicates middle ear effusion, it is not a verification of AOM even when children are symptomatic. Consequently, the diagnosis of AOM and OME should always be verified by pneumatic otoscopy.

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**TABLE 2. Tympanograms in Relation to Otoscopic Diagnoses in 1006 Successful Examinations at Asymptomatic Visits**

<table>
<thead>
<tr>
<th>Tympanogram type</th>
<th>Healthy Middle Ear (N = 736)</th>
<th>Air Interface OME (N = 133)</th>
<th>Complete OME (N = 135)</th>
<th>Air Interface AOM (N = 0)</th>
<th>Complete AOM (N = 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (N = 570)</td>
<td>526</td>
<td>30</td>
<td>14</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C1 (N = 192)</td>
<td>157</td>
<td>20</td>
<td>15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C2 (N = 45)</td>
<td>21</td>
<td>14</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cs (N = 17)</td>
<td>9</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B (N = 182)</td>
<td>23</td>
<td>61</td>
<td>96</td>
<td>0</td>
<td>2*</td>
</tr>
</tbody>
</table>

*The other child had slightly bulging tympanic membrane in examination, and the following day developed fever and respiratory symptoms. The other child, whose middle ear had been completely healthy 15 days earlier, had moderately bulging tympanic membrane in examination and had no symptoms preceding or afterward.*
REFERENCES


