Audiometric Testing Guideline Adherence in Children Undergoing Tympanostomy Tubes: A Population-Based Study

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Abstract

Objective. Tympanostomy tube (TT) insertion is the most common ambulatory surgery performed on children. American Academy of Otolaryngology—Head and Neck Surgery Foundation (AAO-HNSF) Clinical Practice Guidelines (CPGs) recommend hearing testing for all pediatric TT candidates. The aim of this study was to assess audiometric testing in this population.

Study Design. Retrospective population-based cohort study.

Setting. All hospitals in the Canadian province of Ontario.

Subjects and Methods. All patients 12 years of age and younger who underwent at least 1 TT procedure between January 1993 and June 2016. The primary outcomes were the percentage of patients who underwent a hearing test within 1 year before and/or 1 year after surgery.

Results. A total of 316,599 bilateral TT procedures were performed during the study period (1993 to 2016). Presurgical hearing tests increased from 55.7% to 74.9%, and postsurgical hearing tests increased from 42.2% to 68.9%. Younger surgeons demonstrated a greater adherence to the CPGs (relative risk [RR], 1.22; 95% CI, 1.08-1.38; \( P = .001 \)). Remarkably, there was not a spike in preoperative hearing tests following the introduction of the CPGs in 2013 (RR, 1.12; 95% CI, 0.85-1.47; \( P = .432 \)). Presurgical hearing testing ranged from 26.1% to 83.5% across health regions.

Conclusion. In this cohort of children who underwent TT placement, the trends of preoperative and postoperative audiometric testing are increasing but are still lower than recommended by the CPGs, despite a tripling of practicing audiologists. This study describes the current state of testing in Ontario and highlights issues of access to audiology services, possible parent preferences, and the importance of ongoing continuing medical education for all health care practitioners.

Keywords
tympanostomy tubes, audiometric testing, guideline adherence, population research

M**y**ringotomy with tympanostomy tube insertion (TT) is the most common surgery performed on children in North America.** The most common indications for TT in children are recurrent acute otitis media (AOM) and chronic otitis media with effusion (OME).** As these conditions are associated with hearing loss, and one of the goals of TT placement is to improve hearing, the assessment of pre- and postoperative hearing is important. American Academy of Otolaryngology—Head and Neck Surgery Foundation (AAO-HNSF) Clinical Practice Guidelines (CPGs)** recommend that age-appropriate hearing tests are performed prior to surgery if the child becomes a candidate for TT placement (key action statement 2). Preoperative audiological testing determines appropriate expectations for hearing improvement with surgery and may detect permanent (sensorineural) hearing loss. Although not a formal guideline, postoperative hearing testing should at least be performed in any child with a hearing loss prior to TT placement.** Furthermore, given that the incidence of hearing loss in the population of patients who undergo TT is as high as 14%, postoperative testing is warranted in all children in this population.**

Despite these points, recent studies suggest that the use and perceived value of perioperative audiograms vary among otolaryngologists.** Furthermore, adherence to key

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action statements in otolaryngology–head and neck surgery CPGs varies from 0% to 98.9%. A survey of American Society of Pediatric Otolaryngology members revealed a lack of consensus regarding the necessity of preoperative audiograms and variation in the perceived value of preoperative audiograms as a quality metric. This apparent discrepancy between guidelines and practice was demonstrated in a retrospective review of OME management in the United Kingdom, which found that recommended audiometric testing was upheld in just 55% of cases. To our knowledge, a similar study has not been conducted in Canada, and rates of hearing assessment with TT remain unknown. The purpose of this study was to explore hearing assessment practices among physicians in Ontario, Canada. Using administrative health service records, we investigated the use of preoperative and postoperative hearing tests in pediatric patients who underwent TT.

Methods

Ethics Approval

This study was approved by the Queen’s University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board (HSREB), project 6017300.

Setting

Ontario is the largest province in Canada, with a population of over 13 million residents. Hospitals are required to report all operative procedures, both same day and inpatient. The Canadian health care system is a publicly funded and administered system governed by the Canada Health Act. This act mandates comprehensive universal coverage for all medically necessary services, including TT. Private health insurance for these services is prohibited. As such, this surgical procedure is available to all persons equally. Audiometric testing is also covered by the public health care system and billable to the provincial government (Ontario Health Insurance Plan [OHIP] in Ontario). Diagnostic hearing assessments are billable to OHIP when the professional component (interpretation of the hearing assessment) is performed by a qualified physician and the technical component (performance of the hearing assessment) is performed by an audiologist (or equivalent). This is standard practice for children seen in consultation in an otolaryngologist’s office (community otolaryngology clinic, community hospital, or academic health sciences center) for consideration of TT.

Study Type/Design

This study was a retrospective population-based cohort study. Administrative data sets housed at the Institute for Clinical Evaluative Sciences (ICES) were used to obtain the data for this study. ICES is an independent, nonprofit research organization funded by the Ontario Ministry of Health and Long-Term Care (MOHLTC) whose data holdings include all health care–related events for the population of Ontario. The Registered Persons Database (RPDB) is a repository of demographic information for all residents of Ontario who are eligible for the OHIP. RPDB is maintained by the MOHLTC and contains information on health card number, date of birth, sex, address, and deceased date (where applicable). Personal identifying information in RPDB is removed at ICES, and each unique health number is converted into an anonymous unique identifier, the ICES Key Number (IKN). The IKN is a common identifier that is used to link data sources within ICES. The OHIP database contains data on the fee-for-service claims submitted by physicians and paid by the universal health care system. The ICES Physician Database (IPDB) includes data of birth, sex, medical school graduation year, and specialization of the treating physician.

The data set was created at ICES Queen’s based on all patients age 12 years and younger who had undergone at least 1 TT procedure. Physician billing (OHIP fee code) records from January 1, 1993, to June 30, 2016, were searched for Ontario children who had undergone at least 1 TT placement (Table 1). We habitually exclude patients from the analysis if a valid IKN was not available or age/sex information was missing; however, in this study, there were zero patients who were excluded for these reasons. Only patients with bilateral TT placement were evaluated in this study. The index surgery date was the first use of the Z914 OHIP fee code. All subsequent uses of this OHIP fee code during the study period were captured. This data set was then linked to patient demographic and geographic data and to physician billing data for audiometric testing (Table 1), thus creating the clinical story for each anonymized patient.

Main Outcomes

The primary outcomes were measures (ie, ≥1 OHIP fee code record) of audiometric testing in the 1 year prior to TT procedure and audiometric testing in the 1 year after the TT procedure.

Statistical Analysis

Percentages were first calculated for preoperative and postoperative audiometric and impedance testing by the year of the TT procedure in 1993 to 2016. With preoperative audiometric testing as the main interest, percentages were further calculated by younger and older surgeons (based on their median age of 46 years; age 46 or 47 was consistently the median across all years of analysis, with a range of 45-49 years of age) at the time of the TT procedure and the corresponding Local Health Integration Network (LHIN) health regions of the place of residence for the TT procedures in 2012 to 2016. Health care in Ontario is provided by the provincial government, with administration of services geographically divided into 14 LHINs. These LHINs are mandated to plan, fund, and integrate health care services in their regions. The different LHINs span the spectrum from highly rural to highly urbanized populations.

Poisson regression was then used to investigate the practice of audiometric and impedance testing. Given the recent AAO-HNSF guidelines introduced in July 2013, the associations of preoperative and postoperative audiometric and impedance testing between two 3-year periods, August 1,
2010, to June 30, 2013 (3 years prior to guidelines), and
August 1, 2013, to June 30, 2016 (3 years after the guide-
lines), were examined. The association of preoperative
audiometric testing was also examined for younger/older
surgeons, adjusting for the year of their TT procedure.
Analyses were performed using the SAS Enterprise
Guide software version 7.1 (SAS Institute, Cary, North
Carolina) at ICES. The 2-sided statistical significance was
determined by a $P$ value $\leq .05$.

**Results**

Over the study period, 316,599 bilateral TT procedures
were performed in Ontario. The trend of TT placement is
decreasing over time (Figure 1). In contrast, the size of the
population of children aged 0 to 14 years in Ontario over
the course of this study has remained stable.\(^{10}\) In the
Ontario pediatric population, the overall trend of audi-
ometric testing has been essentially stable for the most recent
15 years (Figure 2).

In contrast, the trends of both preoperative and post-
operative audiometric testing are increasing over time (Figure 3). At all time points, preoperative testing is more
commonly performed than postoperative testing. The trends
of both preoperative and postoperative impedance testing
are also increasing over time (Figure 4). However, the pre-
operative and postoperative audiometric and impedance test-
ing did not significantly increase following introduction of
the July 2013 AAO-HNSF guidelines\(^3\) (Table 2). Upon
division of the surgeons into the younger 50% and the older
50%, preoperative audiometric testing was consistently
more commonly performed by the younger surgeons (rela-
tive risk [RR], 1.22; 95% confidence interval [CI], 1.08-
1.38; $P = .001$) (Figure 5).

Finally, there was considerable variability in preopera-
tive audiometric testing by geographic region in the years
analyzed, with an overall average percentage of 71.7% (Figure 6).

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**Table 1. Ontario Health Insurance Plan (OHIP) Administrative Codes for Procedures and Audiometric Testing.**

<table>
<thead>
<tr>
<th>Procedure or Test</th>
<th>OHIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myringotomy with insertion of ventilation (tympanostomy) tube</td>
<td>Z914</td>
</tr>
<tr>
<td>Pure-tone threshold audiometry with or without bone conduction</td>
<td>G440/G525</td>
</tr>
<tr>
<td>Pure-tone threshold audiometry (with or without bone conduction) and speech</td>
<td>G441/G526</td>
</tr>
<tr>
<td>reception threshold and/or speech discrimination scores</td>
<td></td>
</tr>
<tr>
<td>Sound field audiometry</td>
<td>G448/G450</td>
</tr>
<tr>
<td>Miscellaneous advanced testing (eg, recruitment, tests of malingering,</td>
<td>G443/G530</td>
</tr>
<tr>
<td>central auditory and stapedial reflex tests)</td>
<td></td>
</tr>
<tr>
<td>Brainstem evoked audiometry</td>
<td>G146/G144</td>
</tr>
<tr>
<td>Impedance audiometry</td>
<td>G442/G529</td>
</tr>
<tr>
<td>Impedance audiometry (manual)(^b)</td>
<td>G434/G527</td>
</tr>
<tr>
<td>Automatic tympanometry (impedance testing)(^b)</td>
<td>G528</td>
</tr>
</tbody>
</table>

\(^a\)The first of each pair of audiometric codes is the technical component billing code, and the second is the professional component billing code.

\(^b\)Codes only used prior to 2001. These codes were removed from the fee schedule in 2001.
Discussion

This study provided a unique opportunity to evaluate CPG adherence in audiometric testing preoperatively and postoperatively in patients who underwent TT. A large comprehensive data set was acquired through administrative health data records in the Canadian province of Ontario. A total of 316,599 bilateral TT procedures were evaluated. Over 70% of the included procedures were first TT procedure per patient. Although we chose to evaluate data for any TT procedure (not just the first), a parallel analysis was performed for first TT procedure per patient, and the results were essentially identical (data not shown). For brevity, only data for “any TT procedure” were presented.
Over time, the yearly trend of TT placement has declined by almost half. Over the course of this study, there have been refinements in the indications for TT.3,11 The focus of this article, however, was the usage of audiometric testing in children undergoing tympanostomy tubes.

We attribute the sudden drop in billed audiometric testing from 2000 to 2002 to the introduction of the Ontario Infant Hearing Program (IHP). Under the IHP, testing of newborns with suspected hearing loss was not billable to OHIP and thus not captured in our analysis. Although the overall pediatric population annual trend of audiometric tests has remained constant over the past 15 years, the proportion of pediatric TT patients who underwent preoperative and postoperative audiometric (and impedance testing) continues to rise. While this rise is encouraging, the guidelines would indicate that the preoperative rate should be closer to 100%. Even for tubes placed in 2016, the percentage is still below 75%. This is in the context of a tripling of practicing audiologists in Ontario from 242 in 1993 to 768 in 2017 (College of Audiologists and Speech-Language Pathologists of Ontario). As all audiologists practicing in Ontario must be registered with this college, these numbers represent the actual available audiologists. Even more intriguing is the finding that the increased testing did not significantly change following the publication of the AAO-HNSF July 2013 guidelines. Ryan7 reported that barriers to adherence to CPGs can be divided into patient, clinician, and system factors. In the present study, patient factors may include difficulty (or perceived difficulty on the part of the caregivers) in performing some audiometric tests in young children. Clinician factors may include a disagreement with CPGs on the part of the physician as to the necessity of preoperative audiometric testing in the setting of perceived definitive pathology.5,6 System factors may include availability of audiometric equipment and trained audiologists, which could partially explain the considerable geographic variation in preoperative testing that was found in the present study. It is encouraging, however, that the trend of audiometric testing in these patients continues to rise. The present study has removed the common barrier of adherence (to CPGs) assessment, that being the limitation of most retrospective reviews to 1 center or institution. With comprehensive data from the largest Canadian province, this study’s findings have broad generalizability.

The adherence to the particular key action statement studied in this article was found to be higher in younger surgeons. This confirms previous research that demonstrated higher guideline adherence in younger professionals.12,13 Although it could be declared that the results purely represent a tendency for younger physicians to order more tests, it has been shown that younger physicians adhere more closely to new guidelines and screening practices.12 However, even the younger surgeons in this study do not completely adhere to the guideline recommendations. We believe that these points underscore the tremendous value of continuing medical education (CME) programs that have been developed by otolaryngology–head and neck surgery societies.

Considerable geographical region variability in preoperative audiometric testing exists in Ontario. We chose to anonymize the regions, as the goal was to highlight variability and provide

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Figure 5. Preoperative audiometric testing for children (aged 12 years and younger) who underwent tympanostomy tube (TT) placement, based on the age of the operating surgeon (P = .001).

Figure 6. Geographical region preoperative audiometric testing for children who underwent tympanostomy tube (TT) placement between 2012 and 2016. Local Health Integration Network (LHIN) identities have been anonymized.
a starting point for policy makers to act to standardize care throughout the province. Possible explanations for this geography variability could include access to audiologists or practice patterns of the otolaryngologist–head and neck surgeons in that region. Variability in geographic access to health services has been previously demonstrated in Ontario.\textsuperscript{14-16} As Ontario is a geographically large province (1.55 times the size of Texas) with numerous remote northern communities, equal access to care continues to be a focus of medical and governmental organizations.

This study’s primary strengths are its large sample size with comprehensive capture of data from all pediatric patients in Ontario. There are, however, important limitations. To liberally capture any preoperative audiometric test that may have relevance on the TT procedure, we chose to include all audiometric tests that were performed within 1 year prior to the surgery. The Ontario provincial wait time for a TT procedure is 88 to 115 days from the date of otolaryngology–head and neck surgery consultation (90% of procedures are completed within this timeframe; available data are from April 2009–September 2017).\textsuperscript{17} We believe that the parameters chosen in this study reflect a balance between capture of applicable audiometric testing and minimizing overcapture of nonapplicable testing. Understandably, an audiogram performed 1 year prior to the surgery on a young child likely will not adequately reflect the status of the child’s hearing at surgery, be it normal or abnormal at the time of testing. We highlight, however, that even with this liberal parameter, the preoperative testing is still much lower than we would hope. It is possible the rates of preoperative testing are slightly higher than reported in our study, given the nonbillable infant hearing testing. We, however, believe this to be a small contributor to the studied population overall and a noncontributor to the patients who were over 1 year old at the time of the TT procedure.

This administrative data does not contain the results of the audiometric testing or the indications for TT placement. For patients with preoperative hearing loss, we would expect a much higher percentage of postoperative testing to ensure normalization of hearing and to exclude the underlying possibility of a sensorineural loss or a persistent conductive loss. This scenario cannot be evaluated by the data that we have available.

**Conclusion**

The use of this large comprehensive database provides an opportunity to evaluate the clinical impact and adherence to clinical practice guidelines. In this cohort of children who underwent TT placement, the trends of preoperative and postoperative audiometric testing are increasing but are still much lower than recommended by the CPGs. This study describes the current state of testing in Ontario and highlights the importance for ongoing CME for all health care practitioners.

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**Author Contributions**

Jason A. Beyea, conception, design, data acquisition and analysis, interpretation, drafting and critical revision, final approval, agreement to be accountable for all aspects; Emily Rosen, conception, design, interpretation, critical revision, final approval, agreement to be accountable for all aspects; Trina Stephens, conception, design, interpretation, critical revision, final approval, agreement to be accountable for all aspects; Paul Nguyen, conception, design, data acquisition and analysis, drafting and critical revision, final approval, agreement to be accountable for all aspects; Stephen F. Hall, conception, design, interpretation, critical revision, final approval, agreement to be accountable for all aspects.

**Disclosures**

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**References**


